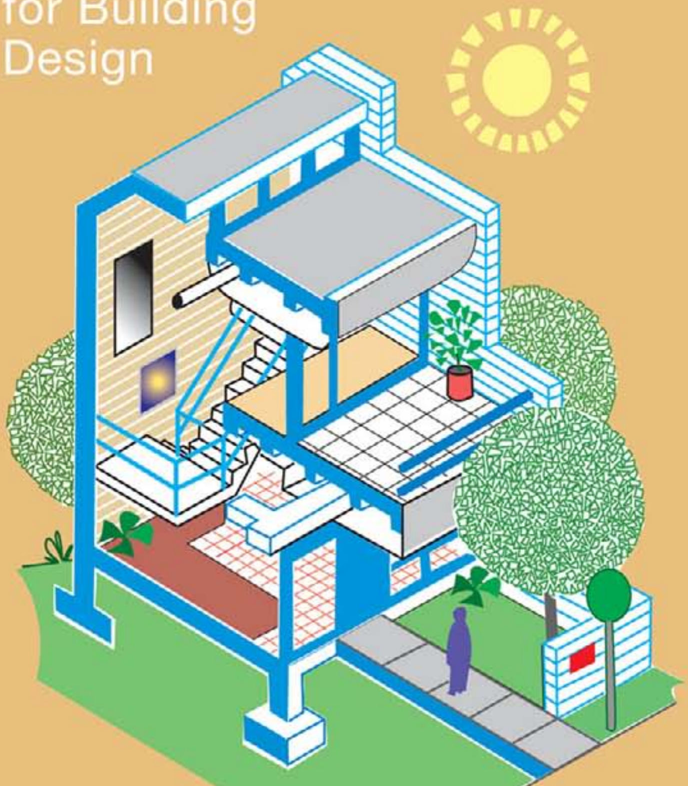
FOURTH EDITION

The Architect's Portable Handbook

First-Step Rules of Thumb for Building Design

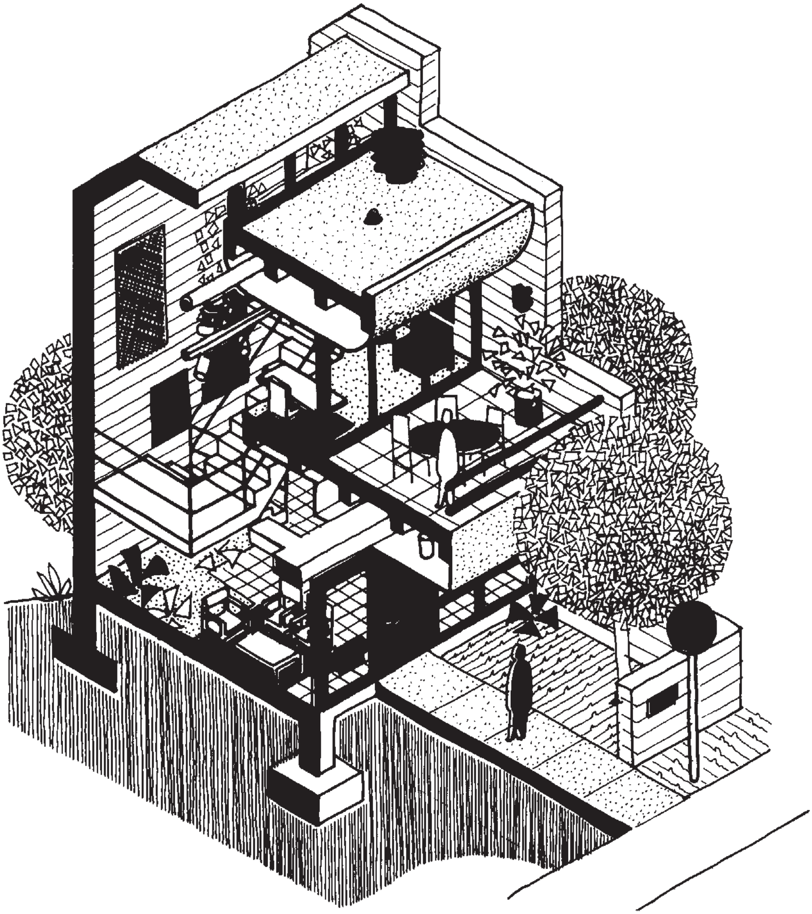


PAT GUTHRIE

The Architect's Portable Handbook

ABOUT THE AUTHOR

John Patten ("Pat") Guthrie, AIA, principal of John Pat Guthrie Architects, Inc., now retired. A resident of Scottsdale, Arizona, Pat has been licensed as an architect in 13 states. He is also the author of *Cross Check: Integrating Building Systems and Working Designs* and *Interior Designer's Portable Handbook* (published by McGraw-Hill) and *Desert Architecture* (self-published). Pat has taught at the FLW School of Architecture at Taliesin West. He and his wife Janet are the parents of two grown children, Eric and Erin. Pat's avocations include world travel, art, sailing, and history.



THE ARCHITECT'S PORTABLE HANDBOOK

FIRST-STEP RULES OF THUMB FOR BUILDING DESIGN

BY PAT GUTHRIE
ARCHITECT

FOURTH EDITION

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Dedicated to:

- *Bill Mahoney of BNI (Building News Inc.) who encouraged me in the first edition*
- *Joel Stein, editor of the first edition*
- *My family (Jan, Eric, and Erin)*
- *The memory of my parents*

The author wishes to thank Bill Mahoney of BNI Building News *for providing some of the costs in this book.*

BNi Building News

Contents

Use this table as a checklist for the design of buildings.

How to Use This Book

The concept of this book is that of a *personal tool* that compacts the 20% of the data that is needed 80% of the time by *design professionals* in the preliminary design of *buildings* of all types and sizes and of the spaces between.

This tool is meant to always be at one's *fingertips* (open on a drawing board or desk, carried in a briefcase, or kept in one's pocket). It is never meant to sit on a bookshelf. It is meant to be *used every day!*

Because design professionals are individualistic and their practices are so varied, the user is encouraged to *individualize this book* over time, by adding notes or changing data as experience dictates.

The addition of rough construction **costs** throughout the book (making this type of handbook truly unique) will date the data. But building laws, new technologies, and materials are changing just as fast. Therefore, this book should be looked on as a *starter of simple data collection* that must be updated over time. New editions *may* be published in the future. See p. 43 for more information on **costs.**

Because this book is so broad in scope, yet so compact, information can be presented only at one place and not repeated. Examples of how to use the information are provided throughout. Information is presented in the form of simple ratios or coefficients that replace the need for *commonsense judgment.*

The whole book is laid out in checklist format, to be quickly read and checked against the design problem at hand.

Where ◯ is shown, refer to p. 657–660 for further explanation of references.

"Notes" pages appear throughout, on which the user is encouraged to keep further information in the form of notes or sketches.

This book is *not a substitute* for professional expertise or other books of a more detailed and specialized nature, but will be a continuing everyday aid that takes the more useful "cream" off the top of other sources.

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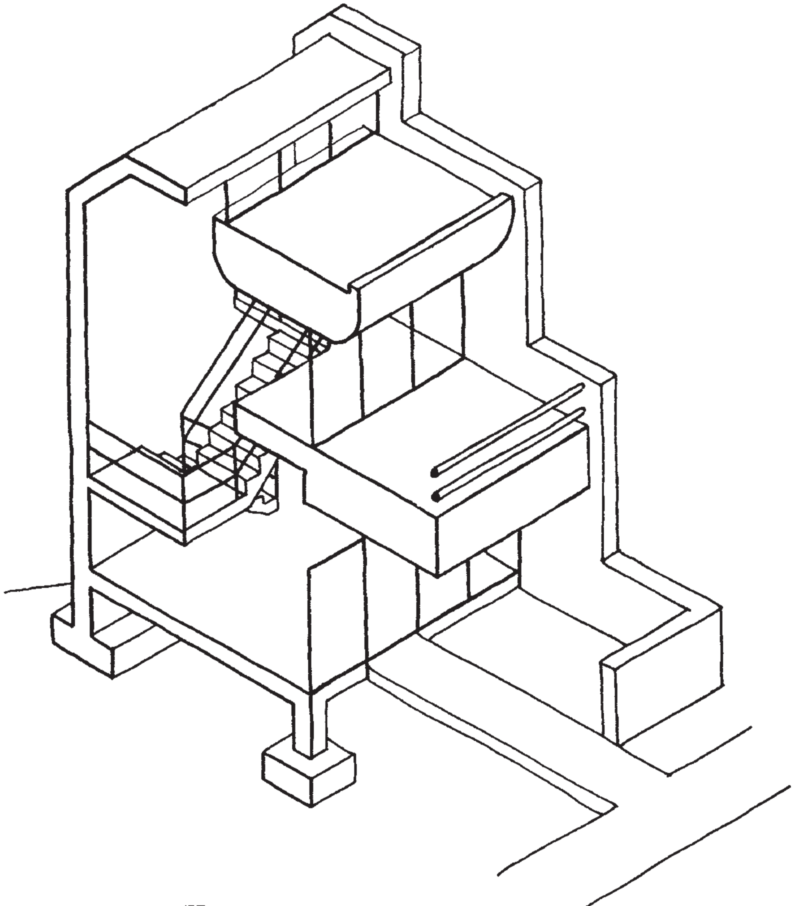


1 GENERAL

NOTES

___ A. PRACTICE (6) (28) (57)

___ 1. **Services:** Use "Schedule of A/E (Architectural/Engineering) Services" on pp. 6–15 to plan the services for building design.

___ 2. **Compensation** (A/E Fees)

___ *a.* See App. A, item E, for A/E fees as a percentage of construction cost by building type.

___ *b.* Total services fees can be broken down as follows:

___ Schematic design phase	15%	or	
___ Design development	20%	25%	Preliminary design
___ Construction documents	40%	50%	Const. doc.
___ Bid/negotiation	5%		
___ Construction administration	20%	25%	Const. adm.
	100%	100%	

___ *c.* Of the total A/E fees, standard *consultants' fees* can be broken out as follows:

___ (1) Civil engineering and landscape architect	2.5 to 6%
___ (2) Structural engineering	1 to 2.5%
___ (3) Mechanical engineering	4 to 10%
___ (4) Electrical engineering	4 to 10%
___ (5) Other	

___ 3. **Rules of Thumb for Business Practice**

___ *a.* Watch *cash flow:* For a small firm, balance checkbook. For a medium or large firm, use cash statements and balance and income statements. Estimate future cash flow based on past, with 15% "fudge factor," plus desired profit. Many architects (and businesses, in general) get in trouble by not immediately paying their bills (to consultants and vendors) as they are paid by their clients.

___ *b.* Have *financial reserves:* Six months' worth.

___ *c.* Monitor *time* by these *ratios:*

___ (1) $\text{Chargeable ratio} = \dfrac{\text{direct job labor cost}}{\text{total labor cost}}$

This tells what percent of total labor cost is being spent on paying work. The higher the percent the better. Typical range is 55 to 85%, but lower than *65%* is poor. However, principals often have a 50% ratio.

___ (2) Multiplier ratio = $\frac{\text{dollars of revenue}}{\text{dollars of direct labor}}$

This ratio is multiplied times wages for billing rates. Usually *2.5 to 3.0.* Will vary with firm and time.

___ (3) Overhead rate: looks at total indirect expenses as they relate to total direct labor. An overhead rate of 180 means $1.80 spent for ea. $1.00 working on revenue-producing projects.

___ (4) Profit: measured as total revenue minus expenses. Expressed as percent of total revenue.

___ *d.* Monitor *accounting reports:* A financial statement consists of:

___ (1) Balance Sheet: Tells where you are on a given date by Assets and Liabilities.

___ (2) Earnings Statement (Profit and Loss): Tells you how you got there by Income less Direct (job) costs, and Indirect (overhead) costs = Profit, or Loss.

___ *e.* *Mark up* for Reimbursable Expenses (travel, printing, etc.): Usually 10%.

___ *f.* Negotiating *contracts*

___ (1) Estimate scope of services.

___ (2) Estimate time, costs, and profit.

___ (3) Determine method of compensation:

___ (*a*) Percent of construction cost

___ (*b*) Lump sum

___ (*c*) Hourly rates

___ (*d*) Hourly rates with maximum "upset" ("not to exceed")

___ *g.* Contract checklist

___ (1) Detailed scope of work, no interpretation necessary.

___ (2) Responsibilities of both parties.

___ (3) Monthly progress payments.

___ (4) Interest penalty on overdue payments.

___ (5) Limit length of construction administration phase.

___ (6) Construction cost estimating responsibilities.

___ (7) For cost-reimbursable contracts, specify a provisional overhead rate (changes year to year).

___ (8) Retainer, applied to fee but not costs.
___ (9) Date of agreement, and time limit on contract.
___ (10) Approval of work—who, when, where.
___ (11) Ways to terminate contract, by both parties.
___ (12) For changes in scope, bilateral agreement, and an equitable adjustment in fee.
___ (13) Court or arbitration remedies and who pays legal fees.
___ (14) Signature and date by both parties.
___ (15) Limits on liability.
___ (16) Time limit on offer.
___ (17) Put it in writing!

6

PHASE 1 PRE DESIGN SCHEDULE OF A/E SERVICES		BY ARCHITECT	BY CONSULTANT	BY OWNER				NOT TO BE DONE
1	PROJECT ADMINISTRATION							
2	COORDINATION/CHECKING							
3	COORD. W/ GOVERNMENT							
4	PROGRAMMING							
5	SPACE DIAGRAMS							
6	SURVEY OF EXIST'G. FACILITIES							
7	MARKETING STUDIES							
8	ECONOMIC STUDIES							
9	PROJECT FINANCING							
10	PROJECT BUDGETING							
11	PRESENTATIONS							

PHASE 2 SITE ANALYSIS SCHEDULE OF A/E SERVICES		BY ARCHITECT	BY CONSULTANT	BY OWNER				NOT TO BE DONE
1	PROJECT ADMINISTRATION							
2	COORDINATION / CHECKING							
3	COORD. W/ GOVERNMENT							
4	SURVEYS							
5	SITE ANALYSIS & SELECTION							
6	SITE DEVELOPMENT PLANNING							
7	SITE UTILIZATION STUDIES							
8	UTILITY STUDIES							
9	ENVIRONMENTAL STUDIES							
10	ZONING							
11	PROJECT SCHEDULING							
12	PROJECT BUDGETING							
13	PRESENTATIONS							

PHASE 3 SCHEMATIC DESIGN SCHEDULE OF A/E SERVICES		BY ARCHITECT	BY CONSULTANT	BY OWNER				NOT TO BE DONE
1	PROJECT COORDINATION							
2	COORDINATION / CHECKING							
3	COORD. W/ GOVERNMENT							
4	ARCHITECTURAL DESIGN							
5	STRUCTURAL DESIGN							
6	MECHANICAL DESIGN							
7	ELECTRICAL DESIGN							
8	CIVIL DESIGN							
9	LANDSCAPE DESIGN							
10	INTERIOR DESIGN							
11	MATERIALS RESEARCH / SPEC'S							
12	PROJECT SCHEDULING							
13	COST ESTIMATING							
14	PRESENTATIONS							

PHASE 4 DESIGN DEVELOPMENT SCHEDULE OF A/E SERVICES		BY ARCHITECT	BY CONSULTANT	BY OWNER				NOT TO BE DONE
1	PROJECT ADMINISTRATION							
2	COORDINATION / CHECKING							
3	COORD. W/ GOVERNMENT							
4	ARCHITECTURAL DESIGN							
5	STRUCTURAL DESIGN							
6	MECHANICAL DESIGN							
7	ELECTRICAL DESIGN							
8	CIVIL DESIGN							
9	LANDSCAPE DESIGN							
10	INTERIOR DESIGN							
11	MATERIALS RESEARCH / SPEC'S							
12	PROJECT SCHEDULING							
13	COST ESTIMATING							
14	PRESENTATIONS							

PHASE 5 CONSTRUCTION DOCUMENTS SCHEDULE OF A/E SERVICES		BY ARCHITECT	BY CONSULTANT	BY OWNER				NOT TO BE DONE
1	PROJECT ADMINISTRATION							
2	COORDINATION / CHECKING							
3	COORD. W/ GOVERNMENT							
4	ARCHITECTURAL DOCUMENTS							
5	STRUCTURAL DOCUMENTS							
6	MECHANICAL DOCUMENTS							
7	ELECTRICAL DOCUMENTS							
8	CIVIL DOCUMENTS							
9	LANDSCAPE DOCUMENTS							
10	INTERIORS DOCUMENTS							
11	SPECIFICATIONS							
12	PROJECT SCHEDULING							
13	COST ESTIMATING							
14	PRESENTATIONS							

PHASE 6 BIDDING OR NEGOTIATIONS SCHEDULE OF A/E SERVICES		BY ARCHITECT	BY CONSULTANT	BY OWNER				NOT TO BE DONE
1	PROJECT ADMINISTRATION							
2	COORDINATION / CHECKING							
3	GOVERNMENT PLAN CHECK							
4	PRE-QUALIFICATION OF BIDDERS							
5	BIDDING MATERIALS							
6	ADDENDA							
7	BIDDING / NEGOTIATIONS							
8	ALTERNATES / SUBSTITUTIONS							
9	SPECIAL BIDDING SERVICES							
10	BID EVALUATION							
11	CONST. CONTRACT AGREEMENTS							

PHASE 7 CONSTRUCTION CONTRACT ADM. SCHEDULE OF A/E SERVICES		BY ARCHITECT	BY CONSULTANT	BY OWNER				NOT TO BE DONE
1	PROJECT ADMINISTRATION							
2	COORDINATION / CHECKING							
3	COORD. W/ GOVERNMENT							
4	OFFICE ADMINISTRATION							
5	FIELD OBSERVATION							
6	PROJECT PRESENTATION							
7	INSPECTION COORDINATION							
8	SUPPLEMENTAL DOCUMENTS							
9	CHANGE ORDERS							
10	SCHEDULE MONITORING							
11	CONSTRUCTION COST ACCOUNTING							
12	PROJECT CLOSEOUT							

	PHASE 8 POST CONST. SERVICES SCHEDULE OF A/E SERVICES	BY ARCHITECT	BY CONSULTANT	BY OWNER				NOT TO BE DONE
1	PROJECT ADMINISTRATION							
2	COORDINATION / CHECKING							
3	COORD. W/ GOVERNMENT							
4	MAINTENANCE AND OPERATIONAL PROGRAMMING							
5	START UP ASSISTANCE							
6	RECORD DRAWINGS							
7	WARRANTY REVIEW							
8	POST CONST. EVALUATION							

PHASE 9 SUPPLEMENTAL SERVICES SCHEDULE OF A/E SERVICES		BY ARCHITECT	BY CONSULTANT	BY OWNER				NOT TO BE DONE
1	SPECIAL STUDIES							
2	RENDERINGS							
3	MODEL CONSTRUCTION							
4	LIFE CYCLE COST ANALYSIS							
5	VALUE ENGINEERING							
6	QUANTITY SURVEYS							
7	DETAILED COST ESTIMATES							
8	ENERGY STUDIES							
9	ENVIRONMENTAL MONITORING							
10	TENANT RELATED SERVICES							
11	GRAPHICS DESIGN							
12	ARTS AND CRAFTS							
13	FURNISHINGS DESIGN							
14	EQUIPMENT							
15	PROJECT PUBLIC RELATIONS							
16	LEASING BROCHURES							
17	EXPERT WITNESS							
18	COMPUTER APPLICATIONS							
19	MATERIALS & SYSTEMS TESTING							

PHASE 9 SUPPLEMENTAL SERVICES — CONTINUED — SCHEDULE OF A/E SERVICES		BY ARCHITECT	BY CONSULTANT	BY OWNER				NOT TO BE DONE
20	DEMOLITION SERVICES							
21	MOCK UPS							
22	PHOTOGRAPHY							
23	MOTION PICTURES							
24	COORD. W/ NON-DESIGN PROFESSIONALS							
25	SPECIAL DISCIPLINES CONSULTANTS							
26	SPECIAL BLD'G. TYPE CONSULTANTS							

NOTES

___ B. "SYSTEMS" THINKING (Q)

In the planning and design of buildings, a helpful, all-inclusive tool is to think in terms of overall "systems" or "flows." For each of the following checklist items, follow from the beginning or "upper end" through to the "lower end" or "outfall":

___ 1. <u>**People Functions**</u>

- ___ *a.* Follow flow of occupants from one space to another. This includes sources of vertical transportation (stairs, elevators, etc.) including pathways to service equipment.
- ___ *b.* Follow flow of occupants to enter building from off site.
- ___ *c.* Follow flow of occupants to exit building as required by code, in case of an emergency.
- ___ *d.* Follow flow of accessible route as required by law.
- ___ *e.* Follow flow of materials to supply building (including furniture and off site).
- ___ *f.* Follow flow of trash to leave building (including to off site).
- ___ *g.* Way finding: do graphics or other visual clues aid flow of the above six items?

___ 2. <u>**Structural Functions**</u>

- ___ *a.* Follow flow of gravity loads from roof down columns, through floors, to foundations and soils.
- ___ *b.* Follow flow of lateral loads:
  - ___ (1) Earthquake from ground up through foundations, columns, walls, floors, and roof.
  - ___ (2) Wind from side walls to roof and floors, through columns, to foundations and the earth.
  - ___ (3) Follow flow of uplift loads from wind and earthquake by imagining the roof being pulled up and that there are positive connections from roof to columns and walls (through floors) down to foundations and the earth.

___ 3. <u>**Water, Moisture, and Drainage**</u>

- ___ *a.* Drain the rain. Follow rainwater from highest point on roof to drain, through the piping system to outfall (storm sewer or site) off site.
- ___ *b.* Follow rainwater from highest points of site, around building, to outfall off site.
- ___ *c.* Follow rain or moisture at exterior walls and windows down building sides or "weeped" through

assemblies to outfall. Remember: Moisture moves from more to less. Moisture moves from warm to cold.

___ *d.* Follow vapor from either inside or outside the building, through the "skin" (roof and walls) to outfall. Things get wet. Let them dry out.

___ *e.* Follow water supply from source to farthest point of use.

___ *f.* Follow contaminated water from farthest point of use to outfall (sewer main or end of septic tank).

___ *g.* Follow vapor flow into materials over year and allow for blockage, swelling, or shrinkage.

___ **4. <u>Heat</u>** (flows from warm to cold)

___ *a.* Follow sun paths to and into building to plan for access or blocking.

___ *b.* Follow excessive external (or internal) heat through building skin and block if necessary.

___ *c.* Follow source of internal heat loads (lights, people, equipment, etc.) to their "outfall" (natural ventilation or AC, etc.).

___ *d.* Follow heat flow into materials over a year, a day, etc. and allow for expansion and contraction.

___ **5. <u>Air</u>**

___ *a.* Follow wind patterns through site to encourage or block natural ventilation through building, as required.

___ *b.* Follow air patterns through building. When natural ventilation is used, follow flow from inlets to outlets. When air is still, hot air rises and cold air descends.

___ *c.* Follow forced air ventilation patterns through building to address heat (add or dissipate) and odors. CFM out equals CFM in.

___ **6. <u>Light</u>**

___ *a.* Follow paths of natural light (direct or indirect sun) to and into building. Encourage or block as needed.

___ *b.* Follow paths of circulation and at spaces to provide artificial illumination where necessary. This includes both site and building.

___ **7. <u>Energy and Communications</u>**

___ *a.* Follow electric or gas supply from off site to transformer, to breakers or panels to each outlet or point of connection.

___ *b.* Follow telephone lines from off site to TMB to each phone location.

___ 8. <u>Sound</u>

- ___ *a.* Identify potential sound sources, potential receiver locations, and the potential sound paths between the two.
- ___ *b.* Follow sound through air from source to receiver. Mitigate with distance or barrier.
- ___ *c.* Follow sound through structure from source to receiver. Mitigate by isolation of source or receiver.

NOTES

___ C. SPECIFICATIONS (20)

___ **1. Standard outline for writing specification sections:**
___ *a.* General ___ *b.* Products ___ *c.* Execution

___ **2. Quick checklist on products or materials:**
___ *a.* What is it and what does it do?
___ *b.* Who is it made by?
___ *c.* How to apply?
___ *d.* What does it cost?
___ *e.* Warranties?

___ **3. Detailed checklist on evaluating new products or materials:**
___ *a.* *Structural serviceability* (resistance to natural forces such as wind and earthquake; structural adequacy and physical properties such as strength, compression, tension, shear, and behavior against impact and indentation).
___ *b.* *Fire safety* (resistance against the effects of fire such as flame propagation, burnthrough, smoke, toxic gases, etc.).
___ *c.* *Habitability* (livability relative to thermal efficiency, acoustic properties, water permeability, optical properties, hygiene, comfort, light, and ventilation, etc.).
___ *d.* *Durability* (ability to withstand wear, weather resistance such as ozone and ultraviolet, dimensional stability, etc.).
___ *e.* *Practicability* (ability to surmount field conditions such as transportation, storage, handling, tolerances, connections, site hazards, etc.).
___ *f.* *Compatibility* (ability to withstand reaction with adjacent materials in terms of chemical interaction, galvanic action, ability to be coated, etc.).
___ *g.* *Maintainability* (ease of cleaning; repairability of punctures, gouges, and tears; recoating, etc.).
___ *h.* *Code acceptability* (review of code and manufacturer's claims as to code compliance).
___ *i.* *Economics* (installation and maintenance costs).

___ **4. CSI format**

Use this section as a checklist of everything that makes or goes into buildings, to be all-inclusive in the planning and designing of buildings, their contents, and their surroundings:

___ *a.* Uniformat for preliminary systems planning:

PROJECT DESCRIPTION

10—PROJECT DESCRIPTION

___ 1010 Project Summary
___ 1020 Project Program
___ 1030 Existing Conditions
___ 1040 Owner's Work
___ 1050 Funding

20—PROPOSAL, BIDDING, AND CONTRACTING

___ 2010 Delivery Method
___ 2020 Qualifications Requirements
___ 2030 Proposal Requirements
___ 2040 Bid Requirements
___ 2050 Contracting Requirements

30—COST SUMMARY

___ 3010 Elemental Cost Estimate
___ 3020 Assumptions and Qualifications
___ 3030 Allowances
___ 3040 Alternates
___ 3050 Unit Prices

CONSTRUCTION SYSTEMS AND ASSEMBLIES

ELEMENT A—*SUBSTRUCTURE*

___ A10 Foundations
___ A1010 Standard Foundations
___ A1020 Special Foundations
___ A1030 Slab on Grade

___ A20 Basement Construction
___ A2010 Basement Excavation
___ A2020 Basement Walls

ELEMENT B—*SHELL*

___ B10 Superstructure
___ B1010 Floor Construction
___ B1020 Roof Construction

___ B20 Exterior Enclosure
___ B2010 Exterior Walls
___ B2020 Exterior Windows
___ B2030 Exterior Doors

___ B30 Roofing
___ B3010 Roof Coverings
___ B3020 Roof Openings

ELEMENT C—*INTERIORS*

___ C10 Interior Construction
___ C1010 Partitions
___ C1020 Interior Doors
___ C1030 Fittings

___ C20 Stairs
___ C2010 Stair Construction
___ C2020 Stair Finishes

___ C30 Interior Finishes
___ C3010 Wall Finishes
___ C3020 Floor Finishes
___ C3030 Ceiling Finishes

ELEMENT D—*SERVICES*

___ D10 Conveying
___ D1010 Elevators and Lifts
___ D1020 Escalators and Moving Walks
___ D1090 Other Conveying Systems

___ D20 Plumbing
___ D2010 Plumbing Fixtures
___ D2020 Domestic Water Distribution
___ D2030 Sanitary Waste
___ D2040 Rain Water Drainage
___ D2090 Other Plumbing Systems

___ D30 Heating, Ventilating, and Air Conditioning (HVAC)
___ D3010 Energy Supply
___ D3020 Heat Generation
___ D3030 Refrigeration
___ D3040 HVAC Distribution
___ D3050 Terminal and Packaged Units
___ D3060 HVAC Instrumentation and Controls
___ D3070 Testing, Adjusting, and Balancing
___ D3090 Other Special HVAC Systems and Equipment

___ D40 Fire Protection
___ D4010 Sprinklers
___ D4020 Standpipes
___ D4030 Fire Protection Specialties
___ D4090 Other Fire Protection Systems

___ D50 Electrical
___ D5010 Electrical Service and Distribution

___ D5020 Lighting and Branch Wiring
___ D5030 Communications and Security
___ D5090 Other Electrical Systems

___ D60 Basic Materials and Methods

ELEMENT E—*EQUIPMENT AND FURNISHINGS*
___ E10 Equipment
___ E1010 Commercial Equipment
___ E1020 Institutional Equipment
___ E1030 Vehicular Equipment
___ E1090 Other Equipment

___ E20 Furnishings
___ E2010 Fixed Furnishings
___ E2020 Movable Furnishings

ELEMENT F—*SPECIAL CONSTRUCTION AND DEMOLITION*
___ F10 Special Construction
___ F1010 Special Structures
___ F1020 Integrated Construction
___ F1030 Special Construction Systems
___ F1040 Special Facilities
___ F1050 Special Controls and Instrumentation

___ F20 Selective Demolition
___ F2010 Building Elements Demolition
___ F2020 Hazardous Components Abatement

ELEMENT G—*BUILDING SITEWORK*
___ G10 Site Preparation
___ G1010 Site Clearing
___ G1020 Site Demolition and Relocations
___ G1030 Site Earthwork
___ G1040 Hazardous Waste Remediation

___ G20 Site Improvements
___ G2010 Roadways
___ G2020 Parking Lots
___ G2030 Pedestrian Paving
___ G2040 Site Development
___ G2050 Landscaping

___ G30 Site Civil/Mechanical Utilities
___ G3010 Water Supply
___ G3020 Sanitary Sewer

___ G3030 Storm Sewer
___ G3040 Heating Distribution
___ G3050 Cooling Distribution
___ G3060 Fuel Distribution
___ G3090 Other Site Mechanical Utilities

___ G40 Site Electrical Utilities
___ G4010 Electrical Distribution
___ G4020 Site Lighting
___ G4030 Site Communications and Security
___ G4090 Other Site Electrical Utilities

___ G90 Other Site Construction
___ G9010 Service Tunnels
___ G9090 Other Site Systems

ELEMENT Z—*GENERAL*
___ Z10 General Requirements
___ Z1010 Administration
___ Z1020 Quality Requirements
___ Z1030 Temporary Facilities
___ Z1040 Project Closeout
___ Z1050 Permits, Insurance, and Bonds
___ Z1060 Fee

___ Z20 Contingencies
___ Z2010 Design Contingency
___ Z2020 Escalation Contingency
___ Z2030 Construction Contingency

___ *b.* Masterformat for more detailed planning:

INTRODUCTORY INFORMATION
___ 00001 Project Title Page
___ 00005 Certifications Page
___ 00007 Seals Page
___ 00010 Table of Contents
___ 00015 List of Drawings
___ 00020 List of Schedules

BIDDING REQUIREMENTS
___ 00100 Bid Solicitation
___ 00200 Instructions to Bidders
___ 00300 Information Available to Bidders
___ 00400 Bid Forms and Supplements
___ 00490 Bidding Addenda

CONTRACTING REQUIREMENTS

- ___ 00500 Agreement
- ___ 00600 Bonds and Certificates
- ___ 00700 General Conditions
- ___ 00800 Supplementary Conditions
- ___ 00900 Addenda and Modifications

FACILITIES AND SPACES

SYSTEMS AND ASSEMBLIES

CONSTRUCTION PRODUCTS AND ACTIVITIES

DIVISION 1—GENERAL REQUIREMENTS

- ___ 01100 Summary
- ___ 01200 Price and Payment Procedures
- ___ 01300 Administrative Requirements
- ___ 01400 Quality Requirements
- ___ 01500 Temporary Facilities and Controls
- ___ 01600 Product Requirements
- ___ 01700 Execution Requirements
- ___ 01800 Facility Operation
- ___ 01900 Facility Decommissioning

DIVISION 2—SITE CONSTRUCTION

- ___ 02050 Basic Site Materials and Methods
- ___ 02100 Site Remediation
- ___ 02200 Site Preparation
- ___ 02300 Earthwork
- ___ 02400 Tunneling, Boring, and Jacking
- ___ 02450 Foundation and Load-Bearing Elements
- ___ 02500 Utility Services
- ___ 02600 Drainage and Containment
- ___ 02700 Bases, Ballasts, Pavements, and Appurtenances
- ___ 02800 Site Improvements and Amenities
- ___ 02900 Planting
- ___ 02950 Site Restoration and Rehabilitation

DIVISION 3—CONCRETE

- ___ 03050 Basic Concrete Materials and Methods
- ___ 03100 Concrete Forms and Accessories
- ___ 03200 Concrete Reinforcement
- ___ 03300 Cast-In-Place Concrete
  - ___ 03310 Structural Concrete
  - ___ 03330 Architectural Concrete
  - ___ 03340 Low-Density Concrete

- ___ 03350 Concrete Finishing
- ___ 03360 Concrete Finishes
- ___ 03370 Specially Placed Concrete
- ___ 03380 Post-Tensioned Concrete
- ___ 03390 Concrete Curing

___ 03400 Precast Concrete
___ 03500 Cementitious Decks and Underlayment
___ 03600 Grouts
___ 03700 Mass Concrete
___ 03900 Concrete Restoration and Cleaning

DIVISION 4—MASONRY
___ 04050 Basic Masonry Materials and Methods
___ 04200 Masonry Units
- ___ 04210 Clay Masonry Units
- ___ 04220 Concrete Masonry Units
- ___ 04230 Calcium Silicate Masonry Units
- ___ 04270 Glass Masonry Units
- ___ 04290 Adobe Masonry Units

___ 04400 Stone
___ 04500 Refractories
___ 04600 Corrosion-Resistant Masonry
___ 04700 Simulated Masonry
___ 04800 Masonry Assemblies
___ 04900 Masonry Restoration and Cleaning

DIVISION 5—METALS
___ 05050 Basic Metal Materials and Methods
___ 05100 Structural Metal Framing
___ 05200 Metal Joists
___ 05300 Metal Deck
___ 05400 Cold-Formed Metal Framing
___ 05500 Metal Fabrications
- ___ 05510 Metal Stairs and Ladders
- ___ 05520 Handrails and Railings
- ___ 05530 Gratings
- ___ 05540 Floor Plates
- ___ 05550 Stair Treads and Nosings
- ___ 05560 Metal Castings
- ___ 05580 Formed Metal Fabrications

___ 05600 Hydraulic Fabrications
- ___ 05650 Railroad Track and Accessories

___ 05700 Ornamental Metal
___ 05800 Expansion Control
___ 05900 Metal Restoration and Cleaning

DIVISION 6—WOOD AND PLASTICS

- ___ 06050 Basic Wood and Plastic Materials and Methods
- ___ 06100 Rough Carpentry
  - ___ 06110 Wood Framing
  - ___ 06120 Structural Panels
  - ___ 06130 Heavy Timber Construction
  - ___ 06140 Treated Wood Foundations
  - ___ 06150 Wood Decking
  - ___ 06160 Sheathing
  - ___ 06170 Prefabricated Structural Wood
  - ___ 06180 Glue-Laminated Construction
- ___ 06200 Finish Carpentry
  - ___ 06220 Millwork
  - ___ 06250 Prefinished Paneling
  - ___ 06260 Board Paneling
  - ___ 06270 Closet and Utility Wood Shelving
- ___ 06400 Architectural Woodwork
  - ___ 06410 Custom Cabinets
  - ___ 06415 Countertops
  - ___ 06420 Paneling
  - ___ 06430 Wood Stairs and Railings
  - ___ 06440 Wood Ornaments
  - ___ 06445 Simulated Wood Ornaments
  - ___ 06450 Standing and Running Trim
  - ___ 06455 Simulated Wood Trim
  - ___ 06460 Wood Frames
  - ___ 06470 Screens, Blinds, and Shutters
- ___ 06500 Structural Plastics
- ___ 06600 Plastic Fabrications
- ___ 06900 Wood and Plastic Restoration and Cleaning

DIVISION 7—THERMAL AND MOISTURE PROTECTION

- ___ 07050 Basic Thermal and Moisture Protection Materials and Methods
- ___ 07100 Dampproofing and Waterproofing
  - ___ 07110 Dampproofing
  - ___ 07120 Built-up Bituminous Waterproofing
  - ___ 07130 Sheet Waterproofing
  - ___ 07140 Fluid-Applied Waterproofing
  - ___ 07150 Sheet Metal Waterproofing
  - ___ 07160 Cementitious and Reactive Waterproofing
  - ___ 07170 Bentonite Waterproofing
  - ___ 07180 Traffic Coatings
  - ___ 07190 Water Repellants
- ___ 07200 Thermal Protection

- ___ 07210 Building Insulation
- ___ 07220 Roof and Deck Insulation
- ___ 07240 Exterior Insulation and Finish Systems (EIFS)
- ___ 07260 Vapor Retarders
- ___ 07270 Air Barriers

___ 07300 Shingles, Roof Tiles, and Roof Coverings

- ___ 07310 Shingles (Asphalt, Fiberglass Reinforced, Metal, Mineral Fiber Cement, Plastic Shakes, Porcelain Enamel, Slate, Wood, and Wood Shakes)
- ___ 07320 Roof Tiles (Clay, Concrete, Metal, Mineral Fiber Cement, Plastic)
- ___ 07330 Roof Coverings

___ 07400 Roofing and Siding Panels

- ___ 07410 Metal Roof and Wall Panels
- ___ 07420 Plastic Roof and Wall Panels
- ___ 07430 Composite Panels
- ___ 07440 Faced Panels
- ___ 07450 Fiber-Reinforced Cementitious Panels
- ___ 07460 Siding (Aluminum, Composition, Hardboard, Mineral Fiber Cement, Plastic, Plywood, Steel, and Wood)
- ___ 07470 Wood Roof and Wall Panels
- ___ 07480 Exterior Wall Assemblies

___ 07500 Membrane Roofing

- ___ 07510 Built-up Roofing
- ___ 07520 Cold-Applied Bituminous Roofing
- ___ 07530 Elastomeric Membrane Roofing (CPE, CSPE, CPA, EPDM, NBP, and PIB)
- ___ 07540 Thermoplastic Membrane Roofing (EIP, PVC, and TPA)
- ___ 07550 Modified Bituminous Membrane Roofing
- ___ 07560 Fluid-Applied Roofing
- ___ 07570 Coated Foamed Roofing
- ___ 07580 Roll Roofing
- ___ 07590 Roof Maintenance and Repairs

___ 07600 Flashing and Sheet Metal

- ___ 07610 Sheet Metal Roofing
- ___ 07620 Sheet Metal Flashing and Trim
- ___ 07630 Sheet Metal Roofing Specialties
- ___ 07650 Flexible Flashing

___ 07700 Roof Specialties and Accessories

- ___ 07710 Manufactured Roof Specialties (Copings, Counterflashing, Gravel Stops and Fascias, Gutters and Downspouts, Reglets, Roof Expansion Assemblies, and Scuppers)

- ___ 07720 Roof Accessories (Manufactured Curbs, Relief Vents, Ridge Vents, Roof Hatches, Roof Walk Boards, Roof Walkways, Smoke Vents, Snow Guards, and Waste Containment Assemblies)
- ___ 07760 Roof Pavers

___ 07800 Fire and Smoke Protection

- ___ 07810 Applied Fireproofing
- ___ 07820 Board Fireproofing
- ___ 07840 Firestopping
- ___ 07860 Smoke Seals
- ___ 07870 Smoke Containment Barriers

___ 07900 Joint Sealers

DIVISION 8—<u>DOORS AND WINDOWS</u>

___ 08050 Basic Door and Window Materials and Methods

___ 08100 Metal Doors and Frames

- ___ 08110 Steel
- ___ 08120 Aluminum
- ___ 08130 Stainless Steel
- ___ 08140 Bronze
- ___ 08150 Preassembled Metal Door and Frame Units
- ___ 08160 Sliding Metal Doors and Grilles
- ___ 08180 Metal Screen and Storm Doors
- ___ 08190 Metal Door Restoration

___ 08200 Wood and Plastic Doors

___ 08300 Specialty Doors

- ___ 08310 Access Doors and Panels
- ___ 08320 Detention Doors and Frames
- ___ 08330 Coiling Doors and Grilles
- ___ 08340 Special Function
- ___ 08350 Folding Doors and Grilles
- ___ 08360 Overhead Doors
- ___ 08370 Vertical Lift Doors
- ___ 08380 Traffic Doors
- ___ 08390 Pressure-Resistant Doors

___ 08400 Entrances and Storefronts

- ___ 08410 Metal-Framed Storefronts
- ___ 08450 All-Glass Entrances and Storefronts
- ___ 08460 Automatic Entrance Doors
- ___ 08470 Revolving Entrance Doors
- ___ 08480 Balanced Entrance Doors
- ___ 08490 Sliding Storefronts

___ 08500 Windows

- ___ 08510 Steel
- ___ 08520 Aluminum
- ___ 08530 Stainless Steel

    ___ 08540 Bronze
    ___ 08550 Wood
    ___ 08560 Plastic
    ___ 08570 Composite
    ___ 08580 Special Function
    ___ 08590 Window Restoration and Replacement
___ 08600 Skylights
___ 08700 Hardware
___ 08800 Glazing
    ___ 08810 Glass
    ___ 08830 Mirrors
    ___ 08840 Plastic Glazing
    ___ 08850 Glazing Accessories
    ___ 08890 Glazing Restoration
___ 08900 Glazing Curtain Wall
    ___ 08910 Metal-Framed Curtain Wall
    ___ 08950 Translucent Wall and Roof Assemblies
    ___ 08960 Sloped Glazing Assemblies
    ___ 08970 Structural Glass Curtain Walls
    ___ 08990 Glazed Curtain Wall Restoration

DIVISION 9—FINISHES
___ 09050 Basic Finish Materials and Methods
___ 09100 Metal Support Assemblies
___ 09200 Plaster and Gypsum Board
___ 09300 Tile
    ___ 09305 Tile Setting Materials and Accessories
    ___ 09310 Ceramic
    ___ 09330 Quarry
    ___ 09340 Paver
    ___ 09350 Glass Mosaics
    ___ 09360 Plastic
    ___ 09370 Metal
    ___ 09380 Cut Natural Stone Tile
    ___ 09390 Tile Restoration
___ 09400 Terrazzo
___ 09500 Ceilings
    ___ 09510 Acoustical
    ___ 09545 Specialty
    ___ 09550 Mirror Panel Ceilings
    ___ 09560 Textured
    ___ 09570 Linear Wood
    ___ 09580 Suspended Decorative Grids
    ___ 09590 Ceiling Assembly Restoration
___ 09600 Flooring
    ___ 09610 Floor Treatment

- ___ 09620 Specialty Flooring
- ___ 09630 Masonry
- ___ 09640 Wood
- ___ 09650 Resilient
- ___ 09660 Static Control
- ___ 09670 Fluid Applied
- ___ 09680 Carpet
- ___ 09690 Flooring Restoration

___ 09700 Wall Finishes
- ___ 09710 Acoustical Wall Treatment
- ___ 09720 Wall Covering
- ___ 09730 Wall Carpet
- ___ 09740 Flexible Wood Sheets
- ___ 09750 Stone Facing
- ___ 09760 Plastic Blocks
- ___ 09770 Special Wall Surfaces
- ___ 09790 Wall Finish Restoration

___ 09800 Acoustical Treatment
- ___ 09810 Acoustical Space Units
- ___ 09820 Acoustical Insulation and Sealants
- ___ 09830 Acoustical Barriers
- ___ 09840 Acoustical Wall Treatment

___ 09900 Paints and Coatings
- ___ 09910 Paints
- ___ 09930 Stains and Transparent Finishes
- ___ 09940 Decorative Finishes
- ___ 09960 High-Performance Coatings
- ___ 09970 Coatings for Steel
- ___ 09980 Coatings for Concrete and Masonry
- ___ 09990 Paint Restoration

DIVISION 10—<u>SPECIALTIES</u>

- ___ 10100 Visual Display Boards
- ___ 10150 Compartments and Cubicles
- ___ 10200 Louvers and Vents
- ___ 10240 Grilles and Screens
- ___ 10250 Service Walls
- ___ 10260 Wall and Corner Guards
- ___ 10270 Access Flooring
- ___ 10290 Pest Control
- ___ 10300 Fireplaces and Stoves
- ___ 10340 Manufactured Exterior Specialties
- ___ 10350 Flagpoles
- ___ 10400 Identification Devices
- ___ 10450 Pedestrian Control Devices
- ___ 10500 Lockers

___ 10520 Fire Protection Specialties
___ 10530 Protective Covers
___ 10550 Postal Specialties
___ 10600 Partitions
___ 10670 Storage Shelving
___ 10700 Exterior Protection
___ 10750 Telephone Specialties
___ 10800 Toilet, Bath, and Laundry Accessories
___ 10880 Scales
___ 10900 Wardrobe and Closet Specialties

DIVISION 11—EQUIPMENT
___ 11010 Maintenance Equipment
___ 11020 Security and Vault Equipment
___ 11030 Teller and Service Equipment
___ 11040 Ecclesiastical Equipment
___ 11050 Library Equipment
___ 11060 Theater and Stage Equipment
___ 11070 Instrumental Equipment
___ 11080 Registration Equipment
___ 11090 Checkroom Equipment
___ 11100 Mercantile Equipment
___ 11110 Commercial Laundry and Dry Cleaning Equipment
___ 11120 Vending Equipment
___ 11130 Audiovisual Equipment
___ 11140 Vehicle Service Equipment
___ 11150 Parking Control Equipment
___ 11160 Loading Dock Equipment
___ 11170 Solid Waste Handling Equipment
___ 11190 Detention Equipment
___ 11200 Water Supply and Treatment Equipment
___ 11280 Hydraulic Gates and Valves
___ 11300 Fluid Waste Treatment and Disposal Equipment
___ 11400 Food Service Equipment
___ 11450 Residential Equipment
___ 11460 Unit Kitchens
___ 11470 Darkroom Equipment
___ 11480 Athletic, Recreational, and Therapeutic Equipment
___ 11500 Industrial and Process Equipment
___ 11600 Laboratory Equipment
___ 11650 Planetarium Equipment
___ 11660 Observatory Equipment
___ 11680 Office Equipment
___ 11700 Medical Equipment
___ 11780 Mortuary Equipment

___ 11850 Navigation Equipment
___ 11870 Agricultural Equipment
___ 11900 Exhibit Equipment

DIVISION 12—FURNISHINGS
___ 12050 Fabrics
___ 12100 Art
___ 12300 Manufactured Casework
___ 12400 Furnishings and Accessories
___ 12500 Furniture
___ 12600 Multiple Seating
___ 12700 Systems Furniture
___ 12800 Interior Plants and Planters
___ 12900 Furnishings Restoration and Repair

DIVISION 13—SPECIAL CONSTRUCTION
___ 13010 Air-Supported Structures
___ 13020 Building Modules
___ 13030 Special-Purpose Rooms
___ 13080 Sound, Vibration, and Seismic Control
___ 13090 Radiation Protection
___ 13100 Lightning Protection
___ 13110 Cathodic Protection
___ 13120 Preengineered Structures
___ 13150 Swimming Pools
___ 13160 Aquariums
___ 13165 Aquatic Park Facilities
___ 13170 Tubs and Pools
___ 13175 Ice Rinks
___ 13185 Kennels and Animal Shelters
___ 13190 Site-Constructed Incinerators
___ 13200 Storage Tanks
___ 13220 Filter Underdrains and Media
___ 13230 Digester Covers and Appurtenances
___ 13240 Oxygenation Systems
___ 13260 Sludge Conditioning Systems
___ 13280 Hazardous Material Remediation
___ 13400 Measurement and Control Instrumentation
___ 13500 Recording Instrumentation
___ 13550 Transportation Control Instrumentation
___ 13600 Solar and Wind Energy Equipment
___ 13700 Security Access and Surveillance
___ 13800 Building Automation and Control
___ 13850 Detection and Alarm
___ 13900 Fire Suppression

DIVISION 14—CONVEYING SYSTEMS

___ 14100 Dumbwaiters
___ 14200 Elevators
___ 14300 Escalators and Moving Walks
___ 14400 Lifts
___ 14500 Material Handling
___ 14600 Hoists and Cranes
___ 14700 Turntables
___ 14800 Scaffolding
___ 14900 Transportation

DIVISION 15—MECHANICAL

___ 15050 Basic Mechanical Materials and Methods
___ 15100 Building Services Piping
___ 15200 Process Piping
___ 15300 Fire Protection Piping
___ 15400 Plumbing Fixtures and Equipment
___ 15500 Heat-Generation Equipment
___ 15600 Refrigeration Equipment
___ 15700 Heating, Ventilating, and Air Conditioning Equipment
___ 15800 Air Distribution
___ 15900 HVAC Instrumentation and Controls
___ 15950 Testing, Adjusting, and Balancing

DIVISION 16—ELECTRICAL

___ 16050 Basic Electrical Materials and Methods
___ 16100 Wiring Methods
___ 16200 Electrical Power
___ 16300 Transmission and Distribution
___ 16400 Low-Voltage Distribution
___ 16500 Lighting
___ 16700 Communications
___ 16800 Sound and Video

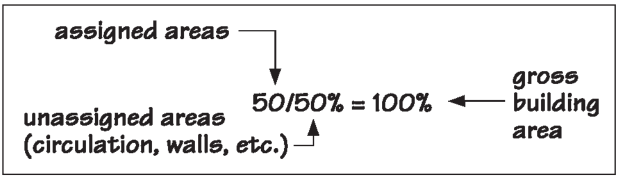
NOTES

___ D. PROGRAMMING (E) (5) (52)

___ 1. ***Programming*** is a process leading to the statement of an architectural problem and the requirements to be met in offering a solution. It is the search for sufficient information to clarify, to understand, to state the problem. Programming is problem seeking and design is problem solving.

___ 2. **Use the Information Index** on pp. 40–41 as a guide for creating a program for more complex projects.

___ 3. **Efficiency Ratios:** Use the following numbers to aid in planning the size of buildings in regard to the ratio of net area to gross area:



Note: The gross area of a building is the total floor area based on outside dimensions. The net area is based on the interior dimensions. For office or retail space, net leasable area means the area of the primary function of the building excluding such things as stairwells, corridors, mech. rooms, etc.

Automobile analogy	For buildings	Ratios
	Common Range	
Super Luxury	Superb	50/50
Luxury	Grand	55/45
Full	Excellent	60/40
Intermediate	Moderate	65/35
Compact	Economical	67/33
Subcompact	Austere	70/30
	Uncommon Range	
	Meager	75/25
	Spare	80/20
	Minimal	85/15
	Skeletal	90/10

See App. A, item B, p. 621 for common ratios by building type.

The following table gives common breakdowns of unassigned areas:

Circulation	16.0	20.0	22.0	24.0	25.0
Mechanical*	5.0	5.5	7.5	8.0	10.0
Structure and walls	7.0	7.0	8.0	9.5	10.0
Public toilets	1.5	1.5	1.5	2.0	2.5
Janitor closets	0.2	0.5	0.5	0.5	1.0
Unassigned storage	0.3	0.5	0.5	1.0	1.5
	30.0%	35.0%	40.0%	45.0%	50.0%

* More detailed HVAC systems space requirements as a percentage of building gross floor area:

Gross floor area (SF)	Residential	Institutional	Assembly	Laboratory
10,000	6	8	9	11
50,000–100,000	4	6	7	10
500,000	3	4	5	8

NOTES

INFORMATION INDEX (52)

	GOALS What does the client want to achieve & why?	**FACTS** What is it all about?
FUNCTION What's going to happen in the building? People Activities Relationships	Mission Maximum number Individual identity Interaction/privacy Hierarchy of values Security Progression Segregation Encounters Efficiency	Statistical data Area parameters Manpower/workloads User characteristics Community characteristics Value of loss Time-motion study Traffic analysis Behavioral patterns Space adequacy
FORM What is there now & what is to be there? Site Environment Quality	Site elements (Trees, water, open space, existing facilities, utilities) Efficient land use Neighbors Individuality Direction Entry Projected image Level of quality	Site analysis Climate analysis Cope survey Soils analysis F.A.R. and G.A.C. Surroundings Psychological implications Cost/SF Building efficiency Functional support
ECONOMY Concerns the initial budget & quality of construction. Initial budget Operating costs Lifecycle costs	Extent of funds Cost effectiveness Maximum return Return on investment Minimize oper. costs Maint. & oper. costs Reduce life cycle costs	Cost parameters Maximum budget Time-use factors Market analysis Energy source-costs Activities & climate factors Economic data
TIME Deals with the influences of history, the inevitability of change from the present, & projections into the future. Past Present Future	Historic preservation Static/dynamic Change Growth Occupancy date	Significance Space parameters Activities Projections Linear schedule

CONCEPTS How does the client want to achieve the goals?	**NEEDS** How much money, space, & quality (as opposed to wants)?	**PROBLEM** What are the significant conditions & the general directions the design of the building should take?
Service grouping People grouping Activity grouping Priority Security controls Sequential flow Separated flow Mixed flow Relationships	Space requirements Parking requirements Outdoor space req'mts. Building efficiency Functional alternatives	Unique and important performance requirements which will shape building design.
Enhancement Climate control Safety Special foundations Density Interdependence Home base Orientation Accessibility Character Quality control	Quality (cost/SF) Environmental & site influences on costs	Major form considerations which will affect building design.
Cost control Efficient allocation Multifunction Merchandising Energy conservation Cost control	Cost estimate analysis Entry budget (FRAS) Operating costs Life cycle costs	Attitude toward the initial budget and its influence on the fabric and geometry of the building.
Adaptability Tailored/loose fit Convertibility Expansibility Concurrent scheduling	Phasing Escalation	Implications of change/growth on long-range performance.

NOTES

___ E. CONSTRUCTION COSTS

Note: Most costs throughout this book (and this chapter) are from the following sources:

(C) (9) (15) (21) (22) (23) (43) (44) (52) (55)

These references are used throughout the book, although not identified at specific places.

___ 1. **This book has rough cost data throughout.** Rough costs are **boldface.** Subcontractor's overhead and profit, plus tax, are included. Both material (M) and labor (L) are included, usually with a general idea of percentage of each to the total (100%). Because there is room for only one cost per "element," often an idea of possible variation (higher or lower) of cost is given. Sometimes two numbers are given—the first being for residential and the second for commercial. One must use judgment in this regard to come up with a reasonable but rough cost estimate. As costs change, the user will have to revise costs in this book. The easiest way to do this will be to add historical modifiers, published each year, by various sources. The costs in this book are approx. costs at mid-2009. Over the last few years costs have increased about 2% to 4% per year. Be sure to compound when using this rule of thumb. See p. 60 for compounding.

EXAMPLE:

A CONSTRUCTION ITEM IN THE BOOK GIVES THE FOLLOWING:
$5.00/SF (40% M & 60% L)(VARIATION OF +100% & −20%).
THIS MEANS THAT AS A GOOD AVERAGE, THE COST OF THE ITEM INSTALLED (WITH THE SUB CONTRACTOR'S OVERHEAD AND PROFIT INCLUDED) IS $5/SF. THE MATERIAL COST IS APPROX. $5 × .40 = $2/SF. THE LABOR COST IS APPROX. $5 × .60 = $3/SF. HOWEVER, A VERY EXPENSIVE VERSION CAN BE ROUGHLY 100% HIGHER ($5 × 2 = $10/SF) OR A CHEAPER VERSION CAN BE ROUGHLY 20% LOWER ($5 × .80 = $4/SF). BUT THE APPROX. AVERAGE IS $5/SF. NOTE THAT THE GENERAL CONTRACTOR'S OVERHEAD AND PROFIT IS NOT INCLUDED. IF THE COST IS SAY 2 YEARS OLD, ASSUMING 3% INFLATION/YEAR, THE $5/SF NOW BECOMES: $5/SF × 1.03 = $5.15/SF × 1.03 = $5.31/SF. A FINAL FACTOR IS LOCATION PER ITEM V OF APPENDIX B. IF YOUR LOCATION IS 90%, THE FINAL ESTIMATED COST IS .9 × $5.31 = $4.78/SF.

___ 2. **Cost Control and Estimating**

Cost estimating can be time-consuming. It can also be dangerous in that wrong estimates may require time-consuming and expensive redesign. From the beginning of a project, responsibility for cost control (if any) should clearly be established. If the architect is responsible for doing estimates, the architect should consider the following points:

___ *a.* Apples to Apples: In discussing costs and budgets with clients and builders, the parties must be sure they are comparing "apples to apples" (i.e., what is included and excluded). Examples of misunderstandings:

___ (1) Cost of land (is usually excluded).
___ (2) Financing costs (are usually excluded).
___ (3) Architectural/Engineering (A/E) fees (are usually excluded).
___ (4) City or government fees (are usually excluded).
___ (5) Is site work included or excluded in a $/SF estimate?
___ (6) Are Furniture, Fixture, and Equipment (FF&E) costs included or excluded (usually excluded)?

EXAMPLE:

AN ARCHITECT IS WORKING FOR A "SPEC" BUILDER. THE ARCHITECT HAS IN MIND A $80/SF BUDGET. THE SPEC. BUILDER HAS IN MIND A $90/SF BUDGET. THE ARCHITECT'S NUMBER HAS A GENERAL CONTRACTOR'S O.H. & P. OF SAY, 20% AS IF THE PROJECT WERE BID OR NEGOTIATED WITH AN INDEPENDENT CONTRACTOR. THE SPEC. BUILDER IS THINKING ABOUT HIS DIRECT COSTS, ONLY. THEY ARE COMPARING "APPLES TO ORANGES", BUT IF THE BUILDER'S NUMBER IS ADJUSTED:

$80/SF × 1.20 = $96/SF

OR IF THE ARCHITECT'S NUMBER IS ADJUSTED:

$90/SF × 0.80 = $72/SF

THEN, THEY ARE TALKING "APPLES TO APPLES".

___ *b.* Variables: The $/SF figures for various building types shown in App. A, item D are for average simple buildings. They (as all other costs in this book) may need to be modified by the following variables:

___ (1) *Location.* Modify costs for actual location. Use modifiers often published or see App. B, item V.

___ (2) *Historical Index.* If cost data is old, modify to current or future time by often-published modifiers.

___ (3) *Building Size.* The $/SF costs may need to be modified due to size of the project (see App. A, item C). Median sizes may be modified roughly as follows:

As size goes down, cost goes up by ratio of *1 to 2.*

As size goes up, cost goes down by ratio of *3 to 1.*

___ (4) *Shape and Perimeter.* Increases in perimeter and more complicated shapes will cause costs to go up. Where single elements are articulated (e.g., rounded corners or different types of coursing and materials in a masonry wall), add 30% to the costs involved.

___ (5) *Height.* As the number of stories goes up the cost goes up due to structure, fire protection, life safety issues, etc. **For each additional story add 1% to 5%.**

___ (6) *Quality of Materials, Construction, and Design.* Use the following rough guidelines to increase or decrease as needed:

Automobile analogy	For buildings	%
Super Luxury	Superb	+120
Luxury	Grand	+60
Full	Excellent	+20
Intermediate	Moderate	100
Compact	Economical	–10
Subcompact	Austere	–20

Note: Quality from lowest to highest can double the cost.

__ (7) *Familiarity.* A builder's familiarity (or lack of) with a building or construction type will affect price.

__ *c.* Costs (and construction scheduling) can be affected by weather, season, materials shortages, labor practices.

__ *d.* Beyond a 20-mile radius of cities, extra transportation charges increase material costs, slightly. This may be offset by lower wage rates. In dense urban areas costs may increase.

__ *e.* In doing a total estimate, an allowance for general conditions should be added. This usually ranges from 5 to 15%, with *10%* a typical average.

__ *f.* At the end of a total estimate, an allowance for the general contractor's overhead and profit should be added. This usually ranges from *10 to 20%.* Market conditions at the time of bidding will often affect this percentage as well as all items. The market can swing 10 to 20% from inactive to active times.

__ *g.* Contingencies should always be included in estimates as listed below. On alterations or repair projects, *20%* is not an unreasonable allowance to make.

__ *h.* Use rounding of numbers in all estimating items.

__ *i.* Consider using "add alternates" to projects where the demand is high but the budget tight. These alternates should be things the client would like but does not have to have and should be clearly denoted in the drawings.

__ *j.* It is often wise for the architect to give estimates in a range.

__ *k.* Because clients often change their minds or things go wrong that cannot be foreseen in the beginning, it may pay to advise the client to withhold from his budget a confidential *5 to 10%* contingency. On the other hand, clients often do this anyway, without telling the architect.

__ *l.* Costs can further be affected by other things:

Government overhead	≈+100%
Award-winning designs are often	≈+200 to 300%

__ **3. Cost Control Procedure**

__ *a.* At the *predesign phase* or beginning of a project, determine the client's *budget* and what it includes, as well as anticipated size of the building. Back out all non construction costs such as cost of land, furniture and fixtures, design fees, etc. Verify, in a simple format (such as $/SF, $/room, etc.) that this is reasonable. See App. A, item D for average $/SF costs as a comparison and guideline.

___ *b.* At the *schematic design phase,* establish a reasonable $/SF target. Include a *15% to 20% contingency.*

___ *c.* At the *design development phase,* as the design becomes more specific, do a "systems" estimate. See Part 13 as an aid. For small projects a "unit" estimate might be appropriate, especially if basic plans (i.e., framing plans, etc.) not normally done at this time can be quickly sketched up for a "take off." Include a *10% to 15% contingency.*

___ *d.* At the *construction documents phase,* do a full unit "take off." For smaller projects, the estimate in the last phase may be enough, provided nothing has changed or been added to the project. Add a *5% to 10% contingency.*

___ **4. Typical Single Family Residential Costs**

The following guidelines may be of use to establish $/SF budgets (site work not included):

___ *a.* Production Homes:

___ (1) For a 4-corner, 1600-SF tract house, wood frame, 1 story, with a 450-SF garage, no basement, and of average quality, use ***$95.00/SF*** (conditioned area only) as a 2009 national average. Break down as follows:

	Item	*% of total*
1	General (including O & P)	18.5
2	Sitework (excavation only)	1
3	Concrete	6
4	Masonry (brick hearth and veneer)	.5
5	Metals	
6	Wood	
	Rough carpentry	17
	Finish carpentry and cabinetry	7.5
7	Thermal and moisture protection (insulation and roofing)	8
8	Doors, windows, and hardware	4
9	Finishes (stucco, wallboard, resilient flooring, carpet, paint)	19
10	Specialties (bath accessories and prefab fireplace)	1.5
11	Equipment (built-in appliances)	1.5
12–14		
15	Mechanical	
	Plumbing	8
	HVAC (heating only)	3
16	Electrical (lighting and wiring)	4.5
		100%

___ (2) Modify as follows:

___ *(a)* For "tract" or repetitive homes deduct 8% to 12%.

___ *(b)* For perimeter per the following percentages:
For 6 corners, add 2½%. For 8 corners add 5½%. For 10 corners add 7½%.

___ *(c)* Quality of construction:

Low	*Average*	*Good*	*Best*
−15%	100%	+20%	+50%

___ *(d)* Deduct for rural areas: 5%

___ *(e)* Add for 1800-SF house (better quality) 4%

___ *(f)* Add for 2000-SF house (better quality) 3%

___ *(g)* Deduct for over 2400 SF house (same quality) 3%

___ *(h)* Add for second story 4%

___ *(i)* Add for split-level house 3%

___ *(j)* Add for 3-story house 10%

___ *(k)* Add for masonry construction 9%

___ *(l)* Add for finished basement 40%

___ *(m)* Adjust for garage (larger or smaller): use 50% of house area.

___ *(n)* *No site work is included!*

___ *b.* Custom-designed homes:
The result of the above can be easily increased by ⅓ to ¾ or more. See App. A, p. 621.

___ **5. <u>Typical Commercial Building Cost Percentages</u>**

Division	New const.	Remodeling
1. General requirements	6 to 8%	about 30%
2. Sitework	4 to 6%	for general
3. Concrete	15 to 20%	
4. Masonry	8 to 12%	
5. Metals	5 to 7%	
6. Wood	1 to 5%	
7. Thermal and moisture protection	4 to 6%	
8. Doors, windows, and glass	5 to 7%	
9. Finishes	8 to 12%	about 30%

10. Specialties*		for divisions
11. Equipment*		8–12
12. Furnishings*	6 to 10%*	
13. Special construction*		
14. Conveying systems*		about 40%
15. Mechanical	15 to 25%	for mech.
16. Electrical	8 to 12%	and elect.
Total	100%	

**Note:* FF&E (Furniture, Fixtures, and Equipment) are often excluded from building cost budget.

___ **6. Guidelines for Tenant Improvements (TI) in Office Buildings:**

___ *a.* To estimate costs: take full building costs (see App. A, item D) less cost for frame and envelope and less ½ mech. and elect. costs.

___ *b.* **Costs for office building frames and envelopes: $40 to $50/SF.**

___ *c.* **TI costs range from $35 to $65/SF (in extreme cases $120/SF).**

___ **7. Guidelines for Demolition**

___ *a.* Total buildings: ***$6 to $10/SF***

___ *b.* Separate elements: ***10% to 50%*** of in-place const. cost of element.

___ **8. Project Budgeting**

___ *a.* At the programming phase a total project budget may be worked using the following guidelines:

A. Building cost (net area/efficiency ratio = Gross area, gross area × unit cost = building cost)	$_____
B. Fixed equipment costs (lockers, kit. equip., etc.), percent of line A*	$_____
C. Site development cost, percent of line A*	$_____
D. Total construction cost (A + B + C)	$_____
E. Site acquisition and/or demolition (varies widely)	$_____
F. Movable equipment (such as furnishings) percent of line A* (also see App. A, item F)	$_____
G. Professional fees (vary from 5 to 10%), percent of line D	$_____
H. Contingencies*	$_____

I.	Administrative costs (varies from 1 to 2%), percent of line D†	$_____
J.	Total budget required (D, E–J)	$_____

*Percentages: low: 5%; medium: 10–15%; high: 20%; very high: 30%.

†For those projects which require financing costs, the following can be added to line J:

1. Permanent financing (percent of line K):
   Investment banker fee varies, 2.5 to 6%.
   Construction loan fee varies, 1 to 2%.
2. Interim financing (percent of line D):
   Approximately varies 1.5 to 2% above prime rate per year of construction time.

___ *b.* How to work back from total budget to building cost:

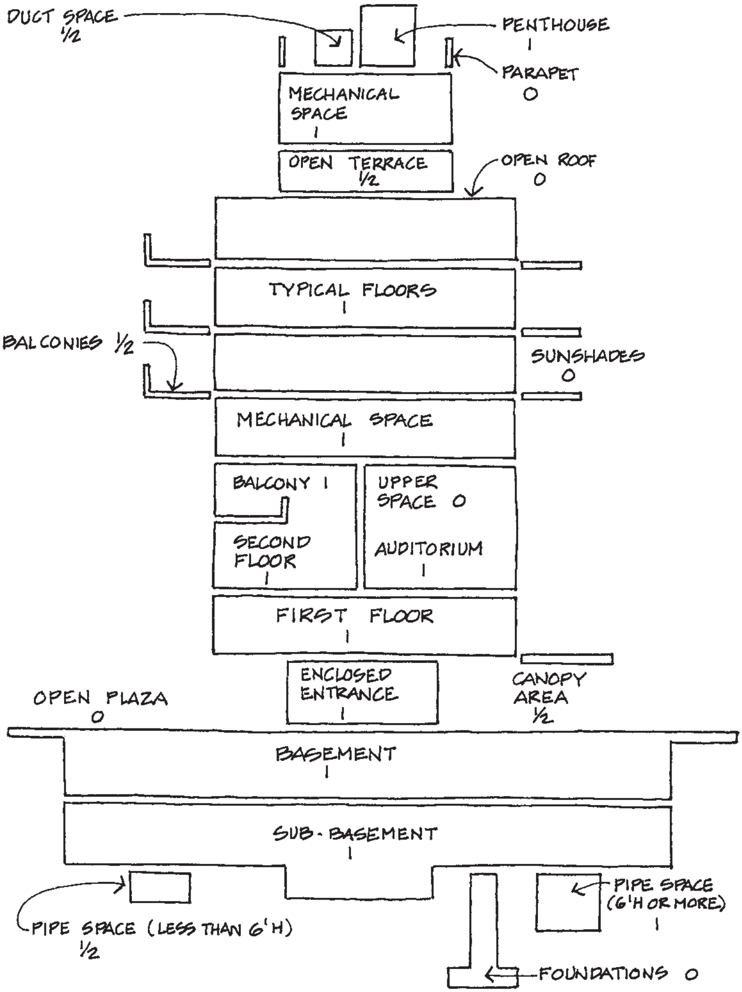
The following formula can be used to reduce line K, total budget required, to line A, building cost:

$$\text{Building cost} = \frac{\text{total budget} - \text{site acquisition}}{X + Y + Z}$$

X = 1 + (___ % fixed equip.) + (___ % site dev.)
Y = (X) [(___ % contingency) + (___ % prof. fee) + (___ % adm. cost)]
Z = ___ % movable equipment

Where necessary, interim financing percentage is added to admin. cost. Permanent financing percentage becomes T in X + Y + Z + T.

___ **9.** **Use Architectural Areas** of Buildings as an aid in cost-estimating. See Architectural Area Diagram on p. 51. When doing "conceptual" estimating, by comparing your project to already built projects you can come up with an adjusted area by adding or subtracting the ratios shown.



ARCHITECTURAL AREA DIAGRAM

EXAMPLE:

PROBLEM: ESTABLISH A FULL PRELM. BUDGET FOR A PROPOSED 25000 SF OFFICE BUILDING ON A 3 ACRE SITE IN WICHITA, KANSAS. WORK UP A RANGE OF LOW, MEDIUM, & HIGH, AND THEN FURTHER DEVELOP THE AVERAGE.

SOLUTION:

	LOW	AVE.	HIGH
A. BASICS			
1. SITE DEV. COSTS (SEE P. 227). THESE ARE $/SF OF SITE LESS BUILDING FOOT PRINT.	3	7	12
2. BUILDING SHELL COSTS (SEE P. 630, APPEN. A, ITEM D). THESE ARE $/SF.	87	113	150
3. T.I. COSTS (SEE P. 49). THESE ARE $/SF.	40	45	50
4. F.F. & E. COSTS (SEE P. 630, APPEN. A, ITEM F). THESE ARE $/SF FOR FURNISHINGS & EQUIP.	12	24	36
B. SPECIFICS		$000	
1. SITE DEV. COSTS: 3AC X 43560 SF/AC LESS 25000 SF BLDG. FOOTPRINT = 105680 SF. MULTIPLY THIS X $/SF IN 1 ABOVE.	634	739.76	1268.16
2. BUILDING SHELL COSTS: 25000 SF X $/SF IN 2, ABOVE.	1812.5	2350	3118.75
S.T. OF G.C. COSTS	$2588.50	$3278.76	$4634.91
SAY:		$ 3 278 000	

3. T.I. COSTS
25000 SF x 75% (SEE P. 630, APP. A, ITEM B) = 18750 SF

– CONTINUED –

LEASE AREA TIMES $/SF OF 3, ABOVE	562.50	656.25	750
SAY:		$ 656 000	
4. F.F. & E. COSTS. MULTIPLY NET AREA OF 18 750 SF X $/SF OF 4, ABOVE	375	468.75	656.25
SAY:		$ 470 000	
5. A/E DESIGN FEES: (%). SEE P. 630, APPEN. A, ITEM E.	3%	6.5%	10%
USE AVE. OF 6.5 % X SHELL & T.I. COSTS OF $ 3 745 000		$ 243 000	

C. SUMMARY

SUMMARY OF AVE. COSTS IN LUMP SUM AND $/SF (GROSS). ADJUST CONST. COSTS FOR WICHITA, KS BY MULTIPLYING BY 0.81 (SEE P. 645, APP. B, ITEM V). ROUND ALL NUMBERS AS THIS IS JUST A PRELIM. BUDGET.

	LUMP SUM	X 0.81 ADJUSTED FOR WICHITA	$/SF (GROSS)
SITE DEV. COSTS:	730 700	599 200	24.00
BUILD'G. SHELL:	2 350 000	1 903 500	76.00
T.I. COSTS:	656 000	521 300	21.00
S.T., G.C. COSTS		$ 3 024 000	$ 121.00/SF
F.F. & E. COSTS		470 000	19.00
A/E FEES		243 400	10.00
TOTALS:		$ 3 737 400	$ 150/SF

___ 10. Value Engineering and Life Cycle Costing

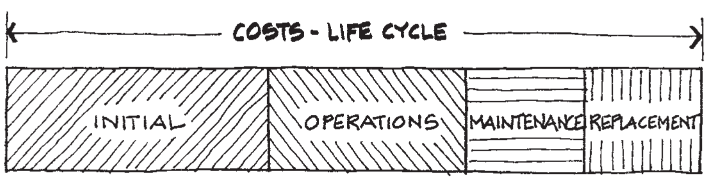
The initial cost of a building appears quite insignificant when compared to the costs incurred to operate and maintain a building over its lifetime. For a 20- to 30-year period, these costs can amount to three or four times the initial cost of construction. Even more impressive is the difference between initial cost and the long-term salary expenditures needed for carrying out the work in a building, where the amount spent on salaries of the people working in the building over 20 to 30 years can be up to 50 times, or more, the initial construction costs.

Considering the overall life of buildings, value engineering (or life cycle costing) is a systematic approach to obtaining optimum value for every dollar spent. *Value* is defined as "the best cost to accomplish the function." From this, *value engineering* then becomes the identification of unnecessary cost. Through a system of investigation, unnecessary expenditures are avoided, resulting in improved value and economy.

In contrast to cost cutting by simply making smaller quantities or using fewer or cheaper materials, this approach analyzes function or method by asking these questions:

What is it?
What does it do?
What must it do?
What does it cost?
What other material or method could be used to do the same job?
What would the alternative cost?

Life cycle costing looks at the total cost over the life of the building as expressed by the following formula: life cycle cost = first cost + maintenance and repair costs + operation costs + replacement costs – salvage value.



NOTES

NOTES

___ F. CONSTRUCTION ADMINISTRATION (43)

___ 1. **Estimate Scheduling**

Project value	*Const. time*
Under $1,400,000	10 months
Up to $3,800,000	15 months
Up to $19,000,000	21 months
Over $19,000,000	28 months

___ *a.* Design time runs 25 to 40% of construction time (up to 100% for small projects, including government review).

___ *b.* Construction time can be affected by building type. Using commercial buildings as a base, modify other building types: industrial: –20%; research and development: +20%; institutional buildings: +30%.

___ 2. **Site Observation Visits**

___ *a.* Take:

___ (1) Plans
___ (2) Specifications
___ (3) Project files
___ (4) Tape
___ (5) Chalk
___ (6) Camera
___ (7) Paper
___ (8) Pencil
___ (9) Calculator
___ (10) Checklist
___ (11) Field report forms
___ (12) Flashlight
___ (13) String line and level

___ *b.* List of site visits for small projects:

___ (1) After building stake out is complete
___ (2) After excavation is complete and rebar is in place
___ (3) When foundation is being placed
___ (4) When under-slab utilities and stem walls under way
___ (5) During placement of concrete slab on grade
___ (6) During masonry and/or frame walls and columns and layout of interior walls
___ (7) During floor and/or roof framing, wall and roof sheathing (prior to roofing)
___ (8) During roofing
___ (9) During drywall, plaster, plumbing, electrical, and HVAC
___ (10) At end of project (punch list)

NOTES

___ G. PRACTICAL MATH AND TABLES

(18) (24) (37) (38) (54) (60)

___ 1. ***General***: Architects seldom have to be involved in higher mathematics, but they need to continually do simple math *well.*

- ___ *a.* For rough estimating (such as in this book) an accuracy of more than 90% to 95% is seldom required.
- ___ *b.* Try to have a rough idea of what the answer should be, before the calculation (i.e., does the answer make sense?).
- ___ *c.* Round numbers off and don't get bogged down in trivia.
- ___ *d.* For final exact numbers that are important (such as final building areas), go slow, and recheck calculations at least once.

___ 2. **Decimals of a Foot**

1″ = .08′	7″ = .58′
2″ = .17′	8″ = .67′
3″ = .25′	9″ = .75′
4″ = .33′	10″ = .83′
5″ = .42′	11″ = .92′
6″ = .50′	12″ = 1.0′

Decimals of an Inch

⅛″ = 0.125″	⅝″ = 0.625″
¼″ = 0.250″	¾″ = 0.750″
⅜″ = 0.375″	⅞″ = 0.875″
½″ = 0.50″	1″ = 1.0″

___ 3. **Simple Algebra**

One unknown and two knowns

$A = B/C$
$B = A \times C$
$C = B/A$

Example: $3 = 15/5$
$15 = 3 \times 5$
$5 = 15/3$

___ 4. **Ratios and Proportions**

One unknown and three knowns (cross multiplication)

$$\frac{A}{B} = \frac{C}{D} \qquad \text{Example: } \frac{X}{5} \times \frac{10}{20} \qquad 20\,X = 5 \times 10$$

$$A \times C = B \times D \qquad X = \frac{5 \times 10}{20} = 2.5 \qquad X = 2.5$$

___ 5. **Exponents and Powers**

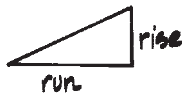
$10^6 = 10 \times 10 \times 10 \times 10 \times 10 \times 10 = 1{,}000{,}000$ [1 + 6 zeros]
$10^0 = 1.0$
$10^{-6} = 0.000001$ [6 places to left or 5 zeros in front of 1]

___ 6. **Percent Increases or Decreases**

50% increase = ½ increase, use × 1.5
100% increase = double, use × 2.0
200% increase = triple, use × 3.0
Example: 20 increases to 25
To find percent increase: 25–20 = 5 [amount of increase]
5/20 = 0.25 or 25% increase

___ 7. **Compounding:** A continual increase or decrease of numbers, over time, that builds on itself. Regarding construction, the % increase of cost per year compounds over the years. Thus, an item that costs $1.00 in 2000 will cost $2.10 in 2005 with 2% inflation per year.

___ 8. **Slopes, Gradients, and Angles**
(see p. 61)



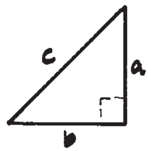
___ *a.* Slope = "rise over run" or

$$\% \text{ slope} = \frac{\text{rise}}{\text{run}} \times 100$$

___ *b.* Gradient:
as ratios of rise to run
Example: expressed as 1 in 12 for a ramp or as 4″ in 12″ for a roof

___ *c.* Angle
Degree angle based on rise and run (see properties of right angles)

___ 9. **Properties of Right Angles**

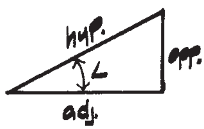


45° angle: $a^2 + b^2 = c^2$

or $c = \sqrt{a^2 + b^2}$

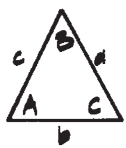
For other right angles use simple *trigonometry*:

Sin angle = opp/hyp
Cos angle = adj/hyp
Tan angle = opp/adj



Use calculators with trig. functions or table on p. 62.

___ 10. **Properties of Non-Right Angles**
Use law of sines:



a/sin A = b/sin B = c/sin C
a/b = sin A/sin B, etc.

___ 11. **Properties of Circles**
A circle is divided into 360 equal parts, called *degrees* (°). One degree is an angle at the center of a circle which cuts off an arc that is 1⁄360 of the circumference. Degrees are subdivided into 60 minutes (′). Minutes are subdivided into 60 seconds (″). See p. 69.

___ 12. **Geometric Figures**
Use the formulas on pp. 67–68 to calculate areas and volumes. Also, see p. 243 for excavation volumes.

__ 13. Equivalents of Measure
See pp. 75 through 82.

Table of Slopes, Grades, Angles

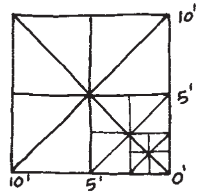
% Slope	Inch/ft	Ratio	Deg. from horiz.
1	⅛	1 in 100	
2	¼	1 in 50	
3	⅜		
4	½	1 in 25	
5	⅝	1 in 20	3
6	¾		
7	⅞		
8	approx. 1	approx. 1 in 12	
9	1⅛		
10	1¼	1 in 10	6
11	1⅜	approx. 1 in 9	
12	1½		
13	1⅝		
14	1¾		
15			8.5
16	1⅞		
17	2	approx. 2 in 12	
18	2⅛		
19	2¼		
20	2⅜	1 in 5	11.5
25	3	3 in 12	14
30	3.6	1 in 3.3	17
35	4.2	approx. 4 in 12	19.25
40	4.8	approx. 5 in 12	21.5
45	5.4	1 in 2.2	24
50	6	6 in 12	26.5
55	6⅝	1 in 1.8	28.5
60	7¼	approx. 7 in 12	31
65	7¾	1 in 1½	33
70	8⅜	1 in 1.4	35
75	9	1 in 1.3	36.75
100	12	1 in 1	45

Trigonometry Tables

Deg	Sin	Cos	Tan	Deg	Sin	Cos	Tan	Deg	Sin	Cos	Tan
1	.0175	.9998	.0175	31	.5150	.8572	.6009	61	.8746	.4848	1.8040
2	.0349	.9994	.0349	32	.5299	.8480	.6249	62	.8829	.4695	1.8807
3	.0523	.9986	.0524	33	.5446	.8387	.6494	63	.8910	.4540	1.9626
4	.0698	.9976	.0699	34	.5592	.8290	.6745	64	.8988	.4384	2.0503
5	.0872	.9962	.0875	35	.5736	.8192	.7002	65	.9063	.4226	2.1445
6	.1045	.9945	.1051	36	.5878	.8090	.7265	66	.9135	.4067	2.2460
7	.1219	.9925	.1228	37	.6018	.7986	.7536	67	.9205	.3907	2.3559
8	.1392	.9903	.1405	38	.6157	.7880	.7813	68	.9272	.3746	2.4751
9	.1564	.9877	.1584	39	.6293	.7771	.8098	69	.9336	.3584	2.6051
10	.1736	.9848	.1763	40	.6428	.7660	.8391	70	.9397	.3420	2.7475
11	.1908	.9816	.1944	41	.6561	.7547	.8693	71	.9455	.3256	2.9042
12	.2079	.9781	.2126	42	.6691	.7431	.9004	72	.9511	.3090	3.0777
13	.2250	.9744	.2309	43	.6820	.7314	.9325	73	.9563	.2924	3.2709
14	.2419	.9703	.2493	44	.6947	.7193	.9657	74	.9613	.2756	3.4874
15	.2588	.9659	.2679	45	.7071	.7071	1.0000	75	.9659	.2588	3.7321
16	.2756	.9613	.2867	46	.7193	.6947	1.0355	76	.9703	.2419	4.0108
17	.2924	.9563	.3057	47	.7314	.6820	1.0724	77	.9744	.2250	4.3315
18	.3090	.9511	.3249	48	.7431	.6691	1.1106	78	.9781	.2079	4.7046
19	.3256	.9455	.3443	49	.7547	.6561	1.1504	79	.9816	.1908	5.1446
20	.3420	.9397	.3640	50	.7660	.6428	1.1918	80	.9848	.1736	5.6713
21	.3584	.9336	.3839	51	.7771	.6293	1.2349	81	.9877	.1564	6.3138
22	.3746	.9272	.4040	52	.7880	.6157	1.2799	82	.9903	.1392	7.1154
23	.3907	.9205	.4245	53	.7986	.6018	1.3270	83	.9925	.1219	8.1443
24	.4067	.9135	.4452	54	.8090	.5878	1.3764	84	.9945	.1045	9.5144
25	.4226	.9063	.4663	55	.8192	.5736	1.4281	85	.9962	.0872	11.4301
26	.4384	.8988	.4877	56	.8290	.5592	1.4826	86	.9976	.0698	14.3007
27	.4540	.8910	.5095	57	.8387	.5446	1.5399	87	.9986	.0523	19.0811
28	.4695	.8829	.5317	58	.8480	.5299	1.6003	88	.9994	.0349	28.6363
29	.4848	.8746	.5543	59	.8572	.5150	1.6643	89	.9998	.0175	57.2900
30	.5000	.8660	.5774	60	.8660	.5000	1.7321	90	1.000	.0000	∞

Note: Deg = degrees of angle; Sin = sine; Cos = cosine; Tan = tangent.

___ 15. **Perspective Sketching**

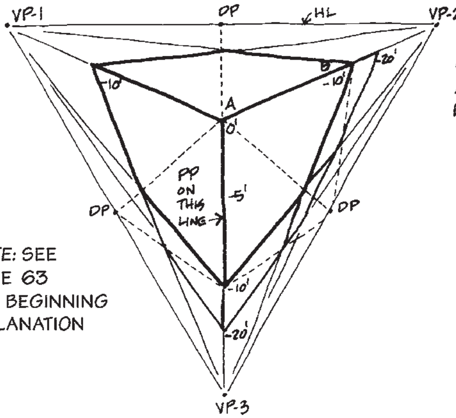


Use the following simple techniques of using 10′ cubes and lines at 5′ with diagonals for quick perspective sketching:

___ *a.* The sketches shown on pp. 64 & 65 show two techniques: The *first* establishes diagonal Vanishing Points (VP) on the Horizon Line (HL) at certain distances from the VPs, also on the HL. 10′ cubes are established by projecting diagonals to the VPs. The *second* technique has 10′ cubes and lines at the 5′ half-points. Diagonals through the half-points continue the 5′ and 10′ module to the VPs. The vertical 5′ roughly equals eye level, and establishes the HL. Half of 5′ or 2.5′ is a module for furniture height and width.

___ *b.* The sketch shown on p. 65 illustrates the most common way people view buildings. That is, close up, at almost a one-point perspective. To produce small sketches, set right vertical measure at ½″ apart. Then, about 10½″ to left, set vertical measure at ⅜″ apart. This will produce a small sketch to fit on 8½ × 11 paper. Larger sketches can be done using these proportions.

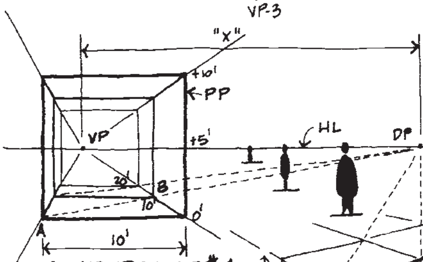
PERSPECTIVE SKETCHING

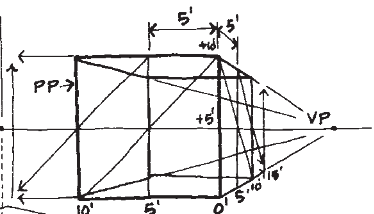


NOTE: SEE PAGE 63 FOR BEGINNING EXPLANATION

THREE POINT

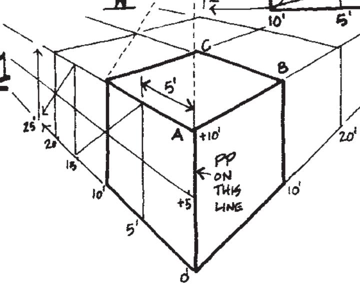
SKETCH AN EQUILATERAL TRIANGLE VP-1, VP-2, & VP-3. SET DP'S HALFWAY ALONG EA. OF THESE LINES. SELECT A NEAR THE CENTER OF TRIANGLE. DRAW A TO VP-2 & EYEBALL 10' LENGTH AB. FINISH 10' CUBE/S BY CONNECTING CORNERS TO DPS TO GET OPPOSITE CORNERS. PROJECT CORNERS TO VPS TO GET SIDES & SO ON. THE SKETCH SHOWN, IS GREATLY EXAGGERATED & CAN BE ADJUSTED BY A LARGER TRIANGLE.





ONE POINT #1

ESTABLISH A DP ON THE HL A DISTANCE "X" EQUAL TO THE DISTANCE FROM THE EYE TO THE PP. THEN CONNECT A TO THE DP ESTABLISHING POINT B, 10' BACK. THE FACE OF THE CUBE AT THE PP IS EYEBALLED.



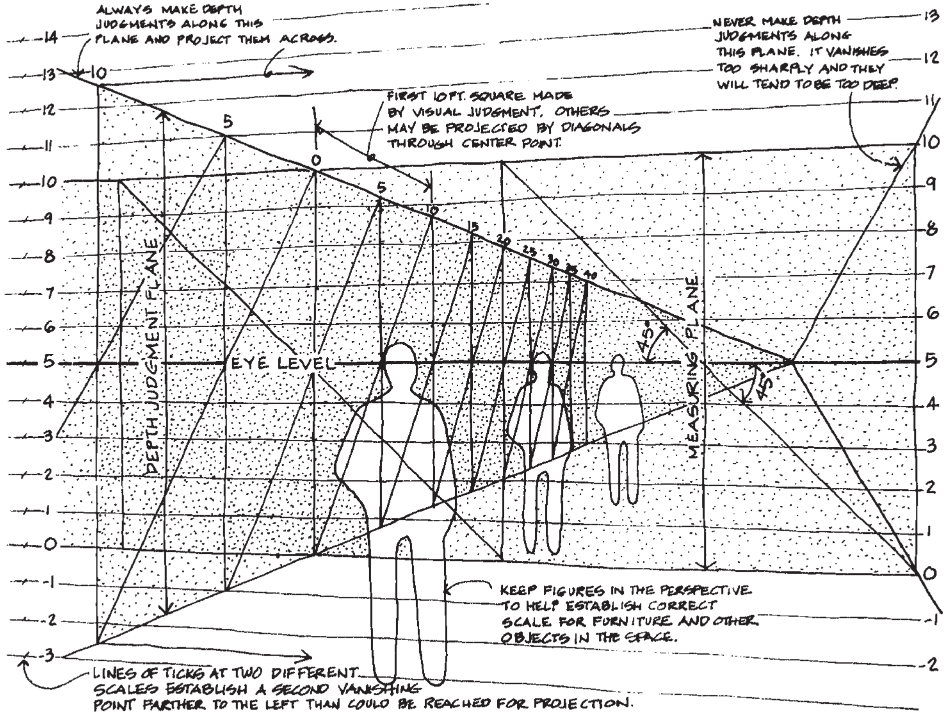
ONE POINT #2

EYEBALL FIRST 5' AND THEN PROJECT DIAGONALS TO CREATE 10' CUBES WITH 5' HALF LINES. THE VERT 5' IS AT EYE LEVEL.

TWO POINT

#1 EYEBALL LVP & RVP AND THEN DP, ALL ON THE HL. CONNECT A TO DP. EYEBALL FIRST 10' ON LINE AB. CONNECT B TO LVP. THE INTERSECTION ESTABLISHES POINT C, 10' BACK, & SO ON.

#2 5' DIAGONALS CAN ALSO BE USED BY EYEBALLING THE FIRST 5'.



PERSPECTIVE

NOTES

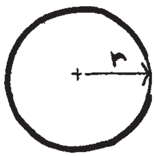
GEOMETRY OF AREA

ABBREVIATIONS

a = LENGTH OF TOP
b = LENGTH OF BASE
h = PERPENDICULAR HEIGHT
r = LENGTH OF RADIUS

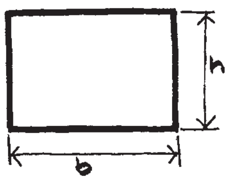
$\pi = 3.1416$

CIRCLE



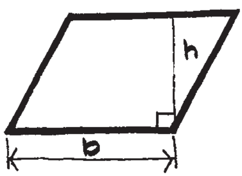
$$\text{AREA} = \pi \times r^2$$

RECTANGLE



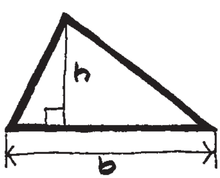
$$\text{AREA} = b \times h$$

PARALLELOGRAM



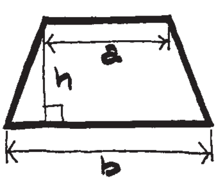
$$\text{AREA} = b \times h$$

TRIANGLE



$$\text{AREA} = \tfrac{1}{2} \times b \times h$$

TRAPEZOID



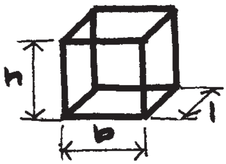
$$\text{AREA} = \frac{(a+b) \times h}{2}$$

GEOMETRY OF VOLUME (54)

ABBREVIATIONS
- b = BREADTH OF BASE
- h = PERPENDICULAR HEIGHT
- l = LENGTH OF BASE
- r = LENGTH OF RADIUS

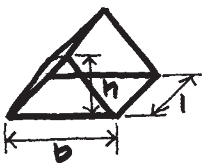
$\pi = 3.1416$

CUBE



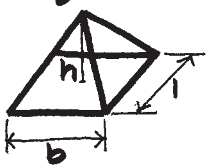
$$\text{AREA} = b \times h \times l$$

PRISM



$$\text{AREA} = \frac{b \times h \times l}{2}$$

PYRAMID

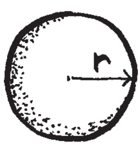


$$\text{AREA} = \frac{b \times h \times l}{3}$$

CYLINDER

$$\text{AREA} = \pi \times r^2 \times l$$

SPHERE

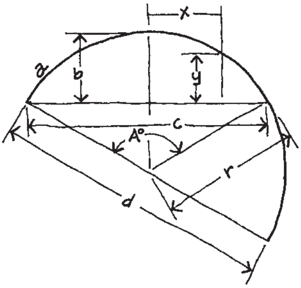


$$\text{AREA} = \frac{4 \times \pi \times r^3}{3}$$

CONE

$$\text{AREA} = \frac{\pi \times r^2 \times h}{3}$$

PROPERTIES OF THE CIRCLE



Circumference $= 6.28318\,r = 3.1416\,d$

Diameter $= 0.31831$ circumference

Area $= 3.1416\,r^2$

Arc $a = \dfrac{\pi r A^\circ}{180^\circ} = 0.017453\,r A^\circ$

Angle $A^\circ = \dfrac{180^\circ a}{\pi r} = 57.29578\,\dfrac{a}{r}$

Radius $r = \dfrac{4b^2 + c^2}{8b}$

Chord $c = 2\sqrt{2br - b^2} = 2r \sin \dfrac{A}{2}$

Rise $b = r - \tfrac{1}{2}\sqrt{4r^2 - c^2} = \dfrac{c}{2} \tan \dfrac{A}{4}$

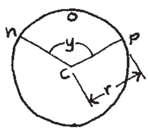
$= 2r \sin^2 \dfrac{A}{4} = r + y - \sqrt{r^2 - x^2}$

$y = b - r + \sqrt{r^2 - x^2}$

$x = \sqrt{r^2 - (r + y - b)^2}$

Diameter of circle of equal periphery as square = 1.27324 side of square
Side of square of equal periphery as circle = 0.78540 diameter of circle
Diameter of circle circumscribed about square = 1.41421 side of square
Side of square inscribed in circle = 0.70711 diameter of circle

CIRCULAR SECTOR



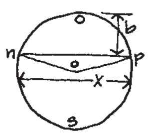
r = radius of circle y = angle ncp in degrees

Area of Sector ncpo = ½ (length of arc nop × r)

$= \text{Area of Circle} \times \dfrac{y}{360}$

$= 0.0087266 \times r^2 \times y$

CIRCULAR SEGMENT



r = radius of circle x = chord b = rise

Area of Segment nop = Area of Sector ncpo − Area of triangle ncp

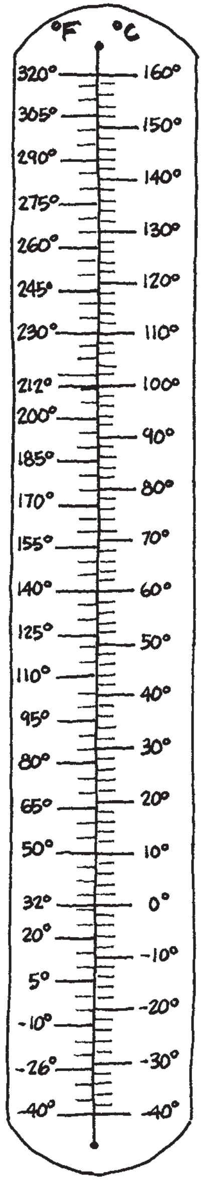
$= \dfrac{(\text{Length of arc nop} \times r) - x(r - b)}{2}$

Area of Segment nsp = Area of Circle − Area of Segment nop

TEMPERATURE

DEG. C = (DEG. F − 32) × .5556

DEG. F = (DEG. C × 1.8) + 32



LENGTHS

METERS* m	INCHES in.	FEET ft.	YARD yd.	RODS r.	CHAINS ch.	MILES, U.S.		KILO-METERS km
						STATUTE	NAUTICAL	
1	39.37	3.28	1.09	0.199	0.05	$0.\overset{3}{0}6214$	$0.\overset{3}{0}5396$	0.001
0.025	1	0.083	0.028	$0.\overset{2}{0}51$	$0.\overset{2}{0}13$	$0.\overset{4}{0}158$	$0.\overset{4}{0}137$	$0.\overset{4}{0}254$
0.305	12	1	0.333	0.06	0.015	$0.\overset{3}{0}189$	$0.\overset{3}{0}165$	$0.\overset{3}{0}305$
0.914	36	3	1	0.18	0.045	$0.\overset{3}{0}568$	$0.\overset{3}{0}493$	$0.\overset{3}{0}914$
5.029	198	16.5	5.5	1	0.25	$0.\overset{2}{0}313$	$0.\overset{2}{0}271$	$0.\overset{2}{0}503$
20.117	792	66	22	4	1	0.013	0.0109	0.020
1609.35	63360	5280	1760	320	80	1	0.868	1.609
1853.25	72962.5	6080.2	2026.7	368.5	92.12	1.15	1	1.853
1000	39370	3280.8	1093.6	198.8	49.71	0.621	0.540	1

* 1 METER (m) = 10 DECIMETERS (dm) = 100 CENTIMETERS (cm) = 1000 MILLIMETERS (mm)

NOTE: NOTATIONS $\overset{2}{0}$, $\overset{3}{0}$, $\overset{4}{0}$, ETC., INDICATE THE NUMBER OF ZEROS.

EXAMPLE: 1 METER = $0.\overset{3}{0}6214$ = 0.0006214 STATUTE MILES.

AREAS

SQUARE METERS SM	SQUARE INCHES SI	SQUARE FEET SF	SQUARE YARDS SY	SQUARE RODS SR	ACRES AC	HECTARES HA	SQUARE MILES STATUTE	SQUARE KILOMETER SQ KM
1	1550.0	10.76	1.196	0.039	$0.{}^{3}_{0}247$	0.0001	$0.{}^{6}_{0}386$	$0.{}^{5}_{0}1$
$0.{}^{3}_{0}65$	1	$0.{}^{2}_{0}69$	$0.{}^{3}_{0}77$	$0.{}^{6}_{0}26$	$0.{}^{6}_{0}16$	$0.{}^{7}_{0}65$	$0.{}^{9}_{0}25$	$0.{}^{9}_{0}65$
0.093	144	1	0.111	$0.{}^{2}_{0}37$	$0.{}^{4}_{0}23$	$0.{}^{5}_{0}93$	$0.{}^{7}_{0}36$	$0.{}^{7}_{0}93$
0.836	1296	9	1	0.333	$0.{}^{3}_{0}21$	$0.{}^{4}_{0}84$	$0.{}^{6}_{0}32$	$0.{}^{6}_{0}84$
25.293	39204	272.25	30.25	1	0.006	$0.{}^{3}_{0}25$	$0.{}^{5}_{0}98$	$0.{}^{4}_{0}26$
4046.87	6272640	43560	4840	160	1	0.405	$0.{}^{2}_{0}16$	$0.{}^{2}_{0}41$
10000	15499969	107639	11959.9	395.37	2.47104	1	$0.{}^{2}_{0}39$	0.01
2589999		27878400	3097600	102400	640	259	1	2.59
1000000		10763867	1195985	39536.6	247.104	100	0.386	1

VOLUMES

CUBIC DECIMETER OR LITERS	CUBIC INCHES	CUBIC FEET	CUBIC YARDS	U.S. QUARTS		U.S. GALLONS		U.S. BUSHELS
				LIQUID	DRY	LIQUID	DRY	
1	61.02	0.035	$0.{}^{2}_{0}13$	1.057	0.908	0.264	0.227	0.028
0.016	1	$0.{}^{3}_{0}58$	$0.{}^{4}_{0}21$	0.017	0.015	$0.{}^{2}_{0}43$	$0.{}^{2}_{0}72$	$0.{}^{2}_{0}47$
28.32	1728	1	0.037	29.92	25.714	7.481	6.429	0.804
764.56	46656	27	1	807.90	694.28	201.97	173.57	21.70
0.946	57.75	0.033	$0.{}^{2}_{0}124$	1	0.859	0.25	0.215	0.027
1.1012	67.20	0.039	$0.{}^{2}_{0}144$	1.1637	1	0.291	0.25	0.031
3.786	231	0.134	$0.{}^{2}_{0}495$	4	3.437	1	0.859	0.107
4.405	268.8	0.156	$0.{}^{2}_{0}576$	4.655	4	1.164	1	0.125
35.24	2150.4	1.244	0.0461	37.24	32	9.309	8	1

U.S. DRY MEASURE: 1 BUSHEL = 4 PECKS = 8 GALLONS = 32 QUARTS = 64 PINTS
U.S. LIQUID MEASURE: 1 GALLON = 4 QUARTS = 8 PINTS = 32 GILLS = 128 FLUID OUNCES
1 U.S. GALLON = 0.83268 IMPERIAL GALLON

WEIGHTS

KILOGRAMS KG	GRAINS	OUNCES		POUNDS		TONS		
		TROY	AVOIR	TROY	AVOIR	NET (SHORT) 2000 LBS	GROSS (LONG) 2240 LBS	METRIC 1000 KG
1	15432.4	32.15	35.27	2.679	2.205	$0.\overset{2}{0}1102$	$0.\overset{3}{0}984$	0.001
$0.\overset{4}{0}648$	1	$0.\overset{2}{0}208$	$0.\overset{3}{0}23$	$0.\overset{3}{0}174$	$0.\overset{3}{0}143$	$0.\overset{7}{0}714$	$0.\overset{7}{0}638$	$0.\overset{7}{0}648$
0.031	480	1	1.097	0.083	0.069	$0.\overset{4}{0}343$	$0.\overset{4}{0}306$	$0.\overset{4}{0}311$
0.024	437.5	0.911	1	0.076	0.063	$0.\overset{4}{0}313$	$0.\overset{4}{0}279$	$0.\overset{4}{0}284$
0.373	5760	12	13.166	1	0.823	$0.\overset{3}{0}411$	$0.\overset{3}{0}367$	$0.\overset{3}{0}373$
0.454	7000	14.58	16	1.215	1	0.0005	$0.\overset{3}{0}446$	$0.\overset{3}{0}454$
907.185	14000000	29166.7	32000	2430.56	2000	1	0.893	0.907
1016.05	15680000	32666.7	35840	2722.22	2240	1.12	1	1.016
1000	15432356	32150.7	35274	2679.23	2204.62	1.102	0.984	1

1 LONG HUNDREDWEIGHT (CWt.) = 1/20 TON = 4 QUARTERS = 8 STONE = 112 LBS = 50.8 kg

DENSITIES

GRAMS PER CU. CENTIMETER g/cm^3	POUNDS PER CU. INCH $lb./in.^3$	POUNDS PER CU. FOOT $lb./ft^3$	POUNDS PER CU. YARD $lb./yd^3$	KILOGRAMS PER CU. METER kg/m^2	POUNDS PER BUSHEL, U.S.	POUNDS PER GALLON, DRY, U.S.	POUNDS PER GALLON, LIQUID, U.S.	KILOGRAMS PER HECTOLITER kg/hl
1	0.036	62.43	1685.56	1000	77.689	9.711	8.345	100
27.68	1	1728	46656	27679.7	2150.4	268.8	231	2767.97
0.016	$0.{}_{0}^{3}579$	1	27	16.02	1.24	0.156	0.134	1.602
$0.{}_{0}^{3}59$	$0.{}_{0}^{4}21$	0.037	1	0.593	0.046	$0.{}_{0}^{2}576$	$0.{}_{0}^{2}495$	0.059
0.001	$0.{}_{0}^{4}36$	0.062	1.686	1	0.078	$0.{}_{0}^{2}97$	$0.{}_{0}^{2}83$	0.10
0.013	$0.{}_{0}^{3}47$	0.804	21.696	12.87	1	0.125	0.107	1.287
0.103	$0.{}_{0}^{2}37$	6.429	173.57	102.97	8	1	0.859	10.297
0.119	$0.{}_{0}^{2}43$	7.481	201.97	119.83	9.31	1.164	1	11.98
0.01	$0.{}_{0}^{3}36$	0.624	16.86	10	0.777	0.097	0.083	1

PRESSURE

PASCALS N/m^2	BARS $10^5 N/m^2$	POUNDS f PER IN^2	ATMOSPHERES	COLUMNS OF MERCURY (0°C, g = 9.807 m/s^2)		COLUMNS OF WATER (15°C, g = 9.807 m/s^2)	
				cm	in	cm	in
1	$0.{}^{4}_{0}1$	$0.{}^{3}_{0}145$	$0.{}^{4}_{0}1$	$0.{}^{3}_{0}75$	$0.{}^{3}_{0}295$	0.0102	0.004
100000	1	14.5	0.99	75	29.53	1020.7	401.8
6894.8	0.0689	1	0.068	5.17	2.04	70.37	27.7
101326	1.01	14.696	1	76	29.92	1034	407.1
1333	0.013	0.193	0.013	1	0.39	13.61	5.357
3386	0.034	0.49	0.033	2.54	1	34.56	13.61
97.98	$0.{}^{3}_{0}98$	0.014	$0.{}^{3}_{0}97$	0.073	0.029	1	0.39
248.9	$0.{}^{2}_{0}25$	0.036	$0.{}^{2}_{0}25$	0.187	0.073	2.54	1

POWER

HORSE-POWER	KILO-WATTS	METRIC HORSE-POWER	kgf·m PER SEC.	FT-LBF PER SEC.	KILO-CALORIES PER SEC.	B.T.U. PER SEC.
1	0.746	1.014	76.04	550	0.178	0.707
1.341	1	1.36	102.0	737.6	0.239	0.948
0.986	0.736	1	75	542.5	0.176	0.697
0.013	$0.{}_{0}^{2}98$	0.013	1	7.23	$0.{}_{0}^{2}23$	$0.{}_{0}^{2}93$
$0.{}_{0}^{2}18$	$0.{}_{0}^{2}14$	$0.{}_{0}^{2}18$	0.138	1	$0.{}_{0}^{3}32$	$0.{}_{0}^{2}13$
5.615	4.187	5.692	426.9	3088	1	3.968
1.415	1.055	1.434	107.6	778.2	0.252	1

ENERGY OR WORK

24

JOULES (NEWTON-METER)	KILOGRAM-METERS	FOOT-POUNDS	KILOWATT HOURS	METRIC HORSE POWER-HOURS	HORSE-POWER-HOURS	LITER-ATMOSPHERES	KILO-CALORIES	BRITISH THERMAL UNITS
1	0.102	0.738	$0.\overset{6}{0}278$	$0.\overset{6}{0}378$	$0.\overset{6}{0}37$	$0.\overset{2}{0}987$	$0.\overset{3}{0}24$	$0.\overset{3}{0}948$
9.807	1	7.233	$0.\overset{6}{0}272$	$0.\overset{6}{0}370$	$0.\overset{6}{0}37$	0.0968	$0.\overset{2}{0}234$	$0.\overset{2}{0}93$
1.356	0.138	1	$0.\overset{6}{0}377$	$0.\overset{6}{0}512$	$0.\overset{6}{0}505$	0.0134	$0.\overset{3}{0}324$	0.0013
3600000	367100	2655000	1	1.36	1.34	35528	859.9	3412
2648000	270000	1952900	0.736	1	0.986	26131	632.4	2510
2684500	2737500	1980000	0.746	1.014	1	26493	641.2	2544
101.33	10.33	74.74	$0.\overset{4}{0}28$	$0.\overset{4}{0}38$	$0.\overset{4}{0}38$	1	0.024	0.096
4186.8	426.9	3088	$0.\overset{2}{0}116$	$0.\overset{2}{0}158$	$0.\overset{2}{0}156$	41.32	1	3.968
1055	107.6	778.2	$0.\overset{3}{0}29$	$0.\overset{3}{0}399$	$0.\overset{3}{0}393$	10.41	0.252	1

Also, see p. 203.

NOTES

NOTES

___ H. BUILDING LAWS

___ 1. *Zoning* (L) (57)

Zoning laws vary from city to city. The following checklist is typical of items in a zoning ordinance:

___ *a.* Zone
___ *b.* Allowable use
___ *c.* Prohibited uses or special-use permit
___ *d.* Restrictions on operation of facility
___ *e.* Minimum lot size
___ *f.* Maximum building coverage
___ *g.* Floor area ratio
___ *h.* Setbacks for landscaping
___ *i.* Building setbacks: front, side, street, rear
___ *j.* Required open space
___ *k.* Maximum allowable height
___ *l.* Restrictions due to adjacent zone(s)
___ *m.* Required parking
___ *n.* Required loading zone
___ *o.* Parking layout restrictions
___ *p.* Landscape requirements
___ *q.* Environmental impact statements
___ *r.* Signage
___ *s.* Site plan review
___ *t.* "Design review"
___ *u.* Special submittals required for approval and/or hearings:
    ___ (1) Fees
    ___ (2) Applications
    ___ (3) Drawings
    ___ (4) Color presentations
    ___ (5) Sample boards
    ___ (6) List of adjacent land owners
    ___ (7) Other
___ *v.* Although not part of the zoning ordinance, private covenants, conditions, and restrictions (CC&Rs) that "run" with the land should be checked.
___ *w.* Other

NOTES

___ 2. **Code Requirements for Residential Construction** (36)
(2000 International Residential Code [IRC])
Use the following checklist for residences. The IRC applies to one- and two-family dwellings and multiple single-family dwellings (townhouses) not more than three stories in height with a separate means of egress, and their accessory structures.

- ___ *a.* Location on lot
  - ___ (1) Openings must be 3′ from property line.
  - ___ (2) Walls less than 3′ must be 1-hour construction.
  - ___ (3) Windows not allowed in exterior walls with a fire separation distance of less than 3′ to the closest interior lot line (usually with parapet).
- ___ *b.* Separation between abutting dwelling units must be a minimum of 1-hour construction (½ hour, if sprinklered).
- ___ *c.* Windows and ventilation
  - ___ (1) Habitable rooms must have natural light and ventilation by exterior windows with area of at least 8% of floor area and 4% must be openable.
  - ___ (2) Bath and laundry-type rooms must have ventilation by operable exterior windows with area of not less than 3 SF (½ to be openable).
  - ___ (3) In lieu of natural ventilation and light, mechanical ventilation and artificial lighting may be used.
  - ___ (4) Any room may be considered as a portion of an adjoining room when at least ½ of area of the common wall is open and provides an opening of at least 1⁄10 of floor area of interior room, but not less than 25 SF.
- ___ *d.* Room dimensions
  - ___ (1) At least one room shall have at least 120 SF.
  - ___ (2) Other habitable rooms, except kitchens, shall have at least 70 SF.
  - ___ (3) Kitchens shall be 50 SF, min.
  - ___ (4) Habitable rooms shall be 7′-0″ min. in any direction.
- ___ *e.* Ceiling heights
  - ___ (1) 7′-0″ min.

- ___ (2) Where exposed beams not less than 4′ apart, bottoms may be at 6′-6″.
- ___ (3) Basements, 6′-8″ min. (6′-4″ to obstructions).
- ___ (4) At sloped ceilings, the min. ceiling height is required at only ½ the area, but never less than 5′ height.

___ *f.* Sanitation

- ___ (1) Every dwelling unit (DU) shall have a kitchen with a sink.
- ___ (2) Every DU shall have a bath with a WC, lavatory, bathtub, or shower.
- ___ (3) Every sink, lavatory, bathtub, or shower shall have hot and cold running water.

___ *g.* Fire warning system (smoke alarms)

- ___ (1) Each dwelling must have smoke detectors in each sleeping room and the corridor to sleeping rooms, at each story (close proximity to stairways), and basement.
- ___ (2) In new construction, smoke detectors are to be powered by building wiring but equipped with backup battery.
- ___ (3) If there are additions or alterations (particularly sleeping rooms being added), the entire building shall have smoke detectors.
- ___ (4) In existing buildings, smoke detectors may be solely battery-operated.

___ *h.* Exits

- ___ (1) Doors
  - ___ (*a*) At least one entry door shall be 3′ wide by 6′-8″ high.
  - ___ (*b*) There must be a floor or landing at each side of each door, not more than 1.5″ below door.
  - ___ (*c*) At exterior, doors may open at the top step; if door swings away from step and step or landing is not lower than 8″, the landing must be the width of stair or door and 36″ deep.
- ___ (2) Emergency exits
  - ___ (*a*) Sleeping rooms and basements with habitable space shall have at least one door or operable window.
  - ___ (*b*) The window shall be operable from the inside and have a minimum clear opening of 5 SF at grade or 5.7 SF (24″ high min., 20″ wide

min.) and sill shall not be higher than 44″ above floor.

___ (*c*) Bars, grilles, or grates may be installed provided they are operable from inside.

___ (*d*) Windows, below grade, shall have a window well. The window shall be 9 SF clear opening, min., and 36″ min. dimension. When the well is deeper than 44″, must provide ladder or steps.

___ *i.* Stairs

___ (1) Min. width = 36″

___ (2) Max. rise: 7¾″

___ (3) Min. run (tread): 10″

___ (4) Variation in treads and risers = ⅜″ max.

___ (5) Winders: require 10″-wide tread at 12″ out from narrow side, but never less than 6″ width at any point.

___ (6) Spiral stairs to have 26″ min. clear width. Tread at 12″ from center to be 7½″. Max. riser = 9½″. Min. headroom = 6′-6″.

___ (7) Handrails

___ (*a*) At least one, at open side, continuous, and terminations to posts or walls

___ (*b*) Height: 34″ to 38″ above tread nosing

___ (*c*) Clearance from walls: 1½″

___ (*d*) Width of grip: 1¼″ to 2⅝″

___ (8) Headroom: 6′-8″ min.

___ (9) Guardrails at floor or roof openings, more than 30″ above grade. Height = 36″ min. If open, submembers must be spaced so a 4″ dia. sphere cannot pass through.

___ *j.* Garages and carports

___ (1) Must separate from DU (dwelling unit) with ½″ gypboard on garage side and 1⅜″ SC wood or 20 min. doors.

___ (2) No openings to sleeping areas allowed.

___ (3) Carports (open on at least two sides) do not apply (for above).

___ (4) Floors must slope to garage door opening.

___ *k.* Fireplaces: See p. 438.

___ *l.* Glazing: See p. 408.

___ *m.* Electrical: See p. 613.

___ *n.* Residential Accessibility (per IBC [see p. 143] and ADA [ANSI]):

___ (1) Facilities *not* required to be accessible:

___ (*a*) Detached 1- and 2-story DU (this section).

___ (*b*) R-1 (boarding houses and hotels, occupancies with not more than 5 rooms for rent.

___ (*c*) R-2 and -3 (apartments and residential care homes) with 3 or fewer DU in a building.

___ (*d*) Existing residential buildings.

___ (*e*) Where unfeasible due to steep grade (see IBC).

___ (2) Facilities required to be accessible:

___ (*a*) Types of accessible units (see ANSI):

___ Type A are to be fully accessible.

___ Type B are to be minimally accessible.

___ (*b*) Scoping:

___ Occupancies R-2 and -3 with more than 5 DUs, every DU to be Type B, except:

___ R-2 with more than 20 DU: 20% (but at least one) to be Type A. Where no elevator, need only be on ground floor. Must have 20% of ground floor DUs as Type B.

___ Sleeping accommodations (for all R, not exempted):

Accessible units	Total units
1	1–25
2	26–50
4	51–75
5	76–100
7	101–150
8	151–200
10	201–300
12	301–400
13	401–500
3%	501–1000
30 + 2 for ea 100 over 1000	over 1000

NOTES

NOTES

___ 3. Building Code (P) (X) (33) (34) (49)

The new 2009 International Building Code (IBC) has been used for this part. Configuring a building that meets fire safety code requirements is one of the architect's primary responsibilities. This handbook uses the IBC as a guide (*with NFPA differences noted*).

Steps in preliminary code check are:

___ *a.* Establish occupant load.
___ *b.* Determine occupancy classification. Also see App. A, item A.
___ *c.* Determine allowable area.
___ *d.* Determine allowable height.
___ *e.* Determine construction type.
___ *f.* Determine hourly ratings of construction components for construction type.
___ *g.* Determine required occupancy separations.
___ *h.* Determine sprinkler requirements.
___ *i.* Determine if area separation walls are needed.
___ *j.* Determine if exterior walls and windows have adequate fire protection.
___ *k.* Check exiting.
___ *l.* Other.

___ *a.* *Occupant Load:* Determining the occupant load from IBC Table A (p. 110), in some cases, will help determine the occupancy classification. When starting a project, a listing of architectural program areas by name, along with their floor area, occupant classification, and occupant load, should be compiled. Total the occupant load to help determine the final overall occupancy classification and for design of the exiting. The occupancy load can always be increased, provided the design of the building follows suit.

___ *b.* *Occupancy Classification:* The building code classifies buildings by occupancy in order to group similar life-safety problems together. Table B (p. 112) provides a concise definition of all occupancy classifications. In some cases, refer to the code for more detail.

___ *c.* *Allowable Floor Area:* Table C on p. 116 coordinates the level of fire hazard (occupancy classification) to the required fire resistance (allowable construction type) by defining the allowable area for a one-story building. High-hazard occupancies (such as large assembly) can be built only out of the most fire-resistant construction types. A lower-risk occupancy (such as a small office or a residence) can be built using any of the construction types. The allowable construction types are listed from left to right in approximately decreasing order of fire safety and construction cost. Thus choosing a construction type as far to the right as possible will provide the least expensive construction for the type of occupancy in question. Another way to reduce costs is to compartmentalize, per p. 97, thus creating two less expensive buildings with a fire wall between.

The floor area of a single basement need not be considered in the calculation of a building's total area, provided the area of the basement does not exceed that permitted for a one-story building.

___ (1) *Area Increases:*

- ___ (*a*) *Sprinkler:* Allowable areas in Table B may be increased by adding automatic sprinklers, as follows:
  - ___ For one-story buildings: 300% increase (Is = 300%).
  - ___ For multistory buildings: 200% increase (Is = 200%).
- ___ (*b*) *Frontage:* Allowable areas (except H-1, -2, or -3) can be further increased by keeping the building away from property lines and other buildings (a property line is usually assumed halfway between two buildings for the purposes of yard separation), or by facing on a wide street. Since this is a credit for enabling fire truck access (as well as for distance from fires at other buildings) these yard widths may have to be measured from the edge of roof overhangs.

  This increase is allowed only when *25%* (or more) of the building's perimeter adjoins an open space of *20′* (or more) width. Increase for frontage is calculated by:

$$I_f = 100\,[F/P - 0.25]\,W/30$$

Where: I_f = % area increase
F = perimeter of building which fronts on min. 20′-wide open space
P = perimeter of building
W = min. width of open space (must be at least 20′) $W/30$ must not exceed 1 (or 2 in some cases)

For rough planning, use the following table of approximations:

Open perimeter	Yard width	Area increase
50%	20′	16.5%
50%	30′	25%
75%	20′	33.3%
75%	30′	50%
100%	20′	50%
100%	30′	75% max.

___ (*c*) *Area of increase for both frontage and sprinkler* is then calculated:

$$A_a = A_t + \left[\frac{A_t I_f}{100} + \frac{A_t I_s}{100}\right]$$

Where: A_a = adjusted allowable area per floor, in SF
A_t = area per floor per Table B
I_f = from preceding formula
I_s = increase due to sprinklers, per (*a*), above

___ (*d*) *Unlimited area buildings and other area increases:*

___ (*i*) *Unlimited area* Buildings permitted under the following conditions:

___ One-story F-2 or S-2 with min. 60′ yard of any construction type.

___ One-story sprinklered Groups A-4, B, F, M, or

S with 60′ yard (sprinklers may be omitted from participant areas of A-4 under specific conditions).

___ Two-story sprinklered B, F, M, or S uses with min. 60′ yards.

___ (*ii*) Reduction of 60′ open space down to 40′ permitted where:

___ Reduction applies to ≤75% of building perimeter.

___ Exterior walls at reduced open space to be min. 3 hours.

___ Openings in wall at reduced open space to be protected 3 hours.

___ (*iii*) In Groups F and S, fire areas of H-2, H-3, and H-4 permitted up to 10% of floor area where located at building perimeter, but not to exceed areas based on Table C plus frontage increases.

___ Such fire areas not located at perimeter only permitted up to 25% of area limitations of Table C.

___ (*iv*) *Group E* occupancies may be unlimited in area where:

___ One story.

___ Type II, IIIA, or IV construction.

___ Each classroom to have two means of egress, with at least one to outside.

___ Sprinklered.

___ 60′ yards.

___ (*v*) *Motion picture theaters* may be unlimited in area where:

___ One story.

- ___ Type I or II construction.
- ___ Sprinklered.
- ___ 60′ yards.

___ (2) *Compartmenting:* A building may be split into compartments (or "fire areas") creating one or more smaller separate buildings. This is done by fire walls which, in most cases, must extend 18″ beyond exterior walls and from the foundation to 30″ above the roof.

___ *d.* *Allowable Building Height:* Table C specifies the maximum number of stories that can be built in a particular construction type. By credit for sprinklers, height may be increased as follows:

___ (1) *Group R* occupancies protected with residential-type sprinklers are allowed height increase of 1 story and 20′ permitted up to a limit of 4 stories or 60′.

___ (2) *All other sprinklered* occupancies, height values in Table C permitted to be increased by 1 story and 20′.

___ (3) *Height increases* for sprinklered buildings are in addition to the area increases (except for I-2 [of Type II-B, III, IV, or V construction] and Group H-1, -2, -3, or -5 occupancies).

___ *e.* *Construction Type:* Based on the preceding, you can now select the construction type. Construction types are based on whether or not the building construction materials are combustible or noncombustible, and on the number of hours that a wall, column, beam, floor, or other structural element can resist fire. Wood is an example of a material that is combustible. Steel and concrete are examples of noncombustible materials. Steel, however, will lose structural strength as it begins to soften in the heat of a fire. Therefore fire proofing is required for steel members for a fire rating.

There are two ways that construction can be resistant to fire. First it can be *fire-resistive*—built of a monolithic, noncombustible material like concrete or masonry. Second, it can be *protected*—encased in a noncombustible material such as steel columns or wood studs covered with gypsum plaster, wallboard, etc.

The following are the construction types per the IBC:

___ *Type I* and *Type II* (*fire-resistive*) construction is noncombustible, built from concrete, masonry, and/or encased steel, and is used when substantial hourly ratings (2 to 3 hours) are required.

___ *Type II-B* construction is of the same materials as already mentioned, but the hourly ratings are lower. Light steel framing would fit into this category.

___ *Type III-A, IV, V-A* construction has noncombustible exterior walls of masonry or concrete, and interior construction of any allowable material including wood.

___ *Type IV* construction is combustible *heavy timber* framing. It achieves its rating from the large size of the timber (2″ to 3″ thickness, min., actual). The outer surface chars, creating a fire-resistant layer that protects the remaining wood. Exterior walls must be of noncombustible materials.

___ *Type V-B* construction is of light wood framing.

Note: As the type number goes up, the cost of construction goes down, so generally use the lowest construction type (highest number) the code allows.

IBC	*I*		*II*		*III*		*IV*	*V*	
	A	*B*	*A*	*B*	*A*	*B*	—	*A*	*B*

___ *f.* <u>*Hourly Ratings:*</u> See Table D for specific requirements of each construction type. See p. 120 on how to achieve these ratings.

___ *g.* <u>*Occupancy Separations:*</u> For hourly ratings, these are determined from Table E. Most buildings will have some mix of occupancies. If one of the occupancies is a minor area and subservient to the major one, the whole building can often be classified by the major occupancy. It will then have to meet the requirements of the more restrictive occupancy, but no separating walls will be necessary.

___ *h.* <u>*Sprinkler Requirements:*</u> A sprinkler system can be used to *substitute for 1-hour construction* if it is not otherwise required by the code and is not used for area or height increases. However, in most cases, exit access corridors, exit stairs, shafts, area separation walls and similar structures must maintain their required fire protection.

A sprinkler system is the most effective way to provide life and fire safety in a building. The IBC requires fire sprinklers in the following situations:

- ___ *Assembly occupancies:* Sprinklers to be provided throughout Group A areas as well as all floors between Group A and level of exit discharge, where:
  - ___ A-1 uses exceeding 12,000 SF, or occupant load > 300.
  - ___ A-2 uses where fire area exceeds 5000 SF, or occupant load > 300.
  - ___ A-3 uses where fire area exceeds 12,000 SF or occupant load > 300.
  - ___ A-4 same as A-3, with exemption for participant sports areas where main floor located at level exit discharge of main entrance and exit.
  - ___ A-5 concession stands, retail areas, press boxes, and other accessory use areas > 1000 SF.
- ___ *Educational occupancies,* where floor area exceeds 20,000 SF or schools below exit discharge level, except where each classroom has one exit door at ground level.
- ___ *Commercial and industrial uses:*
  - ___ Groups F-1 and S-1 where their fire areas > 12,000 SF, or where > 3 stories, or where > 24,000 SF total of all floors.
  - ___ Repair garages under the following conditions:
    - ___ Buildings ≥ 2 stories, including basements where fire area > 10,000 SF.
    - ___ Buildings of one story where fire area > 12,000 SF.
    - ___ Buildings with repair garage in basement.
  - ___ S-2 enclosed parking garage, unless located under Group R-3.
  - ___ Buildings used for storage of commercial trucks or buses where fire area exceeds 5000 SF.
- ___ *Hazardous (H) occupancies.*
- ___ *Institutional (I) occupancies.*
- ___ *Mercantile (M) occupancies where:*
  - ___ Fire area > 12,000 SF.
  - ___ More than 3 stories high.
  - ___ Total fire area on all floors (including mezzanines) > 24,000 SF.

- ___ *Residential occupancies:*
  - ___ R-1 hotel uses, regardless of number of stories or guest rooms (except motels where guest rooms not more than 3 stories above lowest level of exit discharge and each guest room has at least one door direct to exterior egress).
  - ___ R-2 apartment house, congregate residence uses more than 2 stories in height, including basements, or having more than 16 DUs per fire area.
  - ___ R-4 residential care or assisted living facilities having more than 8 occupants per fire area.
- ___ *All occupancies without sufficient fire department access through outside wall at basement or floor in excess of 1500 SF* (Group R-3 and Group U excluded). Sufficient access is 20 SF of openings with a minimum dimension of 30″ per 50 LF of wall. If these openings are on only one side, the floor dimension cannot exceed 75′ from the opening. Furthermore, sprinklers are required in buildings with a floor level that is located 55′ above the lowest level of fire truck access (excluding airport control towers, open parking garages, and F-2 occupancies).
- ___ *Miscellaneous:* Rubbish and linen chutes; nitrate film storerooms; and combustible-fiber storage vaults, atriums, and stages.

  See p. 521 for sprinkler installations.

___ *i.* *Fire Areas, Walls, Barriers, and Partitions:*

- ___ *Fire Areas:* Create separate compartments that are enclosed by fire-resistance-rated elements. These compartments may be due to occupancy separations (per *g,* above), or may be chosen by the architect to obtain greater building size (where each compartment is a separate building).
- ___ *Fire-Resistance-Rated-Elements:*
  - ___ *Fire Walls:* A rated wall (to enclose fire areas) with protected openings that extends continuously from foundation to or through roof (with some exceptions). A collapse from fire on one side will not allow collapse on the other. Used for fire compartments to allow larger buildings. See *c* (2), above. See Table F for required ratings of fire walls.

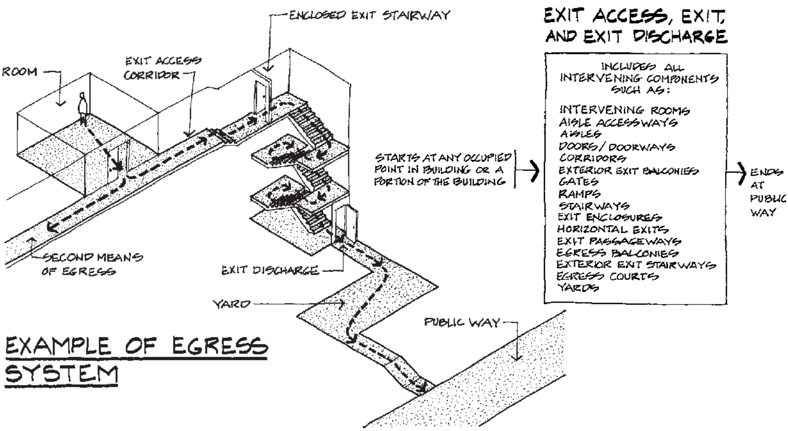
- ___ *Fire Barriers:* A rated wall used for required occupancy separations (see Table E). Note that the rating can be reduced 1 hour (except H and I-2 occupancies) when a sprinkler system is used (even if sprinkler is required). Also used to enclose vertical exit enclosures, exit passageways, horizontal exits, and incidental use areas. Floors that support barriers must be of the same rating (except for some incidental use separations). If building is sprinklered, there is no limit on openings or fire doors; otherwise, the openings are limited to 25% of the length of wall (a single opening is limited to 120 SF). This also applies to fire walls. Openings must be rated per Table G on page 130.
- ___ *Fire Partitions:*
  - ___ One-hour rated walls for:
    - ___ Protected *corridors,* where required by Table H (see p. 131).
    - ___ Separate *dwelling units* (DUs).
    - ___ Separating *guest rooms* in R-1.
    - ___ Separating *tenant spaces* in covered malls.
  - ___ Half-hour-rated walls in *sprinklered* buildings for:
    - ___ Construction Types II-B, III-B, or V-B.
    - ___ Separations of dwelling units or guest rooms.
  - ___ Floors supporting partition must be of same rating (except for ½-hour-rated walls).
  - ___ Openings must be 20 minutes for corridor walls and 45 minutes for others.

___ *j.* *Fire Protection of Exterior Walls and Windows:* This is a function of location of the building on the property and the occupancy type. See Table I, p. 122. As buildings get closer together, or closer to a property line, the requirements becomes more restrictive. See Table I (p. 122) for allowable area openings. Where both protected and unprotected openings are used, the total of openings must not exceed:

$$\frac{A}{a} + \frac{A_u}{a_u} \leq 1.0$$

Where: A = actual area of protected opening
a = allowable area of protected opening
A_u = actual area of unprotected opening
a_u = allowable area of unprotected opening
See Table G (p. 130) for where openings are required to be protected.

___ *k.* *Exiting and Stairs:* At the conceptual stage of architectural design, the most important aspects of the building code requirements are the number and distribution of exits.



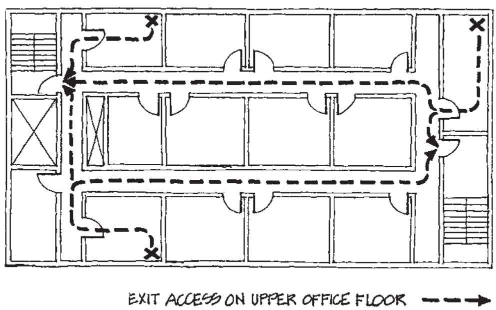
A *means of egress* is a continuous path of travel from any point in a building or structure to the open air outside at ground level (public way). It consists of three separate and distinct parts:

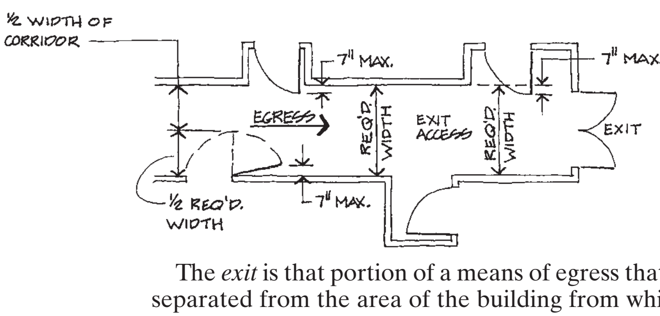
___ 1. Exit access
___ 2. The exit
___ 3. The exit discharge

The *exit access* leads to an exit. See Tables M and N, where only one is required; otherwise a minimum of two exits are almost always required. Other general requirements:

___ 1. Exit width determined by Table J, p. 132, but corridor width is usually no less than 44″. It can be 36″ for fewer than 51 people. School corridors must be 6′ wide. Hospitals 8′ wide. Large residential care homes, 5′ wide.

___ 2. Dead-end corridors are usually limited to 20′ long (in some cases 50′ to 75′).
___ 3. When more than one exit is required, the occupant should be able to go toward either exit from any point in the corridor system.
___ 4. Corridors used for exit access usually require 1-hour construction.
___ 5. Maximum travel distance from any point to an exit is per Table L on p. 133.
___ 6. Handrails or fully open doors cannot extend more than 7″ into the corridor.
___ 7. Doors at their worst extension into the corridor cannot obstruct the required width by more than half.





The *exit* is that portion of a means of egress that is separated from the area of the building from which escape is made, by walls, floors, doors, or other means that provide the protected path necessary for the occupants to proceed with safety to a public space. The most common form the exit takes is an enclosed stairway. In a single-story building the exit is the door opening to the outside.

After determining occupant load (Table A, p. 110) for spaces, rooms, floors, etc., use the following guidelines:

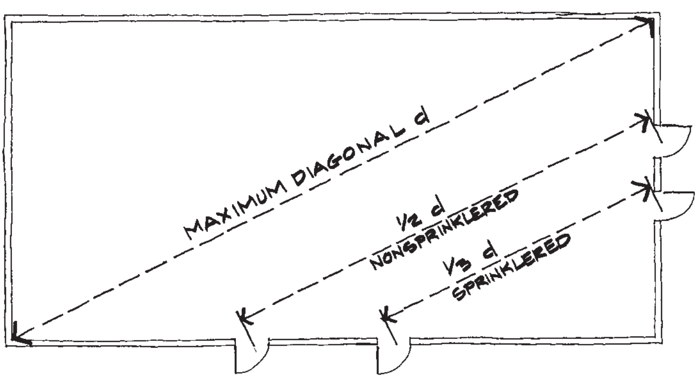
___ 1. In some cases one exit can be used (see above), but often buildings need two exits (see Table K, p. 129). In more than one story, stairs become part of an exit. Elevators are not exits.

___ 2. In buildings 4 stories and higher and in types I and II-B construction, the exit stairs are required to have 2-hour enclosure; otherwise, 1 hour is acceptable.

___ 3. When two exits are required (for unsprinklered buildings), they have to be separated by a distance equal to half the diagonal dimension of the floor and/or room the exits are serving (measured in straight lines). See sketch below. If the building is sprinklered, the minimum separation is ⅓ rd.

___ 4. Where more than two exits are required, two of them need to be separated by at least half the diagonal dimension. The others are spaced to provide good access from any direction.

___ 5. May exit from room through adjoining rooms (except rooms that are accessory or high-hazard occupancy), provided adjoining rooms (other than DUs) are not kitchens, storerooms, toilets, closets, etc. Foyers, lobbies, and reception rooms are



not considered adjoining rooms and can always be exited through.

___ 6. The total exit width required (in inches) is determined by multiplying the occupant load by the factors shown in Table J (p. 132). This width should be divided equally among the required number of exits.

___ 7. Total occupant load for calculating exit stair width is defined as the sum of the occupant load on the floor in question. The maximum exit stair width calculated is maintained for the entire exit. See sketch on p. 104.

___ 8. Minimum exit door width is 36″ with 32″ clear opening. Maximum door width is 48″.

___ 9. The width of exit stairs, and the width of landings between flights of stairs, must all be the same and must meet the minimum exit stair width requirements as calculated or:

44″ min. width for an occupant load of 51 or more

36″ min. width for 50 or less

___ 10. Doors must swing in the direction of travel when serving a hazardous area or when serving an occupant load of 50 or more.

A *horizontal exit* is a way of passage through a 2-hour fire wall into another area of the same building or into a different building that will provide refuge from smoke and fire. Horizontal exits cannot provide more than half of the required exit capacity, and any such exit must discharge into an area capable of holding the occupant capacity of the exit. The area is calculated at 3 SF/occupant. In institutional occupancies the area needed is 15 SF/ambulatory person and 30 SF/nonambulatory person.

Exit discharge is that portion of a means of egress between the termination of an exit and a public way. The most common form this takes is the door out of an exit stairway opening onto a public street. Exits can discharge through a courtyard with 1-hour walls that connect the exit with a public way. 50% of the exits can discharge through a street floor lobby area if the entire street floor is sprinklered, the path through the lobby is unobstructed and obvious, and the level of discharge is separated from floors below.

Smokeproof enclosures for exits are required in any building with floors 75′ above (or 30′ below) the lowest ground level where fire trucks have access. A smokeproof enclosure is an exit stair that is entered through a vestibule that is ventilated by either natural or mechanical means such that products of combustion from a fire will be limited in their penetration of the exit-stair enclosure. Smokeproof enclosures are required to be 2-hour construction. They must discharge directly to the outside or directly through a 2-hour exit passageway to the outside. In a *sprinklered* building, mechanically pressurized and vented stairways can be substituted for smokeproof enclosures.

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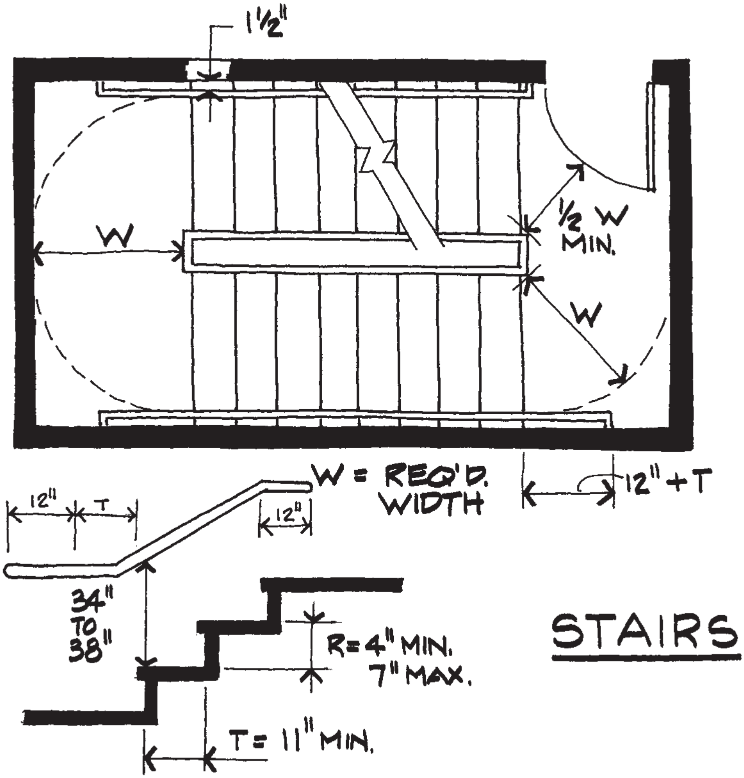
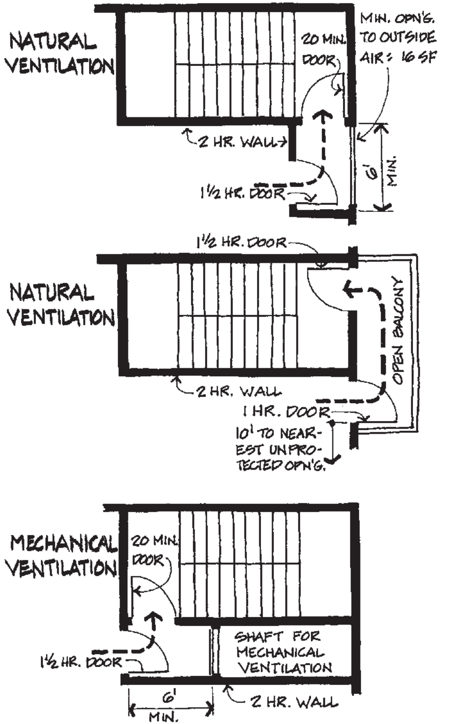
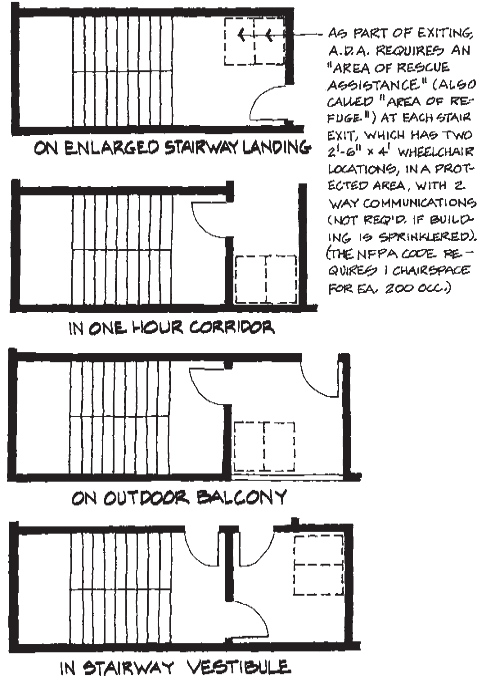

1½"
W
½ W
MIN.
W
W = REQ'D.
WIDTH
12" + T
12"
T
12"
34"
TO
38"
R = 4" MIN.
7" MAX.
T = 11" MIN.
STAIRS



SMOKEPROOF ENCLOSURES



AREAS OF REFUGE

Code Requirements for Stairs

		Riser			
Code requirements	Tread min.	Min.	Max.	Min. width	Headroom
General (including HC)	11″	4″	7″	36″	6–8″
Private stairways (occ. <10)	9″		8″	20″	6–8″
Winding—min. required T at 12″ from narrow side*	6″ at any pt.				
Spiral—at 12″ from column*	7½″			26″	

Only permitted in R-3 dwellings and R-1 private apartments*

Circular: inside radius not less than 2× width of stair, min. T depth = 11″ @ 12″ from inside and 10″ @ inside, 36″ min. width.

Rules of thumb for general stairs:

Interior $2R + T = 25$

Exterior $2R + T = 26$

Open risers not permitted in most situations.

*Requires handrail.

Code Requirements for Ramp Slopes

Type	Max. slope	Max. rise	Max. run
Required for accessibility	1:12*	5′	
Others	1:8*	5′	
Assembly with fixed seats	1:5		
HC, new facilities	1:12*	2.5′	30′
HC, existing facilities	1:10*	6″	5′
	1:8*	3″	2′
HC, curb ramps	1:10	6″	5′
Historic buildings	1:6		

Any walking surface steeper than 5% is a ramp.

Landings are to be as wide as widest ramp to landing. Depth to be 5′ min. Where landing is at a corner, it shall be 5′ × 5′ min.

*Requires handrails for ramps > 1:15.

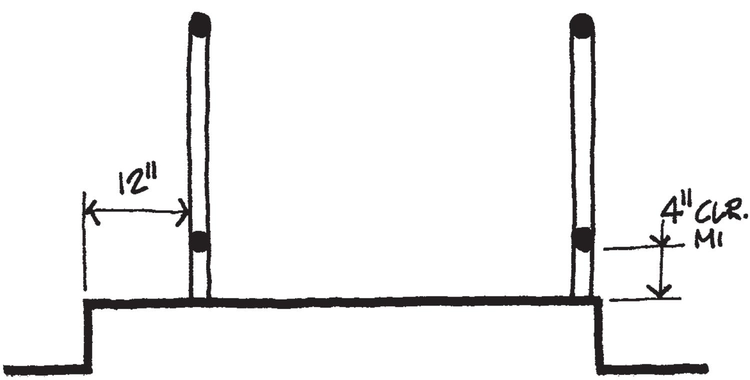


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TABLE A

(34)

TABLE 1004.1.1
MAXIMUM FLOOR AREA ALLOWANCES PER OCCUPANT

FUNCTION OF SPACE	FLOOR AREA IN SQ. FT. PER OCCUPANT
Accessory storage areas, mechanical equipment room	300 gross
Agricultural building	300 gross
Aircraft hangars	500 gross
Airport terminal	
Baggage claim	20 gross
Baggage handling	300 gross
Concourse	100 gross
Waiting areas	15 gross
Assembly	
Gaming floors (keno, slots, etc.)	11 gross
Assembly with fixed seats	See Section 1004.7
Assembly without fixed seats	
Concentrated (chairs only—not fixed)	7 net
Standing space	5 net
Unconcentrated (tables and chairs)	15 net
Bowling centers, allow 5 persons for each lane including 15 feet of runway, and for additional areas	7 net
Business areas	100 gross
Courtrooms—other than fixed seating areas	40 net
Day care	35 net
Dormitories	50 gross

(continued)

TABLE 1004.1.1, *(continued)*
MAXIMUM FLOOR AREA ALLOWANCES PER OCCUPANT

FUNCTION OF SPACE	FLOOR AREA IN SQ. FT. PER OCCUPANT
Educational	
Classroom area	20 net
Shops and other vocational room areas	50 net
Exercise rooms	50 gross
H-5 Fabrication and manufacturing areas	200 gross
Industrial areas	100 gross
Institutional areas	
Inpatient treatment areas	240 gross
Outpatient areas	100 gross
Sleeping areas	120 gross
Kitchens, commercial	200 gross
Library	
Reading rooms	50 net
Stack area	100 gross
Locker rooms	50 gross
Mercantile	
Areas on other floors	60 gross
Basement and grade floor areas	30 gross
Storage, stock, shipping areas	300 gross
Parking garages	200 gross
Residential	200 gross
Skating rinks, swimming pools	
Rink and pool	50 gross
Decks	15 gross
Stages and platforms	15 net
Warehouses	500 gross

For SI: 1 square foot = $0.0929\ m^2$.

TABLE B (IBC 2009) (34)
OCCUPANCY CLASSIFICATIONS

ASSEMBLY GROUP A:

NOTE: A room or space used for assembly purposes by less than 50 persons & accessory to another occupancy shall be included as part of that occupancy.

A-1 Assembly uses, usually with fixed seating, intended for the production and viewing of the performing arts or motion pictures including, but not limited to:

- Motion picture theaters
- Theaters
- TV & radio studios admitting an audience

A-2 Assembly uses intended for food and/or drink consumption including but not limited to:

Banquet halls, Restaurants, Night clubs, Taverns & bars

A-3 Assembly uses intended for worship, recreation, or amusement and other assembly uses not classified elsewhere in Group A, including, but not limited to:

Amusement arcades, Art galleries, Auditoriums, Bowling alleys, Churches, Community halls, Courtrooms, Dance halls, Exhibition halls, Funeral parlors, Gymnasiums, Indoor swimming pools, Indoor tennis courts, Lecture halls, Libraries, Museums, Passenger stations (wait areas), Pool and billiard parlors

A-4 Assembly uses intended for viewing of indoor sporting events and activities with spectator seating, including, but not limited to:

Arenas, Swimming pools, Skating rinks, Tennis courts

A-5 Assembly uses intended for participation in or viewing outdoor activities including, but not limited to:

Amusement park structures, Bleachers, Grandstands, Stadiums

BUSINESS GROUP B:

Includes, among others, the use of a building or structure, or a portion thereof, for office, professional or service-type transactions, including storage of records and accounts. Business occupancies include, but not limited to:

- Airport traffic control towers
- Animal hospitals, kennels & pounds
- Banks
- Barber and beauty shops
- Car wash
- Civic administration
- Clinic - outpatient
- Dry cleaning & laundries (pick-up & delivery stations & self-serv.)
- Educ. occupancies above 12th grade
- Electronic data processing
- Fire & police stations
- Laboratories: testing & research
- Motor vehicle showrooms
- Post offices
- Print shops
- Professional services (architects, attorneys, dentists, physicians, engineers, etc.)
- Radio & TV stations
- Telephone exchanges

EDUCATIONAL GROUP E:

Includes, among others, the use of a building or structure, or a portion thereof, by six or more persons at any one time for educational purposes through the 12th grade. Also, for educational, supervision or personal care services for more than five children older than 2 1/2 years of age.

FACTORY GROUP F:

Includes, among others, the use of a building or structure, or a portion thereof, for assembling, dissembling, fabricating, finishing, manufacturing, packaging, repair or processing operations that are not classified as a Group H hazardous occupancy.

F-1 Moderate Hazard

Factory Industrial uses not classified as F-2, including, but not limited to:

Aircraft	Jute products
Appliances	Laundries
Athletic equip.	Leather products
Automobiles and other motor vehicles	Machinery
	Metals
Bakeries	Millwork
Beverages (alcoholic)	Motion picture & TV filming
Bicycles	
Boats: building	Musical instruments
Brooms or brushes	Optical goods
Business machines	Paper mill or prod.
Cameras & photo equip.	Photographic film
Canvas or sim. fabric	Plastic products
Carpets & rugs (includes cleaning)	Printing or publ.
	Recreational veh.
Clothing	Refuse incineration
Const. & agri machinery	Shoes
Disinfectants	Soaps & detergents
Dry cleaning & dyeing	Textiles
Elect. light plants & power houses	Tobacco
	Trailers
Electronics	Upholstering
Engines (incl. rebuilding)	Wood: distillation
Food processing	Woodworking
Furniture (cabinet)	
Hemp products	

F-2 Low Hazard

Factory Industrial uses that involve the fabrication or manufacturing of noncombustible materials which during finishing, packing or processing do not involve a significant fire hazard, including, but not limited to:

Beverages (nonalcoholic)	Glass products
	Gypsum
Brick & masonry	Ice
Ceramic products	Metal products (fab. & assemb.)
Foundries	

HIGH-HAZARD GROUP H:

The IBC provides a detailed and complicated definition of each classification. Usually the classification will have to be done by the Building Official, the Fire Department, or a special consultant. Because the H occupancies have become so confusing here is a very brief description of each:

H-1: Containing high explosion hazard materials.

H-2: Where flammable or combustible liquids or dusts are being created, mixed, or dispensed.

H-3: Use of flammable or combustible liquids including organic peroxides and oxidizers that present high fire or heat release hazards.

H-4: Containing health hazard materials such as corrosive and toxic chemicals.

H-5: Semiconductor fabrication facilities.

INSTITUTIONAL GROUP I:

This occupancy is where people with physical limitations in a medical setting or people with restricted limitations in a penal setting are housed.

I-1: Housing more than 16 persons in a residential setting (R-3 if 5 or less).

I-2: Medical buildings with 24 hour care of more than 5 people, such as hospitals, nursing homes, etc. (R-3 if less than 5 people). This also includes 24 hour child care under 2 1/2 years old.

I-3: Housing more than 5 people in secured conditions such as prisons and jails. The code further has 5 subconditions.

I-4: Day care facilities (R-3 if 5 or less persons and E under certain conditions).

MERCANTILE GROUP M:

Buildings used for the display, sale, and stocking of goods such as department stores, drug stores, markets, sales rooms, retail or wholesale stores. This also includes motor vehicle service stations.

RESIDENTIAL GROUP R:

NOTE: One and two family dwellings are covered under the International Residential Code (IRC). See page 71. Otherwise:

R-1: Transient lodging (under 30 days), including hotels and motels.

R-2: Three or more dwelling units (DUs) where occupancy is mainly permanent, such as apartments, dormitories, convents, fraternity, and sorority houses.

R-3: Buildings containing one or two DUs for adult or child care of any age for less than 24 hours with not more than 5 people.

R-4: Residential care or assisted living facilities, where number of residents is greater than 5 but not greater than 16.

STORAGE GROUP S:

Warehousing, subdivided as follows:

S-1 MODERATE-HAZARD:

Stores flammable products that are not classified as H. This also includes some car repair garages and aircraft hangars. See code for details.

S-2 LOW-HAZARD:

Storage of noncombustible materials. See code for details.

UTILITY GROUP U:

Building of an accessory nature, not classified elsewhere. Carports and private garages are included.

OTHER SPECIAL OCCUPANCIES:

Covered Mall Buildings

High Rise Buildings (above 75' high).

Atriums

Underground Buildings

NOTES

TABLE C 34

TABLE 503
ALLOWABLE BUILDING HEIGHTS AND AREAS[a]

Building height limitations shown in feet above grade plane. Story limitations shown as stories above grade plane.
Building area limitations shown in square feet, as determined by the definition of "Area, building," per story

GROUP		TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
	HEIGHT(feet)	UL	160	65	55	65	55	65	50	40
		STORIES(S) AREA (A)								
A-1	S A	UL UL	5 UL	3 15,500	2 8,500	3 14,000	2 8,500	3 15,000	2 11,500	1 5,500
A-2	S A	UL UL	11 UL	3 15,500	2 9,500	3 14,000	2 9,500	3 15,000	2 11,500	1 6,000
A-3	S A	UL UL	11 UL	3 15,500	2 9,500	3 14,000	2 9,500	3 15,000	2 11,500	1 6,000
A-4	S A	UL UL	11 UL	3 15,500	2 9,500	3 14,000	2 9,500	3 15,000	2 11,500	1 6,000
A-5	S A	UL UL	UL UL	UL UL	UL UL	UL UL	UL UL	UL UL	UL UL	UL UL
B	S A	UL UL	11 UL	5 37,500	3 23,000	5 28,500	3 19,000	5 36,000	3 18,000	2 9,000
E	S A	UL UL	5 UL	3 26,500	2 14,500	3 23,500	2 14,500	3 25,500	1 18,500	1 9,500
F-1	S A	UL UL	11 UL	4 25,000	2 15,500	3 19,000	2 12,000	4 33,500	2 14,000	1 8,500
F-2	S A	UL UL	11 UL	5 37,500	3 23,000	4 28,500	3 18,000	5 50,500	3 21,000	2 13,000
H-1	S A	1 21,000	1 16,500	1 11,000	1 7,000	1 9,500	1 7,000	1 10,500	1 7,500	NP NP

TABLE 503, *(continued)*
ALLOWABLE BUILDING HEIGHTS AND AREAS[a]
Building height limitations shown in feet above grade plane. Story limitations shown as stories above grade plane.
Building area limitations shown in square feet, as determined by the definition of "Area, building," per story

GROUP		TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
	HEIGHT(feet)	UL	160	65	55	65	55	65	50	40
		STORIES(S) AREA (A)								
H-2[d]	S	UL	3	2	1	2	1	2	1	1
	A	21,000	16,500	11,000	7,000	9,500	7,000	10,500	7,500	3,000
H-3[d]	S	UL	6	4	2	4	2	4	2	1
	A	UL	60,000	26,500	14,000	17,500	13,000	25,500	10,000	5,000
H-4	S	UL	7	5	3	5	3	5	3	2
	A	UL	UL	37,500	17,500	28,500	17,500	36,000	18,000	6,500
H-5	S	4	4	3	3	3	3	3	3	2
	A	UL	UL	37,500	23,000	28,500	19,000	36,000	18,000	9,000
I-1	S	UL	9	4	3	4	3	4	3	2
	A	UL	55,000	19,000	10,000	16,500	10,000	18,000	10,500	4,500
I-2	S	UL	4	2	1	1	NP	1	1	NP
	A	UL	UL	15,000	11,000	12,000	NP	12,000	9,500	NP
I-3	S	UL	4	2	1	2	1	2	2	1
	A	UL	UL	15,000	10,000	10,500	7,500	12,000	7,500	5,000
I-4	S	UL	5	3	2	3	2	3	1	1
	A	UL	60,500	26,500	13,000	23,500	13,000	25,500	18,500	9,000
M	S	UL	11	4	2	4	2	4	3	1
	A	UL	UL	21,500	12,500	18,500	12,500	20,500	14,000	9,000
R-1	S	UL	11	4	4	4	4	4	3	2
	A	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
R-2	S	UL	11	4	4	4	4	4	3	2
	A	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
R-3	S	UL	11	4	4	4	4	4	3	3
	A	UL	UL	UL	UL	UL	UL	UL	UL	UL

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TABLE 503, *(continued)*
ALLOWABLE BUILDING HEIGHTS AND AREAS[a]
Building height limitations shown in feet above grade plane. Story limitations shown as stories above grade plane. Building area limitations shown in square feet, as determined by the definition of "Area, building," per story

		TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
	HEIGHT(feet)	UL	160	65	55	65	55	65	50	40
GROUP		STORIES(S) AREA (A)								
R-4	S	UL	11	4	4	4	4	4	3	2
	A	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
S-1	S	UL	11	4	2	3	2	4	3	1
	A	UL	48,000	26,000	17,500	26,000	17,500	25,500	14,000	9,000
S-2[b, c]	S	UL	11	5	3	4	3	5	4	2
	A	UL	79,000	39,000	26,000	39,000	26,000	38,500	21,000	13,500
U[c]	S	UL	5	4	2	3	2	4	2	1
	A	UL	35,500	19,000	8,500	14,000	8,500	18,000	9,000	5,500

For SI: 1 foot = 304.8 mm, 1 square foot = $0.0929 \, m^2$.

A = building area per story, S = stories above grade plane, UL = Unlimited, NP = Not permitted.

a. See the following sections for general exceptions to Table 503:
   1. Section 504.2, Allowable building height and story increase due to automatic sprinkler system installation.
   2. Section 506.2, Allowable building area increase due to street frontage.
   3. Section 506.3, Allowable building area increase due to automatic sprinkler system installation.
   4. Section 507, Unlimited area buildings.

b. For open parking structures, see Section 406.3.

c. For private garages, see Section 406.1.

d. See Section 415.5 for limitations.

NOTES

TABLE D

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TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (hours)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A[d]	B	A[d]	B	HT	A[d]	B
Primary structural frame[g] (see Section 202)	3[a]	2[a]	1	0	1	0	HT	1	0
Bearing walls									
Exterior[f, g]	3	2	1	0	2	2	2	1	0
Interior	3[a]	2[a]	1	0	1	0	1/HT	1	0
Nonbearing walls and partitions Exterior	See Table 602								
Nonbearing walls and partitions Interior[e]	0	0	0	0	0	0	See Section 602.4.6	0	0
Floor construction and secondary members (see Section 202)	2	2	1	0	1	0	HT	1	0
Roof construction and secondary members (see Section 202)	$1^1/_2$[b]	1[b, c]	1[b, c]	0[c]	1[b, c]	0	HT	1[b, c]	0

TABLE 601, *(continued)*
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (hours)

For SI: 1 foot = 304.8 mm.

a. Roof supports: Fire-resistance ratings of primary structural frame and bearing walls are permitted to be reduced by 1 hour where supporting a roof only.

b. Except in Group F-1, H, M and S-1 occupancies, fire protection of structural members shall not be required, including protection of roof framing and decking where every part of the roof construction is 20 feet or more above any floor immediately below. Fire-retardant-treated wood members shall be allowed to be used for such unprotected members.

c. In all occupancies, heavy timber shall be allowed where a 1-hour or less fire-resistance rating is required.

d. An approved automatic sprinkler system in accordance with Section 903.3.1.1 shall be allowed to be substituted for 1-hour fire-resistance-rated construction, provided such system is not otherwise required by other provisions of the code or used for an allowable area increase in accordance with Section 506.3 or an allowable height increase in accordance with Section 504.2. The 1-hour substitution for the fire resistance of exterior walls shall not be permitted.

Not less than the fire-resistance rating required by other sections of this code.

f. Not less than the fire-resistance rating based on fire separation distance (see Table 602).

g. Not less than the fire-resistance rating as referenced in Section 704.10

TABLE I 34

TABLE 705.8
MAXIMUM AREA OF EXTERIOR WALL OPENINGS BASED ON FIRE SEPARATION DISTANCE AND DEGREE OF OPENING PROTECTION

FIRE SEPARATION DISTANCE (feet)	DEGREE OF OPENING PROTECTION	ALLOWABLE AREA[a]
0 to less than 3[b, c]	Unprotected, Nonsprinklered (UP, NS)	Not Permitted
	Unprotected, Sprinklered (UP, S)[i]	Not Permitted
	Protected (P)	Not Permitted
3 to less than 5[d, e]	Unprotected, Nonsprinklered (UP, NS)	Not Permitted
	Unprotected, Sprinklered (UP, S)[i]	15%
	Protected (P)	15%
5 to less than 10[e, f]	Unprotected, Nonsprinklered (UP, NS)	10%[h]
	Unprotected, Sprinklered (UP, S)[i]	25%
	Protected (P)	25%
10 to less than 15[e, f, g]	Unprotected, Nonsprinklered (UP, NS)	15%[h]
	Unprotected, Sprinklered (UP, S)[i]	45%
	Protected (P)	45%

TABLE 705.8, *(continued)*

MAXIMUM AREA OF EXTERIOR WALL OPENINGS BASED ON FIRE SEPARATION DISTANCE AND DEGREE OF OPENING PROTECTION

FIRE SEPARATION DISTANCE (feet)	DEGREE OF OPENING PROTECTION	ALLOWABLE AREA[a]
15 to less than 20[f, g]	Unprotected, Nonsprinklered (UP, NS)	25%
	Unprotected, Sprinklered (UP, S)[i]	75%
	Protected (P)	75%
20 to less than 25[f, g]	Unprotected, Nonsprinklered (UP, NS)	45%
	Unprotected, Sprinklered (UP, S)[i]	No Limit
	Protected (P)	No Limit
25 to less than 30[f, g]	Unprotected, Nonsprinklered (UP, NS)	70%
	Unprotected, Sprinklered (UP, S)[i]	No Limit
	Protected (P)	No Limit
30 or greater	Unprotected, Nonsprinklered (UP, NS)	No Limit
	Unprotected, Sprinklered (UP, S)[i]	Not Required
	Protected (P)	Not Required

TABLE 705.8, *(continued)*
MAXIMUM AREA OF EXTERIOR WALL OPENINGS BASED ON FIRE SEPARATION DISTANCE AND DEGREE OF OPENING PROTECTION

For SI: 1 foot = 304.8 mm.
UP, NS = Unprotected openings in buildings not equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1.
UP, S = Unprotected openings in buildings equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1.
P = Openings protected with an opening protective assembly in accordance with Section 705.8.2.

a. Values indicated are the percentage of the area of the exterior wall, per story.
b. For the requirements for fire walls of buildings with differing heights, see Section 706.6.1.
c. For openings in a fire wall for buildings on the same lot, see Section 706.8.
d. The maximum percentage of unprotected and protected openings shall be 25 percent for Group R-3 occupancies.
e. Unprotected openings shall not be permitted for openings with a fire separation distance of less than 15 feet for Group H-2 and H-3 occupancies.
f. The area of unprotected and protected openings shall not be limited for Group R-3 occupancies, with a fire separation distance of 5 feet or greater.
g. The area of openings in an open parking structure with a fire separation distance of 10 feet or greater shall not be limited.
h. Includes buildings accessory to Group R-3.
i. Not applicable to Group H-1, H-2 and H-3 occupancies.

NOTES

TABLE E (34)

TABLE 508.4
REQUIRED SEPARATION OF OCCUPANCIES (HOURS)

OCCUPANCY	A[d], E		I-1, I-3, I-4		I-2		R		F-2, S-2[b], U		B, F-1, M, S-1		H-1		H-2		H-3, H-4, H-5	
	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
A[d], E	N	N	1	2	2	NP	1	2	N	1	1	2	NP	NP	3	4	2	3[a]
I-1, I-3, I-4	—	—	N	N	2	NP	1	NP	1	2	1	2	NP	NP	3	NP	2	NP
I-2	—	—	—	—	N	N	2	NP	2	NP	2	NP	NP	NP	3	NP	2	NP
R	—	—	—	—	—	—	N	N	1[c]	2[c]	1	2	NP	NP	3	NP	2	NP
F-2, S-2[b], U	—	—	—	—	—	—	—	—	N	N	1	2	NP	NP	3	4	2	3[a]
B, F-1, M, S-1	—	—	—	—	—	—	—	—	—	—	N	N	NP	NP	2	3	1	2[a]
H-1	—	—	—	—	—	—	—	—	—	—	—	—	N	NP	NP	NP	NP	NP
H-2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	NP	1	NP
H-3, H-4, H-5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1[e, f]	NP

TABLE 508.4, *(continued)*
REQUIRED SEPARATION OF OCCUPANCIES (HOURS)

For SI: 1 square foot = 0.0929 m^2.

S = Buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1.

NS = Buildings not equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1.

N = No separation requirement.

NP = Not permitted.

a. For Group H-5 occupancies, see Section 903.2.5.2.
b. The required separation from areas used only for private or pleasure vehicles shall be reduced by 1 hour but to not less than 1 hour.
c. See Section 406.1.4.
d. Commercial kitchens need not be separated from the restaurant seating areas that they serve.
e. Separation is not required between occupancies of the same classification.
f. For H-5 occupancies, see Section 415.8.2.2.

TABLE F (34)

TABLE 602
FIRE-RESISTANCE RATING REQUIREMENTS FOR EXTERIOR WALLS BASED ON FIRE SEPARATION DISTANCE[a, e]

FIRE SEPARATION DISTANCE = X (feet)	TYPE OF CONSTRUCTION	OCCUPANCY GROUP H[f]	OCCUPANCY GROUP F-1, M, S-1[g]	OCCUPANCY GROUP A, B, E, F-2, I, R, S-2[g], U[b]
$X < 5$[c]	All	3	2	1
$5 \leq X < 10$	IA Others	3 2	2 1	1 1
$10 \leq X < 30$	IA, IB IIB, VB Others	2 1 1	1 0 1	1[d] 0 1[d]
$X \geq 30$	All	0	0	0

For SI: 1 foot = 304.8 mm.

a. Load-bearing exterior walls shall also comply with the fire-resistance rating requirements of Table 601.

b. For special requirements for Group U occupancies, see Section 406.1.2.

c. See Section 706.1.1 for party walls.

d. Open parking garages complying with Section 406 shall not be required to have a fire-resistance rating.

e. The fire-resistance rating of an exterior wall is determined based upon the fire separation distance of the exterior wall and the story in which the wall is located.

f. For special requirements for Group H occupancies, see Section 415.3.

g. For special requirements for Group S aircraft hangars, see Section 412.4.1.

TABLE K (34)

TABLE 1021.1
MINIMUM NUMBER OF EXITS FOR OCCUPANT LOAD

OCCUPANT LOAD (persons per story)	MINIMUM NUMBER OF EXITS (per story)
1-500	2
501-1,000	3
More than 1,000	4

TABLE M (34)

TABLE 1015.1
SPACES WITH ONE EXIT OR EXIT ACCESS DOORWAY

OCCUPANCY	MAXIMUM OCCUPANT LOAD
A, B, E[a], F, M, U	49
H-1, H-2, H-3	3
H-4, H-5, I-1, I-3, I-4, R	10
S	29

a. Day care maximum occupant load is 10.

TABLE G (34)

TABLE 715.4
FIRE DOOR AND FIRE SHUTTER FIRE PROTECTION RATINGS

TYPE OF ASSEMBLY	REQUIRED ASSEMBLY RATING (hours)	MINIMUM FIRE DOOR AND FIRE SHUTTER ASSEMBLY RATING (hours)
Fire walls and fire barriers having a required fire-resistance rating greater than 1 hour	4 3 2 $1^1/_2$	3 3[a] $1^1/_2$ $1^1/_2$
Fire barriers having a required fire-resistance rating of 1 hour:		
Shaft, exit enclosure and exit passageway walls	1	1
Other fire barriers	1	$^3/_4$
Fire partitions:		
Corridor walls	1 0.5	$^1/_3$ [b] $^1/_3$ [b]
Other fire partitions	1 0.5	$^3/_4$ $^1/_3$
Exterior walls	3 2 1	$1^1/_2$ $1^1/_2$ $^3/_4$
Smoke barriers	1	$^1/_3$ [b]

a. Two doors, each with a fire protection rating of $1^1/_2$ hours, installed on opposite sides of the same opening in a fire wall, shall be deemed equivalent in fire protection rating to one 3-hour fire door.

b. For testing requirements, see Section 715.4.3.

TABLE H (34)

TABLE 1018.1
CORRIDOR FIRE-RESISTANCE RATING

OCCUPANCY	OCCUPANT LOAD SERVED BY CORRIDOR	REQUIRED FIRE-RESISTANCE RATING (hours)	
		Without sprinkler system	With sprinkler system[c]
H-1, H-2, H-3	All	Not Permitted	1
H-4, H-5	Greater than 30	Not Permitted	1
A, B, E, F, M, S, U	Greater than 30	1	0
R	Greater than 10	Not Permitted	0.5
I-2[a], I-4	All	Not Permitted	0
I-1, I-3	All	Not Permitted	1[b]

a. For requirements for occupancies in Group I-2, see Sections 407.2 and 407.3.
b. For a reduction in the fire-resistance rating for occupancies in Group I-3, see Section 408.8.
c. Buildings equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1 or 903.3.1.2 where allowed.

TABLE J (34)

TABLE 1005.1
EGRESS WIDTH PER OCCUPANT SERVED

OCCUPANCY	WITHOUT SPRINKLER SYSTEM		WITH SPRINKLER SYSTEM[a]	
	Stairways (inches per occupant)	Other egress components (inches per occupant)	Stairways (inches per occupant)	Other egress components (inches per occupant)
Occupancies other than those listed below	0.3	0.2	0.2	0.15
Hazardous: H-1, H-2, H-3 and H-4	0.7	0.4	0.3	0.2
Institutional: I-2	NA	NA	0.3	0.2

For SI: 1 inch = 25.4 mm. NA = Not applicable.

a. Buildings equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1 or 903.3.1.2.

TABLE L (34)

TABLE 1016.1
EXIT ACCESS TRAVEL DISTANCE[a]

OCCUPANCY	WITHOUT SPRINKLER SYSTEM (feet)	WITH SPRINKLER SYSTEM (feet)
A, E, F-1, M, R, S-1	200	250[b]
I-1	Not Permitted	250[c]
B	200	300[c]
F-2, S-2, U	300	400[c]
H-1	Not Permitted	75[c]
H-2	Not Permitted	100[c]
H-3	Not Permitted	150[c]
H-4	Not Permitted	175[c]
H-5	Not Permitted	200[c]
I-2, I-3, I-4	Not Permitted	200[c]

For SI: 1 foot = 304.8 mm.

a. See the following sections for modifications to exit access travel distance requirements:
   Section 402.4: For the distance limitation in malls.
   Section 404.9: For the distance limitation through an atrium space.
   Section 407.4: For the distance limitation in Group I-2.
   Sections 408.6.1 and 408.8.1: For the distance limitations in Group I-3.
   Section 411.4: For the distance limitation in special amusement buildings.
   Section 1014.2.2: For the distance limitation in Group I-2 hospital suites.
   Section 1015.4: For the distance limitation in refrigeration machinery rooms.
   Section 1015.5: For the distance limitation in refrigerated rooms and spaces.
   Section 1021.2: For buildings with one exit.
   Section 1028.7: For increased limitation in assembly seating.
   Section 1028.7: For increased limitation for assembly open-air seating.
   Section 3103.4: For temporary structures.
   Section 3104.9: For pedestrian walkways.

b. Buildings equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1 or 903.3.1.2. See Section 903 for occupancies where automatic sprinkler systems are permitted in accordance with Section 903.3.1.2.

c. Buildings equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1.

TABLE N (34)

TABLE 1021.2
STORIES WITH ONE EXIT

STORY	OCCUPANCY	MAXIMUM OCCUPANTS (OR DWELLING UNITS) PER FLOOR AND TRAVEL DISTANCE
First story or basement	A, B[d], E[e], F[d], M, U, S[d]	49 occupants and 75 feet travel distance
	H-2, H-3	3 occupants and 25 feet travel distance
	H-4, H-5, I, R	10 occupants and 75 feet travel distance
	S[a]	29 occupants and 100 feet travel distance
Second story	B[b], F, M, S[a]	29 occupants and 75 feet travel distance
	R-2	4 dwelling units and 50 feet travel distance
Third story	R-2[c]	4 dwelling units and 50 feet travel distance

For SI: 1 foot = 304.8 mm.

a. For the required number of exits for parking structures, see Section 1021.1.2.

b. For the required number of exits for air traffic control towers, see Section 412.3.

c. Buildings classified as Group R-2 equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1 or 903.3.1.2 and provided with emergency escape and rescue openings in accordance with Section 1029.

d. Group B, F and S occupancies in buildings equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1 shall have a maximum travel distance of 100 feet.

e. Day care occupancies shall have a maximum occupant load of 10.

NOTES

NOTES

EXAMPLE PROBLEM

ROUGHLY CHECK FOR CODE REQUIREMENTS FOR THE DESIGN OF A NEW CORPORATE HEADQUARTERS IN A SUBURBAN SETTING ON A LARGE SITE. THE PRESENT THINKING IS TO HAVE A 3 STORY OFFICE BUILDING WITH 2 FLOORS OF PARKING IN THE BASEMENT, BELOW. BECAUSE OF INSURANCE, THE BUILDING WILL BE FULLY SPRINKLERED. PRESENT THINKING IS FOR A STEEL & GLASS BLD'G. & A CONCRETE BASEMENT.

CHECK AGAINST IBC 2009 CODE

FOLLOWING THE SEQUENCE, STARTING ON PAGE 89:

a. OCCUPANT LOAD PER TABLE A IS: BUSINESS = 100 SF/OCC.
PARKING = 200 SF/OCC.

b. OCCUPANCY: PER TABLE B IS: OFFICE = B, PARKING GARAGE = S-2

c. ALLOWABLE AREA: (PER TABLE C)

OCC.		I		II		III		IV	V	
		A	B	A	B	A	B		A	B
B	S	UL	11	5	3	5	3	5	3	2
	A	UL	UL	37500	23000	28500	19000	36000	18000	9000
S-2	S	UL	11	5	3	4	3	5	4	2
	A	UL	79000	39000	26000	39000	26000	38500	21000	13500

SELECT II-B CONST. FOR A STEEL STRUCTURE = 23000 SF/FL
HOLD OFF ON S-2 SELECTION FOR NOW.

(1) AREA INCREASES
SPRINKLER CREDIT:
(a.) SINCE BUILDING IS TO BE SPRINKLERED:
$I_S = 200\%$

(b) FRONTAGE CREDIT:
ASSUME BUILDING TO HAVE FIRE DEPT. ACCESS AROUND WHOLE BUILDING. ∴ $I_f = 75\%$

(c) INCREASE FOR (a) & (b), ABOVE:

$$A_a = A_t + \left[\frac{A_t\ I_f}{100} + \frac{A_t\ I_s}{100}\right]$$

$$A_a = 23000 + \left[\frac{23000 \times 75}{100} + \frac{23000 \times 200}{100}\right]$$

$$A_a = 23000 + 17250 + 46000$$

$$A_a = 86\,250 \text{ SF / FLOOR}$$

× 3 FLOORS

258 750 SF TOTAL FOR 3 STORY OFFICE

(d) UNLIMITED AREA
S-2 PARKING GARAGE ALLOWED UNLIMITED AREA BECAUSE OF TOTAL F.D. ACCESS AROUND BLD'G.

(2) COMPARTMENTING:
IN THEORY, THE BUILDING COULD BE ENDLESS IN SIZE IF COMPARTMENTED WITH 3 HOUR FIRE WALLS, MAKING IT INTO SEPARATE 258 750 SF BUILDINGS. BECAUSE OF LAND AREA & COSTS, WE WILL NOT DO THIS.

d. ALLOWABLE HEIGHT
PER TABLE C, WE ARE ALLOWED 4 STORIES. BY HAVING SPRINKLERS, WE ARE ALLOWED A TOTAL OF 5 STORIES. BECAUSE OF COST, WE WILL STAY WITH 3 STORIES.

e. CONSTRUCTION TYPE
II-B IS UNPROTECTED NON COMBUSTIBLE (STEEL) CONST.

f. HOURLY RATINGS: PER TABLE D, II-B IS 0 HOURS FOR ALL ELEMENTS.

g. OCCUPANCY SEPARATION: PER TABLE E, A 0 HOUR SEP. WALL IS REQ'D. BETWEEN A B & S-2. WE WILL MAKE THIS A 6" CONCRETE SLAB.

h. SPRINKLER REQUIREMENTS: S-2 PARKING GARAGES ARE REQ'D. TO BE SPRINKLERED, BUT WE ARE PLANNING TO SPRINKLER THE WHOLE BUILDING ANYWAY.

i. FIRE AREAS, WALLS, BARRIERS, & PARTITIONS.

FIRE AREAS = N/A

FIRE WALLS = N/A

FIRE BARRIERS = 2 HOUR BARRIER @ GROUND FLOOR, (PER g., ABOVE) + FIRE STAIRS.

FIRE PARTITIONS = N/A

ONE HOUR RATED WALLS = PER TABLE H, NO RATING DUE TO SPRINKLERS.

1/2 HOUR RATED WALLS = REQ'D. IN II-B SPRINKLERED.

j. EXTERIOR WALLS

PER TABLE J: NO RATING REQ'D. BECAUSE > 30' TO ℄.

k. EXITING:

1. FOR OFFICE: $\frac{86250 \text{ SF/FL}}{100 \text{ SF/OCC.}} = 862.5$ OCC./FL
2. PER TABLE K: MUST HAVE 3 EXITS PER FLOOR.
3. FOR TYPE II-B, MUST HAVE 2 HR. WALLS @ EXIT STAIRS.
4. EXITS MUST BE SEPARATED BY 1/2 DIAGONAL & 3RD AT REASONABLE DISTANCE.
5. EXIT WIDTH PER TABLE J (W/ SPRINKLERS):

   0.2"/OCC. FOR STAIRWAYS

   0.15"/OCC. FOR OTHER

862.5 OCC./FL ÷ 3 EXITS = 287.5 OCC./EXIT

287.5 OCC. × 0.2"/OCC. = 57½" OR 4'-9½" FOR STAIR WIDTH.

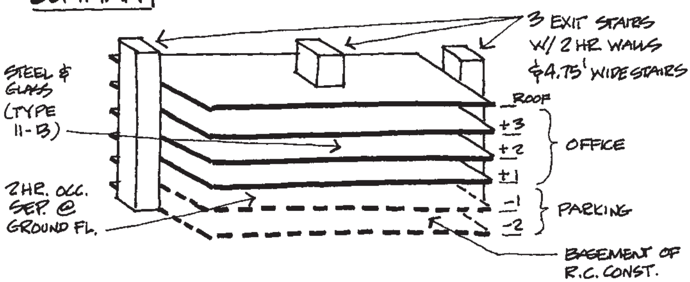
287.5 OCC. X 0.15"/OCC. = 43.125", SAY 44" OR 3'-8" CORRIDORS.

BASEMENT PARKING GARAGE:
THE PARKING GARAGE IS PLANNED TO BE 2 FLOORS BELOW THE OFFICE BUILDING. SINCE IT IS PLANNED TO BE CONC. CONST., IT WILL BE IN EFFECT I-A CONSTRUCTION, WHICH ALLOWS UNLIMITED AREA (EVEN THOUGH WE ARE LIMITING IT TO THE FOOT PRINT OF THE OFFICE BUILDING, ABOVE). THE OCC. LOAD FACTOR IS 200 SF/OCC. PER TABLE A. AT:

$$\frac{86250 \text{ SF/FL}}{200 \text{ SF/OCC}} = 431.25 \text{ OCC./FL.}$$

PER TABLE K, 2 EXITS ARE REQ'D.

SUMMARY



AREA & OCCUPANT LOAD TABLE

	FLOOR	DESIGNATION	USE	AREA	FACTOR	OCC.
	1	B	OFFICE	86250	100	862.5
	2	"	"	"	"	"
	3	"	"	"	"	"
S.T.		B	OFFICE	258750 SF		2587.5 OCC.
	-1	S-2	PARKING	86250	200	431.25
	-2	"	"	"	"	"
S.T.		S-2	PARKING	172500 SF		862.5 OCC.
TOTAL		BUILDING		431250 SF		3450 OCC.

NOTES

NOTES

___ 4. ***Accessibility (ADA requirements)*** (27)

___ *a.* *General:* This section concerns accessibility for the disabled as required by *ADA,* the Americans with Disabilities Act (Title 3, the national civil rights law), in nongovernment buildings (Title 2 applies to government buildings), as amended by ICC/ANSI A 117.1—1998. Local or state laws may (in part) be more restrictive regarding alterations and new buildings. For each item under consideration, *the more restrictive law applies.*

___ *b.* *ADA* applies to:

___ (1) *Places of public accommodation* (excluding private homes and clubs, as well as churches). Often, buildings will have space both for the general public and for employees only.

___ (2) *Commercial facilities* (employees only) requirements are less restrictive, requiring only an accessible entry, exit, and route through each type of facility function. Only when a disabled employee is hired (under Title 1) do more restrictive standards apply.

___ *c.* *Existing buildings* are to comply by removing "architectural barriers," as much as possible, when this is "readily achievable" (not requiring undue expense, hardship, or loss of space). This effort, in theory, is to be ongoing until all barriers are removed. When barriers can't be readily removed, "equivalent facilitation" is allowed. Priorities of removal are:

___ (1) Entry to places of public accommodation

___ (2) Access to areas where goods and services are made available to the public

___ (3) Access to restroom facilities

___ (4) Removal of all other barriers

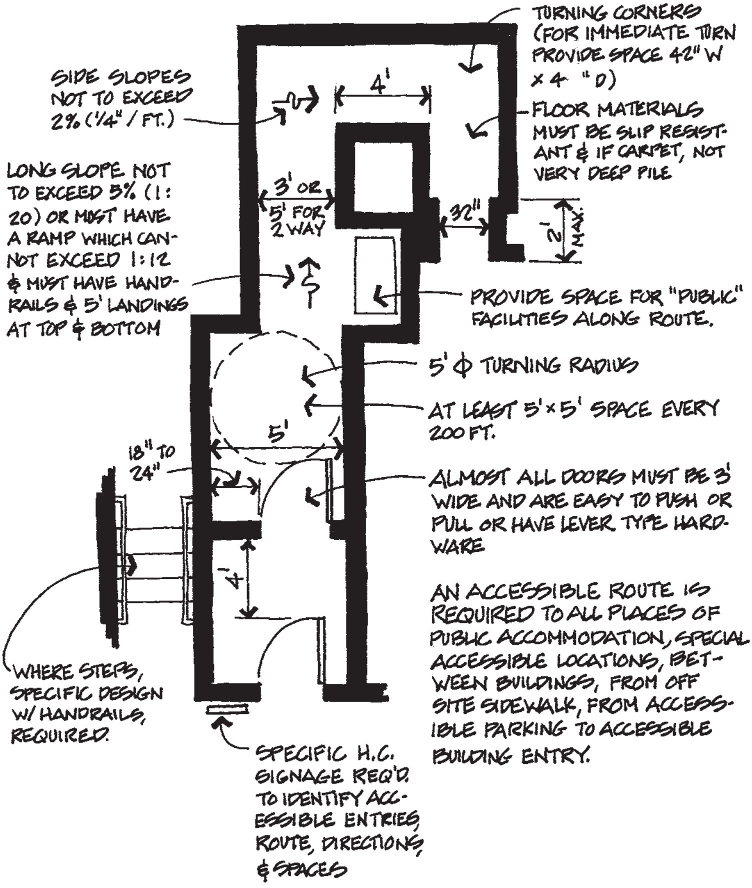
___ *d.* *Alterations* to existing buildings require a higher standard. To the maximum extent possible, the altered portions are to be made accessible. If the altered area is a "primary function" of the building, then an accessible "path of travel" must be provided from the entry to the area (including public restrooms, telephones, and drinking fountains), with exemption only possible when cost of the path exceeds 20% of the cost to alter the primary function.

___ *e.* *New buildings or facilities* must totally comply, with only exceptions being situations of "structural impracticability."

___ *f.* See *Index,* p. 665, for a complete list of *ADA* requirements.

ACCESSIBLE ROUTE PER A.D.A.

(INTERIOR AND EXTERIOR)



AN ACCESSIBLE ROUTE IS REQUIRED TO ALL PLACES OF PUBLIC ACCOMMODATION, SPECIAL ACCESSIBLE LOCATIONS, BET-WEEN BUILDINGS, FROM OFF SITE SIDEWALK, FROM ACCESS-IBLE PARKING TO ACCESSIBLE BUILDING ENTRY.

NOTES

NOTES

___ I. STRUCTURAL SYSTEMS

(A) (1) (2) (10) (13) (16) (26) (34) (50)

Deciding which structural system to use is one of the most prominent choices the architect will have to make. Factors affecting the choice:

___ 1. Construction type by code
___ 2. Long vs. short spans
___ 3. Live loads
___ 4. Low vs. high rise
___ 5. Lateral and uplift
___ 6. Rules of thumb for estimating structural sizes

___ 1. **Construction Type by Code** (also see p. 94)

___ *a.* *Type I, A and B Construction*—require noncombustible materials (concrete, masonry, and steel) and substantial fire-resistive ratings (2, 3, and 4 hours). Both these construction types can be used to build large, tall buildings. The difference is that Type I has no height or area limits for most occupancies. Type I construction requires 3- and 4-hour fire resistance for structural members. Type II has a maximum height limit of 160′ as well as floor area and maximum story limitations as a function of occupancy. Type II requires 3- and 2-hour ratings and thus is less expensive. Typical systems are:

Concrete solid slabs	10′–25′ spans
Concrete slabs win drop panels	20′–35′
Concrete 2-way slab on beam	20′–35′
Concrete waffle slabs	30′–40′
Concrete joists	25′–45′
Concrete beams	15′–40′
Concrete girders	20′–60′
Concrete tees	20′–120′
Concrete arches	60′–150′
Concrete thin shell roofs	50′–70′
Steel decking	5′–15′
Steel beams	15′–60′
Steel plate girders	40′–100′

___ *b.* *Type II, A and B*—uses structural members of noncombustible construction materials for exterior walls, interior bearing walls, columns, floors, and roof. This is usually steel framing combined with concrete or masonry walls. Typical systems are:

Steel decking	5′–15′ spans
Steel beams	15′–60′

Steel joists	15′–60′
Steel plate girders	40′–100′
Steel trusses	40′–80′

___ c. *Type III, A and B*—has exterior walls of noncombustible construction material, usually masonry or concrete; interior columns, beams, floors, and roofs can be constructed of any material, including wood. Typical systems are:

Wood joists	10′–25′ spans
Wood beams	15′–30′
Wood girders	20′–35′
Glu-lam beams	15′–120′
Wood trusses	30′–100′

___ d. *Type IV Heavy Timber Construction*—achieves its fire resistance from the large size of the timber members used to frame it (2″ actual +). Exterior walls must be noncombustible. Typical systems are:

Wood planks, T and G, 3″	2′–6′ spans
Wood beams, 6 × 10, min.	15′–30′
Wood girders, 6 × 10, min.	20′–35′
Wood trusses supporting floors 8″ oc. min. and roofs 6″ × 8″	30′–100′
Wood arches supporting floors 8′ oc. min. and roofs 6″ × 8″ min.	30′–120′
Wood glu-lam beams	15′–120′

___ e. *Type V, A and B*—is essentially light wood-frame construction. Typical systems are:

Plywood	2′–4′ spans
Wood planks	2′–6′
Wood joists	10′–25′
Wood beams	15′–30′
Wood girders	20′–35′
Glu-lam beams	15′–150′
Wood trusses	30′–100′

Note: When tentative structural system selected, see Part 13 for details and ***costs.***

___ 2. <u>Long vs. Short Spans</u>

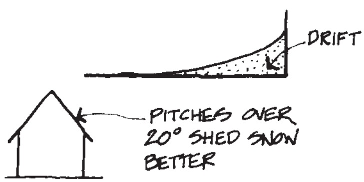
Select shortest span for required functional use of the space. *Short spans* (10′, 20′, or 30′) suggest beams, girders, and slabs in bending. This method encloses the space economically with a minimum of structural depth.

Long spans (50′ to 100′ and beyond) suggest the use of shape to aid the structural material. Arches, shells, domes, space frames trusses, and similar structures use their shape to help the structural material span the long distance.

Extra-long spans (such as stadiums) involve roofs spanning great distances. The economics suggest tension and inflatable membrane structures.

___ **3. Loads** (vertical)

- ___ *a.* Roof
  - ___ (1) *Live loads* are determined by occupancy and roof slope use. See p. 150.
  - ___ (2) *Snow loads* should be considered when required (especially when loads are 20 lb/SF or more). See App. B, item T. Take into account:
    - ___ (*a*) Heavier loads at drift locations
    - ___ (*b*) Pitch of roof
    - ___ (*c*) Roof valleys



- ___ *b.* Floor: see p. 150.

___ **4. Low- vs. High-Rise**

Low-rise (1 to 6 stories) structural design is dominated by the collection of dead and live loads through slabs, beams, and girders onto the walls and columns where the load is taken down to the foundation and onto the earth below.

High-rise (above 6 stories) design is dominated by the need to withstand the lateral loading of wind and earthquake on the building. This domination of lateral loading forces a building to become more symmetrical as it gets taller. There is substantial additional cost involved in a high-rise solution because of this increased need to resist lateral loads.

Costs: For each added story, add 1% to 5%.

TABLE 1607.1
MINIMUM UNIFORMLY DISTRIBUTED LIVE LOADS, L_o, AND MINIMUM CONCENTRATED LIVE LOADS[g]

OCCUPANCY OR USE	UNIFORM (psf)	CONCENTRATED (lbs.)
1. Apartments (see residential)	—	—
2. Access floor systems Office use Computer use	 50 100	 2,000 2,000
3. Armories and drill rooms	150	—
4. Assembly areas and theaters Fixed seats (fastened to floor) Follow spot, projections and control rooms Lobbies Movable seats Stages and platforms Other assembly areas	 60 50 100 100 125 100	—
5. Balconies (exterior) and decks[h]	Same as occupancy served	—
6. Bowling alleys	75	—
7. Catwalks	40	300
8. Cornices	60	—
9. Corridors, except as otherwise indicated	100	—
10. Dance halls and ballrooms	100	—
11. Dining rooms and restaurants	100	—
12. Dwellings (see residential)	—	—
13. Elevator machine room grating (on area of 4 in^2)	—	300
14. Finish light floor plate construction (on area of 1 in^2)	—	200
15. Fire escapes On single-family dwellings only	100 40	—
16. Garages (passenger vehicles only) Trucks and buses	40 See Section 1607.6	Note a

TABLE 1607.1, *(continued)*
MINIMUM UNIFORMLY DISTRIBUTED LIVE LOADS, L_o, AND MINIMUM CONCENTRATED LIVE LOADS[g]

OCCUPANCY OR USE	UNIFORM (psf)	CONCENTRATED (lbs.)
17. Grandstands (see stadium and arena bleachers)	—	—
18. Gymnasiums, main floors and balconies	100	—
19. Handrails, guards and grab bars	See Section 1607.7	
20. Hospitals		
Corridors above first floor	80	1,000
Operating rooms, laboratories	60	1,000
Patient rooms	40	1,000
21. Hotels (see residential)	—	—
22. Libraries		
Corridors above first floor	80	1,000
Reading rooms	60	1,000
Stack rooms	150[b]	1,000
23. Manufacturing		
Heavy	250	3,000
Light	125	2,000
24. Marquees	75	—
25. Office buildings		
Corridors above first floor	80	2,000
File and computer rooms shall be designed for heavier loads based on anticipated occupancy	—	—
Lobbies and first-floor corridors	100	2,000
Offices	50	2,000
26. Penal institutions		—
Cell blocks	40	
Corridors	100	
27. Residential		—
One- and two-family dwellings		
Uninhabitable attics without storage[i]	10	
Uninhabitable attics with limited storage[i, j, k]	20	
Habitable attics and sleeping areas	30	
All other areas	40	
Hotels and multifamily dwellings		
Private rooms and corridors serving them	40	
Public rooms and corridors serving them	100	

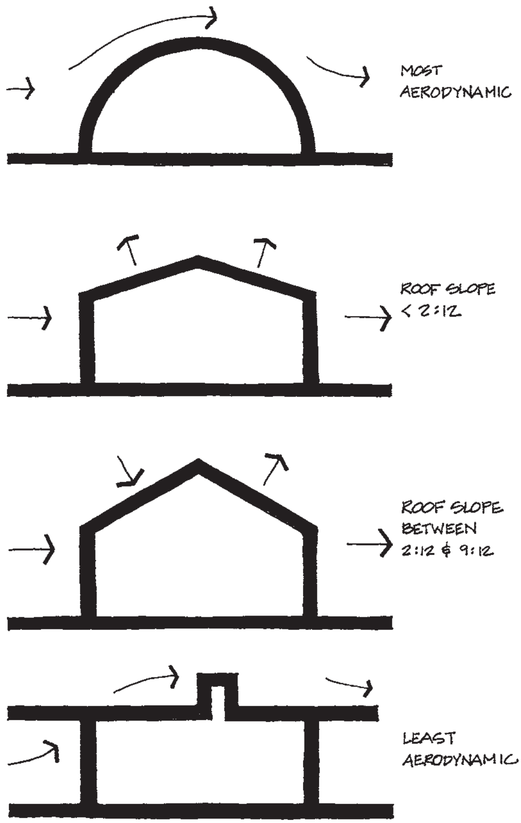
TABLE 1607.1, *(continued)*
MINIMUM UNIFORMLY DISTRIBUTED LIVE LOADS, L_o, AND MINIMUM CONCENTRATED LIVE LOADS[g]

OCCUPANCY OR USE	UNIFORM (psf)	CONCENTRATED (lbs.)
28. Reviewing stands, grandstands and bleachers	Note c	
29. Roofs		
All roof surfaces subject to maintenance workers		300
Awnings and canopies		
Fabric construction supported by a lightweight rigid skeleton structure	5 nonreducible	
All other construction	20	
Ordinary flat, pitched, and curved roofs	20	
Primary roof members, exposed to a work floor		
Single panel point of lower chord of roof trusses or any point along primary structural members supporting roofs:		
Over manufacturing, storage warehouses, and repair garages		2,000
All other occupancies		300
Roofs used for other special purposes	Note 1	Note 1
Roofs used for promenade purposes	60	
Roofs used for roof gardens or assembly purposes	100	
30. Schools		
Classrooms	40	1,000
Corridors above first floor	80	1,000
First-floor corridors	100	1,000
31. Scuttles, skylight ribs and accessible ceilings	—	200
32. Sidewalks, vehicular driveways and yards, subject to trucking	250[d]	8,000[e]
33. Skating rinks	100	—

NOTES

___ 5. **Lateral and Uplift:** Beyond vertical loads, consideration should always be given to horizontal and uplift forces. For these, the UBC factors in the *importance* of the occupancies ("essential occupancy with higher safety factor") such as hospitals, police and fire stations, emergency structures, hazardous-materials facilities, etc.

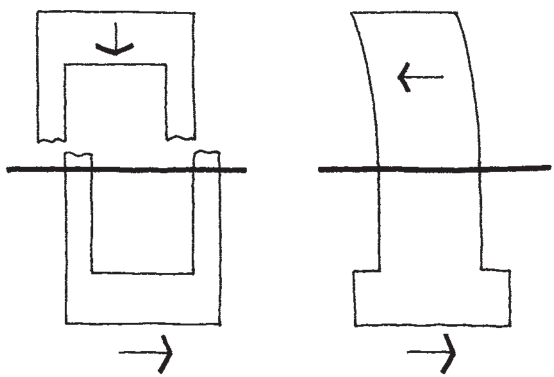
___ *a.* The force a *wind* exerts varies according to the square of its speed. If wind doubles, its pressure quadruples. If wind speed halves, its pressure is quartered. *Wind forces* are based on known *wind speeds.* Minimum is usually 70 mph (13 lb/SF) and maximum usually 130 mph (44 lb/SF) for hurricanes (with the range between being 4 lb to 7 lb/SF added



for each additional 10 mph). See App. B, item S. Added to this are *factors for height* of the building. Wind creates a suction effect on any roof slope of less than about 20°. Also, see p. 374 for shingles. *Note:* The new building codes have revised wind speeds for gusts. It was decided, for simplicity's sake, to keep the 1997 UBC data.

___ *b.* *Seismic forces* are caused by ground waves due to earthquake shock, causing vertical and horizontal movement.

The weight of the building usually absorbs the vertical element, leaving the horizontal force transmitted through the building foundations to the structure above. The weight of the building resists side movement. Present engineering procedure is to design the building for a side force, like wind.



Seismic forces grow in proportion to the weight of the building and the square of its height. The total seismic force the building must withstand is a percent of its total weight. This force is usually 10 to 50% of the total weight of the building. In determining the required force, the 1997 UBC considered:

___ (1) *Risk:* based on location. Zones 4 and 3 are the most hazardous. Zones 0 and 1 are the least hazardous. See App. B, item E.
Note: The new building codes have made seismic engineering much more complicated.

It was decided, for simplicity's sake, to keep the data from the 1997 UBC.

Costs increase about 1% to 2% for every increase in zone (2% to 5% for high-rise, and 5% to 8% for long-span, heavy construction).

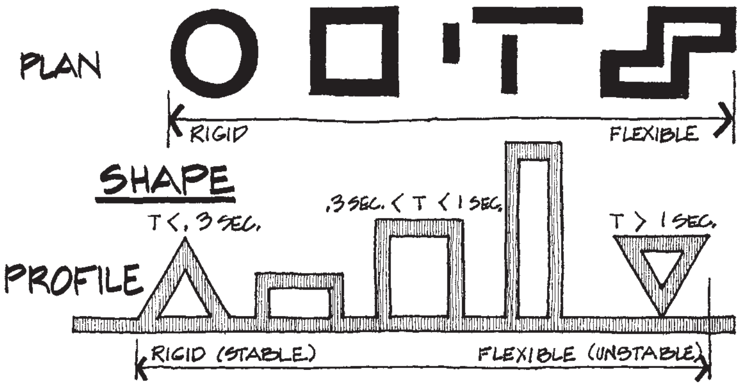
___ (2) Importance of *occupancy:* See p. 154.

___ (3) *Soils* and site geology: Rock-like materials are best. Soft clays are poor. Deep deposits of soft soils tend to produce ground surface motion with longer periods, whereas shallow deposits of stiff soils result in shorter periods. Because of the potential for resonance to increase the motion imposed on a building, more rigid designs will probably perform better on soft soils, whereas more flexible designs will perform better on stiffer soils.

___ (4) *Resistance* of the structure:

- ___ (*a*) The less weight the better
- ___ (*b*) The more flexible the better, or
- ___ (*c*) The stiffer the better

___ *c.* Lateral design and overall building shape



RESISTING ELEMENTS

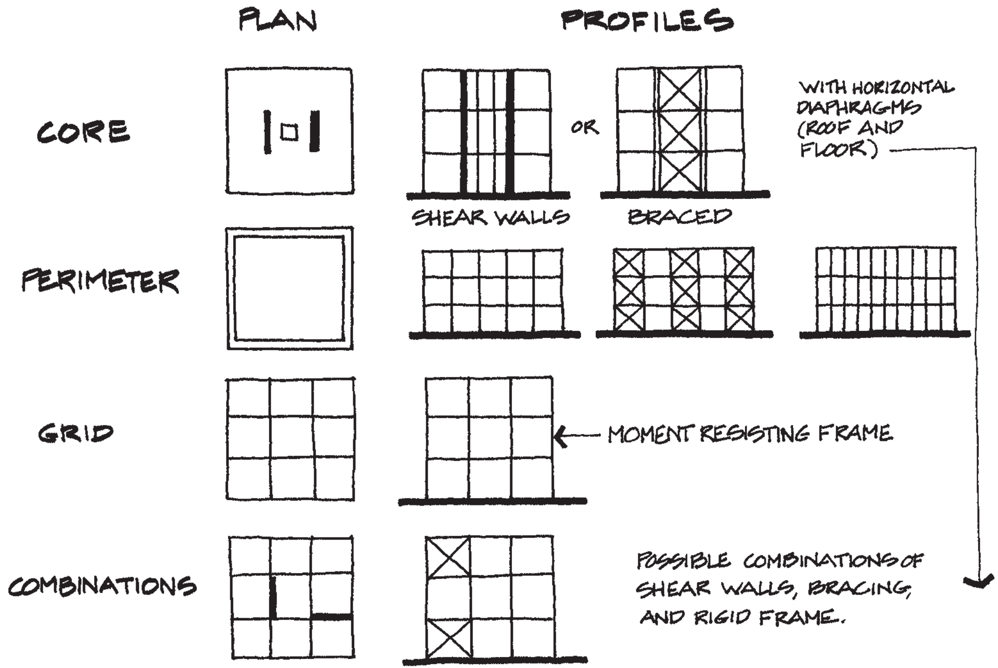
TYPE	HORZ.	VERT.	WOOD (FLEX.)	MAS. (RIGID)	CONC. (RIGID)	STEEL (BOTH)
SHEAR WALL		●	●	●	●	
BRACED FRAME	●	●			●	●
RIGID FRAME*	●	●			●	●
DIAPHRAGM	●		●		●	●

(The columns WOOD, MAS., CONC. and STEEL are grouped under the heading USUAL MATERIALS.)

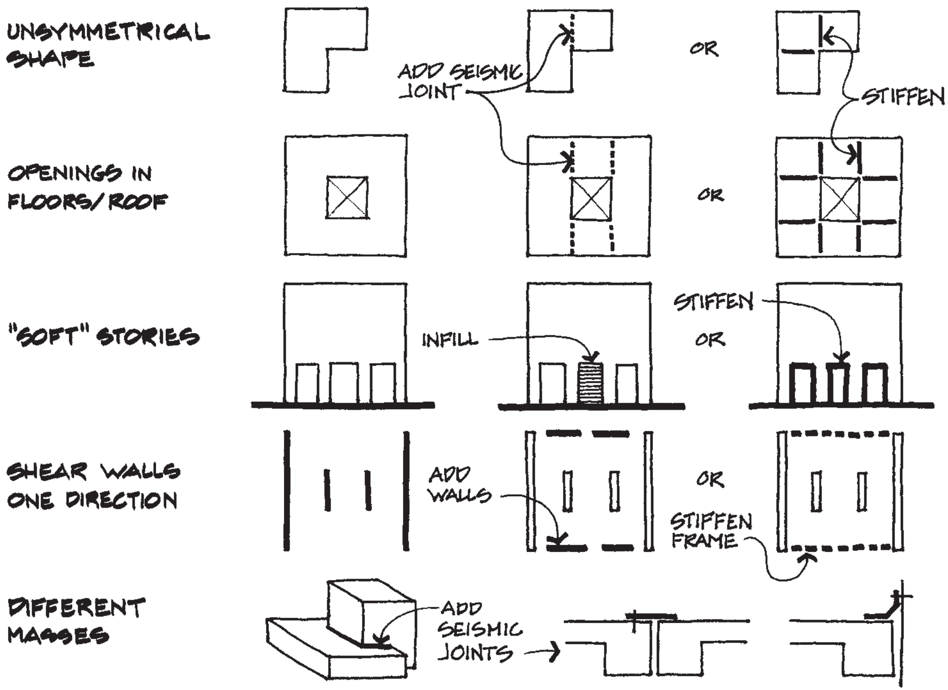
*ALSO TERMED "MOMENT RESISTING FRAME", IS ACTUALLY VERY FLEXIBLE W/ POSSIBLE SWAY AND NON-STRUCTURAL DAMAGE.

DESIGNS CAN MIX VARIOUS ELEMENTS. THE AMOUNT NEEDED IS BASED ON THE AMOUNT OF FORCE TO BE RESISTED. THESE ELEMENTS MUST BE FACED <u>BOTH WAYS</u>, IDEALLY IN EQUAL AMOUNTS, OR THE BUILDING WILL BE SUBJECT TO TORSION.

LATERAL DESIGN STRATEGIES



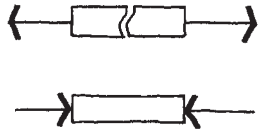
DESIGN FOR IRREGULARITIES

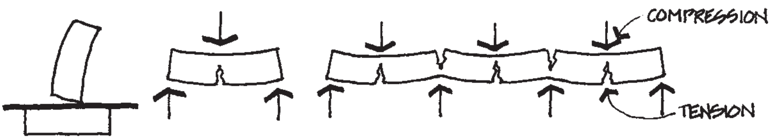


___ *d.* Nonstructural seismic considerations
In seismic zones 3 and 4, the following things should be considered:
- ___ (1) Overhead utility lines, antennae, poles, and large signs pose a hazard.
- ___ (2) Secure and brace roof-mounted and floor-mounted equipment for lateral load and uplift. This would include AC equipment, hot water heaters, and electrical service sections.
- ___ (3) Brace structure-supported piping and ducts for side sway. Avoid long, straight runs.
- ___ (4) Brace structure-supported suspended ceilings for side sway. Allow for movement where wall occurs.
- ___ (5) Sleeve piping through foundation walls.
- ___ (6) Locate building exits to avoid falling elements such as power poles or signs.
- ___ (7) Anchor veneers to allow for movement.
- ___ (8) Partitions should be constructed to assume the added seismic lateral load caused by the furniture or equipment.
- ___ (9) Seismic joints should include partition construction details to provide a continuous separation through the roof, floor, walls, and ceiling.
- ___ (10) Interior partitions and fire-rated walls that are floor-to-floor need to be designed for lateral movement. Also, consider corners, tee-junctions of walls, and junctions of walls and columns.
- ___ (11) Brace suspended light fixtures. Consider plastic rather than glass lenses.
- ___ (12) Battery-powered emergency lighting needs positive attachment.
- ___ (13) Use tempered or laminated glass, or plastic, at large-glass areas that could cause damage. Use resilient mountings.
- ___ (14) Laterally secure tall furniture and shelving.

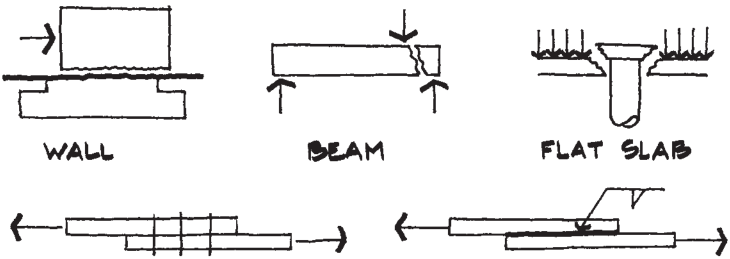
___ **6. Structural Components** *(A Primer):* Many of today's engineering courses have become so cluttered with theory and mathematics that even graduate engineers sometimes lose sight of the simple basic principles. Use this section to remind you of basic structural principles.

___ *a.* Types of forces
___ (1) Tension
___ (2) Compression
___ (3) Bending

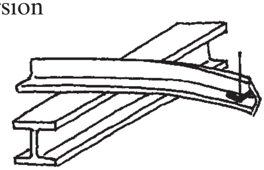




___ (4) Shear



___ (5) Torsion



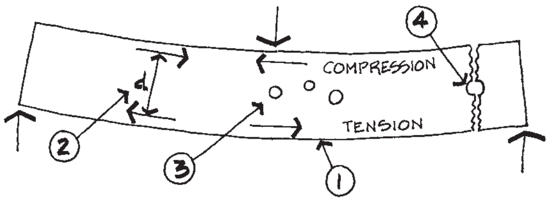
___ (6) Buckling

___ *b.* Beams

___ (1) Simple beams have tension at the bottom and compression at the top.

___ (2) If the beam is made deeper, "d" (the moment arm) is increased and the compressive and tensile forces decreased. The deeper the beam, the stronger.

___ (3) Within limits, small holes can often be cut through the beams at center, middepth, without harm. But notches or holes at top or bottom will reduce strength.

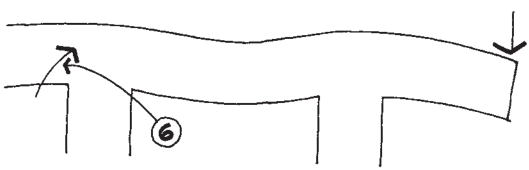


___ (4) Since shear is usually greatest close to the supports, judgment must be used regarding cutting holes or notches in the web close to the support. Also, see p. 347.

___ (5) Continuous beams can often carry more load than simple span beams.

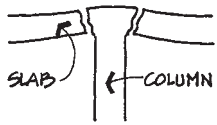
___ (6) A point to watch for in cantilever and continuous beams is possible uplift at a rear support.

___ (7) Beams may be fixed or restrained. The bending stress at midspan is less (so beam depth is less) but connections become more involved.



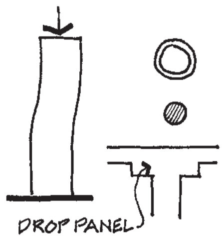
___ *c.* <u>Slabs</u>

___ (1) Are nothing more than wide, flat beams.



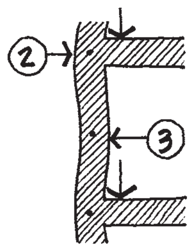
___ (2) Generally, by far, the greatest stress in flat slabs occurs where the columns try to punch through the slab. Slab openings next to columns can trigger failures!

___ *d.* <u>Columns:</u> Because of the tendency for columns to buckle, fatter ones carry more load than thinner ones (with same cross-sectional area and length).



___ *e.* <u>Walls</u>

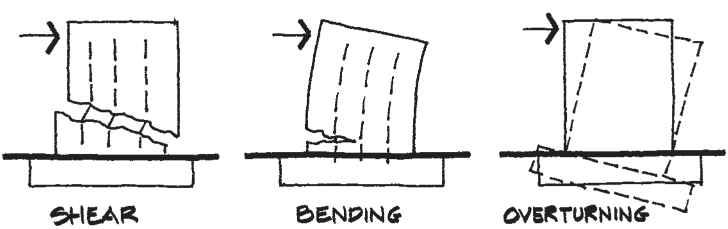
___ (1) Bearing walls act as wide, flat columns, carrying their loads in compression.



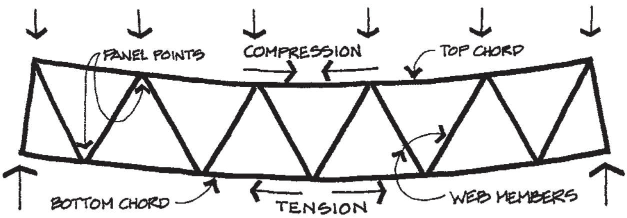
___ (2) Walls must be tied to the floor and roof.

___ (3) Bond beams tie the wall together, so more of it will act to resist any specific load.

___ (4) Shear walls fail by:



__ *f.* Trusses



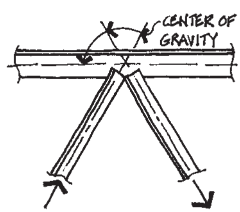
__ (1) A truss is a structural framework composed of a series of straight members so arranged and fastened together that external loads applied at the joints will cause only direct stress in the members.

__ (2) Trusses are usually lighter and more efficient than solid beams carrying the same load, but take more vertical space.

__ (3) Trusses are made by a series of triangles supporting load at panel points. Patterns other than triangles can change shape easily and must be avoided or specially treated.

__ (4) When the external loads act downward and the truss is supported at its ends, the upper chord is always in compression and the lower chord is always in tension, similar to a simple beam. The web members are in either tension or compression.

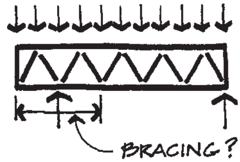
__ (5) Connections of web and chords become very important. The center of gravity of intersecting web members should meet at or very close to the center of gravity of the chord.



__ (6) Loads should be carried at the panel points, not between. This is probably the most common problem with trusses.

__ (7) Field shifting or removal of web members to allow passage of ducts or other items may be dangerous.

___ (8) If trusses cantilever over a support or are continuous over a support, the bottom chords must often be braced against sideways buckling where they are in compression.



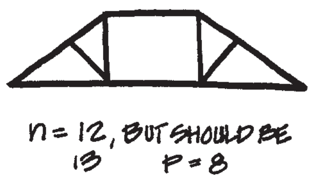
___ (9) Classification

___ (*a*) *Complete frame* is made up of the minimum number of members required to provide a complete system of triangles.

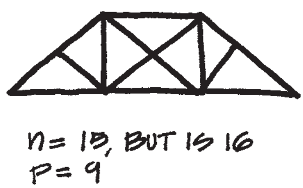
$$n = 2p - 3$$

where n = min. number of necessary members
p = number of panel points

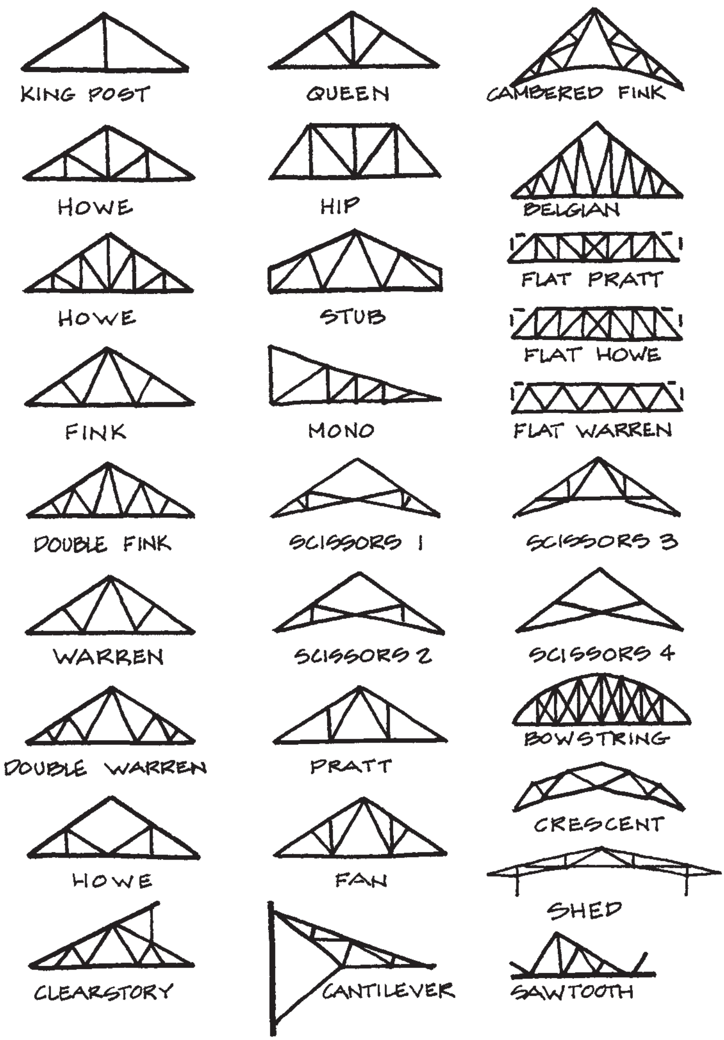
___ (*b*) *Incomplete frame* is where the number of members is less than required.



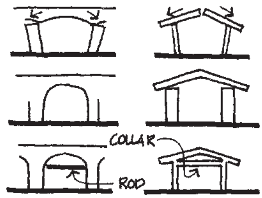
___ (*c*) *Redundant frame* contains a greater number of members than required.



___ (10) Truss types are based on form, method of support, or arrangement of web bracing. A truss can be made to just about any shape. Following are common types:



___ *g.* <u>Arches</u> (or sloped roofs) Need resistance to lateral thrust by either of the following:



___ (1) Strengthening or thickening the supports

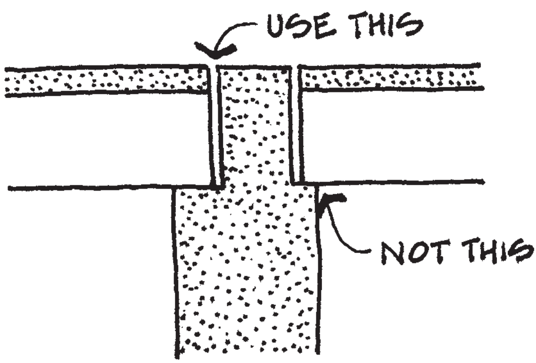
___ (2) Tension members added

___ *h.* <u>Connections</u>

___ (1) Redundancy ensures structural integrity by increasing the number of pathways by which structural forces may travel to the ground.

___ (2) Connections are usually the most critical elements of any structure. Statistically, failures are much more apt to occur at a connection than anywhere else. When connections fail, they often fail suddenly, not giving the warnings of deflection and cracking inherent in, say, a bending failure of a beam. Thus a connection failure is apt to be more hazardous to life and limb than are some other types of failures.

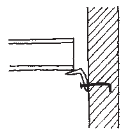
___ (3) Connections are often more sensitive to construction tolerances or errors than are the structural members themselves.



___ (4) In cases where a strong material (such as steel or prestressed concrete) must be connected to a weaker material (such as concrete blocks), the stronger material may carry a load that is not easily carried by the weaker. The connection must spread the load over a large area of the weaker material and must also not cause undue bending.

___ (5) Don't pare connection designs to the bone! Estimate the maximum amount of probable field error and design the connection for it. If possible, provide a second line of defense. Try to make connections as foolproof as possible. Allow as much room as possible for field tolerances.

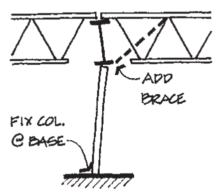
___ (6) Where possible, locate construction joints at a point of low beam shear and locate connections where loads transmitted through the connection are a minimum.



___ (7) Consider the prying, levering, or twisting action in connections. Consider the effects of connection eccentricities on the members themselves.

___ (8) Consider the effects of shrinkage or other lateral movement.

___ (9) Use care in stacking beams and girders on top of columns, particularly deep beams and girders that want to overturn. Provide bracing.



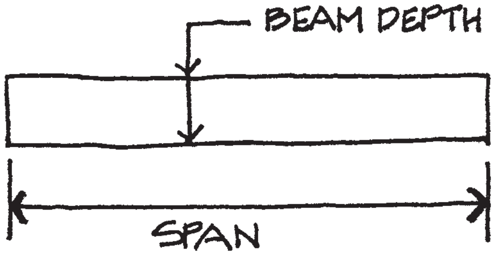
___ (10) Consider using shop over field connections, when possible, because they are done under more favorable conditions.

___ **7. *Rules of Thumb for Estimating Structural Sizes (Span-to-Depth Ratios):*** Most rules of thumb for structural estimating are based on *span-to-depth ratios.* First select likely spans from structural systems (page 147). Then, *the span in feet or inches is divided by the ratio to get the depth in either feet or inches.* The higher the number the better.

Example: If ratio is 8 and span is 8 ft, then depth is 1 ft.

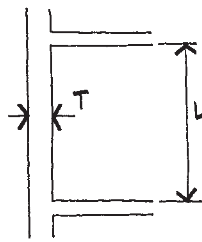
Ratios for Typical Elements:

Beams and joists of all kinds range from 10 to 24. Use lower ratios for heavy or concentrated loads. The ratio of *20* is a good all-purpose average for steel, wood, and concrete.



Cantilevered beams: In general, the optimal length of a cantilever is *one-third* the supported span.

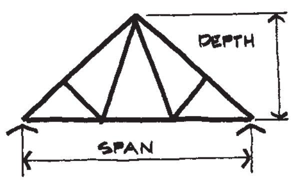
Columns: The ratios of unbraced length to least thickness of most column types range from 10 to 30, with *20* being a good average.



Slabs: Reinforced concrete slabs of various types have ratios ranging from 20 to 35, with *24* being a good average.

SEE BEAM

Trusses of various types and materials have ratios ranging from 4 to 12. The lower ratio is appropriate for trusses carrying heavy floor loads or concentrated loads. The ratio *8* is a good average for estimating roof trusses.



For more specific ratios based on materials and specific types of structural elements, see pp. 285, 307, 331, and 353.

NOTES

___ J. ENERGY: Passive and Active Approaches to Conservation

(8) (16) (40) (46) (59)

___ 1. Building Type

All buildings produce internal heat. All buildings are affected by external loads (heating or cooling) based on the climate and internal loads (heat from equipment, lights, people, etc.). Large commercial buildings tend to be internally dominated. Residences or small commercial buildings tend to be the exact opposite.

___ 2. Human Comfort

The comfort zone may be roughly defined as follows: Most people in the temperate zone, sitting indoors in the shade in light clothing, will feel tolerably comfortable at temperatures ranging from *70° to 80°F* as long as the relative humidity lies between *20% and 50%.* As humidity increases, they will begin to become uncomfortable at lower and lower temperatures until the relative humidity reaches *75% to 80%,* when discomfort at any temperature sets in. But if they are sitting in a draft, the range of tolerable temperature shifts upward, so that temperatures of *85°F* may be quite comfortable in the *20% to 50%* relative humidity range, if local air is moving at *200 ft/min.* Indoor air moving more slowly than *50 ft/min* is generally unnoticed, while flows of *50 to 100 ft/min* are pleasant and hardly noticed. Breezes from *100 to 200 ft/min* are pleasant but one is constantly aware of them, while those from *200 to 300 ft/min* are first slightly unpleasant, then annoying and drafty. See psychrometric chart on p. 175 for *passive* and *active* strategies.

___ 3. Climate

In response to a climate, if a building is to be designed for "passive" (natural) strategies, it is important to determine the demands of the climate. Is the climate severe (for either heating or cooling, as well as humidity) or temperate? Which predominates, heating or cooling? Is the climate wet or dry? Once the climatic demands are determined, what climatic elements are available to offer comfort relief? Is sun available for winter heating? Are breezes available for summer cooling?

In the United States there are roughly four basic climate zones, as shown on the map on p. 174. Climatic profiles of four cities that represent these zones are plotted on psychrometric charts (see pp. 176 through 179) suggesting strategies that can be used in a "design with climate" approach. Note that the cities (except New York) are extremes of their zones. Also on these pages are added the solar load diagrams, whose outside rings indicate air temperature (each line 2°F higher) and arrows indicating total clear sky (direct and diffuse) radiation impacting the sides of a building (each arrow reprenting 250 BTU/SF/day). At the bottom of the page the solar loads are expressed in numerical values.

In determining passive and energy conservation strategies for a building in an unfamiliar climate consult App. B to make the following determinations:

___ *a.* If two-thirds of the heating degree days (HDD) exceed the cooling degree days, *winter heating* will need to be the predominant strategy or a major consideration.

___ *b.* If cooling degree days (CDD) are greater than two-thirds of the heating degree days, *summer cooling* should be the major strategy or consideration.

___ *c.* If two-thirds of the heating degree days roughly equals the cooling degree days, both winter heating and summer cooling will be needed strategies though these will be likely *temperate* climates.

___ *d.* When heating degree days exceed 6000, a *severely cold climate* will have to be designed for.

___ *e.* When cooling degree days exceed 2000, a *severely hot climate* will have to be designed for.

___ *f.* When annual average evening relative humidity exceeds 80% and rainfall averages 40″/yr, or more, an *extremely humid climate* will have to be designed for.

___ *g.* When annual average evening relative humidity is less than 65% and rainfall averages 15″/yr, or less, an *extremely dry climate* will have to be designed for.

___ *h.* When annual winter sunshine exceeds 50%, *passive winter heating* may be a good strategy, if needed. Summer shading will be an important factor in a hot climate.

___ *i.* In the continental United States, winds generally blow from west to east. Warm breezes born in the Caribbean or mid-Pacific usually arrive from the southwest, while cold fronts arriving from the arctic tend to blow from the northwest. Most locations in the United States have annual average daily wind exceeding 5 mph, so *natural ventilation* as a means of cooling may be a good strategy, if needed. See Item R, Appendix B, p. 638. The site wind speeds are generally less than NOAA data, usually collected

EXAMPLE:

PROBLEM: DETERMINE LIKELY "PASSIVE" & ENERGY CONSERVATION STRATEGIES FOR A BUILDING SITE IN ALBUQURQUE, NEW MEXICO.

SOLUTION:

1. CLIMATE STRATEGIES:

   CHECK STRATEGIES STARTING ON P. 171 AGAINST CLIMATE DATA IN APPENDIX B ON P. 637 (LINE 26 FOR ALBUQUERQUE.)

   a. WINTER HEATING (APP. B, ITEMS L & M) (.66 × 4414 HDD = 2913 = 2913 HDD > 1254 CDD)
   b. THROUGH f. DO NOT APPLY TO ALBUQUERQUE.
   g. DRY CLIMATE (APP. B, ITEMS I & O).
   h. SUNSHINE FOR WINTER HEATING (APP. B, ITEM K).
   i. USE BREEZES FOR COOLING IN MILD SUMMERS.

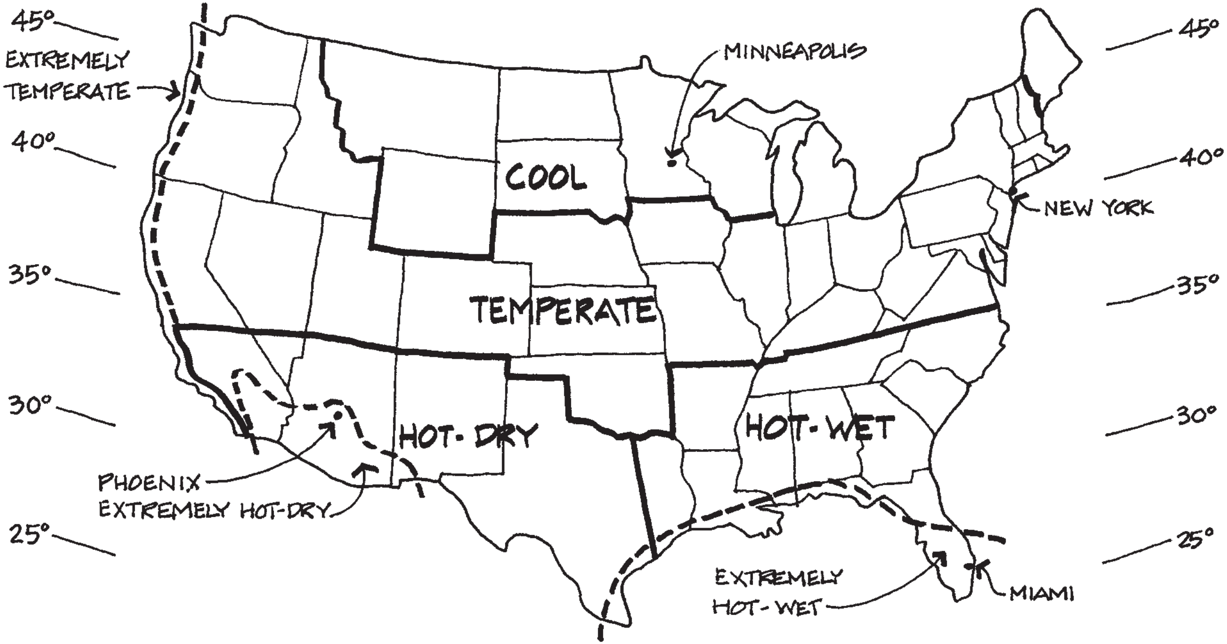
   SUMMARY:

   EVEN THOUGH ALBUQUERQUE IS A DESERT WITH ONLY 8" OF RAIN PER YEAR (ITEM I), DUE TO ITS ELEVATION OF 5310' (ITEM B), IT HAS MILD SUMMERS WHERE NATURAL BREEZES MAY HELP COOLING. ITS WINTERS REQUIRE HEATING. BECAUSE OF THE LARGE AMOUNT OF YEARLY SUNSHINE OF 76% (ITEM K), PASSIVE SOLAR HEATING IS A VERY LIKELY STRATEGY TO USE.

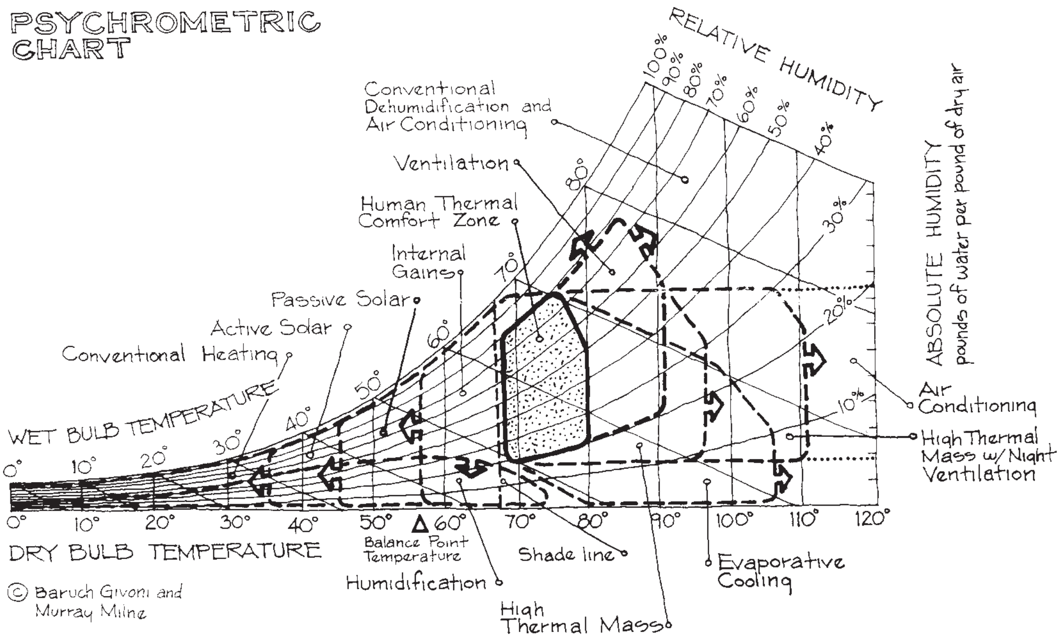
2. DESIGN STRATEGIES (USING CHECKLIST ON P. 180):

   FOR WINTER HEATING, CONSIDER PASSIVE SOLAR (8) & (9), + (14) THROUGH (21).

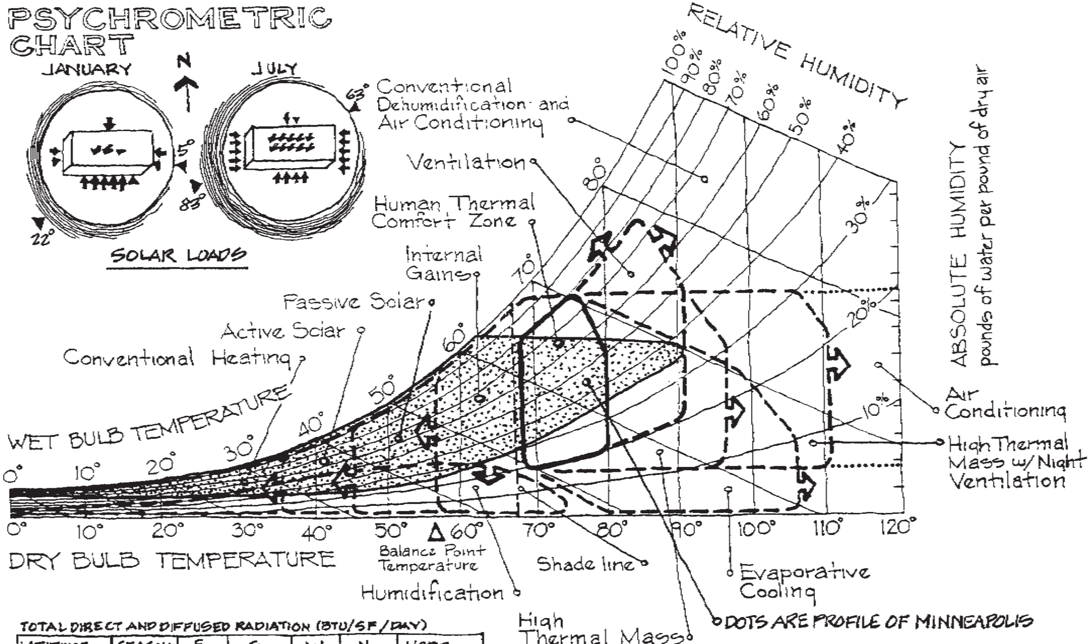
   FOR SUMMER COOLING CONSIDER NATURAL BREEZE (45) THROUGH (54).



CLIMATE ZONES OF THE UNITED STATES


PSYCHROMETRIC CHART
RELATIVE HUMIDITY
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
Conventional Dehumidification and Air Conditioning
Ventilation
Human Thermal Comfort Zone
Internal Gains
Passive Solar
Active Solar
Conventional Heating
WET BULB TEMPERATURE
0°
10°
20°
30°
40°
50°
60°
70°
80°
ABSOLUTE HUMIDITY
pounds of water per pound of dry air
Air Conditioning
High Thermal Mass w/ Night Ventilation
0°
10°
20°
30°
40°
50°
Δ 60°
70°
80°
90°
100°
110°
120°
DRY BULB TEMPERATURE
Balance Point Temperature
Shade line
Evaporative Cooling
Humidification
High Thermal Mass
© Baruch Givoni and Murray Milne

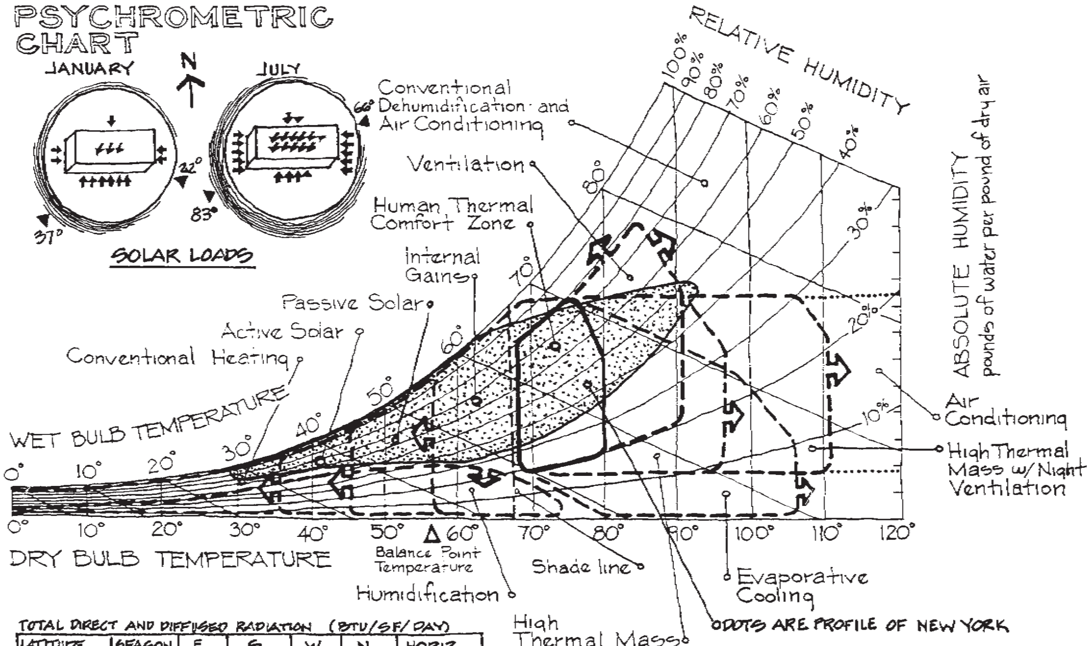
MINNEAPOLIS, MINNESOTA



TOTAL DIRECT AND DIFFUSED RADIATION (BTU/SF/DAY)

LATITUDE	SEASON	E	S	W	N	HORIZ.
44°	WINTER	416	1374	416	83	654
	SUMMER	1314	979	1314	432	2536

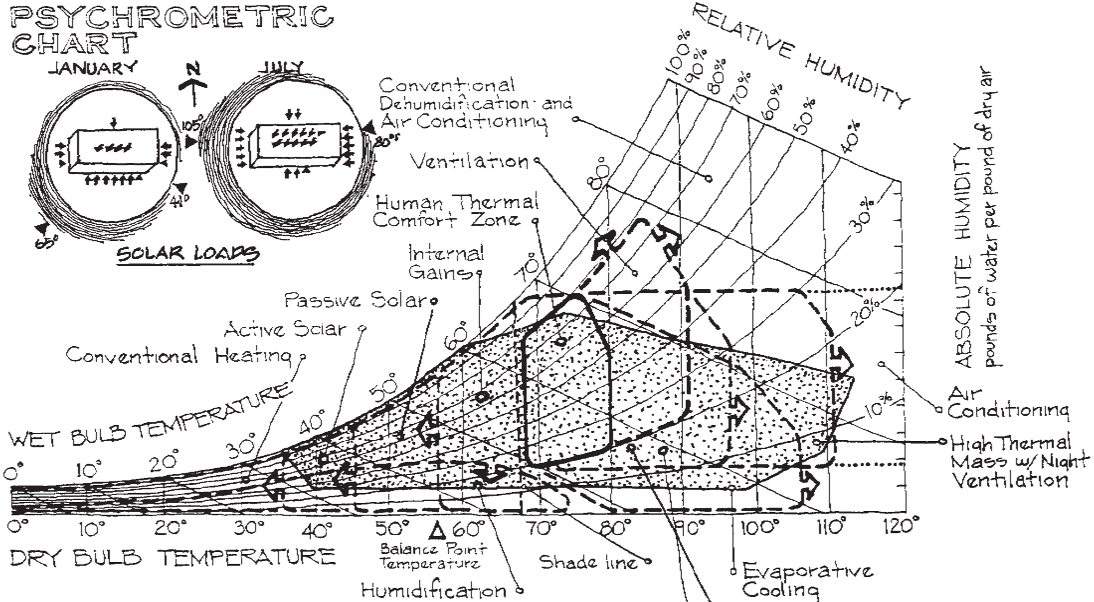
NEW YORK, NEW YORK



TOTAL DIRECT AND DIFFUSED RADIATION (BTU/SF/DAY)

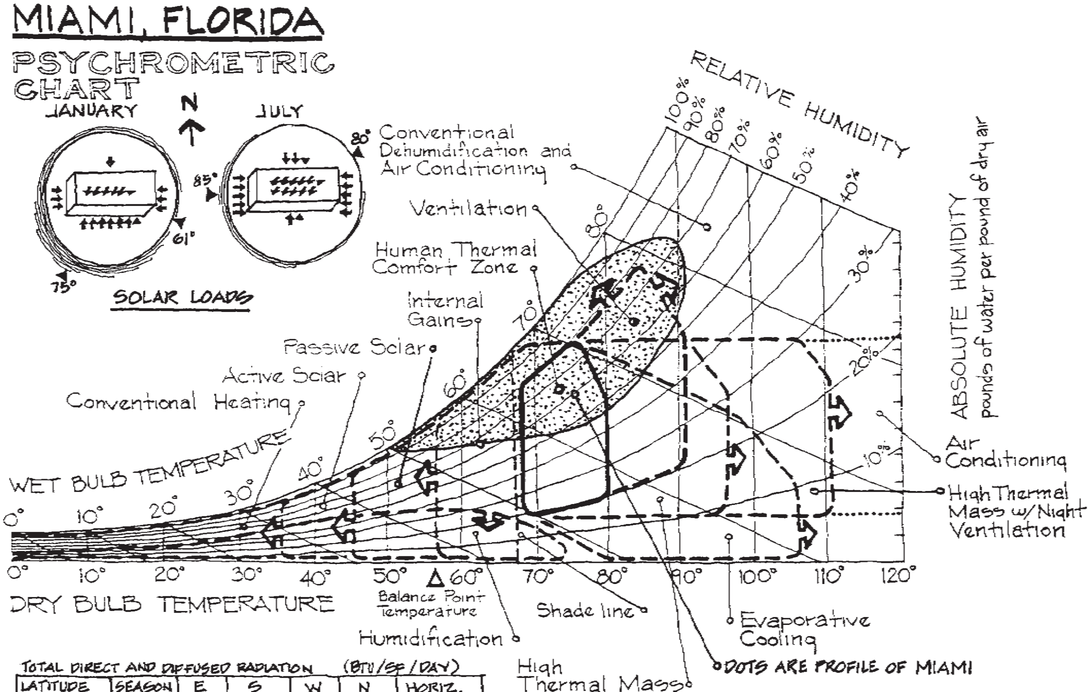
LATITUDE	SEASON	E	S	W	N	HORIZ.
40°	WINTER	517	1489	517	119	787
	SUMMER	1277	839	1277	430	2619

PHOENIX, ARIZONA



TOTAL DIRECT AND DIFFUSED RADIATION (BTU/SF/DAY)

LATITUDE	SEASON	E	S	W	N	HORIZ.
32°	WINTER	620	1606	620	140	954
	SUMMER	1207	563	1207	452	2596



TOTAL DIRECT AND DIFFUSED RADIATION (BTU/SF/DAY)

LATITUDE	SEASON	E	S	W	N	HORIZ.
24°	WINTER	734	1620	734	152	1414
	SUMMER	1193	344	1193	616	2568

at airports. But this may also be a problem if in a cold climate.

__ *j.* *Microclimates* at specific sites can vary from the overall climate due to:

- __ (1) Large bodies of water (10°F milder).
- __ (2) Built-up area (5°F warmer).
- __ (3) Elevation (5°F cooler for each 1000 ft rise).
- __ (4) Land forms: Tops of hills receive wind. Valleys get cool in evenings. Breezes rise up slopes in day and descend in evenings: South slopes receive most year-around sun; north, the least, with east and west slopes the most summer morning and afternoon sun.
- __ (5) Ground: The more heat a ground surface absorbs during the day, the warmer the air is at night. Light surfaces are cooler and more reflective than dark. Also, an area in sun will be about 12° warmer than in shade.

__ *k.* The three-tier approach to conservation:

Heating	Cooling	Lighting
1. Conservation	Heat avoidance	Daylight
2. Passive solar	Passive cooling	Daylight
3. Heating equipment	Cooling equipment	Electric lighting

__ **4. Checklist for Passive Building Design** (Strategies for Energy Conservation):

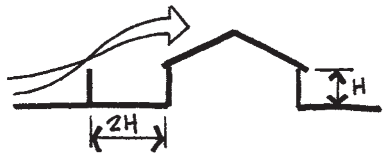
Note: During design, develop an energy strategy based on the needs (building type) and location, as previously discussed. For instance, it might be a tightly sealed, minimum-surfaced box to withstand the winters in Minneapolis, or it might be an open design to take advantage of sea breezes in Miami, or it might be a maximum-shade layout to avoid summer sun in Phoenix, or it might be a combination of winter and summer strategies for a temperate zone such as New York City (and most of the United States). Use this section to remind you of things that might be added to your design. Many of the following items conflict, so it is impossible to choose all.

X Cold climate or winter

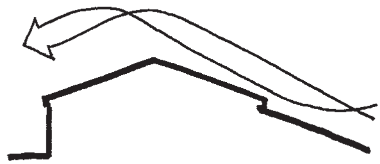
  X Hot climate or summer

Windbreaks: Two climatic design techniques serve the function of minimalizing wind exposure.

___ (1) Use neighboring land forms, structures, or vegetation for winter wind protection.



___ (2) Shape and orient building shell to minimize wind turbulence.



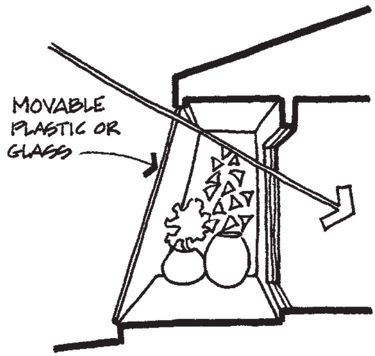
___ (3) When structure is fully exposed to cold winds up the design temperature by:
Roofs × 1.6
Walls × 1.3

Plants and water: Several techniques provide cooling by the use of plants and water near building surfaces and evaporative cooling.

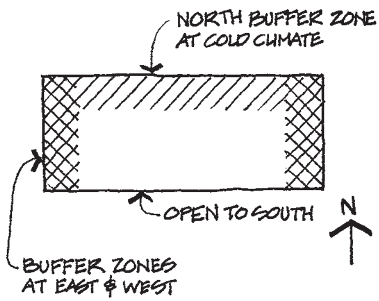
___ (4) Use ground cover and planting for site cooling.
___ (5) Maximize on-site evaporative cooling; ocean or water zones, such as fountains, modify climate 10°F.
___ (6) Use planting next to building skin.
___ (7) Use roof spray or roof ponds for evaporative cooling.

Indoor/outdoor rooms: Courtyards, covered patios, seasonal screened and glassed-in porches, greenhouses, atriums, and sunrooms can be located in the building plan for summer cooling and winter heating benefits, as with these three techniques.

__ __ (8) Provide outdoor semiprotected areas for year-round climate moderation.



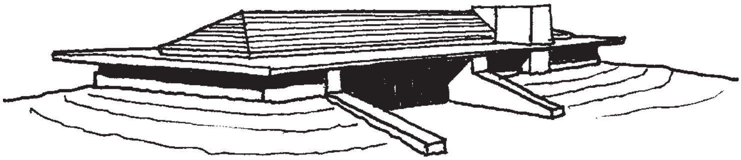
__ (9) Provide solar-oriented interior zone for maximizing heat.



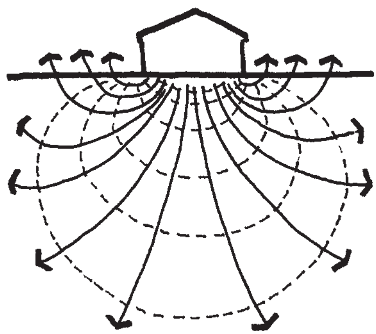
__ __ (10) Plan specific rooms or functions to coincide with solar orientation (i.e., storage on "bad" orient such as west, living on "good" such as south).

Earth sheltering: Techniques such as using earth against the walls of a building or on the roof, or building a concrete floor on the ground, have a number of climatic advantages for winter insulation and wind protection, as well as for summer cooling.

__ __ (11) Recess structure below grade or raise existing grade for earth-sheltering effort.



__ __ (12) Use slab-on-grade construction for ground temperature heat exchange. See p. 368 for perimeter insulation.

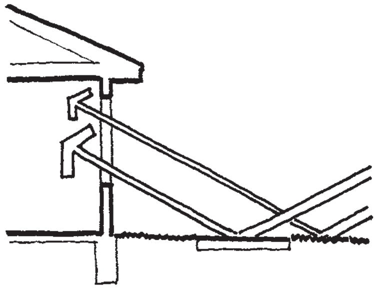


__ __ (13) Use sod roofs (12″ of earth will give about a 9-hour time lag).

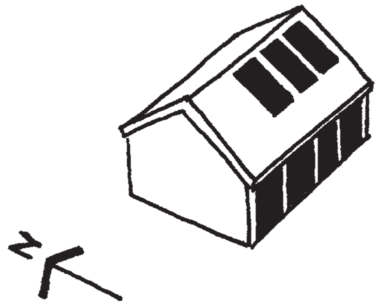
__ (14) Use high-capacitance materials at interiors to store "coolth." Works best with night ventilation.

Solar walls and windows: Using the winter sun for heating a building through solar-oriented windows and walls is covered by a number of techniques, listed as follows.

__		(15) Maximize reflectivity of ground and building surfaces outside windows facing winter sun.

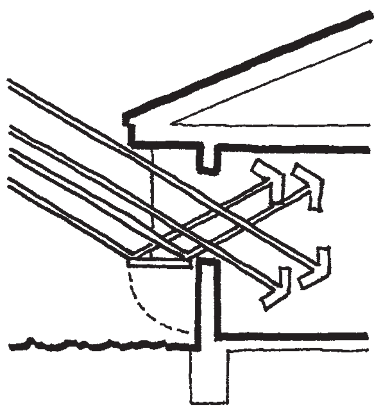


Cold	Hot	
__		(16) Shape and orient building shell to maximize exposure to winter sun. Glass needs to face to within 15 degrees of due south.
__		(17) Use high-capacitance materials to store solar heat gain. Best results are by distributing "mass" locations throughout interior. On average, provide 1 to 1¼ CF of concrete or masonry per each SF of south-facing glass. For an equivalent effect, 4 times more mass is needed when not exposed to sun. Do not place carpeting on these floor areas.
	__	(18) This same "mass effect" (see 17) can be used in reverse in hot, dry (clear sky) climates. "Flush" building during cool night to precool for next day. Be sure to shade the mass. A maximum area of up to 2″-thick clay, concrete, or plaster finishes work best. The night average wind speed is generally about 75% of the average 24-hour wind speed reported by weather bureaus. About 30 air changes per hour is an adequate rate to cool the building.
__	__	(19) Use solar wall and/or roof collectors on south-oriented surfaces (also hot-water heating). Optimum tilt angle for roof solar collectors is equal to latitude of site (+/– 15°). See p. 541.



___ (20) Maximize south-facing glazing (with overhangs as needed). On average, south-facing glass should be 10 to 25% of floor area. For north latitude/cold climates this can go up to 50%. For south latitude/hot climates this strategy may not be appropriate.

___ (21) Provide reflective panels outside of glazing to increase winter irradiation.



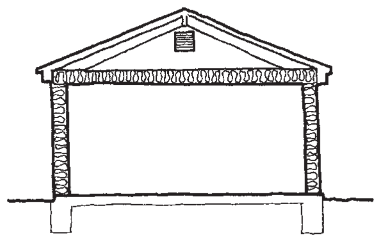
___ (22) Use skylights for winter solar gain and natural illumination. See p. 569.

Thermal envelope: Many climatic design techniques to save energy are based on insulating the interior space from the exterior environment.

__ __ (23) Minimize the outside wall and roof areas (ratio of exterior surface to enclosed volume). Best ratios:

2-story dome—12%; 2-story cylinder—14%
2-story square—15%; 3-story square—16%
1-story square—17%

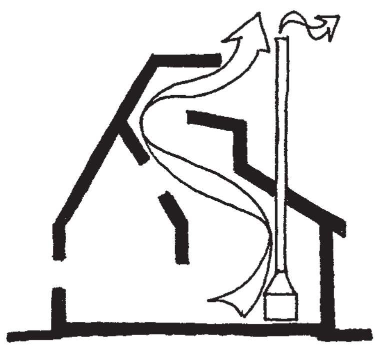
__ __ (24) Use attic space as buffer zone between interior and outside climate. Vent above ceiling insulation. See p. 363.



Cold Hot

__ (25) Use basement or crawl space as buffer zone between interior and ground. See p. 368 for insulation. Provide drainage systems around perimeter to keep soil dry (and thus a higher R value).

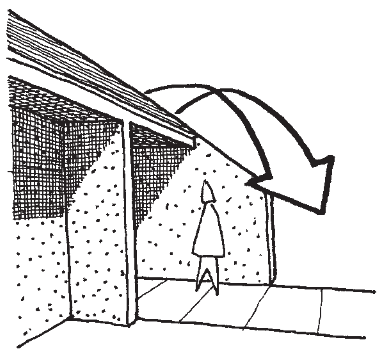
__ __ (26) Provide air shafts for natural or mechanically assisted house-heat recovery. This can be recirculated warm at high ceilings or recovered heat from chimneys.



__ (27) Centralize heat sources within building interior. (Fireplaces, furnaces, hot water heater, cooking, laundry, etc.) Lower level for these most desirable.

__ (28) Put heat sources (HW, laundry, etc.) outside air-conditioned part of building.

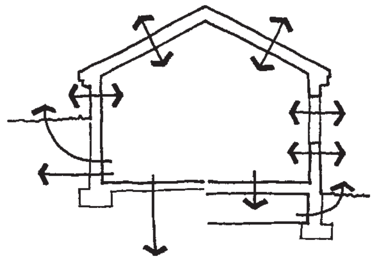
__ __ (29) Use vestibule or exterior "wind shield" at entryways. Orient away from undesirable winds.



__ __ (30) Locate low-use spaces, storage, utility, and garage areas to provide buffers. Locate at "bad" orientations (i.e., on north side in cold climate or west side in hot climate).

__ __ (31) Subdivide interior to create separate heating and cooling zones. One example is separate living and sleeping zones.

__ __ (32) Select insulating materials for resistance to heat flow through building envelope. For minimum insulation recommendations, see p. 194 and/or guidelines by *ASHRAE* 90A-80. If walls are masonry, insulation is best on outside.

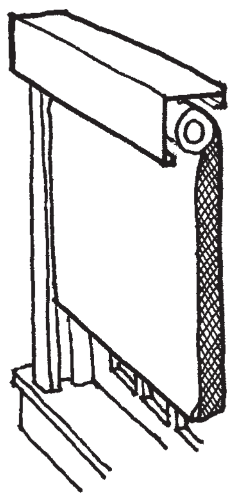


__ __ (33) Apply vapor barriers to control moisture migration. See p. 365.

__ (34) Use of radiant barriers. See p. 367.

__ __ (35) Develop construction details to minimize air infiltration and exfiltration. See p. 385.

__ __ (36) Provide insulating controls at glazing. See section entitled "Glass," starting at p. 407.



__ __ (37) Minimize window and door openings (usually N [for cold climates], E, and W).

__ __ (38) Detail window and door construction to prevent undesired air infiltration and exfiltration. See p. 390 for doors and p. 395 for windows.

__ __ (39) Provide ventilation openings for air flow to and from specific spaces and appliances (such as cooking ranges and fireplaces). See p. 438 for fireplaces.

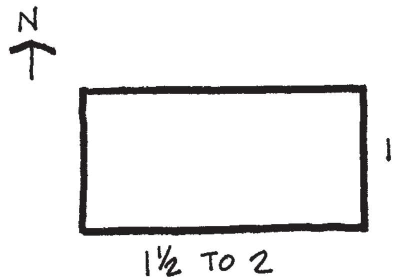
Cold Hot

Sun shading: Because the sun angles are different in summer than in winter, it is possible to shade a building from summer sun while allowing sun to reach the building surfaces and spaces in the winter.

__ (40) Minimize reflectivity of ground and building faces outside windows facing summer sun. As an example, a south-facing wall will receive an additional half of its direct solar gain from a concrete slab outside. Reduced paving and maximized landscaping will minimize solar reflection.

__ (41) Use neighboring land forms, structures, or vegetation for summer shading.

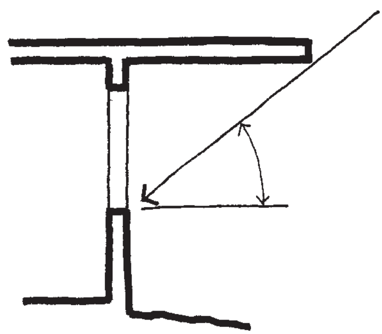
___ (42) Shape and orient building shell to minimize solar exposure. Best rectangular proportions are 1 (east and west) to between 1.5 and 2 (north and south).



___ (43) Provide shading for walls exposed to summer sun. For landscaping, see p. 267.

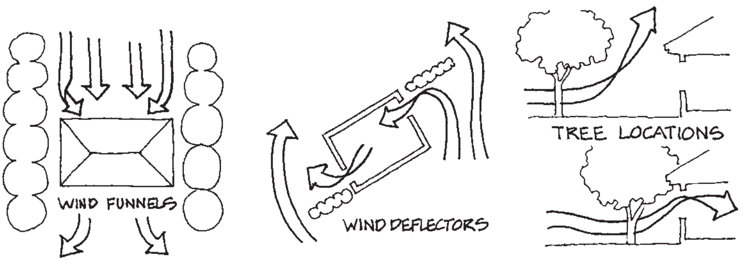
___ (44) Use heat-reflective materials on solar-oriented surfaces. White or light colors are best.

___ (45) Provide shading for glazing exposed to sun. For south-facing walls, at 50° latitude, most references recommend a shade angle of 60° (from the horizon). For each 5° of decreasing latitude, the angle increases 5°. But this rule would not apply to locations of extended overheated seasons, such as Miami and Phoenix, where the angle should be more like 45°. Also see p. 451.



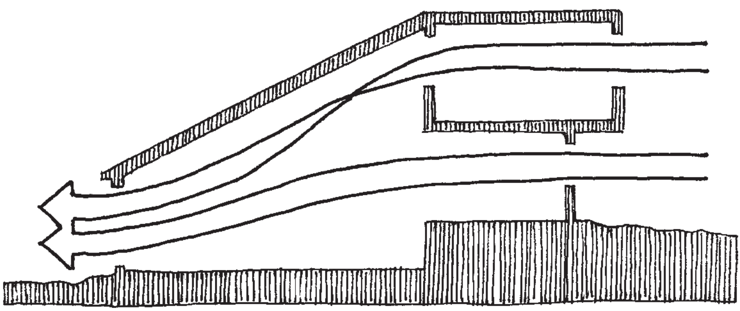
Natural ventilation: A simple concept by which to cool a building.

___ (46) Use neighboring land forms, structures, or vegetation to increase exposure to breezes.



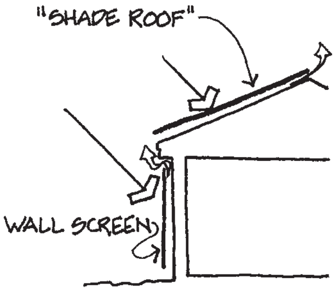
___ (47) Shape and orient building shell to maximize exposure to breezes. Long side should face prevailing breeze within 20 to 30 degrees.

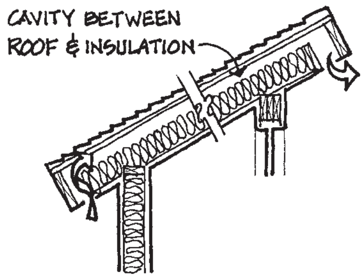
___ (48) Use "open plan" interior to promote air flow.



___ (49) Provide vertical air shafts to promote interior air flow. Also see (26).

___ (50) Use double roof and wall construction for ventilation within the building shell.





___ (51) Locate and size door and window openings to facilitate natural ventilation from prevailing breezes. For best results:
Windows on opposite sides of rooms.
Inlets and outlets of equal size giving maximum air change.
A smaller inlet increases air speed. However, adequate airflows can be maintained for anywhere from 40/60 to 60/40 splits between inlets and outlets. Window sizing can be roughly figured by taking the building volume × 30 air changes/hour. Then, to get total airflow, take the average wind speed in miles/hour, convert it to feet/min. (× 5280 ÷ 60). Divide desired airflow by wind speed to get inlet area. However, the wind speed will be reduced if its angle to the inlet is less than 90° by a factor of 1 to 3.5 up to a 70° angle. Furthermore, the interior wind speed will be further reduced by screens and awnings ranging from 15 to 35%.

___ (52) Use wing walls, overhangs, and louvers to direct summer wind flow into interior.

___ (53) Use louvered wall for maximum ventilation control.

___ (54) Use operable roof monitors for "stack effect ventilation." Also see (26).

Cold Hot

___ (55) Often fan power is needed to help ventilation cooling. See 5*a* (below).

___ 5. **Checklist for Active Building Design** (Strategies for Energy Conservation)

- ___ *a.* Whenever possible, use fans in lieu of compressors, as they use about 80% less energy. In residential, this may take the form of "whole-house" fans to cool the building and ceiling fans to cool people in specific locations. Also see *o,* below.
- ___ *b.* Design for natural lighting in lieu of artificial lighting. In hot climates or summers, avoid direct sun. See p. 569.
- ___ *c.* Lighting consumes about 8% of the energy used in residences and 27% in commercial buildings nationwide. Use high-efficiency lighting (50–100 lumens per watt). See Part 16A. Provide switches or controls to light only areas needed and to take advantage of daylighting. See Part 16B.
- ___ *d.* Use gas rather than electric when possible, as this can be up to 75% less expensive.
- ___ *e.* Use efficient equipment and appliances
  - ___ (1) Microwave rather than convection ovens.
  - ___ (2) Refrigerators rated 5–10 kBtu/day or 535–1070 kwh/yr.
- ___ *f.* If fireplaces, use high-efficiency type with tight-fitting high-temperature glass, insulated and radiant-inducing boxed with outside combustion air. See p. 438.
- ___ *g.* Use night setback and load-control devices.
- ___ *h.* Use multizone HVAC.
- ___ *i.* Locate ducts in conditioned space or tightly seal and insulate.
- ___ *j.* Insulate hot and cold water pipes (R = 1 to 3).
- ___ *k.* Locate air handlers in conditioned space.
- ___ *l.* Install thermostats away from direct sun and supply grilles.
- ___ *m.* Use heating equipment with efficiencies of 70% for gas and 175% for electric, or higher.
- ___ *n.* Use cooling equipment with efficiencies of SEER = 10, COP = 2.5 or higher.
- ___ *o.* Use "economizers" on commercial HVAC to take advantage of good outside temperatures.
- ___ *p.* At dry, hot climates, use evaporative cooling.

___ *q.* Use gas or solar in lieu of electric hot water heating. Insulate hot water heaters. For solar hot water, see p. 525.

___ *r.* For solar electric (photovoltaic), see p. 616.

___ *s.* For some building types and at some locations, utilities have peak load rates, such as on summer afternoons. These peak rates should be identified and designed for. Therefore, designing for peak loads may be more important than yearly energy savings. In some cases saving energy and saving energy cost may not be the same. Large buildings sometimes use thermal storage systems, such as producing ice in off-peak hours to use in the heat of the day. These systems work best in areas with large daily and yearly temperature swings, high electricity costs, and big cost differences between on- and off-peak rates.

___ *t.* HVAC system as a % of total energy use:

Residential	
Cold climate	70%
Hot climate	40%
Office	
Cold climate	40%
Hot climate	34%

___ *u.* TBSs (total building management systems) conserve considerable energy.

___ **6. Energy Code** (ASHRAE 90A—1980). For U values, see p. 368.

___ *a.* Although there are more current national energy codes, these envelope guidelines, based on the old ASHRAE 90A, should help the designer determine if a preliminary design is in the "ballpark." These rules of thumb are for building envelope only. Should the walls fail to meet code requirements, the roof can be made to compensate, and vice versa. Should these rough preliminary calculations fail, this may indicate that either the design is poor from an energy conservation standpoint or that other features (such as passive heating) need to be considered by more stringent calculation or computer modeling.

Use the following steps to roughly check for compliance:

___ *b.* Approximate compliance can be checked by using the following formulas:

___ (1) For Walls, Winter Heating:

$$Uw = \frac{(Uw_1 \times Aw_1) + (Ug_1 \times Ag_1) + (Ud_1 \times Ad_1)}{Aw}$$

___ (2) For Walls, Summer Cooling:

$$OTTVw = \frac{(Uw_1 \times Aw_1 \times Tdeg) + (Ag_1 \times SF_1 \times SC_1) + (Ug_1 \times Ag_1 \times \varnothing t)}{Aw}$$

___ (3) For Roofs, Winter Heating:

$$Ur = \frac{(Ur_1 \times Ar_1) + (Ug_1 \times Ag_1)}{A_{\text{Total Roof}}}$$

___ (4) For Roofs, Summer Cooling:

$$OTTVr = \frac{(Ur_1 \times Ar_1 \times Tdeg) + (138 \times Ag_1 \times Sc_1) + (Ug_1 \times Ag_1 \times \varnothing t)}{A_{\text{Total Roof}}}$$

where:

Uw, Ur are the overall wall and roof U values.

OTTVw and r are the overall wall and roof cooling thermal transfer values.

Uw_1, Ur_1 are the U values of the wall and roof components.

Aw_1, Ar_1 are the areas of the *solid* wall and roof components.

Ug_1, Ag_1 are the U values and areas for glass.

Ud_1, Ad_1 are the U values and areas for doors.

HDD = Heating degree days.

TDEQ = Temp. difference factor for thermal mass. See p. 369 for wt. of materials. See Figure 4 for values.

SF = Solar factor. See Figure 5.

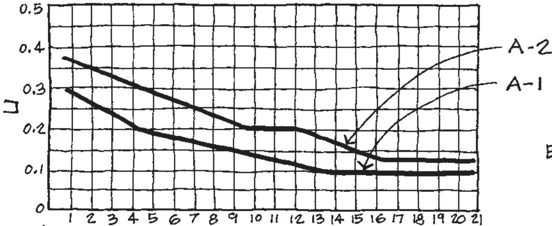
SC = Shading coefficient of glass. See pp. 407 and 411.

$\varnothing t$ is the difference between summer dry-bulb temperature found in App. B, item Q and 78°F indoor temperature.

Note: Where more than one type of wall, roof, window (or skylight) is used, each U and A term in formulas must be expanded (i.e., U_2, A_2, etc.) and totaled.

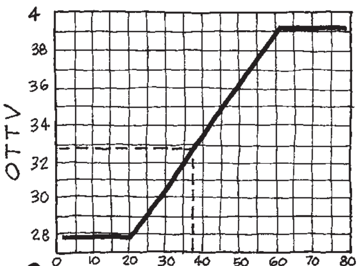
___ *c.* Determine building type
- ___ (1) Type A-1 is 1- and 2-family residential dwellings.
- ___ (2) Type A-2 is all other residential buildings of 3 stories and under, including hotels and motels.
- ___ (3) Type B is all other buildings.

___ *d.* The values determined in *b,* above, must equal or be less than *one-half* the values in the graphs on pp. 197 and 198. The one-half factors in because current codes are more stringent than the old ASHRAE 90-A. For HDD and CDD, see App. A, items L and M.

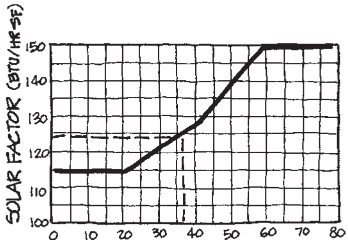


1. TYBE A HDD (IN THOUSANDS) WALLS

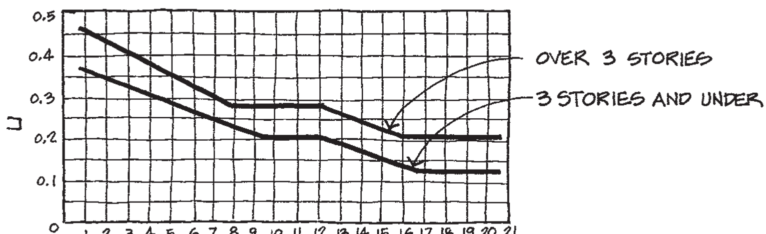
EXAMPLE ------



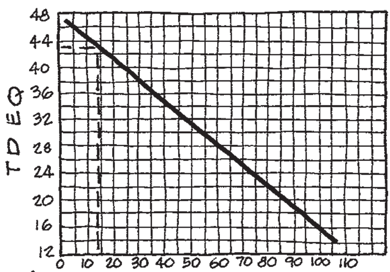
3. TYPE B (DEG. N. LATITUDE)



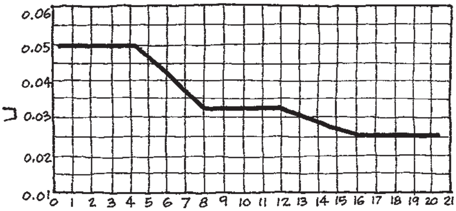
5. DEGREES N. LATITUDE



2. TYPE B HDD (IN THOUSANDS) WALLS

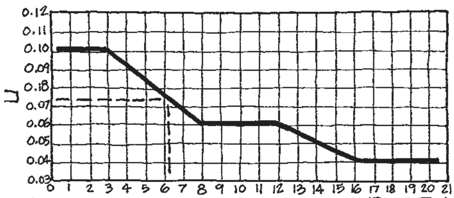


4. WALL CONST. (LBS / SF)

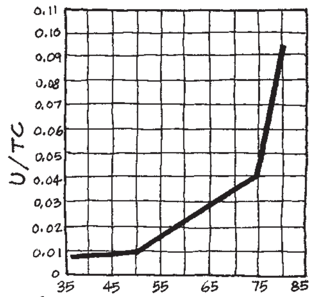


6. TYPE A HDD (IN THOUSANDS) ROOF/CL'G.

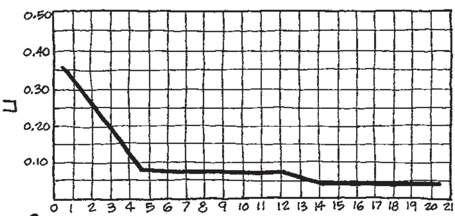
SEE EXAMPLE, P. 212



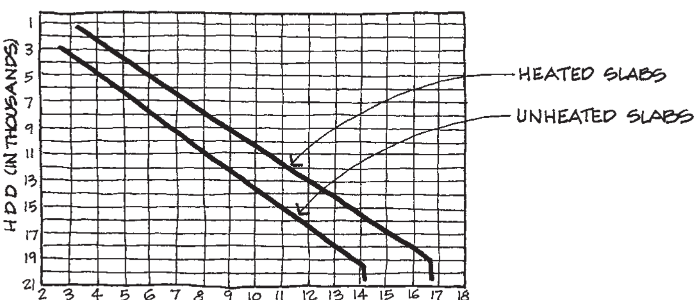
7. TYPE B HDD (IN THOUSANDS) ROOF/CL'G.



8. TD EQ (VOID)



9. HDD (IN THOUSANDS) FLOORS



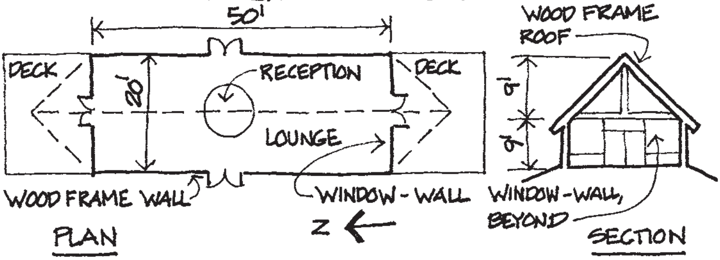
10. R VALUES SLAB

___ *e.* Check compliance:

- ___ (1) Type A-1 and 2 buildings:
  - ___ (*a*) Heating, walls:
    Calculate, using Formula (1), to insure that designed value is ½ or less of the value in Figure 1.
  - ___ (*b*) Heating, roof:
    Calculate, using Formula (3), to insure that designed value is ½ or less of the value in Figure 2.
  - ___ (*c*) Heating, floors over underheated spaces:
    Calculate, using Formula (2), to insure that designed value is ½ or less of the value in Figure 9.
  - ___ (*d*) Slabs on grade must conform to value shown in Figure 10 for perimeter insulation.
    Note: ASHRAE 90-A never required A-1 and 2 buildings to check for summer cooling, but you can check for cooling by using (*c*) and (*d*) below.
- ___ (2) Type B buildings:
  - ___ (*a*) Heating, walls:
    Calculate, using Formula (1), to insure that designed value is ½ or less of the value in Figure 2.
  - ___ (*b*) Heating, roof:
    Calculate, using Formula (3), to insure that designed value is ½ or less of the value in Figure 7.
  - ___ (*c*) Cooling, walls:
    Calculate, using Formula (2), to insure that designed value is ½ or less of the value in Figure 3.
  - ___ (*d*) Cooling, roof:
    Calculate, using Formula (4), to insure that designed value is 4.25 or less.
  - ___ (*e*) Same as 1(*c*) above.
  - ___ (*f*) Same as 1(*d*) above.

EXAMPLE:

PROBLEM: A LODGE BUILDING OF A RESORT IS BEING DESIGNED FOR A MOUNTAIN SITE IN COLORADO SPRINGS, COLORADO. CHECK TO SEE IF THE PRELIMINARY DESIGN, SHOWN BELOW, APPEARS TO BE ENERGY EFFICIENT.



DATA:

LATITUDE: 38°-5 (P. 640)
HDD = 6346 (P. 641)
WALL: U = 0.11, AREA = 900 SF
WINDOW-WALL: (D.G.) = U = 0.5
AREA = 720 SF
ROOF: U = 0.025, AREA = 1273 SF

NOTE: DISREGARD DOORS. ASSUME A TYPE B BUILDING.

SOLUTION: (TYPE B BUILDINGS, P. 199)

a. HEATING, WALLS:

DESIGNED: (FORMULA (1) ON P. 195)

$$U_W = \frac{(U_W \times A_W) + (U_g \times A_g)}{A \text{ OF TOTAL WALL}}$$

$$= \frac{(0.11 \times 900) + (0.5 \times 720)}{900 + 720} = 0.28$$

REQUIRED: FIGURE 2 (P. 197) = 0.28 ÷ 2 = 0.14

PROBLEM ! : DESIGNED IS HIGHER THAN REQ'D.

b. HEATING, ROOF:

DESIGNED: (FORMULA 3 ON P. 195)

$$U_r = \frac{U_r \times A_r}{A \text{ TOTAL ROOF}} = \frac{0.025 \times 1273}{1273} = 0.025$$

-CONTINUED-

REQUIRED: FIGURE 7 (P. 210) = 0.072 ÷ 2 = 0.0375

OK, DESIGNED IS LESS THAN REQUIRED

c. COOLING, WALLS:

DESIGNED: (FORMULA 2 ON P. 195)

$$OTTV_W = \frac{(U_{W1} \times A_{W1} \times TD_{EQ}) + (A_g \times SF \times SC) + (U_g \times A_g \times \Delta t)}{\text{AREA OF TOTAL WALL}}$$

WHERE: TD_{EQ} = 43 (FIG. 4), ASSUMING 15#/SF WT.

SF = 125 FOR 38°-5 N. LAT. (FIG. 5)

SC = 0 FOR N. GLASS & 0.5 FOR S. GLASS (SEE P. 195). AS AN AVER. ≈ 0.25

Δt = 91°F (SEE APP. B, ITEM Q, P. 641) LESS 78°F (INDOOR TEMP.) = 13°

$$= \frac{(0.025 \times 900 \times 43) + (720 \times 125 \times 0.25) + (0.025 \times 720 \times 13)}{900 + 720}$$

= 14.6

REQUIRED: (FIGURE 3, P. 197) = 33 ÷ 2 = 16.5

O.K: DESIGNED IS LESS THAN REQ'D.

d. COOLING, ROOF:

DESIGNED: (FORMULA 4, P. 195), NO GLASS!

$$OTTV_r = \frac{(U_r \times A_r \times TD_{EQ})}{\text{AREA OF ROOF}} = \frac{0.025 \times 1273 \times 43}{1273}$$

= 1.075

REQUIRED: 8.5 ÷ 2 = 4.25

OK: DESIGNED IS LESS THAN REQUIRED.

e. N/A (NO FLOOR AREA ABOVE AIR).

f. UNHEATED SLAB: FROM FIGURE 10 (P. 198), SLAB IS REQ'D. TO HAVE R = 5.25 PERIMETER INSULATION.

CONCLUSION:

EVERY ELEMENT HAS PASSED EXCEPT FOR THE WALLS DURING WINTER HEATING. THIS SHOULD NOT BE SURPRISING GIVEN ALL THE GLASS IN SUCH A COLD CLIMATE.

— CONTINUED —

POSSIBLE OPTIONS:

1. LOWER U VALUE OF GLASS:
   USE LOW E, DOUBLE GLAZED W/ R = 3.12 (P. 411).
   $$U = \frac{1}{R} = \frac{1}{3.12} = 0.32$$
   REWORK FORMULA 1:
   $$U_W = \frac{(0.11)(900) + (0.32)(720)}{900 + 720} = 0.2 > 0.14$$
   STILL FAILS
2. LOWER U VALUE STILL FURTHER (SEE P. 368).
3. REDUCE GLASS AREA.
4. UPGRADE ROOF AND/OR OPAQUE WALL U'S TO MAKE UP FOR GLASS.
5. ACCOUNT FOR OTHER FACTORS, SUCH AS 'PASSIVE' SOLAR HEATING (CALCULATING THIS IS BEYOND THE SCOPE OF THIS BOOK, EXCEPT FOR THE PREVIOUS RULES OF THUMB). THIS MAY BE REALISTIC CONSIDERING THE SITE GETS 68% SUN (SEE APP. B, ITEM K, P. 640) WHICH IS ABOVE 50% (SEE ITEM 20, P. 185) AND THE SLAB ON GRADE (ASSUMING NO CARPET) ABSORB THE SUN'S HEAT (SEE ITEM 17, P. 184). BUT THIS APPROACH WOULD PROBABLY REQUIRE A COMPUTER SIMULATION TO PROVE COMPLIANCE IF AN ENERGY CODE WERE IN EFFECT AT THIS LOCATION.

ENERGY CONVERSION FACTORS

FUEL	COAL (LB)	OIL (GAL)	GAS (THERM)	ELECTRIC (KWH)	OAK (LB)	SOLAR (SQUARE)
COAL (LB)	14600 BTU	0.160	0.195	4.28	3.73	0.487
OIL (GAS)	6.23	91000 BTU	1.213	26.67	23.27	3.033
GAS (THERM)	5.137	0.824	75000 BTU	21.97	19.18	2.500
ELECTRIC (KWH)	0.234	0.038	0.046	3,413 BTU	0.87	0.114
OAK (LB)	0.268	0.043	0.052	1.15	3910 BTU	0.130
SOLAR (SQUARE)	2.055	0.330	0.400	8.79	7.67	30,000 BTU

NOTES

___ K. GREEN ARCHITECTURE (SUSTAINABLE BUILDINGS)

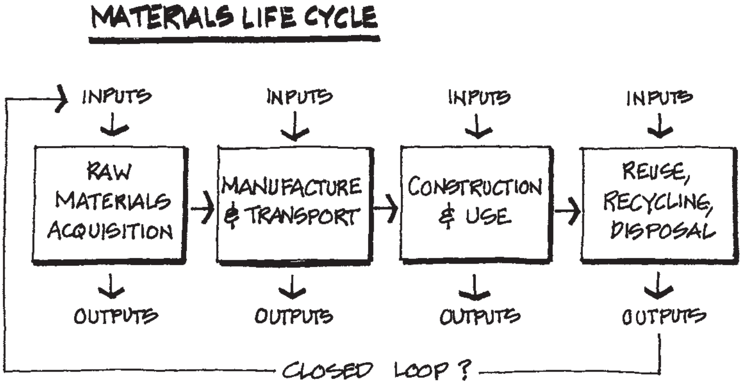
(H) (5) (14)

Green architecture is a whole-systems approach, utilizing design and building techniques to minimize environmental impact and reduce a building's energy consumption while contributing to the health of its occupants. "If brute force doesn't work, you're not using enough of it" has been the typical American approach. The green movement takes the opposite approach.

___ 1. ***General***

- ___ *a.* *Save energy:* Ongoing energy use is the single greatest source of environmental impact from a building. See "Energy," p. 171.
- ___ *b.* *Recycle buildings:* Reuse existing buildings and infrastructure instead of developing open space.

  Note: Unfortunately, it is often less expensive to *remove* existing old buildings and build anew than to preserve but refurbish, in order to bring the old buildings up to the latest codes.
- ___ *c.* *Create community:* Design communities to reduce dependence on the automobile and encourage alternative transportation, including walking.
- ___ *d.* *Reduce material use:* Optimize design to make use of smaller spaces and utilize materials efficiently.
- ___ *e.* *Protect and enhance the site:* Try to work with existing grades and landscaping rather than bulldozing the site.
- ___ *f.* *Select low-impact materials:* Buildings account for about 40% of the material resources flowing through the economy. Specify low-environmental-impact resources and efficient materials. Most environmental impacts associated with building materials occur before installation. Raw materials have been extracted from the ground or harvested from forests. Pollutants have been emitted during manufacture, and energy has been invested during production. Avoid materials that generate pollution, are not salvaged from other uses, deplete limited natural resources, or are made from toxic or hazardous constituents. Specify materials with low embodied energy used in extracting, manufacturing, and shipping.



___ *g.* *Maximize longevity:* Design for durability and adaptability. The longer a building lasts, the longer the period over which to amortize its environmental impacts. Specify durable, nondecaying, easily maintained, or replaceable materials. Design for adaptability (new building uses).

___ *h.* *Save water:* Design buildings and landscape that use water efficiently.

___ *i.* *Make buildings healthy:* Provide a safe, comfortable indoor environment. Over 60,000 commercial chemicals are in use that were unknown 40 years ago. Many common building materials and products produce harmful off-gases.

___ *j.* *Minimize construction and demolition waste:* Return, reuse, and recycle job site waste.

___ **2.** ***Site***

- ___ Minimize impervious paving materials.
- ___ Use asphalt with recycled tire and coating products.
- ___ Use recycled brick, stone, or rubber aggregate surfacing.
- ___ Use walk, road, and parking appurtenances made of recycled plastics and rubber.
- ___ Use fences and gates of recycled plastic and fiberglass.
- ___ Use site furnishings of recycled or salvaged plastics or wood. Materials may be of a toxicity that might not be acceptable inside buildings.
- ___ Use soil and native plants (or special filtration products) to pretreat runoff from paved areas.
- ___ Do rainwater harvesting (collect and reuse rainwater that falls on roofs and site). See (15).

- ___ • Use landscape edging made of recycled plastics and tires.
- ___ • Nontoxic termite treatment.
- ___ • Use pilings of recycled plastics.
- ___ • Use geotextiles for slope stabilization.
- ___ • Use environmental septic systems (nutrient removal).
- ___ • Build "natural" swimming pools.
- ___ • Use organic fertilizers, compost from the site, or hydromulching from recycled paper.
- ___ • Use native plants that require minimum water and drip irrigation or none at all.
- ___ • Use lawns and ground covers that require no mowing.
- ___ • Use salvaged or recycled landscape timbers.

___ 3. *Concrete*

- ___ • Use recycled form products.
- ___ • Use autoclaved aerated concrete.

___ 4. *Masonry*

- ___ • Where appropriate, use strawbale for walls.
- ___ • Where appropriate, use sundried (adobe) or earth (rammed) from site excavation.
- ___ • Use clay bricks with toxicity burned out.
- ___ • Use autoclaved aerated concrete or CMU.
- ___ • Use site stones.
- ___ • Use masonry accessories of recycled products.
- ___ • Use CMU that is specially molded for better R value (integral insulated masonry systems).

___ 5. *Metals*

- ___ • Use of metal framing in lieu of wood reduces depletion of timber growth and can be made from recycled metal. On the other hand, producing metals consumes more energy, and steel production pollutes.

___ 6. *Wood and Plastic* In the United States, building construction accounts for more than 25% of virgin timber use and 16% of water withdrawals. New home construction consumes 40% of all lumber used in the United States. A typical 1700-SF wood-frame home requires clear-cutting 1 acre of forest.

- ___ • Standard structural wood depletes timber growth. Select FSC (Forest Stewardship Council)–certified wood products.
- ___ • Use engineered (such as TJI and TJL) joists made from recycled wood fiber and small trees, although they may off-gas if exposed in the interior.
- ___ • Use structural insulated panels (SIPs).
- ___ • Use nonstructural composite plastic lumber. Plastics are made from nonrenewable petroleum products

and are toxic in a fire. However, some plastic products are made from recycled soda bottles.

- ___ • Use alternative particleboard products (and OSB) made from recycled materials, although they may off-gas if exposed in the interior.
- ___ • Some hardwoods used for interiors (such as mahogany) may deplete tropical forests. Instead, use domestic, temperate-climate hardwoods (plum, cherry, alder, black locust, persimmon, etc.).
- ___ • Use interior veneer woods with recycled backing.
- ___ • Use fiberboard millwork and prefinished panels from wood wastes.

___ 7. ***Thermal and Moisture Protection***

- ___ • Use waterproofing with minimum or no volatile organic compounds (VOCs).
- ___ • Avoid insulation foams expanded with hydrochlorofluorocarbons (HCFCs).
- ___ • Avoid loose-fill insulation materials in unsealed spaces (minimizes air-quality problems).
- ___ • For wood shingles, use FSC-certified wood.
- ___ • For metal roofing, select highest recycle content and high-grade finish.
- ___ • For membrane roofs, select products with recycled content.
- ___ • Use fireproofing with recycled foam and newsprint.
- ___ • Use reclaimed or FSC-certified wood siding.
- ___ • Design green roof systems (roof plantings and gardens).
- ___ • Select insulation with recycled products.
- ___ • Avoid contact with standard fiberglass (probable carcinogen).
- ___ • For asphalt shingles, select products with recycled old shingles.
- ___ • Avoid indoor use of sealants that may contribute to indoor air-quality problems.
- ___ • Use shingles of recycled plastic.

___ 8. ***Doors, Windows, and Glass***

- ___ • Select wood doors that are salvaged or FSC-certified.
- ___ • Select vinyl windows with recycled content.
- ___ • Select wood, plastic, or fiberglass windows with recycled content.

___ 9. ***Finishes***

- ___ • *Gypsum board:* Utilize recycled materials, synthetic gypsum. Collect scrap for recycling use as soil amendment.

- ___ • *Tile work:* Select recycled content material or recycle as mosaic or aggregate.
- ___ • *Acoustic ceiling panels:* Utilize high-recycled-content materials. Utilize perlite or mineralized wood fiber to avoid fiber shedding.
- ___ • *Wood flooring:* Select FSC-certified products. Select salvaged flooring. Select engineered flooring with thick-faced veneers that are able to be refinished. Select nontoxic, low-VOC finishes and additives. Consider bamboo in lieu of wood.
- ___ • *Resilient flooring:* Select materials with low-VOC adhesives. Select recycled-content materials. Vinyl and rubber are the best green materials.
- ___ • *Carpet:* Select materials with low VOC content. Avoid synthetics. Select 100% recycled-content face fiber and backing. Avoid synthetic latex backing.
- ___ • *Painting:* Select low- or no-VOC products. Select the least toxic alternatives. Select recycled content.

___ 10. **Specialties** Not applicable.

___ 11. **Equipment**

- ___ • *Residential appliances:* Select water-conserving appliances with "green seal." Select horizontal-axis clothes washers. Select energy-star-rated appliances.

___ 12. **Furnishings**

- ___ • Select materials with organically grown plant fibers.
- ___ • Select natural dyes or undyed fabrics.
- ___ • Use products with FSC-certified wood.
- ___ • Use refurbished furniture.
- ___ • Select fibers that are naturally pest resistant.
- ___ • Select recycled synthetic fibers.

___ 13. **Special Construction**

- ___ • Use asbestos or lead encapsulation products.

___ 14. **Conveying Systems** Not applicable.

___ 15. **Mechanical**

- ___ • Select low-flow water-efficient plumbing fixtures (1.6 GPF, or below, toilets).
- ___ • Select compost toilet systems.
- ___ • Choose cooling equipment that does not utilize ozone-depleting refrigerants.
- ___ • Design graywater systems.
- ___ • Avoid PVC piping (recycle problems).
- ___ • Use domestic water-heat exchangers.

___ 16. **Electrical** Not applicable.

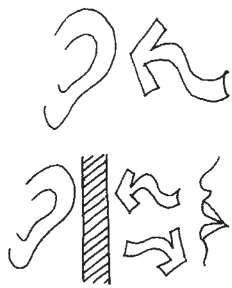
NOTES

___ L. ACOUSTICS (3) (4) (5) (13) (16)

Sound is a series of pressure vibrations that move through an elastic medium. Its alternating compressions and rarefactions may be far apart (low-pitched), close together (high-pitched), wide (loud), or narrow (soft).

All perceived sound has a *source, path,* and *receiver.* Each source has a size, direction, and duration. Paths can be airborne or structure-borne.

Sound has four quantifiable properties: *velocity, frequency, intensity,* and *diffuseness.* Regarding *velocity*, sound travels much faster through solids than air (and faster through warm air than cool air). *Frequency* is sound's vibrations per second, or hertz (Hz). This varies according to its purity and pitch. The average human pitch for hearing is about 1000 Hz. *Intensity* is the power level (or loudness) measured in decibels (dB). Attenuation is the loss of a sound's intensity as it travels outward from a source. *Diffuse* noise (blanket or background noise level) is sound emanating from a multiple of similar sound sources.



There is both a positive function and a negative function to consider in acoustic design.

The positive function is to ensure that the reverberation characteristics of a building are appropriate to their function. See 1 below.

On the negative side, the task is to make certain that unwanted outside noises are kept out of quiet areas of the building. See 2 below.

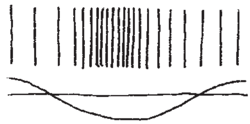
___ 1. *Room Acoustics*

Sound can be likened to light. *Sound control* uses reflection and diffusion to enhance acoustics in such spaces as auditoriums and sound studios, and absorption for noise control in more typical spaces such as offices.

___ *a.* *Reflection:* The geometry of the room is important in effective sound control. Large concave surfaces concentrate sound and should usually be avoided, while convex surfaces disperse sound.

___ *b.* *Diffusion* promotes uniform distribution of continuous sound and improves "liveness" (very important in performing arts). It is increased by objects and surface irregularities. Ideal diffusing surfaces neither absorb nor reflect sound but scatter it.

___ *c.* Absorption (see table on p. 221) provides the most effective form of noise control. Sound pressure waves travel at the speed of sound (1100 fps), which is a slow enough velocity that reflections of the original sound-wave form can interfere with perception of the original, intended signal. *Reverberation time* is the measure of this problem.



Sound of any kind emitted in a room will be absorbed or reflected off the room surfaces. Soft materials absorb sound energy. Hard materials reflect sound energy back into the space. The reflected sound can reinforce the direct sound and enhance communication if the room size and room surfaces are configured appropriately. Annoying reverberation (echoes) occur in rooms more than *30 feet* long. Echoes are stronger when the reflection surface is highly reflective and is concave toward the listener.

The room volume and surface characteristics will determine the reverberation time for the room. <u>Reverberation time</u> is the time in seconds that it takes for a sound to decay through 60 decibels. It is calculated as follows:

$$RT = \frac{0.05 \times \text{Room Volume (cf)}}{\text{Average Absorption of Room}}$$

Desirable room reverberation times are:

Office and commercial spaces	0.5 seconds
Rooms for speech	1.0 seconds
Rooms for music	1.5 seconds
Sports arenas	2.0 seconds

The <u>*absorption,*</u> also called <u>noise reduction coefficient (NRC),</u> of a surface is the product of the acoustic coefficient for the surface multiplied by the area of the surface. The sound absorption of a room is the sum of the sound absorptions of all the surfaces in the room. <u>The higher the coefficient, the more sound absorbed, with *1.0* (complete absorption) being the highest possible.</u> Generally, a material with a coefficient below *0.2* is considered to be reflective and above *0.2* to be absorbing. Some common acoustic coefficients are:

1½″ glass fiber clg. panels	1.0
Carpet and pad	0.6
Acoustic tile (no paint)	0.8
Cloth-upholstered seats	0.6
An audience	0.8
Concrete	0.02
Gypsum board	0.05
Glass	0.09
Tile	0.01
Fabric	0.30

The average absorption coefficient of a room should be at least *0.2.* Average absorption above *0.5* is usually not desirable, nor is it economically justified. A lower value is suitable for large rooms; and larger values for controlling sound in small or noisy rooms. Although absorptive materials can be placed anywhere, ceiling treatment is more effective in large rooms, while wall treatment is more effective in small rooms. If additional absorptive material is being added to a room to improve it, the total absorption should be increased at least *3 times* to bring absorption to between *0.2 and 0.5.* An increase of *10 times* is about the practical limit. Each doubling of the absorption in a room reduces RT by ½.

EXAMPLE:

WHAT IS THE ABSORPTION COEFFICIENT AND REVERBERATION TIME FOR A 20' × 10' × 9'H OFFICE WITH CARPET FLOOR, ACOUSTIC TILE CEILING AND GYPB'D. WALL (BUT 1/3 OF WHICH HAS SOUND ABSORPTION MATERIAL)?

ABSORPTION COEFFICIENT:

FLOOR	0.6 × 200 =	120
2/3 WALL	0.05 × 356 =	18
1/3 WALL	0.8 × 178 =	142
CEILING	0.8 × 200 =	160
		440

$$\text{AVER. COEF. OF ABSORPTION} = \frac{\text{TOTAL ABSORB.}}{\text{TOTAL RM. SURFACE}} = \frac{440}{20 \times 9 \times 2 + 10 \times 9 \times 2 + 10 \times 20 \times 2}$$

$$= \frac{440}{940\ \text{SF}} = 0.47 \quad \text{O.K.}$$

$$\text{REVERBERATION TIME} = \frac{0.05 \times (10 \times 20 \times 9)}{440} = 0.2 < 0.5 \quad \text{O.K.}$$

___ *d.* Other factors affecting acoustics:

___ If a corridor is appreciably higher than it is wide, some absorptive material should be placed on the walls as well as the ceiling, especially if the floor is hard. If the corridor is wider than its height, ceiling treatment is usually enough.

___ Acoustically critical rooms require an appropriate volume of space. Rooms for speech require 120 CF per audience seat. Rooms for music require 270 CF per audience seat.

___ "Ray diagramming" can be a useful tool in sound control. As with light, the reflective angle of a sound wave equals its incident angle. In like manner, concave shapes focus sound and convex shapes disperse sound.

___ Amplification: If listeners are within 110′ of the sound source, a cluster of loudspeakers is usually located well above and slightly in front of the sound source. If some listeners are more than 110′ away, an overhead network of small speakers, located no more than 35′ apart, should be used.

___ 2. **Sound Isolation**

Sound travels through walls and floors by causing building materials to vibrate and then broadcast the noise into the quiet space. There are two methods of setting up the vibration: through structure-borne sound, and air-borne sound.

Structure-borne sound is the vibration of building materials by vibrating pieces of equipment, or caused by walking on hard floors.

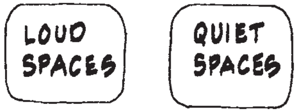
Air-borne sound is a pressure vibration in the air. When it hits a wall, the wall materials are forced to vibrate. The vibration passes through the materials of the wall. The far side of the wall then passes the vibration back into the air.

Noise Reduction and Sound Isolation Guidelines

___ *a.* Choose a quiet, protected site. Orient building with doors and windows away from noise.

___ *b.* Use site barriers such as walls or landscape (dense tree lines or hedges, a combination of deciduous and evergreen shrubs, reduce sound more efficiently).

___ *c.* Avoid placing noisy areas near quiet areas. Areas with similar noise characteristics should be placed next to each other. Place bedrooms next to bedrooms and living rooms next to living rooms.

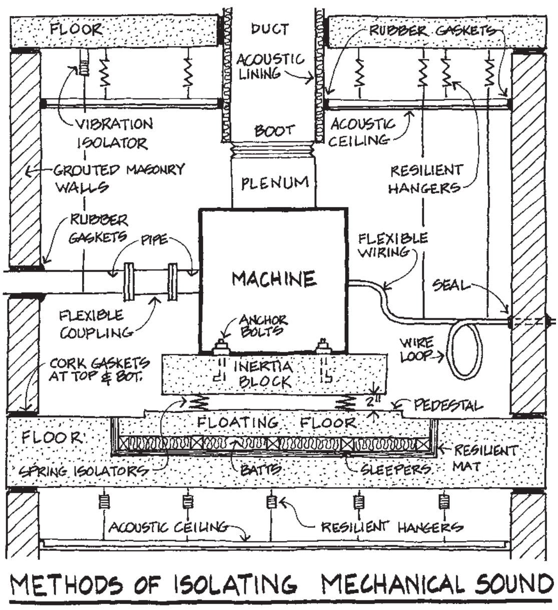


___ *d.* As the distance from the sound source increases, pressure at the listener's ear will decrease by the inverse square law (as with light). Therefore, separate sound sources by distance.

___ *e.* Orient spaces to minimize transmission problems. Space windows of adjoining apartments max. distance apart. Place noisy areas back to back. Place closets between noisy and quiet areas.

___ *f.* Massive materials (concrete or masonry) are the best noise-isolation materials.

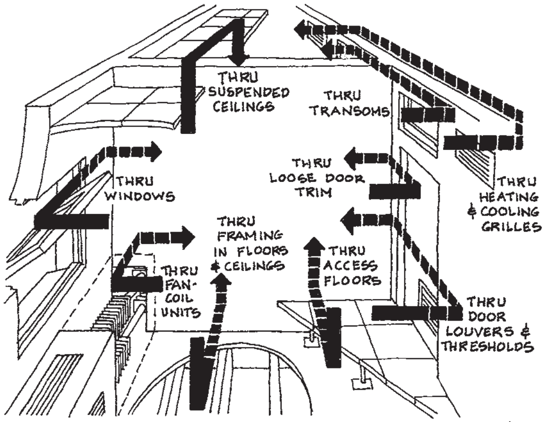
___ *g.* Choose quiet mechanical equipment. Use vibration isolation, sound-absorbing duct lining, resilient pipe connections. Design for low flow velocities in pipes and ducts.



METHODS OF ISOLATING MECHANICAL SOUND

___ *h.* Reducing structure-borne sound from walking on floors is achieved by carpet (with padding, improves greatly).

___ *i.* Avoid flanking of sound over ceilings.

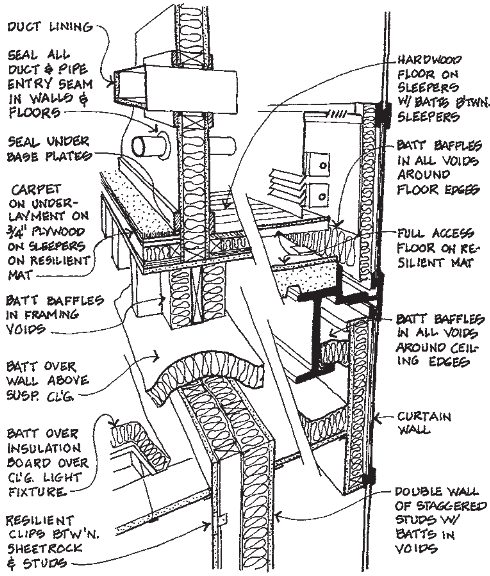


FLANKING SOUND PATHS BETW'N. RM'S.

___ *j.* Avoid flanking of sound at wall and floor intersections.

___ *k.* Wall and floor penetrations (such as elect. boxes) can be a source of sound leakage. A 1-square-inch wall opening in a 100-SF gypsum-board partition can transmit as much sound as the entire partition.

__ *l.* Many sound leaks can be plugged in the same manner as is done for air leaks, by caulking.



REMEDIES FOR REDUCING NOISE TRANSMISSION

__ *m.* Walls and floors are classified by Sound Transmission Class (*STC*), which is a measure of the reduction of loudness provided by various barriers. The higher the number, the better. In determining the required STC rating of a barrier, the following rough guidelines may be used:

__ *n.* The best remedy for reducing impact noise is to cushion the noise at its source.

STC Effect on Hearing

25	Normal speech clearly heard through barrier.
30	Loud speech can be heard and understood fairly well. Normal speech can be heard but barely understood.
35	Loud speech is unintelligible but can be heard.
42–45	Loud speech can be heard only faintly. Normal speech cannot be heard.

46–50 Loud speech not audible. Loud sounds other than speech can be heard only faintly, if at all.

See p. 222 for recommended STC room barriers.

Rough Estimating of STC Ratings

When the wall or floor assembly is less than that desired, the following modifications can be made. Select the appropriate wall or floor assembly. To improve the rating, select modifications (largest number, + ½ next largest, + ½ next largest, etc):

a. Light frame walls

Base design	*STC Rating*
Wood studs W/ ½″ gyp'bd.	32
Metal studs W/ ⅝″ gyp'bd.	39
Modification	*Added STC*
Staggered Studs	+9
Double surface skin	+3 to +5
Absorption insulation	+5

b. Heavy walls
The greater the density, the higher the rating. Density goes up in the following order: CMU, brick, concrete.

Base Design	*STC Rating*
4-inch CMU, brick, concrete	37–41, 42
6-inch	42, 46
8-inch	47, 49, 51
12-inch	52, 54, 56
Modification	*Added STC*
Furred-out surface	+7 to +10
Add plaster, ½″	+2 to +4
Sand-filled cores	+3

c. Wood floors

Base Design	*STC Rating*
½-in plyw'd, subfloor with oak floor, no ceiling	25
Modification	*Added STC*
Add carpet	+10
⅝-inch gyp'bd. ceiling	+10
Add resilient damping board	+7
Add absorbtion insul.	+3

d. Concrete floors

Base Design	*STC Rating*
4-, 6-, 8-inch thick concrete	41, 46, 51
Modification	*Added STC*
Resil. Susp. Ceiling	+12
Add sleepers	+7
Add absorption insul.	+3

e. Glass

¼″ float	26
double glaze	32

f. Doors

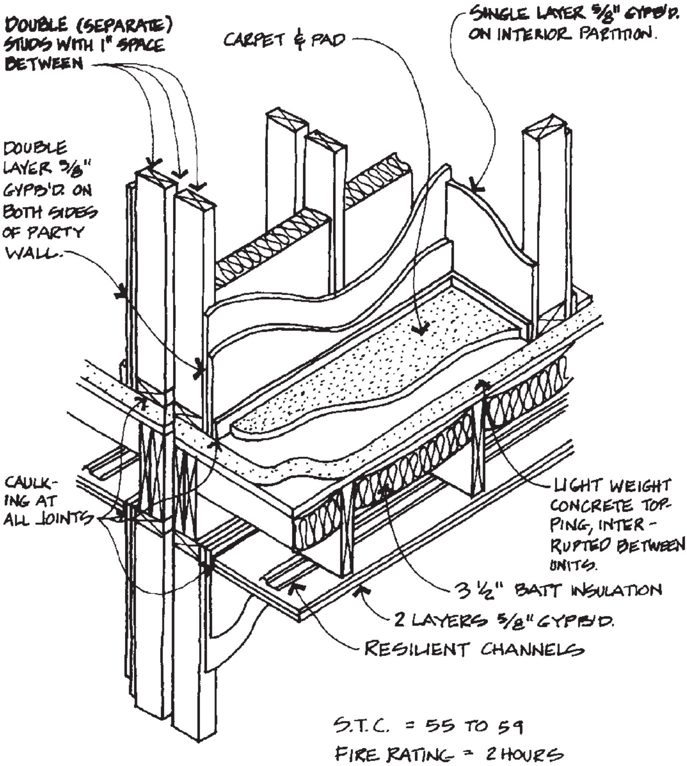
wood HC	26
SC	29
metal	30
special acoustical	35 to 38

Costs: Sound attenuation blankets: 2″ thick = $0.90/SF (10% L and 90% M). Add $0.40 per added inch up to 4″.

EXAMPLE:
ROUGHLY ESTIMATE HOW TO GET S.T.C. = 45 FOR AN OFFICE WALL PARTITION MADE OF WOOD STUDS AND GYPB'D.

FROM ABOVE, A WOOD STUD PARTITION W/ 1/2" GYPB'D. IS ...... S.T.C.= 32

ADD STAGGERED STUDS FOR FULL CREDIT	+9
ADD DOUBLE GYPB'D. FOR 1/2 CREDIT, BOTH SIDES: 1/2 × 5 =	+2.5
ADD ABSORPTION BATTS BETWEEN STUDS: 1/2 × 5 =	+2.5
TOTAL =	46.0



PARTY WALL DETAIL

5

USE OF ABSORPTION IN COMMON OCCUPANCIES			
ROOM OCCUPANCY	CEILING TREATMENT	WALL TREATMENT	SPECIAL
AUDITORIUMS, CHURCHES, THEATERS, CONCERT HALLS, RADIO, RECORDING & T.V. STUDIOS, SPEECH & MUSIC RMS.			●
BOARDROOMS, TELECONFERENCING	●	●	
CLASSROOMS	●	○	
COMMERCIAL KITCHENS	●		
COMPUTER AND BUSINESS MACHINE ROOMS	●		
CORRIDORS AND LOBBIES	○		
GYMNASIUMS, ARENAS, & RECREATIONAL SPACES	●	●	
HEALTH CARE PATIENT ROOMS	●		
LABORATORIES	●		
LIBRARIES	●		
MECHANICAL EQUIPMENT ROOMS			●
MEETING AND CONFERENCE ROOMS	●	○	
OPEN OFFICE PLAN	●	●	
PRIVATE OFFICES	●		
RESTAURANTS	●	○	
SCHOOLS & INDUSTRIAL SHOPS, FACTORIES	●	●	
STORES AND COMMERCIAL SHOPS	●		

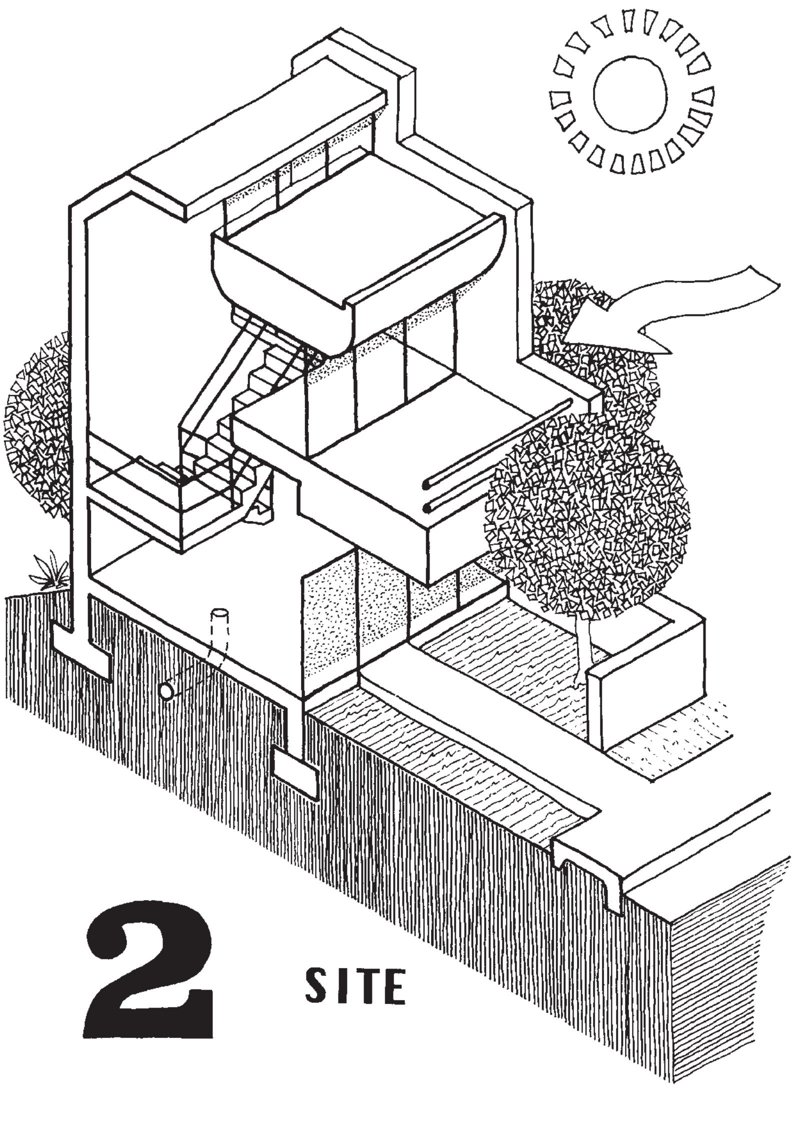
● STRONGLY RECOMMENDED
○ ADVISABLE

SOUND ISOLATION CRITERIA (5)

SOURCE ROOM OCCUPANCY	RECEIVER ROOM ADJACENT	SOUND ISOLATION REQUIREMENT (MINIMUM) FOR ALL PATHS BETWEEN SOURCE AND RECEIVER
EXECUTIVE AREAS, DOCTOR'S SUITES, PERSONNEL OFFICES, LARGE CONFERENCE ROOMS, CONFIDENTIAL PRIVACY REQUIREMENTS	ADJACENT OFFICES AND RELATED SPACES	STC 50-55
NORMAL OFFICES, REGULAR, CONFERENCE ROOMS FOR GROUP MEETINGS, NORMAL PRIVACY REQM'TS	ADJACENT OFFICES & SIMILAR ACTIVITIES	STC 45-50
LARGE GENERAL BUSINESS OFFICES, DRAFTING AREAS, BANKING FLOORS	CORRIDORS, LOBBIES, DATA PROCESSING, SIMILAR ACTIVITIES	STC 40-45
SHOP AND LABORATORY OFFICE IN MANUFACTURING LABORATORY OR TEST AREAS, NORM. PRIVACY	ADJACENT OFFICES, TEST AREAS, CORRID.	STC 40-45
MECHANICAL EQUIPMENT ROOMS	ANY SPACE	STC 50-60 +
MULTIFAMILY DWELLINGS	NEIGHBORS (SEPARATE OCCUPANCY)	
(a.) BEDROOMS	BEDROOMS	STC 48-55
	BATHROOMS	STC 52-58
	KITCHENS	STC 52-58
	LIVING ROOMS	STC 50-57
	CORRIDORS	STC 52-58
(b.) LIVING ROOMS	LIVING ROOMS	STC 48-55
	BATHROOMS	STC 50-57
	KITCHENS	STC 48-50
SCHOOL BUILDINGS		
(a.) CLASSROOMS	ADJ. CLASSROOMS	STC 50
	LABORATORIES	STC 50
	CORRIDORS	STC 45
(b.) LARGE MUSIC OR DRAMA AREA	ADJ. MUSIC OR DRAMA AREA	STC 60
(c.) MUSIC PRACTICE ROOMS	MUSIC PRACTICE RMS	STC 55
INTERIOR OCCUPIED SPACES	EXTERIOR OF BLDG.	STC 35-60
THEATERS, CONCERT HALLS, LECTURE HALLS, RADIO, AND T.V. STUDIOS	ANY AND ALL ADJACENT	USE QUALIFIED ACOUSTICAL CONSULTANT.

NOTES

NOTES



2 SITE

NOTES

___ A. LAND PLANNING (5) (10) (40)

___ 1. *Costs:* **Site work and development costs roughly range from $3 to $12/SF of site area, exclusive of building footprint. This includes parking lot, sidewalks, landscaping, and utilities.**

___ 2. *Slopes:* Use the following guidelines for land selection:

- ___ *a.* Slopes under 1% do not drain well.
- ___ *b.* Slopes under 4% seem flat and are usable for all kinds of activity.
- ___ *c.* Slopes of 4 to 10% are easy grades.
- ___ *d.* Slopes over 10% are steep.
- ___ *e.* Slopes at 15% approach limit of an ordinary loaded vehicle.
- ___ *f.* Slopes at 25% are the limit of mowed surfaces.
- ___ *g.* Slopes over 50% may have erosion problems.

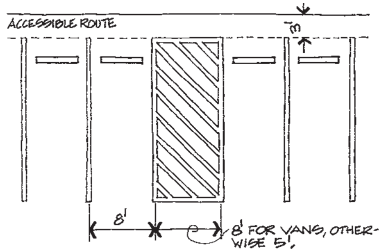
___ 3. *Site Selection* (For Temperate Climates)
Avoid or make special provision for steep north slopes; west slopes facing water; hilltops; frost pockets or positions at the foot of long, open slopes; bare, dry ground; nearby sources of noise or air pollution. Best sites are well-planted middle slopes facing south, near water.

___ 4. *Streets* (Typical Widths)

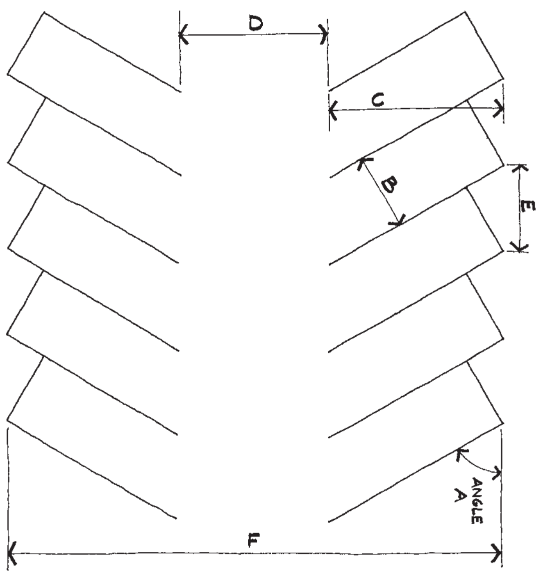
Type	Width	R.O.W.
One-way	18′	25′
Minor road	20′	35′
Minor residential street	26′	
Major street	52′	80′
Highway	12′/lane + 8′ shoulder	up to 400′

___ 5. *Parking*

- ___ *a.* In general, estimate *400 SF/car* for parking, drives, and walks.
- ___ *b.* For very efficient double-bay aisle parking, estimate *300 SF/car* for parking and drives only.
- ___ *c.* Typical parking stall: 9′ × 19′.
- ___ *d.* Parking structure stall: 8.5′ × 19′.
- ___ *e.* Compact parking stall: 7.5′ × 15′.
- ___ *f.* ADA-required. HC parking: To be located as close to the accessible entry as possible. One HC stall for ea. 25 up to 100, then 1 per 50 up to 200, then 1 per 100 up to 500. From 501 to 1000: 2%. Over 1001: 20 + 1 for ea. 100 over 1000. First, plus 1 in every 8 HC stalls shall have 8-ft side aisle (for van parking). All other HC spaces shall have 5-ft side aisle (but may be shared). Stalls to be at least 8 feet wide. Grade at these locations cannot exceed 2%.



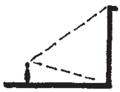
- ___ *g.* Loading dock parking: 10′ × 35′ × 14′ high.
- ___ *h.* One-way drive, no parking: 12′ wide.
- ___ *i.* Two-way drive, no parking: 18′ to 24′ wide.
- ___ *j.* Recommended pavement slope: 1 to 5%.
- ___ *k.* Primary walks: 6′ to 10′ wide.
- ___ *l.* Secondary walks: 3′ to 6′ wide.
- ___ *m.* Walks adjacent to parking areas with overhanging car bumpers: 2.5′ minimum.
- ___ *n.* Above are for rough estimating; always verify local zoning ordinance.
- ___ *o.* See following diagram and table for typical parking lot sizes:



A	B	C	D	E	F	G
					Center-to-center width of two parking rows with access btw'n.	
Parking angle	Stall width	Stall to curb	Aisle width	Curb length	Curb to curb	Overlap center line to center line
0°	7′6″	7.5*	11.0	19.0	26.0	26.0
	8′0″	8.0	12.0	23.0	28.0	—
	8′6″	8.5	12.0	23.0	29.0	—
	9′0″	9.0	12.0	23.0	30.0	—
	9′6″	9.5	12.0	23.0	31.0	—
30°	7′6″	14.0*	11.0	15.0	39.0	32.5
	8′0″	16.5	11.0	16.0	44.0	37.1
	8′6″	16.9	11.0	17.0	44.8	37.4
	9′0″	17.3	11.0	18.0	45.6	37.8
	9′6″	17.8	11.0	19.0	46.6	38.4
40°	8′0″	18.3	13.0	12.4	49.6	43.5
	8′6″	18.7	12.0	13.2	49.4	42.9
	9′0″	19.1	12.0	14.0	50.2	43.3
	9′6″	19.5	12.0	14.8	51.0	43.7
45°	7′6″	15.9*	11.0	10.6	42.8	37.9
	8′0″	19.1	14.0	11.3	52.2	46.5
	8′6″	19.4	13.5	12.0	52.3	46.3
	9′0″	20.1	13.0	13.4	53.2	46.2
	9′6″	20.1	13.0	13.4	53.2	46.5
50°	8′0″	19.7	14.0	10.5	53.4	48.3
	8′6″	20.0	12.5	11.1	52.5	47.0
	9′0″	20.4	12.0	11.7	52.8	47.0
	9′6″	20.7	12.0	12.4	53.4	47.3
60°	7′6″	16.7*	14.0	8.7	47.5	40.4
	8′0″	20.4	19.0	9.2	59.8	55.8
	8′6″	20.7	18.5	9.8	59.9	55.6
	9′0″	21.0	18.0	10.4	60.0	55.5
	9′6″	21.2	18.0	11.0	60.4	55.6
90°	7′6″	15.0*	18.0	7.5	48.0	48.0
	8′0″	19.0	26.0†	8.0	64.0	—
	8′6″	19.0	25.0†	8.5	63.0	—
	9′0″	19.0	24.0†	9.0	62.0	—
	9′6″	19.0	24.0†	9.5	62.0	—

* Based on 15′0″ stall length for compact cars; all others based on 19′0″ stall length.
† Two-way circulation.

___ 6. Open-Space Proportions



AN OBJECT (BUILDING) WHOSE MAJOR DIMENSION (VERTICAL OR HORIZONTAL) EQUALS ITS DISTANCE FROM THE EYE IS DIFFICULT TO SEE AS A WHOLE BUT TENDS TO BE ANALYSED IN DETAIL.

WHEN IT IS TWICE AS FAR, IT APPEARS CLEARLY AS A WHOLE.

WHEN IT IS 3 TIMES AS FAR, IT STILL DOMINATES, BUT IS ALSO SEEN IN RELATION TO OTHER OBJECTS.

WHEN IT IS 4 TIMES, OR MORE, IT BECOMES PART OF THE GENERAL SCENE.

AN EXTERNAL ENCLOSURE IS MOST COMFORTABLE WHEN ITS WALLS ARE 1/2 TO 1/3 AS HIGH AS THE WIDTH OF THE SPACE ENCLOSED.

IF THE RATIO FALLS BELOW 1/4, THE SPACE CEASES TO SEEM ENCLOSED.

LINES OF STREET TREES CAN RE-ESTABLISH A SENSE OF ENCLOSURE IN WIDE SPACES.

NOTES

NOTES

___ B. GRADING AND DRAINAGE

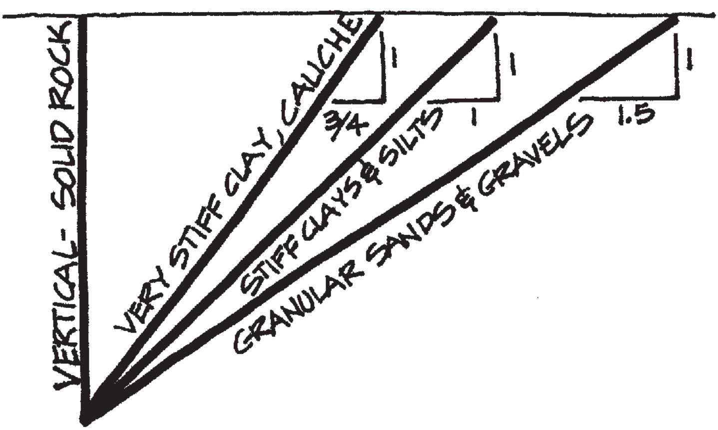
(D) (5) (16) (19) (25) (34) (51)

___ 1. ***Grading for Economy***

- ___ *a.* Keep finished grades as close to the natural as possible.
- ___ *b.* Amounts of cut and fill should balance over the site.

___ 2. ***Maximum Slopes***

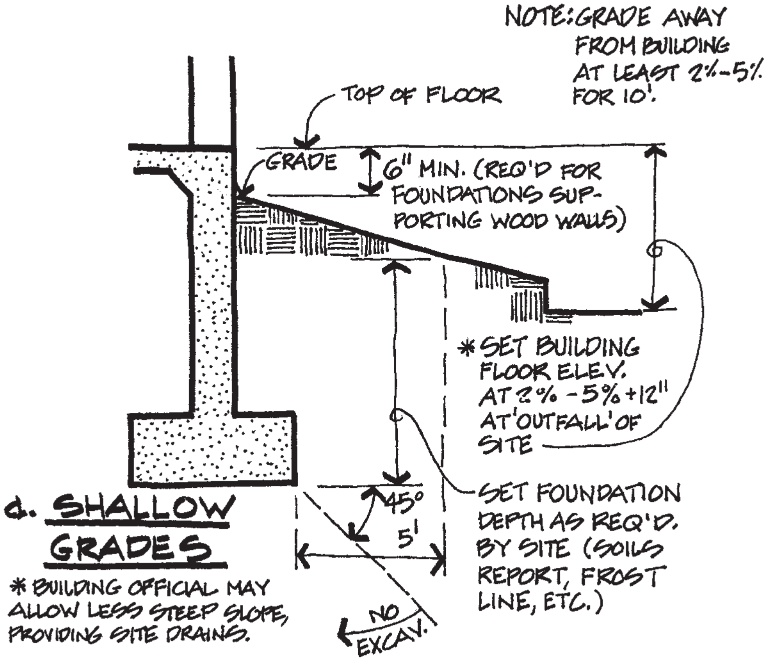
___ *a.*	Solid rock	¼:1
___ *b.*	Loose rock	½:1 (1:1 for round rock)
___ *c.*	Loose gravel	1½:1
___ *d.*	Firm earth	1½:1
___ *e.*	Soft earth	2:1
___ *f.*	Mowing grass	4:1

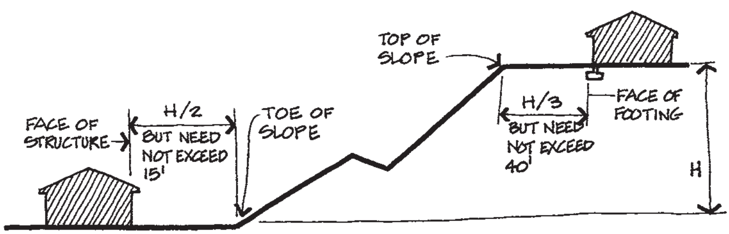


___ 3. *Desirable Grades*

Situation	% of slopes Max.	% of slopes Min.
___ *a.* Paved areas		
___ (1) AC	5	1
___ (2) Concrete	5	0.5
___ *b.* Streets		
___ (1) Length	6–10	0.5
___ (2) Cross	4	2
___ *c.* Walks		
___ (1) Cross slope	2	2
___ (2) Long slope		
___ (3) (Subj. to freeze and accessible)	5	
___ (4) (Not subj. to above)	14	
___ *d.* Ramps		
___ (1) HC-accessible (ADA)	8.33	
___ (2) Nonaccessible	12.5	
___ *e.* At buildings		
___ (1) Grade away 10′		2–5
___ (2) Impervious materials	21	
___ *f.* Outdoor areas		
___ (1) Impervious surface	5	0.5
___ (2) Pervious		
___ (*a*) Ground frost	5	2
___ (*b*) No ground frost	5	1
___ *g.* Swales and gutters (concrete)		.3
___ *h.* Stairs		
___ (1) Landings and treads	2	1

__ 4. *Grades at Buildings*



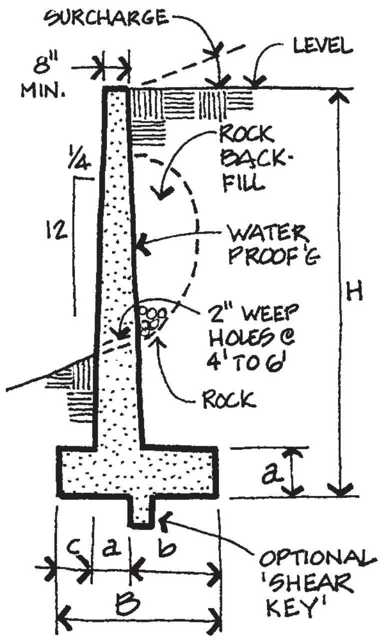


b. STEEP GRADES FOR SLOPES STEEPER THAN 3 TO 1

BUILDING OFFICIAL MAY APPROVE ALTERNATE SETBACKS & CLEARANCES.

5. Retaining Walls

— COSTS ≈ $350/CY, all sizes, not including cut, backfill, or compaction.

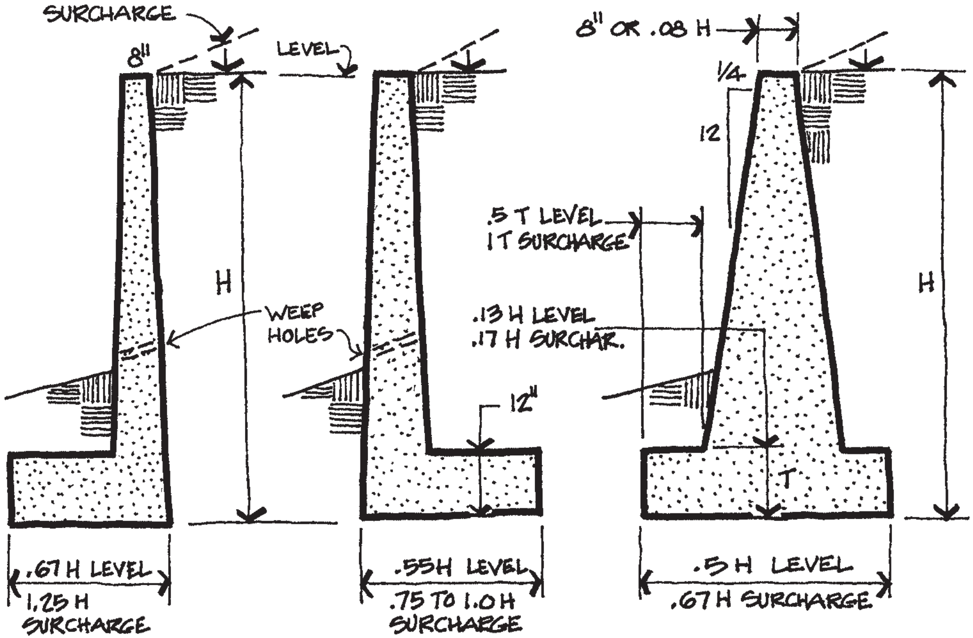


H	B	a	b	c
3'	2.08 (2.67)	.67 (.75)	1.0 (1.5)	.58 (.5)
6'	3.75 (5.33)	.67 (.83)	2.47 (2.93)	.67 (1.58)
9'	5.17 (7.5)	1.0 (1.0)	3.17 (4.17)	1.0 (2.33)
12'	7.25 (12)	1.17 (1.17)	4.58 (7.83)	1.5 (3)
15'	9 (15)	1.33 (1.5)	5.75 (9.75)	1.93 (3.75)
18'	10.83 (18)	1.5 (1.83)	7.08 (11.67)	2.25 (4.5)
21'	12.58 (21)	1.75 (2.17)	8.17 (13.58)	2.67 (5.25)

( ) WITH SURCHARGE; values without parentheses: LEVEL

CANTILEVER RETAINING WALL

1. REINFORCING NOT SHOWN.
2. CONSTRUCTION JOINTS @ 60'.
3. FOR MASONRY, CONTROL JOINTS @ 24'.



CANTILEVER 'L' TYPES   GRAVITY TYPE

___ 6. *Earthwork Conversion Factors*

Native, in-place soils can be compacted for greater density. When dug up the density decreases and the volume increases. Use the following to estimate earthwork volumes:

Soil	In place	Loose	Compacted
Sand	1.00	1.10	.95
Earth	1.00	1.25	.80
Clay	1.00	1.40	.90
Rock (blasted)	1.00	1.5	1.30

___ 7. *Earthwork Costs*

The costs given below are based on machinery-moved and compacted earthwork, normal soils, suburban sites, of medium size (2000–15,000 CY):

___ On site
- **___ Cut — $3.95/CY**
- **___ Hand excavation — $35 to $100/CY**
- **___ Fill and compaction (Compaction 20% of total) — $3.00/CY**

___ Off site
- **___ Import — $6.50/CY (5 miles or less) to $10/CY**
- **___ Export — $5.30/CY (5 miles or less) to $7/CY**

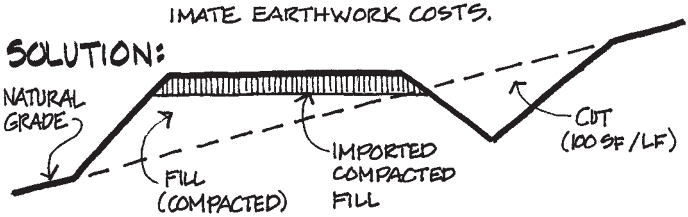
Modifiers:
- **___ Difficult soils (soft clays or hard, cementitious soils) — +100%**
- **___ Hand-compacted — +400 to 500%**
- **___ Volume**
  - **___ Smaller — +50 to 200%**
  - **___ Larger — –0 to 35%**
- **___ Location**
  - **___ Urban sites — +100 to 300%**
  - **___ Rural sites — –0 to 25%**
  - **___ Situations of severe weather (rain or freezing) — +5 to 10%**

Other materials:
- **___ Sand — $7.90 to $13/CY**
- **___ Gravel — $19.80 to $33.00/CY**
- **___ Rock (blasting only)**
  - **___ Rural sites — $7.80 to $10.50/CY**
  - **___ Urban sites — $156/CY**
- **___ Jackhammering — $1780/CY**

EXAMPLE:

PROBLEM: A SLOPING SITE IN PORTLAND, OR. IS TO HAVE A BUILDING PAD OF 90' X 30'. SOILS ARE NOT UNUSUAL OR DIFFICULT. ROUGLY ESTIMATE EARTHWORK COSTS.

SOLUTION:



CUT: 100 SF/LF × 90 LF ÷ 27 = 333 CY @ \$3.95 = \$1315

FILL: 333 CY × 0.3 (COMPACTED) = 100 CY @ \$3.00 = \$300

IMPORTED FILL (COMPACTED):
5' HIGH × 30' × 90' ÷ 27 × 1.25 (LOOSE)
= 625 CY @ \$6.50/CY = \$4600

TOTAL \$6215

ADJUST FOR PORTLAND: 0.95 × \$6215 = SAY \$5900

__ 8. Drainage

__ *a.* General: Rainwater that falls on the surface of a property either evaporates, percolates into the soil (see p. 252), flows off the site, or drains to some point or points on the site. That portion that does not enter the soil is called the *runoff* and provision must be made for this excess water. The grading must be so designed that surface water will flow away from the building. This may sheet-flow across the property line or out driveways to the street. Or, this may necessitate drainage channels with catch basins and storm drains (see p. 259). Each community should be checked for its requirements by contacting the city (or county) engineering or public works department.

__ *b.* Rainfall: For small drainage systems, the maximum rainfall in any *2-year* period is generally used. For a more conservative design, the *5- to 10-year* period may be employed. For establishing floor elevations, *100-year* floods, are often used. Lacking more specific data, see App. B, item J, and divide the quantity by half. One inch of rain per hour is equal to approximately one CF of water falling on one acre of ground per second.

___ *c.* Runoff: Volume may be estimated by:

Q = C × I × A, where:

Q = Quantity of runoff in CF/sec

C = Coefficient of runoff:

Roofs	0.95
Concrete or asphalt	0.95
Gravel areas	
Loose	0.30
Compact	0.70
Vacant land, unpaved streets	
Light plant growth	0.60
No plants	0.75
Lawns	0.35
Wooded areas	0.20

I = Intensity of rainfall in inches per hour

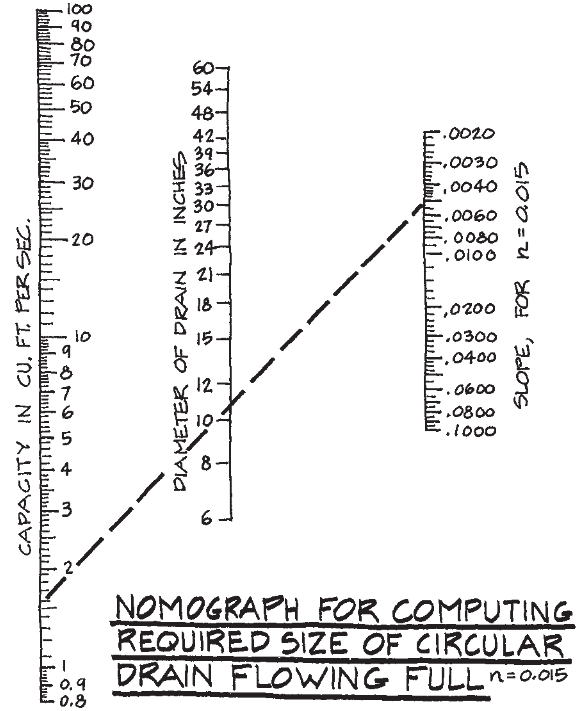
A = Area to be drained, in acres

___ *d.* Dry wells: Slowly drain runoff back into the ground. They should be at least 10′ from septic tanks and lot lines, 20′ from buildings, and 100′ from water supply sources. Their bottoms should lie above the highest annual level of the local water table. They should not be used for toilet wastes. They should not be built in nonporous soil (rock, hard pom, dense clay, etc.).

___ *e.* Storm drains

It is wiser to oversize than economize on size because the cost of a slightly larger conduit, besides being a very small part of the installation cost, is far less than the cost of flooding and erosion that could result.

The following nomograph can be used to estimate storm drain sizes. It is for rough concrete. Materials of smoother surfaces will have smaller sizes. Also, see pp. 259 and 519.



NOMOGRAPH FOR COMPUTING REQUIRED SIZE OF CIRCULAR DRAIN FLOWING FULL n = 0.015

EXAMPLE:

PROBLEM: FIND RUN OFF AND PRELM. SIZE OF STORM DRAIN FOR A BUILDING SITE IN CHICAGO, IL. WITH A LAWN AREA OF 22215 SF AND HARD SURFACE AREAS (PAVING, ROOF, WALKS) OF 13500 SF.

SOLUTION:

1. FIND I FOR CHICAGO (APPENDIX B, ITEM J, P.642) IS 6.3"/HR. BY THE ABOVE RULE OF THUMB (P.240), DIVIDE THIS IN HALF OR 3.2"/HR.

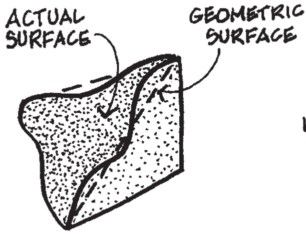
2. $Q_1 = CIA$ (LAWN) = (.35)(3.2)(22215 ÷ 43560) = 0.57
   $Q_2 = CIA$ (HARD) = (.95)(3.2)(13500 ÷ 43560) = 0.94
   1.5 CF/SEC

   NOTE: C LAWN = .35
   C HARD = .95
   CONVERSION OF SF TO AC IS 43560 SF/AC

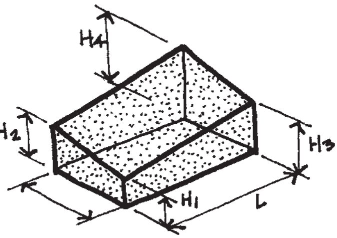
3. ESTIMATE UNDERGROUND PIPE SIZE WITH A 5% SLOPE. SEE DASHED LINE IN ABOVE NOMOGRAPH (P.241) FOR 11 INCH. PIPE. MAKE THIS A 12" ϕ CONC. PIPE.

___ *f.* Flooding: When siting a building near a lake, stream, or river, examine the terrain above the water. If the land slopes gently from the shore, then rises steeply, and then levels out, this probably indicates a floodplain. No building should be placed below the crest of the rise. The damage that can be caused by even a small stream rising to flood stage is staggering. If a stream's speed doubles, its erosive force is 32 times greater. If its speed quadruples, its erosive force increases more than 1000 times.

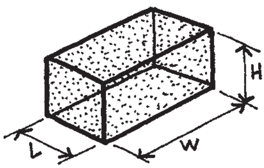
EXCAVATION VOLUMES



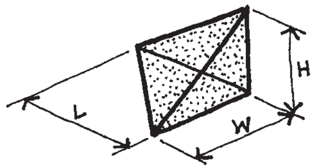
IRREGULAR SURFACES



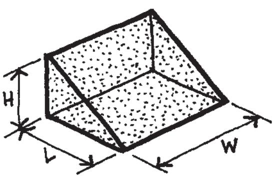
$V = 0.25LW(H_1 + H_2 + H_3 + H_4)$



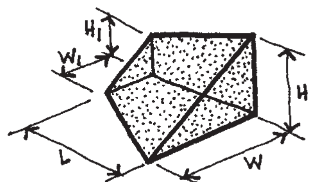
$V = LWH$



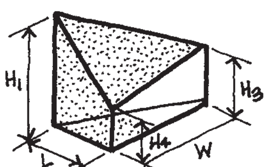
$V = 0.17\,LWH$



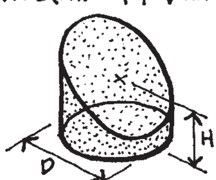
$V = 0.5\,LWH$



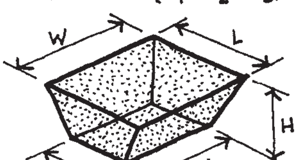
$V = 0.17\,L\left(WH + W_1H_1 + \sqrt{WHW_1H_1}\right)$



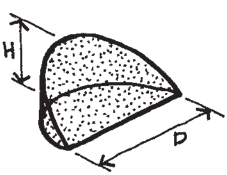
$V = 0.17\,LW(H_1 + H_2 + H_3)$



$V = 0.79\,D^2H$



$V = 0.25H(L + L_1)(W + W_1)$



$V = 1.32\,D^2H$

NOTES

___ C. SOILS (2) (5) (16) (25) (40) (51) (60)

___ 1. **Danger "Flags"**

- ___ *a.* High water table.
- ___ *b.* Presence of trouble soils: Peat, other organic materials, or soft clay, loose silt, or fine water-bearing sand.
- ___ *c.* Rock close to surface.
- ___ *d.* Dumps or fills.
- ___ *e.* Evidence of slides or subsidence.

___ 2. **Ranking of Soil for Foundations**

- ___ *a.* *Best:* Sand and gravel
- ___ *b.* *Good:* Medium to hard clays
- ___ *c.* *Poor:* Silts and soft clays
- ___ *d.* *Undesirable:* Organic silts and clays
- ___ *e.* *Unsuitable:* Peat

___ 3. **Aboveground Indicators:**

- ___ *a.* *Near buildings:* When deep excavations occur near existing buildings there may be severe lateral movement. This requires shoring of adjacent earth and or existing foundations.
- ___ *b.* *Rock outcrops* may indicate bedrock is just underground. Bad for excavating but good for bearing and frost resistance.
- ___ *c.* *Water* (such as a lake) indicates a water table close to grade. Foundations may be expensive and unstable.
- ___ *d.* *Level terrain* usually indicates easy site work, fair bearing, but poor drainage.
- ___ *e.* *Gentle slopes* indicate easy site work and excellent drainage.
- ___ *f.* *Convex terrain* (a ridge) is usually a dry, solid place to build.
- ___ *g.* *Concave terrain* (a depression) usually is a wet and soft place to build.
- ___ *h.* *Steep slopes* indicate costly excavation, potential erosion, and sliding soils.
- ___ *i.* *Foliage:* Some species indicate moist soil. Sparse or no foliage in a verdant area suggests hard, firm soil. Large solitary trees indicate solid ground.

___ 4. **Basic Soil Types (Identification)**

- ___ *a.* *Inorganic* (for foundations)
    - ___ (1) Rock: good bearing but hard to excavate
    - ___ (2) Course grain
        - ___ (*a*) Gravel: 3″ to 2 mm. Well-drained, stable material.

___ (*b*) Sand: 0.05 to 2 mm. Gritty to touch and taste. Good, well-drained material if confined, but “quick” if saturated.

___ (3) Fine grain

___ (*a*) Silt: 0.005 to 0.05 mm. Feels smooth to touch. Grains barely visible. Stable when dry but may creep under load. Unstable when wet. Frost heave problems.

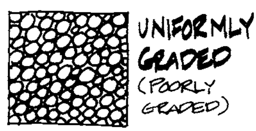
___ (*b*) Clays: Under 0.005 mm. Cannot see grains. Sticks to teeth (or hand, when moist). Wide variety in clays, some suitable and some not. Can become expansive when wet.

___ *b.* *Organic* (not suitable for foundations). Fibrous texture with dark brown or black color.

___ 5. <u>**Most Soils Combine Types**</u>

___ *a.* Consist of air, water, and solids

___ *b.* Size variation of solids a factor



___ 6. Amounts of types of solids vary, giving different characteristics per following table:

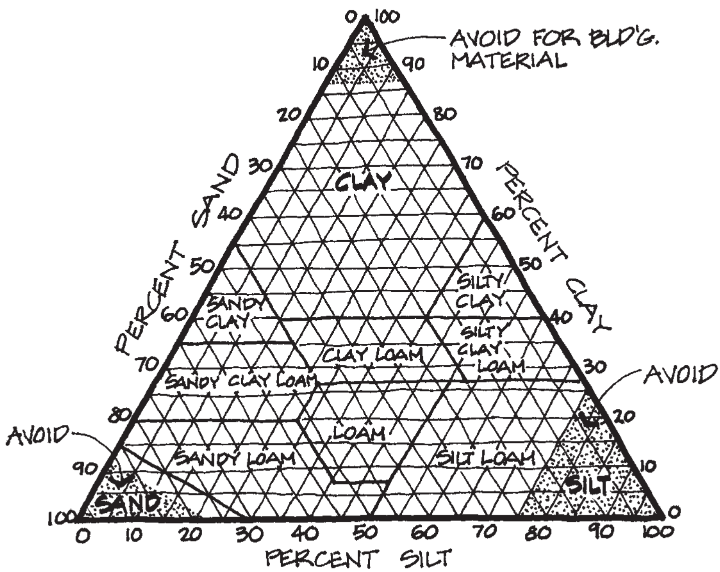
Unified Soil Classification

Soil type	Description	Allow. bearing (lb/SF) (1)	Drainage (2)	Frost heave potent	Expan. potent (3)
___ BR	Bedrock	4000 to 12,000	Poor	Low	Low
Gravels					
Clean gravels					
___ GW	Well-graded gravel-sand mixtures, little or no sands	3000	Good	Low	Low
___ GP	Poorly graded gravels or gravel-sand mixtures, little or no fine	3000	Good	Low	Low
Gravels with fines					
___ GM	Silty gravels, gravel-sand-silt mixtures	2000	Good	Med.	Low
___ GC	Clayey gravels, gravel-clay-sand mixtures	2000	Med.	Med.	Low
Sand					
Clean sands					
___ SW	Well-graded sands, gravelly sands, little or no fines	2000	Good	Low	Low
___ SP	Poorly graded sands or gravelly sands, little or no fines	2000	Good	Low	Low
Sands with fines					
___ SM	Silty sand, sand-silt mixtures	2000	Good	Med.	Low
___ SC	Clayey sands, sand-clay mixture	2000	Med.	Med.	Low
Fine grained					
Silts					
___ ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands w/slight plasticity	1500	Med.	High	Low
___ MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	1500	Poor	High	High

Clays						
___	CL	Inorganic clays of low to med. plasticity, gravelly, sandy, silty, or lean clays	1500	Med.	Med.	Med.
___	CH	Inorganic clays of high plasticity, fat clays	1500	Poor	Med.	High
Organic						
___	OL	Organic silts and organic silty clays	400	Poor	Med.	Med.
___	OH	Organic clays of medium to high plasticity	0	Unsat.	Med.	High
___	PT	Peat and other highly organic soils	0	Unsat.	Med.	High

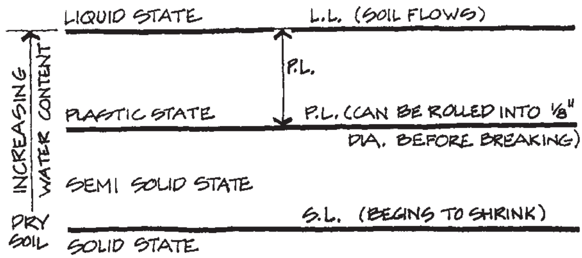
Notes:

1. Allowable bearing value may be increased 25% for very compact, coarse-grained, gravelly or sandy soils, or for very stiff, fine-grained, clayey or silty soils. Allowable bearing value should be decreased 25% for loose, coarse-grained, gravelly or sandy soils or soft, fine-grained, clayey or silty soils.
2. Percolation rate for good drainage is over 4″/hr; medium drainage is 2–4″/hr; poor is less than 2″/hr.
3. Dangerous expansion might occur if these soil types are dry but subject to future wetting.
4. IBC allows to 1500 psf for nonexpansive soils and small buildings.



___ **7. *Clays:*** Usually give greatest problems for foundations.

___ *a.* Measure expansiveness:



The greater the PI (Plasticity Index), the greater the potential for shrinkage and swelling. Some clays swell up to 20-fold with pressures of several tons/SF. Problems of upheaval vs. settlement usually are 2 to 1.

___ *b.* Strength of clays

Consistency	Shear (ton/SF)	Compression (ton/SF)	Rule of thumb
___ Soft	0.25–0.5	<0.5	¼″ pencil makes 1″ penetration with med. effort.
___ Medium stiff	0.5–1.0	0.5–1.0 1.0–2.0	¼″ pencil makes ½″ penetration with med. effort.
___ Very stiff	1.0–3.0	2.0–4.0	¼″ pencil makes ¼″ penetration with much effort.
___ Hard	3.0>	4.0>	¼″ steel rod can penetrate less than ⅛″. Can hardly scratch.

___ **8. Testing**

___ *a.* Simple field tests

___ (1) Separation of gravel

___ (*a*) Remove from sample all particles larger than ⅛″ diameter.

___ (*b*) Estimate percent gravel.

___ (2) Sedimentation test

___ (*a*) Place sample (less gravel) in canteen cup and fill with water.

___ (*b*) Shake mixture vigorously.

___ (*c*) Allow mixture to stand for 30 seconds to settle out.

___ (*d*) Pour off water and save.

___ (*e*) Repeat (b) through (d) above until water poured off is clear.
___ (*f*) Evaporate water from (d) above.
___ (*g*) Estimate percent fines.

___ (3) Comparison of gravel and sand
___ (*a*) Gravels have been removed in test (1).
___ (*b*) Fines have been removed in test (2).
___ (*c*) Dry soil remaining in cup.
___ (*d*) Soil remaining in cup will be sand.
___ (*e*) Compare dry sand in cup with gravel.

___ (4) Dry strength
___ (*a*) Form moist pat 2″ in diameter by ½″ thick.
___ (*b*) Allow to dry with low heat.
___ (*c*) Place dry pat between thumb and index finger only and attempt to break.
___ (*d*) Breakage easy—silt.
Breakage difficult—CL.
Breakage impossible—CH.
(see p. 248, Typical)

___ (5) Powder test
___ (*a*) Rub portion of broken pat with thumb and attempt to flake particles off.
___ (*b*) Pat powders—silt (M).
Pat does not powder—clay (C).

___ (6) Thread test (toughness test)
___ (*a*) Form ball of moist soil (marble size).
___ (*b*) Attempt to roll ball into ⅛″-diameter thread (wooden match size).
___ (*c*) Thread easily obtained—clay (C).
Thread cannot be obtained—silt (M).

___ (7) Ribbon test
___ (*a*) Form cylinder of soil approximately cigar-shaped in size.
___ (*b*) Flatten cylinder over index finger with thumb; attempting to form ribbon 8″ to 9″ long, ⅛″ to ¼″ thick, and 1″ wide.
___ (*c*) 8″ to 9″ ribbon obtained—CH.
Less than 8″ ribbon—CL.

___ (8) Wet shaking test
 ___ (*a*) Place pat of moist (not sticky) soil in palm of hand (vol. about ½ cu. in.).
 ___ (*b*) Shake hand vigorously and strike against other hand.
 ___ (*c*) Observe rapidity of water rising to the surface.
 ___ (*d*) If fast, sample is silty (M).
 If no reaction, sample is clayey (C).

___ (9) Grit, or bite test
 ___ (*a*) Place pinch of sample between teeth and bite.
 ___ (*b*) If sample feels gritty, sample is silt (M).
 ___ (*c*) If sample feels floury, sample is clay (C).

___ (10) Feel test
 ___ (*a*) Rub portion of dry soil over a sensitive portion of skin, such as inside of wrist.
 ___ (*b*) If feel is harsh and irritating, sample is silt (M).
 ___ (*c*) If feel is smooth and floury, sample is clay (C).

___ (11) Shine test
 ___ (*a*) Draw smooth surface, such as knife blade or thumbnail, over pat of slightly moist soil.
 ___ (*b*) If surface becomes shiny and lighter in texture, sample is a high-compressible clay (CH).
 ___ (*c*) If surface remains dull, sample is a low-compressible clay (CL).

___ (12) Odor test
 ___ (*a*) Heat sample with match or open flame.
 ___ (*b*) If odor becomes musty or foul-smelling, this is a strong indication that organic material is present.

___ (13) Cast test
 ___ (*a*) Compress a handful of moist soil into a ball.
 ___ (*b*) Crumbles with handling—GW, SW, GP, or SP.

___ (*c*) Withstands careful handling—SM or SC.
___ (*d*) Handled freely—ML or MH.
___ (*e*) Withstands rough handling—CL or CH.

___ (14) Slaking test
___ (*a*) Place soil or rock in sun to dry.
___ (*b*) Soak in water for 24 hours.
___ (*c*) Repeat (a) and (b) above several times.
___ (*d*) If soil or rock disintegrates, it is poor material.

___ (15) Amounts of soil

	Sieve	Jar of water
___ Gravel	Remains on #10	Settles immediately
___ Sand	Remains on #200	Settles in 30 sec
___ Silt	Goes to bottom	Settles in 15–60 min
___ Clay	Goes to bottom	Settles in several hrs

Measure each amount to get approximate percent of each soil type.

___ (16) Testing for percolation: Absorption capacity of soil for sanitary septic systems (see p. 518) may be checked by digging a test pit at the drain field site in the wet season to the depth that the field will lie. Fill the pit with 2′ of water, let fall to a 6″ depth, and time the drop from 6″ to 5″. Repeat until it takes same time to make the 1″ drop in two tests running. The allowable absorption rate of soil, in gallons per SF of drain field per day, is:

Time for 1″ fall, minutes	Approx. absorption rate, gals per SF per day
___ 5 or less	2.5
___ 8	2.0
___ 10	1.7
___ 12	1.5
___ 15	1.3
___ 22	1.0

Total sewage flow = 100 gal per person per day.

___ *b.* Soils reports and data

Architects are well advised to have their clients obtain soils reports for all projects, even residential.

___ (1) Geotechnical or *soils report recommendations* are based on lab tests of materials obtained from on-site borings. Request the following info:

___ (*a*) Bearing capacity of soil and settlement

___ (*b*) Foundation design recommendations

___ (*c*) Paving design recommendations

___ (*d*) Compaction recommendations

___ (*e*) Lateral strength (active and passive pressure, and coef. of friction)

___ (*f*) Permeability

___ (*g*) Frost depth

___ (2) Typical investigations require *borings* at the center and each corner of the "footprint" of the building, or one per 3000 to 5000 SF.

___ (3) **Costs: Under 10,000 SF: $2000 to $5000. Thereafter: $.20 to $.40/SF up to 100,000 SF. Very large or high-rise projects have large negotiated fees.**

___ (4) Typical soils report strength characteristics:

___ Noncohesive (granular) soils

Relative density	Blows per foot (N)
___ Very loose	0–4
___ Loose	5–10
___ Firm	11–30
___ Dense	31–50
___ Very dense	51+

___ Cohesive (claylike) soils

Comparative consistency	Blows per foot	Unconfined compressed strength (T/SF)
___ Very soft	0–2	0–0.25
___ Soft	3–4	0.25–0.50
___ Med. stiff	5–8	0.50–1.00
___ Stiff	9–15	1.00–2.00
___ Very stiff	16–30	2.00–4.00
___ Hard	31+	4.00+

	Degree of plasticity	PI	Degree of expan. pot.	PI
___	None to slight	0–4	Low	0–15
___	Slight	5–10	Medium	15–25
___	Medium	11–30	High	25+
___	High	31+		

___ (5) For small projects, especially in rural areas, *soils surveys* by USDA Soils Conservation Service are available (free of charge) through the local soil and water conservation district office.

___ **9. Soil Preparation for Foundations**

___ *a.* Soils may or may not have to be prepared for foundations, based on the specific foundation loads and type and nature of the soil.

___ *b.* Problem soils

___ (1) Collapsing soils undergo large reductions in volume as they become wet. This magnifies when foundation loads are applied. These soils are found most extensively as wind- or water-deposited sands and silts, sometimes called loess. Man-made fills can have the same effect. The soils exist as loose deposits, with large void spaces between soil particles.

___ (2) Expansive soils are usually clays. See 7, above.

___ *c.* Compaction is a procedure that increases the density of soil (decreasing the void space and thereby increasing the strength) by either rolling, tamping, or vibrating the surface. Adding moisture increases the density until the optimum moisture at maximum density is obtained. This is given as a percent (usually 90% to 95% desired). Past this, the density decreases.

___ (1) Typical procedure lays down a 6″ to 8″ layer ("lift") of soil, which is watered and compacted. For sand, vibratory compaction equip. is used. Sand cannot be over-compacted. For clay, heavy rollers are best. Clay can be over-compacted.

___ (2) Problem soils may need:

___ (*a*) "Engineered fill" is standard compaction, but with usually a predetermined fill material brought on site, placed, and tested under the supervision of a soils engineer. This may require removing the native problem soil to a predetermined depth.

___ (*b*) Prewetting (causing moisture to penetrate several feet) and then compacting or loading a "surcharge" of soil stockpiled above the native.

___ (*c*) Other:

- ___ "Dynamic" compaction by dropping heavy weights. This can compact 60′ deep.
- ___ Deep vibration by a steel shaft driven into the ground. Water may be forced down the shaft. Compaction can occur at depths of 60′ to 100′. This is economical only when used for large sites.
- ___ Blasting.
- ___ Compaction piles.
- ___ Compaction grouting.
- ___ Stabilization by chemical grouting such as lime (for expansive soils).

___ **10. Laterial**: Many soils, particularly sandy or clayey soils, are only ⅓ as strong laterally as vertically.

___ **11. Foundations**

- ___ *a.* Differential settlement of foundations: ¼″ to ½″, maximum.
- ___ *b.* Depth of foundations should be at or below the local frost line. See App. B, item C.
- ___ *c.* The best solution to avoid potential problems is wide footings with high safety factors.
- ___ *d.* For more on foundations, see pp. 281 and 285.

___ **12. Radon**

- ___ *a.* See App. B for likely radon locations.
- ___ *b.* A colorless, odorless, radioactive gas found in soils and underground water.
- ___ *c.* Is drawn from the soil through the foundation when the indoor pressure is less than the pressure outside, in the soil. This usually occurs in winter.
- ___ *d.* Reduction approaches:

___ (1) For slab-on-grade construction, a normal uniform rock base course, vapor barrier, and concrete slab may be satisfactory.

___ (2) Basements

___ (*a*) Barrier approach, by complete waterproofing.

___ (*b*) Suction approach collects the gas outside the foundation and under the slab, and vents it to the outside. Consists of a collection system of underground pipes (or individual suction pipes at 1/500 SF), and discharge system.

___ (3) **Costs: $420 to $600 during home const., but $600 to $3000 for retrofits.**

___ 13. Termite Treatment

___ *a.* Wood buildings should usually have termite treatment under slab on grade.

___ *b.* Locations where termites are most prevalent are given in App. B, item F.

___ *c.* **Costs: $0.40/SF (55% M and 45% L), variation −35%, +65%.**

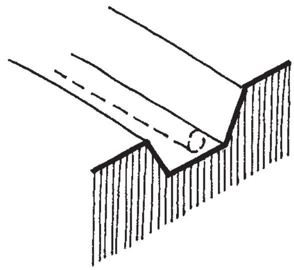
NOTES

NOTES

___ D. UTILITIES (30)

At the beginning of a project, the architect should verify utility needs and availability. The five main utilities are water, sewer, power, gas, and telephone—with storm drains and cable TV as added options.

UTILITY TRENCHES



Typical Costs for Trench, Excavation, and Compacted Backfill:

- ___ **For 2′ × 2′ trench with 0 to 1 side slope: $0.75/SF sect./LF trench**
- ___ **Double cost for 2 to 1 side slope. Add 1% for each additional ft depth past 2′.**
- ___ **Add to above cost of pipe or conduit listed below.**

___ 1. Storm Drains

- ___ *a.* Most expensive, avoid where possible.
- ___ *b.* Separate from sanitary sewer.
- ___ *c.* Manholes at ends, at each change of horizontal or vertical direction, and each 300′ to 500′.
- ___ *d.* Surface drain no more than 800′ to 1000′ to catch basins, or 500′ if coming from two directions.
- ___ *e.* 4′ deep in cold climates, or at least below frost line.
- ___ *f.* Minimum slope of 0.3% for a minimum velocity of 2′/sec (never exceed 10′/sec)
- ___ *g.* 12″ minimum diameter in 3″ increments up to 36″.
- ___ *h.* See p. 239 for sizing.

See below for Costs.

___ 2. Sanitary Sewer

- ___ *a.* CO at ends, branchings, turns (less than 90°).
- ___ *b.* Typically, 4″ for house branch up to 8″ diameter for mains and laterals. 6″ for most commercial.
- ___ *c.* Street mains often at –6′, or greater.
- ___ *d.* Slopes of from 1⁄16″ to 1⁄4″/ft.
- ___ *e.* Place below water lines or 10′ away.
- ___ *f.* Also see p. 518.

Typical Costs for Drainage and Sewage Piping: (per LF)

- ___ **Reinforced concrete: 12″ to 84″ diameter = $1.80 to $5.50/inch dia.**
- ___ **Corrugated metal: 8″ to 72″ diameter = $1.75 to $3.95/inch dia.**
- ___ **Plain metal: 8″ to 72″ diameter = $1.30 to $3.90/inch dia. (storm drains only)**
- ___ **PVC: 4″ to 15″ diameter = $1.50 to $1.65/inch dia.**
- ___ **Clay: 4″ to 36″ diameter = $1.90 to $5.40/inch dia.**

Typical Costs for MH and Catch Basins:
- ___ **For 4′ × 4′ deep, C.M.U. or P.C.C. = $2160**
- ___ **Adjust: +10% for brick, +15% for C.I.P. conc.**
- ___ **Add: $540 each ft down to 14′.**

___ 3. Water
- ___ *a.* Flexible in layout.
- ___ *b.* Best located in Right-of-Way (ROW) for mains.
- ___ *c.* Layouts: branch or loop (best).
- ___ *d.* Affected by frost. Must be at –5′ in cold climates, or at least below frost line.
- ___ *e.* Place water main or line above and to one side of sewer.
- ___ *f.* Valves at each branch and at each 1000′ max.
- ___ *g.* FHs laid out to reach 300′ to buildings but no closer than 25′ to 50′. Sometimes high-pressure fire lines installed.
- ___ *h.* Typical size: 8″ dia., min., mains
6″ dia., min., branch
- ___ *i.* Typical city pressure 60 psi (verify)
- ___ *j.* Where city water not available, wells can be put in (keep 100′ from newest sewer, drain field, or stream bed).
- ___ *k.* Also, see p. 516.

Typical Costs for Piping (per LF):
- ___ **Iron: 4″ dia. to 18″ dia. = $4.75/inch dia.**
- ___ **Copper: ¾″ dia. to 6″ dia. = $8.80 to $27.60/inch dia.**
- ___ **PVC: 1½″ dia. to 8″ dia. = $3.00/inch dia.**

___ 4. Power and Telephone
- ___ *a.* Brought in on primary high-voltage lines, either overhead or underground.
- ___ *b.* Stepped down at transformers to secondary (lower voltage) lines. Secondary lines should be kept down to 400′ or less to building service-entrance sections.
- ___ *c.* Underground distribution may be 2 to 5 times more expensive but is more reliable, does not interfere with trees, and eliminates pole clutter. Always place in conduit.
- ___ *d.* If overhead, transformers are hung on poles with secondary overhead to building. Guyed poles typically 125′ (max.) apart. Where not in R.O.W., 8′ easement required. For footings, provide 1′ of inbedment per every 10′ of height plus 1 extra foot.
- ___ *e.* See p. 609.

Typical Costs for Conduit: 3″ to 4″: $5.25 to $7.90/LF
PC conc. transformer pad, 5′ sq.: $70/ea.

___ 5. Gas

___ *a.* Underground, similar to water. Piping must be corrosion protected.

___ *b.* Main problem is danger of leakage or explosion, so lines should be kept away from buildings, except at entry.

___ *c.* As a rule, meter each building separately.

___ *d.* Lines should not be in same trench as electric cable.

___ *e.* Also see p. 525.

Typical Costs for Gas Piping:

___ **Plastic: $2.95 for 1¼″ to $10.00/LF for 4″ dia.**

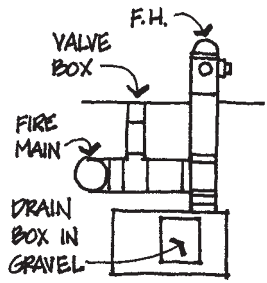
___ **Steel: $31.65/LF for 5″ dia. to $58.55/LF for 8″ dia.**

___ 6. Fire Protection: Generally, fire departments want:

___ *a.* Fire hydrants at streets or drives that are located about 300 ft apart and located so that a 300-ft hose can extend around building.

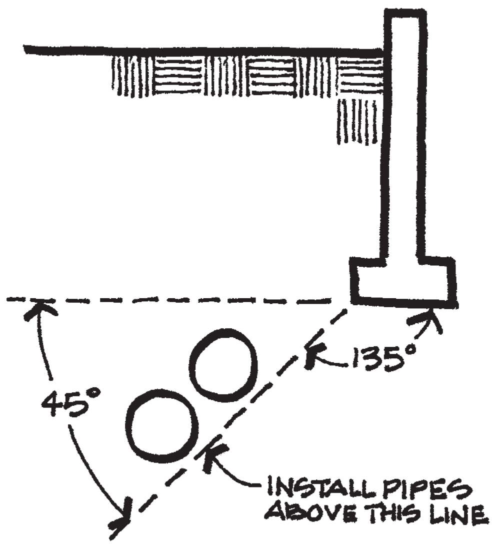
___ *b.* Min. of at least 16-ft-wide drives around building, with 30′ to 60′ turning radius for fire truck access.

___ *c.* Also see p. 521.



Typical Costs:

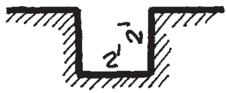
Piping costs, same as water (iron or PVC)
Hydrants: $2280/ea.
Siamese: $260 to $430/ea.



EXAMPLE:

PROBLEM: ESTIMATE THE COST OF A NEW 200' LONG UNDERGROUND, 1½" PVC WATER LINE FOR A BUILDING SITE IN LOS ANGELES, CA. THIS WILL BE PUT IN DURING ROUGH GRADING, PRIOR TO PAVING AND LANDSCAPING.

SOLUTION:



1. 2' SQ. TRENCH EXCAV. & FILL: \$0.65 (P 259) x 4 SF x 200' = \$520
2. 1½" PVC LINE: 1.5" x \$2.50/" DIA (P 260) x 200' = \$750

\$1270

3. LOS ANGELES COST FACTOR (SEE APP. B, ITEM V, P. 638) x 1.07

\$1359

SAY: \$1360

NOTES

___ E. SITE IMPROVEMENTS

Item	Costs
___ 1. Paving	
___ *a.* Asphalt:	
2″ AC	**$.60 to $1.20/SF (70%M and 40%L)**
For each added inch:	**Increase 25 to 45%**
4″ base:	**$.45 to .70/SF (60%M and 40%L)**
For each added inch:	**Increase 25%**
___ *b.* Concrete drives, walks, patios: ½″ score joints at 5′ and expan. joints at 20′ to 30′	
4″ concrete slab:	**$2.00 to 2.60/SF (60%M and 40%L)**
Add:	
For base	**See AC, above**
For each inch more	**Add 15%**
For reinforcing	**5 to 10%**
For special finishes	**Add 100%**
For vapor barriers	**See p. 365.**
___ 2. Miscellaneous Concrete	
___ *a.* Curb	**$10.80/LF (30%M and 70%L)**
___ *b.* Curb and gutter	**$16.80/LF**
Add for "rolled"	**+25%**
___ *c.* Conc. parking bumpers	**$.60/ea. (65%M and 35%L)**
___ *d.* Paint stripes	**$.40/LF (20%M and 80%L)**
___ 3. Fences and Walls	
___ *a.* Chain link	
4′ high	**$6.65 to $9.60/LF (50%M and 50%L)**
6′ high	**$7 to $10.00/LF**
___ *b.* Wrought iron, 3′ to 4′	**$28/LF (70%M and 30%L)**
___ *c.* Wood fencing	**$2.25 to $9.60/SF (60%M and 40%L) depending on material, type, and height**
___ *d.* Walls	**See Parts 3 and 4.**
___ 4. Site Lighting	
___ *a.* Pole mounted for parking lot, 20′ to 40′ high	**$2040 to $4200/ea.**
___ 5. Carports and Canopies (no foundations)	**$2160–$4800/car**

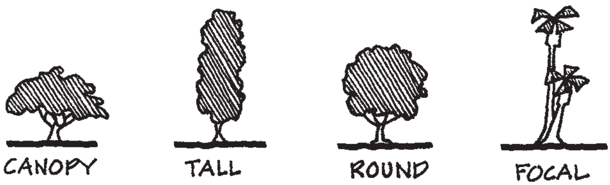
NOTES

___ F. LANDSCAPING AND IRRIGATION

___ 1. <u>*General*</u>

- ___ *a.* Landscaping can be one of the greatest aesthetic enhancements for the design of buildings.
- ___ *b.* Landscaping can be used for energy conservation. See p. 181.
- ___ *c.* Landscaping can be used for noise reduction. See p. 214.
- ___ *d.* At locations with expansive soils, be careful about plants and irrigation next to buildings.
- ___ *e.* Trees can be used to address the design needs of a project by directing pedestrian or vehicle movement, framing vistas, screening objectional views, and defining and shaping exterior space. Trees can also be used to modify the microclimate of a site and help conserve building energy use from heating and cooling systems. Mature trees and ground cover absorb or delay runoff from storm water at a rate 4 to 5 times that of bare ground.
- ___ *f.* Existing: Mature trees will not survive a violent change of habitat. The ground may not be cut away near their roots, nor may more than a few inches be added to grade; though a large well with radial drains and 6″ of crushed stone out to the drip may work. As a rule, though, up to 50% of the root system can be lost without killing a plant, providing the other 50% is completely undisturbed. Trees which grew in a wood must be preserved in a clump, since they have shallow roots, while trees that were originally isolated or in open fence lines should be kept so.
- ___ *g.* As a general rule, trees should be located no closer to buildings than the extent of the mature "drip line." When closer, deeper foundations may be needed, especially in expansive soils.
- ___ *h.* Good ventilation is a must for interior plants, but AC supply should be directed away from plants due to winter overheating. For interior plants and pots, see p. 461.

___ *i.* Trees are often selected by profile for aesthetics and function:



___ 2. Materials

___ *a.* Select material based on USDA Plant Zones, shown below. See App. B, item H, for various zones.

Zone	Approx. range of ave. annual min. temp.
2	–50 to –40°F
3	–40 to –30°F
4	–30 to –20°F
5	–20 to –10°F
6	–10 to 10°F
7	0 to –30°F
8	10 to 20°F
9	20 to 30°F
10	30 to 40°F

___ *b.* Next, select plants for microclimate of site (see p. 181) and location around building, as follows:
- ___ (1) Shaded locations and north sides
- ___ (2) Semi-shaded locations and east sides
- ___ (3) Sunny locations and south and west sides

___ *c.* Select material by the following types:
- ___ (1) Large trees (over 20′, often up to 50′ high)
- ___ (2) Small trees (under 20′ high)
- ___ (3) High shrubs (over 8′ high)
- ___ (4) Moderate shrubs (4′ to 8′ high)
- ___ (5) Low shrubs (under 4′ high)
- ___ (6) Ground covers (spreading plants under 24″ high)

___ *d.* Select material based on growing season, including:
- ___ (1) Evergreen versus deciduous
- ___ (2) Annuals (put in seasonally, not returning) versus perennials (die in winter but return in spring)

___ *e.* Selection based on aesthetics:
  ___ (1) Shape (see item 1-*h*, above) and texture
  ___ (2) Color, often dependent on blooming season

Rule of Thumb: Costs of overall landscaping = $2 to $5/SF of landscape area.

Costs shown below: 50%M and 50%L, variation of +/–25%, depending on soil and growing season. For *commercial jobs, add 20%* due to warranties and maintenance.

Trees	**15 gal $100/ea.**	**Shrubs 1 gal $9/ea.**
	24″ box (1″c) $250/ea.	**5 gal $25/ea.**
	specimens $400 to $2500/ea.	**specimens $60/ea.+**

Vines	**1 gal**	**$8.50/ea.**	**Ground covers**	
	5 gal	**$25/ea.**	**plants 1 gal**	**$9/ea.**
			lawn sod (incl. topsoil)	**$.50 to $.75/SF**
			lawn seed	**$.25/SF**
			hydroseeding (seed, mulch, binder, and fertilizer)	**$0.06/SF**

Other

Brick or concrete border	**$7.50/LF to $12.50**
Rock	**$2.50 to $6.50/SY**
Preemergent	**$.08/SF**
Pots, 14″ ceramic with saucer	**$100/ea.**

___ **3. Irrigation**

___ *a.* Can be in the following forms:

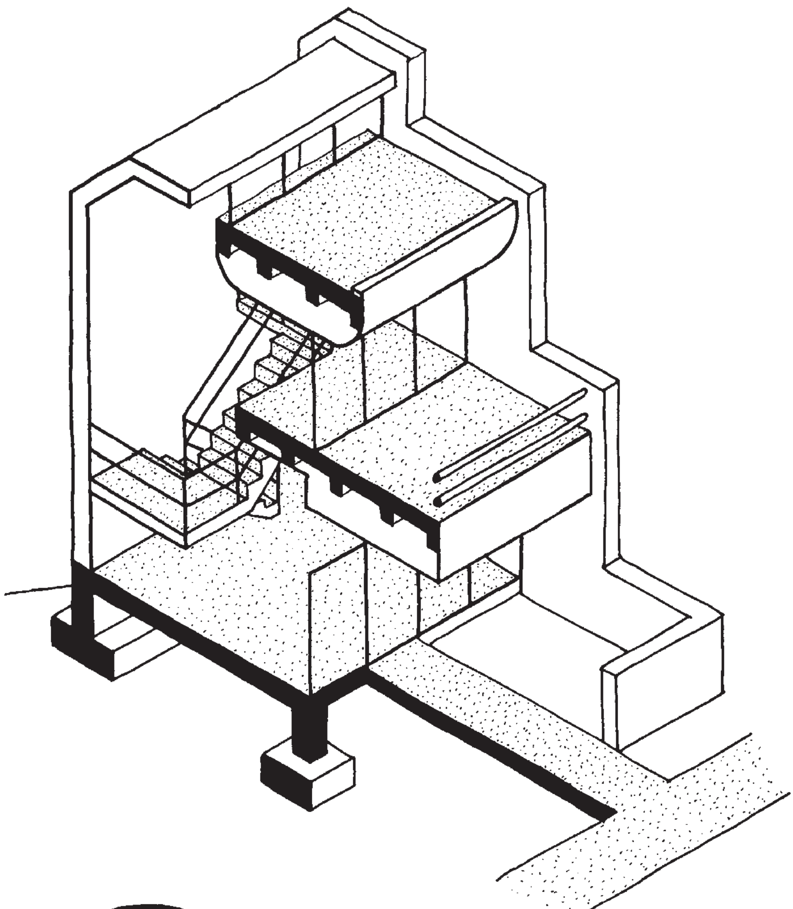
Type	Material	**Costs**
Bubbler	Plants and trees	**$.50/SF**
Spray	Lawn	**$.30–$.50/SF**
Drip	Plants and trees	**$.50/SF**

___ *b.* System should "tee" off water line before entering building. The tee size usually ranges between ¾″ and 2″.

___ *c.* Controls usually require a 110V outlet.

___ *d.* Backflow prevention unit usually required by code.

NOTES



3 CONCRETE

NOTES

___ A. CONCRETE MATERIALS

(A) (5) (26) (50) (58) (60) (61)

___ 1. General Cast-in-Place Costs

  ___ ***a.*** **Substructure: $200 to $500/CY (40%M and 60%L)**

  ___ ***b.*** **Superstructure: $600 to $1300/CY (30%M and 70%L)**

___ 2. Concrete: Consists of (using the general 1-2-3 mix, 1 part cement, 2 parts sand, and 3 parts rock, plus water):

  ___ *a.* Portland cement

    ___ (1) Type I: Normal for general construction.

    ___ (2) Type II: Modified for a lower heat of hydration, for large structures or warm weather.

    ___ (3) Type III: Modified for high, early strength, where forms must be removed as soon as possible, such as high-rise construction or cold weather.

    ___ (4) Type IV: Modified for low heat for very large structures.

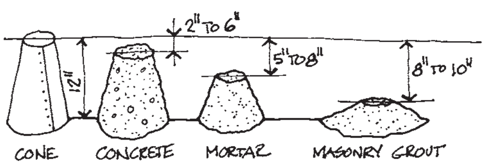
    ___ (5) Type V: Modified for sulfate resistance.

    ___ (6) Types IA, IIA, or IIIA: Air-entrained to resist frost.

  ___ *b.* Fine aggregate (sand): ¼″ or smaller.

  ___ *c.* Course aggregate (rock and gravel): ¼″ to 2″.

  ___ *d.* Clean water: Just enough to permit ready working of mix into forms. Mix should not slide or run off a shovel. Major factor effecting strength and durability is the *water-cement ratio,* expressed as gallons of water per sack of cement (usually ranging from 5 to 8). Slump is a measure of this:



___ 3. Structural Characteristics (Primer)

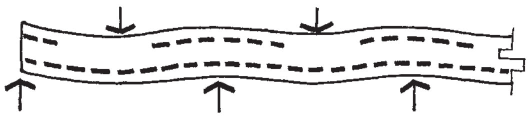
  ___ *a.* Strength

AVERAGE PHYSICAL PROPERTIES

MATERIAL	ELASTIC LIMIT (PSI)		ULTIMATE STRENGTH (PSI)			ALLOWABLE WORKING UNIT STRESS (PSI)				MODULE OF ELAST. (PSI)	WEIGHT (LB./C.F.)
	TENSION	COMPRESS.	TENSION	COMPRESS.	SHEAR	TENSION	COMPRESS.	SHEAR	EXTR. FIBER BEND		
CONCRETE				2500			1125	75		3000M	150

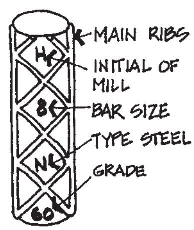
___ *b.* Bending

___ (1) Concrete is strong in compression but has little dependable tensile strength. Steel is strong in tension. When they are combined in a reinforced concrete bending member, such as a beam or slab, the concrete resists compression and the steel resists the tension. Thus, the reinforcing must be located at the tension face of the member.



Reinforcing splices in continuous-top reinforcing are usually located at midspan. Splices at bottom reinforcing are usually located over supports.

___ (2) Reinforcing: Steel bars start at #2s, which are ¼″ dia. Sizes go up to #11s, with each size an added ⅛″. All bars are deformed except #2s. A common problem is trying to cram too many bars into too small a section.

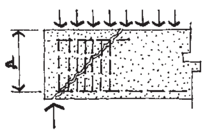


REINFORCING BARS: GRADES & SIZES

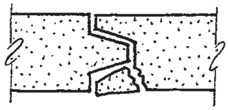
	ENGLISH		METRIC	
GRADES:	40 60 75		300 420 520	
SIZES:	SIZE	DIAMETER (IN)	SIZE	DIAMETER (MM)
	#3	0.375	#10	9.5
	#4	0.500	#13	12.7
	#5	0.625	#16	15.9
	#6	0.750	#19	19.1
	#7	0.875	#22	22.2
	#8	1.000	#25	25.4
	#9	1.128	#29	28.7
	#10	1.270	#32	32.3
	#11	1.410	#36	35.8
	#14	1.693	#43	43.0
	#18	2.257	#57	57.3

___ (3) Shear

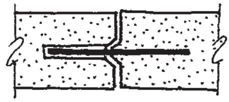
___ (*a*) When concrete fails in shear it is generally due to a tension failure along a diagonal line. Vertical steel "stirrups" or diagonal bars are often used to tie the top and bottom parts together across the potential crack and prevent failure. This steel must be placed accurately in the field.



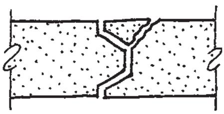
___ (*b*) The weakness of concrete in diagonal tension leads to problems with keys and construction joints.



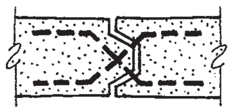
SPALLED KEY



BETTER



SPALLED KEY



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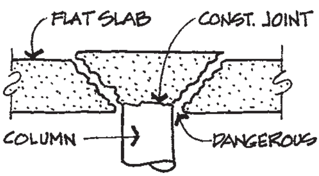
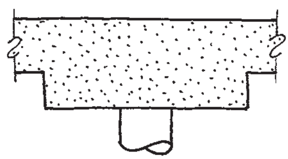


CONSTRUCTION JOINT IN COLUMN POURED TOO HIGH



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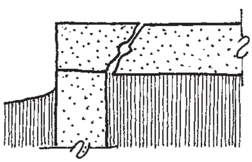
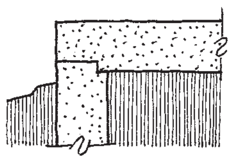
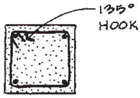
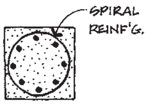
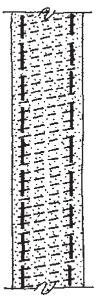




__ (4) Bond: Reinforcing lap splices need to be long enough to bond with the concrete. These splices close to the surface are weak, so reinforcing needs to be centered or kept clear of surfaces. In general, bars should not be lap-spliced at points of maximum stress.







___ (5) Columns

___ (*a*) In columns, both the concrete and the steel can work in compression.

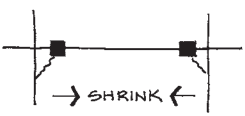
___ (*b*) Bars need steel ties to keep them from buckling outward. Also, closely spaced ties help confine the concrete against breaking apart.

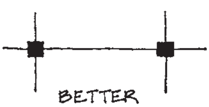
___ (*c*) 90° hooks are often used, but should *not* be used in seismic areas. The best anchor for the end of a tie is a 135° hook around the rebar and back into the concrete.

___ (*d*) The ultimate in tying bars against outward buckling and confining concrete against breaking apart is the spirally reinforced column.

___ (*e*) Reinforcing is often lap-spliced at floor levels.

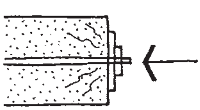
___ (6) Concrete shrinks: Details must allow for this. Try to avoid locking fresh concrete between two immovable objects. Pouring sequences should consider this problem.





___ (7) Prestressed Concrete:

___ (*a*) Differs from ordinary, reinforced concrete in that prestressing steel is under a very high tension, compressing the concrete together, before any load is placed on the member. This strengthens the concrete in shear as well as bending. This requires very high-strength steel which is impractical in ordinary reinforced concrete but results in large steel savings.

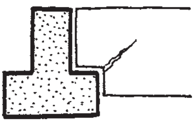


___ (*b*) *Posttensioning* involves tightening the rods or cables *after* the concrete is poured and cured. This concentrates a large stress at each end of the cables and requires special care (bearing plates, special hardware, reinforcing, etc.) to prevent failure at these points. If an end connection fails in unbonded posttensioning, there's no reinforcing strength left!

___ (*c*) *Pretensioning* has none of these "all the eggs in one basket" problems. Pretensioning lends itself to precast, plant-produced members, while posttensioning lends itself to work at the job site.

___ (*d*) Problems

___ 1. Continuing shrinkage is the most common problem with prestressed concrete. All details must consider long-term shrinkage.



___ 2. Notches in precast tees at bearing may cause problems. Use quality bearing pads.

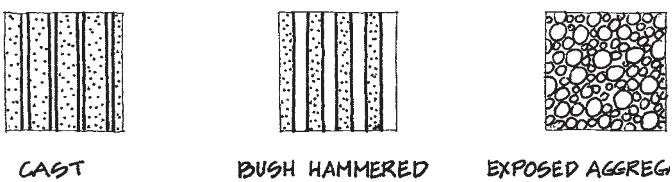
___ **4. Testing:** Typical design compressive strengths are f′c = 2500 to 3000 psi. To be sure of actual constructed strengths, compressive cylinder tests are made:

7-Day Break	28-Day Break
60 to 70% of final strength	Final strength

The UBC requires average of three tests to meet or exceed f′c. No test must fall below f′c by 500 or more psi.

___ **5. Finishes:** Different wall finishes can be achieved by:

Type	**Cost**
___ *a*. Cast shapes and textures	**$3.30 to $7.00/SF**
___ *b*. Abrasive treatment (bush hammering, etc.)	**$1.50 to $6.00/SF**
___ *c*. Chemical retardation (exposed aggregate, etc.)	**$0.90/SF**



NOTES

NOTES

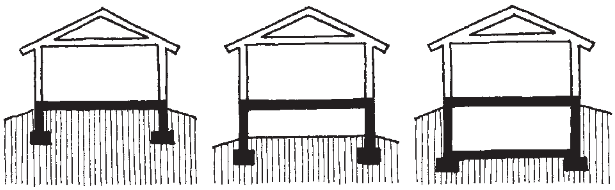
___ B. FOUNDATIONS

___ 1. **Functions**

- ___ *a.* Transfers building loads to ground
- ___ *b.* Anchors the building against wind and seismic loads
- ___ *c.* Isolates the building from frost heaving
- ___ *d.* Isolates building from expansive soils
- ___ *e.* Holds building above or from ground moisture
- ___ *f.* Retards heat flow to or from conditioned space
- ___ *g.* Provides storage space (basements)
- ___ *h.* Provides living space (basements)
- ___ *i.* Houses mechanical systems (basements)

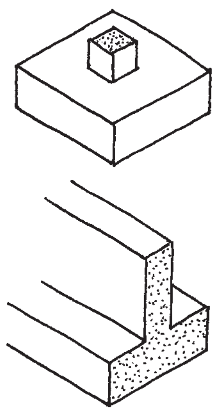
___ 2. **Types**

___ *a.* Slab-on-grade ___ *b.* Crawl space ___ *c.* Basement

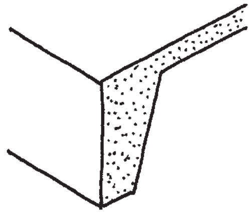


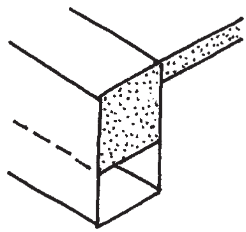
___ 3. **Types**

___ *a.* *Spread Footings:* Used for most buildings where the loads are light and/or there are strong, shallow soils. At columns, they are a single "spot" square directly bearing on the soils. Bearing walls have an elongation of the above. These are almost always of reinforced concrete.

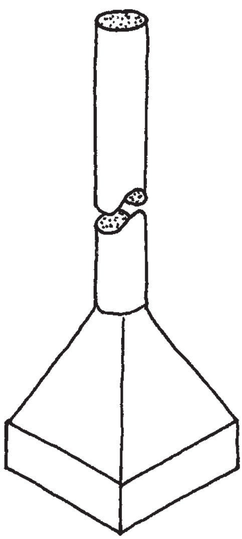


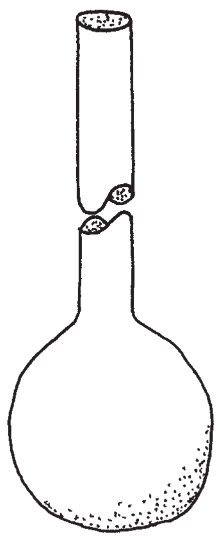
___ b. *Grade Beams:* These are used where upper soils are weak. They take wall loads and transfer them over to column foundations as if the beam were in the air. They are of reinforced concrete. Where soils are expansive, forms are sometimes hollow at the bottom to allow for soil heave without lifting the beam. This system is usually used with drilled piers at the columns.



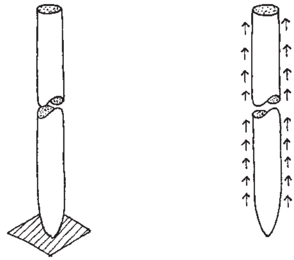


___ c. *Drilled Piers or Caissons:* These are used for heavy loads and/or where the soil is weak down to a stronger depth. These are almost always of reinforced concrete.

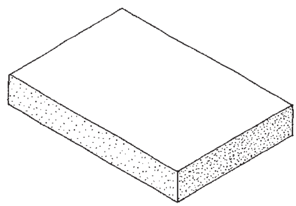




___ *d.* *Piles:* These are used for heavy loads and/or where deep soils are weak. End bearing piles are driven down to a deep bearing stratum. Friction piles are used where there is no reasonable bearing stratum and they are driven until a certain amount of resistance (from skin friction against the soil) is obtained to counteract the column load. Piles can be timber, reinforced concrete, or steel (with concrete fill).



___ *e.* *Rafts or Mats:* Reinforced concrete rafts or mats can be used for small, light-load buildings on very weak and expansive clays. These are often post-tensioned concrete. They can also be used at the bottom of subbasements of very large buildings where there are deep mushy soils. Either way, they allow the building to "float" on or in the soil, like a raft or ship.



___ **4. Depths** (spread footings) should be at or below frost line (see App. B, item C):

___ *a.* No Freeze 1′–6″
___ *b.* +20ºF 2′–6″
___ *c.* +10ºF 3′–0″
___ *d.* 0ºF 3′–6″
___ *e.* –10ºF 4′–0″
___ *f.* –20ºF 4′–6″

___ **5. Differential Settlement:** ¼″ to ½″

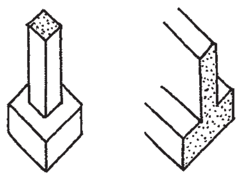
NOTES

___ C. CONCRETE MEMBERS (SIZES AND COSTS) (A) (1) (13) (31)

See p.168 for span-to-depth ratios.

___ 1. *Concrete Substructure*

___ *a.* *Spread footings*



Spread footings located under walls and columns are appropriate for low-rise buildings (one to four stories) where soil conditions are firm enough to support the weight of the building on the area of the spread footings. When needed, footings at columns can be connected together with grade beams to provide more lateral stability in earthquakes. Spread footings are the most widely used type of footing, especially in mild climates, because they are the most economical. Depth of footing should be below topsoil and frost line, on compacted fill (or firm native soil) but should be above water table.

Concrete spread footings are normally 1′ thick, but at least as thick as the width of stem wall. Width is normally twice that of stem wall. Typical column footings are 4′ square for one-story buildings. Add 1′ for each story up to ten stories.

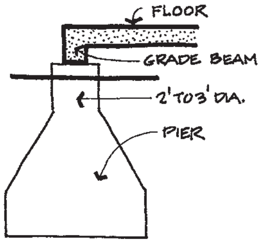
Approximate cost for a column-spread footing (M and L) with excavation, backfill, and reinforcing with 3000 psi concrete, 3′ × 3′, 12″: $60 to $150/ea.

Approximate cost for a wall-spread (strip) footing (stem wall not included), 12″ × 2′ W is $30/LF.

Approximate cost of concrete stem walls: 6″ × 4′ high is $49.50/LF.

___ *b.* *Other foundation systems:* As the weight of the building increases in relation to the bearing capacity (or depth of good bearing) soil, the footings need to expand in size or different systems need to be used.

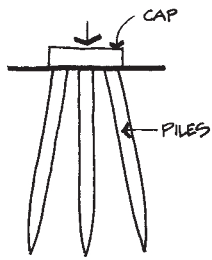
___ (1) For expansive soils with low to medium loads (or high loads with rock not too far down), *drilled piers* *(caissons) and grade* *beams* can be used. The pier may be straight like a column or "belled" out to spread the load at the bearing level of soil. The grade beam is designed to resist expansion or compression of the soil as if it were in the air.



Approximate cost of a 28″ deep × 1′ wide, 8-KLF load *grade beam* spanning 15′ is $65/LF (M and L).

Approximate cost of a 2′ × 50′ concrete caisson (3000 psi concrete) is $2380/each (M and L).

___ (2) <u>*Piles:*</u> Piles are long columns that are driven into the ground. Piles transfer the loads to a lower, stronger stratum or can transfer the load by friction along the length of the pile (skin friction). Piles are usually grouped together under a footing (pile cap) of reinforced concrete. Piles should be at least 2.5′ apart.



Approximate cost of reinforced concrete (3000 psi) *PILE CAP* for two piles with a dimension of 6.5′ × 3.5′ by 1′–8′ deep for 45K load is $460/ea. (M & L).

Different types of piles, their loads, and approximate costs (M and L):

___ CIP concrete, end-bearing, 50k, with 12″ to 14″ steel shell, 25′ long, $870/ea.

___ Precast concrete, end-bearing, 50k, 10″ sq., 50′ long, $655/ea.

___ Steel pipe, end-bearing, 50k, 12″ dia., 50′ long, $2095/ea.

__ Steel H Piles, end-bearing, 100k, 50′ long, $1540/ea.
__ Steel-step tapered, end-bearing, 50k, 50′ long, $880/ea.
__ Treated wood pile, 3 ea. in cluster, end-bearing, 50k, 25′ long, $1945/ea. group.
__ Pressure-injected footings, end-bearing, 50k, 50′ long, $1860/ea.

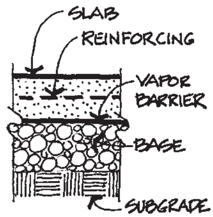
__ (3) <u>*Mat foundations:*</u> For poor soil conditions and tall buildings (10 to 20 stories) with their overturning moments, a mat foundation is required. A mat foundation is a large mass of concrete laid under the entire building. Mat foundations range from 4′ to 8′ thick.

Approximate cost: **See p. 273.**

__ 2. <u>Concrete Superstructure</u>

__ *a.* <u>*Concrete slabs*</u>

__ (1) <u>*Slab-on-grade:*</u> General rule on paving slabs is that depth should be ½ to ⅓ of average annual frost penetration.



Typical thickness:

Floors	4″
Garage Floors	5″
Terraces	5″
Driveways	6″ to 8″
Sidewalks	4″ to 6″

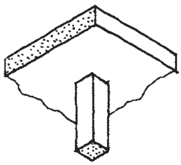
Approximate cost of 4″ reinforced slab is $3.00 to $3.60/SF.
For rock base see p. 265.
For vapor barrier see p. 365.
For compacted subgrade see p. 238.
For termite treatment see p. 256.

__ (2) <u>*Reinforced concrete slabs in the air:*</u> For general span-to-depth ratios, see p. 168.

__ (*a*) *One-way slab*

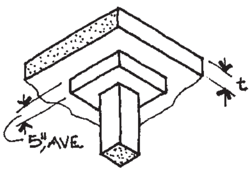
__ Usual spans: 6′ to 20′

__ Typical SDR:
20 for simple spans
28 for continuous spans



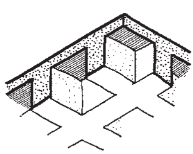
___ (*b*) *Two-way flat plate slabs*
- ___ Flat plate
  - ___ Usual spans of 20′ to 30′.
  - ___ Usual thickness: 6″ to 12″
  - ___ Usual maximum ratio of long to short side of bay: 1.33.
  - ___ Typical ratio of span to depth: 30.
  - ___ Another common rule is to allow 1″ thickness for each 3′ of span.

Approximate costs of $10.55/SF (15′ bays, 40 psf) to $12.95/SF (25′ bays, 125 psf). 25%M and 75%L.



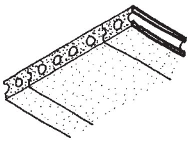
___ (*c*) *Flat slab with drop panels*
- ___ Usual spans: 25′ to 36′
- ___ Usual thickness: 6″ to 12″
- ___ Usual maximum ratio of long to short side of bay: 1.33
- ___ Side of drop panels: +/– ⅓ span
- ___ Typical ratios of span to depth 24 to 30

Approximate costs of $11.00/SF (15′ bays, 40 psf) to $14/SF (35′ bays, 125 psf). 35%M & 65%L.



___ (*d*) *Two-way waffle slabs*
- ___ Longer 2-way spans and heavier load capacity.
- ___ Usual spans: 25′ to 40′.
- ___ Standard pan sizes: 20″ to 30″ square with other sizes available. Standard pan depths 8″ to 20″ in 2″ increments.
- ___ Usual maximum ratio of long to short side of bay is 1.33.
- ___ Typical ratio of span to depth: 25–30.

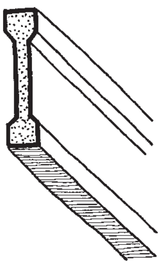
Approximate cost of $15.50/SF (20′ bays, 40 psf) to $19.55/SF (40′ bays, 125 psf). 40%M and 60%L.



__ (*e*) *Precast, prestressed concrete planks*
- __ Thickness of 6″ to 12″ in 2″ increments.
- __ Spans of 8′ to 36′.
- __ Span-to-depth ratio of approximately 30 to 40.
- __ 1½″ to 2″ conc. topping often used for floors.

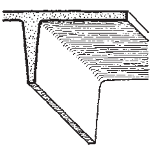
Approximate cost of \$8.65/SF for 6″ thick (85% M and 15% L) with 35% variation higher or lower. Add \$0.25 for each added 2″. Add \$2.40/SF for topping.

__ *b.* *Concrete beams and joists*



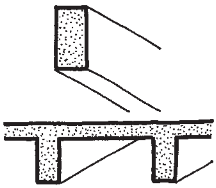
__ (1) Precast concrete I beams (prestressed)
- __ (*a*) Typical beam thickness of 12″ to 16″.
- __ (*b*) Spans range from 20′ to 100′.
- __ (*c*) Approximate ratios of span to depth of 15 to 25.

Approximate cost of \$65.70/LF for 15′ span and \$288/LF for 55′ span (90% M and 10% L) with variations of 20% higher or lower.



__ (2) Prestressed T beams (single and double tees)
- __ (*a*) Typical flange widths of ½ to ⅓ the effective depth (8′ to 10′).
- __ (*b*) Usual spans of 20′ to 120′.
- __ (*c*) Approximate ratio of span-to-depth ratio: 24 to 32.
- __ (*d*) Usually has 1½″ to 2″ concrete topping for floors.

Approximate cost of double tee 2′ deep × 8′ wide with 35′ to 80′ span is \$6.30 to \$8.00/SF (90% M and 10% L) with variation of 10% higher or lower.



___ (3) Concrete beams and joists.

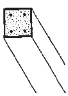
SDR:

simply supported	=	16
one end continuous	=	18.5
both ends continuous	=	21
cantilever	=	8

Width should be ½ to ¼ the total depth.

Approximate cost of P.C. beam, 20′ span is $70.00/LF (70% M and 30% L). Cost can go 3 times higher with 45′ spans and heavy loads.

___ *c.* *Concrete columns*



- ___ (1) Round columns usually 12″ minimum.
- ___ (2) Rectangular: 12 in sq. minimum.
- ___ (3) Usual minimum rectangular tied columns 10″ × 12″.
- ___ (4) Square or round spiral columns: 14″; add 2″ for each story.
- ___ (5) Most columns are "short": maximum height *10* times least cross-section dimension. Typical column height is 12.5′ for multistory building.
- ___ (6) Maximum unbraced height for "engineered" long columns: *20* times least cross-section dimension.

Approximate cost of $55 to $100/LF (30% M and 70% L). Use lower number for single-story, min. loads, and min. reinforcing.

___ *d.* *Concrete walls*

___ (1) Wall Thickness

- ___ (*a*) Multistory: 8″ top 15′, add 1″ for each successive 25′ down.
- ___ (*b*) Basements: 8″ minimum.
- ___ (*c*) Nonbearing: Minimum thickness 6″. Maximum ratio of unsupported height: 25 to 30.
- ___ (*d*) Precast wall panels: Minimum thickness: 5½″. Maximum ratio of unbraced length to thickness: 45.

Approximate cost of $18.40/SF for 6″, reinf. wall (65% M and 35% L) with variation of 35% higher for special finishes. Add $1.00 per each added inch thickness.

___ (2) “Tilt-up” (on site precast)

___ (*a*) Height-to-thickness ratio: 40 to 50.

___ (*b*) Typical heights: 22′ to 35′.

___ (c) Typical thickness: 5½″ to 8″.

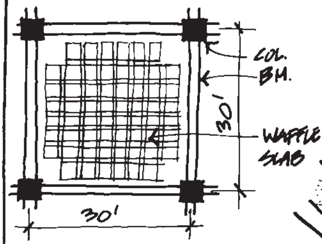
___ (*d*) Typical use: Favorable climate, 20,000 SF size building or larger. Time and material savings can cut cost ≈ ⅓, depending on height and area, compared to masonry.

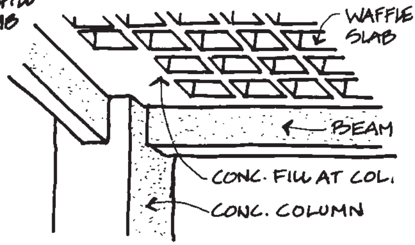
Costs: $8.40 to $14.40/SF (45% M and 55% L), costs can double for special finishes. Add ≈ 30% for concrete columns.

EXAMPLE:

PROBLEM:

SKETCH UP A ROUGH DESIGN & ESTIMATE OF COSTS FOR A 30' × 30' BAY FLOOR SYSM. USING WAFFLE SLAB, CONC. BEAMS AT THE PERIMETER, & CONCRETE COLUMNS.





SOLUTION:

A. SIZE

1. WAFFLE SLAB (P. 288)
   SDR: 25 TO 30 FOR 30' SPAN = 1.2' to 1.0', SAY 14" DEEP

2. BEAM (P. 290)
   SDR: 18 FOR 30' SPAN = 1.67' DEEP
   WIDTH: 1/2 TO 3/4 DEPTH = .83' TO 1.25'
   SAY 12" W × 1'-8" D

3. COLUMN (P. 290)
   WIDTH: HEIGHT ÷ 10 = 1.8'   SAY 1'-10" SQ.

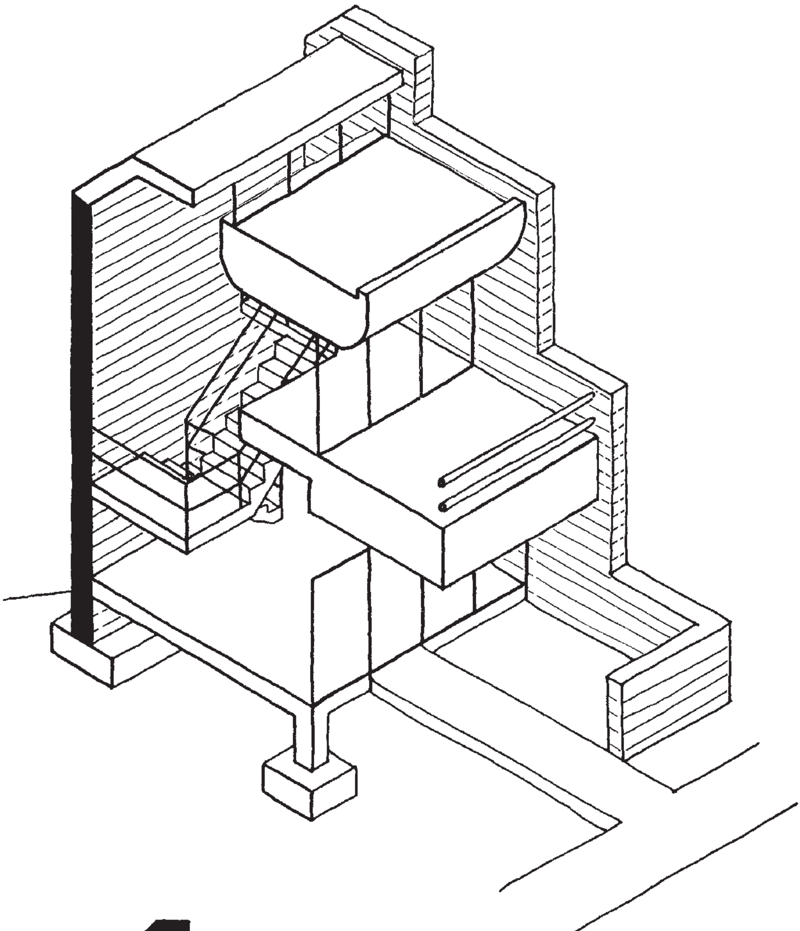
B. COST

1. WAFFLE SLAB: (1/2 BETW'N \$15.50 & \$19.55) ≈ \$19.50/SF
2. BEAM: SAY \$65/LF × (30' × 4) ÷ (30'²) ≈ \$8.65/SF
3. COLUMNS: SAY \$65/LF × (18' × 4) ÷ (30'²) ≈ \$5.20/SF

\$33.35/SF

NOTES

NOTES



4 MASONRY

NOTES

___ A. MASONRY MATERIALS

___ 1. **General:** Masonry consists of:

___ *a.* Brick

___ (1) Fired

___ (2) Unfired ("adobe")

___ *b.* Concrete block (concrete masonry units or CMU)

___ *c.* Stone

___ *d.* Glass block

___ 2. **Structural Characteristics**

___ *a.* Strength

AVERAGE PHYSICAL PROPERTIES

MATERIAL	ELASTIC LIMIT (PSI)		ULTIMATE STRENGTH (PSI)			ALLOWABLE WORKING UNIT STRESS (PSI)				MODULE OF ELAST. (PSI)	WEIGHT (LB./C.F.)
	TENSION	COMPRESS.	TENSION	COMPRESS.	SHEAR	TENSION	COMPRESS.	SHEAR	EXTR. FIBER BEND.		
ADOBE				300-500			30	8			110
BRICK				2800		800	100-250	50	2500_M		120
C.M.U.				1500		500	300	38	1900_M		145
STONE				2500			200-400	8			145

___ *b.* Load centers on masonry must lie within the center ⅓ of its width.

___ *c.* Reinforcing: Like concrete, masonry is strong in compression, but weak in tension. Therefore, steel reinforcement must usually be added to walls to simulate columns and beams.

___ (1) Like *columns:* Vertical bars @ 2′ to 4′ oc.

___ (2) Like *beams:* "Bond Beams" @ 4′ to 8′ oc.

___ (3) Also, added *horizontal wire reinforcement* (ladder or truss type) @ 16″ oc. vertically, to help resist lateral forces and cracking.

___ 3. **Bonds**

___ *a.* Structural (method of laying units together):

___ (1) Overlapping units.

___ (2) *Metal ties* (should be galvanized with zinc coating of 2 oz/SF, or stainless steel). Wire ties usually @ every 3 SF, or . . .

Metal anchors, usually at 16″ oc, vertical and 24″ oc, horizontal.

___ (3) Grout and mortar:

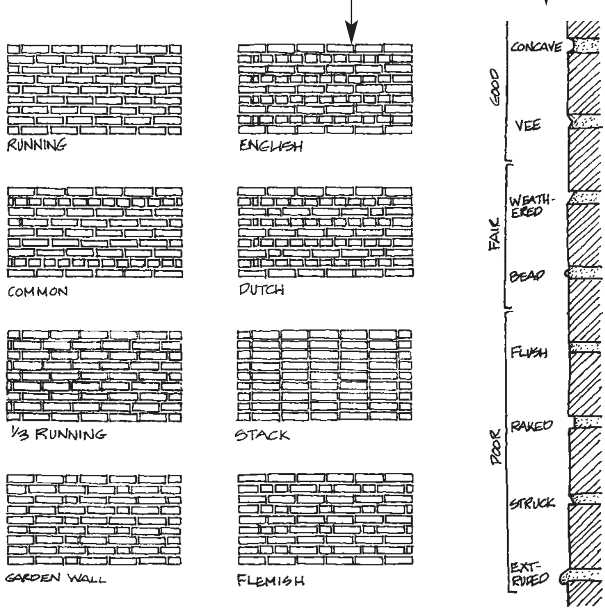
___ (*a*) *Grout:* A "soup" of sand, cement, water, and often pea gravel that encases reinforcing bars. Usually 2000 psi comp. strength. Always poured in cavities with high slump. Except for adobe brick, the mortar is considerably weaker than the bricks or blocks. The mortar is more elastic amd its joints shrink more. See p. 273.

___ (*b*) *Mortar:* Stiffer mix of sand, cement, lime, and water, to bond units together by trowel work. Types:

- ___ N General purpose, medium strength, for above grade.
- ___ M High strength, for high compression, above-grade.
- ___ S High strength, for compression and tension.
- ___ O High lime, low strength, easily workable for veneers not subject to freezing.
- ___ K Low strength, for interiors.

___ (4) Bond joints

___ (5) Bond patterns



___ 4. **Control and Expansion Joints**

___ *a.* Width

___ (1) Thermal movement. See p. 382. = ___
Plus,

___ (2) Movement due to moisture: = ___

___ (*a*) Bricks expand; should be laid wet.

___ (*b*) Concrete blocks shrink like concrete; should be laid dry.
Plus,

___ (3) Construction tolerance. = ___

Total width = ___

___ *b.* Locations

___ (1) Corners

___ (2) Length of walls: 20′ to 25′ oc.

___ (3) Offsets, returns, and intersections.

___ (4) Openings:

___ (*a*) One side of opening, less than 6′ wide.

___ (*b*) Two sides of opening, greater than 6′ wide.

___ (5) Against other materials.

___ 5. **Embedments:** The best metal today for embedment in concrete or masonry is stainless steel, followed by bronze, then brass; however, most structural embedments remain galvanized steel.

___ 6. **Coatings:** Must be (see p. 424)

___ (1) "Bridgeable" (seal cracks)

___ (2) Breathable (do not trap vapor)

___ 7. **Brick**

___ *a.* Types

___ (1) Common (building)

___ (2) Face

___ (*a*) FBX Select

___ (*b*) FBS Standard

___ (*c*) FBA Architectural

___ (3) Clinker

___ (4) Glazed

___ (5) Fire

___ (6) Cored

___ (7) Sand-lime (white, yellow)

___ (8) Pavers

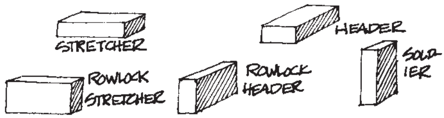
___ *b.* Weatherability

___ (1) NW Negligible weathering; for indoor or sheltered locations and warm climates.

___ (2) MW Moderate weather locations.

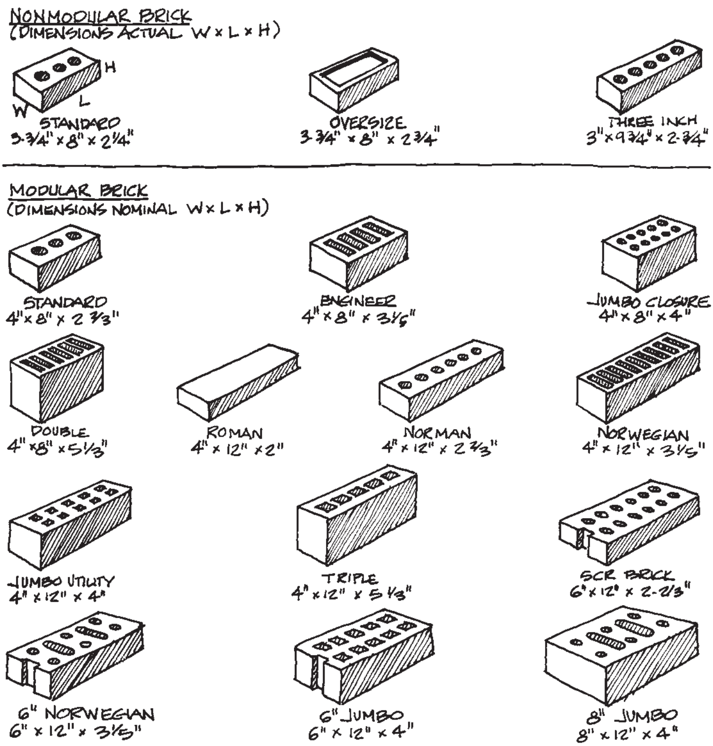
__ (3) SW Severe weather locations and/or earth contact as well as cold, wet climates.

__ *c.* Positions



__ *d.* Sizes:
(modular brick based on 4″ module with ⅜″ jt.)

__ *e.* Coursing: See p. 301.



__ **8. Concrete Block (CMU)**

__ *a.* Types: Plain (gray), colored, pavers, special shapes (such as "slump"), and special surfaces (split faced, scored, etc.).

__ *b.* Size: See p. 302.

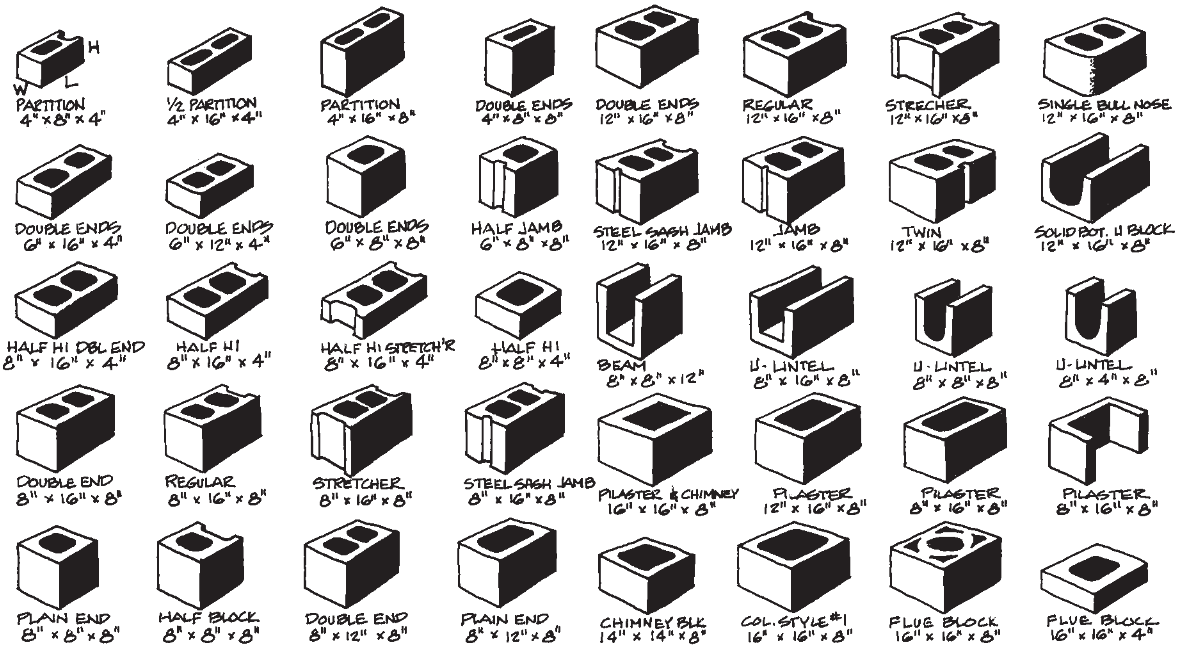
__ *c.* Coursing: See p. 303.

BRICK COURSING

COURSE	NONMODULAR						MODULAR				
	2 1/4" THICK BRICKS		2 5/8" THICK BRICKS		2 3/4" THICK BRICKS		NOMINAL THICKNESS (HEIGHT) OF BRICK				
	3/8" JOINT	1/2" JOINTS	3/8" JOINT	1/2" JOINT	3/8" JOINT	1/2" JOINT	2"	2 2/3"	3 1/5"	4"	5 1/3"
1	2 5/8"	2 3/4"	3"	3 1/8"	3 1/8"	3 1/4"	2"	2 11/16"	3 3/16"	4"	5 5/16"
2	5 1/4"	5 1/2"	6"	6 1/4"	6 1/4"	6 1/2"	4"	5 5/16"	6 3/8"	8"	10 11/16"
3	7 7/8"	8 1/4"	9"	9 3/8"	9 3/8"	9 3/4"	6"	8"	9 5/8"	1'-0"	1'-4"
4	10 1/2"	11"	1'-0"	1'-0 1/2"	1'-0 1/2"	1'-1"	8"	10 11/16"	1'-0 13/16"	1'-4"	1'-9 5/16"
5	1'-1 1/8"	1'-1 3/4"	1'-3"	1'-3 5/8"	1'-3 5/8"	1'-4 1/4"	10"	1'-1 5/16"	1'-4"	1'-8"	2'-2 11/16"
6	1'-3 3/4"	1'-4 1/2"	1'-6"	1'-6 3/4"	1'-6 3/4"	1'-7 1/2"	1'-0"	1'-4"	1'-7 3/16"	2'-0"	2'-8"
7	1'-6 3/8"	1'-7 1/4"	1'-9"	1'-9 7/8"	1'-9 7/8"	1'-10 3/4"	1'-2"	1'-6 11/16"	1'-10 3/8"	2'-4"	3'-1 5/16"
8	1'-9"	1'-10"	2'-0"	2'-1"	2'-1"	2'-2"	1'-4"	1'-9 5/16"	2'-1 5/8"	2'-8"	3'-6 11/16"
9	1'-11 5/8"	2'-0 3/4"	2'-3"	2'-4 1/8"	2'-4 1/8"	2'-5 1/4"	1'-6"	2'-0"	2'-4 13/16"	3'-0"	4'-0"
10	2'-2 1/4"	2'-3 1/2"	2'-6"	2'-7 1/4"	2'-7 1/4"	2'-8 1/2"	1'-8"	2'-2 11/16"	2'-8"	3'-4"	4'-5 5/16"
11	2'-4 7/8"	2'-6 1/4"	2'-9"	2'-10 3/8"	2'-10 3/8"	2'-11 3/4"	1'-10"	2'-5 5/16"	2'-11 3/16"	3'-8"	4'-10 11/16"
12	2'-7 1/2"	2'-9"	3'-0"	3'-1 1/2"	3'-1 1/2"	3'-3"	2'-0"	2'-8"	3'-2 3/8"	4'-0"	5'-4"
13	2'-10 1/8"	2'-11 3/4"	3'-3"	3'-4 5/8"	3'-4 5/8"	3'-6 1/4"	2'-2"	2'-10 11/16"	3'-5 5/8"	4'-4"	5'-9 5/16"
14	3'-0 3/4"	3'-2 1/2"	3'-6"	3'-7 3/4"	3'-7 3/4"	3'-9 1/2"	2'-4"	3'-1 5/16"	3'-8 13/16"	4'-8"	6'-2 11/16"
15	3'-3 3/8"	3'-5 1/4"	3'-9"	3'-10 7/8"	3'-10 7/8"	4'-0 3/4"	2'-6"	3'-4"	4'-0"	5'-0"	6'-8"
16	3'-6"	3'-8"	4'-0"	4'-2"	4'-2"	4'-4"	2'-8"	3'-6 11/16"	4'-4 3/16"	5'-4"	7'-1 5/16"
17	3'-8 5/8"	3'-10 3/4"	4'-3"	4'-5 1/8"	4'-5 1/8"	4'-7 1/4"	2'-10"	3'-9 5/16"	4'-6 3/8"	5'-8"	7'-6 11/16"
18	3'-11 1/4"	4'-1 1/2"	4'-6"	4'-8 1/4"	4'-8 1/4"	4'-10 1/2"	3'-0"	4'-0"	4'-9 5/8"	6'-0"	8'-0"
19	4'-1 7/8"	4'-4 1/4"	4'-9"	4'-11 3/8"	4'-11 3/8"	5'-1 3/4"	3'-2"	4'-2 11/16"	5'-0 13/16"	6'-4"	8'-5 5/16"
20	4'-4 1/2"	4'-7"	5'-0"	5'-2 1/2"	5'-2 1/2"	5'-5"	3'-4"	4'-5 5/16"	5'-4"	6'-8"	8'-10 11/16"
21	4'-7 1/8"	4'-9 3/4"	5'-3"	5'-5 5/8"	5'-5 5/8"	5'-8 1/4"	3'-6"	4'-8"	5'-7 3/16"	7'-0"	9'-4"
22	4'-9 3/4"	5'-0 1/2"	5'-6"	5'-8 3/4"	5'-8 3/4"	5'-11 1/2"	3'-8"	4'-10 11/16"	5'-10 3/8"	7'-4"	9'-9 5/16"
23	5'-0 3/8"	5'-3 1/4"	5'-9"	5'-11 7/8"	5'-11 7/8"	6'-2 3/4"	3'-10"	5'-1 5/16"	6'-1 5/8"	7'-8"	10'-2 11/16"
24	5'-3"	5'-6"	6'-0"	6'-3"	6'-3"	6'-6"	4'-0"	5'-4"	6'-4 13/16"	8'-0"	10'-8"

CONCRETE BLOCK TYPES & SIZES

NOMINAL DIMENSIONS W × L × H (ACTUAL DIMENSIONS ARE 3/8" LESS)



CONCRETE BLOCK COURSING

CSC	4" HIGH BLK.	8" HIGH BLK.	CSC	4" HIGH BLK.	8" HIGH BLK.
1	4"	8"	38	12'-8"	25'-4"
2	8"	1'-4"	39	13'-0"	26'-0"
3	1'-0"	2'-0"	40	13'-4"	26'-8"
4	1'-4"	2'-8"	41	13'-8"	27'-4"
5	1'-8"	3'-4"	42	14'-0"	28'-0"
6	2'-0"	4'-0"	43	14'-4"	28'-8"
7	2'-4"	4'-8"	44	14'-8"	29'-4"
8	2'-8"	5'-4"	45	15'-0"	30'-0"
9	3'-0"	6'-0"	46	15'-4"	30'-8"
10	3'-4"	6'-8"	47	15'-8"	31'-4"
11	3'-8"	7'-4"	48	16'-0"	32'-0"
12	4'-0"	8'-0"	49	16'-4"	32'-8"
13	4'-4"	8'-8"	50	16'-8"	33'-4"
14	4'-8"	9'-4"	51	17'-0"	34'-0"
15	5'-0"	10'-0"	52	17'-4"	34'-8"
16	5'-4"	10'-8"	53	17'-8"	35'-4"
17	5'-8"	11'-4"	54	18'-0"	36'-0"
18	6'-0"	12'-0"	55	18'-4"	36'-8"
19	6'-4"	12'-8"	56	18'-8"	37'-4"
20	6'-8"	13'-4"	57	19'-0"	38'-0"
21	7'-0"	14'-0"	58	19'-4"	38'-8"
22	7'-4"	14'-8"	59	19'-8"	39'-4"
23	7'-8"	15'-4"	60	20'-0"	40'-0"
24	8'-0"	16'-0"	61	20'-4"	40'-8"
25	8'-4"	16'-8"	62	20'-8"	41'-4"
26	8'-8"	17'-4"	63	21'-0"	42'-0"
27	9'-0"	18'-0"	64	21'-4"	42'-8"
28	9'-4"	18'-8"	65	21'-8"	43'-4"
29	9'-8"	19'-4"	66	22'-0"	44'-0"
30	10'-0"	20'-0"	67	22'-4"	44'-8"
31	10'-4"	20'-8"	68	22'-8"	45'-4"
32	10'-8"	21'-4"	69	23'-0"	46'-0"
33	11'-0"	22'-0"	70	23'-4"	46'-8"
34	11'-4"	22'-8"	71	23'-8"	47'-4"
35	11'-8"	23'-4"	72	24'-0"	48'-0"
36	12'-0"	24'-0"	73	24'-4"	48'-8"
37	12'-4"	24'-8"	74	24'-8"	49'-4"

___ 9. **Stone**

___ *a.* Type unit

___ (1) *Ashlar:* Best for strength and stability; is square-cut on level beds. Joints of ½″ to ¾″.

___ (2) *Squared stone* (coursed rubble): Next-best for strength and stability; is fitted less carefully than ashlar, but more carefully than rubble.

___ (3) *Rubble:* Built with a minimum of dressing, with joints unevenly coursed, or in a completely irregular pattern. Stones are lapped for bond and many stones extend through wall (when full-width wall) to bond it transversely. If built carefully, with all interstices completely filled with good cement mortar, has ample durability for ordinary structures.

___ *b.* Typical materials

___ (1) Limestone

___ (2) Sandstone

___ (3) Quartzite

___ (4) Granite

___ *c.* Wall types

___ (1) Full width

___ (2) Solid veneer (metal ties to structural wall)

___ (3) Thin veneer (set against mortar bed against structural wall)

___ *d.* Pattern types (see p. 310)

NOTES

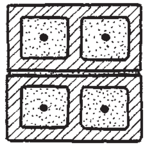
NOTES

___ B. MASONRY MEMBERS (SIZES AND COSTS) (A) (1) (13) (31)

See p. 168 for span-to-depth ratios.

___ 1. Concrete Block (CMU)

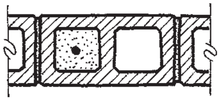
___ *a.* CMU columns
See p. 169 for general rule of thumb. Max. ht. to thickness ratio = *20.* Min. size = 12″ × 12″.



___ *b.* CMU walls

___ (1) Nominal min. thickness: 6″

___ (2) Ratio of unsupported length or ht. to thickness: *25 to 35*



Costs: CMU (Reg. wt., gray, running bond, typ. reinf'g. and grout)

4″ walls:	**$7.20/SF**	**(Typical 25 to 30%M and 75 to 70%L)**
6″ walls:	**$7.80/SF**	
8″ walls:	**$9.00/SF**	**(Variations for special block, such as glazed, decorative, screen, etc. + 15% to 150%)**
12″ walls:	**$11.10/SF**	

Deduct 30 to 40% for residential work.

___ 2. Brick Masonry

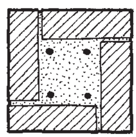
___ *a.* Columns

___ (1) See p. 169 for general rule of thumb.

___ (2) Usual min. dimension of 12″ (sometimes 8″).

___ (3) Maximum height = 20 × least dimensions.

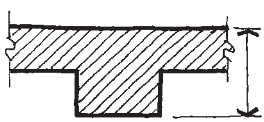
___ (4) If unreinforced = 10 × least dimensions.



Costs: 12″ × 12″, standard brick: $41.40/VLF (20%M and 80%L).

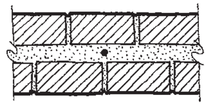
___ *b.* Pilasters

___ (1) Usually considered when wall is 20′ high or more.



___ (2) Typically needed under beams or heavy trusses.
___ (3) Depth of pilaster: 1/12 of wall height.

___ *c.* Brick walls



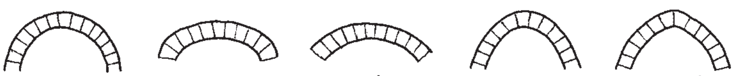
___ (1) Maximum ratio of unsupported length or height to thickness: 20.
___ (2) Reinforced bearing walls: Nominal minimum thickness: 6″.
___ (3) Unreinforced bearing wall:
1 story: 6″ min. thickness
2 stories: 12″ thick
+ 35′: 12″ upper 35′ and + 4″ added to each 35′ below
___ (4) Cavity walls: Typical nominal minimum dimensions of 10″ (including 2″ air space).

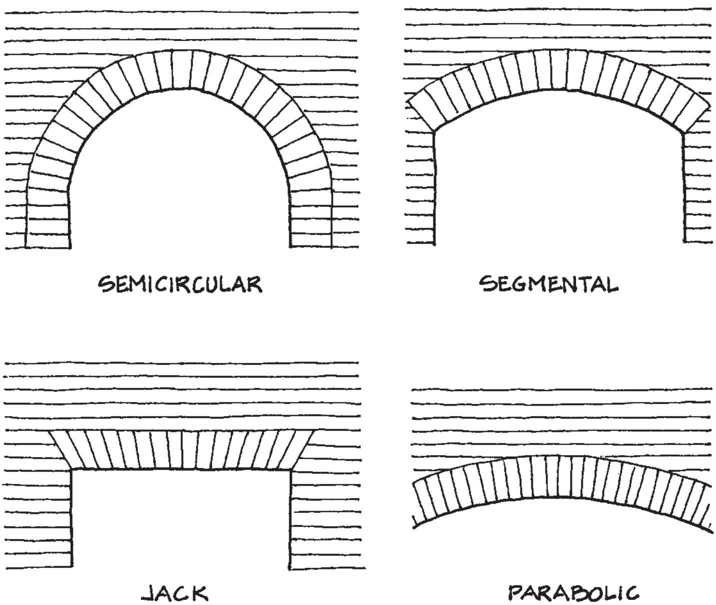
Costs: Standard brick, running bond w/reinforcing (25%M & 75%L) (Variations of +5%, –20%):

4″, single wythe, veneer:	**$13.20/SF**
8″, double wythe, cavity-filled:	**$27.60/SF**
12″, triple wythe, cavity-filled:	**$40.80/SF**

For other bonds, add 15% to 30%

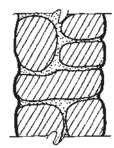
___ *d.* Brick arches
___ (1) Minor arches:
___ (*a*) Span: Less than 6′
___ (*b*) Configuration: All
___ (*c*) Load: Less than 1000 PLF
___ (*d*) Span-to-rise: *0.15 max.*
___ (2) Major arches:
___ (*a*) Span: Over 6′
___ (*b*) Configuration: Semicircular & parabolic
___ (*c*) Load: Over 1000 PLF
___ (*d*) Span-to-rise: greater than *0.15*





___ 3. Stone Masonry

___ *a.* Bearing walls



___ (1) Nominal minimum thickness = 16″.

___ (2) Maximum ratio of unsupported length or height to thickness = 14.

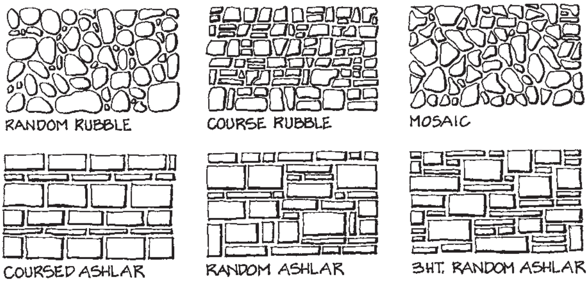
___ *b.* Nonbearing walls

___ (1) Nominal minimum thickness = 16″, veneer = 1½″ cut stone, 4″ rough.

___ (2) Maximum ratio of unsupported length or height to thickness = 18.

Costs: 4″ veneer (most common): $14.40 to $17.40/SF (40%M and 60%L) (Variation: + 50%)

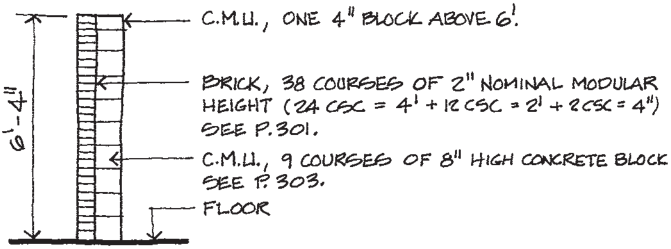
18″ rough stone wall (dry): $52.80/CF (40% and 60%L)



EXAMPLE:

PROBLEM: A WALL OF BRICK VENEER AND C.M.U. BACKUP IS TO BE 6'-4" HIGH. FIGURE THE COURSING FOR BOTH BRICK VENEER AND CONCRETE BLOCK.

SOLUTION:



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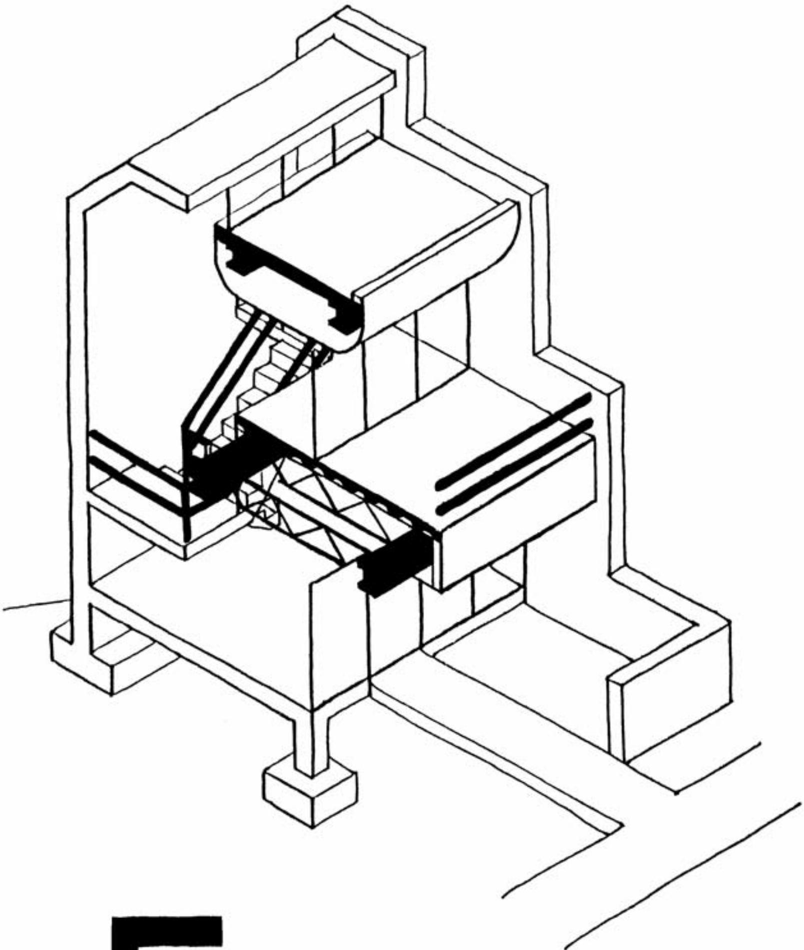


5 METALS

NOTES

___ A. METAL MATERIALS

(4) (16) (26) (42) (50) (60)

___ 1. General

___ *a.* Ferrous metals (contains iron)

___ (1) Iron: Soft, easily worked, oxidizes rapidly, susceptible to acid.

___ (2) Cast iron: Brittle, corrosion-resistant, high-compressive strength. Used for gratings, stairs, etc.

___ (3) Malleable iron: Same as above, but better workability.

___ (4) Wrought iron: Soft, corrosion- and fatigue-resistant, machinable. Used for railings, grilles, screws, and ornamental items.

___ (5) Steel: Iron with carbon. Strongest metal. Used for structural purposes. See p. 316.

___ (6) Stainless steel: An alloy for max. corrosion resistance. Used for flashing, handrails, hardware, connections, and equipment.

___ *b.* Nonferrous metals (not containing iron)

___ (1) Aluminum: Soft, ductile, high corrosion resistance, low strength.

___ (2) Lead: Dense, workable, toxic, corrosion-resistant. Improved with alloys for hardness and strength. Used as waterproofing, sound isolation, and radiation shielding.

___ (3) Zinc: Corrosion-resistant, brittle, low-strength. Used in "galvanizing" of other metals for corrosion resistance for roofing, flashing, hardware, connections, etc.

___ (4) Chromium and nickel: Used as alloy for corrosion-resistant bright "plating."

___ (5) Monel: High corrosion resistance. Used for fasteners and anchors.

___ (6) Copper: Resistant to corrosion, impact, and fatigue. Ductile. Used for wiring, roofing, flashing, and piping.

___ (7) Bronze: An alloy for "plating."

___ (8) Brass: Copper with zinc. Used for hardware, handrails, grilles, etc.

___ 2. Corrosion to Metals

___ *a.* Galvanic action, or corrosion, occurs between dissimilar metals or metals and other metals when sufficient moisture is present to carry an electric current. The farther apart two metals are on the following list, the greater the corrosion of the more susceptible one:

Anodic (+): Most susceptible to corrosion
Magnesium
Zinc
Aluminum
Cadmium
Iron/steel
Stainless steel (active)
Soft solders
Tin
Lead
Nickel
Brass
Bronzes
Nickel-copper alloys
Copper
Stainless steel (passive)
Silver solder
Cathodic (–): Least susceptible to corrosion

___ *b.* Metals deteriorate also when in contact with chemically active materials, particularly when water is present. Examples include aluminum in contact with concrete or mortar, and steel in contact with treated wood.

___ **3. Gauges:** See pp. 317 and 318.

___ **4. Structural Steel**

___ *a.* General: Steel is stronger and springier than any major structural material, and its fairly uniform molecularity makes every member nearly the same as every other. When extreme stresses deform steel past its elastic limit, it doesn't break. However, its strength lowers rapidly when exposed to fire. The most commonly used strength grade of steel is 50,000 psi yield strength (grade 50) with some 36,000 psi (A-36) still available. For heavily loaded members such as columns, girders, or trusses—where buckling, lateral stability, deflection, or vibration does not control member selection—higher-yield strength steels may be economically used. A 50,000 psi yield strength is most frequently used among high-strength, low-alloy steels.

METAL GAUGES

GAUGE NO.	GRAPHIC SIZES	U.S. STD. REVISED		GRAPHIC SIZES
		DECIMAL	FRACTION	
000		.3750"	3/8"	
00		.3437"	11/32"	
0		.3125"	5/16"	
1.		.2812"	9/32"	
2.		.2656"	17/64"	
3.		.2391"	15/64"	
4.		.2242"	7/32°	
5.		.2092"	13/64"	
6.		.1943"	3/18"	

7	■	.1793"	11/64" +	●
8	■	.1644"	11/64" −	●
9	■	.1495"	6/32" −	●
10	■	.1345"	9/64" −	●
11	■	.1196"	1/8" −	●
12	■	.1046"	7/64" −	●
13	■	.0897"	3/32" −	●
14	■	.0747"	5/64" −	●
15	■	.0673"	1/16" +	●
16	■	.0598"	1/16" −	●
17	■	.0538"	3/64" +	●
18	■	.0478"	3/64" +	●
19	■	.0418"	3/64" −	●
20	■	.0359"	1/32" +	●
21	■	.0329"	1/32" +	●
22	■	.0299"	1/32" −	●
23	■	.0269"	1/32" −	●
24	■	.0239"	1/32" −	●
25	■	.0209"	1/64" +	●
26	■	.0179"	1/64" +	●
27	■	.0164"	1/64" +	●
28	■	.0149"	1/64" −	●
29	■	.0135"	1/64" −	●
30	■	.0120"	1/64" −	●

High-strength, low-alloy steels are available in several grades and some possess corrosion resistance to such a degree that they are classified as "weathering steel."

Concrete and masonry reinforcing steel (rebar) are 40,000 psi and 60,000 psi. Wire mesh is 60 to 70 ksi.

AVERAGE PHYSICAL PROPERTIES

MATERIAL	ELASTIC LIMIT (PSI)		ULTIMATE STRENGTH (PSI)			ALLOWABLE WORKING UNIT STRESS (PSI)				MODULE OF ELAST. (PSI)	WEIGHT (LB./C.F.)
	TENSION	COMPRESS.	TENSION	COMPRESS.	SHEAR	TENSION	COMPRESS.	SHEAR	EXTR. FIBER BEND.		
CAST IRON			25000	75000	20000		9000			12000 M	450
WROUGHT IRON	25000	25000	48000	48000	40000	12000	12000	8000	12000	28000 M	485
STEEL A-36	36000	36000	70000	70000	55000	22000	20000	14500	24000	29000 M	490
ALUM. ALLOY 6061-T6	35000		38000		30000	15000			12000	10000 M	170

___ *b.* Economy: The weight of structural steel per SF of floor area increases with bay size, as does the depth of the structure. Cost of steel may not rise as rapidly as weight, if savings can be realized by reducing the number of pieces to be fabricated and erected. Improved space utilization afforded by larger bay sizes is offset by increases in wall area and building volume resulting from increased structure depth.

Steel frame economy can be improved by incorporating as many of the following cost-reducing factors into the structure layout and design as architectural requirements permit.

___ (1) Keep columns in line in both directions and avoid offsets or omission of columns.

___ (2) Design for maximum repetition of member sizes within each level and from floor to floor.

___ (3) Reduce the number of beams and girders per level to reduce fabrication and erection time and cost.

___ (4) Maximize the use of simple beam connections by bracing the structure at a limited number of moment-resisting bents or by the most efficient method, cross-bracing.

___ (5) Utilize high-strength steels for columns and floor members where studies indicate that cost can be reduced while meeting other design parameters.

___ (6) Use composite design, but consider effect of in-slab electric raceways or other discontinuities.

___ (7) Consider open-web steel joists, especially for large roofs of one-story structures, and for floor framing in many applications.

The weight of steel for roofs or lightly loaded floors is generally least when long beams and short girders are used. For heavier loadings, long girders and short filler beams should result in less steel weight. The most economical framing type (composite; noncomposite, simple spans, etc.) and arrangement must be determined for each structure, considering such factors as structure depth, building volume, wall area, mechanical system requirements, deflection or vibration limitations, wind or seismic load interaction between floor system, and columns or shear walls.

___ *c.* *Composite construction* combines two different materials or two different grades of a material to form a structural member that utilizes the most desirable properties of each materials.

___ (1) Composite systems currently used in building construction include:

___ (*a*) Concrete-topped composite steel decks

___ (*b*) Steel beams acting compositely with concrete slabs

___ (*c*) Steel columns encased by or filled with concrete

___ (*d*) Open-web joists of wood and steel or joists with plywood webs and wood chords

___ (*e*) Trusses combining wood and steel

___ (*f*) Hybrid girders utilizing steel of different strengths

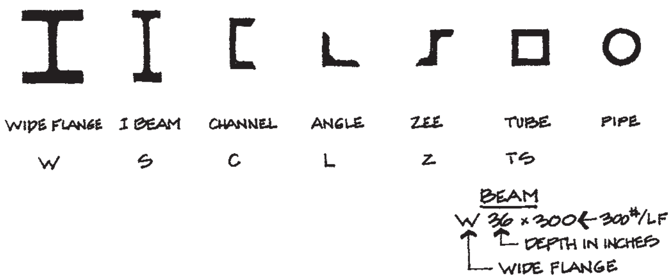
___ (*g*) Cast-in-place concrete slabs on precast concrete joists or beams

___ (2) To make two different materials act compositely as one unit, they must be joined at their interface by one or a combination of these means:

___ (*a*) Chemical bonding (concrete)
___ (*b*) Gluing (plywood, glulam)
___ (*c*) Welding (steel, aluminum)
___ (*d*) Screws (sheet metal, wood)
___ (*e*) Bolts (steel, wood)
___ (*f*) Shear studs (steel to concrete)
___ (*g*) Keys or embossments (steel deck to concrete, concrete to concrete)
___ (*h*) Dowels (concrete to concrete)
___ (*i*) Friction (positive clamping force must be present)

Individual elements of the composite unit must be securely fastened to prevent slippage with respect to one another.

___ *d.* Shapes and designations

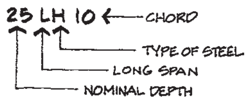


___ *e.* Open-web steel joists
___ (1) Types

TYPE	DESIGNATION	DEPTHS *	SPANS	BEARINGS			
				MASONRY	CONC.	STEEL	DEPTH
ECONOMY	K SERIES	8" TO 30"	8' - 60'	4 - 6"	4"	2½"	2½"
LONG SPAN	LH SERIES	18" TO 48"	25' - 96'	6 - 12"	6 - 9"	4"	5"
DEEP LONG SPAN	DLH SERIES	52" TO 72"	89' - 144'				

* IN 2 INCH INCREMENTS

___ (2) Joist designation



___ (3) Use K Series for roofs, short spans, or light loads.

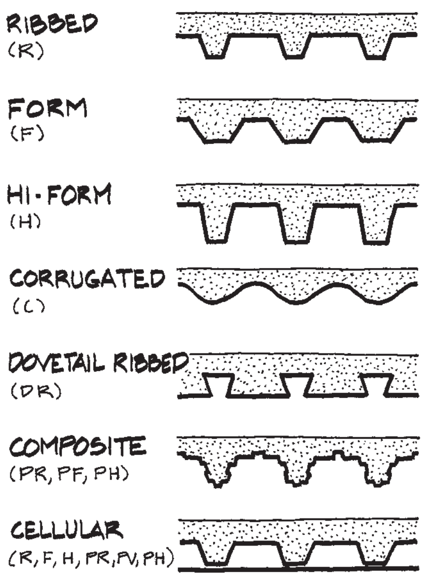
___ (4) Use LH Series for floors, longer spans, or heavier loads. Use DHL Series for longer spans.

___ (5) Horizontal or diagonal bridging is required to prevent lateral movement of top and bottom chords, usually from 10 to 15 oc.

___ (6) Overhangs can be created by extending top chords (up to 5′6″).

___ *f.* Steel decking

___ (1) Types:

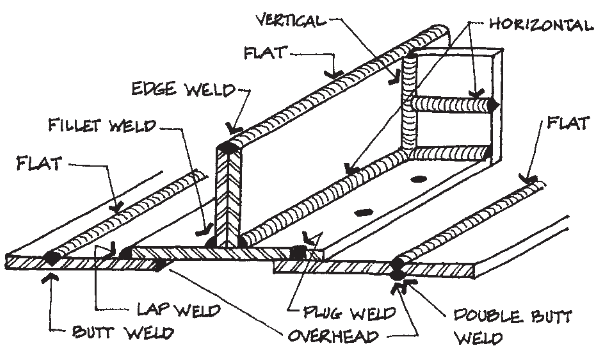


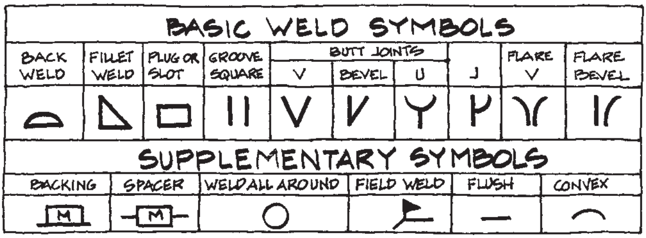
___ (2) Fire rating usually dictates thickness.

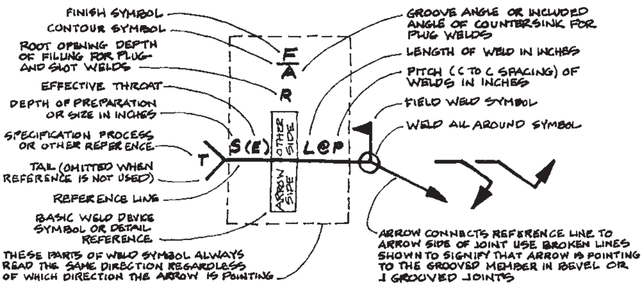
Total w/conc.	Deck	Span
2½″ to 5″	1½″	2′ to 6′
4″ to 6″	1½″	6′ to 12′
5½″ to 7½″	3″	9′ to 16′

___ (3) Gauges: 16, 18, 20, 22
___ (4) For shorter spans, usually 8′, plain roof decks with rigid insulation on top are often used. For this type:
___ (*a*) Small openings up to 6″ sq. may be cut without reinforcing. Larger openings require steel framing.
___ (*b*) Roof-mounted equipment cannot be placed directly on deck, but must be supported on structure below.

___ *g.* Structural connections
___ (1) Rivets (hardly used anymore)
___ (2) Bolts
___ (3) Welds

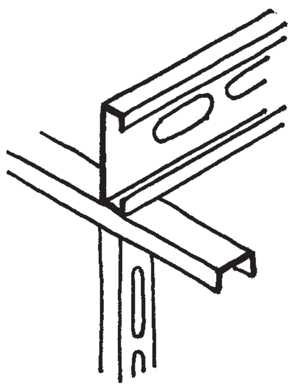






__ 5. **Light Metal Framing**

- __ *a.* Joists
  - __ (1) Makes an economical floor system for light loading and spans up to 32′
  - __ (2) Depths: 6″, 8″, 9″, 10″, 12″
  - __ (3) Spacings: 16″, 24″, 48″ oc
  - __ (4) Gauges: 12 through 18 (light = 20–25 GA; structural = 18–12 GA)
  - __ (5) Bridging, usually 5′ to 8′ oc



- __ *b.* Studs
  - __ (1) Sizes
    - __ (*a*) Widths: ¾″, 1″, 1⅜″, 1⅝″, 2″
    - __ (*b*) Depths: 2½″, 3⅝″, 4″, 6″, 8″

___ (2) Gauges: 14, 15, 16, 18, 20
___ (3) Spacings: 12″, 16″, 24″ oc

___ **6. Miscellaneous Metals**

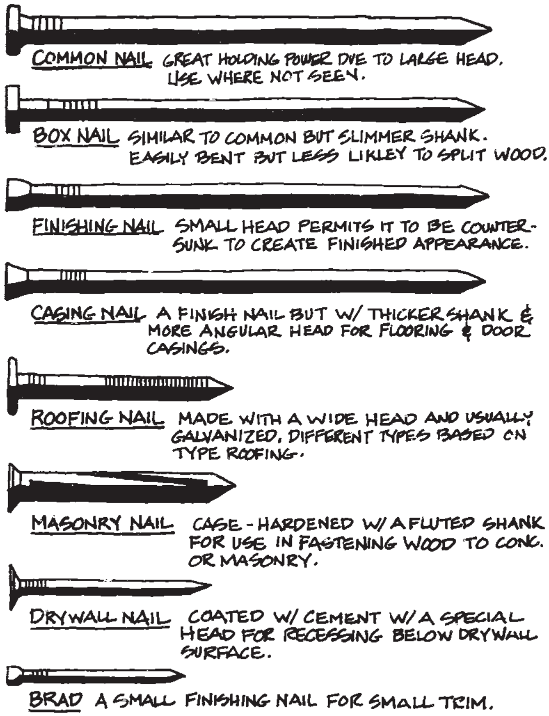
___ *a.* Nails

___ (1) Size:

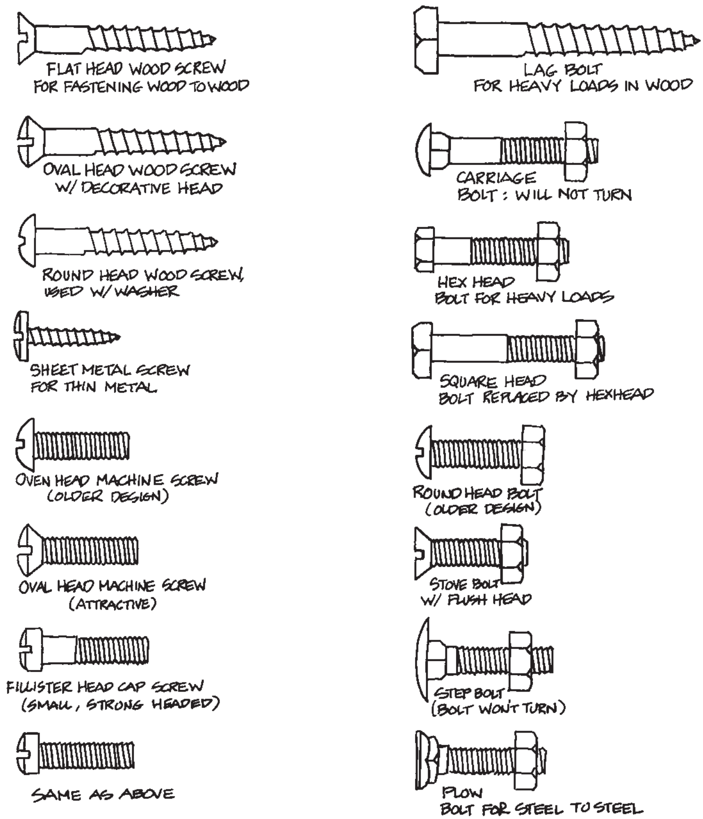
Penny	Gauge	Length
2	15	1″
3	14	1¼″
4	12½	1½″
5	12½	1¾″
6	11½	2″
7	11½	2¼″
8	10¼	2½″
9	10¼	2¾″
10	9	3″
12	9	3¼″
16	8	3½″
20	6	4″
30	5	4½″
40	4	5″
50	3	5½″
60	2	6″

Rule of thumb: Use nail with length 3× thickness of board being secured.

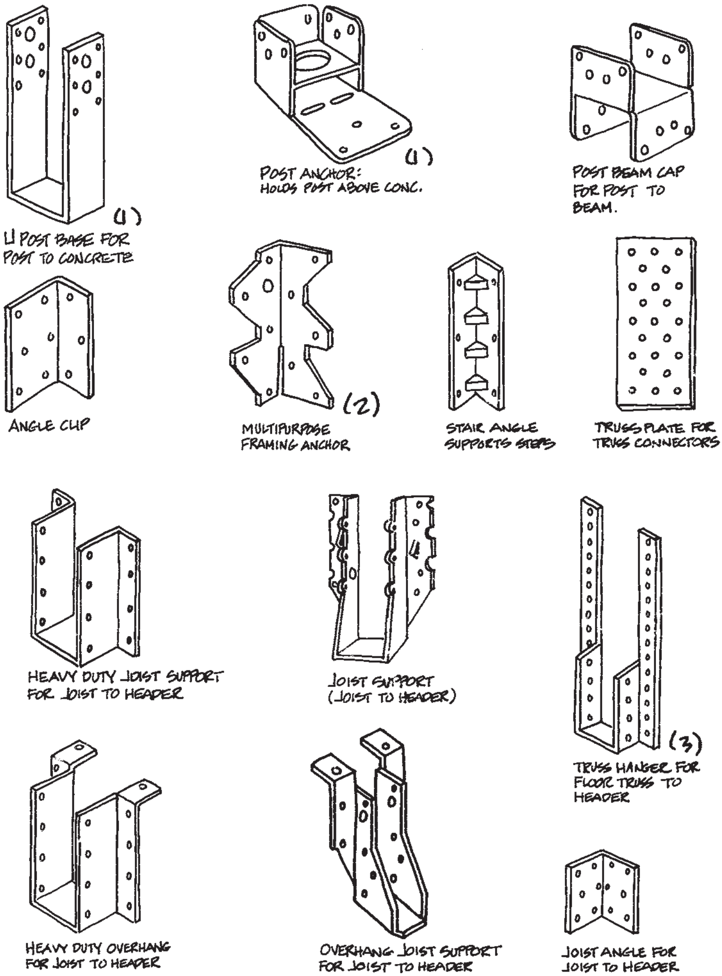
__ (2) Types


COMMON NAIL GREAT HOLDING POWER DUE TO LARGE HEAD. USE WHERE NOT SEEN.
BOX NAIL SIMILAR TO COMMON BUT SLIMMER SHANK. EASILY BENT BUT LESS LIKLEY TO SPLIT WOOD.
FINISHING NAIL SMALL HEAD PERMITS IT TO BE COUNTER-SUNK TO CREATE FINISHED APPEARANCE.
CASING NAIL A FINISH NAIL BUT W/ THICKER SHANK & MORE ANGULAR HEAD FOR FLOORING & DOOR CASINGS.
ROOFING NAIL MADE WITH A WIDE HEAD AND USUALLY GALVANIZED. DIFFERENT TYPES BASED ON TYPE ROOFING.
MASONRY NAIL CASE-HARDENED W/ A FLUTED SHANK FOR USE IN FASTENING WOOD TO CONC. OR MASONRY.
DRYWALL NAIL COATED W/ CEMENT W/ A SPECIAL HEAD FOR RECESSING BELOW DRYWALL SURFACE.
BRAD A SMALL FINISHING NAIL FOR SMALL TRIM.

___ *b.* Screws and bolts

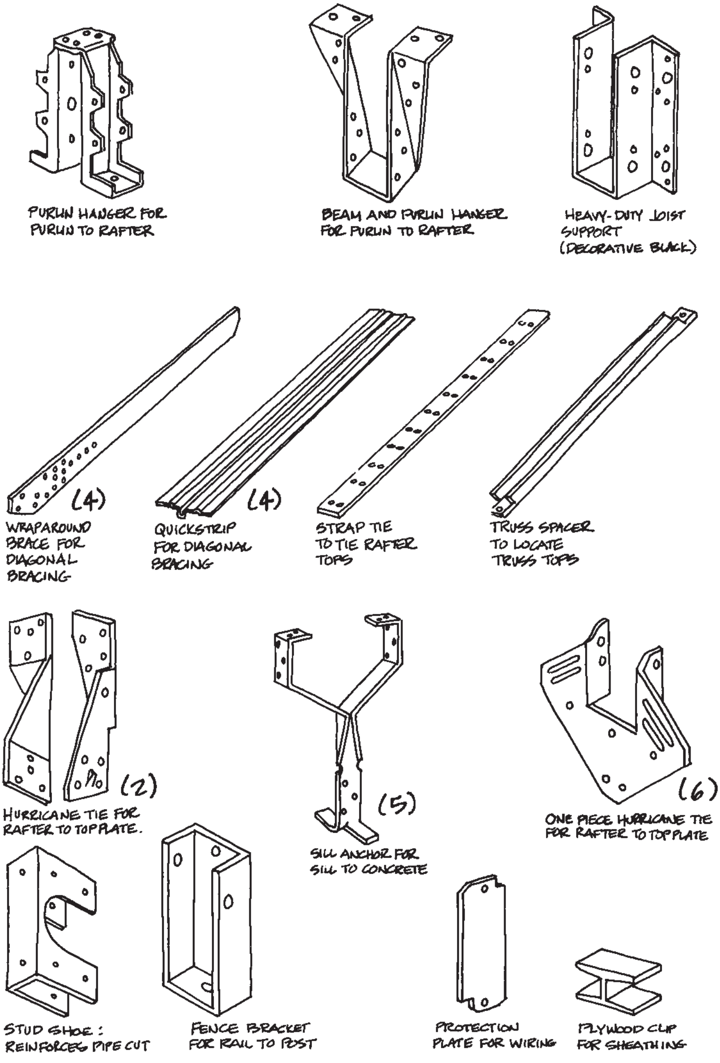


__ *c.* Timber connectors (see p. 353 for **costs**)



Notes: Numbers in parentheses below, with corresponding uses, refer to connectors illustrated above.

(1) Individual post base supports in concrete foundations.
(2) Truss or joist to plate and stud to plate, every other member (every member in high-wind regions).
(3) For hanging a beam from a truss or deep beam, above.



(4) High lateral wall braces used mainly for erection bracing at each corner.
(5) To hold sill in place at each corner and every 4′ to 6′ o.c.
(6) Can be used for pitched joist to wall or plate.

NOTES

___ B. STEEL MEMBERS (SIZES AND COSTS)

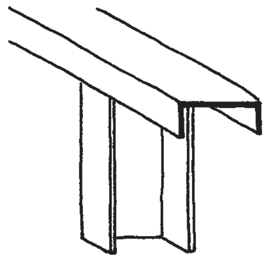
(A) (1) (13) (31) (36)

See p. 168 for span-to-depth ratios.

___ 1. ***General Costs:*** **Steel framing for 1-story building: $13.20/SF to $16.80/SF**
For 2- to 6-story: +$1.35/SF

___ 2. **Light Steel Construction**

___ *a.* Stud walls



___ (1) Widths of 1⅝″, 2½″, 3⅝″, 4″, and 6″.

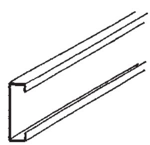
___ (2) Maximum heights range from 9′ to 16′.

___ (3) Available in load-bearing (LB), 14 GA to 20 GA, and non-load-bearing (NLB), 26 GA to 14 GA.

Costs: 3⅝″ studs, LB, 16″ oc: $2.25 /SF wall area (20%M and 80%L)

Deduct or add 10% for each increment of size.
For 24″ oc: –25%
For 12″ oc: +25%
For NLB (25 GA): –30%

___ *b.* Joists



___ (1) Span 15′ to 30′.

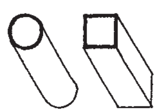
___ (2) See p. 169 for rule of thumb on span-to-depth ratio.

___ (3) Typical savings of 16″ to 24″ oc.

Costs: 8″ deep, 16″ oc, 40 psf, 15′ span: $3.85/SF floor

Add 15% for each added 5′ span up to 25′.
For 30′ span, add 75%.
24″ oc, about same cost.

___ *c.* Steel pipe and tube columns



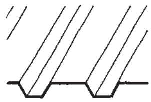
___ (1) Minimum pipe diameter: 3½″. Minimum tube size: 3″ sq.

__ (2) In general, assuming normal load conditions, the minimum diameter in inches can be estimated by multiplying the height in feet by *0.33*.

Costs: 3″ dia. or 3″ sq., 10′ unsupported height: $18/LF (55%M and 45%L). Cost can go up to double as load, height, and size (up to 8″) increase.

__ 3. <u>Heavy Steel Construction</u>

__ *a.* <u>Steel decking</u>



__ (1) For roofs, depths range from 1½″ to 3″, for spans of 6′ to 18′.

__ (2) For floors, depths range from 1½″ to 3″ for spans of 7′ to 12′.

__ (3) For cellular steel floors:
Thickness: 4″ to 7½″
Spans: 8′ to 16′

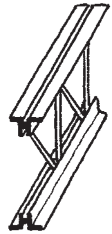
__ (4) Gauges range from 24 to 18 in increments of 2.

Costs: 1½″, 22 GA, galvanized, non-composite roof deck: $1.30/SF (60%M and 40%L). Add $0.25 for each jump in heavier gauge to 16 GA.

1⅝″, 18 GA, galvanized, cellular floor deck: $6.00/SF (85%M and 15%L). $7.00 for 3″. $10.60 for 4½″.

4″ concrete on 1½″, 22 GA deck, 6′ span, 125 psf: $3.95/SF (45%M and 55%L). Add 4% for each added foot in span up to 10′.

__ *b.* <u>Open-web joists</u>



__ (1) Span range: 8′ to 48′, up to 145′ for long-span joist.

__ (2) Spacings: 4′ to 8′ at floors, 8′ at roofs.

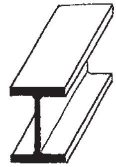
__ (3) Manufactured in 2″ increments from 8″ to 30″ deep and 18″ to 72″ for long-span type.

__ (4) Range of span-to-depth ratios: 19 to 24.

__ (5) Designations: Economy K Series, long-span LH Series, and deep, long-span DLH Series.

Costs: K Series: $8.40 to $10.20/LF (50%M and 50%L)
LH Series: $13.80 to $30/LF
DLH $21.60 to $55/LF

___ *c.* Steel beams



- ___ (1) Usual spans of 10′ to 60′.
- ___ (2) Typical bay sizes of 30′ to 40′.
- ___ (3) For roof beams, depth of beam in inches can be estimated at *0.5* times the span in feet.
- ___ (4) For floor beams, depth of beam in inches can be estimated at *0.6* times the span in feet.
- ___ (5) Steel plate girders: Spans range from 60′ to 100′, with approximate span-to-depth ratio of 14.

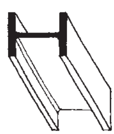
Typical costs for steel beams: *$2160* to *$2640* per ton (50% M and 50% L). For small projects use larger costs. For large projects (over 4 stories) use smaller costs.

Use the following table to help estimate weight from depth estimated in item 3 or 4, above.

Beam depth (″)	**Roof (lb/LF)**	**Floor (lb/LF)**
8	**18**	**24**
10	**22**	**26**
12	**26**	**30**
14	**30**	**38**
16	**36**	**45**
18	**40**	**50**
21	**55**	**62**
24	**62**	**76**
27	**84**	**94**

Table based on minimum roof live load of 20 psf. Add 15–25% more weight for snow, etc. For girders, add 25%.

___ *d.* Steel columns



- ___ (1) See p. 169 for span-to-depth ratio.
- ___ (2) In general, the 6 and 8 W columns carry most lightweight, low-rise construction. The 10, 12, and 14 W columns have capacities in various weights, to handle a large variation of extremes in lengths and loads.
- ___ (3) Maximum stock size in length is 40′. Column length in high-rise is 25′.

___ (4) Safe loads for normal single-story heights can be related to the weights of steel sections. For lightweight sections, the safe load in kips equals approximately 4 times the weight of the section per foot. For heavyweight sections the safe load equals approximately 5 times the weight of the steel section per foot.

Costs: See floor beams, above, and increase weight by 30%.

___ *e.* Steel trusses (see p. 164)

___ (1) Flat or arched steel trusses

Spans: 30′ to 220′
Span-to-depth ratio: 10 to 12
Spacings: 12′ to 20′.

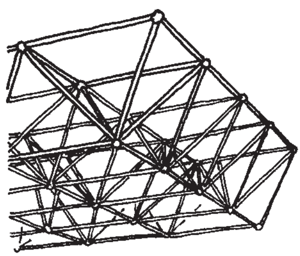
___ (2) Triangular steel trusses

Spans: 30′ to 150′
Span-to-depth ratios: 2.5 to 4.5
Spacings: 12′ to 20′.

Costs: $85 to $180/LF (70%M and 30%L)

___ 4. Space Frames

___ *a.* Spans: In theory are unlimited, but in reality are limited by thermal expansion. Typical spans are 30′ to 120′, with cantilevers of 15% to 30% of span.



___ *b.* Span-to-depth ratios:

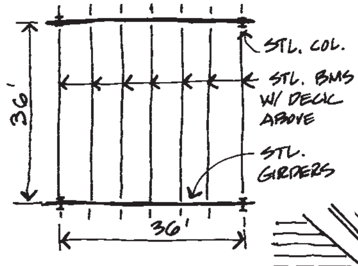
Roof
Column support: *18*
Edge support: *20* to *25*
Floor: *16* to *20* (not usually used for floors).

___ *c.* Modules: Depth to width of 1:3 to 7:10.

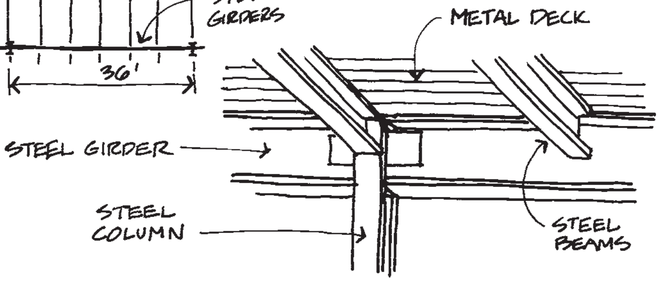
Costs: $25 to $45/SF (65%M and 35%L)

EXAMPLE:

PROBLEM:



SKETCH UP A ROUGH DESIGN & ESTIMATE OF COSTS FOR A 36' × 36' BAY FLOOR SYSTEM FOR STEEL CONSTRUCTION.



SOLUTION:

A. SIZE

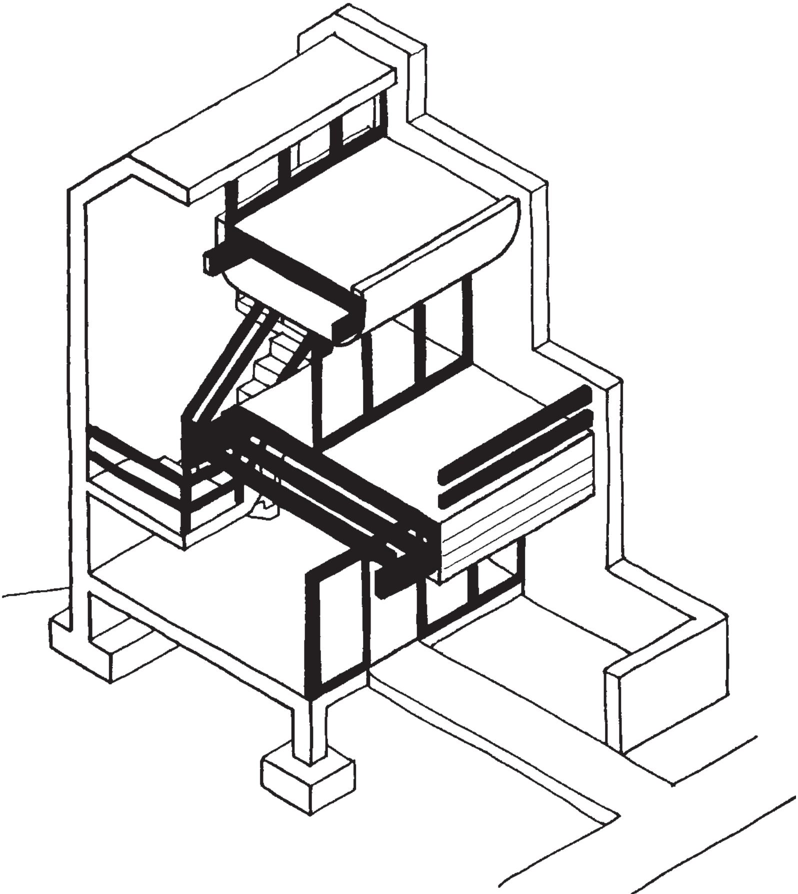
1. FLOOR (P. 332): USE 4" CONC. ON 1½", 22 GA. DECK W/ 6' SPANS, BM. TO BM., DEPTH: 4" + 1½" = 5½"
2. BEAMS: (P.333), DEPTH: 0.6 × 36' = 21½", SAY 21"
3. GIRDERS: (P.333), DEPTH: 21" TO 36' ÷ 14 = 30", SAY 27"
4. COLUMNS: (P.333), SIZE: 12' ÷ 24 = 0.5' SAY 8"W

B. COSTS

1. FLOOR: 4" CONC. ON 1½" MET. DECK W/ 6' SPAN ≐ $3.95
2. BEAMS:
   21" = 62#/LF × 7 EA × 36' SPAN = 15624#
   15624# ÷ 2000#/TON × $2200/TON ÷ 36' × 36' ≐ $13.25
3. GIRDERS:
   27" = 84# × 1.25 (P.333) × 4 EA × 36' =
   15120# ÷ 2000#/TON × $2200/TON ÷ 36' × 36' ≐ $12.85
4. COLUMNS:
   8" = 24#/LF × 1.3 (P.333) × 4 EA × 12' =
   1498# ÷ 2000#/TON × $2200/TON ÷ 36' × 36' ≐ $1.25

$31.30/SF

NOTES



6 WOOD

NOTES

___ A. WOOD MATERIALS

(A) (5) (15) (16) (17) (26) (41) (50) (60)

___ 1. **General** (*Note:* See p. 350 for species table. See pp. 326–329 for nails and connectors.)

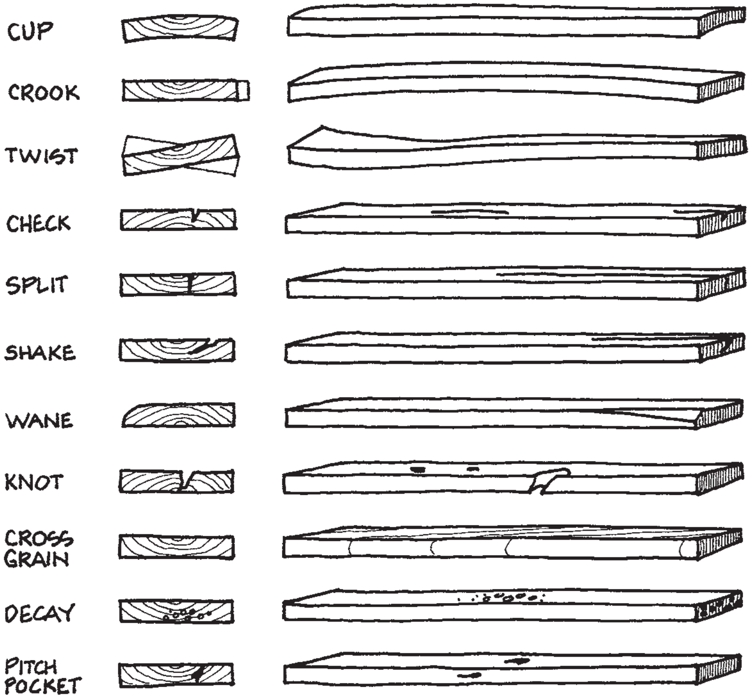
- ___ *a.* *Two general types of wood* are used in buildings:
  - ___ (1) Softwood (from evergreen trees) for general construction
  - ___ (2) Hardwood (from deciduous trees) for furnishings and finishes
- ___ *b.* *Moisture and shrinkage:* The amount of water in wood is expressed as a percentage of its oven-dry (dry as possible) weight. As wood dries, it first loses moisture from within the cells without shrinking; after reaching the fiber saturation point (dry cell), further drying results in shrinkage. Eventually wood comes to dynamic equilibrium with the relative humidity of the surrounding air. Interior wood typically shrinks in winter and swells in summer. Average equilibrium moisture content ranges from 6% to 11%, but wood is considered dry enough for use at 12% to 15%. The loss of moisture during seasoning causes wood to become harder, stronger, stiffer, and lighter in weight. Wood is most decay-resistant when moisture content is under 20%.

___ 2. **Lumber**

- ___ *a.* *Sizes*
  - ___ (1) Sectional

Nominal sizes	*To get actual sizes*
2×'s up to 8×'s	deduct ½″
8×'s and larger	deduct ¾″

  - ___ (2) Lengths
    - ___ (*a*) Softwoods: cut to lengths of 6′ to 24′, in 2′ increments
    - ___ (*b*) Hardwoods: cut to 1′-long increments
- ___ *b.* *Economy:* best achieved when layouts are within a 2′- or 4′-module, with subdivisions of 12″, 16″, 24″, and 48″
- ___ *c.* *Defects*



__ *d.* *Grades*

__ (1) *Factory or shop-type lumber:* used primarily for remanufacturing purposes (doors, windows, millwork, etc.).

__ (2) *Yard-type lumber*

__ (*a*) Boards:

__ 1″ to 1½″ thick, 2″ and wider

__ Graded for appearance only

__ Used as siding, subflooring, trim

__ (*b*) Dimensioned lumber:

__ 2″ to 4″ thick, 2″ and wider

__ Graded for strength (stress gr.)

__ Used for general construction

___ Light framing: 2″ to 4″ wide
___ Joists and planks: 6″ and wider
___ Decking: 4″ and wider (*select and commercial*).

___ (*c*) Timbers:
___ 5″ × 5″ and larger
___ Graded for strength and serviceability
___ May be classified as "structural."

___ (3) *Structural grades* (in descending order, according to stress grade):
___ (*a*) Light framing: *Construction, Standard,* and *Utility*
___ (*b*) Structural light framing (joists, planks): *Select Structural, No. 1, 2, or 3* (some species may also be appearance-graded for exposed work).
___ (*c*) Timber: *Select Structural No. 1.*

Note: Working stress values can be assigned to each of the grades according to the species of wood.

___ (4) *Appearance grades*
___ (*a*) For natural finishes: *Select A or B.*
___ (*b*) For paint finishes: *Select C or D.*
___ (*c*) For general construction and utility: *Common, Nos. 1 thru 5.*

___ *e.* *Pressure-treated wood (wood preservative):* Softwood lumber treated by a process that forces preservative chemicals into the cells of the wood. The result is a material that is immune to decay. This should not generally be used for interiors. Where required:
___ (1) In direct contact with earth
___ (2) Floor joists less than 18″ (or girders less than 12″) from the ground
___ (3) Plates, sills, or sleepers in contact with concrete or masonry
___ (4) Posts exposed to weather or in basements
___ (5) Ends of beams entering concrete or masonry, without ½″ air space
___ (6) Wood located less than 6″ from earth
___ (7) Wood structural members supporting moisture-permeable floors or roofs, exposed to

weather, unless separated by an impervious moisture barrier

- ___ (8) Wood retaining walls or crib walls
- ___ (9) For exterior construction such as stairs and railings, in geographic areas where experience has demonstrated the need

___ *f.* *Fire-retardant-treated (FRT) wood:* Heavy timber (thick timber) is generally assumed to be resistive because it produces a charred surface when burned, which retards further burning. Smaller wood members can be fire protected by coverings, coatings, and treatments. Modern fire-retardant treatment of wood consists of various organic and inorganic chemicals, followed by kiln drying to reduce moisture to 15 to 19%. All proprietary FRTs must conform to UL classifications. See p. 445 for fireproofing.

___ *g.* *Framing-estimating rules of thumb:* For 16-inch oc stud partitions, estimate one stud for every LF of wall, then add for top and bottom plates. For any type of framing, the quantity of basic framing members (in LF) can be determined based on spacing and surface area (SF):

12 inches oc	1.2 LF/SF
16 inches oc	1.0 LF/SF
24 inches oc	0.8 LF/SF

(Doubled-up members, bands, plates, framed openings, etc., must be added.) For cost of framing accessories and connectors, see p. 353. Estimating lumber can be done in *board feet* where one BF is the amount of lumber in a rough-sawed board one foot long, one foot wide, and one inch thick (144 cubic inches) or the equivalent volume in any other shape. As an example, one hundred one-inch by 12-inch dressed boards, 16 feet long, contain:

$$100 \times 1 \times 12 \times 16/12 = 1600 \text{ BF}$$

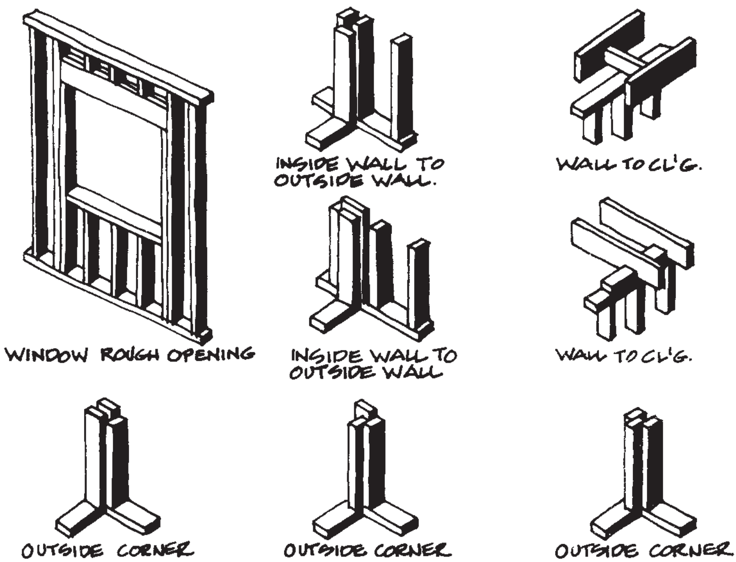
Use the following table to help estimate board feet:

BF per SF of surface

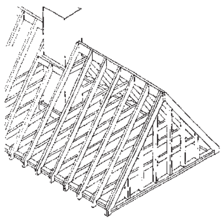
	12-inch oc	16-inch oc	24-inch oc
2 × 4s	0.8	0.67	0.54
2 × 6s	1.2	1.0	0.8
2 × 8s	1.6	1.33	1.06
2 × 10s	2.0	1.67	1.34
2 × 12s	2.4	2.0	1.6

__ 3. Details

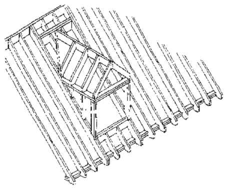
__ *a.* Walls:



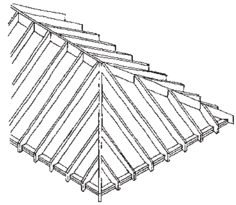
__ *b.* Roofs:



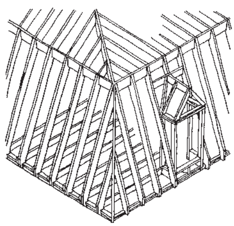
GABLE ROOF



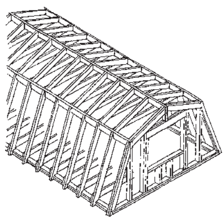
DORMER



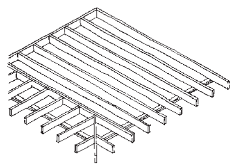
HIP ROOF



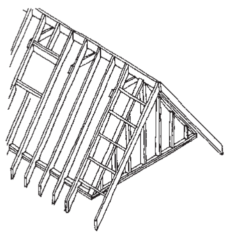
MANSARD ROOF



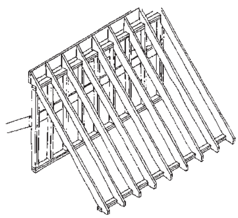
GAMBREL ROOF



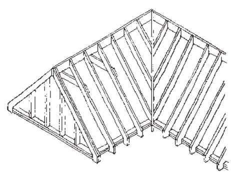
FLAT ROOF



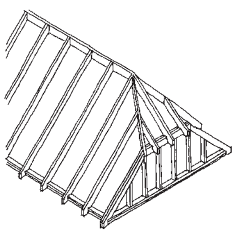
GABLE ROOF WITH OVERHANG



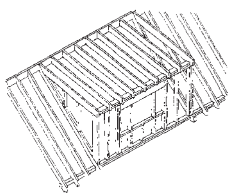
SHED ROOF



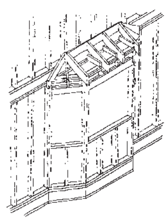
INTERSECTING ROOF



HIP GABLE ROOF



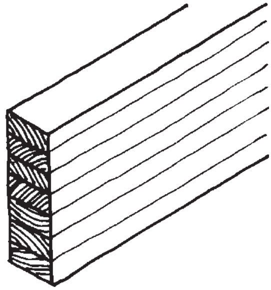
SMALL SHED DORMER



BAY WINDOW

___ 4. **Laminated Lumber**

___ *a.* *Laminated timber* (glu-lam beams): For large structural members, these are preferable to solid timber in terms of finished dressed appearance, weather resistance, controlled moisture content, and size availability. See p. 355.



___ *b.* *Sheathing Panels*

___ (1) *Composites:* veneer faces bonded to reconstituted wood cores

___ (2) *Nonveneered panels:*

___ (*a*) Oriented Strand Board (OSB).

___ (*b*) Particle Board

___ (3) Plywood

___ (*a*) Two main types

___ *Exterior grade*

_ Made with waterproof adhesive

_ C-grade face or better

_ For permanent exterior use

___ *Interior grade*

_ Made with water-resistant adhesives

_ D-grade face or better

___ (*b*) Grading according to face veneers

___ N All heartwood or all sapwood (for natural finish)

___ A Smooth paint grade

___ B Solid smooth surface

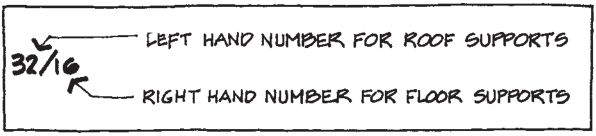
___ C Sheathing grade (lowest grade for exterior use)

___ D Lowest grade of interior plywood

___ (*c*) Engineered grades:

___ *Structural I and II, Standard,* and *C-C Exterior*

___ Span identification index



___ (*d*) Thickness: 3 ply = ¼, ⅜
5 ply = ½, ⅝, ¾
7 ply = ⅞, 1, 1⅛, and 1¼ inch

Use a minimum of ⅝″ or ¾″ where there are snow loads.

___ (*e*) Size sheets: 4′ (or 5′) × 8′ (or 12′)

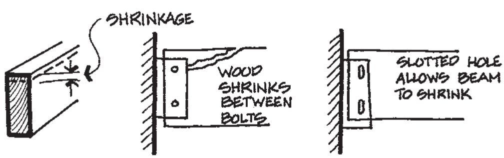
___ 5. <u>Structural Wood</u>

___ *a.* Strengths

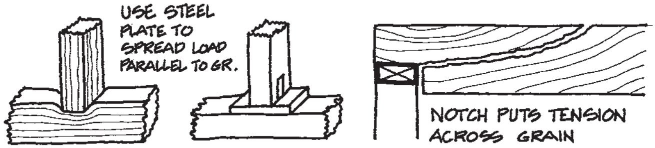
AVERAGE PHYSICAL PROPERTIES

MATERIAL	ELASTIC LIMIT (PSI)		ULTIMATE STRENGTH (PSI)			ALLOWABLE WORKING UNIT STRESS (PSI)				MODULE OF ELAST. (PSI)	WEIGHT (LB./C.F.)
	TEN-SION	COMP-RESS.	TEN-SION	COMP-RESS.	SHEAR	TEN-SION	COMP-RESS.	SHEAR	EXTR. FIBER BEND.		
PARALLEL TO GRAIN	3000	3000	10000	8000	500	1200	1000	100	1200	12000 M	40
PERPENDICU-LAR TO GRAIN					3000		300	400			

___ *b.* Wood shrinks across grain much more than parallel to grain. Avoid locking nonshrinking materials to wood.



___ *c.* Wood is much weaker across grain than parallel to grain in both tension and compression. A cross-grain angle greater than 1 in 10 seriously weakens the wood in bending.



___ *d.* Wood beams deflect or sag more under long-term loads than they do at the beginning. Long-term sag is about 1½ to twice beginning sag.

___ *e.* Wood beams may be weak in resistance to horizontal shear. Since this shear is closest to beam supports, *holes through wood* beams should be avoided near supports. Notches on the ends of joists should not exceed ¼ the depth. Holes bored in joists should not be within *2″* of top or bottom and their diameter should not be greater than ⅓ *depth*. Notches at top and bottom should not exceed ⅙ *depth* and should not be in middle ⅓ *of span*. Holes bored in studs should not be greater than *40%* (60% if studs doubled) and should not be closer to the edge than ⅝″.

___ **6. Finish Wood (Interior Hardwood Plywoods)**

___ *a.* *Sizes*

- ___ (1) Thicknesses: ⅛″ to 1″ in 1⁄16″ and ⅛″ increments
- ___ (2) Widths: 18, 24, 32, 36, 48 inches
- ___ (3) Lengths: 4, 5, 6, 7, 8, 10 feet

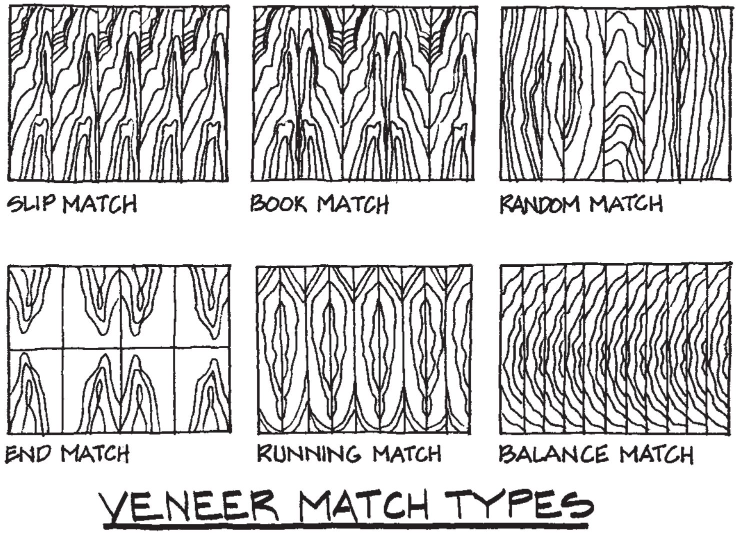
___ *b.* *Types*

- ___ (1) Technical: fully waterproof bond
- ___ (2) Type I (exterior): fully waterproof bond/weather- and fungus-resistant
- ___ (3) Type II (interior): water-resistant bond
- ___ (4) Type III (interior): moisture-resistant bond

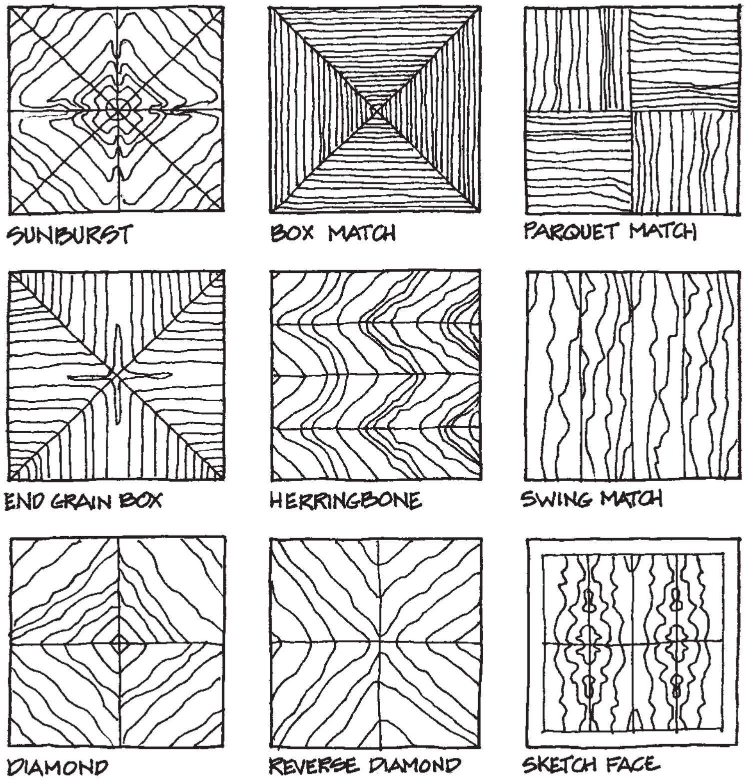
___ *c.* *Grades*

- ___ (1) Premium 1: very slight imperfections
- ___ (2) Good 1: suitable for natural finishes
- ___ (3) Sound 2: suitable for painted finishes
- ___ (4) Utility 3: may have open defects
- ___ (5) Backing 4: may have many flaws

__ *d. Grains and patterns*



Costs: Prefinished plywood paneling: $2.20 to $7.20/SF
Trim: $4.20 to $7.80/LF
Cabinetry: See p. 455



SPECIAL WOOD VENEER MATCHING OPTIONS

— 7. SPECIES

● DENOTES COMMON USES & PROPERTIES
○ POSSIBLE OR LIMITED USE
□ TREATED WOOD ONLY
+ FLAME SPREAD RATING
SCALE OF 1 TO 10 WHERE 1 IS LOWEST & 10 IS HIGHEST.

			TYP. FORMS				USES					
							BLD'G.				PART'N	
	SPECIES	COLOR	VENEERS	BOARDS/PLANK	DIMENSION	STRIPS/BLOCK	POSTS	FRAMING	SHEATHING	SIDING	FRAMING	PANELING
	SOFTWOODS											
1	CEDAR, WESTERN RED	RED BROWN TO WHITE SAPW	○	●	●		●	●	●	●	●	●
2	CYPRESS, BALD	YELLOWISH BROWN					●	●	●	●	●	●
3	FIR, DOUGLAS (COAST)	REDDISH TAN		●	●	●	●	●	●	●	●	○
4	HEMLOCK, WESTERN	PALE BROWN		●	●		●	●	●	●	●	
5	LARCH, WESTERN	BROWN					●	●	●	●	●	
6	PINE - LEDGEPOLE			●	●		○	●	○	○	○	
7	- PONDEROSA	WHITE TO PALE YELLOW		●	●		○	●	○	●	●	●
8	- RED	LIGHT BROWN		●	●		○	●	○	●	●	●
9	- SOUTHERN	WHITE TO PALE YELLOW		●	●	●	○	●	●	●	●	●
10	- SUGAR	CREAMY WHITE					●	●	●	●	●	●
11	REDWOOD - OLD GROWTH	DEEP RED TO DARK BROWN	○	●	●		●	○	○	●	○	●
12	SPRUCE - BLACK						○	○	○	○	○	
13	- ENGLEMAN	CREAMY WHITE		●	●		○	○	○	○	○	
14	- RED						○	●	○	○	○	
15	-SITKA	LIGHT YELLOWISH TAN		●	●		○	●	○	○	○	
	HARDWOODS											
1	ASH, WHITE	CREAMY WHITE TO LT. BROWN	●			○						○
2	BEECH	WHITE TO REDDISH BROWN	●			●						●
3	BIRCH, YELLOW	LIGHT BROWN	●			●						●
4	CHERRY	REDDISH BROWN	●			●						●
5	ELM, AMERICAN	BROWN	●									●
6	LOCUST, BLACK	GOLDEN BROWN					○					○
7	MAHOGANY	REDDISH BROWN	●			●						●
8	MAPLE (HARD) SUGAR	WHITE TO REDDISH BROWN	●			●						●
9	OAK, RED	REDDISH TAN TO BROWN	●			●						●
10	POPLAR, YELLOW	WHT. TO BRN W/ GR. CAST	●							○		●
11	ROSE WOOD	MIXED REDS, BROWN, BLACK	●									●
12	TEAK	TAWNY YELLOW TO DRK BRN	●			●						●
13	WALNUT, BLACK	DARK BROWN	●	○								●

USES													PROPERTIES									NOTES	
FLOORS			ROOF		FOUND./OUTDOOR						EQUIPT.												
JOISTS	ROUGH	FINISH	RAFTERS	DECKING	PILES	WD. FOUND	RET. WALLS	POSTS	DECKS	FURNITURE	CABINETS	FURNITURE	SHRINKAGE	BEND'G STR'G	COMPRESSION ∥	COMPRESSION ⊥	HARDNESS, SIDE	IMPACT, BEND'G	RESIST TO DECAY	WEATHERING	PAINTABILITY		
																						SOFTWOOD	
○			●	●				●	●	●	○	○	2	4	5	4	3	4	8	7	7	+78	1
○			●	●				●	●	●	○	○	5	6	6	6	6	6	8	7	7	+115	2
●	●	●	●	●	■	■	■	■	■				7	7	7	6	7	6	6	5	4	+145-150	3
●			●	●		■	■	■	■				7	6	6	5	6	7	5	5	5	+140-155	4
●			●	●	□				●				8	3	7	6	7	6	6	5	4		5
○			●						■				5	4	5	4	4	5	5	5	5	+60-75	6
○			●	●		■	■		■		○	○	4	3	4	5	4	5	5	5	6	+120-245	7
○			●	●		■			●		○	○	5	5	5	5	5	6	5	5	4	+105-200	8
○	●	●	●	●	■	■	■	■	■				7	7	7	6	7	6	5	5	5	+142	9
○			●	●					■		○	○	3	3	4	3	3	4	5	5	6		10
○			○	●				●	■	●	○	○	2	5	6	5	5	4	8	7	7	+75	11
○			○	○					□				5	4	5	3	5	5	5	5	5		12
○			○	○					□				5	3	3	3	3	4	5	5	5		13
○			○	○					□				6	5	5	5	5	4	5	5	5		14
○			●	●					□				6	5	5	5	5	5	5	5	5		15
																						HARDWOOD	
		○										●	5	6	6	6	6	6	4	5	5		1
											●	●	8	5	5	5	5	5	5	5	6		2
		○									●	●	7	5	4	4	5	6	5	5	6	+105-110	3
		○									●	●	3	4	5	3	4	3	6	5	5		4
												●	6	3	3	8	4	4	5	5	5		5
						○	○	○					2	8	8	8	8	5	8	5	5		6
		●									○	○											7
		●									○	●	6	6	6	6	6	5	5	5	6	+104	8
		●									○	○	7	3	3	5	5	3	5	5	5	+100	9
											○	○	4	3	3	2	3	3	5	5	7	+170-185	10
											●	●											11
		○		○						○	●	●											12
		○									●	●	4	6	6	4	6	4	7	6	5	+130-140	13

NOTES

___ B. WOOD MEMBERS (SIZES AND COSTS)

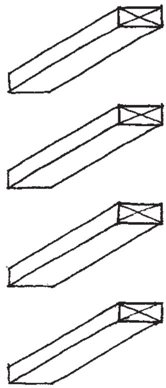
(A) (1) (13) (16) (31)

___ **1.** ***General:*** See p. 168 for span-to-depth ratios.
Rough lumber costs by board feet:

Studs	**\$0.65/BF**
Posts	**\$0.70/BF**
Joists	**\$0.70/BF**
Beams (Doug. Fir)	**\$0.85/BF**

Note: The above are material costs only. Total in-place cost may be estimated by *doubling* the above numbers.

Note: As a general rule, add 5% to 10% to framing costs for connections. Use the higher % for seismic zones.



___ **2. Light-Frame Construction**

___ *a.* Stud walls: Usually 2 × 4s or 2 × 6s at 16″ oc or 24″ oc with one bottom and two 2× top plates.

Costs: 2 × 4s at 24″oc: \$1.20/SF (50% M and 50% L) with variation of ±10%. Add 30% for each spacing jump (i.e., 16″ and 12″ oc).

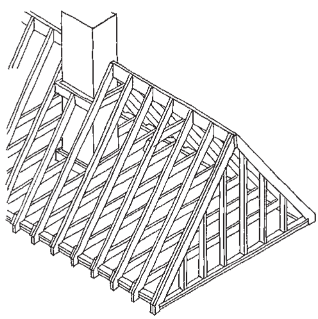
2 × 6s at 24″oc: \$1.60/SF (M, L, variation, and spacing, same as above).

___ *b.* Roof joists and rafters: Rule of thumb for roof joists, rafters, and ceiling joists: Quick estimates of joist depths in inches can be made by multiplying span in feet by:

0.45 for ceiling joists

0.5 for roof joists

Usual spacing: 24″ oc.



For more precise sizing, see p. 358.

Costs: 2 × 6s at 24″oc: $1.90/SF (50% M and 50% L), variation of + 10%. Add 30% for each spacing increase (i.e., 16″ and 12″oc. 2 × 8s: $2.35/SF. 2 × 10s: $2.65/SF. 2 × 12s: $3.25/SF.

Ceiling joists: + 8%

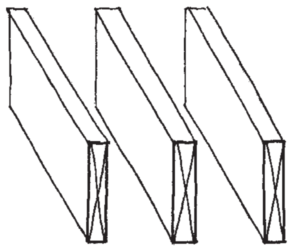
___ *c.* Floor joists

___ (1) See p. 168 for general rule span-to-depth ratio.

___ (2) Usual span range: 8′ to 24′.

___ (3) Usual spacing: 16″ oc.

___ (4) For more precise sizing, see p. 358.



Costs: 2 × 6s at 24″ oc: $1.85/SF (50%M and 50%L).
16″ oc: $2.40/SF.
12″ oc: $2.55/SF.

2 × 8 @ 24: $2.35/SF
2 × 10 @ 24: $2.65/SF
2 × 12 @ 24: $3.25/SF

___ 3. Heavy Timber Construction

___ *a.* Wood beams

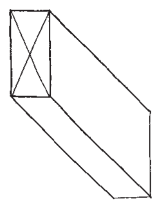
___ (1) Solid wood beams

___ (*a*) Minimum size of 4 × 6

___ (*b*) Thickness range: 2″ to 14″

___ (*c*) Spacing range: 4′ to 20′.

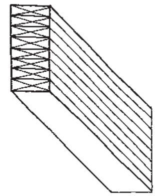
___ (*d*) Approximate span-to-depth ratios: *16 to 20.*



___ (2) Solid wood girders: Commonly used span-to-depth ratio for girders with concentrated load is *12.* Width will be *3/4* to *1/2* of depth. To estimate depth in inches, multiply span in feet by *1.*

Approximate cost range from $4.90/LF for 4 × 8s to $7.50/LF for 4 × 12s. $7.75/LF for 6 × 8s to $11.50/LF for 6 × 12s (65% M and 35% L).

__ *b.* <u>Glu-lam beams</u>



__ (1) Minimum depth of 9″.
__ (2) Usual span range: 16′ to 100′ for roofs and 14′ to 40′ for floors.
__ (3) Spacing: 8′ to 30′.
__ (4) Thickness range from 3⅛″ to 10¾″.
__ (5) Approximate span-to-depth ratio: *16 to 20.*
__ (6) Ratio of depth to width is about 2 to 1 for light beams and 3 to 1 for large members.
__ (7) Depth varies in 1½″ increments.

Approximate costs: Douglas fir, industrial grade:

3⅛″ × 6″: \$5.15/LF (45%M and 55%L). Add \$2.70 for each 3″ depth to 18″.

3½″ × 9″: \$10.90/LF (90%M and 10%L). Add \$2.15 for each 3″ to 15″.

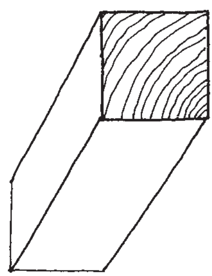
5⅛″ × 6″: \$7.80/LF (50%M and 50%L). Add \$4.10 for each 3″ depth to 24″.

5⅛″ × 9″: \$14.50/LF. Add \$4.15 for each 3″ to 15″.

6¾″ × 12″: \$20.65/LF (75%M and 25%L). Add \$5.75 for each 3″ depth to 24″.

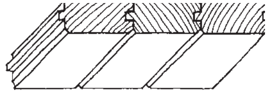
5⅛″ × 24″: \$36.15/LF

For architectural grade, add 20%.
For prestain, add 10%.



__ *c.* <u>Columns and posts:</u> The ratios of unbraced length to least thickness of most types range from 10 to 30 with *20* a good average.

Approximate costs of *\$4.65/LF* for 4 × 4 to *\$8.40/LF* for 6 × 6 (same M and L ratios as beams).



__ *d.* Wood decking
- __ (1) Thickness: 2″ to 4″
- __ (2) Span-to-depth ratio: *25 to 48*
- __ (3) Spans: 4′ to 8′

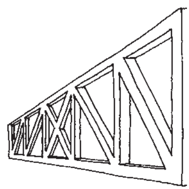
Approximate costs of $4.80/SF for 3″ fir to $9.60/SF for 4″ cedar (70% to 90% M, 30% to 10% L).

__ **4. Trusses**

__ *a.* Light frame trusses
- __ (1) Usually 2′ oc
- __ (2) Roof span-to-depth ratio: *15–20*
- __ (3) Floor span-to-depth ratio: *12 to 15*
- __ (4) Usual spans 30′ to 60′

Approximate cost range: Fink truss, 2 × 4s, 3 to 12 slope, 24′ span: $120/each (55% M and 45% L).

King post, 2 × 4s, 4 to 12 slope, 42′ span: $215/each (75% M and 25% L).

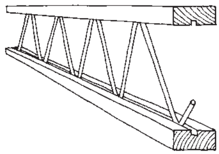


__ *b.* Heavy wood trusses
- __ (1) Flat trusses
  - __ (*a*) Typical range of spans: 40′ to 160′
  - __ (*b*) Spacing 12′ to 20
  - __ (*c*) Usual ratio of truss depth to span ranges from *1 to 8* to *1 to 10.*
- __ (2) Bowstring trusses
  - __ (*a*) Typical range of spans: 40′ to 200′
  - __ (*b*) Spacing: 12′ to 20′
  - __ (*c*) Usual span-to-depth ratio of *6 to 8*
- __ (3) Triangular trusses (see p. 164)
  - __ (*a*) Typical range of spans: 40′ to 100′
  - __ (*b*) Spacing 12′ to 20′
  - __ (*c*) Usual span-to-depth ratio: *1 to 6*

___ (4) Two- and three-hinge arches
- ___ (*a*) Typical range of spans: 20′ to 150′
- ___ (*b*) Spacing: 8′ to 20′
- ___ (*c*) Usual ratios of total arch heights to span: *1 to 4* to *1 to 8.*
- ___ (*d*) Span-to-depth ratio: *25*

___ (5) Lamella arch
- ___ (*a*) Typical range of spans: 40′ to 150′
- ___ (*b*) Usual ratios of arch height to span: *1 to 4* to *1 to 6*

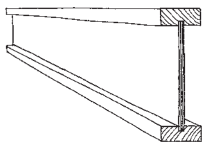
___ *c.* Open web joists (T.J.L.)



- ___ (1) Spacing: 24″, 32″, 48″ oc
- ___ (2) Spans: 25′ to 40′
- ___ (3) Span-to-depth ratio: *17 to 18*
- ___ (4) 2″ to 4″ depth increments

Costs: *$2.70 to $4.15/SF (70% M and 30% L)*

___ *d.* Plywood web joists (T.J.I.)



- ___ (1) Spacing: 24″, 32″ oc
- ___ (2) Spans: 20′ to 35′
- ___ (3) Span-to-depth ratio: *20 to 24*
- ___ (4) 2″ depth increments

Costs: $2.90 to $3.20/SF *(65% M and 35% L)*

___ **5. Plywood Sheathing** (see p. 345)
Usually minimum thickness for safe wall sheathing should be ½″.

Costs: Roof and floor sheathing (65% M and 35% L)
⅜″ = $1.20/SF
½″ = $1.30/SF
⅝″ = $1.45/SF
¾″ = $1.80/SF
For wall sheathing, add 7% to 8%.

TABLE FOR ALLOWABLE SPANS FOR WOOD FLOOR JOISTS & ROOF RAFTERS

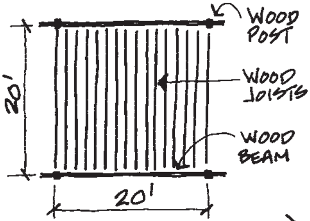
THIS TABLE IS BASED ON DOUGLAS FIR/LARCH NO. 2 & SOUTHERN PINE NO. 2 OR BETTER. REDUCE ALLOWABLE SPAN BY 7% FOR HEM-FIR NO. 2. THIS TABLE IS FOR BOTH HIGH & LOW SLOPE ROOFS.

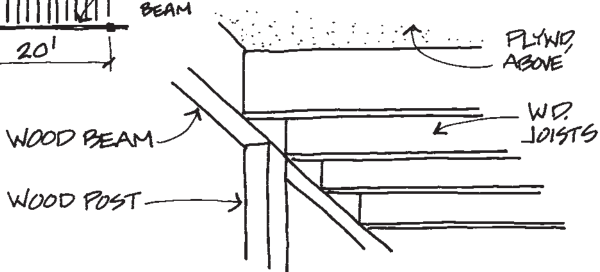
MEMBER SIZE →	2×6			2×8			2×10			2×12		
ON CENTER SPACING IN INCHES →	12	16	24	12	16	24	12	16	24	12	16	24
ALLOWABLE MAX. SPAN IN FT. & IN. ↘ / CONDITIONS & LOADS ↓												
FLOOR JOISTS, (L/360) 40#/SF LIVE LOAD W/10#/SF DEAD LOAD	10-9	9-9	8-1	14-2	12-7	10-3	17-9	15-5	12-7	20-7	17-10	14-7
W/20#/SF DEAD LOAD	10-6	9-1	7-5	13-3	11-6	9-5	16-3	14-1	11-6	18-10	16-3	13-4
CEILING JOISTS, (L/240) 10#/SF LIVE LOAD (W/5#/SF. D.L.)	19-6	17-8	14-10	25-8	23-0	18-9			22-11			
ROOF RAFTERS OR JOISTS NO CEILING (10#/SF DEAD LOAD) (L/180) 20#/SF LIVE LOAD	16-7	14-4	11-9	21-0	18-2	14-10	25-8	22-3	18-2		25-9	18-2
30#/SF SNOW LOAD	13-9	11-11	9-9	17-5	15-1	12-4	21-4	18-5	15-1	24-8	21-5	17-6
DRYWALL CEILINGS, 30#/SF SNOW L. (FOR 20#/SF LIVE LOAD INCREASE SPANS 15%) (L/240) 10#/SF DEAD LOAD	13-6	11-11	9-9	17-5	15-1	12-4	21-4	18-5	15-1	24-8	21-5	17-6
20#/SF DEAD LOAD	12-4	10-8	8-8	15-7	13-6	11-0	19-1	16-6	13-6	22-1	19-2	15-7

EXAMPLE:

PROBLEM:

SKETCH UP A ROUGH DESIGN & ESTIMATE OF COSTS FOR A 20' × 20' BAY WOOD FLOOR SYSTEM. FL. HT. IS 9'.





SOLUTION:

A. SIZE

1. SUBFLOOR: USE 1" PLYWOOD (P. 357) — 1"
2. JOISTS (P. 354): USE 2×12's @ 12" O.C., — 12"
3. BEAM (P. 354):
   20' SPAN ÷ 16 TO 20 SDR = 1.25' TO 1.0', SAY 6"×12"
4. POSTS (P. 355):
   8' HT ÷ 10 to 30 = 0.8' TO 0.27' WIDTH, SAY 6"×6"

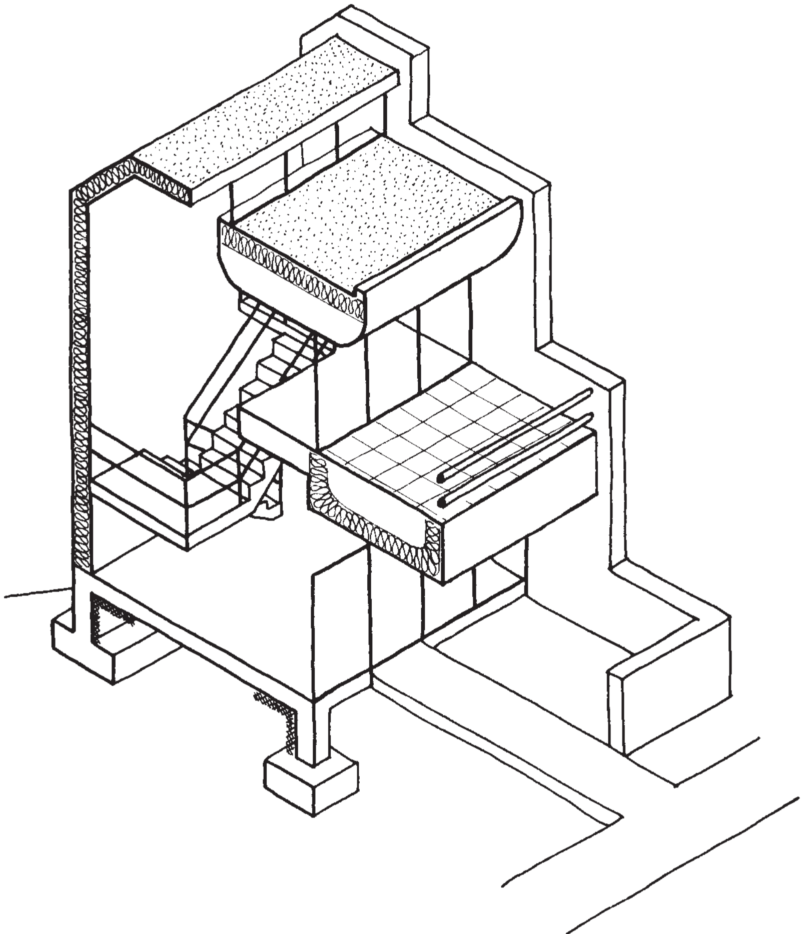
B. COSTS

1. SUBFLOOR: 1" PLYWOOD — SAY 1.90 *
2. JOISTS: 2×12's @ 24" = $3.25
   ×2 FOR 12" O.C. — ≈ 6.50
3. BEAMS: $11.50/LF × 2 EA × 20' ÷ 20'×20' ≈ 1.15
4. POSTS: $8.40/LF × 8' × 4 EA ÷ 20'×20' ≈ 0.67

$10.22/SF

* ON P. 357 PLYWOOD COSTS ONLY GO UP TO 3/4", SO THE 1" COST OF $1.90 IS A REASONABLE GUESS.

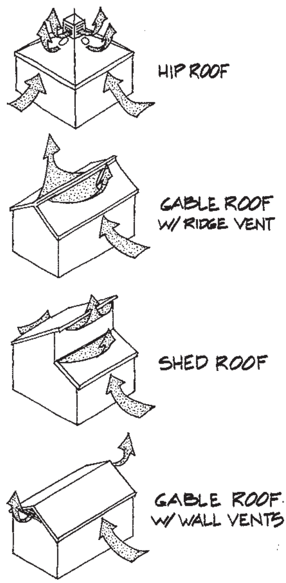
NOTES



7 THERMAL AND MOISTURE PROTECTION

NOTES

___ A. ATTIC AND CRAWL SPACE VENTILATION (5)



___ **1. When there is attic space under roof, *venting of attic will:***
- ___ *a.* Reduce heat buildup.
- ___ *b.* Provide escape route for moisture.
- ___ *c.* In cold climates, help prevent ice dams from forming.

___ **2. Even when there is *no attic,*** the venting effect can still be achieved with at least a *1″* air space above the insulation.

___ **3. In some cases,** the argument can be made for having *no venting* at all. This can be done in dry climates and building types where vapor is less of a problem or if the “wet” side of the roof is sealed against vapor migration. Because the codes require venting but often are not enforced, this needs to be checked with building officials.

___ **4. Venting can be done by:**
- ___ *a.* Cross-ventilation
- ___ *b.* Stack effect
- ___ *c.* Fans

___ **5. The IBC requires that where climatic conditions warrant,** attics or enclosed rafters should have net free ventilating area of at least 1⁄150 of the plan area (½ should be upper ventilators at least 3′ above eaves). This can be reduced to 1⁄300 if a vapor barrier is on warm side of attic insulation.

___ **6. Under-floor crawl space** should have a net free vent area of 1 SF for each 150 SF of crawl space (or 1⁄1500 when ground has a vapor barrier).

___ **7. Area required to provide 1 SF vent:**

¼″ Screen	1 SF
¼″ Screen w/louvers	2 SF
⅛″ Screen	1.25 SF
⅛″ Screen w/louvers	2.25 SF
1⁄16″ Screen	2 SF
1⁄16″ Screen w/louvers	3 SF

Costs: Louvers with screens: $12.50 to $24.60/SF (35% M and 65% L)

___ B. WATER AND DAMPPROOFING (5)

___ 1. *Waterproofing* is the prevention of water flow (usually under hydrostatic pressure such as saturated soil) into the building. This is usually basement walls or decks. This can be by:

- ___ *a.* Membranes: Layers of asphalt with plies of saturated felt or woven fabric
- ___ *b.* Hydrolithic: Coatings of asphalt or plastics (elastomeric)
- ___ *c.* Admixtures: To concrete

Typical costs:

Elastomeric, 1/32″ neoprene: $3.95/SF (50% M and 50% L)
Bit. membrane, 2-ply felt: $1.70/SF (35% M and 65% L)

___ 2. *Dampproofing* is preventing dampness (from earth or surface water without hydrostatic pressure) from penetrating into the building. This can be:

- ___ *a.* Below grade: 2 coats asphalt paint, dense cement plaster, silicons, and plastics.
- ___ *b.* Above grade: See paints and coatings, p. 424.
- ___ *c.* An excellent way to prevent water damage to buildings is to insert a layer of 90-lb roll roofing (not tar paper) in every seam between wood, metal, and masonry, as well as metal to metal (that is far apart in the galvanic series).

Typical costs:

Asphalt paint, per coat: $0.25/SF (50% M and 50% L)

___ C. VAPOR BARRIERS (5)

___ 1. ***General***

___ *a.* Vapor can penetrate walls and roof by:

___ (1) Diffusion—vapor passes through materials due to:

___ (*a*) Difference in vapor pressure between inside and outside.

___ (*b*) Permeability of construction materials.

___ (2) Air leakage by:

___ (*a*) Stack effect

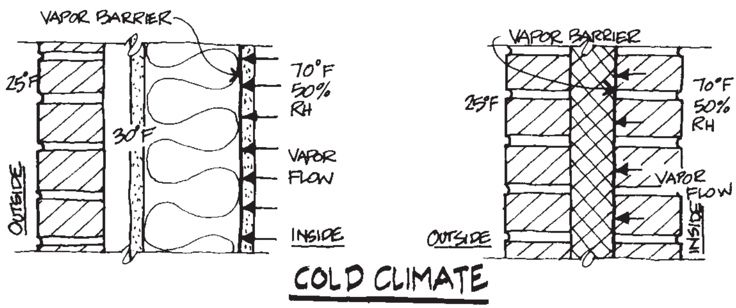
___ (*b*) Wind pressure

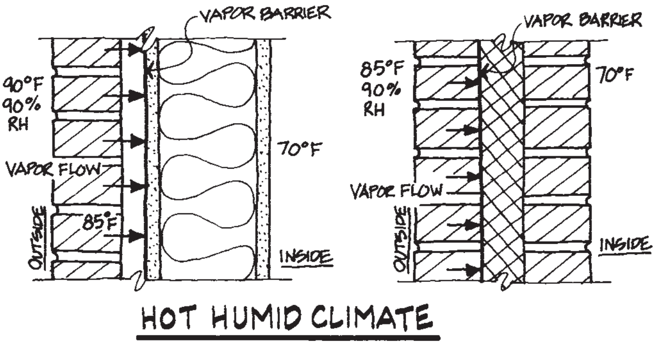
___ (*c*) Building pressure

___ *b.* Vapor is not a problem until it reaches its *dew point* and condenses into moisture, causing deterioration in the building materials of wall, roof, and floor assemblies.

___ 2. ***Vapor Barriers:*** Should be placed on the warm or humid side of the assembly. For *cold* climates this will be toward the inside. For warm, humid climates, this will be toward the outside. Barriers are also often put under slabs-on-grade to protect flooring from ground moisture.

Vapor barriers are measured by *perms* (grains/SF/hr/inch mercury vapor pressure difference). One grain equals about one drop of water. For a material to qualify as a vapor barrier, its perm rate must be *1.0* or less. A good perm rate for foil laminates, polyethylene sheets, etc. equals *0.1* or less (avoid aluminum foil against mortar). See p. 369 for perms of various materials. Care must be taken against puncturing the barrier.





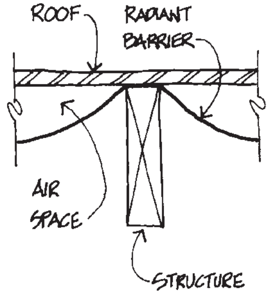
Other methods are elastomeric coatings on interior wallboard in cold climates and at exterior masonry or stucco walls in hot, wet climates. See p. 424 for coatings. Care must be taken to caulk all joints and cracks (see p. 382).

___ 3. Roof Vapor Retarders
- ___ *a.* As a general guide, vapor retarders should be considered for use when:
  - ___ (1) The outside, mean, average January temperature is below 40°F.
  - ___ (2) The expected winter, interior, RH is 45% or greater.
- ___ *b.* Vapor retarders generally fall into two classes:
  - ___ (1) Bituminous membranes: A typical 2-ply installation using 3 moppings of steep asphalt rates at less than .005 perms.
  - ___ (2) Sheet systems, with sealed laps, such as PVC films, kraft paper, or alum. foil, with perm ratings ranging from 0.10 to 0.50.
- ___ *c.* When vapor is a concern in top of deck insulation, moisture relief vents (preferably one-way) at a min. of one per 1000 SF should be considered.

___ 4. Asphalt Saturated Felts: See p. 378.

Typical costs: Polyethylene sheets, 2–10 mill. $.20 to $.30/SF

___ D. RADIANT BARRIERS (4)



___ 1. **Radiant barriers _reflect_ long-wave (invisible) radiation** created by the sun heating the exterior skin of the building.

___ 2. **Use for _hot climates or summer_** conditions only. Effective for retarding the penetration of exterior summer heat into building, but not the other way in winter.

___ 3. **Most critical _locations:_**

- ___ *a.* The roof is most critical because it faces the sun.
- ___ *b.* Use at walls can be effective when:
  - ___ (1) On east and west sides.
  - ___ (2) Climate is less than 2000 HDD and greater than 2500 CDD. See p. 637.
  - ___ (3) On south walls when climate is greater than 3500 CDD.

  Note: For HDD and CDD, see App. B, items L and M.

___ 4. **Radiation is blocked by a _reflective surface_ next to an air space.** The barrier can be on either side of the air space, or on both sides.

___ 5. **The reflective surface can be _foil-faced batting, reflective aluminum foil sheets, or reflective paint._**

___ 6. ***Emissivity* is a measure of radiant-barrier effectiveness** (the lower the e-number the better):

- ___ *a.* Minimum for foils should be e = 0.06.
- ___ *b.* Minimum for paints should be e = 0.23

___ 7. **_Added R_ value can be approximated for summer at *e* = 0.05:**

- ___ *a.* Horizontal air space: Reflectance up, R = 5.3
  Reflectance both sides, R = 6.0
- ___ *b.* Vertical air space: Reflectance out, R = 3.6
  Reflectance both sides, R = 4.6

___ 8. **Must guard against _dust reducing barrier effectiveness._**

Costs: Aluminum foil barrier: $.30/SF (70% M and 30% L)

___ E. INSULATION (5) (10)

___ **1. Insulation is the entrapment of air within modern lightweight materials,** to resist heat flow. It is generally made as batts, boards, and fills.

___ **2. For minimum total resistance (ΣR) for building elements,** find Insulation Zone from App. B, item U., then refer to below:

	Min. insulation, R		
Zone	Cl'g.	Wall	Floor
1	19	11	11
2	26	13	11
3	30	19	13
4	38	19	19
5	38	19	22
6	49	22	22

___ **3. In the design of a building, design the different elements** (roof, wall, floor) to be at the minimum ΣR. Each piece of construction has some resistance, with lightweight insulations doing the bulk of the resistance of heat flow.

$$\Sigma R = \underset{*}{R1} + R2 + R3 + R4 + \underset{*}{R5}, \text{ etc.} \qquad \text{*(air films)}$$

See p. 369 for resistance (r) of elements to be added.

Another common term is U Value, the coefficient of heat transmission.

$$U = \text{Btuh/ft}^2/°\text{F} = \frac{1}{\Sigma R}$$

___ **4. Other factors in control of heat flow**

___ *a.* The *mass* (density or weight) of building elements (such as walls) will delay and store heat. Time lag in hours is related to thermal conductivity, heat capacity, and thickness. This increases as weight of construction goes up with about *½% per lb/CF.* Desirable time lags in temperate climates are: Roof—12 hrs; north and east walls—0 hrs; west and south walls—8 hrs. This effect can also be used to increase R values, at the approximate rate of *+0.4%* for every added lb/CF of weight.

___ *b.* *Light colors* will reflect and *dark colors* will absorb the sun's heat. Cold climates will favor dark surfaces, and the opposite for hot climates. For summer roofs, the overall effect can be 20% between light and dark.

___ *c.* See page 367 for radiant barriers.

__ **5. Typical Batts:**

R = 11	3½″ thick
R = 19	6″
R = 22	6½″
R = 26	8¼″
R = 30	9″

Typical Costs:

C.L. 'G. batt, 6″ R = 19: $1.20/SF (60% M and 40% L)
9″ R = 30: $1.30/SF
Wall batt, 4″ R = 11: $.65/SF (50% M and 50% L)
6″ R = 19: $.85/SF
Add $.05/SF for foil backs.
Rigid: $0.70 to $1.80/SF, 1″, R = 4 , $1.20 to $4.20/SF, 3″, R = 12.5.

__ **6. Insulating Properties of Building Materials:**

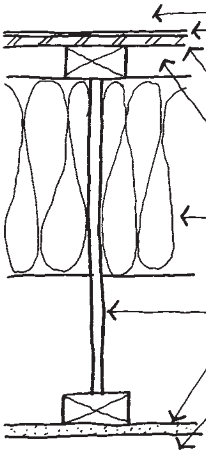
Material	Wt. #/CF	r value (per in)	Perm
Water	60		
Earth dry	75 to 95	.33	
saturated		.05	
Sand/gravel dry	100–120		
wet			
Concrete req.	150	.11	
lt. wt.	120	.59	
Masonry			
Mortar	130	.2	
Brick, common	120	.2	1 (4″)
8″ CMU, reg. wt.	85	1.11	.4
lt. wt.	55	2	
Stone	±170	.08	
Metals			
Aluminum	165	.0007	0 (1 mil)
Steel	490	.0032	
Copper	555	.0004	
Wood			
Plywood	36	1.25	½″ = .4 to 1
Hardwood	40	.91	
Softwood	30	1.25	2.9 (¾″)
Waterproofing			.05
Vapor barrier			.05

Material	Wt. #/CF	r value (per in)	Perm
Insulations			
Min. wool batt	4	±3.2	>50
Fill		3.7	>50
Perlite	11	2.78	
Board polystyrene		4	1–6
fiber		2.94	
glass fiber		4.17	
urethane		8.5	
Air			
Betwn. nonrefl.		1.34	
One side refl.		4.64	
Two sides refl.			
Inside film		.77 (ave)	
Outside film			
winter		.17	
summer		.25	
Roofing (see p. 373)			
Doors			
Metal			
Fiber core		1.69	
Urethane core		5.56	
Wood, solid 1¾″		3.13	
HC 1⅜″		2.22	
Glass, single	160	(see p. 411)	
Plaster (stucco)	110	.2	
Gypsum	48	.6	
CT	145		
Terrazzo			
Acoustical CLGs			
Resilient flooring		.05	
Carpet and pad		2.08	
Paint			.3 to 1 (see p. 424)

EXAMPLE:

PROBLEM: USING ROOF ASSEMBLY B (P. 478), ADD ROOFING, INSULATION, AND CEILING. ESTIMATE TOTAL U VALUE & COSTS. THE BUILDING IS IN PHOENIX, AZ.

SOLUTION:

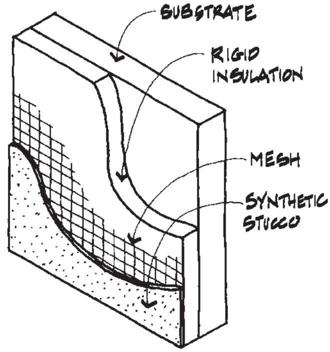


MT'L.	R		$/SF	
AIR	0.25	①	—	②
B.U. ROOF	0.88	③	1^{30}	④
½" PLYWD.	0.63	⑤	⑥	⑦
AIR	4.64	①	—	⑧
INSULATION	26.0		1^{30}	⑧
STRUCTURE	—		4^{00}	⑥
½" GYP'BD	0.3		$0.^{70}$	⑨
AIR	0.77		—	
	ΣR = 33.47		$$7^{30}$/SF	
			× 0.89 PHX, AZ	
	U = 0.30 ⑩		$$6^{50}$/SF	

NOTES:

① SEE P. 370.
② ASSUME SUMMER.
③ SEE P. 379.
④ WITH CAP SHEET.
⑤ SEE P. 369.
⑥ STRUCTURE COST, SEE P. 478, ASSUME $$4^{00}$/SF.
⑦ ½ OF R OF 1.25 FOR ½" PLYWOOD
⑧ BATT W/ ALUM. FOIL FACE UP. ASSUME $$1^{30}$/SF. SEE P. 369.
⑨ GYPB'D: ½ × .6R = .3R (SEE P. 370 & P. 416)
⑩ COULD ADD ANOTHER R = 5.3 FOR RADIANT BARRIER EFFECT IN SUMMER. SEE P. 367.

___ F. EXTERIOR INSULATION AND FINISHING SYSTEMS (EIFS)



__ 1. **Exterior Insulation** and Finishing Systems (EIFS) provide a stucco appearance using exterior insulation. They involve a combination of exterior-applied synthetic stucco on rigid insulation on a substrate (see item 32 on p. 188). Substrate can be masonry, gypsum board, plywood, etc.

__ 2. **Rigid insulation** is typically expanded polystyrene (R/in. = 4.17) of 1″ up to 4″ thickness, and is usually applied by adhesive.

__ 3. **Synthetic stucco** is applied after a fiber mesh is embedded in an adhesive.

Costs: For 1″ board $9.60/SF (30% M and 70% L), + 30% variation. Add $0.25/SF for each added 1″ of insulation.

___ G. ROOFING (C) (V) (5) (34) (47) (48) (58)

For costs, see p. 378. As a rule of thumb, add 30% to roofing costs for flashing and edge conditions.

___ 1. General

___ *a.* Shape (see p. 363)

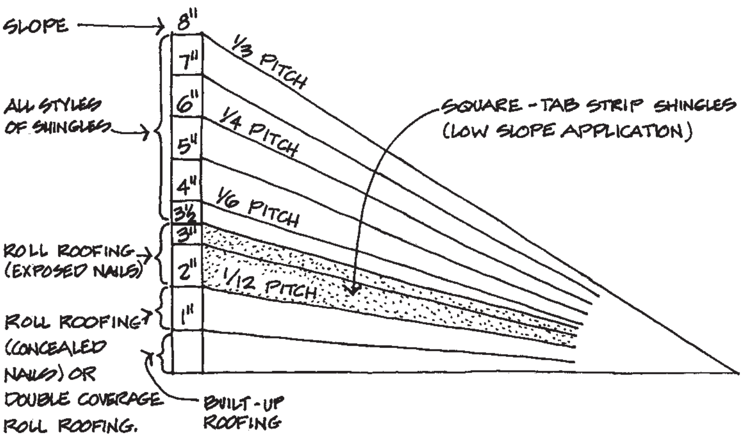
___ (1) Flat

___ (2) Hip

___ (3) Gable

___ (4) Shed

___ *b.* Pitch: See p. 61 for slopes. Use the following graphic as a guide for roofing selection:



MIN. PITCH & SLOPE REQUIREMENTS FOR VARIOUS ASPHALT ROOFING PRODUCTS

___ *c.* Drainage: See p. 519.

___ *d.* Fire resistance: Per the IBC, roofing is designated as either nonrated or rated. When rated, roofing must be not readily flammable, provide a degree of fire protection to the deck, not slip from position, and not produce flying brands during a fire. Rated roofs are broken down as follows:

___ (1) Class A: Resists severe fires, flames on top do not spread more than 6′, and no burn through roof. Examples: roofing tile, exposed concrete, and metal.

___ (2) Class B: Resists moderate fires, flames on top do not spread more than 8′, and no burn through roof. Example: metals.

___ (3) Class C: Resists light fires, flames on top do not spread more than 13′, and some burn through roof.

___ *e.* Minimum code requirements per IBC.

Const. type:	I-A	I-B	II-A	II-B	III-A	III-B	IV	VA	VB
Roof Class	B	B	B	C	B	C	B	B	C

Note: For class C, also see 2-a-(4), below.

___ **2. Basic Roofing Types**

___ *a.* Shingles and tiles

___ (1) Normally have felt underlayment.

___ (2) Laid on pitched roofs of greater than 3 in 12 (or 2 in 12 with special underlayment).

___ (3) At high-wind locations, shingles have tendency to blow off roof edges, unless special attachment.

___ (4) Class C may include certain wood shingles or shakes on buildings of 2 stories or less, 6000 SF max. area, where edge is not less than 10′ from lot line.

___ *b.* Single ply

___ (1) Modified bitumen

___ (*a*) APP: rubber-like sheets, can be dead-level, often with underlayment.

___ (*b*) SBS: same as above, but more flexible sheets.

___ (2) Single ply (without underlayment), can be dead-level.

___ (*a*) EPDM: single rubberized sheets, sealed at seams, unattached or adheared to substrate. Can be rock ballasted. Normally black.

___ (*b*) CSPE ("Hypalon"): Like above, but using a synthetic rubber that is normally white.

___ (*c*) PVC: Like above, but using plastic-like sheets that are normally white.

___ *c.* Coal tar pitch

___ (1) Like a built-up roof, of asphaltic products, except coal tar has a lower melt point and is better at self-sealing punctures.

___ (2) Use on very low slopes (1% to 2%).
___ (3) Coal tar can be hazardous to work with.

Coal tar is normally 50% more expensive than built-up roofing.

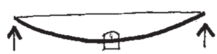
___ *d.* Metal roofing
___ *e.* Urethane
 ___ (1) Sprayed-on insulation with sprayed-on waterproof coating
 ___ (2) Very good for irregular-shaped roofs
 ___ (3) Weak point is delicate coating on top, which is susceptible to puncture
___ *f.* Built-up: Plies of asphalt-impregnated sheets (often fiberglass) that are adhered together with hot asphalt moppings. (See Design Checklist which follows.)

DESIGN CHECKLIST

___ 1. Roof leaks are often associated with edges and penetrations. Therefore, these require the greatest amount of care.

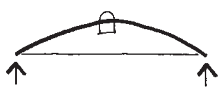
___ 2. "Flat" roofs should never be dead-level. Design substrate or structure for minimum of 2% (¼″ per ft) to 4% (½″ per ft) slope for drainage.

___ 3. Place drains at midspans, where deflection of structure is greatest.



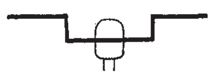
___ 4. When drains must be placed at columns or bearing walls, add another ½% (approx. 1/240 the span) to allow for deck or structure deflection.

___ 5. Where camber is designed into structural members, this must also be calculated into the required slope.



___ 6. Provide drainage "crickets" ("saddles") to allow water flow around equipment platforms or against parapets.

___ 7. To prevent ponding, roof drains are best recessed. Drains should be cast iron.



___ 8. For roof drains, scuppers, gutters, downspouts, etc., see p. 520.

___ 9. The drainage system should be laid out to accommodate any required building expansion joints. See p. 382.

___ 10. Roof expansion joints should be provided at structural joints; where steel frame or deck changes direction; where separate wings of L, U, or T shapes; where different types of deck materials meet; where additions meet existing buildings; where unheated areas meet heated areas; and where movement between vertical walls and roof may occur.

___ 11. Where expansion joints are not used, provide area dividers at *150* to *200* ft, laid out in square or rectangular areas, not restricting the flow of water.

___ 12. All horizontal-to-vertical intersections, such as walls and equipment platforms, should have 45° cants, crickets, flashing, and counter-flashing. Curbs should be 8″ to 14″ high so that there is at least 8″ between top of curb and roof. Premanufactured metal curbs should be 16 GA (or 18 GA with bracing).

___ 13. Roof penetrations of pipes and conduits should be grouped and housed. Keep minimum of 18″ between curbs, pipes, and edges of roof. If pitch pockets must be used, reduce size so that no more than 2″ separate edge of metal and edge of penetration.

___ 14. If substrate is preformed rigid insulation, two layers (with offset joints) are best, with top layer installed with long dimension of boards perpendicular to drainage and end joints staggered. Surface must be prepared prior to roofing.

___ 15. Use vapor retarder when needed. See p. 365.

___ 16. Substrate Decks

  ___ *a. Plywood* should be interior type with exterior glue, graded C-D, or better. Joints should be staggered and blocked or ply clipped. Base ply should be mechanically fastened.

  ___ *b. Wood planks* should be min. nominal 1″, T&G, with cracks or knotholes larger than ½″ covered with sheet metal. Edge joints should be staggered. Use separator sheet, mechanically fastened as base ply.

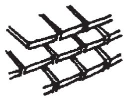
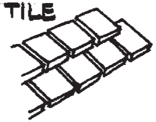
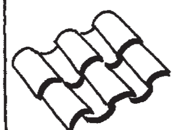
  ___ *c. Steel decks* should be 22 GA or heavier. Rigid insulation should be parallel to flutes, which are perpendicular to slope.

___ d. *Cast-in-place concrete* should be dry, then primed, unless rigid insulation used; then use vapor retarder or vent insulation.

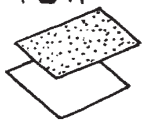
___ e. *Precast concrete* should have rigid insulation. Do not apply first ply to planks.

___ f. *Lightweight concrete or gypsum concrete* must be dry and then have a coated base ply or vented base ply mechanically attached.

ROOFING COMPARISON (DATA AND COSTS)

TYPE		SLOPE IN./FT. MIN.	SLOPE IN./FT. MAX	UNDER-LAYM'T	FASTENERS	WT. #/SQ	r PER IN.	FIRE CL.	LIFE, YRS	TYPICAL COSTS (ADD +30% FOR EDGE CONDITIONS)
UNDERLAYMENT/ ROLL ROOFING 	FELT			N/A		15 30	.06			$0.14/SF (10% M & 90% L) $0.18/SF
SHINGLES 	ASPHALT	4	12	15# FELT	GALV. STEEL OR ALUM. ROOF NAILS	300	.44	C	25 TO 40	$115 TO $200/SQ (55% M & 45% L)
	FIBERGLASS	2		30#		250		A		
	WOOD SHAKES	3		30# FELT OR ON WD. STRIPES	CORR. RESIST. NAILS	150 300	.87	B *	25 50	$235 TO $565/SQ (60% M & 40% L) $265 TO $385/SQ * ADD $100/SQ FOR FIRE RETARDING
TILE 	SLATE	4 TO 6		30# FELT	COPPER WIRE & NAILS	700 TO 4000	.05	A		$720 TO $1540/SQ (70% M & 30% L)
	"SPANISH" CLAY	4		30# FELT	NON-COR. COPPER NAILS	800 TO 1450	.01	A		$600 TO $995/SQ (65% M & 35% L)
	CONC.				10d COR. RESIST. GALV., COPPER OR S.S. BOX NAILS	950		A		$370 TO $480/SQ

ROOFING COMPARISON (DATA AND COSTS)

TYPE		SLOPE IN./FT. MIN	MAX	UNDER-LAYM'T	FASTEN-ERS	WT. #/SQ	r PER IN.	FIRE CL.	LIFE, YRS	TYPICAL COSTS (ADD +30% FOR EDGE CONDITIONS)
METAL 	STANDING SEAM, 22 TO 26 GA, PAINTED	3		30# FELT	ANCHOR CLIPS, GAL. NAILS OR SCREWS	130			30 TO 50	\$325 TO \$640/SQ (80% M & 20% L) COPPER: \$1080/SQ STAINLESS S.: \$1200/SQ. MONEL: \$1320/SQ
"FLAT" 	BUILT-UP	1/4		N/A	N/A			A TO C	20	\$120 TO 180/SQ (30% M & 70% L)
	W/ GRAVEL		3			550				ADD \$40/SQ FOR GRAVEL
	W/ CAP SHEET		6				.88			ADD \$25/SQ FOR CAP SHT.
	SINGLE PLY			40# FIBERGLASS		40		A TO C		\$155 TO 335/SQ
	URETHANE W/ ELAST. COATING					2.5 #/CF	7.2			\$430 TO 480/SQ (2")

NOTES

___ H. FLASHING (5)

___ **1. Purpose:** To stop water penetration at joints and intersections of building elements by use of pliable, long-lasting materials.

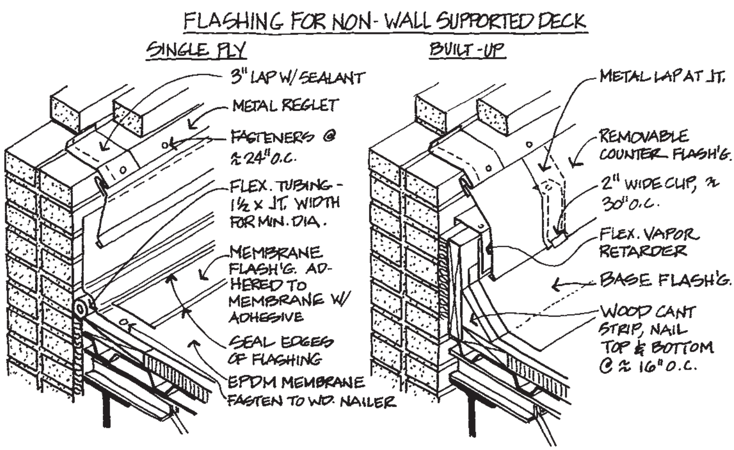
___ **2. Materials**

- ___ *a.* Stainless steel: *best*
- ___ *b.* Copper
- ___ *c.* Aluminum
- ___ *d.* Galvanized metal (must be painted)
- ___ *e.* Flexible (PVC, EPDM, etc.)
- ___ *f.* Felt: *worst*

___ **3. Locations**

- ___ *a.* At *roof*
  - ___ (1) Edges
  - ___ (2) Where roof meets vertical elements, such as walls
  - ___ (3) Penetrations
- ___ *b.* At *walls*
  - ___ (1) Copings at top
  - ___ (2) Foundation sills
  - ___ (3) Openings (heads/sills)

___ **4. Typical Details**



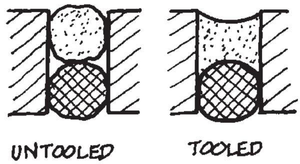
Costs: Complete roof to parapet assembly: ≈ $20.80/LF
Complete edge of roof assembly: ≈ $15.95/LF
Metal flashing: $6.85 to $10.30/SF (10% M and 90% L)
Copper flashing: $7.80 to $10.80/SF (45% M and 55% L)

___ I. JOINTS (4) (5) (11)

___ 1. *General*

___ *a.* Joints need to be planned because buildings and construction materials move small amounts over time.

The two greatest sources of joint failure are failure to clean the joint and failure to tool the sealant.



___ *b.* Types

___ (1) *Expansion joints* allow for movement. These will often go completely through the building structure with columns on each side of joint. See p. 159 for seismic joints.

___ (2) *Control joints* allow for control of cracking of finish materials by providing an indention to induce the crack in a straight line. See p. 276 for concrete slabs. See p. 299 for masonry. See p. 376 for roofing. See p. 415 for plaster.

___ (3) *Weather seals* reduce infiltration through building from outside (or vice versa).

___ *c.* Locations (Expansion Joints)

___ (1) New building adjoining existing structure

___ (2) Long, low building abutting higher building

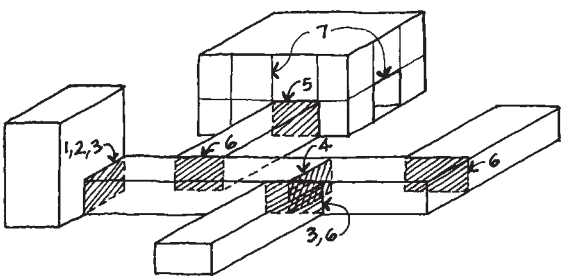
___ (3) Wings adjoining main structure

___ (4) Long buildings: 125′ for masonry, and 200′ for steel or concrete buildings, but 100′ is a conservative rule of thumb.

___ (5) Long, low connecting wings between buildings

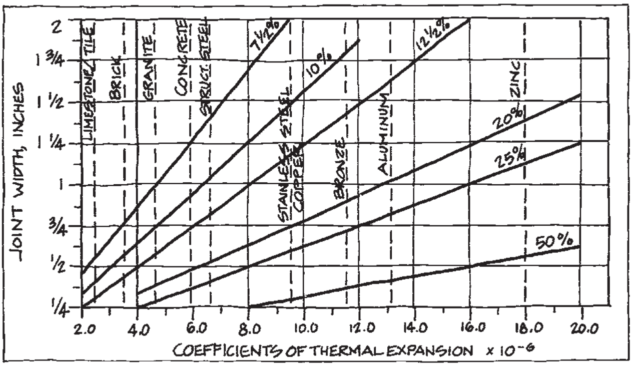
___ (6) Intersections at wings of L-, T-, or U-shaped buildings

___ (7) Control joints along walls and at openings



__ *d.* Components
- __ (1) Sealant
- __ (2) Joint filler

__ *e.* Widths = thermal expansion + moisture + tolerance.
- __ (1) Thermal expansion = Ec × ∅t × L
  - __ (*a*) Ec, coefficient of thermal expansion of material, as follows:



JOINT WIDTHS FOR SEALANTS WITH VARIOUS MOVEMENT CAPABILITIES FOR 10 FOOT PANELS AT Δt OF 130°F

  - __ (*b*) ∅t = max. probable temp. difference the material will experience over time. For ambient conditions, take the difference between items P and Q in App. B. Because materials absorb and/or retain heat, the result should be increased for the type of material (can easily double).
  - __ (*c*) L = Length in inches.
- __ (2) *Moisture* can add to expansion or to shrinkage, depending on the material. See p. 299.
- __ (3) *Construction tolerance:* depends on material. For PC concrete panels use ⅛″ for 10′ lengths and ¼″ for 30′ lengths.

<u>EXAMPLE</u>: ASSUME CONC. WALL PANELS, 5' WIDE. EXPECT CONC. Δt OF 120°F & A TOLERANCE OF 1/8". USE A SEALANT W/ 20% MOVEMENT CAPABILITIES.

FROM CHART ABOVE: $1/2'' \left(\frac{120°F}{130°F}\right) + 1/8'' = 19/32''$ OR 5/8"

SINCE PANEL IS 5' WIDE: $5/8'' \div 2 = 5/16''$ OR <u>3/8"</u>

___ *f.* Depths:

Joint width	Depth of sealant: Concrete, masonry, stone	Depth of sealant: Metal, glass, and other nonporous materials
Min. ¼″	¼″	¼″
¼″ to ½″	Same as width	¼″
½″ to 1″	One-half width	One-half width
1″ to 2″	Max. ½″	Max. ½″

___ 2. <u>Sealants</u>

COMPARATIVE PROPERTIES OF SEALANTS

LEGEND: 1 = POOR, 2 = FAIR, 3 = GOOD, 4 = VERY GOOD, 5 = EXCELLENT

	SEALANT TYPES: BUTYL	ACRYLIC, WATER BASE	ACRYLIC, SOLVENT BASE	POLYSULFIDE, ONE PART	POLYSULFIDE, TWO PART	POLYURETHANE ONE PART	POLYURETHANE TWO PART	SILICONE	NOTES
RECOMMENDED MAX. JOINT MOVEMENT, %±	7.5	7.5	12.5	25	25	15	25	25	(1)
LIFE EXPECTANCY IN YEARS	10+	10	15-20	20	20	20+	20+	20+	
MAX. JOINT WIDTH (INCHES)	3/4	3/8	3/4	3/4	1	3/4	1-2	3/4	(2)
ADHESION TO: WOOD	●	●	●	●	●	●	●	●	(3)
METAL	●	●	●	●	●	●	●	●	(3)
MASONRY/CONC.	●	●	●	●	●	●	●	●	(3)
GLASS	●	●	●	●	●	●	●	●	(3)
PLASTIC	●	●	●					●	
CURING TIME (DAYS)	120	5	14	14+	7	7+	3-5	2-5	(4,5)
MAX. ELONGATION (%)	40	60	60+	300	600	300+	400+	250+	
SELF LEVELING AVAILABLE	N/A		●	●	●		●	●	
NON-SAG AVAILAB.	N/A	●	●	●	●	●	●	●	
RESISTANCE TO: (SEE LEGEND) ULTRAVIOLET	2-3	1-3	3-4	2	2-3	3	3	5	
CUT / TEAR	2	1-2	1	3	3	4-5	4-5	1-2	
ABRASION	2	1-2	1-2	1	1	3	3	1	
WEATHERING	2	1-3	3-4	3	3	3-4	3-4	4-5	
OIL/GREASE	1-2	2	3	3	3	3	3	2	
COMPRESSION	2-3	1-2	1	3	3	4	4	4-5	
EXTENSION	1	1-2	1	2-3	2-3	4-5	4-5	4-5	

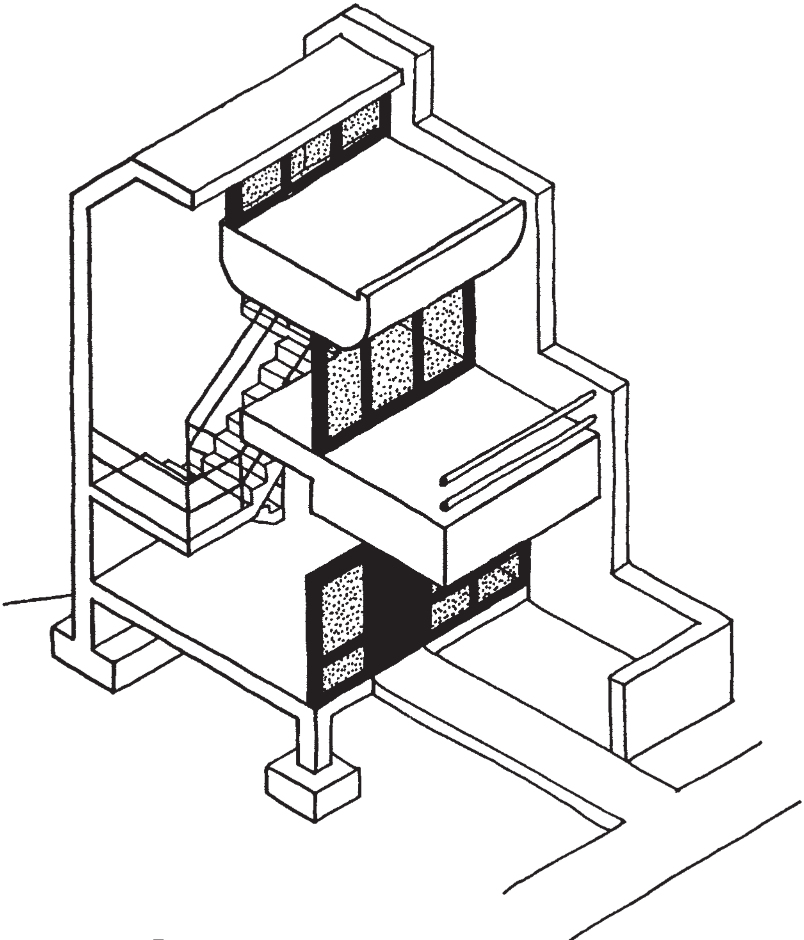
(1) SOME HIGH PERFORMANCE URETHANES & SILICONES HAVE MOVEMENT CAPABILITIES UP TO 50%.
(2) FIGURES GIVEN ARE CONSERVATIVE. VERIFY W/ MANUFACTURER.
(3) PRIMER MAY BE REQUIRED.
(4) CURE TIME FOR LOW TO MED. MODULES SILICONE IS ABOUT 2 HOURS.
(5) SILICONE CAN BE APPLIED OVER A WIDE TEMPERATURE RANGE.

__ 3. **Checklist of Infiltration Control**

- __ *a.* Tighten seals around windows and doors, and weather stripping around all openings to the outside or to unconditioned rooms.
- __ *b.* Caulk around all windows and doors before drywall is hung. Seal all penetrations (plumbing, electrical, etc.).
- __ *c.* Insulate behind wall outlets and/or plumbing lines in exterior walls.
- __ *d.* Caulk under headers and sills.
- __ *e.* Fill spaces between rough openings and millwork with insulation (best application with foam).
- __ *f.* Install dampers and/or glass doors on fireplaces, combined with outside combustion air intake.
- __ *g.* Install backdraft dampers on all exhaust fan openings.
- __ *h.* Close core voids in tops of block foundation walls.
- __ *i.* Control concrete and masonry cracking.
- __ *j.* Use airtight drywall methods.

Costs:	**Exterior joint, ½″ × ½″**	**\$2.70/LF (20% M and 80% L)**
	Interior	**\$2.40/LF**
	For joint fillers and gaskets add 50% to 100%	

NOTES

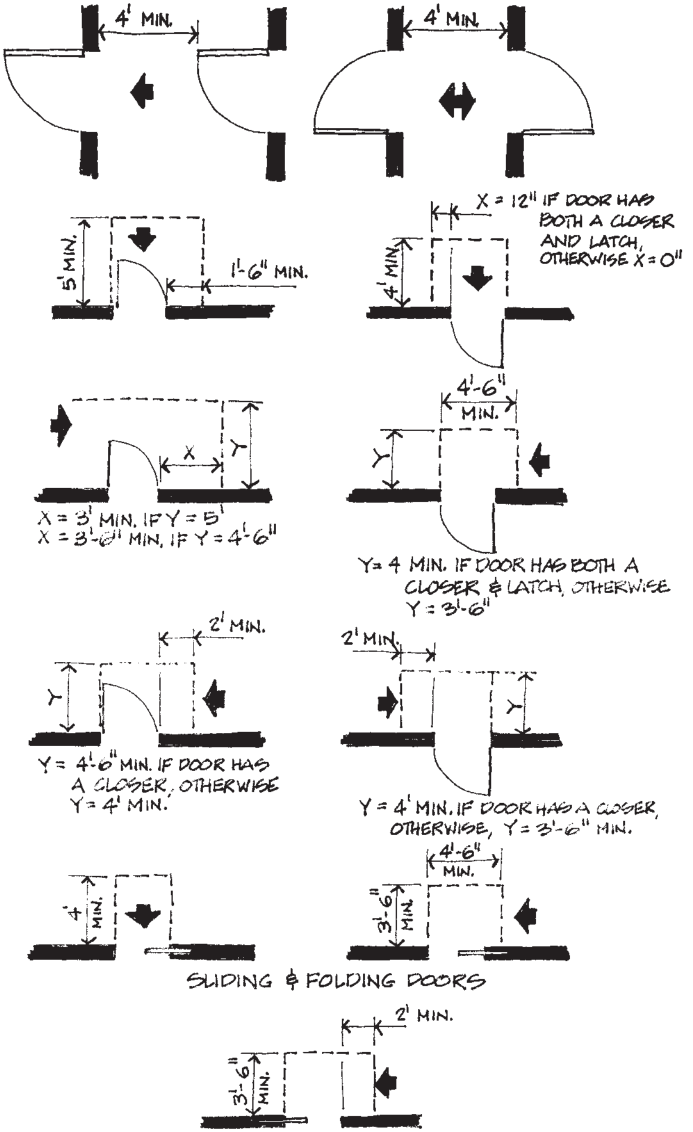


8 DOORS, WINDOWS, AND GLASS

NOTES

___ A. DOORS (5) (10) (17) (27) (60)

___ 1. *Accessible Door Approach* (ADA) (20)



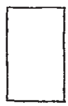
NOTE: ALL DOORS IN ALCOVES SHALL COMPLY W/ FRONT APPROACHES.

__ 2. *General*

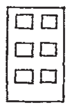
__ *a.* Types by operation
- __ (1) Swinging
- __ (2) Bypass sliding
- __ (3) Surface sliding
- __ (4) Pocket sliding
- __ (5) Folding

__ *b.* Physical types

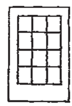
(1) Flush



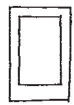
(2) Panelled



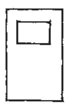
(3) French



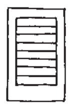
(4) Glass



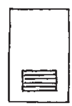
(5) Sash



(6) Jalousie

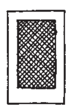


(7) Louver

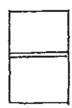


(8) Shutter

(9) Screen



(10) Dutch



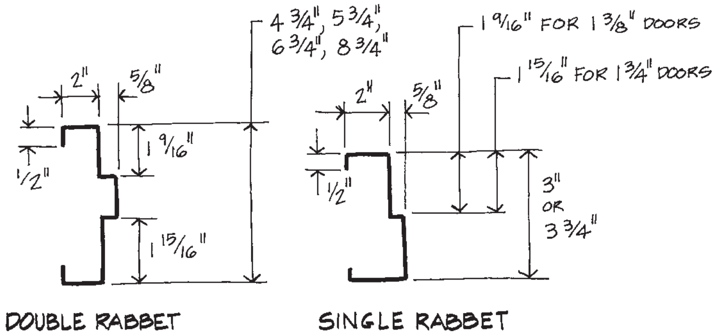
__ *c.* Rough openings (door dimensions +)

	Width	Height
In wood stud walls (r.o.)	+3½″	+3½″
In masonry walls (m.o)	+4″	+2″ to 4″

__ *d.* Fire door classifications: see p. 130.

__ *e.* Energy conservation: Specify doors not to exceed:
- __ (1) Residential: 0.5 CFM/SF infiltration
- __ (2) Nonresidential: 11.0 CFM/LF crack infiltration
- __ (3) Insulated to R=2.

___ 3. *Hollow Metal Doors and Frames*



___ *a.* Material (for gauges, see p. 317). Typical gauges of doors (16, 18, 20) and frames (12, 14, 16, 18)

Use	Frame	Door face
Heavy (entries, stairs public toilets, mech. rms.)	12, 14	16
Medium to low (rooms, closets, etc.)	14, 16, 20	18

___ *b.* Doors (total door construction of 16 to 22 GA)

Thickness	1¾″ and 1⅜″
Widths	2′ to 4′ in 2″ increments
Heights	6′8″, 7′, 7′2″, 7′10″, 8′, 10′

Costs: Frames: 3′ × 7′, 18 GA $8.00/SF (of opening) or 16 GA at $9.20/SF (60% M and 40% L), can vary ±40%.

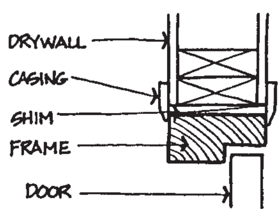
Doors: 3′ × 7′, 20 GA, 1¾″: $17.50/SF (85% M and 3′ × 6′8″, 20 GA, 1⅜″: $16.80/SF 15% L).

Add: lead lining: $720/ea., 8″ × 8″ glass, $145/ea., soundproofing $35/ea., 3-hour $145/ea., ¾-hour $30/ea.

___ 4. *Wood Doors*

___ *a.* Types

___ (1) Flush
___ (2) Hollow core
___ (3) Solid core
___ (4) Panel (rail and stile)



___ *b.* Sizes
Thickness: 1¾″ (SC), 1⅜″ (HC)
Widths: 1′6″ to 3′6″ in 2″ increments
Heights: 6′, 6′6″, 6′8″, 6′10″, 7′

___ *c.* Materials (birch, lavan, tempered hardboard)

Flush	Panel
Hardwood veneer	#1: hardwood or pine for transp. finish
Premium: for transp. finish	#2: Doug fir plywood for paint
Good #3: For paint.	
Sound: (for paint only)	

___ *d.* Fire doors (with mineral composition cores) B and C labels.

Typical costs:

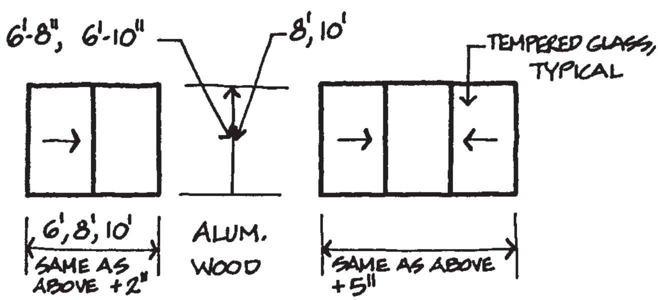
Wood frame: interior, pine: $4.80/SF (of opening)
exterior, pine: $9.35/SF
(triple costs for hardwoods)

Door: H.C. 1⅜″, hardboard $6.35/SF
S.C. 1¾″, hardboard $13.00/SF (75% M and 25% L)
Hardwood veneers about same costs.

For carved solid exterior doors, multiply costs by 4 to 6.

___ 5. *Other Doors*

___ *a.* Sliding glass doors



Typical costs (aluminum with ¼″ tempered glass):

$840 to $1080/ea. (85% M and 15% L)

12′ wide: $1465 to $2160/ea.

Add 10% for insulated glass.

__ *b.* Aluminum "storefront" (7′ ht. typical)

Typical cost with glass: $40/SF (85% M and 15% L). Variation of –25% to +55%.

__ *c.* Residential garage doors
8′ min. width/car (9′ recommended)
6′6″ min. height (7′2″ min. ceiling).

Costs: $34.50/SF (75% M and 25% L)

__ *d.* Folding doors
2 panels: 1′6″, 2′0″, 2′6″, 3′0″ openings
4 panels: 3′0″, 4′0″, 5′0″, 6′0″ openings
6 panels: 7′6″ opening
8 panels: 8′0″, 10′0″, 12′0″ openings

Costs: Accordion-folding closet doors with frame and trim: $27.60/SF

NOTES

___ B. WINDOWS (5) (17) (42) (60)

For costs, see p. 398.

___ 1. *General*

___ *a.* In common with walls, windows are expected to keep out:

- winter wind
- rain in all seasons
- noise
- winter cold
- winter snow
- bugs and other flying objects
- summer heat

They are expected, at the same time, to let in:

- outside views
- ventilating air
- natural light
- winter solar gain

___ *b.* Size designations: 3′ W × 6′ H = 3060

___ *c.* For types by operation, see p. 398.

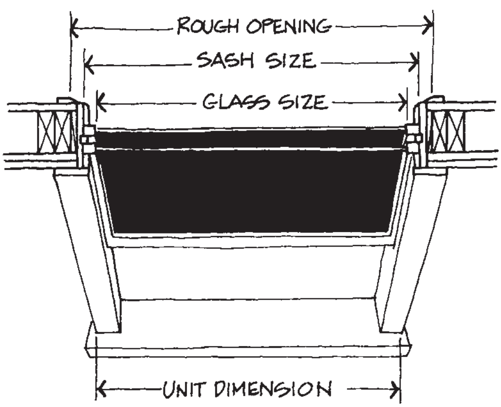
___ *d.* For aid to selection of type, see p. 396.

___ *e.* Windows come in aluminum, steel, and wood. See pp. 400 and 401 for typical sizes.

___ *f.* Fire-rated windows: see p. 122.

___ *g.* Energy conservation: Specify windows to not exceed 0.34 CFM per LF of operable sash crack for infiltration (or 0.30 CFM/SF). NFRC ratings:

U factor of .50 (0.25, better)
SHGC of .40

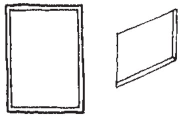
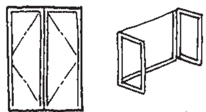
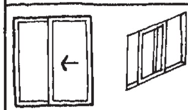


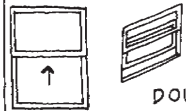
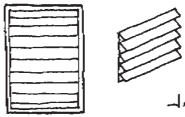
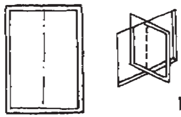
● INDICATES CHARACTERISTICS	WINDOW TYPES													
DISADVANTAGES	DOUBLE HUNG	DOUBLE HUNG, REVERSED	CASEMENT, OUT	CASEMENT, IN	AWNING, CANOPY	PIVOTED, VERTICAL	PIVOTED, HORIZONTAL	TOP HINGED, OUT	BOTTOM HINGED, IN	FIXED SASH	JALOUSIE	MONITOR, CONTINUOUS	PROJECTED	HORIZONTAL SLIDING
ONLY 50% OF AREA OPENABLE	●	●												●
DOESN'T PROTECT FROM RAIN, WHEN OPEN	●	●	●			●								●
INCONVENIENT OPER. IF OVER OBSTRUCTION	●	●					●	●						●
HAZ'D. IF LOW VENT NEXT TO WALK			●		●	●	●	●				●	●	
REQUIRES WEATHER STRIPPING	●	●	●	●		●	●	●	●					●
HORZ. MEMBERS OBSTRUCT VIEW	●	●			●		●				●	●	●	
VERT. MEMBERS OBSTRUCT VIEW			●	●										●
WILL SAG IF NOT STRUCTURALLY STRONG			●	●										
GLASS QUICKLY SOILS WHEN VENT OPEN					●		●	●	●		●	●	●	
INFLOWING AIR CANNOT BE DIVERTED DOWN	●	●	●		●	●		●	●		●		●	●
EXCESSIVE AIR LEAKAGE											●			
HARD TO WASH											●			
INTERFERES W/ FURNITURE, DRAPES, ETC.				●		●	●		●					
SCREENS-STORM SASH DIFFICULT TO PROV'D.						●	●							●
SASH HAS TO BE REMOVED FOR WASHING	●							●		●		●		●

○ INDICATES CHARACTERISTICS	WINDOW TYPES													
ADVANTAGES	DOUBLE HUNG	DOUBLE HUNG, REVERSED	CASEMENT, OUT	CASEMENT, IN	AWNING, CANOPY	PIVOTED, VERTICAL	PIVOTED, HORIZONTAL	TOP HINGED, OUT	BOTTOM HINGED, IN	FIXED SASH	JALOUSIE	MONITOR, CONTINUOUS	PROJECTED	HORIZONTAL SLIDING
NOT APT TO SAG	●	●			●	●	●	●	●	●		●		●
SCREEN & STORM SASH EASY TO INSTALL	●	●		●	●			●						●
PROVIDES 100% VENT OPENING			●	●	●	●	●	●	●		●	●		
EASY TO WASH W/ PROPER HARDWARE		●		●		●	●		●					
WILL DEFLECT DRAFTS			●	●	●	●	●		●		●	●		
OFFERS RAIN PROTECTION, PARTLY OPEN					●		●	●	●		●	●	●	
DIVERTS INFLOWING AIR UPWARD					●		●		●		●	●	●	
ODD SIZES ECONOMICALLY AVAILABLE											●			●
LARGE SIZES PRACTICAL										●				●

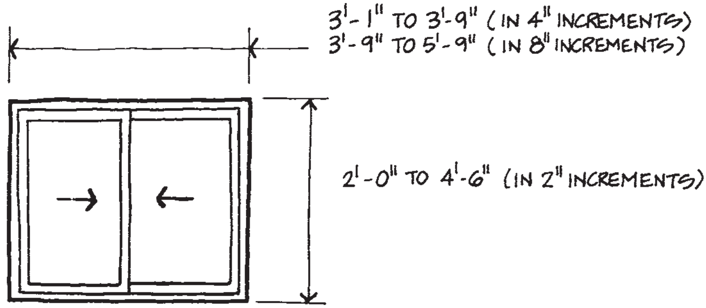
WINDOW TYPES BY OPERATION AND MATERIAL & COSTS

NOTE: GLASS EXCLUDED IN COSTS * (90% M & 10% L)

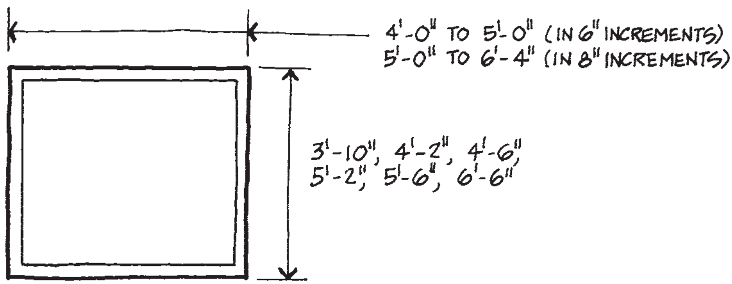
TYPE	VENT	ALUMINUM	STEEL	WOOD
 FIXED	0%	$18.35/SF AVE. (70% M & 30% L) VARIATION ± 7%	$25/SF AVE.	$34.50/SF AVE. * VARIATION -10% +20% PICTURE WINDOW
 CASEMENT	100%		$25 TO $35/SF AVE. (85% M & 15% L)	$50/SF AVE * VARIATION +70%, -40%
PROJECTED  AWNING  HOPPER	50 TO 100%	$33.50 TO $40.80/SF AVE. (75% M & 25% L)	$35 TO $40/* SF AVE.	$55/SF AVE. (85% M & 15% L) VARIATION +60%, -40%
 SLIDING	50 TO 100%	$25 TO $26/SF AVE. (80% M & 20% L)		$35/SF AVE. VARIATION ± 60%

 DOUBLE-HUNG	50%	$25.50 TO $28.20/ SF AVE. *	$47/SF AVE *	$41.00/SF AVE. (85%M & 15%L) VARIATION +70%, -45%
 JALOUSIE	100%	$27.60/SF AVE. (80% M & 20%L)		
 PIVOTING	100%		$27.60/SF AVE. (85% M & 15%L)	

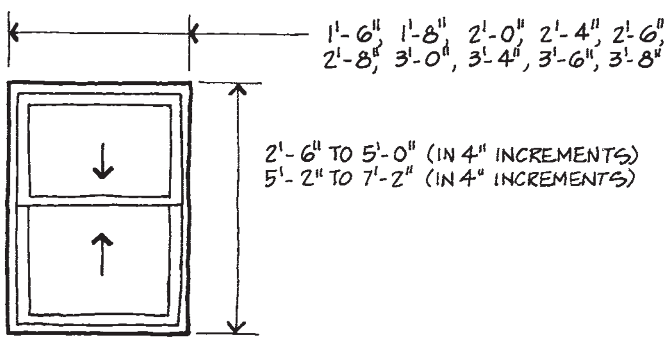
TYPICAL WOOD WINDOW SASH SIZES



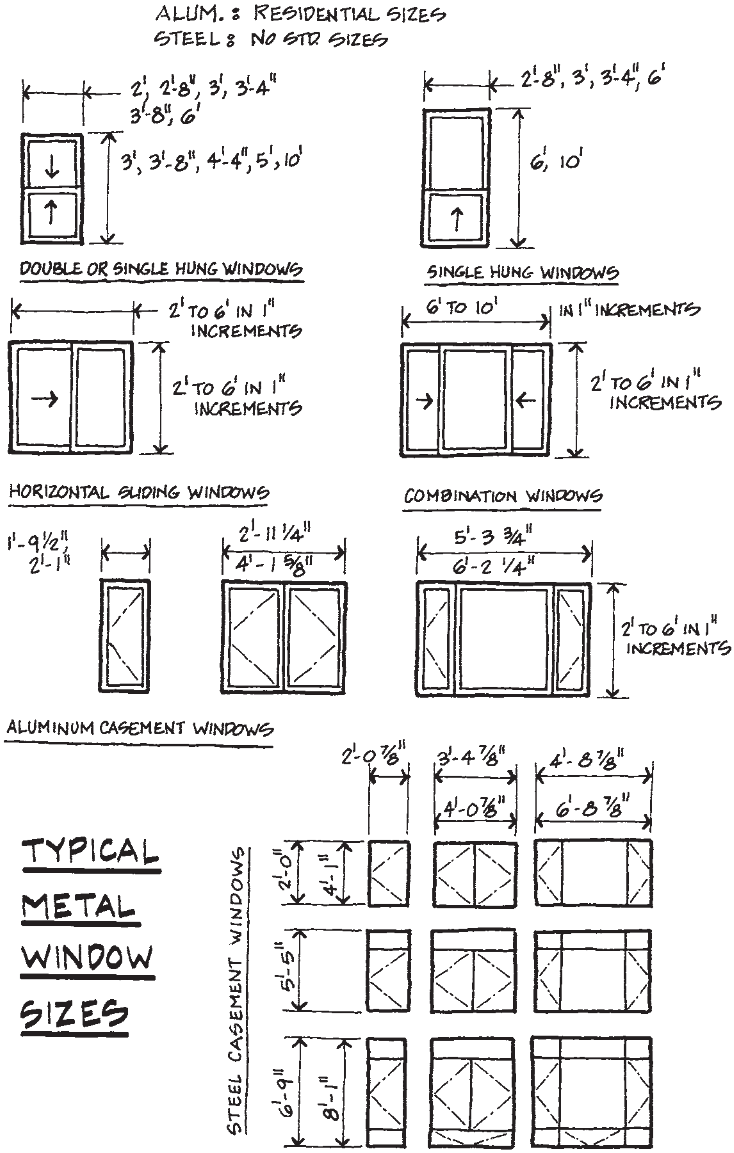
HORIZONTAL SLIDING WINDOWS



PICTURE WINDOWS



DOUBLE HUNG WINDOWS

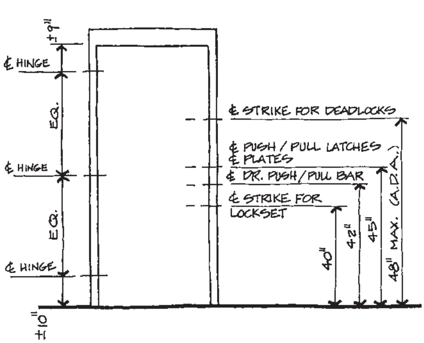

ALUM. : RESIDENTIAL SIZES
STEEL : NO STD SIZES
2', 2'-8", 3', 3'-4"
3'-8", 6'
3', 3'-8", 4'-4", 5', 10'
DOUBLE OR SINGLE HUNG WINDOWS
2'-8", 3', 3'-4", 6'
6', 10'
SINGLE HUNG WINDOWS
2' TO 6' IN 1" INCREMENTS
2' TO 6' IN 1" INCREMENTS
HORIZONTAL SLIDING WINDOWS
6' TO 10' IN 1" INCREMENTS
2' TO 6' IN 1" INCREMENTS
COMBINATION WINDOWS
1'-9½", 2'-1"
2'-11¼"
4'-1⅝"
5'-3¾"
6'-2¼"
2' TO 6' IN 1" INCREMENTS
ALUMINUM CASEMENT WINDOWS
TYPICAL METAL WINDOW SIZES
STEEL CASEMENT WINDOWS
2'-0⅞"
3'-4⅞"
4'-0⅞"
4'-8⅞"
6'-8⅞"
2'-0"
4'-1"
5'-5"
6'-9"
8'-1"

NOTES

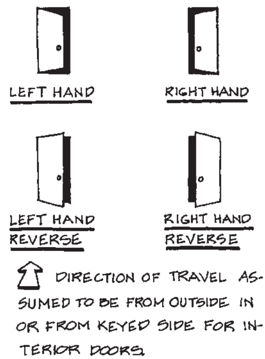
___ C. HARDWARE (17) (27)

___ **1. General Considerations:** How to . . .
- ___ *a.* Hang the door
- ___ *b.* Lock the door
- ___ *c.* Close the door
- ___ *d.* Protect the door
- ___ *e.* Stop the door
- ___ *f.* Seal the door
- ___ *g.* Misc. the door
- ___ *h.* Electrify the door

___ **2. Recommended Locations**



___ **3. Door Hand Conventions**



___ **4. Specific Considerations**
- ___ *a.* Function and ease of operation
- ___ *b.* Durability in terms of:
  - ___ (1) Frequency of use
    - ___ (*a*) Heavy
    - ___ (*b*) Medium
    - ___ (*c*) Light
  - ___ (2) Exposure to weather and climate (aluminum and stainless steel good for humid or coastal conditions)
- ___ *c.* Material, form, surface texture, finish, and color.

___ **5. Typical Hardware**
- ___ *a.* Locksets (locks, latches, bolts)
- ___ *b.* Hinges
- ___ *c.* Closers
- ___ *d.* Panic hardware
- ___ *e.* Push/pull bars and plates

- ___ *f.* Kick plates
- ___ *g.* Stops and holders
- ___ *h.* Thresholds
- ___ *i.* Weatherstripping
- ___ *j.* Door tracks and hangers

___ **6. Materials**

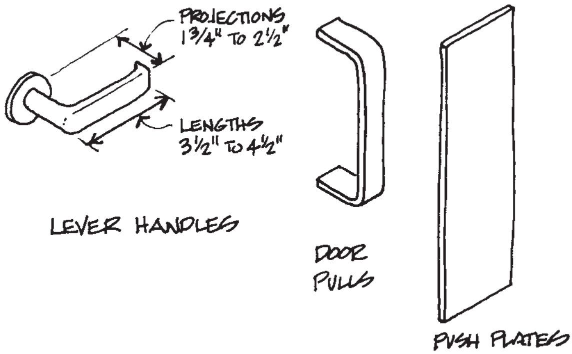
- ___ *a.* Aluminum
- ___ *b.* Brass
- ___ *c.* Bronze
- ___ *d.* Iron
- ___ *e.* Steel
- ___ *f.* Stainless steel

___ **7. Finishes**

BHMA #	US #	Finish	Base material
___ 600	US P	Primed for painting	Steel
___ 601	US 1B	Bright japanned	Steel
___ 602	US 2C	Cadmium plated	Steel
___ 603	US 2G	Zinc plated	Steel
___ 605	US 3	Bright brass, clear coated	Brass*
___ 606	US 4	Satin brass, clear coated	Brass*
___ 611	US 9	Bright bronze, clr. coat	Bronze*
___ 612	US 10	Satin bronze, clear coated	Bronze*
___ 613	US 10B	Oxidized satin bronze, oil rubbed	Bronze*
___ 618	US 14	Bright nickel plated, clear coated	Brass, Bronze*
___ 619	US 15	Satin nickel plated, clear coated	Brass, Bronze*
___ 622	US 19	Flat black coated	Brass, Bronze*
___ 624	US 20A	Dark oxidized statuary bronze, clr. coat	Bronze*
___ 625	US 26	Bright chromium plated	Brass, Bronze*
___ 626	US 26D	Satin chromium plated	Brass, Bronze*
___ 627	US 27	Satin aluminum, clr. coat	Aluminum
___ 628	US 28	Satin aluminum, clear anodized	
___ 629	US 32	Bright stainless steel	
___ 630	US 32D	Satin stainless steel	
___ 684	—	Black chrome, bright	Brass, Bronze*
___ 685	—	Black chrome, satin	Brass, Bronze*

*Also sometimes applicable to other base materials.

__ 8. ADA-Accessible Hardware



__ 9. Costs:

Residential: **$115/door (80% M and 20% L)**
Variation −30%, +120%

Commercial:

Office:

Interior: **$235/door (75% M and 25% L)**

Exterior: **$450/door (add ≈ $510 for exit devices)**

Note: Special doors, such as for hospitals, can cost up to $685/door

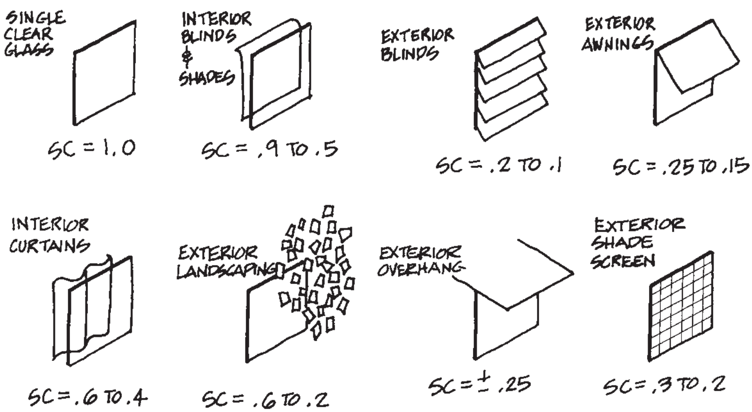
NOTES

___ D. GLASS (34) (60)

___ **1. *General:*** Glass is one of the great modern building materials because it allows the inside of buildings to have a *visual relationship* with the outside. However, there are a number of *problems to be overcome:*

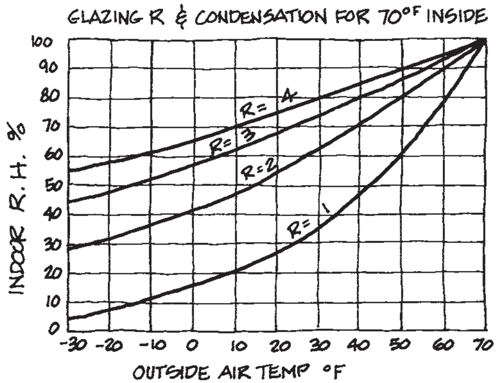
___ **2. Energy:** Because more *heat flows through glass than any other building material,* it must be sized and located carefully. See p. 184.

___ *a.* Solar: When *heating is needed,* glass can be used on south sides to help. See p. 185. When *heating is to be avoided,* it is best to place glass on north or south sides, avoiding the east and west. The *shading coefficient* (SC) is the ratio of the total solar heat gain to that of ⅛″ clear glass. 1.0 is no shade, so the lower the number the better. The shading coefficient is approx. equal to the SHGC × 1.15. The solar heat gain coefficient (SHGC) has replaced the SC as the standard indicator of shading ability. SHGC is the fraction of all solar radiation released inside. It is expressed as between 0 and 1, with the lower having more shading ability.

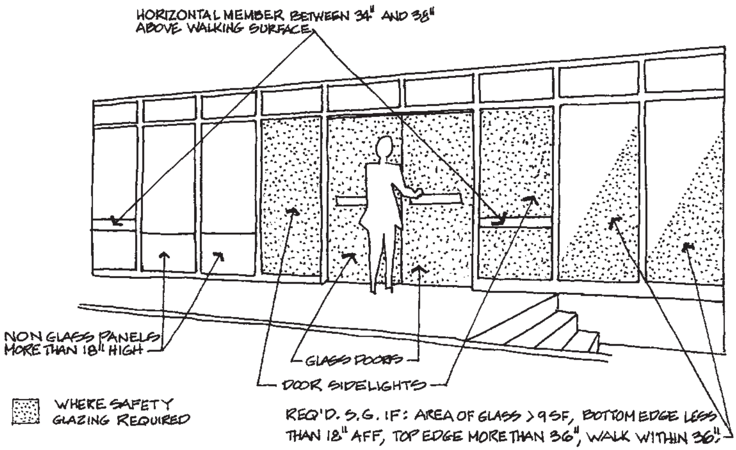


___ *b.* Conduction/convection heat flow: Also transfers heat, since glass is a poor insulator. See p. 368.

___ 3. **Condensation:** As room air comes in contact with cold glass, it drops in temperature, depositing excess water vapor on the surface as liquid condensate. Use the following graph to select glazing to avoid this:



___ 4. **Legal Requirements:** The IBC requires *safety glazing* at locations hazardous to human impact. Safety glazing is *tempered glass, wired glass,* and *laminated glass.* Hazardous locations are:



SAFETY GLAZING

___ *a.* Glazing in swinging doors (except jalousies)
___ *b.* Sliding and bifold doors
___ *c.* Storm doors
___ *d.* At doors and enclosures (where bottom of glass is less than 60″ AFF and 60″ from water edge) for hot tubs, whirlpools, saunas, steam rooms, bathtubs, and showers
___ *e.* Glazing adjacent to doors within 24″; also at less than 60″ AFF (except where there is a perpendicular wall between the door and glass, and at R-2 occ., in walls perpendicular to door)
___ *f.* Glass panels where (all conditions apply):
  ___ (1) Pane greater than 95F
  ___ (2) Bottom less than 18″ AFF
  ___ (3) Top greater than 36″ AFF
  ___ (4) Walking surface within 36″ of glass
  (Except a rail at walking side at 34″ to 38″ AFF)
  (Except outer pane of insulating glass at 25′ or more above adj. surface (walk, roof, etc.)
___ *g.* Railings
___ *h.* Glass adjacent to stairways, landings, and ramps, where:
  ___ (1) Within 36″ of walking surface
  ___ (2) Within 60″ of bottom tread
  ___ (3) Bottom less than 60″ or nose of tread walking surface

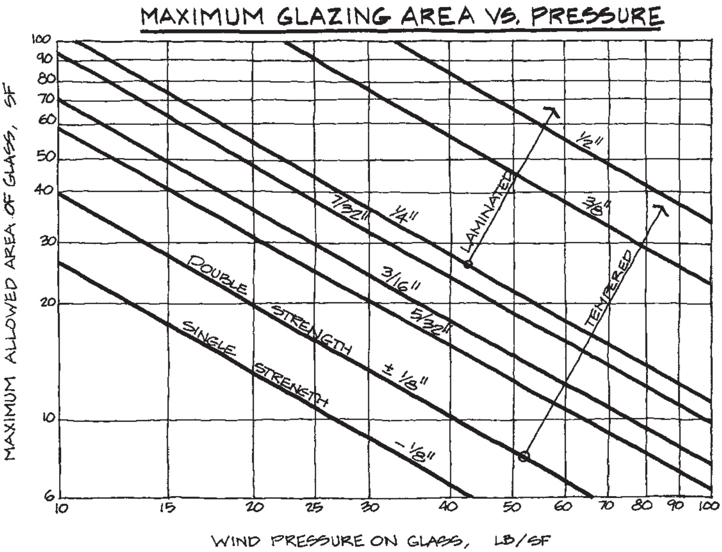
___ 5. **Sizing of Glass**
___ *a.* Determine wind speeds at site by consulting App. B, item S. Convert to pressure:

Wind pressure at 33′ height

Wind (MPH)	70	80	90	100	110	120	130
Pressure (PSF)	12.6	16.4	20.8	25.6	31.0	36.9	43.3

__ *b.* Multiply results by the following factors:
  __ (1) For low, normal, open sites: 1.5
  __ (2) For high, windy, or gusty sites: 3.0

__ *c.* Select glass size from below:



__ **6. Costs:**

¼″ clear float glass: $8.40 to $10.80/SF (45% M and 55% L)

Modifiers:

Thickness:

⅛″ glass	**−30%**
⅜″ glass	**+40%**
½″ glass	**+110%**

Structural:

Tempered	**+20%**
Laminated	**+100%**

Thermal:

Tinted or reflective	**+20%**
Double-glazed and/or low E	**+100%**

EXAMPLE:

PHOENIX, AZ, S = 75 MPH (SEE APP. B, ITEM 6, ON P. 641) EQUALS ≈ 13.25 PSF. FOR NORMAL SITE : 1.5 × 13.25 = 20 PSF.

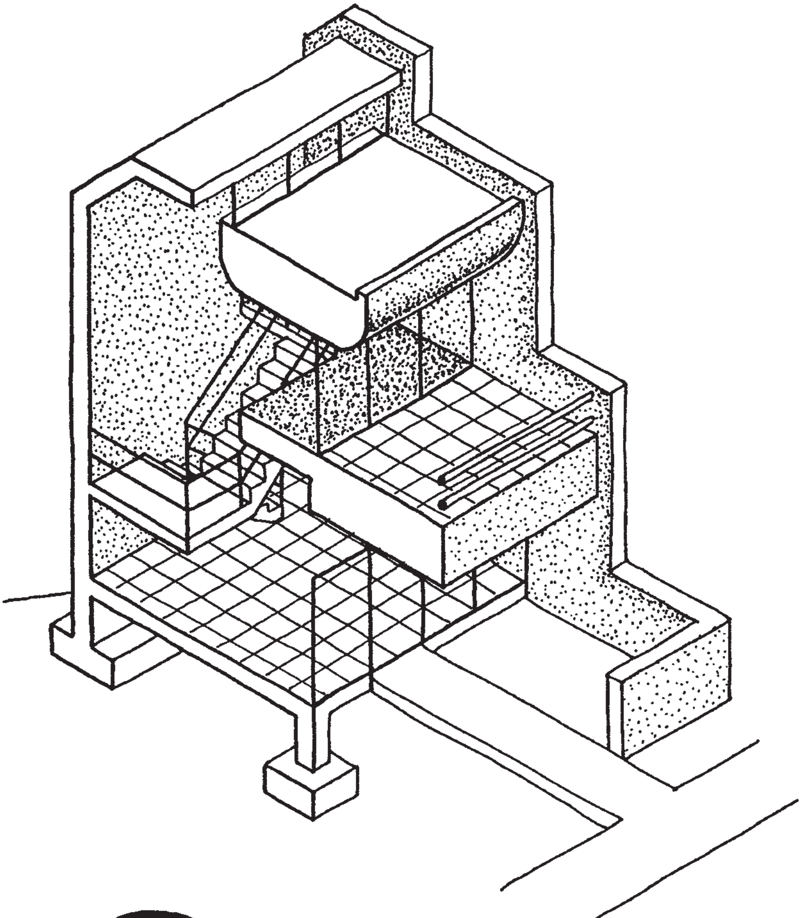
COULD USE : 55 SF OF 1/4" GLASS, OR
20 SF OF DS GLASS, OR
15 SF OF SS GLASS

___ 7. Typical Glazing Characteristics

Glazing type	R value	Shade coef.	Vis. trans. (%)	Perf. index	SHGC
___ Single-Glazed (SG), clr.	0.90	1.00	90	0.90	0.86
___ SG gray-tinted	″	0.69	43	0.62	
___ SG bronze-tinted	″	0.71	52	0.73	
___ SG green-tinted	″	0.71	75	1.09	
___ SG reflective	″	0.51	27	0.53	
___ SG low-E, clear	1.40	0.74	84	1.14	
___ SG low-E, gray	″	0.50	41	1.82	
___ SG low-E, bronze	″	0.52	49	0.94	
___ SG low-E, green	″	0.56	71	1.27	
___ Double-Glazed (DG), clr.	2.00	0.84	80	0.95	0.76
___ DG gray-tinted	″	0.85	39	0.69	
___ DG bronze-tinted	″	0.59	47	0.80	0.62
___ DG green-tinted	″	0.60	68	1.13	
___ DG reflective	″	0.42	26	0.62	
___ DG low-E, clear	3.12	0.67	76	1.13	0.74
___ DG low-E, gray	″	0.42	37	0.88	
___ DG low-E, bronze	″	0.44	44	1.00	
___ DG low-E, green	″	0.47	64	1.36	
___ DG polyfilm, clear	4.5	0.42	53	1.26	
___ DG polyfilm, gray	″	0.27	26	0.96	
___ DG polyfilm, bronze	″	0.29	32	1.10	
___ DG polyfilm, green	″	0.29	45	1.55	
___ DG spectrally selective	4.17	0.47	72	1.53	0.41
___ Triple-Glazed (TG), clr.	3.22	0.81	75	0.93	0.69
___ TG, low-E	9.09	0.57	68	1.19	0.49

Note: Performance Index ("Coolness Index") = Visual Transmission/Shading Coefficient. The higher the number the better.

NOTES

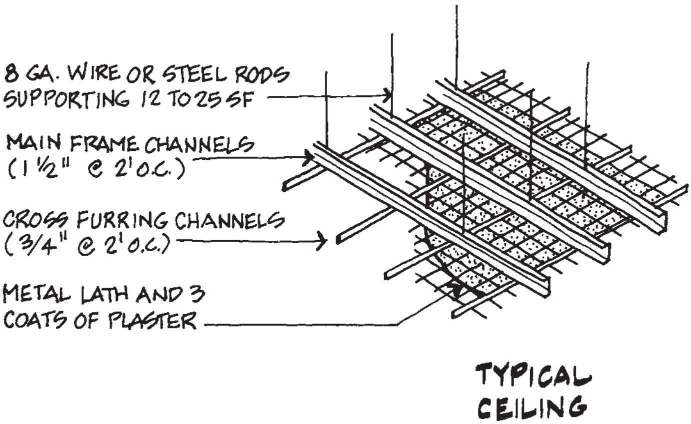


9 FINISHES

NOTES

___ A. PLASTER

Note: For EIFS, see p. 372.



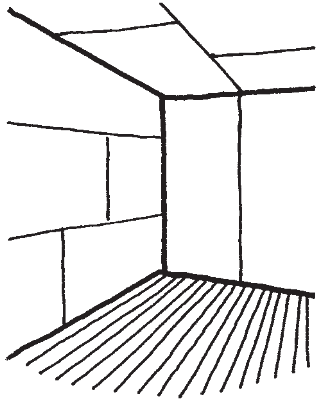
___ 1. **Exterior** (stucco) of cement plaster.
___ 2. **Interior** of gypsum plaster.
___ 3. **Wall supports** usually studs at between 12″ and 24″ oc. If wood, use 16″ oc min.
___ 4. **Full plaster**—3 coats (scratch brown, and finish), but walls of masonry can have 1 or 2 coats.
___ 5. **Joints:** Interior ceilings: 30′ oc max.
Exterior walls/soffits: 10′ to 20′ oc.
___ 6. **Provide vents** at dead air spaces (½″/SF).
___ 7. **Curing:** 48 hrs moist curing, 7 days between coats.

Costs:

Ceilings with paint, plaster, and lath	**$2.40 to $7.80/SF (25% M and 75% L), can vary up to +60% for plaster**
Walls of stucco with paper-backed wire lath	**$2.65/SF for stucco + $1.20/SF for lath (50% M and 50% L)**

__ B. GYPSUM WALLBOARD (DRYWALL)

(4) (12)



__ 1. **Usually in 4′ × 8′** (or 12′) sheets from ¼″ to 1″ thick in about ⅛″ increments.

__ 2. **Attach** (nail or screw) against wood or metal framing—usually at 16″ (fire rating) to 24″ oc.

__ 3. **Type "X", ⅝″** will give 1 hr. fire rating. Roughly each additional ½″ layer will give 1 hr. rating up to 4 hours, depending on backing and application.

__ 4. **Water-resistant** (green) available for wet areas or exterior.

For exterior soffit venting, see p. 363.

Costs:

½″ gyp. bd.	**$.80/SF ceilings**
on wood	**$1.20/SF columns and beams**
frame	**$.80/SF walls**
(Approx. 50% M and 50% L)	

Increase 5% for metal frame. Varies about 15% in cost for ⅛′ ea. thickness. Add $.10/SF for fire resistance. Add $.17/SF for water resistance. Add $.50/SF for joint work and finish.

EXAMPLE:

FIND THE COST OF 5/8" GYPB'D. WALL ON FRAME, READY FOR PAINT.

1/2" = $0.80/SF (WALL) + .10¢ (15% FOR EXTRA 1/8" THICKNESS) + $0.50 FOR FINISH.

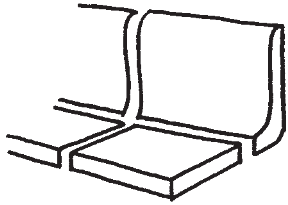
∴ 5/8" = $1.40 /SF, SAY $1.40/SF

___ C. TILE (4) (12)

___ 1. **Settings**

___ *a.* Thick set (¾″ to 1¼″ mortar bed) for slopes.

___ *b.* Thin set (⅛″ mortar or adhesive) for faster and less expensive applications.



___ 2. **Joints:** ⅛″ to ¼″ (can be epoxy grouted for quarry tile floors).

___ 3. **Types**

___ *a.* Ceramic glazed and unglazed for walls and floors of about ¼″ thick and 4–6″ SQ. Many trim shapes available.

___ *b.* Ceramic mosaic for walls and floors of about ¼″ thick and 1″ to 2″ SQ.

___ *c.* Quarry tile of earth tones for strong and resistant flooring. Usually ½″ to ¾″ thick by 4″ to 9″ SQ.

Typical Costs:

Note: Costs can vary greatly with special imports of great expense.

Glazed wall tile: $7.10/SF (50% M and 50% L), variation of –25%, +100%

Unglazed floor mosaic: $10.65/SF (65% M and 35% L), variation of +35%, –10%

Unglazed wall tile: $7.90/SF (40% M and 60% L), variation of +35%, –15%

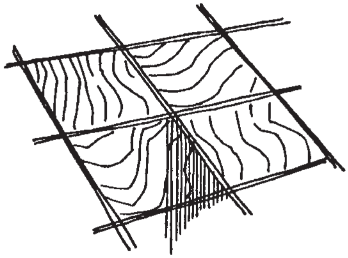
Quarry tile: $11.65/SF (same as above), variation of ±10%

Bases: $11.65/LF (same as above), variation of ±10%

Additions: color variations: +10 to 20%
abrasive surface: +25 to 50%

___ D. TERRAZZO (4) (12)

___ 1. **A poured material** (usually ½″ thick) of stone chips in a cement matrix, usually with a polished surface.



___ 2. **Base of sand** and concrete.

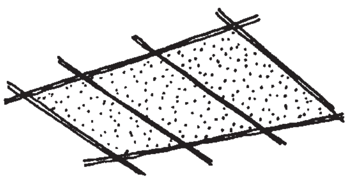
___ 3. **To prevent cracking,** exposed metal dividers are set approx. 3′ to 6′ oc each way.

___ 4. **Newer, high-strength terrazzo** (with chemical binders) is thin set with far less jointing. Can also come in tile pavers of about 1″ thick × 9″ SQ to 2′ SQ.

Costs: $13.50/SF to $18.00/SF (45% M and 55% L)
Tiles: $20.50 to $33.50/SF

___ E. ACOUSTICAL TREATMENT (4) (12)

___ 1. **Acoustical Ceilings:** Can consist of small (¾″ thick × 1′ SQ) mineral fiber tiles attached to wallboard or concrete (usually glued). Also, acoustical mineral fibers with a binder can be shot on gypsum board or concrete.



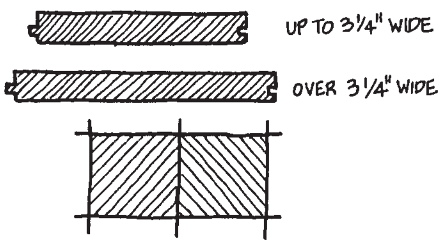
Costs: Small tiles $1.30 to $1.80/SF (40% M and 60% L)

___ 2. **Suspended Acoustical Tile Ceilings:** Can be used to create a plenum space to conceal mechanical and electrical functions. Typical applications are 2′ SQ or 2′ × 4′ tiles in exposed or concealed metal grids that are wire-suspended as in plaster ceilings. The finishes can vary widely.

Costs: Acoustical panels $1.20 to $2.40/SF (70% M and 30% L)
Suspension system $1.20 to $1.50/SF (80% M and 20% L)
When walls do *not* penetrate ceilings, can save $0.10 to $0.25/SF.

___ F. WOOD FLOORING (4) (12)

___ 1. **See p. 356 for structural decking.**
___ 2. **Finished flooring can be of hardwoods or softwoods,** of which oak, southern pine, and Douglas fir are the most commonly used.
___ 3. **All-heartwood grade of redwood** is best for porch and exterior flooring.
___ 4. **If substrate is concrete,** often flooring is placed on small wood strips (sleepers); otherwise flooring is often nailed to wood substrates (plywood or wood decking).
___ 5. **Because wood is very susceptible to moisture,** allowance must be made for movement and ventilation. Allow expansion at perimeters. Vapor barriers below concrete slabs are important.
___ 6. **Use treated material in hot,** humid climates.
___ 7. **Three types of wood flooring:**
  ___ *a.* Strip
  ___ *b.* Plank
  ___ *c.* Block (such as parque)



Typical Costs:

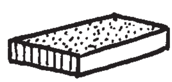
Wood strip fir $6.00/SF (70% M and 30% L)
Oak +90% +10% finish
Maple +100% clean and wax = $0.40/SF

___ G. MASONRY FLOORING (4) (12)

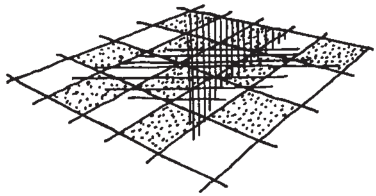
See Part 4 on materials.

Typical Costs:

1¼″ × 4″ × 8″ brick: $11.00/SF
(65% M and 35% L)
Add 15% for special patterns.



___ H. RESILIENT FLOORING (4) (12)



___ **1. Consists of sheets** or tiles of vinyl, cork, rubber, linoleum, or asphalt with *vinyl* the most commonly used.

___ **2. Is approx. 1/16″ to 1/8″** thick with tiles being 9″ SQ to 12″ SQ.

___ **3. Applied to substrate with mastic.** Substrate may be plywood flooring, plywood or particleboard over wood deck, or concrete slabs.

___ **4. *Vapor barriers*** often required under slabs.

___ **5. *Vinyl base*** is often applied at walls for this and other floor systems.

A wide range of colors and patterns is available for flooring.

Typical Costs:

Solid vinyl tile 1/8 × 12 × 12	**$3.60/SF (75% M and 25% L), can go up 20% for various patterns and colors; double for "conductive" type.**
Sheet vinyl	**$3.30/SF (90% M and 10% L), variation of −70% and +100% due to various patterns and colors.**
Vinyl wall base	**$2.10/LF (40% M and 60% L). Can vary +15%.**
Stair treads	**$9.60/LF (60% M and 40% L). Can vary from −10% to +40%.**

___ I. CARPETING (J) (5) (60)

___ **1. Most wall-to-wall carpeting** is produced by looping yarns through a coarse-fiber backing, binding the backs of the loops with latex, then applying a second backing for strength and dimensional stability. Finally the loops may be left uncut for a rough, nubby surface or cut for a soft, plush surface.

___ **2. The quality of carpeting** is often determined by its *face weight* (ounces of yarn or pile per square yard), not its total weight. Weights run:

- ___ *a.* Low traffic: 20–24 oz/SY
- ___ *b.* Medium traffic: 24–32 oz/SY
- ___ *c.* High-end carpet: 26–70 oz/SY

___ **3. A better measure of comparison:**

$$\textit{weight density factor} = \frac{\text{face weight} \times 36}{\text{pile height}} = \text{oz/CY}$$

Ideally, this should be as follows:

- ___ *a.* Residential: 3000 to 3600 oz/CY
- ___ *b.* Commercial: 4200 to 7000 oz/CY

___ **4. Flame spread:** see p. 446.

___ **5. There are two basic carpet installation methods:**

- ___ *a.* *Padded and stitched* carpeting: Stretched over a separate pad and mechanically fastened at joints and the perimeter. Soft foam pads are inexpensive and give the carpet a soft, luxurious feel. The more expensive jute and felt pads give better support and dimensional stability. Padding adds to foot comfort, helps dampen noise, and some say, adds to the life of the carpet.
- ___ *b.* *Glued-down* carpets: Usually used in commercial areas subject to heavily loaded wheel traffic. They are usually glued down with carpet adhesive with a pad. This minimizes destructive flexing of the backing and prevents rippling.

___ **6. Maintenance Factors**

- ___ *a.* Color: Carpets in the midvalue range show less soiling than very dark or very light colors. Consider the typical regional soil color. Specify patterned or multicolored carpets for heavy traffic areas in hotels, hospitals, theaters, and restaurants.
- ___ *b.* Traffic: The heavier the traffic, the heavier the density of carpet construction. If rolling traffic is a factor, carpet may be of maximum density for minimum resistance to rollers. Select only level-loop or dense, low-cut pile.

__ 7. Carpet Materials:

Fiber	Advantages	Disadvantages
Acrylic (rarely used)	Resembles wool	Not very tough; attracts oily dirt
Nylon (most used)	Very tough; resists dirt, resembles wool; low-static buildup	None
Polyester deep pilings	Soft and luxurious	Less resilient; attracts oily dirt
Polypropylene indoor-outdoor	Waterproof; resists fading and stains; easy to clean	Crushes easily
Wool	Durable; easy to clean; feels good; easily dyed	Most expensive

__ 8. **Costs: (90% M and 10% L) (Variation ±100%)** **See p. 461 for interiors wholesale/retail advice.** **Figure 10% waste.**

Repair/level floors: $2.15 to $8.00/SY (45% M and 55% L)

Padding
Sponge: $7.40/SY (70% M and 30% L) Variation ±10%
Jute: –10%
Urethane: –25%

Carpet
Acrylic, 24 oz, med. wear: $27.10/SY
28 oz, med./heavy: $33.60/SY

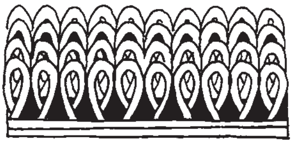
Residential
Nylon, 15 oz, light traffic: $19.50/SY
28 oz, med. traffic: $23.75/SY

Commercial
Nylon, 28 oz, med. traffic: $25.00/SY
35 oz, heavy: $29.50/SY
Wool, 30 oz, med. traffic: $49.50/SY
42 oz, heavy: $54.00/SY

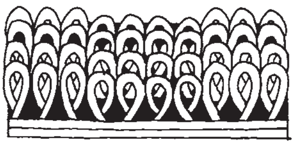
Carpet tile: $3.30 to $6.60/SY

CARPET TYPES

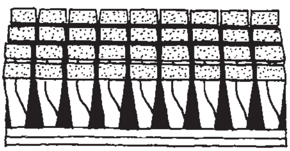
TYPE OF WEAVE — CHARACTERISTICS AND BEST USES



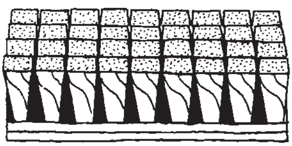
LEVEL LOOP : EVEN HEIGHT, TIGHTLY SPACED UN-CUT LOOPS. TEXTURE IS HARD AND PEBBLY. HARD WEARING AND EASY TO CLEAN. IDEAL FOR OFFICES AND HIGH TRAFFIC AREAS.



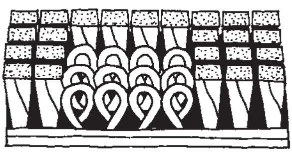
MULTI-LEVEL LOOP : UNEVEN HEIGHT IN PATTERNS, TIGHTLY SPACED UNCUT LOOPS. TEXTURE IS HARD & PEBBLY. HARD-WEARING & EASY TO CLEAN. IDEAL FOR OFFICES AND HIGH TRAFFIC AREAS.



PLUSH 'CUT' PILE : EVENLY CUT YARNS WITH MINIMAL TWIST. EXTREMELY SOFT, VELVETY TEXTURE. VACUUMING AND FOOTPRINTS APPEAR AS DIFFERENT COLORS, DEPENDING ON LIGHT CONDITIONS. IDEAL FOR FORMAL ROOMS W/ LIGHT TRAFFIC.



FRIEZE 'CUT' PILE : EVENLY CUT YARNS WITH TIGHT TWIST. EXTREMELY SOFT, VELVETY TEXTURE. VACUUMING AND FOOTPRINTS AP-PEAR AS DIFFERENT COLORS, DEPENDING ON LIGHT CONDITIONS. IDEAL FOR FORMAL RM'S WITH LIGHT TRAFFIC.



CUT AND LOOP : COMBINATION OF BOTH PLUSH AND LEVEL-LOOP. HIDES DIRT FAIRLY WELL. IDEAL FOR RESIDENTIAL APPLICATIONS.

INDOOR-OUTDOOR : CUT, TIGHTLY TWISTED YARNS THAT TWIST UPON THEMSELVES. TEXT-URE IS ROUGH. HIDES DIRT EXTREMELY WELL AND IS NEARLY AS TOUGH AS LEVEL-LOOP. IDEAL FOR RESIDENTIAL APPLICATIONS.

___ J. PAINT AND COATINGS (R) (T) (17) (60)

___ 1. *General*

- ___ *a.* Paints and coatings: are liquids (the "vehicle") with pigments in suspension, to protect and decorate building surfaces.
- ___ *b.* Applications: brushed, rolled, sprayed
- ___ *c.* Failures: 90% are due to either moisture problems or inadequate preparation of surface.
- ___ *d.* Surface Preparation:
  - ___ (1) Wood: Sand if required; paint immediately.
  - ___ (2) Drywall: Let dry (0 to 7 days). If textured surface is required, prime prior to texturing.
  - ___ (3) Masonry and stucco: Wait for cure (28 days).
- ___ *e.* Qualities:
  - ___ (1) Thickness
    - ___ (*a*) Primers (and "undercoats"): ½ to 1 dry mills/coat.
    - ___ (*b*) Finish coats: 1 to 1½ dry mills/coat.
  - ___ (2) Breathability: Allowing vapor passage to avoid deterioration of substrate and coating. Required at (see p. 365):
    - ___ (*a*) Masonry and stucco: 25 perms
    - ___ (*b*) Wood: 15 perms
    - ___ (*c*) Metals: 0 perms
- ___ *f.* Paint Surfaces:
  - ___ (1) Flat: Softens and distributes illumination evenly. Reduces visibility of substrate defects. Not easily cleaned. Usually used on ceilings.
  - ___ (2) Eggshell: Provides most of the advantages of gloss without glare.
  - ___ (3) Semigloss
  - ___ (4) Gloss: Reflects and can cause glare, but also provides smooth, easily cleanable, nonabsorbtive surface. Increases visibility of substrate defects.
- ___ *g.* Legal Restrictions:
  - ___ (1) Check state regulations on paints for use of volatile organic compounds (VOC), use of solvents, and hazardous waste problems.
  - ___ (2) Check fire department restrictions on spraying interiors after occupancy or during remodelling.

___ 2. Material Types

- ___ *a.* Water-repellent preservatives: For wood.
- ___ *b.* Stains: Solid (opaque), semitransparent, or clear.
- ___ *c.* Wood coatings: Varnish, shellac, lacquers.
- ___ *d.* Wood primer-sealer: Designed to prevent bleeding through of wood resin contained in knots and pitch pockets, and to seal surface for other coatings. Usually apply 2 coats to knots. Since primer-sealer is white, cannot be used on clear finishes.
- ___ *e.* Latex primer: Best first coat over wallboard, plaster, and concrete. Adheres well to any surface except untreated wood.
- ___ *f.* Alkyd primer: Used on raw wood. Latex "undercoats" can also be used.
- ___ *g.* CMU filler: A special latex primer for reducing voids and to smooth surface on masonry. Does not waterproof.
- ___ *h.* Latex paint: A synthetic, water-based coating, this is the most popular paint because it complies with most environmental requirements, is breathable, and cleans up with water. Use for almost all surfaces including primed (or undercoated) wood. Adheres to latex and flat oils. Avoid gloss oils and alkyds other than primers. Subdivided, as follows:
  - ___ (1) Polyvinyl acetate (PVA): Most commonly used. Provides 25+ perms.
  - ___ (2) Acrylic: Smoother, more elastic, more durable, often used as a primer. Provides less than 5 perms.
- ___ *i.* Alkyd paint: A synthetic semisolvent-based coating, replacing the old oils. This seems to be going out of use due to environmental laws. Used for exterior metal surfaces. Not breathable.

___ 3. Paint Systems and Costs **(30% M and 70% L) The following was developed for the SW U.S. Add 10% for the rest of the country.**

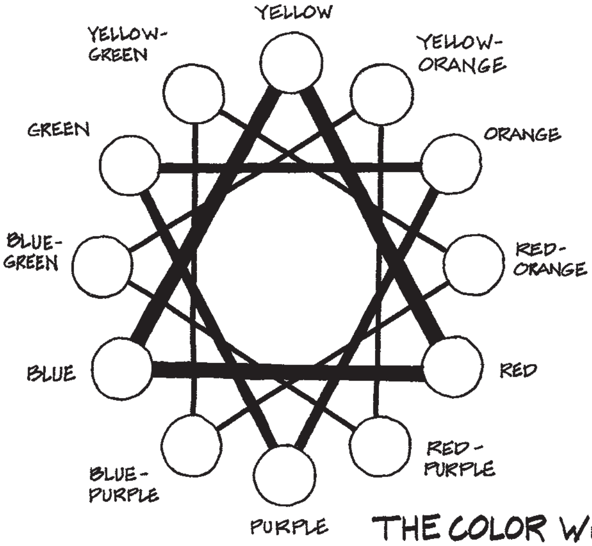
<u>Comparison of Paint Finish Systems</u>: ICI Paints

T

Product Type	Applied Cost per sq. ft.	Areas of Use	Benefits	Liabilities
<u>Interior</u>: (premium finishes)				
Latex Flat Wall Paint (GWB = 2 coats)	30¢ - 35¢	Any interior surface where a flat appearance is desired.	Almost unlimited color selection, washable, low odor, dries fast, excellent touch-up and coverage.	Flats are considered washable but not scrubbable(like enamels).
Latex Eggshell Enamel (1 coat primer, 2 coats finish)	40¢ - 50¢	Where a slightly higher sheen is desired instead of a flat.	Same as flat, but more durable and scrubbable than a flat with greater moisture resistance; best quality eggshell enamels have good "block resistance".	More scrubbable than a flat, but less durable than a higher sheen.
Latex Semi-Gloss Enamel (1 coat primer, 2 coats finish)	40¢ - 50¢	Kitchens, bathrooms, doors and trim, cabinets, etc., wherever a medium sheen is needed.	Same as flat, but another step up in durability, scrubbability and moisture resistance compared to a lower sheen product; best quality semi-gloss enamels have good "block resistance".	Increased scrubbability over any lower sheen product, but not as durable as higher sheens. (Note: As sheens rise, hiding is reduced.)
Latex Gloss Enamel (1 coat primer, 2 coats finish)	40¢ - 50¢	Kitchens, bathrooms, doors and trim, cabinets, etc., wherever a high sheen is required.	Same as flat, but a high gloss product with maximum durability, scrubbability and moisture resistance when compared to a lower sheen product.	Highest degree of scrubbability, but lowest hiding.
Waterborne Semi-Gloss or Gloss Epoxy (2-component) (1 coat primer, 2 coats finish)	70¢ - 85¢	Any interior wall surface, metal, concrete block and wood. Ideal for hard usage areas in schools, hospitals, restaurants, public buildings and factories.	Same as latex products, but provides maximum durability and highest performance in a hard, tough and stain-resistant finish.	Dries for recoat overnight, but does not fully cure for 7 days.
<u>Exterior</u>: (premium finishes)				
Latex Heavy-Bodied Stain (Wood = 2 coats)	35¢ - 40¢	Exterior wood surfaces, especially fascias and soffits, where grain of the wood's natural texture is to be highlighted.	Extensive color selection, water-repellent, mildew-resistant, low odor and guards against wood rot.	Not recommended for wood decks, floors, outdoor wood furniture, or brushed or abraded plywood surfaces.

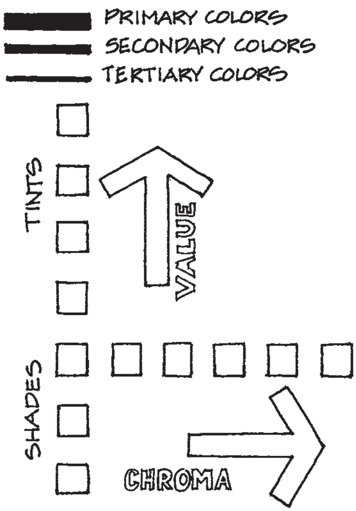
Latex Heavy-Bodied Stain (Wood = 2 coats)	35¢ - 40¢	Exterior wood surfaces, especially fascias and soffits, where grain of the wood's natural texture is to be highlighted.	Extensive color selection, water-repellent, mildew-resistant, low odor and guards against wood rot.	Not recommended for wood decks, floors, outdoor wood furniture, or brushed or abraded plywood surfaces.
Latex Flat Finish (1 coat primer, 2 coats finish)	40¢ - 50¢	Any exterior surface where a flat appearance is desired.	Almost unlimited color selection, washable, low odor, dries fast, excellent touch-up and coverage, can be applied over a variety of properly primed surfaces; fade, chalk and mildew resistant.	Exterior flats do not tend to be as 'self-cleaning' as enamels.
Latex Satin Enamel (1 coat primer, 2 coats finish)	40¢ - 50¢	Where a slightly higher sheen is desired rather than a flat.	Same as flat, but more durable than a flat with greater 'self-cleaning' attributes. Moisture, fade, chalk and mildew resistant.	Easier to clean than a flat, but less durable than a higher sheen.
Latex Semi-Gloss Enamel (1 coat primer, 2 coats finish)	40¢ - 50¢	Use wherever a medium sheen finish is desired.	Same as flat, but another step up in moisture resistance and durability compared to a lower sheen product. Excellent fade, chalk and mildew resistance.	Increased cleanability over any lower sheen product, but not as durable as higher sheens.
Latex Gloss Enamel (1 coat primer, 2 coats finish)	40¢ - 50¢	Use wherever a high gloss finish is desired.	Same as flat, but a high gloss product with excellent durability, moisture resistance, fade, chalk and mildew resistance, when compared to a lower sheen enamel.	Highest degree of cleanability and durability, but least amount of hide.
Aliphatic Urethane Gloss Enamel (2-component) (1 coat primer, 2 coats finish)	70¢ - 85¢	A high-performance, chemically-cured urethane enamel.	Exceptional gloss and color retention, excellent abrasion and chemical resistance, wide color selection (including safety colors), excellent resistance to marring, chipping and scratching.	Product cost is highest of any exterior enamel, but length of service is longest with highest UV protection. Has also been used as anti-graffiti coating. Best applied by a painting contractor with product experience.
Power-washing	8¢ - 12¢	Exterior concrete and CMU surfaces.	Best method for cleaning exterior surfaces prior to repainting.	None.

___ K. COLOR (12) (16) (45)



THE COLOR WHEEL

(FOR PIGMENTS)



THINK OF COLOR IN THREE DIMENSIONS:

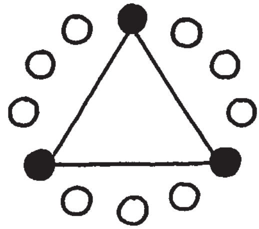
1. HUE ("COLOR")
2. VALUE (LIGHT TO DARK)
3. CHROMA (SATURATION-INTENSITY)

COLOR CONTRASTS

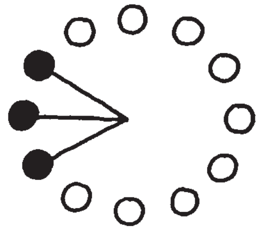
1. ONE COLOR VS. ANOTHER
2. DARK VS. LIGHT
3. COMPLEMENTARY (RED VS. GREEN, YELLOW VS VIOLET, . ORANGE VS BLUE)
4. WARM VS COOL (HOT RED-ORANGE - YELLOW VS COOL BLUE - GREEN)
5. SMALL VS LARGE

__ 1. <u>Basic Color Schemes</u>

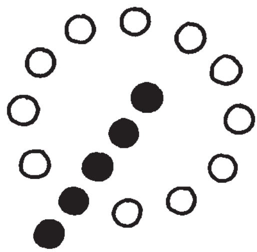
__ a. *Triadic schemes.* Made from any three hues that are equidistant on the color wheel.



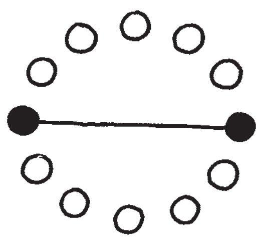
__ b. *Analogous or related schemes.* Consist of hues that are side by side.



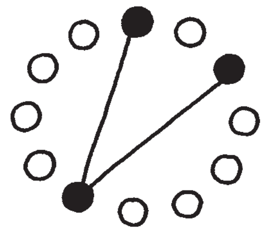
__ c. *Monochromatic schemes.* Use only one color (hue) in a range of values and intensities, coupled with neutral blacks or whites.



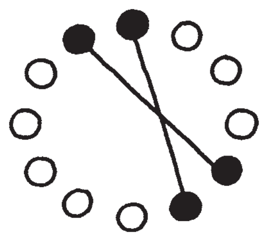
__ d. *Complementary schemes.* Use contrast by drawing from exact opposites on the color wheel. Usually, one of the colors is dominant while the other is used as an accent. Usually vary the amount and brightness of contrasting colors.



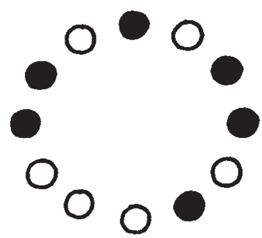
___ *e.* *Split complementary schemes.* Consist of one hue and the two hues on each side of its compliment.



___ *f.* *Double complementary schemes.* Composed of two adjacent hues and their respective hues, directly opposite on the color wheel.



___ *g.* *Many-hued schemes.* Those with more than three hues. These usually need a strong dose of one color as a base with added colors that are closely matched in value.



___ 2. **Rules of Thumb**

___ *a.* Your dominant color should cover about ⅔ of the room's area. Equal areas of color are usually less pleasing. Typical areas to be covered by the main color are the walls, ceiling, and part of the floor.

___ *b.* The next most important color usually is in the floor covering, the furniture, or the draperies.

___ *c.* The accent colors act as the "spice" for the scheme.

___ *d.* Study the proposed colors in the lighting conditions of where they will be used (natural light, type of artificial light).

___ *e.* The larger the area, the brighter a color will seem. Usually duller tones are used for large areas.

___ *f.* Contrast is greater from light to dark than it is from hue to hue or dull to bright saturation.
___ *g.* Colors that seem identical but are slightly different will seem more divergent when placed together.
___ *h.* Bold, warm (red/orange) and dark colors will "advance." These can be used to bring in end walls, to lower ceilings, or to create a feeling of closeness in a room.
___ *i.* Cool (blue/green), dull and light colors "recede." These can be used to heighten ceilings or to widen a room.
___ *j.* Related colors tend to blend into "harmony."
___ *k.* From an economic point of view, dark colors absorb more light (and heat) and will require more lighting. Light colors reflect light, requiring less lighting.
___ *l.* Colors will appear darker and more saturated when reflected from a glossy surface than when reflected from a matte surface.
___ *m.* A color on a textured surface will appear darker than on a smooth surface.
___ *n.* Bright colors increase in brilliance when increased in area, and pale colors fade when increased in area.
___ *o.* Incandescent (warm) lighting normally adds a warming glow to colors. Under this light, consider "cooling" down or graying bright reds, oranges, or yellows.
___ *p.* Low atmospheric lighting tends to gray down colors.
___ *q.* Fluorescent lighting changes the hue of colors in varying ways depending on the type used. In some instances it will accent blue tones and make reds look colder. It may make many colors look harsher.
___ *r.* Southern exposures will bring in warm tones of sunlight.
___ *s.* Northern exposures will bring in cool light.
___ *t.* Cool pale colors tend to promote relaxation and shorten the passing of time. Therefore, they are good for repetitive work. Warm bright colors tend to promote activity and heighten awareness of time. Therefore, they are better for entertainment and romantic settings
___ *u.* Cool colors tend to make warm conditions more tolerable. Warm colors do the same for cold conditions.
___ *v.* Advancing colors (red-yellow) usually make objects larger. Receding colors (green-violet) usually make things look smaller.

___ 3. **Percent Light Reflected from Typical Walls and Ceilings**

Class	Surface	Color	% Light reflected
Light	Paint	white	81
		ivory	79
		cream	74
	Stone	cream	69
Medium	Paint	buff	63
		lt. green	63
		lt. grey	58
	Stone	grey	56
Dark	Paint	tan	48
		dk. grey	26
		olive green	17
		lt. oak	32
		mohogany	8
	Cement	natural	25
	Brick	red	13

___ 4. **Typical Reflectance %**

___ *a.* Commercial

Ceiling 80%
Walls 50%
Floors 20%

___ *b.* Industrial

Ceiling 50%
Walls 50%
Floor 20%

___ *c.* Classrooms

Ceiling 70–90%
Walls 40–60%
Floor 30–50%
Desk top 35–50%
Blackboard 20%

___ 5. **Surfaces:**

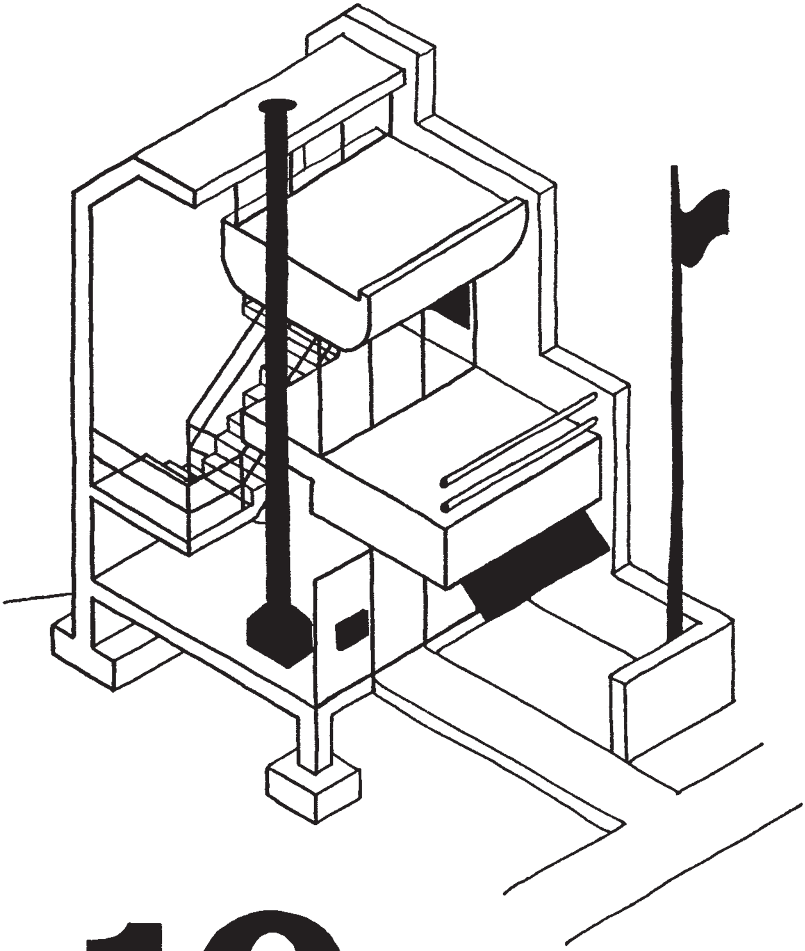
___ *a.* Specular: A smooth, shiny surface that casts a mirrorlike image of the arriving light.

___ *b.* Matte: A smooth, dull surface that emits an inarticulate shine.

___ *c.* Diffuse: A rough, dull surface that widely scatters the arriving light.

NOTES

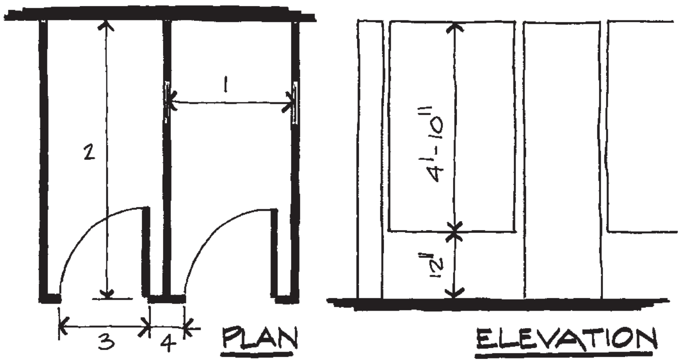
NOTES



10 SPECIALTIES

NOTES

___ A. TOILET PARTITIONS (4)



___ **1. Typical widths:** 2′6″, 2′8″, 2′10″ (most-used), and 3′0″
___ **2. Typical depths:**
   ___ *a.* Open front: 2′6″ to 4′0″
   ___ *b.* Closed front (door): 4′6″ to 4′9″
___ **3. Typical doors:** 1′ 8″, 1′10″, 2′0″, 2′4″, and 2′6″
___ **4. Typical pilasters:** 3, 4, 5, 6, 8, or 10 inches
___ **5. For HC-accessible,** see pp. 512–514.

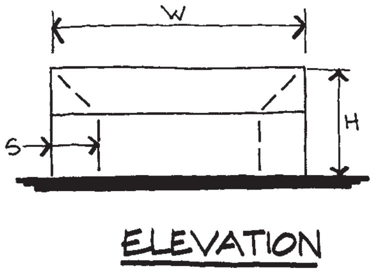
Costs: $720 to $1080/each compartment

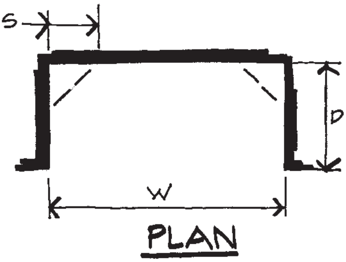
Ceiling-mounted partitions, with plastic-laminate finish, are the least expensive.

___ B. FIREPLACES (5)

___ **1. Typical Opening Sizes** (see drawings below):

W	H	D	S
2′	1.5′ to 1.75′	1.33′ to 1.5′	
3′	2′	1.67′	6½″
4′	2.12′	1.75′	6″
5′	2.5′ to 2.75′	2′ to 2.17′	9″
6′	2.75′ to 3′	2.17′ to 2.33′	9″





___ **2. For energy conservation, provide:**

___ *a.* Outside combustion air ducted to firebox

___ *b.* Glass doors

___ *c.* Blower

___ **3. Per IBC:**

___ *a.* Hearth extension to front must be 16″ (or 20″ if opening greater than 6 SF).

___ *b.* Hearth extension to side must be 8″ (or 12″ if opening greater than 6 SF).

___ *c.* Thickness of wall of firebox must be 10″ brick (or 8″ firebrick).

___ *d.* Top of chimney must be 2′ above any roof element within 10′.

Costs: Fabricated metal: $600 to $1800 (75% M and 25% L)
Masonry: $6000 to $18,000

___ C. GRAPHICS (M) (10)

___ **1. General:** Visual identification and direction by signage is very important for "wayfinding" to, between, around, in, and through buildings. Signage is enhanced by:

- ___ *a.* Size
- ___ *b.* Contrast
- ___ *c.* Design of letter character and graphics.

___ **2. Road Signage:** Can be roughly estimated as follows:

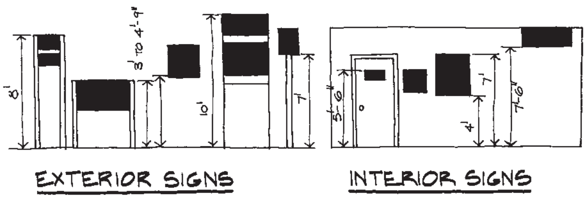
SPEED MPH	VIEWING DISTANCE	VIEWING ANGLE	SIGN SIZE SF	COPY SIZE INCH HT.
15	220′		8	
30	310′		40	5
40	450′	35°		7
45	660′		90	
50	545′	30°		8½
60	610 - 880′	20°	150	9½

___ **3. Building Signage**

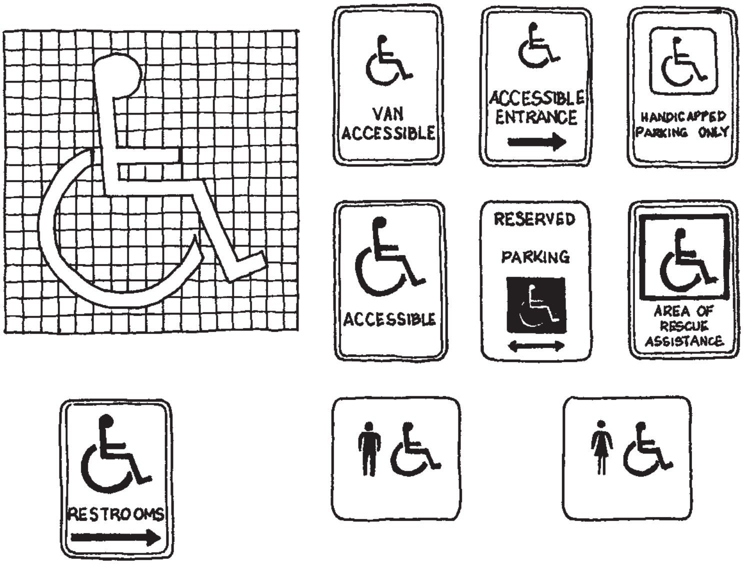
- ___ *a.* Site directional/warning signs should be:
  - ___ (1) 6′ from curb
  - ___ (2) 7′ from grade to bottom
  - ___ (3) 100′–200′ from intersections
  - ___ (4) 1 to 2.5 FT SQ
- ___ *b.* Effective pedestrian viewing distance 20′ to 155′
- ___ *c.* Effective sign size: ≈10′/inch height (10′ max. viewing distance per inch of height of sign).
- ___ *d.* Effective letter size: ≈50′/inch height.
- ___ *e.* As a rule, letters should constitute about 40% of sign and should not exceed 30 letters in width.
- ___ *f.* Materials
  - ___ (1) Exterior
    - ___ (*a*) Building: fabricated aluminum, illuminated plastic face, back-lighted, cast aluminum, applied letter, die-raised, engraved, and hot-stamped.
    - ___ (*b*) Plaque and sign: cast bronze or aluminum, plastic/acrylic, stone, masonry, and wood.

___ (2) Interior
___ (*a*) Permanent mounting: vinyl tape/adhesive backing, silastic adhesive, or mechanical attachment.
___ (*b*) Semipermanent: vinyl tape square on inserts.
___ (*c*) Changeable: dual-lock mating fasteners, magnets, magnetic tape or tracks.

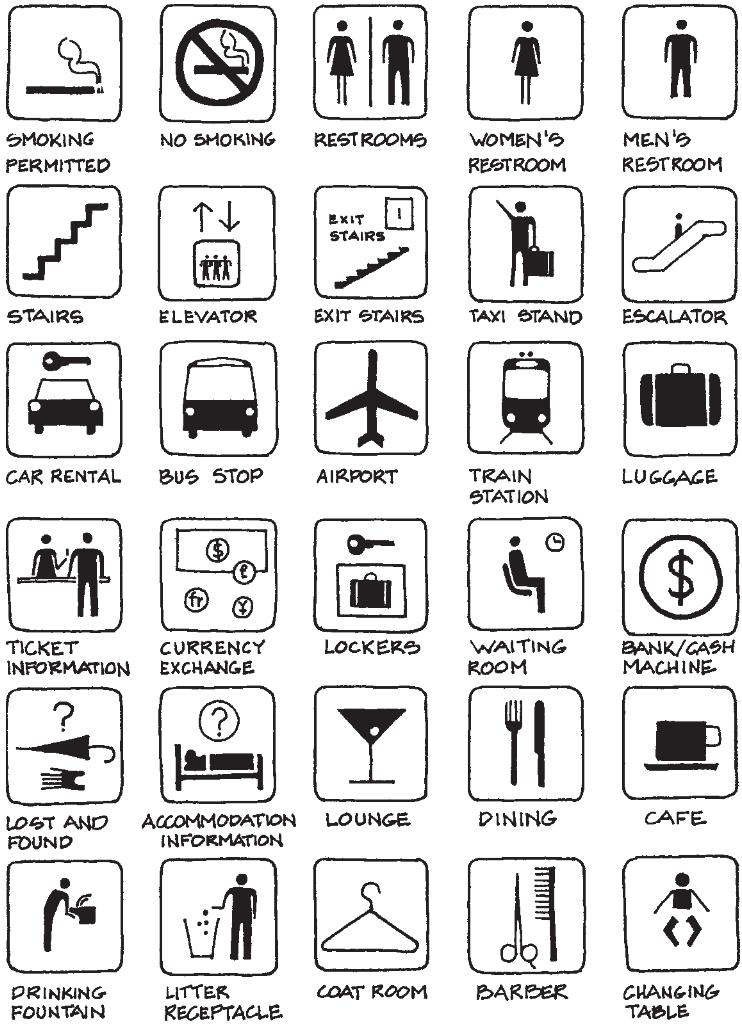
___ *g.* Mounting heights



___ *h.* Accessibility signage per ADA required at:
___ (1) Accessible parking, see p. 227.
___ (2) Building entries (when accessible, not required when all are).
___ (3) Accessible facilities, such as at rest rooms (when accessible, not required when all are).
___ (4) ADA (ANSI) now requires both tactile and visual (with contrast) graphics. Graphics may be mounted on the push side of doors, on side (pull side) of doors (18″), or on nearest adjacent wall when no space is available by the door. Visual graphics (except for elevators) are to be mounted 3′–4″ to 5′–10″ above floor (with ⅝″- to 1¾″-high characters) when viewed from up to 15′; 5′–10″ to 10′ AF (with 2″- to 2¾″-high characters) when viewed from 15′ to 21′; and 10′ AF (with 3″-high characters + ⅛″/ft. beyond 21′) when viewed from greater than 21′. Tactile and braille graphics are to be mounted between 4′ and 5′ AF (except for elevators). Tactile characters are to be ⅝″ to 2″ high and braille ½″ to ¾″. Pictograms (of high contrast) are to have 6″-high backgrounds.


VAN
ACCESSIBLE
ACCESSIBLE
ENTRANCE
HANDICAPPED
PARKING ONLY
ACCESSIBLE
RESERVED
PARKING
AREA OF
RESCUE
ASSISTANCE
RESTROOMS

___ *i* Other common signs and symbols:


SMOKING PERMITTED
NO SMOKING
RESTROOMS
WOMEN'S RESTROOM
MEN'S RESTROOM
STAIRS
ELEVATOR
EXIT STAIRS
EXIT STAIRS
TAXI STAND
ESCALATOR
CAR RENTAL
BUS STOP
AIRPORT
TRAIN STATION
LUGGAGE
TICKET INFORMATION
CURRENCY EXCHANGE
LOCKERS
WAITING ROOM
BANK/CASH MACHINE
LOST AND FOUND
ACCOMMODATION INFORMATION
LOUNGE
DINING
CAFE
DRINKING FOUNTAIN
LITTER RECEPTACLE
COAT ROOM
BARBER
CHANGING TABLE

NOTES

___ D. FIREPROOFING (1) (5) (34)

___ **1. See p. 94 for requirements.**

___ **2. Thicknesses** (in inches) of fire resistance structural materials will give hourly ratings, as follows:

ITEM	NON-COMBUSTIBLE 4 HOUR	3 HOUR	2 HOUR	1½ HOUR	1 HOUR	0 HOUR	HEAVY TIMBER	LIGHT WOOD FRAME
STEEL, STRUCTURAL*	←	SEE	NOTE	3	BELOW	→		↑
LT. GA. JOISTS, STUDS					SEE NOTE 3C			
CONCRETE, COLUMNS		14"	12"	10"	8"			SEE NOTE 3, BELOW
WALLS	6-8"	6½"	6"	5"	3½"			
SLABS		6¼"	5"	4⅓"	3½"			
POST TENSION FLOOR		6¼"	5"	4¼"	3½"			
PRE-CAST CONC. COL.		12"	10"	3"	6"			
BEAMS		9½"	7"	7"	4"			
WALLS		6½"	6"	5"	3½"			
SLABS		6¼"	5"	4⅓"	3½"			
PLANKS		8"+2" TOP'G.	8"	8"	8"			
TEE BMS			3¼"	2¾"	1¾"	← TOPPING		
BRICK MASONRY WALLS,	6-8"	8"	6"	6"	4"			
VAULTS, & DOMES (RISE NOT LESS THAN 1/12 SPAN		8"	8"	6"	4"			
C.M.U. MASONRY WALLS	8" SOLID	8"	8"	6"	4"			
WOOD: COLUMNS, FLOOR							8×8	
ROOF							6×8	
BEAMS, FLOOR							6×10	
ROOF							4×6	
TRUSSES, FLOOR							8×8	
ROOF							4×6	
WOOD DECK, FLOOR							3"+1"	
ROOF							1⅛"-2"	↓

* AT 20' ABOVE FLOOR, OPEN STEEL STRUCTURE DOES NOT NEED FIRE PROTECTION.

___ **3. Fire-resistive materials** may be applied to structural members to protect from fire. Use the above table, as well as the following:

___ *a.* Concrete: 1″ ≈ 2 hr. 2″ to 3″ ≈ 4 hr.

___ *b.* Solid masonry: 2″ ≈ 1 hr., add 1″/hr to 4″ ≈ 4 hr.

___ *c.* Plaster: 1″ ≈ 1 hr., add 1″/hr.

___ *d.* Vermiculite (spray-on): 1″ ≈ 4 hr.

___ *e.* Gypsum wallboard: 2 layers ½″ type "X" or 1 layer of ⅝″ type "X" ≈ ¾ to 1 hr.

Costs: Spray-on vermiculite: $3.60/SF surface/inch thickness

___ **4. Flame Spread:** The IBC requires finish materials to resist the spread of fire as follows:

___ *a.* Maximum flame-spread class

INTERIOR FINISHES — TABLE 803.4

TABLE 803.4
INTERIOR WALL AND CEILING FINISH REQUIREMENTS BY OCCUPANCY[k]

GROUP	SPRINKLERED[l]			UNSPRINKLERED		
	Vertical exits and exit passageways[a,b]	Exit access corridors and other exitways	Rooms and enclosed spaces[c]	Vertical exits and exit passageways[a,b]	Exit access corridors and other exitways	Rooms and enclosed spaces[c]
A-1 & A-2	B	B	C	A	A[d]	B[e]
A-3[f], A-4, A-5	B	B	C	A	A[d]	C
B, E, M, R-1, R-4	B	C	C	A	B	C
F	C	C	C	B	C	C
H	B	B	C[g]	A	A	B
I-1	B	C	C	A	B	B
I-2	B	B	B[h,i]	A	A	B
I-3	A	A[j]	C	A	A	B
I-4	B	B	B[h,i]	A	A	B
R-2	C	C	C	B	B	C
R-3	C	C	C	C	C	C
S	C	C	C	B	B	C
U	No restrictions			No restrictions		

For SI: 1 inch = 25.4 mm, 1 square foot = 0.0929 m^2.

a. Class C interior finish materials shall be permitted for wainscotting or paneling of not more than 1,000 square feet of applied surface area in the grade lobby where applied directly to a noncombustible base or over furring strips applied to a noncombustible base and fireblocked as required by Section 803.3.1.
b. In vertical exits of buildings less than three stories in height of other than Group I-3, Class B interior finish for unsprinklered buildings and Class C interior finish for sprinklered buildings shall be permitted.
c. Requirements for rooms and enclosed spaces shall be based upon spaces enclosed by partitions. Where a fire-resistance rating is required for structural elements, the enclosing partitions shall extend from the floor to the ceiling. Partitions that do not comply with this shall be considered enclosing spaces and the rooms or spaces on both sides shall be considered one. In determining the applicable requirements for rooms and enclosed spaces, the specific occupancy thereof shall be the governing factor regardless of the group classification of the building or structure.
d. Lobby areas in A-1, A-2 and A-3 occupancies shall not be less than Class B materials.
e. Class C interior finish materials shall be permitted in places of assembly with an occupant load of 300 persons or less.
f. For churches and places of worship, wood used for ornamental purposes, trusses, paneling or chancel furnishing shall be permitted.
g. Class B material required where building exceeds two stories.
h. Class C interior finish materials shall be permitted in administrative spaces.
i. Class C interior finish materials shall be permitted in rooms with a capacity of four persons or less.
j. Class B materials shall be permitted as wainscotting extending not more than 48 inches above the finished floor in exit access corridors.
k. Finish materials as provided for in other sections of this code.
l. Applies when the vertical exits, exit passageways, exit access corridors or exitways, or rooms and spaces are protected by a sprinkler system installed in accordance with Section 903.3.1.1 or Section 903.3.1.2.

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___ *b.* Flame-spread classification

Class	Flame-spread index
A	0 to 25
B	26 to 75
C	76 to 200

___ *c.* Use finishes to meet above requirements
- ___ (1) For woods, see p. 351.
- ___ (2) Aluminum: 5 to 10
- ___ (3) Masonry or Concrete: 0
- ___ (4) Gypsum wallboard: 10 to 25
- ___ (5) Carpet: 10 to 600
- ___ (6) Mineral-fiber sound-absorbing panels: 10 to 25
- ___ (7) Vinyl tile: 10 to 50
- ___ (8) Chemically treated wood fiberboard: 20 to 25
- ___ (9) Certain intumescent paints can reduce the flame spread of combustible finishes to as low as class A.

___ **5. Floor Finishes:** Most floor finishes present little if any hazard due to flame spread. Carpet is the exception.

___ Types:

Class I (radiant flux of 0.45 W/cm^2 or more) more resistant to flame spread. This is usually of a low pile and/or natural fiber.

Class II (radiant flux of 0.22 W/cm^2) less resistant. This is usually of a high pile and/or synthetic fiber.

Sprinklers can allow Class II where I is required.

___ **6. Trim and Decorations on Walls and Ceilings:**
- ___ Must be at least Class C.
- ___ Limited to 10% of area (except sprinklered auditoriums may be up to 50%).
- ___ At Group I-3 occupancies, only noncombustible materials allowed.
- ___ At Groups A, E, I, R-1, and R-2 dormitories, only flame-resistant or noncombustible materials allowed.

___ **7. See p. 342** for fire-retardant-treated wood.

___ **8. Fire Loads:** Interior building contents that will start or contribute to a fire. These typically range from 10 (residential) to 50 PSF (office), and can be reduced 80% to 90% by use of metal storage containers for paper.

___ 9. Fire Extinguishers:

FIRE CLASSIFICATIONS FOR SELECTING FIRE EXTINGUISHERS

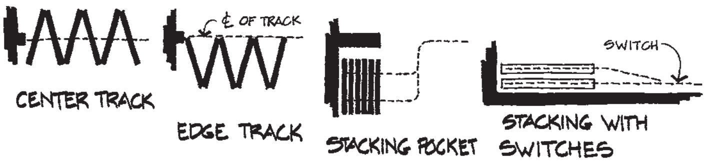
LETTER SYMBOL AND COLOR	PICTURE SYMBOL	DESCRIPTION
GREEN 		CLASS A: FIRES INVOLVING ORDINARY COMBUSTIBLE MATERIALS (SUCH AS WOOD, CLOTH, PAPER, RUBBER, AND MANY PLASTICS) THAT REQUIRE THE HEAT ABSORBING (COOLING) EFFECTS OF WATER OR WATER SOLUTIONS, OR THE COATING EFFECTS OF CERTAIN DRY CHEMICALS THAT RETAIRD COMBUSTION.
RED 		CLASS B: FIRES INVOLVING FLAMMABLE OR COMBUSTIBLE LIQUIDS FLAMMABLE GASES, GREASES AND SIMILAR MATERIALS THAT ARE BEST EXTINGUISHED BY EXCLUDING AIR (OXYGEN), INHIBITING THE RELEASE OF COMBUSTIBLE VAPORS OR INTERRUPTING THE COMBUSTION CHAIN REACTION.
BLUE 		CLASS C: FIRES INVOLVING ENERGIZED ELECTRICAL EQUIPMENT WHERE SAFETY TO THE OPERATOR REQUIRES THE USE OF ELECTRICALLY NONCONDUCTIVE EXTINGUISHING AGENTS.
YELLOW 		CLASS D: FIRES INVOLVING COMBUSTIBLE METALS (SUCH AS MAGNESIUM, TITANIUM, ZIRCONIUM, SODIUM, LITHIUM, AND POTASSIUM).

Costs:	**Fire extinguishers:**	**$115 to $300/ea**
	Cabinet:	**$120/ea**
	Hose & Cabinet:	**$265/ea**

___ 10. **Keep in mind** that for *life safety,* smoke control in buildings is as important as suppressing fire.

___ E. OPERABLE PARTITIONS (5)

___ 1. Types



___ 2. Data

- ___ (1) Stack widths:
  - ___ (*a*) Accordion: 5″ to 12″
  - ___ (*b*) Panels: 15″ to 17″
- ___ (2) Stack depths: Usually ⅙ to ⅛ of opened width.
- ___ (3) Panels usually 48″ wide.
- ___ (4) Acoustic: STC 43 to 54 available.
- ___ (5) Flame spread: Class I available.

Costs:

- ___ **Folding, acoustical, vinyl, wood-framed: $75.00 to $100/SF (70% M and 30% L) Variation: –35% to +50%.**
- ___ **Accordion, vinyl-faced: $18.50 to $43.80/SF, Variation: ±20%**

___ F. BATHROOM ACCESSORIES

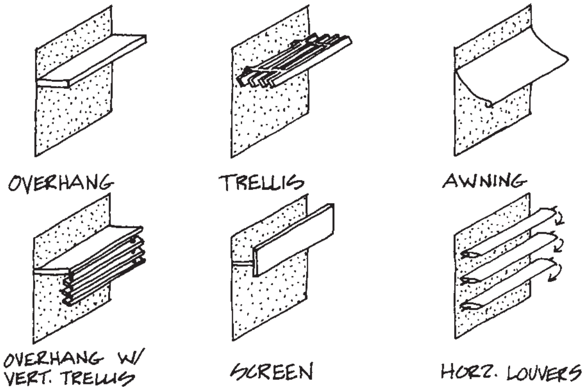
Costs given are for average quality. For better finishes (i.e., brass), add 75% to 100%:

- ___ **Mirrors** — **$35/SF (90% M and 10% L) variation of ±25%**
- ___ **Misc. small items (holders, hooks, etc.)** — **$20 to $35/ea. (double, if recessed)**
- ___ **Bars**
  - **Grab** — **$40 to $55/ea.**
  - **Towel** — **$20 to $35/ea.**
- ___ **Medicine cabinets** — **$95–$120/ea.**
- ___ **Tissue dispensers** — **$35 to $70/ea.**
- ___ **Towel dispensers** — **$155 to $480/ea. (increase by 2½ times if waste receptacle included)**

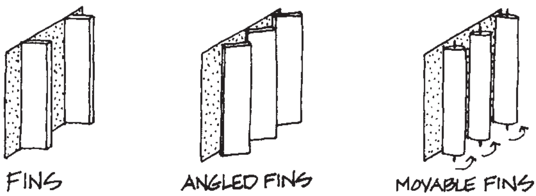
___ G. SUN CONTROL (4)

___ 1. Types

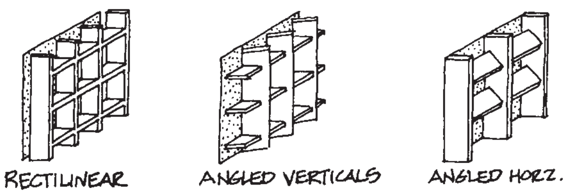
___ *a.* Horizontal (usually best on south side)



___ *b.* Vertical (usually best on east and west sides)



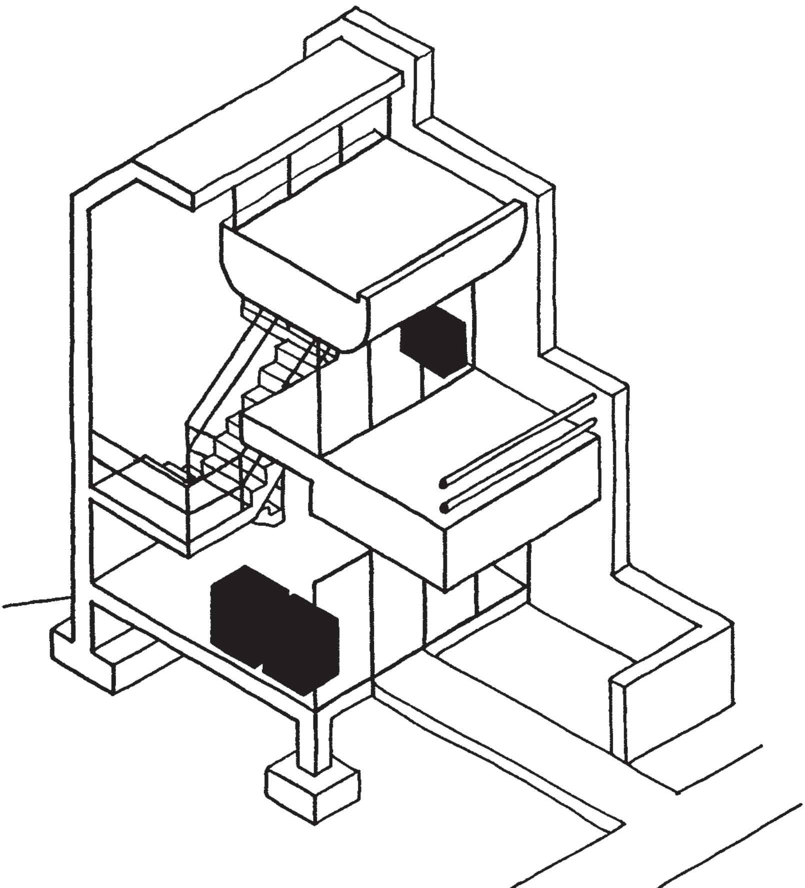
___ *c.* Egg crates (best for hot climates)



Costs:

___	**Canvas awnings**	**\$57.50 to \$130/SF (70% M and 30% L)** **Variation −75%, +300%** **Other types of awnings (alum., painted, plastic, or security) are 1½ to 2½ times.**
___	**Cloth patio covers**	**≈\$4.80/SF (55% M and 45% L)**
___	**Metal carports**	**See p. 265.**

NOTES



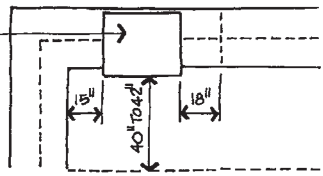
11 EQUIPMENT

NOTES

___ A. RESIDENTIAL KITCHENS (5)

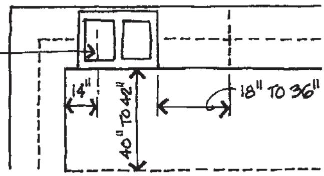
(See p. 193, Energy Conservation)

___ A. REFRIGERATOR
33"W × 32"D × 66"H
$840 TO $2640

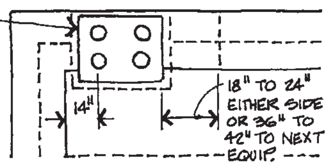


___ B. DISHWASHER
23"W × 24"D × 33"H
$600 TO $990

___ C. SINK
$480 TO $790

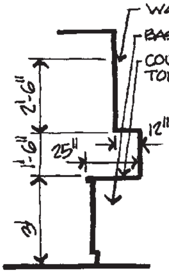


___ D. RANGE / OVEN
36"W × 27"D × 36"H
$1200 TO $3300

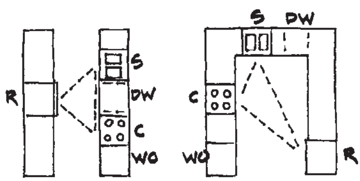


___ E. WALL OVEN (MICROWAVE)
25"W × 22"D × 18"H
(CUPBOARDS USUALLY ABOVE & BELOW
$380 TO $800

COSTS: (STD. GR.)
WALL CAB. $85/LF
BASE CAB. $155/LF
COUNTER TOPS: $35 TO $85/LF
(90% M & 10% L)
VARIATIONS:
PREM. GR +65% M
ECON. GR −45% M



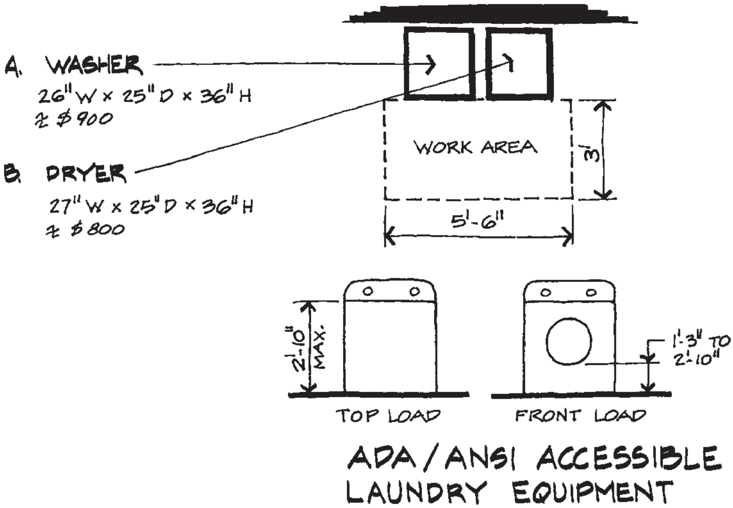
SECT. THRU COUNTER



R = REFRIGERATOR
C = COOKING (RANGE/OVEN)
S = SINK
DW = DISHWASHER
WO = WALL OVEN

NOTES:
1. TOTAL LENGTH OF WORK TRIANGLE 23 TO 26 LF.
2. SMALL KITCHENS: 10 TO 20 LF COUNTER / EQ.
3. MIN. 18SF OF STOR. SPACE + 6 SF / PERSON SERVED.

___ B. RESIDENTIAL LAUNDRIES (5)



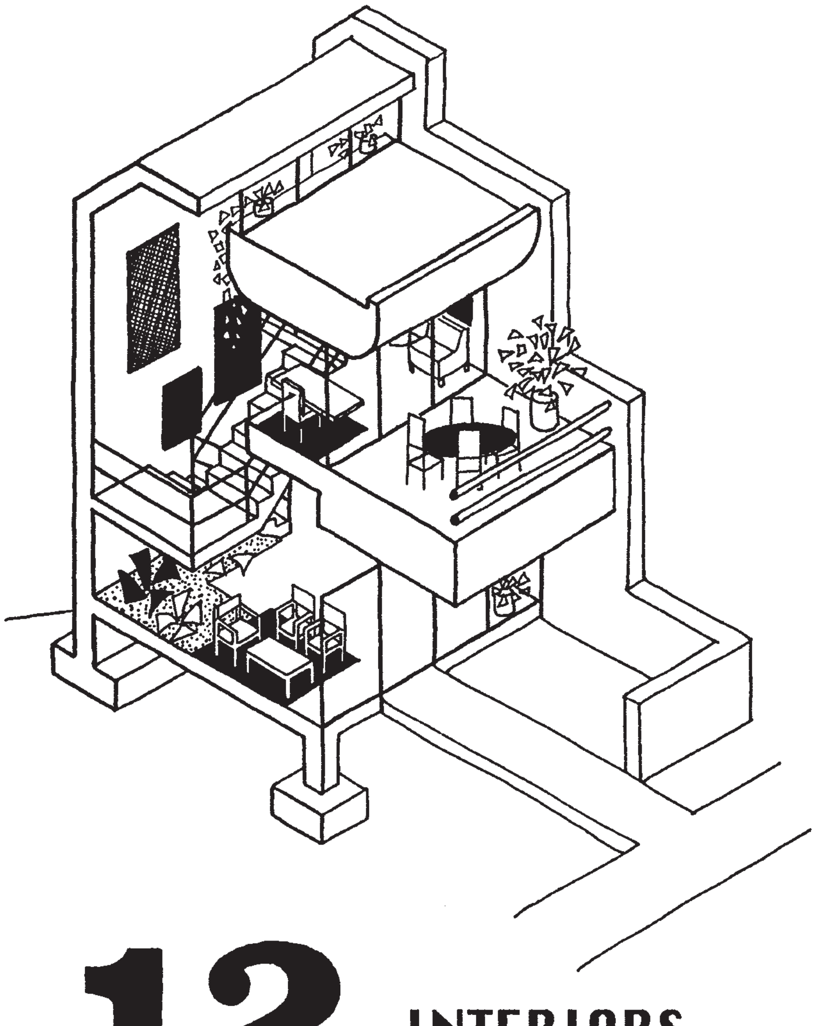
___ C. MISCELLANEOUS COSTS

(Also see item F, p. 621)

___	**1. Bank Counter**	**$2400 to $6000/teller**
___	**2. Barber**	
	Total equipment	**$3000 to $6360/chair**
___	**3. Cash Register**	**$660 to $3000/reg.**
___	**4. Commercial Kitchen Equip.**	
	By area:	
	(Office)	**$82 to $130/SF kit.**
	(Restaurant)	**$100 to $165/SF kit.**
	(Hospital)	**$100 to $180/SF kit.**
	By item:	
	Work tables	**$320 to $400/LF**
	Serving fixtures	**$330 to $425/LF**
	Walk-ins	**$60 to $200/SF (add $1900/ ton for refrigeration machinery)**

___	5. Library	
	Shelf	$150/LF (–20%, +10%)
	Carrels	$825 to $960/ea.
	Card catalog	$120/tray
___	6. Religious	
	Wood altar	$1800 to $10800
	For pews, see p. 462	
___	7. Safes	
	(Office) 4 hr., 1.5′ × 1.5′ × 1.5′	$4200
	(Jeweler's) 63″ × 25″ × 18″	$25000
___	8. Theater	
	Total equipment	$100 to $600/SF stage
	For seating, see p. 462	
___	9. Trash Compactors	$11400 to $12800/ea.
___	10. Vacuum Cleaning Equip.	$930 for first 1200 SF; then add $0.15/SF

NOTES



12 INTERIORS

NOTES

___ A. GENERAL COSTS (K) (U) (W) (5) (12) (27)

Costs for furniture and interior objects will vary more than any other item for buildings. These can vary as much as –75% to +500% (or more). Costs given in this part are a reasonable middle value and are "for trade" wholesale. Retail can go up 60% to 175%. Cost location factors given in App. B, line V will not apply as furniture costs are rather uniform across country.

___ B. MISCELLANEOUS OBJECTS

___ 1. Artwork (photos, reproductions, etc.): **$60 to $330/ea.**
___ 2. Ash urns and trash receptacles: **$120 to $380/ea.**
___ 3. Blinds: **$5.50 to $8.80/SF**
___ 4. Draperies: **$25 to $135/SY**
___ 5. Rugs and mats: **$25 to $130/SY**
___ 6. Interior plants: see p. 267. **For artificial silk plants, double or triple landscape costs.**
___ 7. Fabrics: Association of Contract Textiles (ACT) recommendations. Check for following:

___ *a.* Flammability
Upholstery must pass CAL 117.
Drapery must pass NFPA 701.
Wall covering must pass ASTM E-84.

___ *b.* Abrasion resistance

a	A	Test
15,000 double rubs	30,000 double rubs 40,000	Wyzenbeek Martindale

___ *c.* Colorfastness to light
Must pass Class 4 (40 to 60 hours exposure for UV).

___ *d.* Colorfastness to wet and dry crocking (Pigment colorfastness in fabric). See p. 428 for color.

___ *e.* Miscellaneous other physical properties

___ (1) Brush pill test: measures tendency for ends of a fiber to mat into fuzz balls.

___ (2) Yard/seam slippage test: establishes fabric's likeliness to pull apart at seams. Must pass 25 lbs for upholstery and 15 lbs on drapery.

___ (3) Breaking/tensile strength test: evaluates fabric's breaking or tearing. Must pass:

Upholstery	50 lbs
Panel fabrics	35 lbs
Drapery over 6 oz	25 lbs
under 6 oz	15 lbs

___ C. FURNITURE

(Also see Item F, p. 621)

___ 1. <u>Miscellaneous</u>

___ *a.* Theater **$155 to $295/seat**

___ *b.* Church Pews **$85 to $145/seat**

___ *c.* Dormitory **$2520 to $4680/student**

___ *d.* Hospital Beds **$1090 to $1770/bed**

___ *e.* Hotel **$1980 to $10360/room**

___ *f.* Multiple Seating

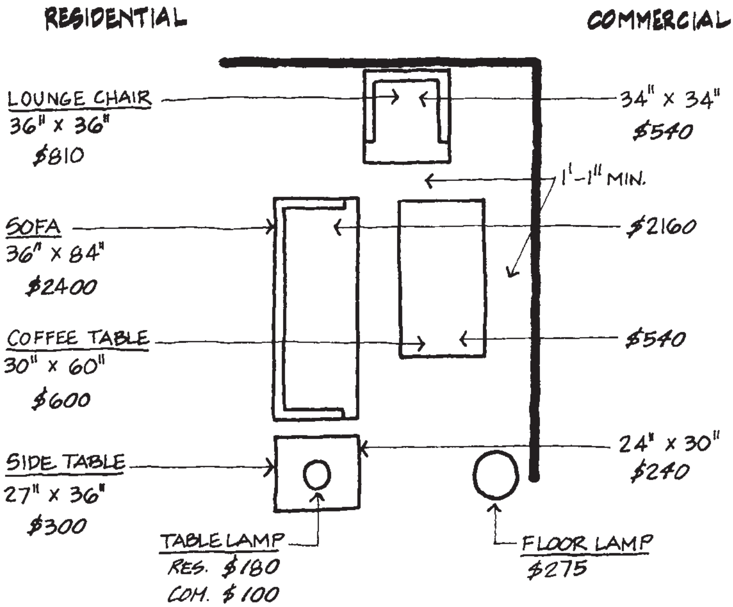
Classroom **$85 to $155/seat**

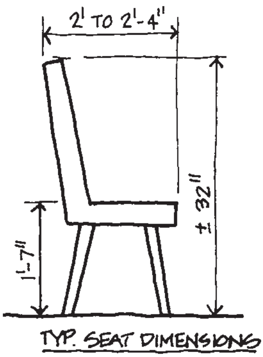
Lecture Hall **$165 to $480/seat**

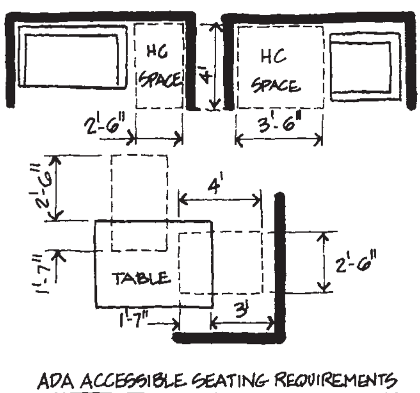
Auditorium **$130 to $265/seat**

__ 2. Living/Waiting

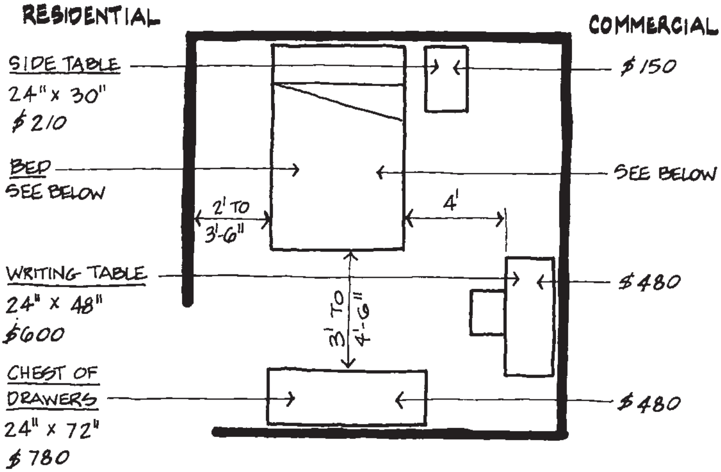
Note: Desirable conversation area is a 10′ diameter.







___ 3. Bedroom/Guestroom

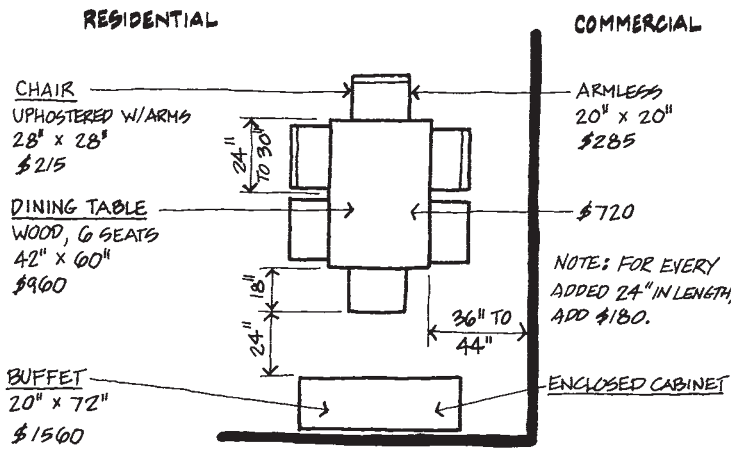


BED SIZES

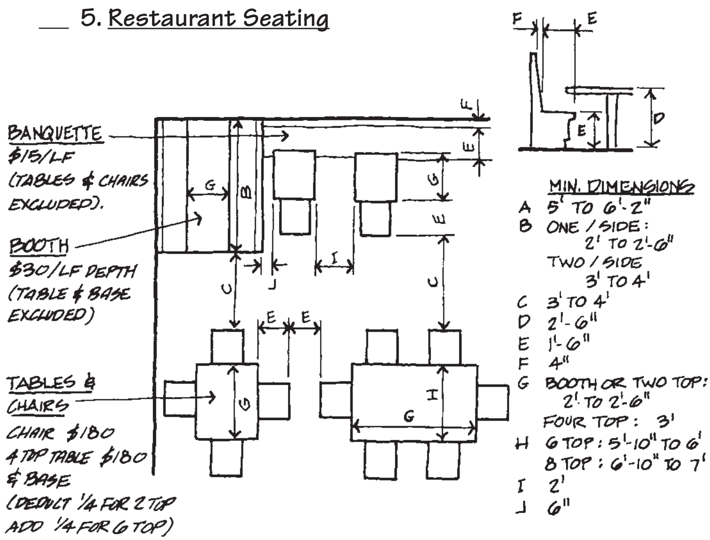
	W	L
KING	72	84
QUEEN	60	82
DOUBLE	54	82
SINGLE	39	82
DAY BED	30	75
CRIB	30	53

COST: BEDS: $600 TO $1200/EA
(mattress cost additional
$100 to $2400+ per set)

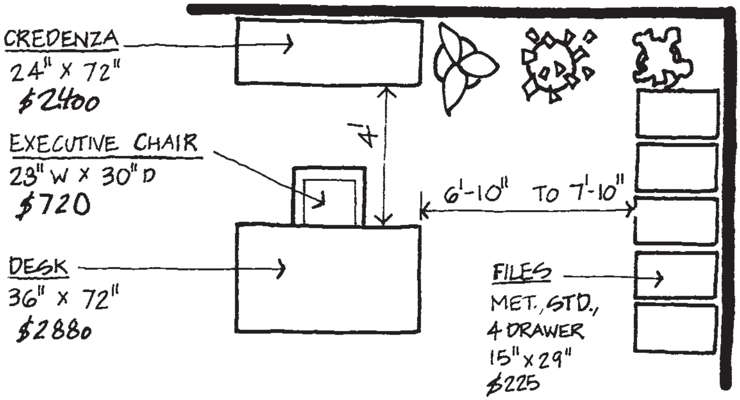
___ 4. Dining/Conference

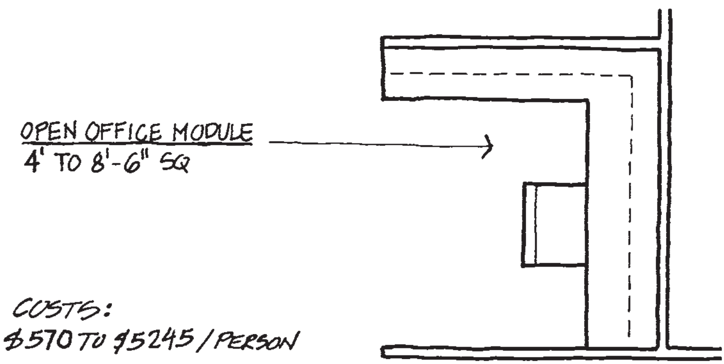


___ 5. Restaurant Seating



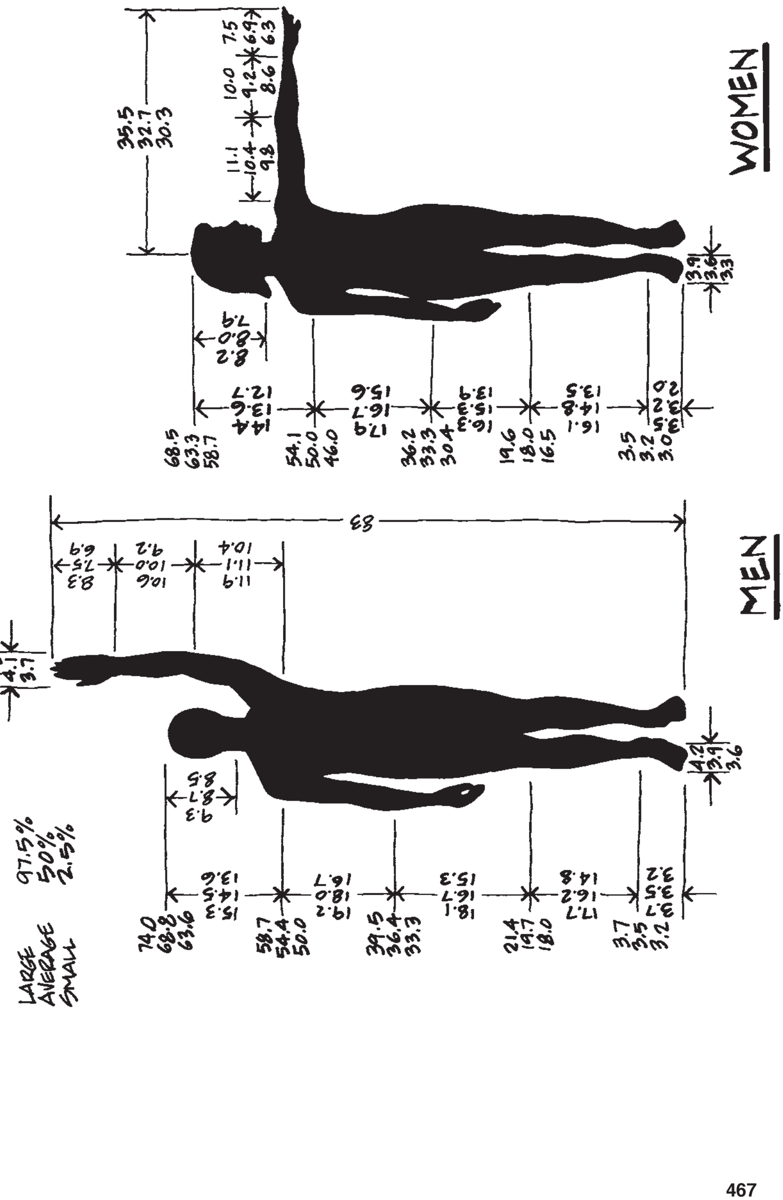
___ 6. Office

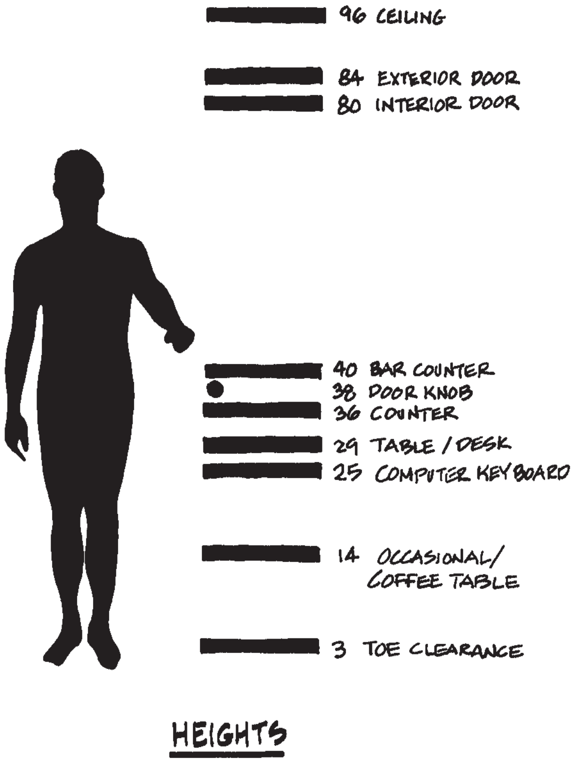

CREDENZA
24" x 72"
$2400
EXECUTIVE CHAIR
23" W x 30" D
$720
DESK
36" x 72"
$2880
4'
6'-10" TO 7'-10"
FILES
MET., STD.,
4 DRAWER
15" x 29"
$225

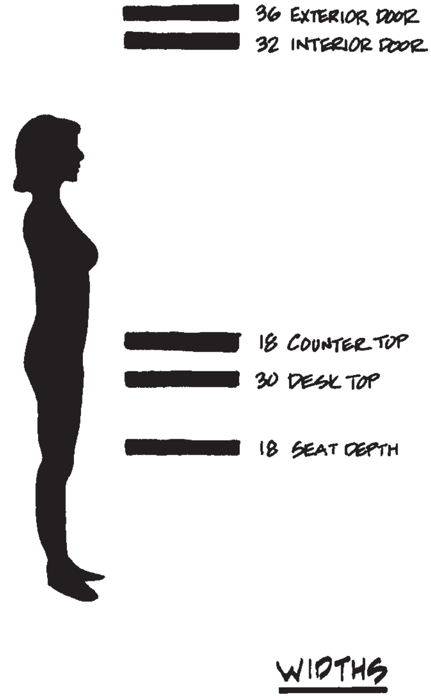

OPEN OFFICE MODULE
4' TO 8'-6" SQ
COSTS:
$570 TO $5245 / PERSON

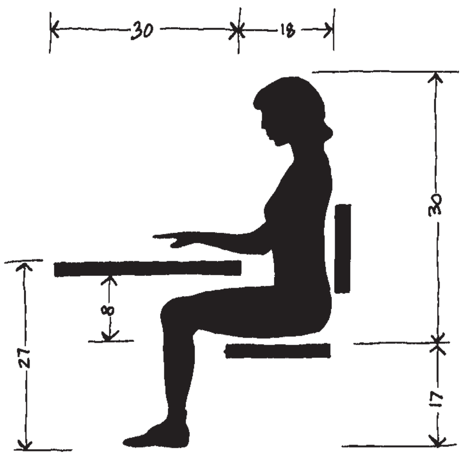
___ D. HUMAN DIMENSIONS

Note: All dimensions are in inches.

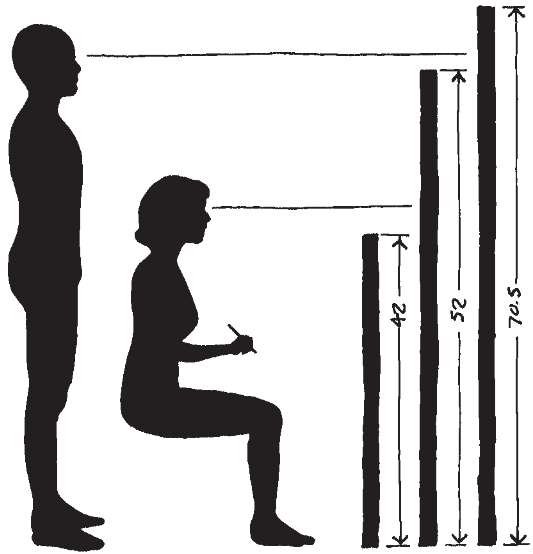



96 CEILING
84 EXTERIOR DOOR
80 INTERIOR DOOR
40 BAR COUNTER
38 DOOR KNOB
36 COUNTER
29 TABLE / DESK
25 COMPUTER KEYBOARD
14 OCCASIONAL/ COFFEE TABLE
3 TOE CLEARANCE
HEIGHTS

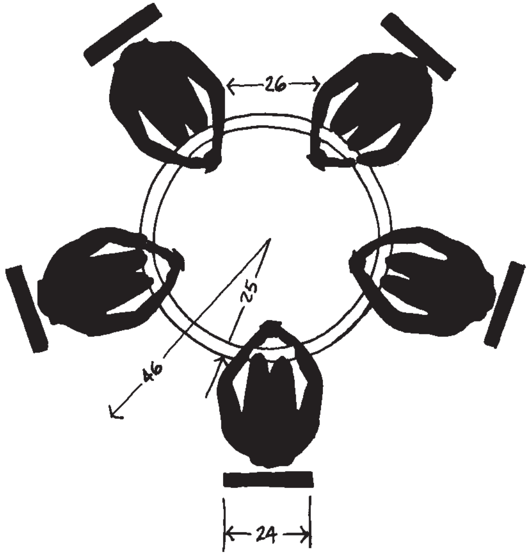

36 EXTERIOR DOOR
32 INTERIOR DOOR
18 COUNTER TOP
30 DESK TOP
18 SEAT DEPTH
WIDTHS



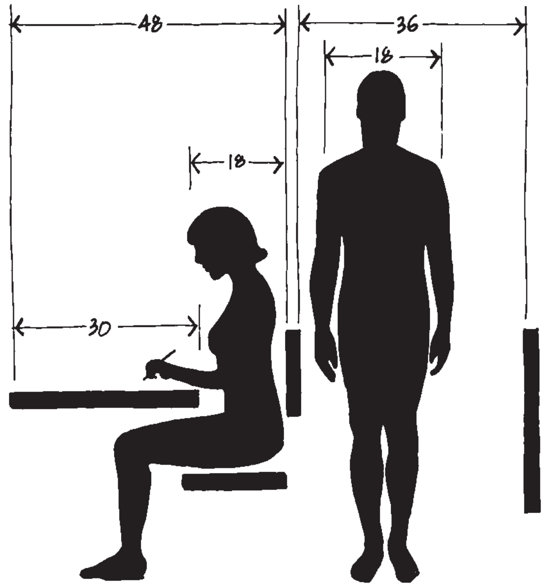
WORKSTATION



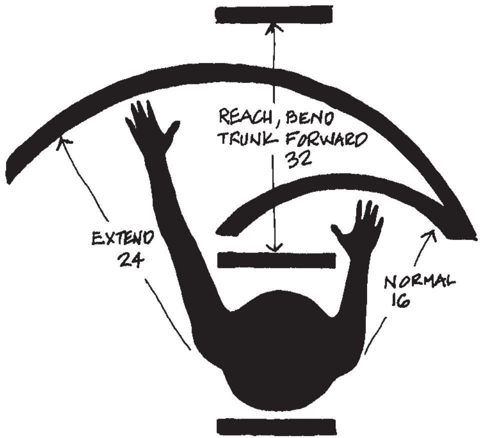
PARTITION HEIGHTS



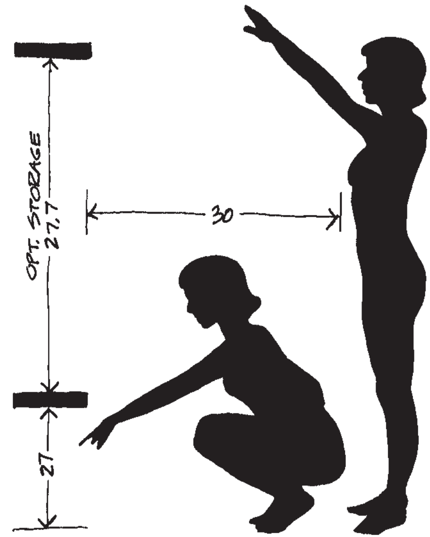
CONFERENCE



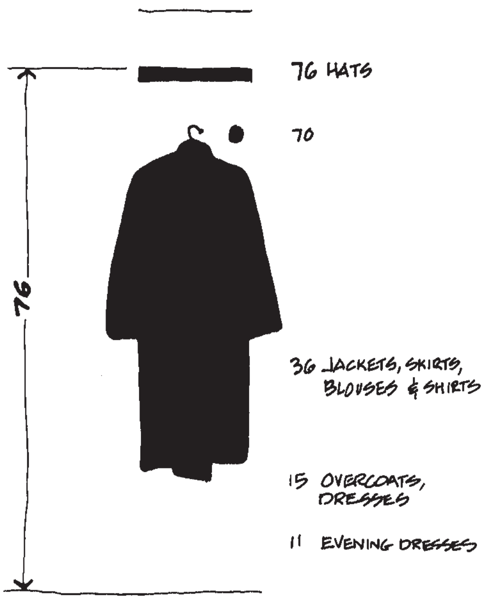
CORRIDOR/CLEARANCE



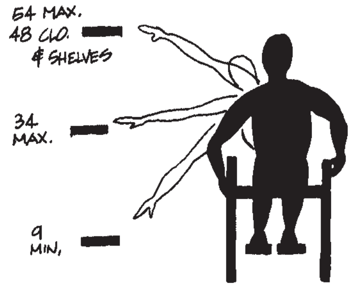
REACH



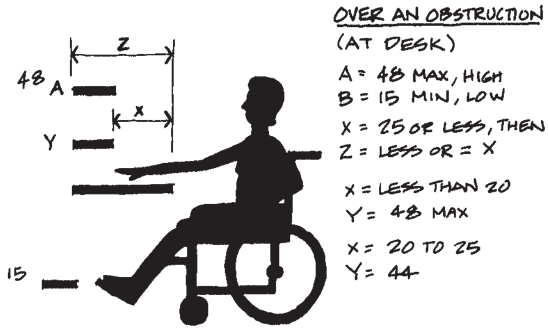
OVERHEAD/ UNDER COUNTER REACH



CLOSET



SIDE REACH

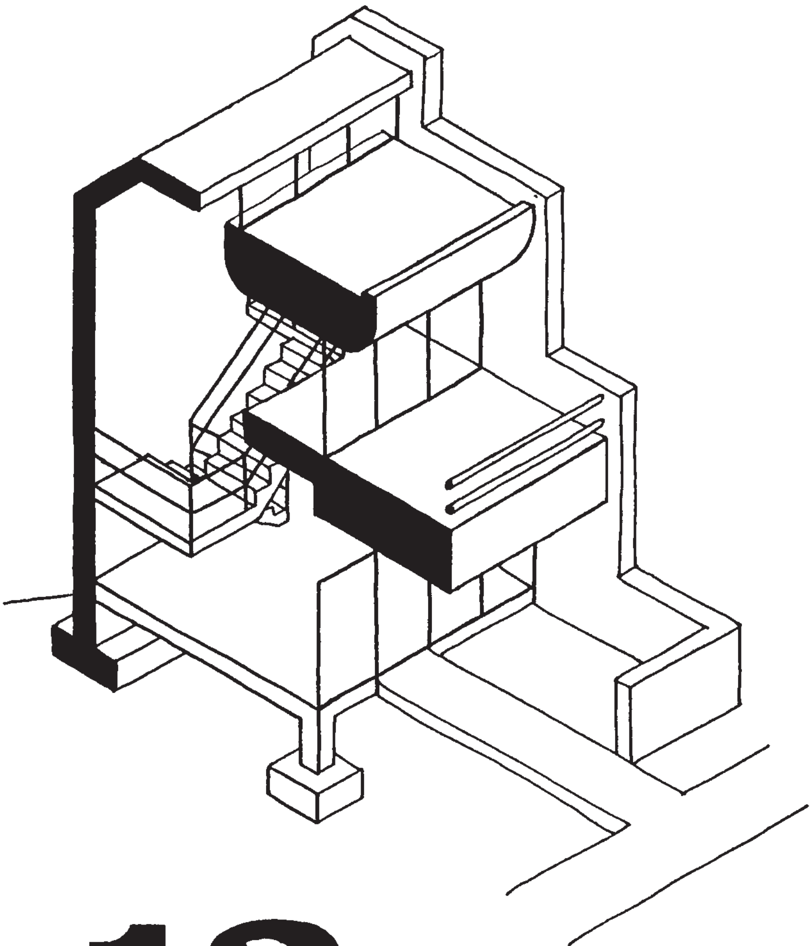


FORWARD REACH

WHEELCHAIR (ADA)

NOTES

NOTES



13 ASSEMBLIES

NOTES

___ A. ROOF STRUCTURE ASSEMBLIES (5)

___ 1. **Use the tables** on pp. 478–481 to help select a *roof structure assembly*. See p. 373 for roof coverings. Cross-sections on each table illustrate various assemblies, with *depth* of assembly in inches. Columns bearing the following numbers on each table show:

___ 2. ***Standard member sizes* in inches**

___ 3. ***Dead loads* in pounds per square foot**

___ 4. **Suitable *live load* range in pounds per square foot**

___ 5. **Span range in feet**

___ 6. **Typical bay size in square feet**

___ 7. **Suitable for *inclined roofs:***

Y = yes

N = no

___ 8. **Service plenum notes**

Between structural members

Under structure

___ 9. ***U value* (without insulation)**

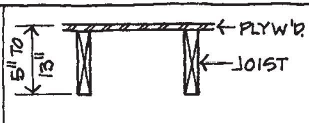
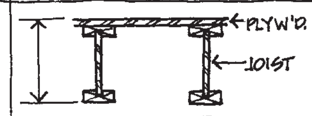
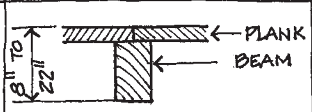
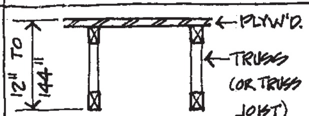
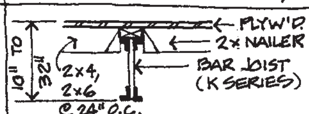
___ 10. ***Acoustical:*** Comparative resistance to sound transmission:

Impact	E = Excellent	F = Fair
Airborne	G = Good	P = Poor

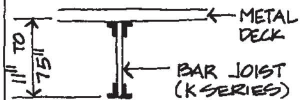
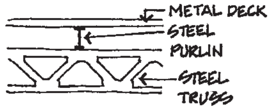
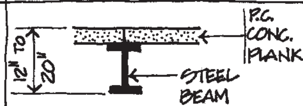
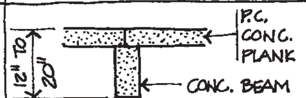
___ 11. ***Fire rating* in hours**

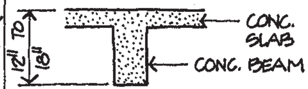
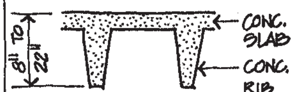
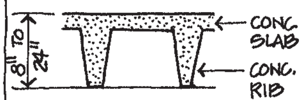
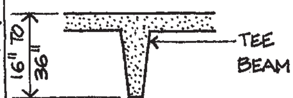
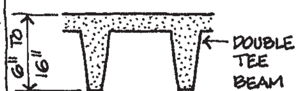
___ 12. ***Construction type classification* by code (IBC)**

___ 13. **Total costs in $/SF of roof area**

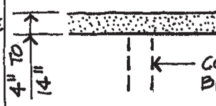
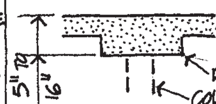
1 ROOF STRUCTURE ASSEMBLIES		2 SIZE (INCHES)	3 DEAD LOAD (PSF)	4 LIVE LOAD (PSF)	5 SPAN (FEET)	6 BAY SIZE	7 SUITABLE FOR SLOPE	8 SERVICE PLENUM	9 U VALUE	10 ACOUSTIC IMPACT	AIR	11 FIRE RATING (HRS)	12 CONST. TYPE (IBC)	13 COST ($/SF)
A. WOOD RAFTER OR JOIST		2×4, 6, 8, 10 & 12	4 TO 8	30 TO 50	TO 22		Y	BETWEEN RAFTERS, ONE-WAY	.71 - .51	P	F		V	2.70-10.20
B. PLYW'D. JOIST									.71 - .51					3.90-6.00
C. WOOD BEAM & PLANK		PLANKS OF 2, 3, OR 4	5 TO 12	20 TO 50	8 TO 34		Y	UNDER STRUCTURE OR ONE WAY BETW'N BEAMS	.27 - .17	P	F		IV	6.00-14.10
D. WOOD TRUSSES (OR TRUSS JOISTS)		12 TO 144	5 TO 15	20 TO 50	30 TO 50		Y	BETWEEN & THRU TRUSSES	.71 - .51	P	F		V	4.10 - 4.95
E. STEEL JOIST		8 TO 30	8 TO 20	20 TO 50	TO 40	35' SQ TO 40' SQ	Y	BETWEEN & THRU BAR JOIST	.7 - .5		G		III	3.95-5.40

ROOF STRUCTURE ASSEMBLIES

1		2 SIZE (INCHES)	3 DEAD LOAD (PSF)	4 LIVE LOAD (PSF)	5 SPAN (FEET)	6 BAY SIZE	7 SUITABLE FOR SLOPE	8 SERVICE PLENUM	9 U VALUE	10 ACOUSTIC IMPACT	ACOUSTIC AIR	11 FIRE RATING (HRS)	12 CONST. TYPE (IBC)	13 COST ($/SF)
F. STEEL JOIST		8 TO 72	6 TO 24	20 TO 50	35 TO 60		Y	BETWEEN & THRU BAR JOIST	.94 - 1.02	E W/ INSUL. ON DECK	G		III	2.60 - 4.30
G. STEEL TRUSSES		VARIES	15 TO 25	20 TO 60	100 TO 200		Y PITCH TRUSSES	BETWEEN & THRU TRUSSES	.94 - 1.02	F	F		III	14.45 - 20.70
H. STEEL FRAME		PLANK 16 - 48 W 4 - 12 D	40 TO 75	30 TO 70	20 TO 60	30 TO 40	Y	UNDER STRUCTURE	1.6 - 2.34	F	F	2 TO 4	II	11.55 - 12.20
I. PRECAST CONCRETE		PLANK 16 - 48 W 4 - 12 D	40 TO 75	30 TO 70	20 TO 60	30 TO 40	Y	UNDER STRUCTURE	1.6 - 2.34	F	F	2 TO 4	I	16.80
J. ONE-WAY CONCRETE SLAB			50 TO 120	> 100	10 TO 25	20	N	UNDER STRUCTURE	1.6 - 1.68	G	G	3	I	18.50 - 21.00

1 ROOF STRUCTURE ASSEMBLIES		2 SIZE (INCHES)	3 DEAD LOAD (PSF)	4 LIVE LOAD (PSF)	5 SPAN (FEET)	6 BAY SIZE	7 SUITABLE FOR SLOPE	8 SERVICE PLENUM	9 U VALUE	10 ACOUSTIC IMPACT	AIR	11 FIRE RATING (HRS)	12 CONST. TYPE (IBC)	13 COST ($/SF)
K. TWO-WAY CONCRETE SLAB			50 TO 120	> 100	10 TO 30		N	UNDER STRUCTURE	1.6 - 1.7	G	G	3	I	18.60 - 21.00
L. ONE-WAY RIBBED CONCRETE SLAB		20 & 30 W 6 TO 20 D	40 TO 90	> 100	15 TO 50	3 TO 30	N	BETWEEN RIBS, ONE-WAY	1.6 - 1.7	G	G	3	I	9.35 - 14.00
M. WAFFLE SLAB (2 WAY RIB)		19 OR 30 SQ 6 TO 20 D	75 TO 105	> 100	25 TO 60	35	N	UNDER STRUCTURE	1.6 - 1.7	G	G	3	I	15.60 - 19.55
N. PRE-CAST CONCRETE TEE		16 TO 36 D	65 TO 85	20 TO 80	80 TO 100		Y	BETWEEN RIBS, ONE WAY	1.6 - 1.7	F	G	3	I	11.00
O. PRE-CAST DOUBLE TEE		4,5,6,& 10' W 6 TO 16" D	35 TO 55	25 TO 60	20 TO 75		Y	BETWEEN BEAMS, ONE-WAY	1.6 - 1.7	G	G	3	I	6.30 - 8.10

ROOF STRUCTURE ASSEMBLIES

1		2 SIZE (INCHES)	3 DEAD LOAD (PSF)	4 LIVE LOAD (PSF)	5 SPAN (FEET)	6 BAY SIZE	7 SUITABLE FOR SLOPE	8 SERVICE PLENUM	9 U VALUE	10 ACOUSTIC IMPACT	ACOUSTIC AIR	11 FIRE RATING (HRS)	12 CONST. TYPE (IBC)	13 COST ($/SF)
P. CONCRETE FLAT SLAB			50 TO 160	> 100	35	35	N	UNDER STRUCTURE	1.6 - 1.7	G	G	3	1	10.55 - 12.95
Q. CONCRETE FLAT SLAB W/ DROP PANEL		4 TO 5" SLAB	50 TO 200	> 100	40	35	N	UNDER STRUCTURE	1.6 - 1.7	G	G	3	1	11.10 - 16.80

NOTES

___ B. FLOOR STRUCTURE ASSEMBLIES (5)

___ 1. **Use the tables** on pp. 484–487 to help select a *floor structure assembly.* Cross-sections on each table illustrate various assemblies, with *depth* of assembly in inches. Columns bearing the following numbers on each table show:

___ 2. ***Standard member sizes*** **in inches**

___ 3. ***Dead loads*** **in pound per square foot**

___ 4. **Suitable *live load* range in pounds per square foot**

___ 5. ***Span*** **range in feet**

___ 6. **Typical bay size**

___ 7. **Service *plenum* notes**

Between structural members
Under structure

___ 8. **Acoustical: Comparative resistance to sound transmission:**

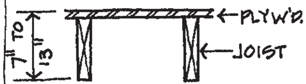
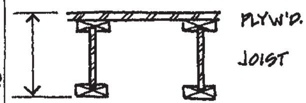
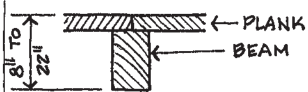
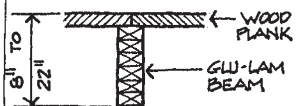
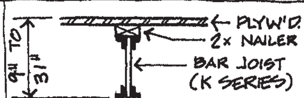
Impact	E = Excellent	F = Fair
Airborne	G = Good	P = Poor

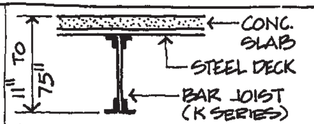
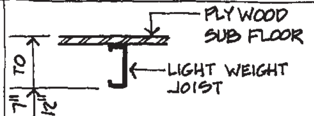
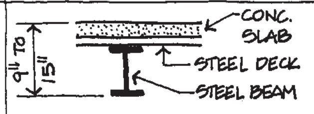
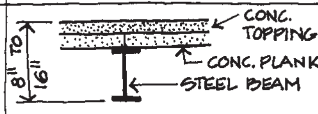
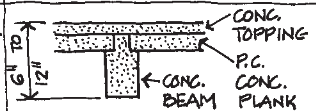
___ 9. ***Fire-resistive*** **ratings, in hours, per code and Underwriters:**

___ 10. ***Construction type classification*** **by code (IBC)**

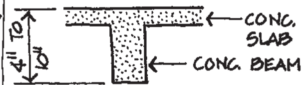
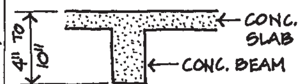
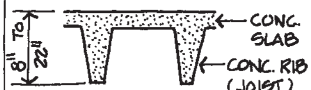
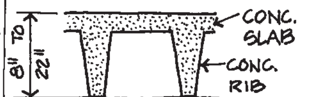
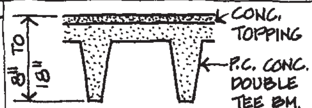
___ 11. **Total costs in $/SF of floor area**

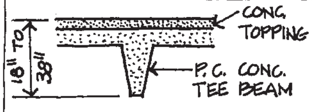
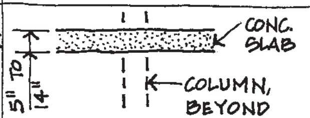
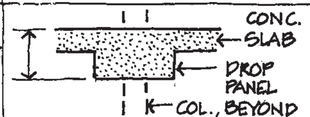
FLOOR STRUCTURE ASSEMBLIES

1		2 SIZE (INCHES)	3 DEAD LOAD (PSF)	4 LIVE LOAD (PSF)	5 SPAN (FEET)	6 BAY SIZE (FT. SQ.)	7 SERVICE PLENUM	8 ACOUSTIC IMPACT	ACOUSTIC AIR	9 FIRE RATING (HR)	10 CONST. TYPE (IBC)	11 COST ($/SF)
A. WOOD JOIST	 7" TO 13"; PLYW'D.; JOIST	2×6, 8, 10 & 12 D	5 TO 8	30 TO 40	TO 18		BETWEEN JOISTS, ONE-WAY	P	F		V	3.60-6.95
B. WOOD TRUSS OR PLYW'D. JOISTS	 PLYW'D.; JOIST	PLYW'D JOISTS 12, 14, 16, 18, & 20 D	6 TO 12	30 TO 40	12 TO 30		BETWEEN & THRU TRUSSES	P	F		V	4.50-5.75
C. WOOD BEAM & PLANK	 8" TO 22"; PLANK; BEAM	PLANK 2, 3, & 4	6 TO 16	30 TO 40	10 TO 22	15 TO 20	UNDER STRUCTURE	P	F		IV	6.00-14.40
D. GLU-LAM BEAM & PLANK	 8" TO 22"; WOOD PLANK; GLU-LAM BEAM	PLANK 2, 3, & 4	6 TO 20	30 TO 40	8 TO 34	20 TO 25	UNDER STRUCTURE	P	F		IV	6.00-14.10
E. STEEL JOIST	 9" TO 31"; PLYW'D.; 2× NAILER; BAR JOIST (K SERIES)	JOIST 8 TO 30 D	8 TO 20	30 TO 40	16 TO 40	25 TO 30	BETWEEN & THRU JOIST	P	P		III	4.55-5.40

1 FLOOR STRUCTURE ASSEMBLIES		2 SIZE (INCHES)	3 DEAD LOAD (PSF)	4 LIVE LOAD (PSF)	5 SPAN (FEET)	6 BAY SIZE (FT. SQ.)	7 SERVICE PLENUM	8 ACOUSTIC IMPACT	ACOUSTIC AIR	9 FIRE RATING (HR)	10 CONST. TYPE (IBC)	11 COST ($/SF)
F. STEEL JOIST		JOIST 8 TO 75 D	30 TO 110	30 TO 100	16 TO 40	25 TO 30	BETWEEN & THRU JOIST	P	F		II	5.10 - 6.10
G. LIGHT WEIGHT STEEL FRAME			6 TO 20	30 TO 60	10 TO 22	10 TO 15	UNDER STRUCTURE	P	P		III	5.40 - 6.40
H. STEEL FRAME			35 TO 60	30 TO 100	16 TO 35	30 TO 35	UNDER STRUCTURE	P	F	1 (SLAB)	II	8.40 - 11.70
I. STEEL FRAME		PLANK 16 TO 48 W 4 TO 12 D	40 TO 75	60 TO 150	15 TO 20	30 TO 40	UNDER STRUCTURE	F	F	1 TO 2 (SLAB)	II	13.00-14.80
J. PRE-CAST CONCRETE		PLANK 16 TO 48 W 4 TO 12 D	40 TO 75	60 TO 150	35 TO 60	30 × 40	UNDER STRUCTURE	F	F	2 TO 4	I	16.30-19.00

FLOOR STRUCTURE ASSEMBLIES

1		2 SIZE (INCHES)	3 DEAD LOAD (PSF)	4 LIVE LOAD (PSF)	5 SPAN (FEET)	6 BAY SIZE (FT. SQ.)	7 SERVICE PLENUM	8 ACOUSTIC IMPACT	ACOUSTIC AIR	9 FIRE RATING (HR)	10 CONST. TYPE (IBC)	11 COST ($/SF)
K. ONE-WAY CONCRETE SLAB			50 TO 120	40 TO 150	10 TO 20	20	UNDER STRUCTURE	G	G	2 TO 4	1	14.15 - 16.55
L. TWO-WAY CONCRETE SLAB			50 TO 120	40 TO 250	10 TO 30		UNDER STRUCTURE	G	G	2 TO 4	1	12.95-16.30
M. ONE-WAY RIBBED CONCRETE		20 & 30 W 6 TO 20 D	40 TO 90	40 TO 150	15 TO 50	20 TO 30	UNDER STRUCTURE	G	G	1 TO 2	1	16.20-16.55
N. CONCRETE WAFFLE SLAB		19 OR 30 W 6 TO 20 D	75 TO 105	60 TO 200	25 TO 40	35	UNDER STRUCTURE	G	G	1 TO 2	1	15.60-19.80
O. PRE-CAST CONCRETE DOUBLE TEE		4,5,6,8,10 W 6 TO 16" D	50 TO 80	40 TO 150	20 TO 50		UNDER STRUCTURE	F	G	1 TO 2	1	8.70-10.50

1 FLOOR STRUCTURE ASSEMBLIES		2 SIZE (INCHES)	3 DEAD LOAD (PSF)	4 LIVE LOAD (PSF)	5 SPAN (FEET)	6 BAY SIZE (FT. SQ.)	7 SERVICE PLENUM	8 ACOUSTIC IMPACT	ACOUSTIC AIR	9 FIRE RATING (HR)	10 CONST. TYPE (IBC)	11 COST ($/SF)
P. PRE-CAST CONCRETE SINGLE TEE		16 TO 36 D TEE BEAM	50 TO 90	40 TO 150	26 TO 65		UNDER STRUCTURE	F	G	1 TO 2	I	13.45
Q. CONCRETE FLAT PLATE			60 TO 125	60 TO 200	18 TO 35	35	UNDER STRUCTURE	G	G	2 TO 4	I	13.20
R. CONCRETE SLAB W/ DROP PANEL		4 TO 5 D SLAB	75 TO 170	60 TO 250	20 TO 40	35	UNDER STRUCTURE	G	G	2 TO 4	I	16.80

NOTES

___ C. WALLS (5)

___ 1. **Use the tables** on pp. 490–491 to help select a *wall assembly.* See Part 9 for finishes. Cross-sections on each table illustrate various assemblies; columns bearing the following numbers show:

___ 2. **Overall *thickness* in nominal inches**

___ 3. ***Weight* in pounds per square foot**

___ 4. **Vertical *span* range for unsupported height in feet**

___ 5. **Heat transmission *coefficient*** *U value* in BTU/hr/SF/°F (see p. 368)

___ 6. **Resistance to airborne *sound* transmission** (see p. 211)

___ 7. ***Fire* resistance rating in hours** (see pp. 94 and 445)

___ 8. **IBC *construction type*** (see p. 93)

___ 9. **Costs in $/SF of wall surface (one side). Wall finishes (paint, etc.) are not included.**

1			2	3	4	5	6	7	8	9
WALL ASSEMBLIES			THICKNESS (INCHES)	WEIGHT (PSF)	VERTICAL SPAN (FEET)	U VALUE	ACOUSTICAL	FIRE RAT'G (HOURS)	CONST. TYPE (HOURS)	COST ($/SF)
A.	C.M.U.	C.M.U.	8 12	55 85	UP TO 13 UP TO 20	0.56 0.49	FAIR TO GOOD FAIR TO GOOD	2-4 4	I & II	9.00 11.10
B.	C.M.U. & INSUL.	C.M.U. INSULATION (2") GYPB'D.	8+ 12+	60 90	UP TO 13 UP TO 20	0.21 0.20	EXCELLENT	2-4 4	↓	12.25 14.40
C.	C.M.U. & BRICK	BRICK C.M.U. INSULATION (2") GYPB'D.	4 + 4 4 + 8	75 100	UP TO 13 UP TO 20	0.19 0.18	EXCELLENT	3-4 4	↓	23.75 25.45
D.	CAVITY	BRICK AIR SPACE INSUL. (2") C.M.U. GYP'B.	4+2+4 4+2+8	75 100	UP TO 9 UP TO 13	0.12 0.11	EXCELLENT	4	↓	23.65 25.55
E.	C.M.U. & STUCCO	STUCCO C.M.U. INSUL. (2") GYPB'D.	8+	67	UP TO 13	0.16	GOOD	2-4	↓	14.95
F.	WOOD STUD	PLYW'D. WD. STUDS INSUL. W/ VAPOR B. GYPB'D.	4 6	12 16	UP TO 14 UP TO 20	0.06 0.04	POOR TO FAIR	1	V	3.90 5.34
G.	BRICK, WOOD STUD	BRICK PLYW'D. WD STUDS INSUL. GYPB'D.	4 + 4	52	UP TO 14	0.07	GOOD TO EXCELLENT	1-2	V	18.30 TO 18.80
H.	METAL STUD	EXT. WALL FINISH METAL STUDS INSUL. GYPB'D.	4 5	14 18	UP TO 13 UP TO 17	0.06 0.04	POOR TO FAIR	1-2	I-II	3.80 4.20
I.	BRICK, METAL STUD	BRICK PLYW'D. METAL STUDS INSULATION GYPB'D.	4 + 4	54	UP TO 15	0.07	GOOD TO EXCELLENT	1-2	I-II	17.60 TO 18.10

WALL ASSEMBLIES

1			2 THICKNESS (INCHES)	3 WEIGHT (PSF)	4 VERTICAL SPAN (FEET)	5 U VALUE	6 ACOUSTICAL	7 FIRE RAT'G (HOURS)	8 CONST. TYPE (HOURS)	9 COST ($/SF)
J.	INSULATED SANDWICH PANEL	METAL SKIN, AIRSPACE, INSUL., METAL SKIN	5	6		0.05	POOR TO GOOD		II-B	5.50
K.	CONCRETE	REINF. CONCRETE	8 12	92 138	UP TO 17 UP TO 25	0.68 0.55	GOOD	4 4	I	20.40 24.50
L.	CONCRETE & INSULATION	REINF. CONCRETE, INSULATION (2"), GYPB'D.	8+	97	UP TO 17	0.13	GOOD	4	III	23.70
M.	BRICK, CONCRETE, INSUL.	BRICK, CONCRETE, INSUL. (2"), GYPB'D.	4+8	112	UP TO 17	0.13	EXCELLENT	4	III	36.90
N.	PRECAST CONCRETE	REINF. CONCRETE, INSULATION (2"), GYPB'D.	2+ 4+	23 46	UP TO 6 UP TO 12	0.99 0.85	POOR TO FAIR	1-3	III	11.65 17.75
O.	PRECAST CONCRETE SANDWICH	P.C. CONCRETE, INSULATION	5	45	UP TO 14	0.14	FAIR	1-3	I & II	14.40
P.	GLAZED CURTAIN WALL	ALUM, GLAZING	5				POOR			SG 48 DG 69 MAX 150

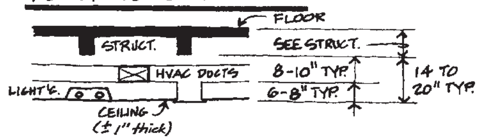
NOTES

CEILING SELECTION TABLE

ASSEMBLY	COST COMPARISON	WEIGHT (LBS/SF)	SOUND: ABSORB.	SOUND: TRANSM.	LATERAL LOAD	IMPACT	UPLIFT	DEFLECTION	HUMIDITY	FINISH: PRE-	FINISH: IN PLACE: TEXT.	FINISH: IN PLACE: PAINT	NOTES
SUSP. ACOUSTIC TILE W/ EXPOSED GRID	1 TO 2	2 TO 3	G	F TO P	F TO P	P TO F	P TO G	G	P TO F	●			
SUSP. ACOUSTIC TILE W/CONCEALED GRID	4 TO 5	↓	↓	↓	F	P	G	↓	↓	●			
SUSP. PLASTER	3 TO 5	4 TO 6	P	G	P	↓	↓	F TO P	P		●	●	
SUSP. GYPBOARD	2 TO 3	3 TO 4	↓	↓	G	↓	↓	↓	F TO P		●	●	
ACOUSTIC TILE ATTACHED	4 TO 5	2 TO 3	G	G	N/A	↓	N/A	N/A	P TO F			● *	* "NON-BRIDGING" PAINT
SPRAY ON	1 TO 2	.2 TO .3	↓	↓	↓	↓	↓	↓	P		●		

● DENOTES COMMON USAGE
P = POOR
F = FAIR
G = GOOD

FLOOR TO CEILING SPACE



FLOORING SELECTION TABLE

TYPE	COST COMPARISON	WEIGHT (PSF)	COMFORT	MOISTURE			TRAFFIC					IMPACT	CLEANING		LOCATION				SUBSTRATE		*	CONDUCTIVE	OTHER
							FOOT			WHEEL													
				DRY	OCC. WET	FREQ. WET	LOW	MOD.	HIGH	RUB.	STEEL		MILD	HEAVY	OUTSIDE	BELOW GR.	ON GRADE	ABOVE GR.	WOOD	CONC.	SLIP RESIST.		
STONE	.9 TO 3	15 TO 40	P	●	●	●	○	●	●	○		●	●	○	●	●	●	●		●	○		
BRICK	.4 TO .9	20 TO 40	P	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●	○		
CONCRETE	1.2 - 2.5	10 TO 75	P	●	●	●	●	●	●	●	○	●	●	●	●	●	●	●		●	●	○	
C.T.	2 - 4	4 - 6	P	●	●	●	●	●	●	○			●	●	●	●	●	●	●	●	●	●	
Q.T.	4 - 5.5	4 - 6	P	●	●	●	●	●	●	○		●	●	●	●	●	●	●	●	●	●		
RESILIENT	.6 - 2	1 - 2	G	●	●		●	●		●▪		●	●				●	●	●	●	●	●	
WOOD	3 - 5	1 - 10	F	●	●		●	●		●		○	●				●	●	●	●	●		
CARPET	1.5 - 5	.5 - 1	G	●			●	●				●	●				●	●	●	●	●	○	
EPOXY	3 - 5	3 - 7	F	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	

● DENOTES COMMON USAGE OR SUITABILITY

○ DENOTES POSSIBLE OR LIMITED USAGE OR SUITABILITY

* SLIP RESISTANCE

RECOMMENDATIONS FOR STATIC COEFFICIENT OF FRICTION :
NORMAL = 0.5 MIN, H.C. (ADA) = 0.6 MIN, RAMP = 0.8 MIN.

0.2 OR LESS IS VERY SLICK. 0.3 TO 0.4 IS SMOOTH. BROOM FINISH CONCRETE IS USUALLY 0.5 TO 0.7. GRIT STRIPES FOR STAIRS OR RAMPS ARE 0.8 OR ABOVE.

THE COEFFICIENT OF FRICTION IS THE RATIO OF HORIZONTAL FORCE TO VERTICAL FORCE. WAXES SHOULD MEET ASTM D-2047.

NOTES

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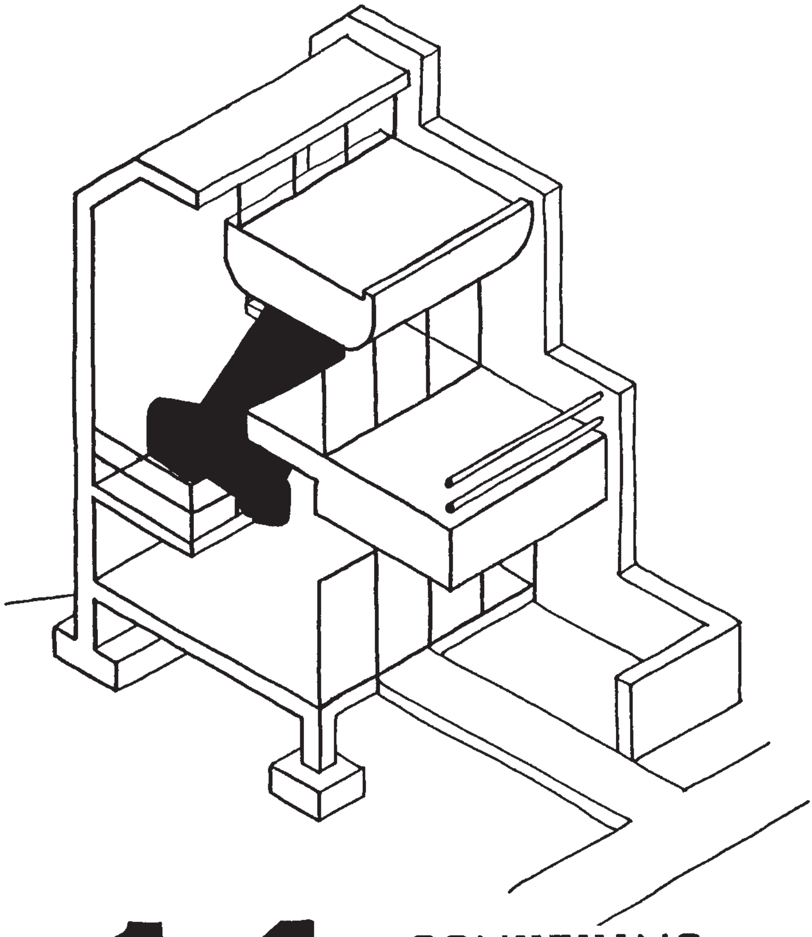


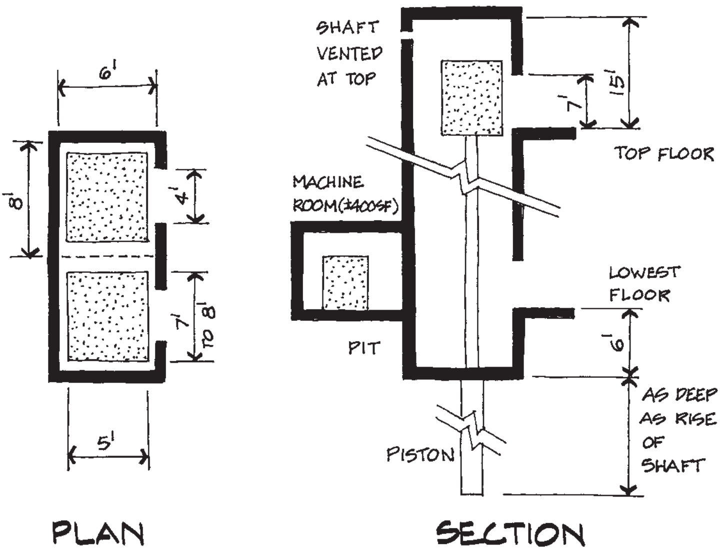
14 CONVEYING SYSTEMS

NOTES

___ A. ELEVATORS (13) (16)

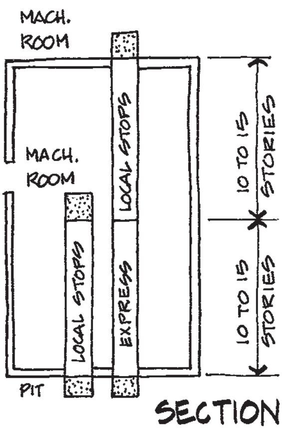
Per A.D.A. one elevator is required in any building more than 3 stories high or with more than 3000 SF of area on each floor.

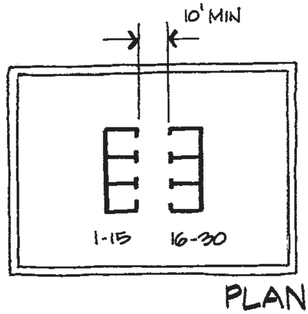
___ 1. Hydraulic: The least expensive and slower type. They are moved up and down by a piston. This type is generally used in low-rise buildings (2 to 4 stories) in which it is not necessary to move large numbers of people quickly.

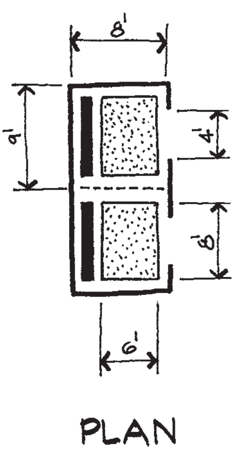


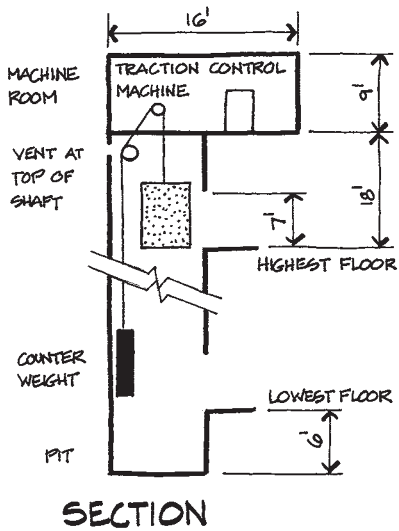
Costs:	
Passenger elevators	**$61,200 (50 fpm, 2000 lbs) to $76,800 (150 fpm, 3000 lbs) per shaft. 3 stops, 3 openings. Add: 50 fpm/stop = +$4200; 500 lb/stop = +$4200; stop = +$6300; custom interior = +$6000.**
Hydraulic freight elevators	**$68,100 (50 fpm, 3000 lbs) to $103,300 (150 fpm, 6000 lbs).**

___ 2. **Traction Elevators:** Traction elevators hang on a counterweighted cable and are driven by a traction machine that pulls the cable up and down. They operate smoothly at fast speeds and have no limits. Typically, penthouse floor area equals twice the shaft area. A machine room is located either next to the penthouse or on any floor next to the shaft. The shafts, penthouse, pit, and landings are all major special components in the building and often comprise more than 10% of its costs.









Costs:	
Passenger elevators/shaft	**$79,200 (50 fpm, 2000 lbs) to $152,400 (300 fpm, 4000 lbs) for 6 stops, 6 openings. Add: stop = +$4800; 50 fpm/stop = +$2400; 500 lb/stop = +$2400; opening per stop = +$5400; custom interior = +$5760.**
Freight elevators (2 stops)/shaft	**$120,000 (50 fpm, 3500 lbs) to $141,600 (200 fpm, 5000 lbs).**

___ 3. Elevator Rules of Thumb

___ *a.* Commercial

___ (1) One passenger elevator for each 30,000 SF of net floor area.

___ (2) One service elevator for each 300,000 SF of net floor area.

___ (3) Lobby width of 10′ minimum.

___ (4) Banks of elevators should consist of 4 or fewer cars so that people can respond easily to the arrival of an elevator.

___ (5) In high buildings, the elevator system is broken down into zones serving groups of floors, typically 10 to 15 floors. Elevators that serve the upper zones express from the lobby to the beginning of the upper zone. The elevators that serve the lower zones terminate with a machine room above the highest floor served.

___ (6) Very tall buildings have sky lobbies served by express elevators. People arriving in the lobby take an express elevator to the appropriate sky lobby where they get off the express elevator and wait for the local elevator system.

___ (7) Lay out so that maximum walk to an elevator does not exceed 200′.

___ (8) Per ADA, accessible elevators *are* required at *shopping centers* and offices of *health care* providers. Elevators are *not* required in facilities that are less than 3 stories or less than 3000 SF per floor. But, if elevators are provided, at least one will be accessible (see p. 502).

___ *b.* Residential

___ (1) In hotels and large apartment buildings, plan on one elevator for every 70 to 100 units.

___ (2) In a 3- to 4-story building, it is possible to walk up if the elevator is broken, so one hydraulic elevator may be acceptable.

___ (3) In the 5- to 6-story range, two elevators are necessary. These will be either hydraulic (slow) or traction (better).

___ (4) In the 7- to 12-story range, two traction elevators are needed.

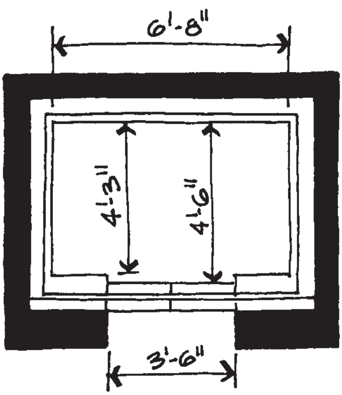
___ (5) Above 12 stories, two to three traction elevators are needed.

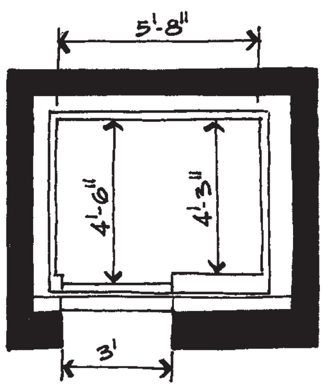
___ (6) Very tall buildings will require commercial-type applications.

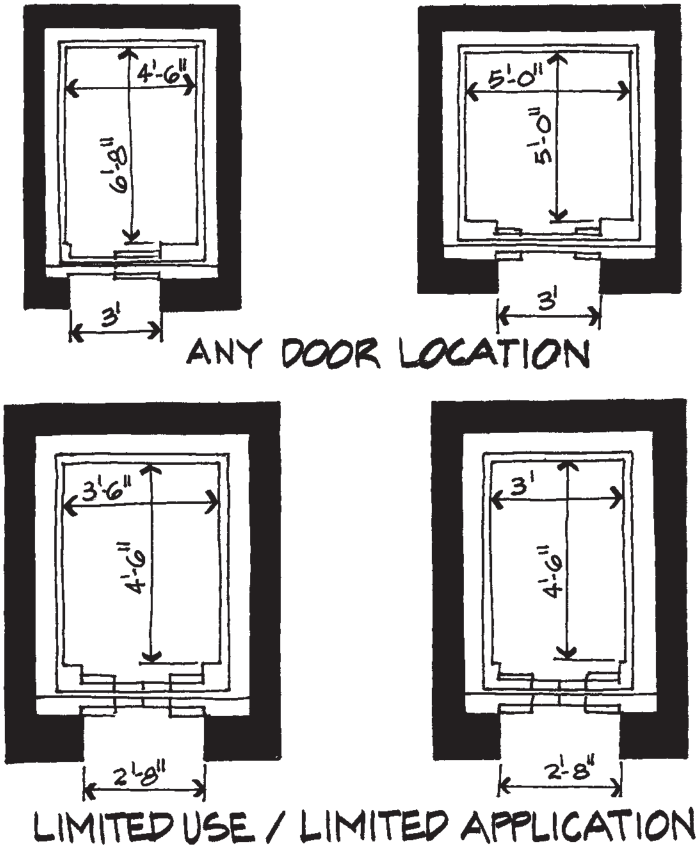
___ (7) Plan adequate space and seating at lobby and hallways.

___ *c.* Where elevators are provided in buildings of 4 stories or more, at least one must accommodate an ambulance stretcher.

___ *d.* ADA-accessible elevators (see item 8, p. 501):



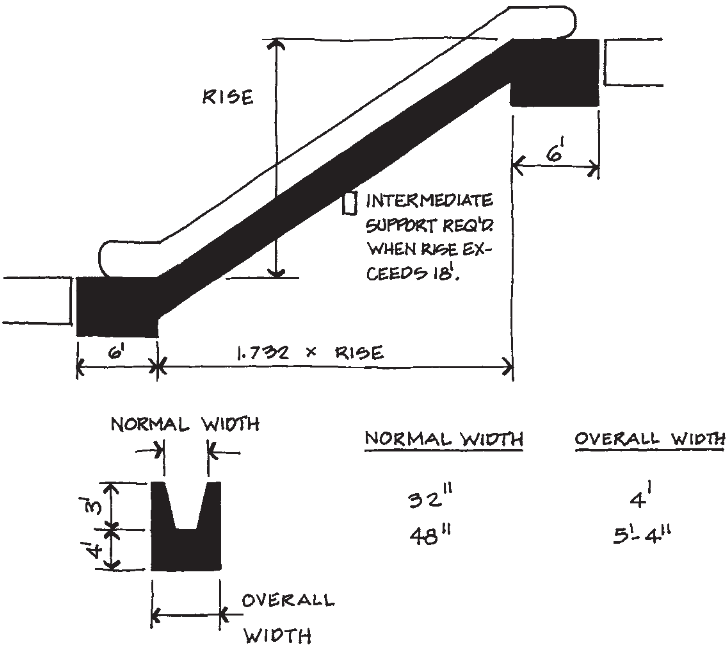



4'-6"
6'-8"
3'
5'-0"
5'-0"
3'
ANY DOOR LOCATION
3'-6"
4'-6"
2'-8"
3'
4'-6"
2'-8"
LIMITED USE / LIMITED APPLICATION

NOTES

___ B. ESCALATORS

Escalators require ⅓ the floor area of elevators to deliver the same passenger loads, need not have pits or penthouses, and can traverse tall floor-to-floor heights. But above 2 levels, riders prefer elevators.



Typically, ceiling-to-floor heights are 4′ due to underside machinery at each end. Risers are 8″ and step slopes are 30°.

Costs:
Escalator costs range from $106,500 for 12′ rise, 32″ width, to $167,400 for 25′ rise, 48″ width. For glass side enclosure add $13,800 to $16,200.

Rules of Thumb

1. All escalators rise at a 30-degree angle.
2. There needs to be a minimum of 10′ clear at top and bottom landings.
3. Provide beams at top and bottom for the escalator's internal truss structure to sit on.
4. The escalator will require lighting that does not produce any distorting shadows that could cause safety problems.
5. Escalators need to be laid out with a crowded flow of people in mind. Crossover points where people will run into each other must be avoided.
6. Current trends in the design of retail space use the escalators as a dramatic and dynamic focal feature of open atrium spaces.
7. Because escalators create open holes through building floor assemblies, special smoke and fire protection provisions are necessary.

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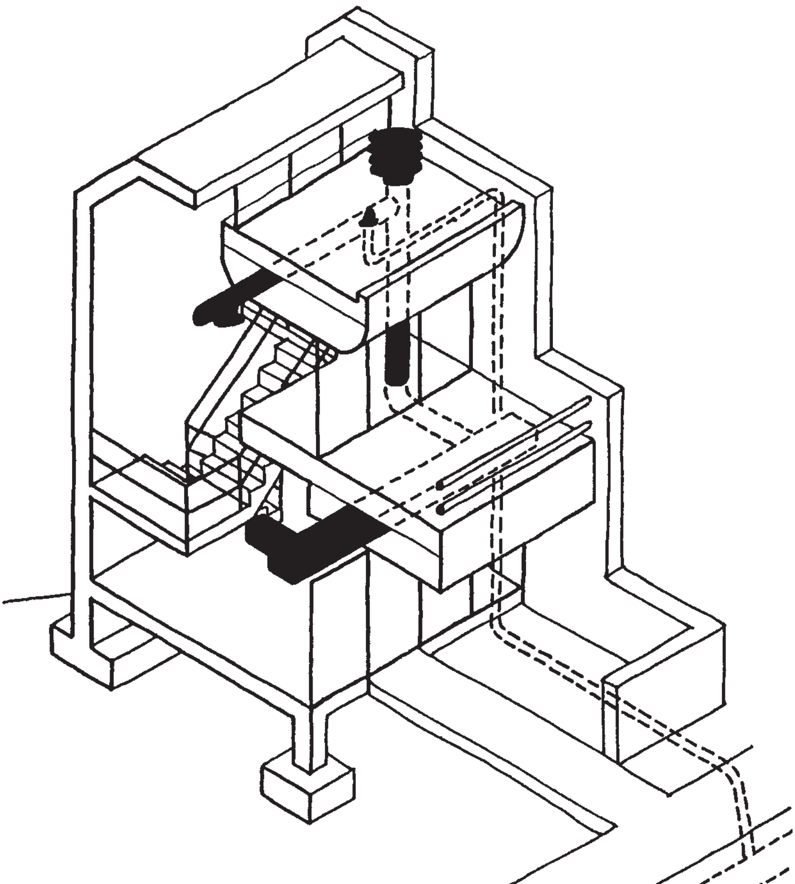


15 MECHANICAL

NOTES

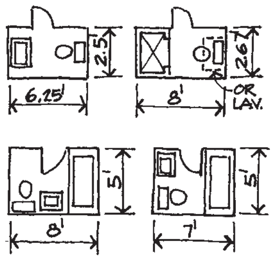
___ A. THE PLUMBING SYSTEM

(B) (1) (5) (10) (13) (27) (32) (34) (35)

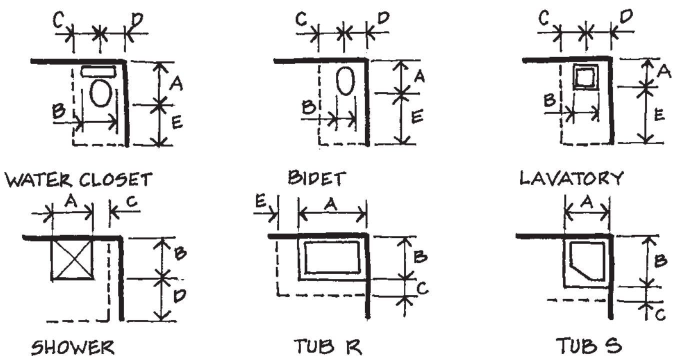
See p. 259 for exterior utilities.
See p. 512 thru 514 for toilet rms.
See p. 526 for fixture count 2009 IPC and p. 533 for UPC.

The following systems need to be considered:

- ___ 1. **Fixture count by code**
- ___ 2. **Water supply** (p. 516)
- ___ 3. **Plumbing fixtures** (p. 517)
- ___ 4. **Sanitary sewer** (p. 518)
- ___ 5. **Rain water/storm sewer** (p. 519)
- ___ 6. **Fire protection** (p. 521)
- ___ 7. **Landscape irrigation** (p. 525)
- ___ 8. **Gas** (p. 525)
- ___ 9. **Other specialties** (process, etc.)



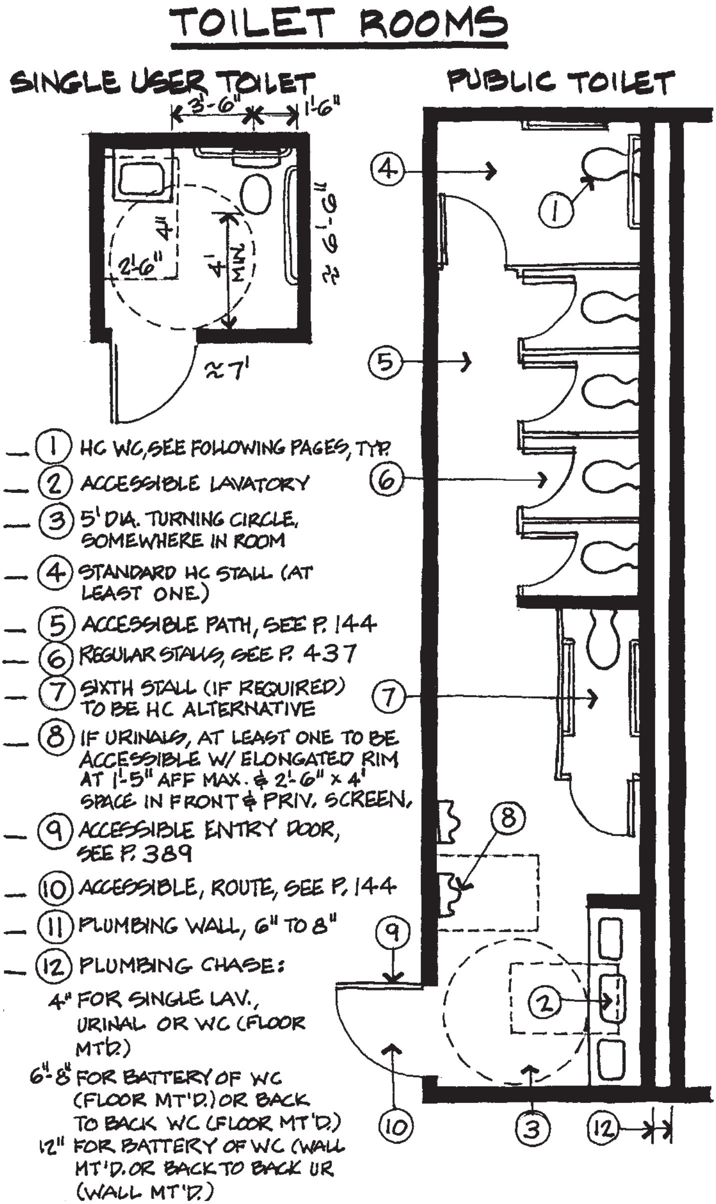
RESIDENTIAL BATHROOMS

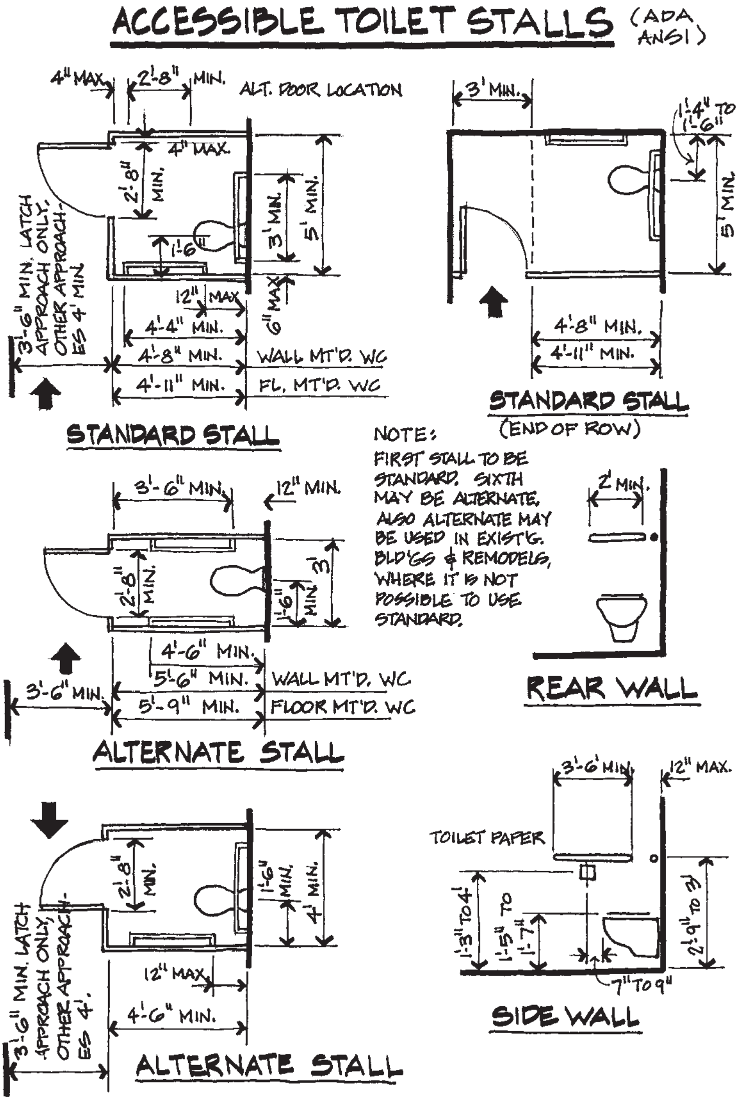


FIXTURE SIZES AND CLEARANCES (INCHES)

FIXTURE	A		B		C		D		E	
	MIN.	LIB.	MIN.	LIB.	MIN.	LIB.	MIN.	LIB.	MIN.	LIB.
WATER C.	27	31	19	21	12	18	15	22	18	34 - 36
BIDET	25	27	14	14	12	18	15	22	18	34 - 36
LAVATORY	16	21	18	30	2	6	14	22	18	30
SHOWER	32	36	34	36	2	8	18	34		
TUB R	60 STD	72	30 STD	42	2	8	18 - 20	30 - 34	2	8
TUB S	38		39		2	4				

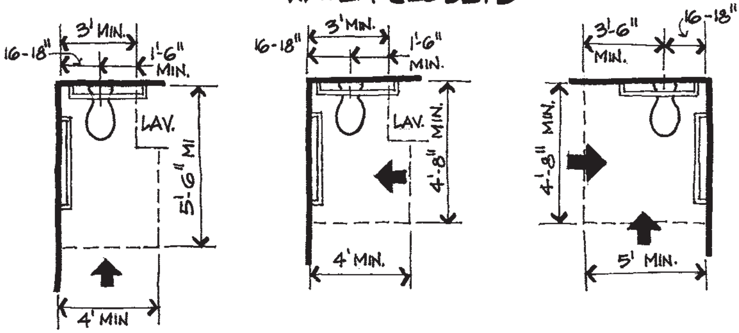
NOTE: FOR H.C. ACCESSIBILITY, SEE FOLLOWING PAGES


TOILET ROOMS
SINGLE USER TOILET
3'-6"
1'-6"
4'
2'-6"
4' MIN.
≈ 6'-6"
≈ 7'
PUBLIC TOILET
1 HC WC, SEE FOLLOWING PAGES, TYP.
2 ACCESSIBLE LAVATORY
3 5' DIA. TURNING CIRCLE, SOMEWHERE IN ROOM
4 STANDARD HC STALL (AT LEAST ONE)
5 ACCESSIBLE PATH, SEE P. 144
6 REGULAR STALLS, SEE P. 437
7 SIXTH STALL (IF REQUIRED) TO BE HC ALTERNATIVE
8 IF URINALS, AT LEAST ONE TO BE ACCESSIBLE W/ ELONGATED RIM AT 1'-5" AFF MAX. & 2'-6" x 4' SPACE IN FRONT & PRIV. SCREEN.
9 ACCESSIBLE ENTRY DOOR, SEE P. 389
10 ACCESSIBLE, ROUTE, SEE P. 144
11 PLUMBING WALL, 6" TO 8"
12 PLUMBING CHASE:
4" FOR SINGLE LAV., URINAL OR WC (FLOOR MT'D.)
6"-8" FOR BATTERY OF WC (FLOOR MT'D.) OR BACK TO BACK WC (FLOOR MT'D.)
12" FOR BATTERY OF WC (WALL MT'D. OR BACK TO BACK UR (WALL MT'D.)

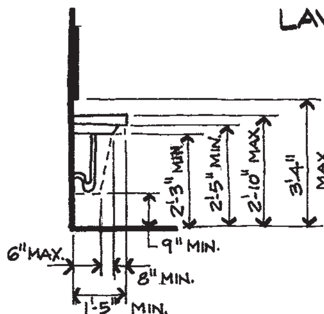

ACCESSIBLE TOILET STALLS (ADA ANSI)
4" MAX.
2'-8" MIN.
ALT. DOOR LOCATION
4" MAX.
2'-8" MIN.
1'-6"
3' MIN.
5' MIN.
12" MAX
6" MAX
4'-4" MIN.
4'-8" MIN.
WALL MT'D. WC
4'-11" MIN.
FL. MT'D. WC
3'-6" MIN. LATCH APPROACH ONLY, OTHER APPROACH-ES 4' MIN.
STANDARD STALL
3' MIN.
1'-4" TO 1'-6"
5' MIN.
4'-8" MIN.
4'-11" MIN.
STANDARD STALL
(END OF ROW)
NOTE:
FIRST STALL TO BE STANDARD. SIXTH MAY BE ALTERNATE. ALSO ALTERNATE MAY BE USED IN EXIST'G. BLD'GS & REMODELS, WHERE IT IS NOT POSSIBLE TO USE STANDARD.
3'-6" MIN.
12" MIN.
2'-8" MIN.
1'-6" MIN.
3'
4'-6" MIN.
5'-6" MIN.
WALL MT'D. WC
3'-6" MIN.
5'-9" MIN.
FLOOR MT'D. WC
ALTERNATE STALL
2' MIN.
REAR WALL
2'-8" MIN.
1'-6" MIN.
4' MIN.
12" MAX.
4'-6" MIN.
3'-6" MIN. LATCH APPROACH ONLY, OTHER APPROACH-ES 4'.
ALTERNATE STALL
3'-6" MIN.
12" MAX.
TOILET PAPER
1'-3" TO 4'
1'-5" TO 1'-7"
2'-9" TO 3'
7" TO 9"
SIDE WALL

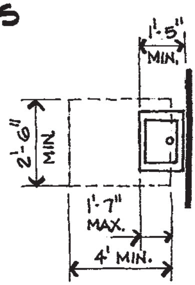
ACCESSIBLE FIXTURES (ADA)

WATER CLOSETS

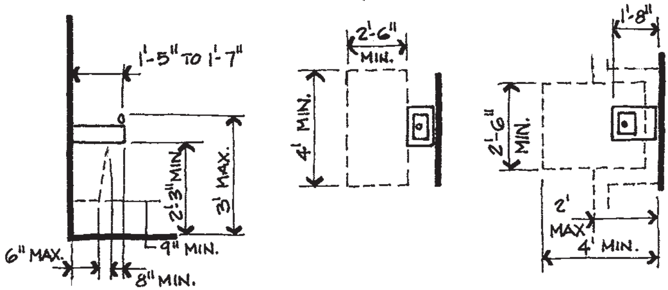


LAVATORIES





DRINKING FOUNTAINS



Costs: As a rough rule of thumb, estimate $1250 to $2000/fixture (50% M and 50% L) for all plumbing within the building. Assume 30% for fixtures and 70% for lines. Also, of the lines, assume 40% for waste and 60% for supply. For more specifics on fixtures, only:

	Residential			
Fixture	**Low**	**Medium**	**High**	**Commercial**
WC	**$200**	**$550**	**$935**	**$110 to $330**
Lavatories	**$150**	**$280**	**$500**	**same**
Tub/shower	**$500**	**$750**	**$2000**	
Urinals				**$275 to $660**
Kitchen sinks	**$200**	**$500**	**$800**	

Initial cost is typically only a portion of projected life cycle costs. In commercial buildings a fixture's cost is usually no more than the cost to maintain it for a few months, so any fixtures that reduce maintenance cost usually pay for themselves quickly. When renovating existing buildings, all old piping should be thoroughly cleaned or replaced.

___ 1. ***Fixtures Required by Code***

Presently, two plumbing codes rule: the International Plumbing Code (IPC; usually associated with the IBC building code) and the Uniform Plumbing Code. You will need to know which code governs to determine your required fixture count.

- ___ *a.* IPC Requirements:
  - ___ (1) See p. 526 for fixture count table.
  - ___ (2) Urinals may be substituted for water closets up to 67%.
  - ___ (3) Number of users based on occupant load by the IBC. Usually this will be split 50% for each sex.
  - ___ (4) Separate toilets for each sex are not required for private facilities or where occupant load is less than 15. Can use a unisex toilet.
  - ___ (5) The IBC requires an extra unisex toilet at assembly and mercantile occupancies when the combined fixture count is 6 or more water closets.
  - ___ (6) Toilets for *public* must be within 500′ (300′ in malls) and not more than 1 story above or below.

___ (7) Toilets for employees must be within 500′ (300′ from tenant space) and not more than 1 story above or below.

___ (8) The IBC does not allow toilet rooms to open directly to food service kitchens.

___ *b.* UPC requirements:

___ (1) See p. 533 for fixture count table.

___ (2) The number of users is based on occupant load determined by the building code and is split 50% for each sex, except in residences and where occupant load is 10 or less (in which a single-user toilet may be used).

___ (3) Toilet rooms must be no more than 1 story away.

___ (4) Toilet rooms used in private offices do not count toward the number required.

___ (5) Business and mercantile occupancies:

___ (*a*) A single-user toilet may be used when area is not more than 1500 SF.

___ (*b*) Customer and employee toilets may be combined but must use count that is highest in each type.

___ (*c*) For stores, toilet rooms for customers cannot be more than 500′ away. But at stores of 150 SF or less, employee toilets cannot be more than 300′ away.

___ (6) Food service establishments: When occupant load is 100 or more, must have separate toilet rooms for customers and employees.

___ (7) Water conservation required as follows:

Water closets:	1.6 gal/flush, max.
Urinals:	1.0 gal/flush, max.
Lavatories:	2.2 gal/min, max. (or not more than ¼ gal per use).
Kitchen sinks:	2.2 gal/min, max.
Shower heads:	2.5 gal/min, max.

___ **2. *Water Supply***

There are four kinds of water demand: occupancy, special loads, climate control, and fire protection. The water supply is under pressure, so there is flexibility in layout of the water main to the building. In warm climates the *water meter* can be outside, but in cold climates it must be in a heated space.

For small buildings allow a space of *20″ W × 12″D × 10″H.* After entering the building the water divides into a hot- and cold-water distribution system at the hot water heater. For small buildings allow for a *gas heater* a space *3′ sq. dia. × 60″H* and for *electric heaters, 24″ dia. × 53″H.* Where bathrooms are spread far apart, consideration should be given to multiple hot water heaters or circulated hot water. Provide *30″ × 30″* space in front of appliances for maintenance.

Costs: Residential: $660 to $1980/ea.
Commercial: $1980 to $3960/ea. (80% M and 20% L).

Electric is cheaper for small buildings but high for large buildings.

___ If the water is "hard" (heavy concentration of calcium ions), a *water softener* may be needed. Provide *18″ dia. × 42″ H* space.

Costs: ≈ $890

___ If water is obtained from a private *well,* a pump is needed. If the well is *deep,* the pump is usually at the bottom of the well. For this case provide space for a pressure tank that is *20″ dia. × 64″H.* If the well is *shallow* (20′ to 25′ deep) the pump may be provided inside the building. Space for pump and tank should be *36″W × 20″D × 64″H.*

Costs: $185 to $265 per LF of well shaft

___ Water supply *pipes* are usually copper or plastic and range from ½″ to 2″ for small buildings, but 2½″ to 6″ for larger buildings or higher-water-use buildings. Hot and cold pipes are usually laid out parallel. Piping should be kept out of exterior walls in cold climates to prevent winter freeze-ups. The cost of insulation is usually quickly returned by savings in reduced heat loss. As the pipe diameter increases, this becomes more so due to greater volume and surface area.

___ The city water pressure will push water up 2 or 3 stories. Buildings taller than this will need a *surge tank and water pressure pumps.* This equipment takes approximately *100 to 200 SF* of space.

Costs: $6000 to $24,000

___ 3. *Plumbing Fixtures*

The men's and women's *restrooms* need to be laid out to determine their size and location in the building. Economical solutions are shared plumbing walls (toilet rooms back to back) and for multistory buildings, stacked layouts.

___ In *cold* climates, chases for plumbing lines should not be on exterior walls, or if so, should be built in from exterior wall insulation.

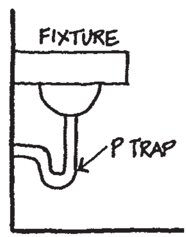
___ Public buildings should have one janitor sink per 100 occupants, on each floor.

Costs: See p. 515.

___ 4. *Sanitary Sewer*

Sewage flow is usually considered to be 95% of supply water flow. Horizontal runs of drainage piping are difficult to achieve inside the building. Pipe pitches should be at least ¼″/ft. Straight runs should not exceed 100′ for metal (or 30′ for plastic) piping. Cleanouts should be located at every direction change exceeding 45°, and every 50′ to 100′. The best arrangement is to bring the plumbing straight down (often along a column) and make connections horizontally under the building. Piping should not pass within 2 vertical feet above any electrical service unless contained in secondary piping.

___ The *sanitary drainage system* collects waste water from the plumbing fixtures, which flows by gravity down through the building and out into the city sewer. Because of the slope requirement, long horizontal runs of drainage pipe will run out of ceiling space to fit in. Ideally, sanitary drainage pipes (called plumbing stacks) should run vertically down through the building collecting short branch lines from stacked bathrooms. A *4″* stack can serve approx. *50* WCs and accompanying lavatories. A *6″* stack can serve approximately *150* WCs and lavatories. Pipes are typically of cast iron or plastic (ABS). Each fixture is drained through a "P" trap with a water seal. This, and venting the system to the roof, keeps sewer gases from entering the building.



___ The *building drain* runs horizontally under the building collecting waste water from multiple vertical stacks. A *4″ to 6″* pipe requires a minimum slope of *1%,* and an *8″* pipe requires a minimum slope of ½%. The lowest (or basement) *floor elevation* needs to be set higher than the rim elevation of the next upsteam manhole of the sewer main. If the building drain is below the sewer main, an automatic underground *ejector pump* is needed.

___ At sites where city sewer mains do not exist, a *septic system* will be needed. The size and configuration of private disposal systems vary widely depending on soil conditions, topography, local laws, and the regulated capacity of the system. The most common type includes a *septic tank* (usually 1000 to 1500 gallons) and a *disposal field* of open-joint pipe below the ground which should slope 1⁄16 to 3⁄8″/ft (max.). Soil saturation at the wettest time of the year determines final design. The lowest part of pipe trench must lie above the highest water table level. As a starting point, allow an area of nearly level ground *40′ × 80′* with short side against building. No part of this area may be closer than *100′* to a well, pond, lake, stream, or river, or 8′ from a building. Both tank and field are best located in grassy open areas, and not under parking or drives where heavy loads could compact the soil above. Also see p. 252.

___ Water reclaimed (*graywater*) from certain plumbing fixtures as well as runoff from roofs, parking areas, and driveways may be reused after minor treatment, in fire sprinklers, for toilet flushing, in numerous industrial operations, as well as for landscape irrigation.

Costs: $13,800

___ *Solid waste* is often handled by a *compactor* for larger buildings. A compactor room of *60 SF* is sufficient for a small apartment building; *150 to 200 SF* for a larger building; and much larger for industrial. If a chute is used, plan on *15″ to 30″ diameter, with 24″* a typical dimension. Grease interceptors are required for restaurants, cafeterias, and auto repair shops.

Costs: See p. 457.

___ 5. <u>*Rainwater/Storm Sewer*</u>

The rainwater that falls on the roof and the grounds of a building needs to be collected and channeled into the city storm drain system. If there is none, the site is drained to the street or to retention basins (if required). See page 239.

___ The *roof* slope must be arranged to channel water to drain points, where drainage pipes can carry the water down through the building and out into the storm drainage system (or sheet-drained on to the site).

___ The storm drainage water is kept separate from the sanitary drainage water so the sewage treatment system will not become overloaded in a rain. The following *guidelines* can be used in planning a storm drainage system:

___ *a.* *"Flat" roofs* need a minimum slope of *2%*.

___ *b.* Except for small roof areas there should be more than one drain point on a roof area.

___ *c.* *Roof drain leaders* are best *located* near exterior walls or interior columns, not at midspans of the structures.

___ d. *Backup drains or scuppers* should be provided in case main drains become clogged. These should be *4″* up slope or *2″* above drain. For small buildings, scuppers at exterior walls may be used.

___ e. At *sloped roofs,* water may shed off the edge, or to avoid this, roof *gutter and downspouts* may be used. Downspouts typically range from *3″ to 6″* in 1″ increments. Common provision for average rain conditions is *1 square inch* of cross section for each *150 SF* of roof area. Where parapets are long or tall, include ½ of their surface area to catch driving rain from one direction. Estimate area of sloped roofs as follows:

Pitch	Factor
Level to 3″/ft	1.00
4″ to 5″/ft	1.05
6″ to 8″/ft	1.10
9″ to 11″/ft	1.20
12″/ft	1.30

___ f. Horizontal *storm drain* pipes have a minimum slope of *1%*. The best strategy is to route them vertically down through the building, with a minimum of horizontal lines.

___ g. For estimating drain lines and downspouts:

Intensity, inch/hr. (see App. B, item J)	SF roof per sq. in, downspout or drain
2	600
3	400
4	300
5	240
6	200
7	175
8	150
9	130
10	120
11	110

___ h. *Gutters:* Depth should be between ½ to ¾ the width but should be deeper where pitches exceed ¼″/LF. Minimum pitch should be 1⁄16″/LF. Widths usually range from 4″ to 8″. Long runs should have expansion joints at 60′ max. (at pitch peaks).

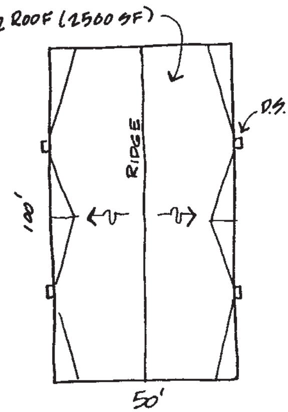
___ *i.* *Leaders or downspouts:* Every roof plane should have at least two in case one is blocked, and each one should have a sectional area of at least 1 sq in per 100 SF of roof (7 sq in min.). They should be 20′ to 50′ apart.

Costs: $145 to $300/roof drain (for gutter and downspouts, assume ½ to ⅔ cost)

EXAMPLE:

PROBLEM:

FIGURE ROOF DRAINAGE FOR A ROOF THAT IS 50' x 100' IN MIAMI, FLORIDA. THE ROOF HAS A CENTER RIDGE AND IS TO BE SLOPED TO DOWNSPOUTS AT EXTERIOR WALLS.



SOLUTION:

1. AREA OF ROOF = 50' x 100' ÷ 2 SYSTEMS = 2500 SF
2. FOR MIAMI, FL (APP. B, ITEM 1, P. 642) RAIN = 7.8"/HR.
3. ASSUME 3" x 3" DOWNSPOUTS = 9 SQ in/D.S.
4. NUMBER OF DOWNSPOUTS (SEE P. 520) @8"/HR = 150 SF/SQ IN/DS

$$\frac{\text{2500 SF ROOF SYSTEM}}{\text{150 SF/IN}} = \text{16.6 SQ IN.}$$

$$\frac{\text{16.6 SQ IN}}{\text{9 SQ IN/D.S}} = \text{2 DOWNSPOUTS PER SIDE}$$

___ 6. *Fire Protection*

(See p. 261 for fire hydrants)

___ *a.* A *sprinkler system* is the most effective way to provide fire safety. Research indicates sprinklers will extinguish or contain 95% of fires

that start. Water supply and pressure are critical. At a minimum, should have 1-hour water supply.

- ___ (1) The IBC requires sprinklers at certain occupancies (see p. 94). Also see item I in App. A.
- ___ (2) Sprinkler *spacing* (maximum coverage per sprinkler):
  - ___ Light hazard (Class I)
    - 200 SF for smooth ceiling and beam-and-girder construction
    - 225 SF if hydraulically calculated for smooth ceiling, as above
    - 130 SF for open wood joists
    - 168 SF for all other types of construction
    - At both sides of a fire barrier (horizontal exit adjacent to egress doorways). See p. 92. Also, accessible roofs require one outlet.
  - ___ Ordinary hazard (Class II)
    - 130 SF for all types of construction, except:
    - 100 SF for high-pile storage (12′ or more).
  - ___ Extra hazard (Class III)
    - 90 SF for all types of construction
    - 100 SF if hydraulically calculated.
  - ___ High-piled storage (CHS) warehouses containing combustible items that are stored more than 15′ high.
- ___ (3) Notes
  - ___ (*a*) Most buildings will be the *225 SF* spacing.
  - ___ (*b*) Maximum spacing for light and ordinary hazard = 15′
    High-pile and extra hazard = 12′
  - ___ (*c*) Small rooms of light hazard, not exceeding *800 SF:* locate sprinklers max. of *9*′ from walls.
  - ___ (*d*) Maximum distance from walls to last sprinkler is ½ *spacing* (except at small rooms). Minimum is *4*″.
  - ___ (*e*) City ordinances should be checked to verify that local rules are not more stringent than IBC requirements.

___ (*f*) The sprinkler riser for small buildings usually takes a space about *2′6″ square.* Pumps and valves for larger buildings take up to about *100 to 500 SF.*

___ (*g*) Types

___ 1. Wet-pipe (water is always in pipe up to sprinkler head)

___ 2. Antifreeze

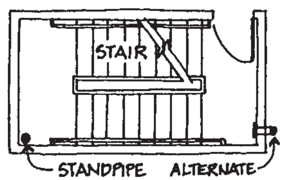
___ 3. Drypipe (water no further than main; used where freezing is a problem)

___ 4. Preaction (fast response)

___ 5. Deluge

___ 6. Foam water (petroleum fires)

Costs: Wet pipe systems: $1.20 to $4.20/SF
For dry pipe systems, add $.60/SF.

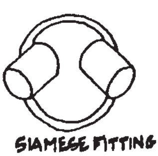


___ *b.* Large buildings often also require a *standpipe,* which is a large-diameter water pipe extending vertically through the building with fire-hose connections at every floor. The system is either wet or dry. The IBC defines three classes.

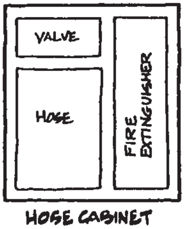
___ (1) *Class I* is dry with 2½″ outlets. There is a connection point on every landing of every required stairway above or below grade, and on both sides of a horizontal exit door. This type of standpipe is for the fire department to connect their large hoses to.

___ (2) *Class II* is wet with 1½″ outlets and a hose. This type is located so that every part of the building is within 30′ of a nozzle attached to 100′ of hose. This type is for use by building occupants or the fire department.

___ (3) *Class III* is wet with 2½″ outlets and 1½″ hose connections. These are located according to the rules for both Class I and II.



Often, two *Siamese* fittings are required in readily accessible locations on the outside of the building to allow the fire department to attach hoses from pumper trucks to the dry standpipe and to the sprinkler riser.



Also, when required, *fire hose cabinets* will be located in such a way that every point on a floor lies within reach of a *30′* stream from the end of a *100′* hose. A typical recessed wall cabinet for a wet standpipe hose and fire extinguisher is *2′ 9″ W × 9″ D × 2′ 9″ H.* See UBC Table 9-A below for standpipe requirements.

__ c. *Fire alarm and detection systems:* One of the most effective means of occupant protection in case of a fire incident is the availability of a fire alarm system. An alarm system provides early notification to occupants of the building in the event of a fire, thereby providing a greater opportunity for everyone in the building to evacuate or relocate to a safe area. Where required (occupancies):

- __ (1) Group A, when 300 or more occupants.
- __ (2) Group B and M, when over 500 occupants. Where more than 100 persons occupy spaces above or below the lowest level of exit discharge, a manual fire alarm must be installed.
- __ (3) Group E, where occupant load is 50 or more.
- __ (4) Group F, where multileveled and occupant load is 500 or more is housed above or below the level of exit discharge.
- __ (5) Group H, semiconductor fabrication or manufacture of organic coatings.
- __ (6) Group I, both manual fire alarm and automatic fire detection system.
- __ (7) Residential: Certain residential structures require fire alarm and smoke detectors. This applies to hotels and other R-1 buildings. There is an exception to the required manual alarm system for such occupancies less than 3 stories in height where all guest rooms are completely separated by minimum 1-hour fire partitions and each unit has an exit directly to a yard, egress court, or public way. In R-2 buildings, alarms are

required where more than 16 DUs are located in a single structure, or DUs are placed a significant distance vertically from the egress point at ground level.

__ 7. ***Landscape Irrigation*:** See p. 269.

__ 8. ***Gas:*** To allow for the gas meter and piping, provide a space *1′6″ W × 1′D × 2′H.* Where natural gas is not available, propane, butane, and other flammable gases can be used to heat spaces and run stoves and hot-water heaters in homes, low-rise apartments, and small commercial buildings. A typical installation is a large cylinder located just outside the building and should be accessible by truck and well ventilated. The line to the building should be flexible (no iron or steel) and, at best, 10′ from windows and stairways.

__ 9. ***Solar Hot Water Systems***

- __ *a.* In U.S., average person uses *20 gal.* of HW/day.
- __ *b.* Mount collectors at tilt equal to about the site latitude.
- __ *c.* Typical collectors are 4′ × 8′ and 4′ × 10′.
- __ *d.* Typical relationship between collector area and storage volume is *1:3* to *1:7* gal. per SF of collector.
- __ *e.* Type of systems
  - __ (1) *Open loop, recirculation:* The most widely used system in climates where freezing is of little concern.
  - __ (2) *Open loop, drain down:* Includes valving arrangement from collectors and piping when water temperature approaches freezing.
  - __ (3) *Closed loop, drain back:* Use of separate fluid (such as water) circulated through collectors where it is heated and transferred to HW storage through heat exchanger.
  - __ (4) *Closed loop, antifreeze:* Most widely used with heat exchanger.
- __ *f.* Auxiliary heat: Typically an electric element in HW tank top.
- __ *g.* For rough estimates:
  - __ (1) Northeast U.S.: 60 SF collector and 80 gallon tank will provide 50% to 75% need of a family of four.
  - __ (2) Southwest U.S.: 40 SF of collector will do same.

Costs: $4500 to $10,000 per system

TABLE 403.1
MINIMUM NUMBER OF REQUIRED PLUMBING FIXTURES[a]
(See Sections 403.2 and 403.3)

NO.	CLASSIFICATION	OCCUPANCY	DESCRIPTION	WATER CLOSETS (URINALS SEE SECTION 419.2)		LAVATORIES		BATHTUBS/ SHOWERS	DRINKING FOUNTAIN[e, f] (SEE SECTION 410.1)	OTHER
				MALE	FEMALE	MALE	FEMALE			
1	Assembly	A-1[d]	Theaters and other buildings for the performing arts and motion pictures	1 per 125	1 per 65	1 per 200		—	1 per 500	1 service sink
		A-2[d]	Nightclubs, bars, taverns, dance halls and buildings for similar purposes	1 per 40	1 per 40	1 per 75		—	1 per 500	1 service sink
			Restaurants, banquet halls and food courts	1 per 75	1 per 75	1 per 200		—	1 per 500	1 service sink
		A-3[d]	Auditoriums without permanent seating, art galleries, exhibition halls, museums, lecture halls, libraries, arcades and gymnasiums	1 per 125	1 per 65	1 per 200		—	1 per 500	1 service sink
			Passenger terminals and transportation facilities	1 per 500	1 per 500	1 per 750		—	1 per 1,000	1 service sink
			Places of worship and other religious services.	1 per 150	1 per 75	1 per 200		—	1 per 1,000	1 service sink

TABLE 403.1, *(continued)*
MINIMUM NUMBER OF REQUIRED PLUMBING FIXTURES[a]
(See Sections 403.2 and 403.3)

NO.	CLASSIFICATION	OCCUPANCY	DESCRIPTION	WATER CLOSETS (URINALS SEE SECTION 419.2)		LAVATORIES		BATHTUBS/ SHOWERS	DRINKING FOUNTAIN[e, f] (SEE SECTION 410.1)	OTHER
				MALE	FEMALE	MALE	FEMALE			
1 (cont.)	Assembly (cont.)	A-4	Coliseums, arenas, skating rinks, pools and tennis courts for indoor sporting events and activities	1 per 75 for the first 1,500 and 1 per 120 for the remainder exceeding 1,500	1 per 40 for the first 1,520 and 1 per 60 for the remainder exceeding 1,520	1 per 200	1 per 150	—	1 per 1,000	1 service sink
		A-5	Stadiums, amusement parks, bleachers and grandstands for outdoor sporting events and activities	1 per 75 for the first 1,500 and 1 per 120 for the remainder exceeding 1,500	1 per 40 for the first 1,520 and 1 per 60 for the remainder exceeding 1,520	1 per 200	1 per 150	—	1 per 1,000	1 service sink
2	Business	B	Buildings for the transaction of business, professional services, other services involving merchandise, office buildings, banks, light industrial and similar uses	1 per 25 for the first 50 and 1 per 50 for the remainder exceeding 50		1 per 40 for the first 80 and 1 per 80 for the remainder exceeding 80		—	1 per 100	1 service sink

TABLE 403.1, *(continued)*
MINIMUM NUMBER OF REQUIRED PLUMBING FIXTURES[a]
(See Sections 403.2 and 403.3)

NO.	CLASSIFICATION	OCCUPANCY	DESCRIPTION	WATER CLOSETS (URINALS SEE SECTION 419.2)		LAVATORIES		BATHTUBS/ SHOWERS	DRINKING FOUNTAIN[e, f] (SEE SECTION 410.1)	OTHER
				MALE	FEMALE	MALE	FEMALE			
3	Educational	E	Educational facilities	1 per 50		1 per 50		—	1 per 100	1 service sink
4	Factory and industrial	F-1 and F-2	Structures in which occupants are engaged in work fabricating, assembly or processing of products or materials	1 per 100		1 per 100		(see Section 411)	1 per 400	1 service sink

TABLE 403.1, *(continued)*
MINIMUM NUMBER OF REQUIRED PLUMBING FIXTURES[a]
(See Sections 403.2 and 403.3)

NO.	CLASSIFICATION	OCCUPANCY	DESCRIPTION	WATER CLOSETS (URINALS SEE SECTION 419.2)		LAVATORIES		BATHTUBS/ SHOWERS	DRINKING FOUNTAIN[e, f] (SEE SECTION 410.1)	OTHER
				MALE	FEMALE	MALE	FEMALE			
5	Institutional	I-1	Residential care	1 per 10		1 per 10		1 per 8	1 per 100	1 service sink
		I-2	Hospitals, ambulatory nursing home patients[b]	1 per room[c]		1 per room[c]		1 per 15	1 per 100	1 service sink per floor
			Employees, other than residential care[b]	1 per 25		1 per 35		—	1 per 100	—
			Visitors, other than residential care	1 per 75		1 per 100		—	1 per 500	—
		I-3	Prisons[b]	1 per cell		1 per cell		1 per 15	1 per 100	1 service sink
			Reformitories, detention centers, and correctional centers[b]	1 per 15		1 per 15		1 per 15	1 per 100	1 service sink
			Employees[b]	1 per 25		1 per 35		—	1 per 100	—
		I-4	Adult day care and child care	1 per 15		1 per 15		1	1 per 100	1 service sink

TABLE 403.1, *(continued)*
MINIMUM NUMBER OF REQUIRED PLUMBING FIXTURES[a]
(See Sections 403.2 and 403.3)

NO.	CLASSIFICATION	OCCUPANCY	DESCRIPTION	WATER CLOSETS (URINALS SEE SECTION 419.2)		LAVATORIES		BATHTUBS/ SHOWERS	DRINKING FOUNTAIN[e, f] (SEE SECTION 410.1)	OTHER
				MALE	FEMALE	MALE	FEMALE			
6	Mercantile	M	Retail stores, service stations, shops, salesrooms, markets and shopping centers	1 per 500		1 per 750		—	1 per 1,000	1 service sink
7	Residential	R-1	Hotels, motels, boarding houses (transient)	1 per sleeping unit		1 per sleeping unit		1 per sleeping unit	—	1 service sink
		R-2	Dormitories, fraternities, sororities and boarding houses (not transient)	1 per 10		1 per 10		1 per 8	1 per 100	1 service sink
		R-2	Apartment house	1 per dwelling unit		1 per dwelling unit		1 per dwelling unit	—	1 kitchen sink per dwelling unit; 1 automatic clothes washer connection per 20 dwelling units

TABLE 403.1, *(continued)*
MINIMUM NUMBER OF REQUIRED PLUMBING FIXTURES[a]
(See Sections 403.2 and 403.3)

NO.	CLASSIFICATION	OCCUPANCY	DESCRIPTION	WATER CLOSETS (URINALS SEE SECTION 419.2)		LAVATORIES		BATHTUBS/ SHOWERS	DRINKING FOUNTAIN[e, f] (SEE SECTION 410.1)	OTHER
				MALE	FEMALE	MALE	FEMALE			
7 (cont.)	Residential (cont.)	R-3	One- and two-family dwellings	1 per dwelling unit		1 per dwelling unit		1 per dwelling unit	—	1 kitchen sink per dwelling unit; 1 automatic clothes washer connection per dwelling unit
		R-3	Congregate living facilities with 16 or fewer persons	1 per 10		1 per 10		1 per 8	1 per 100	1 service sink
		R-4	Residential care/assisted living facilities	1 per 10		1 per 10		1 per 8	1 per 100	1 service sink
8	Storage	S-1 S-2	Structures for the storage of goods, warehouses, storehouse and freight depots. Low and Moderate Hazard.	1 per 100		1 per 100		See Section 411	1 per 1,000	1 service sink

TABLE 403.1, *(continued)*
MINIMUM NUMBER OF REQUIRED PLUMBING FIXTURES[a]
(See Sections 403.2 and 403.3)

a. The fixtures shown are based on one fixture being the minimum required for the number of persons indicated or any fraction of the number of persons indicated. The number of occupants shall be determined by the *International Building Code.*

b. Toilet facilities for employees shall be separate from facilities for inmates or patients.

c. A single-occupant toilet room with one water closet and one lavatory serving not more than two adjacent patient sleeping units shall be permitted where such room is provided with direct access from each patient sleeping unit and with provisions for privacy.

d. The occupant load for seasonal outdoor seating and entertainment areas shall be included when determining the minimum number of facilities required.

e. The minimum number of required drinking fountains shall comply with Table 403.1 and Chapter 11 of the *International Building Code.*

f. Drinking fountains are not required for an occupant load of 15 or fewer.

TABLE 4-1
Minimum Plumbing Facilities[1]

Each building shall be provided with sanitary facilities, including provisions for persons with disabilities as prescribed by the Department Having Jurisdiction. Table 4-1 applies to new buildings, additions to a building, and changes of occupancy or type in an existing building resulting in increased occupant load. Exception: New cafeterias used only by employees.

The total occupant load shall be determined in accordance with the Building Code. The type of building or occupancy shall be determined based on the actual use of the various spaces within the building. Building categories not shown in Table 4-1 shall be considered separately by the Authority Having Jurisdiction. The minimum number of fixtures shall be calculated at 50 percent male and 50 percent female based on the total occupant load.

Once the occupant load and uses are determined, the requirements of Section 412.0 and Table 4-1 shall be applied to determine the minimum number of plumbing fixtures required.

Type of Building[2] or Occupancy	Water Closets[14] (Fixtures per Person)		Urinals[5, 10] (Fixtures per Person)	Lavatories (Fixtures per Person)		Bathtubs or Showers (Fixtures per Person)	Drinking[3, 13, 17] Fountains (Fixtures per Person)
Assembly places – theatres, auditoriums, convention halls, etc.– for permanent employee use	Male 1: 1-15 2: 16-35 3: 36-55 Over 55, add 1 fixture for each additional 40 persons.	Female 1: 1-15 3: 16-35 4: 36-55	Male 0: 1-9 1: 10-50 Add one fixture for each additional 50 males.	Male 1 per 40	Female 1 per 40		
Assembly places – theatres, auditoriums, convention halls, etc.– for public use	Male 1: 1-100 2: 101-200 3: 201-400 Over 400, add one fixture for each additional 500 males and 1 for each additional 125 females.	Female 3: 1-50 4: 51-100 8: 101-200 11: 201-400	Male 1: 1-100 2: 101-200 3: 201-400 4: 401-600 Over 600, add 1 fixture for each additional 300 males.	Male 1: 1-200 2: 201-400 3: 401-750 Over 750, add one fixture for each additional 500 persons.	Female 1: 1-200 2: 201-400 3: 401-750		1: 1-150 2: 151-400 3: 401-750 Over 750, add one fixture for each additional 500 persons.

TABLE 4-1, *(continued)*
Minimum Plumbing Facilities[1]

Type of Building[2] or Occupancy	Water Closets[14] (Fixtures per Person)	Urinals[5, 10] (Fixtures per Person)	Lavatories (Fixtures per Person)	Bathtubs or Showers (Fixtures per Person)	Drinking[3, 13, 17] Fountains (Fixtures per Person)
Dormitories[9]– School or labor[16]	Male 1 per 10 / Female 1 per 8 Add 1 fixture for each additional 25 males (over 10) and 1 for each additional 20 females (over 8).	Male 1 per 25 Over 150, add 1 fixture for each additional 50 males.	Male 1 per 12 / Female 1 per 12 Over 12, add one fixture for each additional 20 males and 1 for each 15 additional females.	1 per 8 For females, add 1 bathtub per 30. Over 150, add 1 bathtub per 20.	1 per 150[12]
Dormitories – for staff use[16]	Male / Female 1: 1-15 / 1: 1-15 2: 16-35 / 3: 16-35 3: 36-55 / 4: 36-55 Over 55, add 1 fixture for each additional 40 persons.	Male 1 per 50	Male 1 per 40 / Female 1 per 40	1 per 8	
Dwellings[4] Single dwelling Multiple dwelling or apartment house[16]	1 per dwelling 1 per dwelling or apartment unit		1 per dwelling 1 per dwelling or apartment unit	1 per dwelling 1 per dwelling or apartment unit	
Hospital waiting rooms	1 per room		1 per room		1 per 150[12]
Hospitals – for employee use	Male / Female 1: 1-15 / 1: 1-15 2: 16-35 / 3: 16-35 3: 36-55 / 4: 36-55 Over 55, add 1 fixture for each additional 40 persons.	Male 0: 1-9 1: 10-50 Add one fixture for each additional 50 males.	Male 1 per 40 / Female 1 per 40		

TABLE 4-1, *(continued)*
Minimum Plumbing Facilities[1]

Type of Building[2] or Occupancy	Water Closets[14] (Fixtures per Person)	Urinals[5, 10] (Fixtures per Person)	Lavatories (Fixtures per Person)	Bathtubs or Showers (Fixtures per Person)	Drinking[3, 13, 17] Fountains (Fixtures per Person)
Hospitals Individual room Ward room	 1 per room 1 per 8 patients		 1 per room 1 per 10 patients	 per room 1 per 20 patients	 1 per 150[12]
Industrial[6] warehouses, workshops, foundries, and similar establishments – for employee use	Male / Female 1: 1-10 / 1: 1-10 2: 11-25 / 2: 11-25 3: 26-50 / 3: 26-50 4: 51-75 / 4: 51-75 5: 76-100 / 5: 76-100 Over 100, add 1 fixture for each additional 30 persons.		Up to 100, 1 per 10 persons Over 100, 1 per 15 persons[7, 8]	1 shower for each 15 persons exposed to excessive heat or to skin contamination with poisonous, infectious or irritating material	1 per 150[12]
Institutional – other than hospitals or penal institutions (on each occupied floor)	Male / Female 1 per 25 / 1 per 20	Male 0: 1-9 1: 10-50 Add one fixture for each additional 50 males.	Male / Female 1 per 10 / 1 per 10	1 per 8	1 per 150[12]
Institutional – other than hospitals or penal institutions (on each occupied floor) – for employee use	Male / Female 1: 1-15 / 1: 1-15 2: 16-35 / 3: 16-35 3: 36-55 / 4: 36-55 Over 55, add 1 fixture for each additional 40 persons.	Male 0: 1-9 1: 10-50 Add one fixture for each additional 50 males.	Male / Female 1 per 40 / 1 per 40	1 per 8	1 per 150[12]

TABLE 4-1, *(continued)*
Minimum Plumbing Facilities[1]

Type of Building[2] or Occupancy	Water Closets[14] (Fixtures per Person)	Urinals[5, 10] (Fixtures per Person)	Lavatories (Fixtures per Person)	Bathtubs or Showers (Fixtures per Person)	Drinking[3, 13, 17] Fountains (Fixtures per Person)
Office or public buildings	Male / Female 1: 1-100 / 3: 1-50 2: 101-200 / 4: 51-100 3: 201-400 / 8: 101-200 11: 201-400 Over 400, add one fixture for each additional 500 males and 1 for each additional 150 females.	Male 1: 1-100 2: 101-200 3: 201-400 4: 401-600 Over 600, add 1 fixture for each additional 300 males.	Male / Female 1: 1-200 / 1: 1-200 2: 201-400 / 2: 201-400 3: 401-750 / 3: 401-750 Over 750, add one fixture for each additional 500 persons.		1 per 150[12]
Office or public buildings – for employee use	Male / Female 1: 1-15 / 1: 1-15 2: 16-35 / 3: 16-35 3: 36-55 / 4: 36-55 Over 55, add 1 fixture for each additional 40 persons.	Male 0: 1-9 1: 10-50 Add one fixture for each additional 50 males.	Female / Male 1 per 40 / 1 per 40		
Penal institutions – for employee use	Male / Female 1: 1-15 / 1: 1-15 2: 16-35 / 3: 16-35 3: 36-55 / 4: 36-55 Over 55, add 1 fixture for each additional 40 persons.	Male 0: 1-9 1: 10-50 Add one fixture for each additional 50 males.	Male / Female 1 per 40 / 1 per 40		1 per 150[12]
Penal institutions – for prison use Cell Exercise room	 1 per cell 1 per exercise room	 Male 1 per exercise room	 1 per cell 1 per exercise room		 1 per cell block floor 1 per exercise room

TABLE 4-1, *(continued)*
Minimum Plumbing Facilities[1]

Type of Building[2] or Occupancy	Water Closets[14] (Fixtures per Person)	Urinals[5,10] (Fixtures per Person)	Lavatories (Fixtures per Person)	Bathtubs or Showers (Fixtures per Person)	Drinking[3,13,17] Fountains (Fixtures per Person)
Public or professional offices[15]	Same as Office or Public Buildings for employee use[15]	Same as Office or Public Buildings for employee use[15]	Same as Office or Public Buildings for employee use[15]		Same as Office or Public Buildings for employee use[15]
Restaurants, pubs, and lounges[11,15]	Male / Female 1: 1-50 / 1: 1-5 2: 51-150 / 2: 51-150 3: 151-300 / 4: 151-300 Over 300, add 1 fixture for each additional 200 persons.	Male 1: 1-150 Over 150, add 1 fixture for each additional 150 males.	Male / Female 1: 1-150 / 1: 1-150 2: 151-200 / 2: 151-200 3: 201-400 / 3: 201-400 Over 400, add 1 fixture for each additional 400 persons.		
Retail or Wholesale Stores	Male / Female 1:1-100 / 1:1-25 2:101-200 / 2:26-100 3:201-400 / 4:101-200 6:201-300 8: 301-400 Over 400, add one fixture for each additional 500 males and one for each 150 females	Male 0:0-25 1:26-100 2:101-200 3:201-400 4:401-600 Over 600, add one fixture for each additional 300 males	1 per 2 water closets		0: 1-30[17] 1:31-150 One additional drinking fountain for each 150 persons thereafter
Schools – for staff use All schools	Male / Female 1: 1-15 / 1: 1-15 2: 16-35 / 2: 16-35 3: 36-55 / 3: 36-55 Over 55, add 1 fixture for each additional 40 persons.	Male 1 per 50	Male / Female 1 per 40 / 1 per 40		

TABLE 4-1, *(continued)*
Minimum Plumbing Facilities[1]

Type of Building[2] or Occupancy	Water Closets[14] (Fixtures per Person)		Urinals[5, 10] (Fixtures per Person)	Lavatories (Fixtures per Person)		Bathtubs or Showers (Fixtures per Person)	Drinking[3, 13, 17] Fountains (Fixtures per Person)
Schools – for student use Nursery	Male 1: 1-20 2: 21-50 Over 50, add 1 fixture for each additional 50 persons.	Female 1: 1-20 2: 21-50		Male 1: 1-25 2: 26-50 Over 50, add 1 fixture for each additional 50 persons.	Female 1: 1-25 2: 26-50		1 per 150[12]
Elementary	Male 1 per 30	Female 1 per 25	Male 1 per 75	Male 1 per 35	Female 1 per 35		1 per 150[12]
Secondary	Male 1 per 40	Female 1 per 30	Male 1 per 35	Male 1 per 40	Female 1 per 40		1 per 150[12]
Others (colleges, universities, adult centers, etc.)	Male 1 per 40	Female 1 per 30	Male 1 per 35	Male 1 per 40	Female 1 per 40		1 per 150[12]
Worship places educational and activities Unit	Male 1 per 150	Female 1 per 75	Male 1 per 150	1 per 2 water closets			1 per 150[12]
Worship places principal assembly place	Male 1 per 150	Female 1 per 75	Male 1 per 150	1 per 2 water closets			1 per 150[12]

TABLE 4-1, *(continued)*
Minimum Plumbing Facilities[1]

[1] The figures shown are based upon one (1) fixture being the minimum required for the number of persons indicated or any fraction thereof.

[2] Building categories not shown on this table shall be considered separately by the Authority Having Jurisdiction.

[3] Drinking fountains shall not be installed in toilet rooms.

[4] Laundry trays. One (1) laundry tray or one (1) automatic washer standpipe for each dwelling unit or one (1) laundry tray or one (1) automatic washer standpipe, or combination thereof, for each twelve (12) apartments. Kitchen sinks, one (1) for each dwelling or apartment unit.

[5] For each urinal added in excess of the minimum required, one water closet shall be permitted to be deducted. The number of water closets shall not be reduced to less than two-thirds (2/3) of the minimum requirement.

[6] As required by PSAI Z4.1, *Sanitation in Places of Employment*.

[7] Where there is exposure to skin contamination with poisonous, infectious, or irritating materials, provide one (1) lavatory for each five (5) persons.

[8] Twenty-four (24) lineal inches (610 mm) of wash sink or eighteen (18) inches (457 mm) of a circular basin, when provided with water outlets for such space, shall be considered equivalent to one (1) lavatory.

[9] Laundry trays, one (1) for each fifty (50) persons. Service sinks, one (1) for each hundred (100) persons.

[10] General. In applying this schedule of facilities, consideration shall be given to the accessibility of the fixtures. Conformity purely on a numerical basis may not result in an installation suited to the needs of the individual establishment. For example, schools should be provided with toilet facilities on each floor having classrooms.

a. Surrounding materials, wall, and floor space to a point two (2) feet (610 mm) in front of urinal lip and four (4) feet (1,219 mm) above the floor, and not less than two (2) feet (610 mm) to each side of the urinal shall be lined with non-absorbent materials.
b. Trough urinals shall be prohibited.

TABLE 4-1, *(continued)*
Minimum Plumbing Facilities[1]

11 A restaurant is defined as a business that sells food to be consumed on the premises.

a. The number of occupants for a drive-in restaurant shall be considered as equal to the number of parking stalls.
b. Hand-washing facilities shall be available in the kitchen for employees.

12 Where food is consumed indoors, water stations shall be permitted to be substituted for drinking fountains. Offices, or public buildings for use by more than six (6) persons shall have one (1) drinking fountain for the first one-hundred fifty (150) persons and one (1) additional fountain for each three-hundred (300) persons thereafter.

13 There shall be at least one (1) drinking fountain per occupied floor in schools, theatres, auditoriums, dormitories, offices, or public buildings.

14 The total number of water closets for females shall be equal to the total number of water closets and urinals required for males. This requirement shall not apply to Retail or Wholesale Stores.

15 For smaller-type Public and Professional Offices such as banks, dental offices, law offices, real estate offices, architectural offices, engineering offices, and similar uses. A public area in these offices shall use the requirements for Retail or Wholesale Stores.

16 Recreation or community room in multiple dwellings or apartment buildings, regardless or their occupant load, shall be permitted to have separate single-accommodation facilities in common-use areas within tracts or multi-family residential occupancies where the use of these areas is limited exclusively to owners, residents, and their guests. Examples are community recreation or multi-purpose areas in apartments, condos, townhouses, or tracts.

17 A drinking fountain shall not be required in occupancies of 30 or less. When a drinking fountain is not required, then footnotes 3, 12, and 13 are not applicable.

EXAMPLE:

PROBLEM: FIGURE THE REQUIRED PLUMBING FIXTURES FOR A 10000 SF OFFICE SPACE, FIGURE FOR BOTH THE I.P.C. AND THE U.P.C. CODES.

SOLUTION:

A. BY I.P.C. (SEE TABLE A FOR I.B.C. ON P. 110)

1. BUSINESS: 10000 SF ÷ 100 SF/OCC. = 100 USERS ÷ 2 = 50/SEX
2. FIXTURES: (SEE I.P.C. TABLE 403.1, P. 526)

	M (50)	W (50)
WC	~~2~~ 1	2
LAV	1	1
UR	1	

ALSO: 1 DF REQ'D.

B. BY U.P.C. (SEE TABLE 4-1 OF U.P.C., SEE P. 533)

1. FIGURE OCC. LOAD FOR EXITING FROM TABLE 4-1 ASSUME PUBLIC, NOT EMPLOYEE, USE.

   10 000 SF ÷ 100 SF/OCC = 100 OCC ÷ 2 = 50/SEX

2. FIXTURES

	M (50)	W (50)
WC	1	3
LAV	1	1
UR	1	

ALSO: 1 DF REQ'D.

Notes:

1. If you have data to prove occupancy will not be evenly divided, you may use other than 50/50 split.
2. Family or assisted use toilet and bath fixtures can be included in count.

NOTES

___ B. HEATING, VENTILATION, AND AIR CONDITIONING (HVAC) (B) (1) (13) (16)

See p. 546 for selection and **cost** table.

Costs: Equipment 20% to 30%; distribution system 80% to 70%; see p. 546 for cost of different systems. See App. A, item K for % of total construction costs.

During programming it is useful to do a functional partitioning of the building into major zones for:

___ 1. Similar schedule of use
___ 2. Similar temperature requirements
___ 3. Similar ventilation and air quality
___ 4. Similar internal heat generation
___ 5. Similar HVAC needs

During design, if possible, locate spaces with similar needs together. See App. A, item J for SF/ton estimates by building type. See p. 193 for energy conservation and equipment efficiency. As a general rule, provide at least 3′ around all HVAC equipment for maintenance.

___ 1. ***General***

HVAC systems can be divided into four major parts:

___ *a. Source:*

___ (1) The *boiler and chiller* to create heat and cold for the system to use. (In small package systems this is an internal electric coil, gas furnace, or refrigeration compressor).

___ (2) *Cooling tower* (or air-cooled condenser) located outside to exhaust heat.

___ *b. Distribution:*

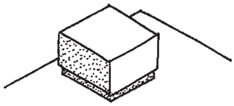
___ (1) *Air handlers* to transfer heat and cold to air (or at least fresh air) to be blown into the building zones. In large buildings this is in a fan room. (In small package systems this is an internal fan.)

___ (2) The *system* of ducts, control boxes, and diffusers to deliver conditioned air to the spaces.

___ *c. Delivery* of diffusers, baseboard radiators, unit heaters, convector cabinets, induction units, etc.

___ 2. ***Systems for Small Buildings***

___ *a. Roof-mounted "package systems"* are typically used for residential and small to medium commercial buildings. They are AC units that house the first three parts in one piece of equipment that usually ends up on the roof. Used usually in warm or temperate climates. Typical sizes:

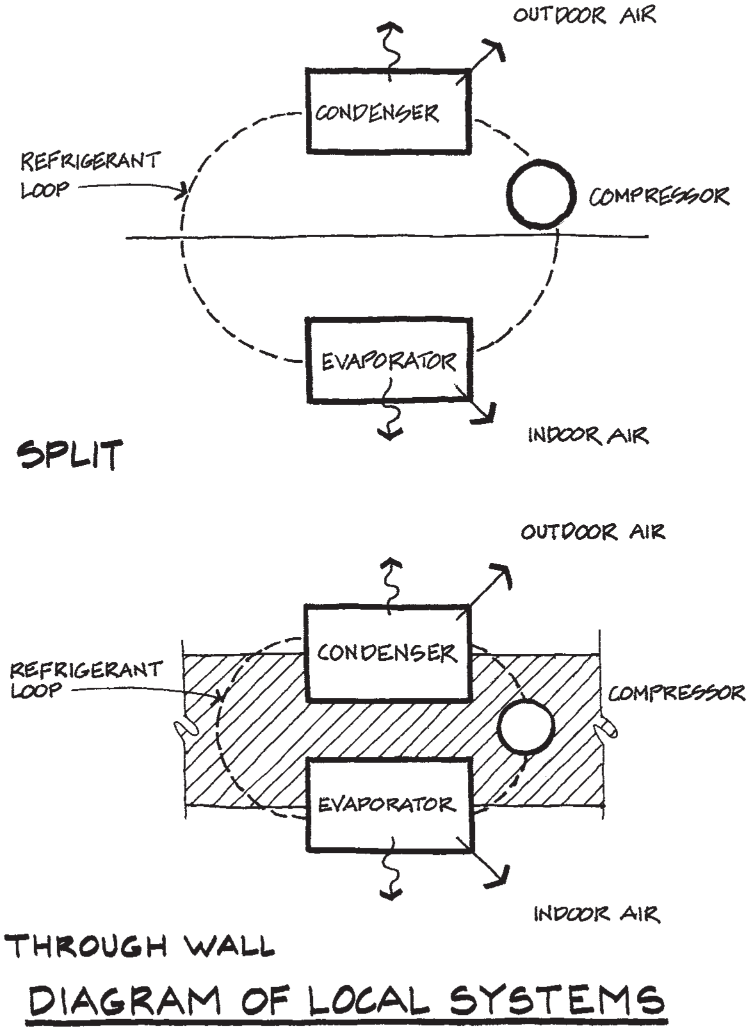


Roof Mounted
"Package" Unit

Size	Area served	Dimensions	System
2 to 5 tons	600 to 1500 SF	6′L × 4′W × 4′H	Single zone constant vol. delivery system; can serve more than one zone with variable air vol. delivery system
5 to 10 tons	1500 to 4500 SF	10′L × 7′W × 5′H	
15 to 75 tons	4500 to 22,500 SF	25′L × 9′W × 6′H	

Notes:

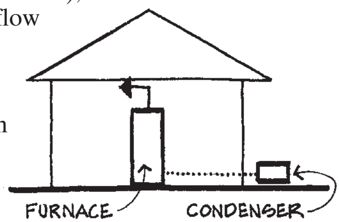
1. Units should have *3′ to 4′* of clearance around.
2. A *ton is 12,000 Btu* of refrigeration.
3. Each *ton is equal to 400 CFM.*


OUTDOOR AIR
CONDENSER
REFRIGERANT LOOP
COMPRESSOR
EVAPORATOR
INDOOR AIR
SPLIT
OUTDOOR AIR
CONDENSER
REFRIGERANT LOOP
COMPRESSOR
EVAPORATOR
INDOOR AIR
THROUGH WALL
DIAGRAM OF LOCAL SYSTEMS

HVAC SYSTEMS AND COSTS

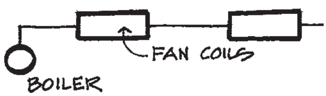
	TYPE	HEATING	COOLING	BUILDING: SMALL	BUILDING: LARGE	FUEL: ELECT.	FUEL: GAS	FUEL: OTHER	DELIVERY SYSTEM: AIR	DELIVERY SYSTEM: PIPES	CHARACTERISTICS: MIN. OPERATING COST IN COLD CLIMATE	MIN. OPERATING COST IN MODERATE CLIMATE	MAX. CONTROL OF AIR VELOCITY & QUALITY	MAX. INDIVIDUAL CONTROL OF TEMP.	MINIMUM NOISE	MINIMUM VISUAL OBTRUSIVENESS	MIN. SPACE FOR EQUIP.	MIN. MAINTENANCE	MIN. FL. TO FL. HT.	MAX. FLEXIBILITY OF RENTAL SPACE	COSTS ±10% (50% M & 50% L): $ PER SF	COSTS ±10% (50% M & 50% L): $/TON OF AC
1	ROOF MT'D. "PACKAGE" UNITS	●	●	●																	6.90	1930
2	CENTRAL FORCED AIR	●		●		●	●		●		●		●		●	●		●			8,65	1655
	(& "SPLIT" SYSTEMS)		●	●		●	●		●				●		●	●		●			8,65	2210
3	FORCED HOT WATER	●		●		●	●			●	●			●	●			●			6.90	2760
4	EVAPORATIVE COOLING		●	●		●			●			●					●				2.80	830
5	THROUGH WALL UNITS	●	●	●		●			●					●			●				2.10	830
6	ELECTRIC BASE BOARD	●		●		●								●	●		●	●			1.80	
7	ELECT. FAN UNIT HEATERS	●		●		●							●				●	●			3.50	
8	RADIANT	●	●	●		●				●					●	●	●	●			2.10	
9	WALL FURNACE	●		●		●											●				3.50	
10	PASSIVE SOLAR	●		●							●	●			●		●	●				
11	ACTIVE SOLAR	●		●						●	●	●			●							
12	STOVES	●		●				●				●	●									
13	SINGLE ZONE CONSTANT VOL.	●	●		●	●	●	●	●				●		●	●		●			8,65	3035
14	MULTI ZONE CONSTANT VOL.	●	●		●	●	●		●			●									12.00	3450
15	VARIABLE AIR VOLUME	●	●		●	●	●	●	●					●	●					●	13.80	3725
16	DOUBLE DUCT	●	●		●	●	●	●	●		●	●	●	●	●	●	●			●	17.20	4140
17	INDUCTION	●	●		●	●	●	●	●	●	●		●	●	●	●				●	13.80	3725
18	FAN COIL WITH AIR	●	●	●	●	●	●		●	●	●	●	●	●		●			●	●	13.80	3450
19	FAN COIL UNITS	●	●	●	●	●	●		●	●	●	●	●	●		●			●	●	12.00	3035
20	HOT WATER BASE BOARDS	●		●	●	●	●	●			●	●			●		●				6.90	

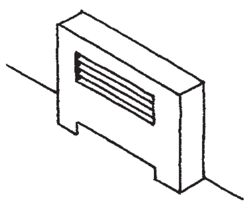
___ b. _Forced-air central heating_ is typically used for residential and light commercial buildings. It heats air with gas, oil flame, or elect. resistance at a furnace. A fan blows air through a duct system. The furnace can be upflow (for basements), side flow, or down flow (for attic). The furnace must be vented. Furnace sizes range between *2′W × 2.5′D × 7′H* to *4′W to 7′D × 7′H.* Main ducts are typically *1′ × 2′* horizontal and *1′ × .33′* vertical.



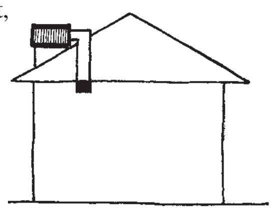
Can add cooling with a "*split system*" by adding evaporator coils in the duct and an exterior condenser. Typical condensers range from *2′W × 2′D × 2′H* to *3.5′W × 4′D × 3′H.*

___ c. _Forced hot water heating_ is typically used for residential buildings and commercial offices. A burner or electric resistance heats water to fin tube convectors (or fan coil unit with blowers). The fueled boiler must be vented and provided with combustible air. Boiler sizes range from *2′W × 2′D × 7′H* to *3′W × 5′D × 7′H.* Fin tube convectors are typically *3″D × 8″H.* Fan coils are *2′W × 2.5′H.* There is *no* cooling.

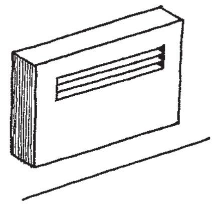




___ d. _Evaporative cooling_ is typically used for residential buildings. It works only in hot, dry climates. A fan draws exterior air across wet pads and into the duct system. There is *no* heating. Cooler size typically is *3′W × 3′D × 3′H.* Main duct is typically *1.5′W × 1.5′D.*

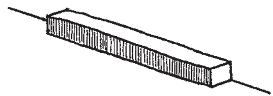


___ *e.* _Through-wall units and package terminal units_ are typically used for motels/hotels as well as small offices. They are self-contained at an exterior wall and are intended for small spaces. These are usually electric (or *heat pump* in mild climates), which are used for *both* heating and cooling. Interior air is recirculated and outside air is added. Typical sizes:



Package Terminal Units	3.5′W × 1.5′D × 1.3′H
Through-Wall Units	2′W × 2′D × 1.5′H

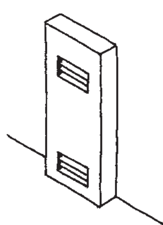
___ *f.* _Electric baseboard convectors_ are typically used for residential buildings and commercial offices. They heat by electrical resistance in *3″D × 8″H* baseboards around the perimeter of the room. There is *no cooling*.



___ *g.* _Electric fan-forced unit heaters_ are much like item *f* above, but are larger because of internal fans recirculating the air. There is *no cooling*. Typical sizes range from *1.5′ W × 8″ D × 8″ H* to *2′ W × 1′ D × 1.8′ H*.

___ *h.* _Radiant heating:_ Electrical resistance wires are embedded in floor or ceiling. There is *no cooling*. An alternative is to have recessed radiant panels, typically *2′ × 2′* or *2′ × 4′*. For alternative cooling and heating use water piping. These are typically residential applications.

___ *i.* _Wall furnaces_ are small furnaces for small spaces (usually residential). They must be vented. There is *no cooling*. They may be either gas or electric. The typical size is *14″W × 12″D × 84″H*.



___ *j.* _Other_ miscellaneous small systems (typically residential):

___ Passive solar heating (see p. 546)

__ Active solar heating
__ Heating stoves (must be properly vented!)

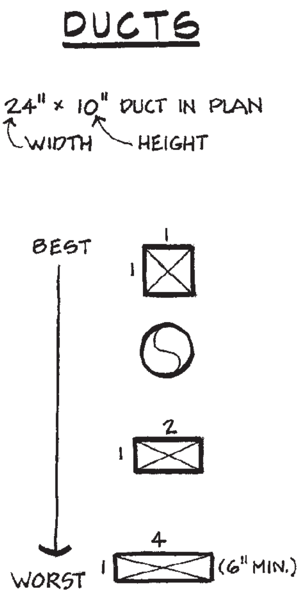
__ 3. ***Custom Systems for Large Buildings***

These are where the first three parts (see p. 543) must have areas allocated for them in the floor plan. In tall buildings due to distance, mechanical floors are created so that air handlers can move air up and down *10 to 15* floors. Thus mechanical floors are spaced *20 to 30* floors apart.

A decentralized chiller and boiler can be at every other mechanical floor or they can be centralized at the top or base of the building with one or more air handlers at each floor. See p. 551 for equipment rooms. *Note:* An alternative for large buildings (but not high rise) is to go with a number of large "package" units on the roof. Instead of installing one large unit, incorporate several smaller units of the same total capacity, then add one more, so any unit may be serviced without affecting the total operation.

__ *a.* Delivery systems

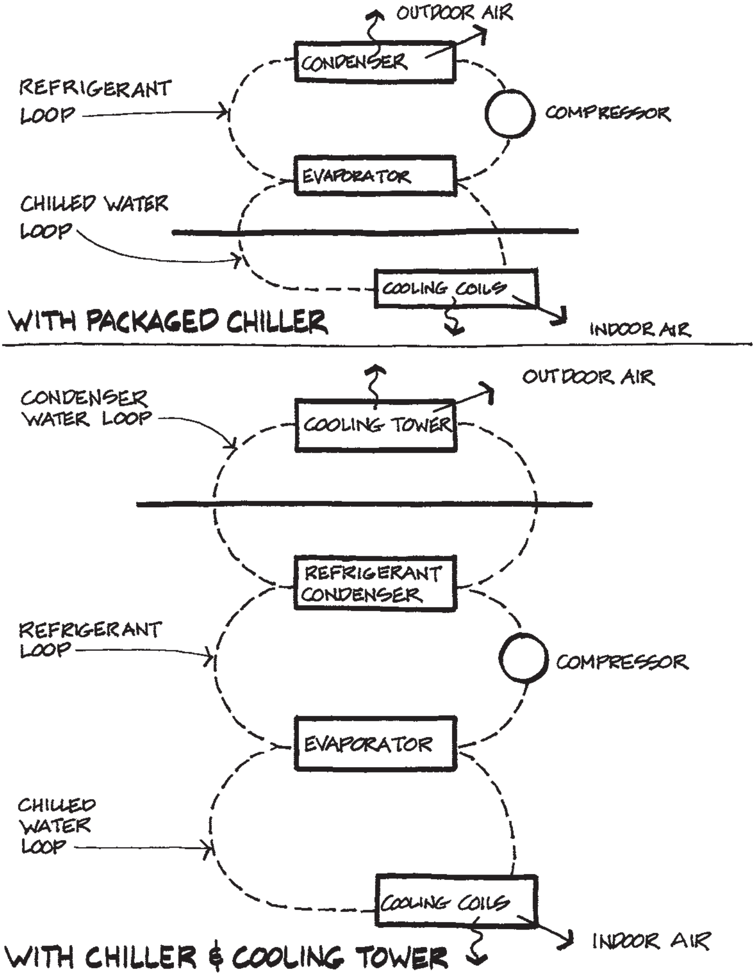
__ (1) *Air delivery systems*:



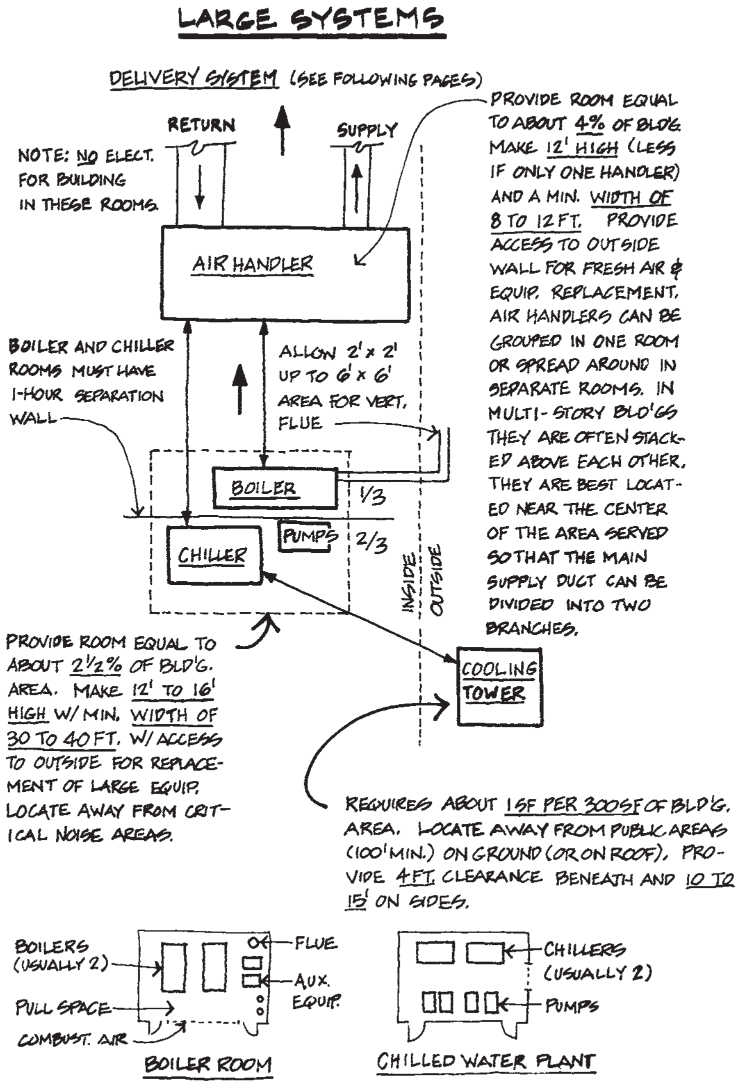
Because of their size, *ducts* are a great concern in the preliminary design of the floor-to-ceiling space. See p. 493. The main supply and return ducts are often run above main hallways because ceilings can be lower and because this provides a natural path of easy access to the majority of spaces served. Ideally, all ducts should be run as straight and clear of obstructions as possible, contain no corners that could collect dirt, and have access portals that allow inspection and cleaning. Horizontal runs should be pitched slightly to prevent moisture collection.

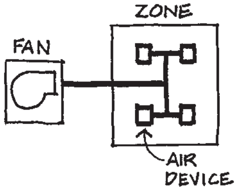
When ducts cross any kind of fire wall or fire barrier, they usually require fire dampers.

Air rates for buildings vary from *1 CFM/SF to 2 CFM/SF* based on usage and climate. Low-velocity ducts require *1 to 2 SF of area per 1000 SF* of building area served. High-velocity ducts require *0.5 to*



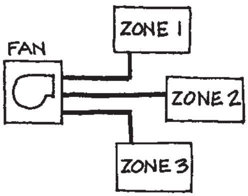
DIAGRAMS OF CENTRAL SYSTEMS


LARGE SYSTEMS
DELIVERY SYSTEM (SEE FOLLOWING PAGES)
RETURN
SUPPLY
NOTE: NO ELECT. FOR BUILDING IN THESE ROOMS.
AIR HANDLER
PROVIDE ROOM EQUAL TO ABOUT 4% OF BLD'G. MAKE 12' HIGH (LESS IF ONLY ONE HANDLER) AND A MIN. WIDTH OF 8 TO 12 FT. PROVIDE ACCESS TO OUTSIDE WALL FOR FRESH AIR & EQUIP. REPLACEMENT. AIR HANDLERS CAN BE GROUPED IN ONE ROOM OR SPREAD AROUND IN SEPARATE ROOMS. IN MULTI-STORY BLD'GS THEY ARE OFTEN STACKED ABOVE EACH OTHER. THEY ARE BEST LOCATED NEAR THE CENTER OF THE AREA SERVED SO THAT THE MAIN SUPPLY DUCT CAN BE DIVIDED INTO TWO BRANCHES.
BOILER AND CHILLER ROOMS MUST HAVE 1-HOUR SEPARATION WALL
ALLOW 2' x 2' UP TO 6' x 6' AREA FOR VERT. FLUE
BOILER
1/3
PUMPS
2/3
CHILLER
INSIDE
OUTSIDE
COOLING TOWER
PROVIDE ROOM EQUAL TO ABOUT 2½% OF BLD'G. AREA. MAKE 12' TO 16' HIGH W/ MIN. WIDTH OF 30 TO 40 FT. W/ ACCESS TO OUTSIDE FOR REPLACEMENT OF LARGE EQUIP. LOCATE AWAY FROM CRITICAL NOISE AREAS.
REQUIRES ABOUT 1 SF PER 300 SF OF BLD'G. AREA. LOCATE AWAY FROM PUBLIC AREAS (100' MIN.) ON GROUND (OR ON ROOF). PROVIDE 4 FT. CLEARANCE BENEATH AND 10 TO 15' ON SIDES.
BOILERS (USUALLY 2)
PULL SPACE
COMBUST. AIR
FLUE
AUX. EQUIP.
BOILER ROOM
CHILLERS (USUALLY 2)
PUMPS
CHILLED WATER PLANT



1.0. Air returns are required and are about the same size, or slightly larger, than the main duct supply. (The above-noted dimensions are interior. Typically, ducts are externally lined with 1″ or 2″ of insulation.)

Costs: Ducts typically cost about 40% of total HVAC costs.



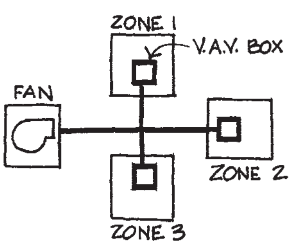
___ (*a*) _Single-zone constant-volume systems_ serve only one zone and are used for large, open-space rooms without diverse exterior exposure. This is a low-velocity system.

___ (*b*) _Multizone constant-volume systems_ can serve up to eight separate zones. They are used in modest-sized buildings where there is a diversity of exterior exposure and/or diversity of interior loads. This is a low-velocity system.

___ (*c*) _Subzone box systems_ often modify single-zone systems for appended spaces. They use boxes that branch off the main supply duct to create separate zones. The size of the boxes can be related to the area served:

Box	Area served
4′L × 3′W × 1.5′H	500 to 1500 SF
5′L × 4′W × 1.5′H	1500 to 5000 SF

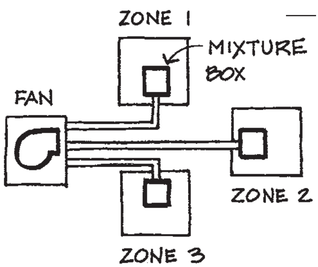
The main ducts can be high-velocity, but the ducts after the boxes at each zone (as well as the return air) are low-velocity.



___ (*d*) _Variable air-volume_ single duct can serve as many subzones as required. It is the dominant choice in many commercial buildings because of its flexibility and energy savings. It is most effectively used for interior zones. At exterior zones hot water or electrical reheat coils are added to the boxes. Each zone's temperature is controlled by the volume of air flowing through its box. Typical above ceiling boxes are:

8″ to 11″H for up to 1500 SF served (lengths up to 5′)
up to 18″H for up to 7000 SF

___ (*e*) Double-duct systems can serve as a good choice where *air quality control* is important. The air handler supplies hot air for one duct and cold air for the other. The mixing box controls the mix of these two air ducts. This system is not commonly used except in retrofits. It is a "caddie" but also a "gas guzzler."

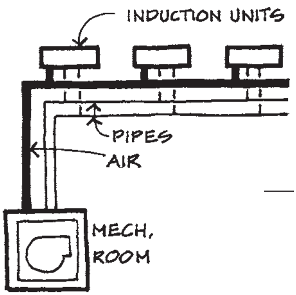


___ (*f*) Variable air-volume dual-duct systems. This system is high-end first cost and most likely used in a retrofit. One duct conveys cool air, one other hot air. This system is most common where a dual-duct constant volume system is converted to VAV. The box is generally controlled to provide either heat or cool air as required in varying quantities.

___ (2) Air/water delivery systems

These types of systems *reduce the ductwork* by tempering air near its point of use. Hot and cold water are piped to remote induction or fan coil units. Since the air ducts carry only fresh air, they can be sized at *0.2 to 0.4 SF per 1000 SF* of area served. The main hot and cold water lines will be *2 to 4 inches* diameter, including insulation, for medium size buildings.

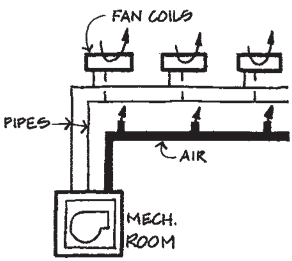
___ (*a*) Induction is often used for the *perimeter of high-rise office building*s and is *expensive*. Air from a central air handler is delivered through high-velocity ducts to each induction unit. Hot and cold lines



run to each unit. Each unit is located along the outside wall, at the base of the windows. They are *6 to 12 inches deep* and *1 to 3 feet high.*

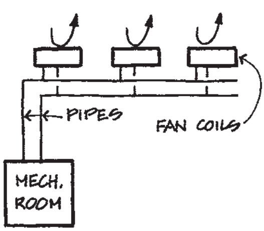
___ (*b*) <u>*Fan coils with supplementary air*</u> are used where there are *many small rooms needing separate control.* Hot and cold water lines are run through the coils. A fan draws room air through the coil for heating and cooling. A separate duct system supplies fresh air from a remote air handler.

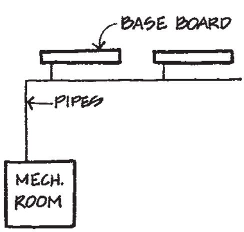
The fan coils are *6 to 12 inches deep and 1 to 3 feet high.* They can also be a vertical shape (*2′ × 2′ × 6′ high*) to fit in a closet. They are often stacked vertically in a tall building to reduce piping. Fan coil units can be located in ceiling space.



___ (3) <u>*Water delivery systems*</u> use hot and cold water lines only. No air is delivered to the areas served.

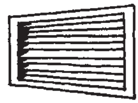
___ (*a*) <u>*Fan coil units*</u> can have hot and/or cold water lines with fresh air from operable windows or an outdoor air intake at the unit.

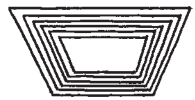




___ (*b*) <u>*Hot water baseboards*</u> supply only heat. Often used in conjunction with a cooling-only VAV system for perimeter zones. Baseboards are *6 inches high by 5 inches deep* and as long as necessary.

__ 4. **Diffusers, Terminal Devices, and Grilles:** Interface the HVAC system with the building interiors for visual impact and thermal comfort. Supply and return grilles or registers should be as far apart as possible in each space (ideally at opposite walls and opposite corners, and one near the ceiling and the other near the floor), and they should be located where occupants or furnishings will not block them. Grilles are side wall devices. Their "throw" should be about ¾ the distance to the other side of the room. Opposite wall should be no greater than about *16′ to 18′* away (can throw up to 30′ in high rooms with special diffusers). Diffusers are down-facing and must be coordinated with the lighting as well as uniformly spaced (at a *distance apart of approximately the floor-to-ceiling height*). Returns should be spaced so as to not interfere with air supply. Assume return air grilles at one per 400 SF to 600 SF.





EXAMPLE:

PROBLEM: DESIGN A PRELIMINARY LAYOUT FOR A 50' × 100', 1 STORY, OFFICE BUILDING WITH A "FLAT" ROOF. THE BUILDING IS TO BE DIVIDED INTO TWO OFFICE AREAS (AND TWO AC ZONES) BY A 5' WIDE HALL RUNNING DOWN THE CENTER. WORK OUT A PRELIMINARY STRUCTURAL ROOF SYSTEM (THAT FULLY SPANS THE BUILDING) TO BE SURE THE DUCTING WILL FIT THROUGH. OFFICE CEILING HEIGHT TO BE 9' AND HALL TO BE 8'. DO A PRELIMINARY COST ESTIMATE OF THE HVAC SYSTEM.

HVAC SYSTEM

SOLUTION:

1. SELECT SYSTEM: SELECT ROOF MOUNTED PACKAGE UNITS (SEE P. 543).
2. SIZE SYSTEM:
   A. FROM BUILDING TYPE (SEE APP. A, ITEM J, P. 630), 250 TO 300 SF/TON

   $$\underset{\text{BLDG}}{(50' \times 100'} - \underset{\text{HALL}}{5' \times 100')} \div \underset{\text{ZONES}}{2} = 2250 \text{ SF/ZONE}$$

   $$\frac{2250 \text{ SF/ZONE}}{250 \text{ TO } 300 \text{ SF/TON}} = 9 \text{ TO } 7.5 \text{ TONS}$$

   B. FROM SYSTEM TYPE (P. 544):
   5 TO 10 TONS = 1500 TO 4500 SF
   BY PROPORTIONS (SEE P. 59) = 6.25 TONS

   C. ESTIMATE <u>8 TONS/ZONE</u> (THIS WILL BE A ROOF MOUNTED UNIT OF ABOUT 10' × 7')

3. LOCATE SUPPLY DIFFUSERS (SD) AND RETURN AIR GRILLES (RAG)
   A. SUPPLY (P. 555): SD AT ABOUT CEILING HT OF 9'. <u>SAY 10' ON MODULE</u>.
   (SEE SKETCH)

–CONTINUED–

B. RETURN (P. 555)

ASSUME RAG FOR EVERY 400 TO 600 SF

400 – 600 SF ÷ 22.5' (WIDTH OF ZONE) = 18 TO 27'

<u>ASSUME RAG AT EACH 22.5' x 25'</u>

4. DUCT SIZES

A SUPPLY

(1) TRUNK (P. 549): $\frac{2250 \text{ SF/ZONE}}{1000 \text{ SF}}$ = 2.25

2.25 x 1 TO 2 SF OF DUCT = 2.25 TO 5 SF

SAY <u>3.5 SF</u> = 2' ϕ OR 1'-10" SQ OR 12" x 3.5"

(2) LINE : ASSUME 1/2 TRUNK

SAY <u>1.75 SF</u> = 1.5' ϕ OR 1.3' SQ OR 12" x 1'-9"

(3) BRANCH : ASSUME TRUNK OF 3.5 SF ÷ 9 EA BRANCHES = .4 SF

SAY <u>.5 SF</u> = .8 ϕ OR 0.3" SQ OR 12" x 10"

B. RETURN

(1) TRUNK : SAME AS SUPPLY OR SLIGHTLY LARGER (SEE P. 549). THEREFORE :

SAY <u>3.5 SF</u> = 2' ϕ OR 1'-10" SQ OR 12" x 3.5'

(2) BRANCH : 1/2 TRUNK

SAY <u>1.75 SF</u> = 1.5' ϕ OR 1.22' SQ OR 1' x 1'-9" OR 10" x 2'

5. SIZE STRUCTURE

A. SELECT TRUSS JOIST ASSEMBLY (C ON P. 477).

B. SELECT OPEN WEB T.J.L. (P. 357).

C. SPACING : 2' O.C.

D. DEPTH = SPAN ÷ S.D.R. = 50' ÷ 17 TO 18 = 2.9' TO 2.8'

<u>SAY 2'-10" DEEP</u>

6. FIT TOGETHER

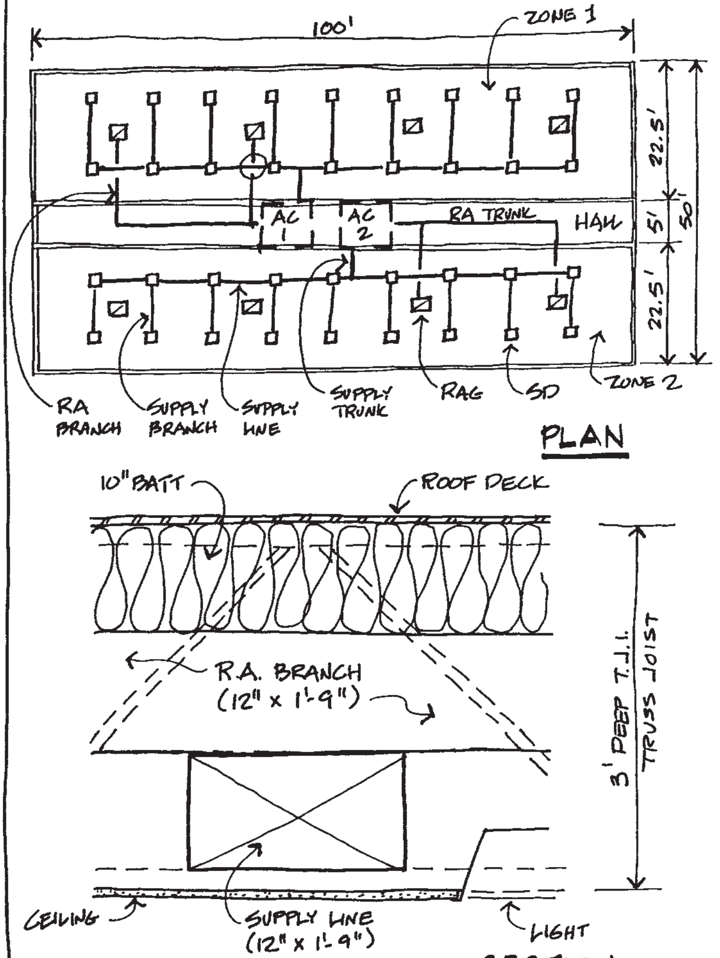
SELECT 12" x 1'-9" SUPPLY LINE UNDER 12" x 1'-9" R.A. BRANCH. SEE SKETCH

7. ESTIMATE OF H.V.A.C. COST (P. 546)

$6.90/SF x 5000 SF = $34500

– CONTINUED –

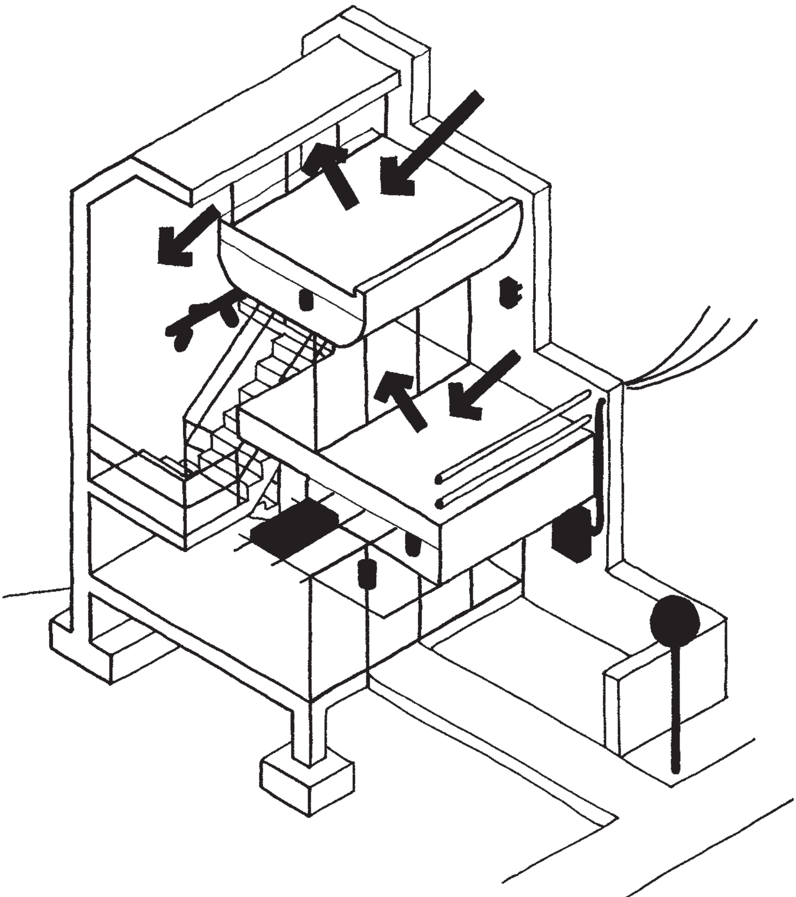
OR $1930/TON x 8 TONS/UNIT x 2 UNITS = $30880
SAY: $20000 TO $30000 (NOT ADJUSTED FOR CITY)



NOTE:
THIS IS A ROUGH LAYOUT ONLY. FIGURE THAT THE ENGINEER WILL DESIGN FOR HALL AC AND THAT THE DUCT SIZE, FROM PRECISE ENGINEERING WILL BE REDUCED ENOUGH FOR THE DUCT INSULATION.

NOTES

NOTES



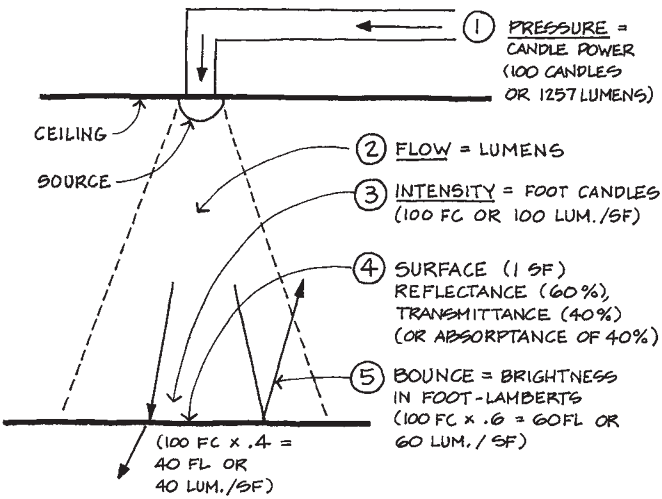
16 LIGHTING AND ELECTRICAL

NOTES

___ A. LIGHTING (13) (16) (56)

___ 1. *General*

___ *a.* Lighting terms and concepts using the analogy of a sprinkler pipe



___ (1) Visible light is measured in lumens.

___ (2) One lumen of light flux spread over one square foot of area illuminates the area to one *footcandle.*

___ (3) The ratio of lumens/watts is called *efficacy,* a measure of *energy efficiency.*

___ (4) The incident angle of a light beam always equals the reflectance angle on a surface.

___ (5) The 1-1-1 Rule: When 1 lumen of light strikes 1SF of perfectly reflective area, 1′ away, at right angles, then 1 lumen of output = 1 fc of incident light = 1 foot-lambert of reflected light.

___ *b.* Considerations in seeing

___ (1) *Contrast* between the object or area being viewed and its surroundings will help vision. Too little will wash out the object. Too much will create glare. Recommended maximum ratios:

___ Task to adjacent area	3 to 1
___ Task to remote dark surface	3 to 1

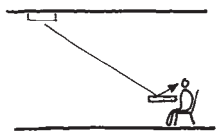
___ Task to remote light surface 1 to 1
___ Window to adjacent wall 20 to 1
___ Task to general visual field 40 to 1
___ Focal point: up to 100 to 1

___ (2) *Brightness* (How much light?). For recommended lighting levels, see d, below, or p. 566.

___ (3) *Size* of that viewed. As the viewing task becomes smaller, the brightness needs to increase and vice versa.

___ (4) *Time:* As the view time is decreased, the brightness and contrast needs to increase and vice versa.

___ (5) *Glare:* Not only can too much contrast create glare, but light sources at the wrong angle to the eye can create glare. Typically, the non-glare angles are from 30° to 60° from the vertical.



___ (6) *Color:* See p. 428.

___ (7) *Interest.*

___ *c.* Types of overall light sources

___ (1) *Task lighting* is the brightest level needed for the immediate task, such as a desk lamp. Select from table on p. 566.

___ (2) *General lighting* is the less bright level of surroundings for both general seeing and to reduce contrast between the task and surroundings. It is also for less intense tasks, such as general illumination of a lobby. This type of lighting can be both natural or artificial.

___ (3) As a *general rule,* general lighting should be about ⅓ that of task lighting down to *20 fc.* Noncritical lighting (halls, etc.) can be reduced to ⅓ of general lighting down to *10 fc.* For more detail, see p. 566.

___ *d.* Typical amounts of light

___ (1) Residential

___ <u>*Casual*</u> activities: 20 fc

___ <u>*Moderate*</u> activities (grooming, reading, and preparing food): up to 50 fc

___ *Extended* activities (hobby work, household accounts, prolonged reading): up to 150 fc

___ *Difficult* activites (sewing): up to 200 fc

___ (2) Commercial

___ *Circulation:* up to 30 fc

___ *Merchandising:* up to 100 fc

___ *Feature* displays: up to 500 fc

___ *Specific* activities (i.e., drafting): 200 fc to 2000 fc

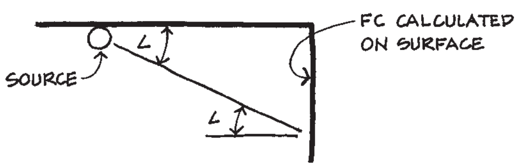
___ (3) For more detailed recommendations, see p. 566.

___ *e.* For recommended room reflectances, see p. 432.

___ *f.* *Calculation* of a point source of light on an object can be estimated by:

$$\text{Foot candles} = \frac{\text{Source}}{\text{distance}^2} \times \text{Cosine of incident angle}$$

SOURCE CAN BE IN CANDLES, LUMENS OR FOOT-LAMBERTS



Light hitting a surface at an angle will illuminate the surface less than light hitting perpendicular to the surface. The cosine of the incident angle is used to make the correction. Doubling the distance from source to surface cuts the illumination of the surface by ¼. Also, see page 601 for other calculations.

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DESIGN LIGHTING LEVELS

	TYPE OF ACTIVITY	TYPE OF LIGHTING	FOOTCANDLES X	FOOTCANDLES Y	FOOTCANDLES Z	TYPICAL SPACES
A	PUBLIC SPACES W/DARK SURROUNDINGS	GENERAL AREA LIGHTING THROUGHOUT SPACES	2	3	5	THEATER, STORAGE
B	SIMPLE ORIENTATION FOR SHORT TEMPORARY VISITS	↓	5	7.5	10	DINING, CORRIDORS, CLOSETS, STORAGE
C	WORKING SPACES WHERE VISUAL TASKS ARE ONLY OCCASIONALLY PERFORMED	↓	10	15	20	WAITING, EXHIBITION, LOBBIES, LOCKERS, RESIDENTIAL DINING, STAIRS, TOILETS, ELEVATORS, LOADING DOCKS
D	PERFORMANCE OF VISUAL TASKS OF HIGH CONTRAST OR LARGE SIZE	ILLUMINATION ON TASK	20	30	50	GENERAL OFFICE, EXAM ROOMS, MANUFACTURING, READING ROOMS, DRESSING, DISPLAY
E	PERFORMANCE OF VISUAL TASKS OF MEDIUM CONTRAST OR SMALL SIZE	↓	50	75	100	DRAFTING, LABS, KITCHENS, EXAM ROOM, SEWING, DESKS, FILES, WORK BENCH, READING, MANUFACTURING, CLASSROOMS
F	PERFORMANCE OF VISUAL TASKS OF LOW CONTRAST OR VERY SMALL AREA	↓	100	150	200	ARTWORK AND DRAFTING, DEMONSTRATION, INSPECTION, SURGERY, LABS, FITTING, RECORDS, CRITICAL AT WORK BENCH, DIFFICULT SEWING, MANUFACTURE ASSEMBLY
G	PERFORMANCE OF VISUAL TASKS OF LOW CONTRAST AND VERY SMALL SIZE OVER A PROLONGED PERIOD.	ILLUMINATION ON TASK BY COMBIN-ATION OF GENERAL AND LOCAL LIGHTING	200	300	500	CRITICAL SURGERY, VERY DIFF-ICULT MANUFACTURING ASSEMBLY, CLOSE INSPECTION
H	PERFORMANCE OF VERY PROLONGED & EXACTING VISUAL TASK	↓	500	750	1000	
I	PERFORMANCE OF VERY SPECIAL TASKS OF EXTREMELY LOW CONTRAST AND SMALL SIZE	↓	1000	1500	2000	

	AGE	% REFL.	SPEED &/OR ACCURACY
X	<40	>70	NOT IMPORT.
Y	40-55	30-70	IMPORT.
Z	>50	<30	CRITICAL

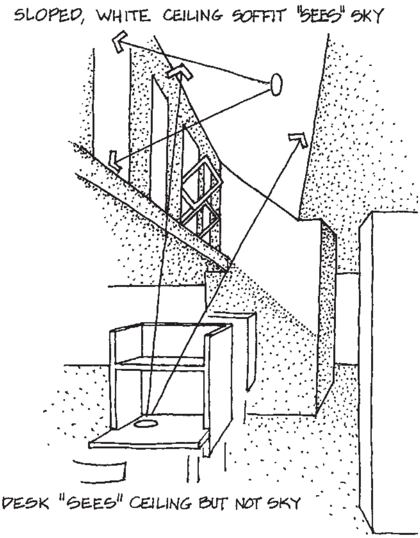
NOTES

NOTES

__ 2. ***Daylighting (Natural Lighting)*** (7) (13) (16) (29)

__ *a.* Before undertaking the design of electric lighting, *daylighting* should be considered. Daylighting is an important connection with the outside world. Even if daylight is not to be used as a primary lighting source, in most buildings there should be some penetration of daylight.

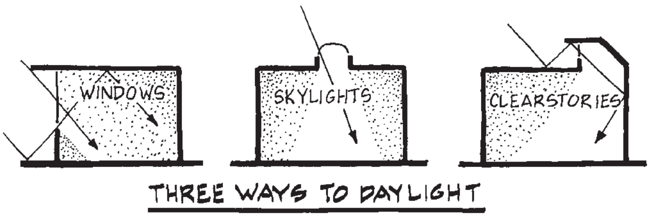
The architectural program can be partitioned into spaces where daylighting can or should be used and spaces where daylight will not be a major factor. The best opportunities for daylight use are in areas where task lighting is not the primary consideration. As the task lighting needs to be more controlled, daylighting becomes more problematic as a lighting solution. Good daylighting opportunities happen where task-lighting needs are not too critical, as in corridors, lobbies, residences. Daylighting is probably not a good idea where task-light constraints are very restrictive, as in a lecture room or hospital operating room.



__ *b.* Daylighting components
- __ (1) Direct sun
- __ (2) Diffuse sky
- __ (3) Indirect sun (sunlight reflected from ground or adjacent structures)

__ *c.* There are many ways to introduce natural light into buildings, ranging from fairly obvious and common methods to new and emerging technologies:
- __ (1) *Perimeter lighting* involves the size and placement of windows and, sometimes, the use of light shelves.
- __ (2) *Top lighting* includes the use of skylights and roof monitors, and even translucent membrane roofs.

___ (3) *Core lighting* involves the use of atriums and light wells.
___ (4) *Optical lighting* includes the use of fiber optics, prisms, mirrors, parabolic reflectors, and other means.



___ *d.* General rules of thumb:
___ (1) Daylighting, even more than artificial lighting, needs to be considered early in the design process.
___ (2) A useful conceptual approach to conceiving a daylighting scheme is to think in terms of bouncing the daylight off exterior and interior surfaces into the area to be lit.
___ (3) Direct sunlight is almost always too bright to work under.
___ (4) Direct sunlight on critical task areas should be avoided.
___ (5) Direct skylight and sunlight should be used sparingly in noncritical areas.
___ (6) For the best daylight, consider increasing the number of windows, rather than just increasing the size of one window or glass area.
___ (7) Daylight should be bounced off surrounding surfaces. In hot climates this should be outside (roofs, ground, walls, etc.) to reduce heat gain.
___ (8) Daylight should be brought in high and let down softly.
___ (9) Daylight can be filtered through trees, plants, screens, and drapes.
___ (10) Daylight from one side of a room can cause a glare problem. Daylight admitted from two or more sides will tend to balance the light in the room.

___ (11) Office building window daylighting usually affects the 15′ perimeter of the plan.

___ (12) North-facing windows, skylights, or clearstories give the best daylight (but may allow excessive heat loss in cold climates with northerly winds).

___ (13) Northern orientations will receive only minor direct solar penetration in the early morning and late afternoon in the summer.

___ (14) North light should be used where soft, cool, uniform illumination is needed.

___ (15) South light should be allowed only where intense, warm, variable illumination is appropriate.

___ (16) Southern orientations are relatively easy to shield from direct solar penetrations by using horizontal louvers or overhangs, provided the cooling season is not too long, as in extremely hot climates.

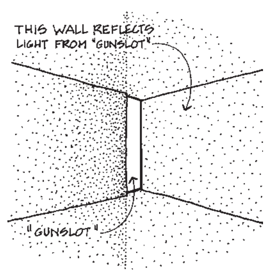
___ (17) Eastern and western orientations are almost impossible to protect from direct solar penetrations (heat and glare) while at the same time allowing occupants to see out the window.

___ (18) See p. 451 for solar control of south-, east-, and west-facing glass.

___ (19) Skylights can be a problem due to heat gain from too much sunlight.

___ (20) Skylights and clearstories can be used to deliver light deep into the interior of a building. Clearstories can be designed to best avoid direct sunlight.

___ (21) "Gun slots" against wall can provide illumination at minimum heat gain.



___ (22) To be economically effective, office daylighting strategies may require *automatic controls* that adjust the level of electric lighting to complement the available natural light during the day. Controls may be photocells, 2- or 3-step lighting, continuous dimming, or motion detectors.

___ (23) New forms of daylighting are *light piping* (optic fiber technology) and translucent roof membranes.

___ (24) Design in light-sensitive applications such as museums must pay particular attention not only to UV but also to the visible light which is responsible for some fading. Certain glazing options will reduce these negative effects of light to acceptable levels.

___ (25) Some new options available to designers promise greater optical control capability. Prismatic elements can provide varying degrees of light control and solar control.

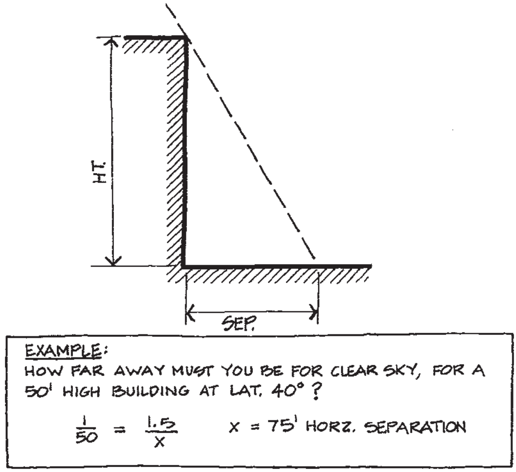
___ *e.* <u>Designing for daylighting:</u>

___ (1) Amount of skylight available (see App. B, item K, for % sun at specific locations). Typically:

Predominantly clear	=	60% or more
Moderate	=	50% to 60%
Heavily covered	=	under 50%

___ (2) Check sky dome for obstructions. Daylighting design requires a building to have line-of-sight access to sufficient sky area for adequate daylight exposure. Use the following ratios to determine clear sky distance from obstructions:

Latitude	Ratio
≤24° (or overcast)	1.2
32°	1.3
40°	1.5
48°	1.8
56°	2.5



___ (3) Building orientation and configuration:

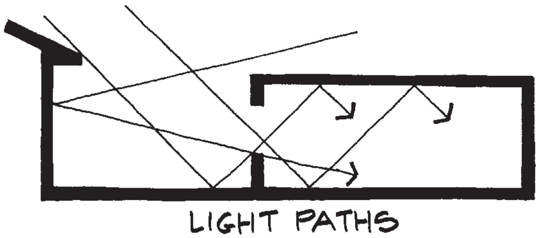
___ (*a*) Orientation:

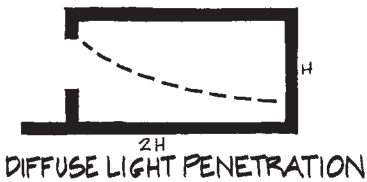
Best	North or south
Worst	West or east

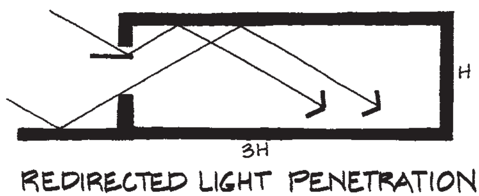
___ (*b*) Building shape:

___ (*i*) <u>Sidelighting</u> (windows or glazed wall areas):

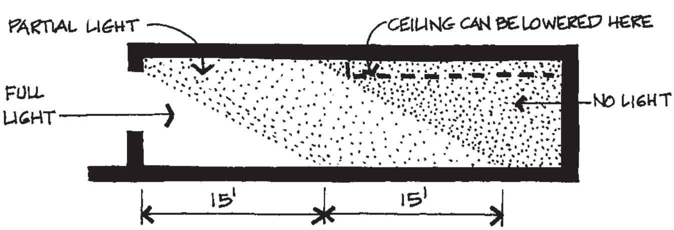
(*a*) For designs that use diffuse daylight from the sky, cloud, or the surrounding environment, it is difficult to provide adequate daylight when the depth of the space is more than 1.5 or 2 times the height of the head of the glass. Designs that redirect daylight and sunlight to the ceiling using light shelves or redirected glazings might be able to expand this to 3 times the ceiling height.



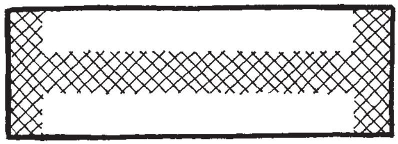




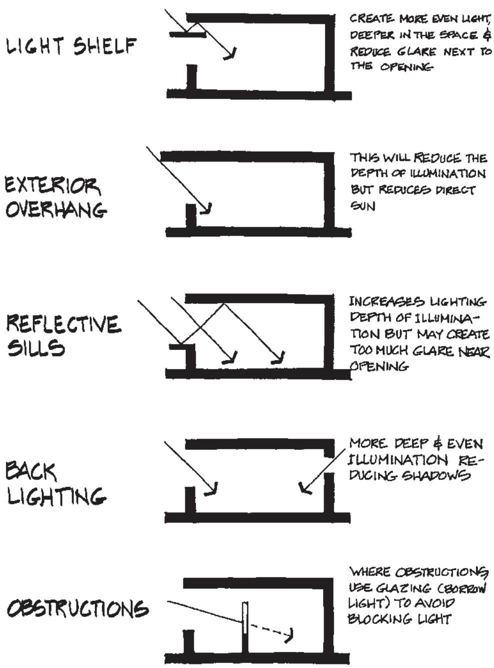
(*b*) Typically for office buildings, the first 15′ depth in from windows gets effective daylight. The next 15′ gets daylight but must be supplemented with artificial light. Past 30′, there is no daylight.



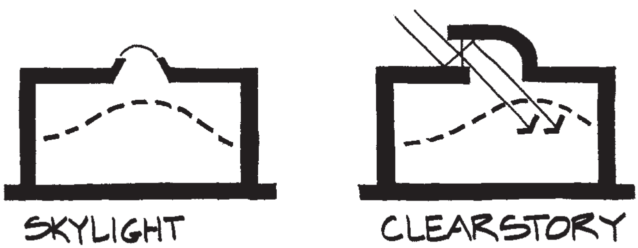
(*c*) Configuration due to side lighting: In general, rectangles, elongated in the EW direction, narrow or elongated plans, L- or U-shaped plans, and courtyards or atrium buildings provide greater access to daylight than more compact arrangements.



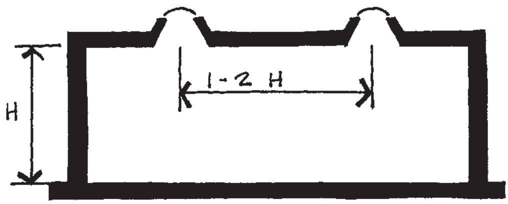
(*d*) Details of sidelighting:



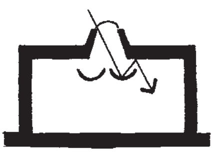
(*ii*) Top Lighting (skylights, clearstorys, and roof monitors): Where occupied areas occur directly below roofs, daylighting may also be provided through top lighting by either skylights or roof monitors (clearstories). Large single-story buildings, such as factories, are well suited to top lighting configurations, as are some top floors of many multistory buildings. Opportunities for top lighting can be increased with building sections that step or are otherwise configured to increase roof areas. Illumination levels from top lighting are roughly 3 times greater than from sidelighting of the same area.



South-facing clearstories provide illumination levels approximately equal to skylights of the same glazing area. Clearstories facing other directions provide approximately half the illumination of a skylight of the same area. Sources of top lighting should be spread no more than 1 to 2 times the height of the opening above the floor.




DEEP PROJECTIONS


INTERIOR REFLECTORS

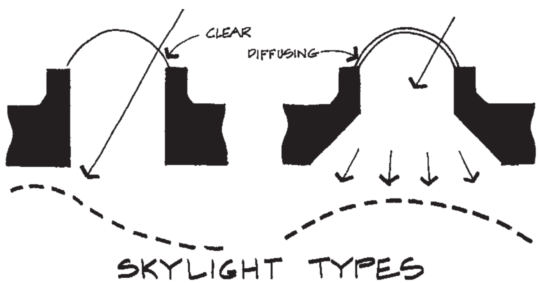
In predominantly overcast areas, top lighting with clear glazing and no other means of sun control may be acceptable, but in most areas, top lighting should be oriented away from the sun or control devices should be used to prevent sunlight passing in unimpeded to the task area.

Interior reflectors, exterior louvers, translucent light-diffusing materials, and deep openings with reflective surfaces can be effective in this regard. Devices located exterior to the opening can exclude solar heat from the interior and may be helpful in areas where high heat gain is common. See item b on p. 172.

When these devices are placed on the inside, they may also be helpful in distributing the daylight farther from the opening and creating more even illumination within the space.

Light distribution from skylights is intrinsically more uniform than that from windows. Light diffusion can be achieved by using diffusing plastic bubble skylights, high transmission glazing with a diffusion screen below, some of the fritted glasses, or laminates with diffusing layers or exterior shading systems.

Light wells can reduce the amount of light entering a space from as little as 10% to as much as 85%. Splayed wells with high-reflectance finishes are the best performers. Adequate daylight in most climates is provided with skylight areas of 4% to 8% with relatively high transmittance glazing. For complete glazed roof areas, the transmittance should be about 5%.



___ *f.* Rules of thumb for *sizing glazing:* Daylight can be used to reduce the need for electrical lighting, but too much daylight can create glare, cause the air conditioning load of the building to rise, or lead to other overheating problems. The following list provides a useful guide to determining the approximate daylight aperture areas that will balance lighting and AC requirements.

Sidelighting

___ (1) *Rough rules of thumb:*

Window openings: *10%* (*min.*) *to 25%* of floor area; *25% to 40%* of wall area

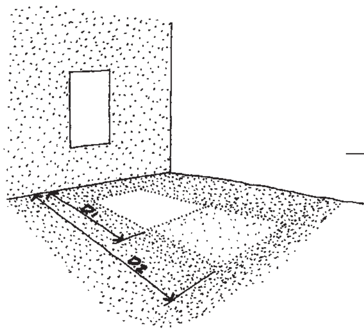
Room depth: *2 to 2½* times window height (usually *15′ to 30′*).

___ (2) Establish desirable illumination levels from p. 566.

___ (3) *Sizing sidelighting:*

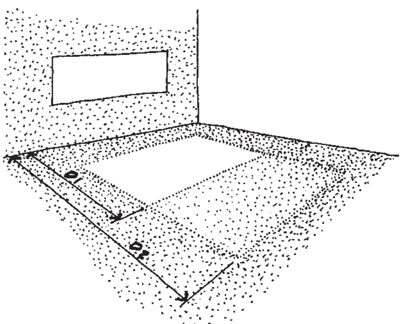
___ (*a*) Window height to depth of penetration of light:

___ (*i*) An 8′- to 9′-high window (H) will give full daylight to a depth of about 15′ (D1). As window height increases, depth increases at a ratio of 1 to 2.



___ (*ii*) An 8′- to 9′-high window (H) will give partial daylighting (requiring additional artificial lights) to a depth of about 25′ to 30′ (D2). As window height increases, depth increases at a ratio of 1 to 3.

(*a*) Window width: To get even light distribution, a window opening should be at least half as wide as the length of its wall.



(*b*) Window area: The following areas light 1500 SF of floor area. Each lighting category (see p. 566) increasingly needs more light and thus greater window area.

Window area in SF (to light 1500 SF of floor)

Category	Sunny		Cloudy
A	10	to	25
B	25	to	55
C	55	to	100
D	100	to	250
E	250	to	500
F+	500	to	1000

To light larger (or smaller) floor areas, as window area increases (or decreases), floor area increases (or decreases) at same ratio.

EXAMPLE

CATEGORY A, CLOUDY, INCREASE FLOOR AREA TO 3000SF.

$\frac{25}{1500} = \frac{X}{3000}$ X = 50SF OF WINDOW

Toplighting

___ (1) *Rough rules of thumb:*

Skylights: *5% to 10%* (*max.*) of ceiling area. Space at *1 to 2* times ceiling-to-workplane height.

Clearstories: *10%* of wall area. Space *1.5* times ceiling-to-workplane height. At a point *15′* from rear wall:

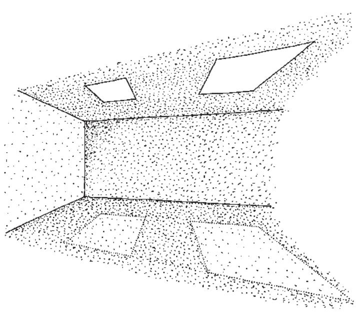
For overcast sky (1500 fc) climates, provide *15″* of glazing height per *10 fc* on average workplane.

For clear climate (5000 fc), provide *2″*.

___ (2) Establish desirable illumination levels from p. 566.

___ (3) *Sizing toplighting:*

___ (*a*) Spacing of skylights and clearstories can be roughly determined as follows:



___ (*i*) Small skylights at 10′ ceiling height (H) should be spaced at 10′ (S). Greater (or less) height to spacing can be determined by a ratio of 1 to 1 (i.e., 30′ H is 30′ S).

___ (*ii*) Clearstories at a 13.5′ ceiling height (H) should be spaced at 20′ (S). Greater (or less) height to spacing can be determined by a ratio of 1 to 1.5.

___ (*iii*) Large skylights (larger than 30 SF) at a ceiling height of 15′ (H) should be spaced at 30′ (S). Greater (or less) height to spacing can be determined by a ratio of 1 to 2.

___ (*b*) Area of glazing: The following toplight areas light 1500 SF of floor area. Each lighting category (see p. 566) increasingly needs more light and thus greater light area. If toplighting is by clearstory and other than south facing, *double* glass areas.

Window area in SF (to light 1500 SF of floor)

Category	Sunny		Cloudy
A	2.5	to	6
B	6	to	12
C	12	to	25
D	25	to	60
E	60	to	120
F+	120	to	250

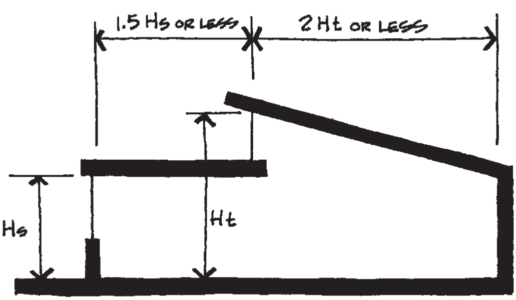
To light larger (or smaller) floor areas, as glass area increases (or decreases), floor area increases (or decreases) at same ratio.

EXAMPLE

CATEGORY A, CLOUDY, 3000 SF FLOOR AREA

$\frac{6}{1500} = \frac{X}{3000}$ X = 12 SF OF TOP LIGHT AREA

Combined side and toplighting can be used to distribute daylighting deeper into the interior than is possible with just sidelighting. Recommended spacings as shown:



__ *g.* Estimating illumination (daylight factors methods)

__ (1) Determine available daylight based on sky conditions (in fc on horizontal surface) and time of day:

	Noon	8 AM or 4 PM
	Clear Sky	
Summer	10,000 to 9000	5250
Spring/Fall	8500 to 7250	3750 to 3500
Winter	5750 to 4000	2500 to 1750
	Partly Cloudy Sky	
Summer	7000 to 6000	3250
Spring/Fall	5500 to 4500	2250 to 2000
Winter	3000 to 2500	1250 to 1000
	Overcast Sky	
Summer	4250 to 2750	2000 to 1500
Spring/Fall	2500 to 1750	1250 to 1000
Winter	1250 to 1000	500

Note: Higher numbers are for lower latitudes (32°N and less). Lower numbers are for higher latitudes (44°N and more).

(2) Calculate the "daylight factor" which ends up being a percentage applied against sky illumination available. This factor is based on a number of design variables, as follows:

__ (*a*) Top lighting

$$\text{Factor} = \frac{(F) \times (U) \times (Ag)}{Af}$$

where F = the window factor, given the amount of skylight incident on the roof. F is equal to 1 for an unobstructed site.

U = the coefficient of utilization-ratio of light reaching the reference plane.

U Values	Average Interior Reflectance 50%	20%
Monitors horizontal to 30°	0.4	0.3
Monitors at 60°	0.25	0.2
Vertical monitors	0.15–0.2	0.1–0.15

Ag = area of glazing
Af = area of floor

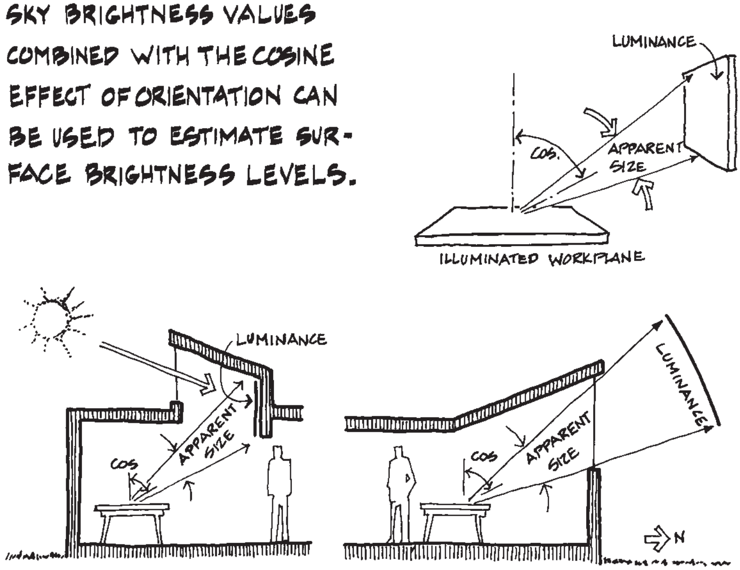
___ (*b*) Side lighting

$$\text{Factor} = \frac{10\,WH^2}{D(D^2 + H^2)} + \frac{4GR}{F(1 - R)}$$

where F = floor area
H = height of top of window above reference plane.
W = width of window
D = distance of window to reference point.
R = reflectance of walls in % (see p. 432)
G = net area of glass

___ (3) Multiply sky illumination in (1) above by the daylight factor from either top lighting (*a*) or side lighting (*b*) to get illumination in fc on work plane.

Note: This method is mainly designed for overcast sky conditions, so the "cosine" method (see p. 565) may be best for direct sunlight.

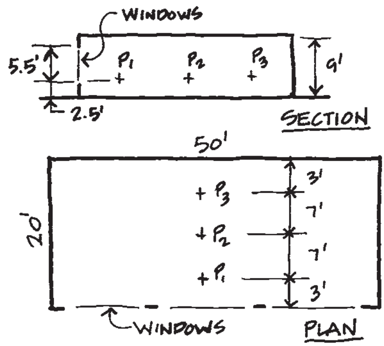


Costs: **Skylights = $7.20 to $220/SF (at average, 80% M and 20% L). Lower number is for large-area skylights and vice versa.**

EXAMPLE:

PROBLEM:

ESTIMATE DAYLIGHTING AT THE 3 LOCATIONS IN THE ILLUSTRATED ROOM. ESTIMATE THE 3 SKY CONDITIONS. THE SITE IS CHICAGO, IL. FIGURE THE 3 SEASONS AND 2 TIMES A DAY.



SOLUTION:

1. AVAILABLE ILLUMINATION FOR CHICAGO, AT LATITUDE 41°-5 & 52% SUN (SEE APP. B, ITEMS A & K, P. 642) WOULD BE THE LOWER MIDDLE OF THE NUMBERS ON P. 582. ASSUME:

	NOON	8 AM & 4 PM
CLEAR SKY		
SUMMER	9200 FC	5250 FC
SPRING / FALL	7500 FC	3600 FC
WINTER	4200 FC	1800 FC
PARTLY CLOUDY SKY		
SUMMER	6200 FC	3250 FC
SPRING / FALL	4700 FC	2100 FC
WINTER	2600 FC	1000 FC
OVERCAST SKY		
SUMMER	2800 FC	1600 FC
SPRING / FALL	1800 FC	1100 FC
WINTER	1100 FC	500 FC

SELECT BRIGHTEST : SUMMER, NOON = 9200 FC
SELECT DIMMEST : WINTER, 8AM OR 4 PM = 500 FC
ANALYZE THESE TWO EXTREMES

2. DAYLIGHT FACTOR FOR WINDOW "SIDELIGHTING":

$$F = \frac{10\,W H^2}{D(D^2 + H^2)} + \frac{4\,GR}{F(1-R)}$$

- CONTINUED -

WHERE: F = 20' × 50' = 1000 SF
H = 5.5'
W = 45'
D = P1 = 3', P.2 = 9', P-3 = 17'
G = 5.5' × 45' = 247.5 SF
R = ASSUME 50%

$$F = \frac{10\,(45)\,(5.5^2)}{(3, 9, \&\ 17)\,(D^2 + 30.25)} + \frac{4\,(247.5)\,(50)}{1000\,(1 - 50)}$$

F = P_1 = 115.6 = 1.156
P_2 = 14.6 = .146
P_3 = 3.5 = .035

3. ILLUMINATION: AVAILABLE DAYLIGHT OF 9200 FC & 500 FC × FACTORS:

	SUMMER NOON	WINTER, AM & PM
P-1	10600 FC *	575 FC*
P-2	1340 FC	75 FC
P-3	322 FC	20 FC

* SINCE THESE NUMBERS ARE GREATER THAN THE AVAILABLE DAYLIGHT, TAKE 90% OF AVAILABLE DAYLIGHT: 8280 FC 450 FC

- IF THE WINDOW IS FACING SOUTH, THE ILLUMINATION WILL BE TOO BRIGHT (AT LEAST AT P-1) AND BLINDS (OR SPECIAL GLASS) WILL HAVE TO BE USED IN SUMMER.

- IF THE WINDOW IS FACING NORTH, THE CLEAR SKY RESULTS ARE INVALID. USE PARTLY CLOUDY CONDITIONS.

- THE P-3 POSITION IN WINTER WILL PROBABLY NOT HAVE ENOUGHT 'NATURAL' ILLUMINATION, SO ELECTRIC LIGHTING WILL HAVE TO BE ADDED ALONG THE REAR WALL.

NOTES

NOTES

___ **3. Electric (Artificial) Lighting**

(B) (S) (5) (13) (16) (56)

For energy conservation, see p. 193. For site-lighting costs, see p. 265.

___ *a.* Lamp types

___ (1) *Incandescent* lamps produce a warm light, are inexpensive and easy to use but have limited *lumination per watt (20 to 40)* and a short life. *Normal voltage* lamps produce a point source of light. Most common shapes are A, R, and PAR. *Low voltage* lamps produce a very small point of intense brightness that can be focused into a precise beam of light (for merchandise or art). These are usually PAR shapes or designed to fit into a parabolic reflector. Sizes are designated in ⅛ inch of the widest part of lamp. Tungsten-Halogen (quartz) and low voltage are a special type of incandescent. Quartz is another type of incandescent that has high-intensity white light with slightly longer life.

___ (2) *Gaseous discharge* lamps produce light by passing electricity through a gas. These lamps require a ballast to get the lamp started and then to control the current.

___ (*a*) *Fluorescent lamps* produce a wide, linear, diffuse light source that is well-suited to spreading light downward to the working surfaces of desks or displays in a commercial environment with normal ceiling heights (*8′ to 12′*). Lamps are typically 17, 25, or 32 watts. The deluxe lamps have good color-rendering characteristics and can be chosen to favor the *cool* (*blue*) or the *warm* (*red*) end of the spectrum. *Dimmers for fluorescents are expensive.* Fluorescent lamps produce more *light per watt of energy (70–85 lumens/watt)* than incandescent; thus operating costs are low. The purchase price and length of life of fluorescent lamps are greater than for incandescent and less than for HID. Four-feet lamp lengths utilize 40 watts and are most common. *Designations are F followed by wattage, shape, size, color, and a form factor.*

___ (*b*) *High-intensity discharge* (*HID*) lamps can be focused into a fairly good beam of light. These lamps, matched with an appropriate fixture are well-suited to beaming light down to the working place from a high ceiling (*12′ to 20′*). *Dimming HID lamps is difficult. The lamps are expensive but produce a lot of light and last a long time.* If there is a power interruption, HID lamps will go out and cannot come on again for about *10 minutes* while they cool down. Therefore, *in an installation of HID lamps, a few incandescent or fluorescent lamps are needed to provide backup lighting.* Since they operate at high temperatures, they would be a poor choice for low ceilings, wall sconces, or any other close-proximity light source. They would also be a poor choice in assemblies and other occupancies where power outages could cause panic.

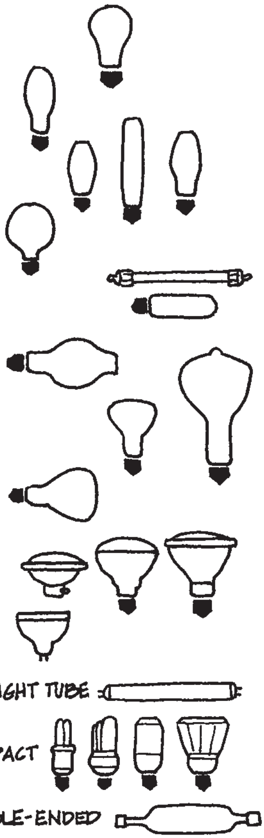
___ *Mercury vapor* (MV; the *bluish* street lamps). Because they emit a blue-green light, they are excellent for highlighting foliage, green copper exteriors, and certain signage. Deluxe version is warmer. *35 to 65 lumens/watt.* This is not much used anymore.

___ *Metal halide* (MH) are often *ice blue cool* industrial-looking lamps. Deluxe color rendering bulbs are 50 to 400 watts, and almost as good as deluxe fluorescent for a warmer effect. Efficiency is *80 lumens/watt.*

- ___ *High-pressure sodium* (HPS) produces a *warm golden yellow* light often used for highways. Bulbs are 35 to 400 watts. Deluxe color rendering is almost as cool as deluxe fluorescent for a cooler effect. Efficiency is *100 lumens/watt.*
- ___ *Low-pressure sodium* (LPS) produces a *yellow* color which makes all colors appear in shades of grey. They are excellent for promoting plant growth indoors. Bulbs are typically 35 to 180 watts. Used for parking lots and roadways. Efficiency is *150 lumens/watt.*

___ (*c*) *Cold cathode* (neon) has a color dependent on the gas and the color of the tube. *Can be most any color.* Does not give off enough light for detailed visual tasks, but does give off enough light for *attracting attention,* indoors or out.

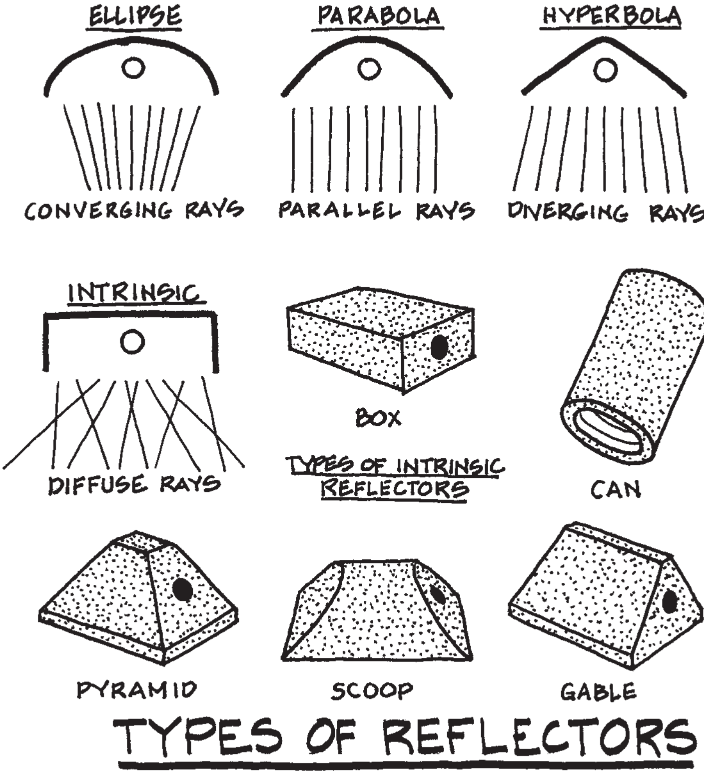
COMMON LAMP SIZES & SHAPES



LAMP SHAPE TYPE DESIGNATION	LAMP SIZE (NOS = DIAMETERS IN 1/8") I	Q	F	MV	MH	HP	LP
A	15-25	–	–	23	–	–	–
E	–	–	–	23-28	17-37	25	–
ED	–	–	–	17-37	–	17-37	–
G	16-40	–	–	–	–	–	–
T	8-21	3-5	–	–	15	10	17-21
BT	–	–	–	37-56	37-56	–	–
R	14-60	12-30	–	40-60	40-60	–	–
ER	30-40	–	–	–	–	–	–
PAR	16-64	16-64	–	38	38	38	–
	BEAM SPREADS RANGE FROM 5° TO 130°						
MR	–	11-16	–	–	–	–	–
STRAIGHT TUBE	8-10 L=24"	–	5-17 L=4-96"	–	–	–	–
COMPACT	–	–	9-40	–	–	–	–
DOUBLE-ENDED	–	3-6 L=4-10"	–	–	6-8 L=4-14"	–	–

1. LAMP SHAPE DESIGNATIONS: **A** = ARBITRARY OR STANDARD, **E** = ELONGATED, **ED** = ELLIPSOIDAL, **G** = GLOBE, **R** = REFLECTOR, **ER** = ELLIPTICAL REFLECTOR, **PAR** = PARABOLIC ALUMINIZED REFLECTOR, **T** = TUBULAR, **BT** = BLOWN TUBE, **MR** = MULTIFACETED REFLECTOR (SMALL QUARTZ CAPSULE IN A FACETED GLASS REFLECTOR).
2. LAMP TYPE DESIGNATIONS: **I** = INCANDESCENT, **Q** = QUARTZ, **F** = FLUORESCENT, **MV** = MERCURY VAPOR, **MH** = METAL HALIDE, **HP** = HIGH PRESSURE SODIUM, **LP** = LOW PRESSURE SODIUM.

___ *b.* Types of reflectors:



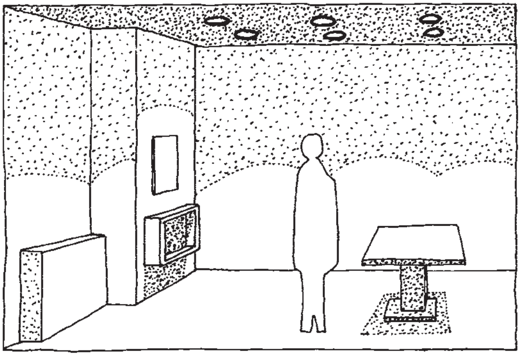
___ *c.* Lighting systems and fixture types

Note: Costs include lamps, fixture, and installation labor, but not general wiring. As a rule of thumb, fixtures are 20% to 30%, and distribution (not included in following costs) is 30% to 70%.

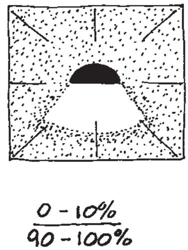
___ (1) *General room lighting*

A large proportion of commercial space requires even illumination on the workplace. This can be done a number of ways.

___ (*a*) *Direct lighting* is the most common form of general room lighting.



DIRECT



All recessed lighting is an example of a direct lighting system, but a pendant fixture could be direct if it emits virtually no light above the horizontal. Unless extensive wall washing, or high light levels (as with fluorescent for general office lighting) are used, the overall impression of a direct lighting system should be one of low general brightness with the possibility of higher intensity accents.

A guide to determine max. spacing is the *spacing-to-mounting-height ratio*. The mounting height is the height from the working place (*usually 2.5' above floor*) to the level of the height fixtures. Note that the ratio does not apply to the end of oblong fixtures due to the nature of their light distribution.

$$\text{Spacing} = \left(\frac{\text{S}}{\text{MH}}\right) \times (\text{Mounting Ht.})$$

EXAMPLE:

WHAT IS AN AVERAGE FLUORESCENT FIXTURE SPACING IF THE CEILING IS 9' AND THE S/MH RATIO IS TO BE 1.5?

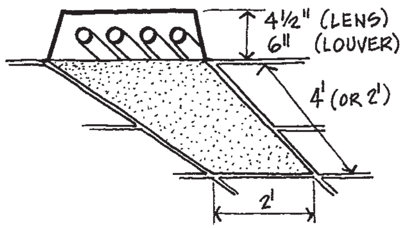
SPACING = (1.5)(9' − 2.5') = 9.75'

SAY: 10'

Types of direct lighting are:

___ *Wide-beam diffuse lighting* is often fluorescent lights for normal ceiling heights (8′ to 12′). The fixtures will produce a repetitive two-dimensional pattern that becomes the most prominent feature of the ceiling plane. Typical S/MH = *1.5*.

Typical recessed fluorescent fixture:



Costs: 2′ × 4′ = $100 to $170/ea. (85% M and 15% L), variation of −10%, +20%.

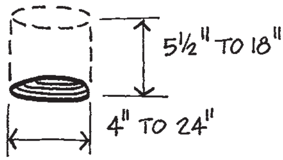
2′ × 2′ = 10% less

1′ × 4′ = +10% more

___ *Medium-beam downlighting* is produced with a fixture located in or on the ceiling that creates a beam of light directed downward. In the circulation and lobby areas of a building, *incandescent lamps* are often used. For large areas, *HID lamps* are often selected. In both cases the light is in the form of a *conical* *beam,* and *scallops* of light will be produced on wall surfaces.

S/MH is usually about *0.7 to 1.3.*

Typical fixture:



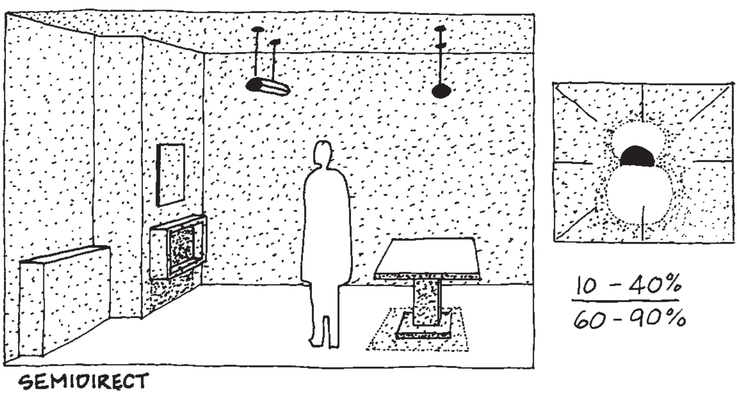
Cost: (per ea. fixture) (Variation of –10 to +35%).

	Res.	Comm.
Low voltage:	**$180**	**$365 (85% M and 15% L)**
Incandescent:	**$75**	**$365 (90% M and 10% L)**
Fluorescent:	**$150**	**$335 (85% M and 15% L)**
HID:	**$180**	**$550 (80% M and 20% L)**

___ *Narrow beam downlights* are often used in the same situation as above, but produce more of a spotlight effect at low mounting heights. This form of lighting is used to achieve even illumination where the ceiling height is relatively high. S/MH is usually *0.3 to 0.9.* Typical fixture same as above.

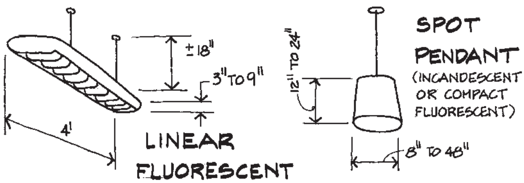
Cost: Same as medium-beam downlighting above.

___ (*b*) *Semidirect lighting*



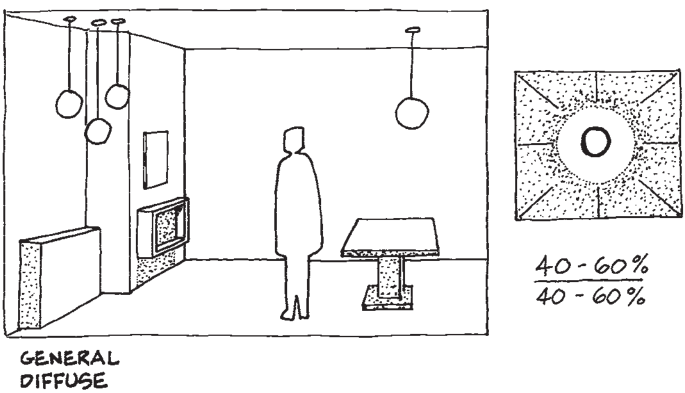
All systems other than direct ones necessarily imply that the lighting fixtures are in the space, whether pendant-mounted, surface-mounted, or portable. A semidirect system will provide good illumination on horizontal surfaces, with moderate general brightness.

Typical fixtures:



Costs: Fluor.: $395 to $920 (90% M and 10% L)
Pendant: $180 to $550 (90% M and 10% L)

__ (*c*) General diffuse lighting

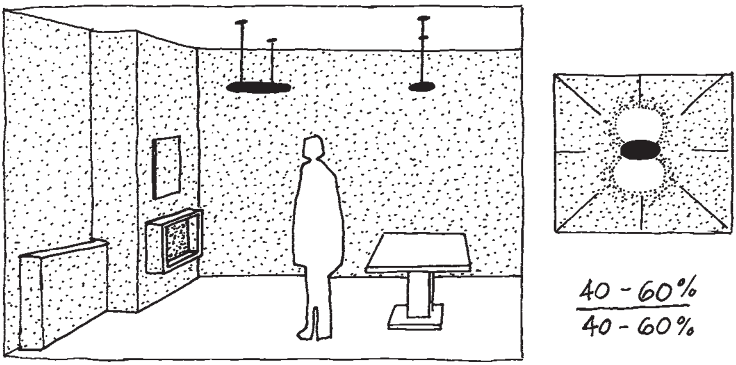


A general diffuse system most typically consists of suspended fixtures, with predominantly translucent surfaces on all sides. Can be incandescent, fluorescent, or HID.

Typical fixture: see sketch above

Costs: $90 to $670 (90% M and 10% L)

___ (*d*) *Direct-indirect lighting*



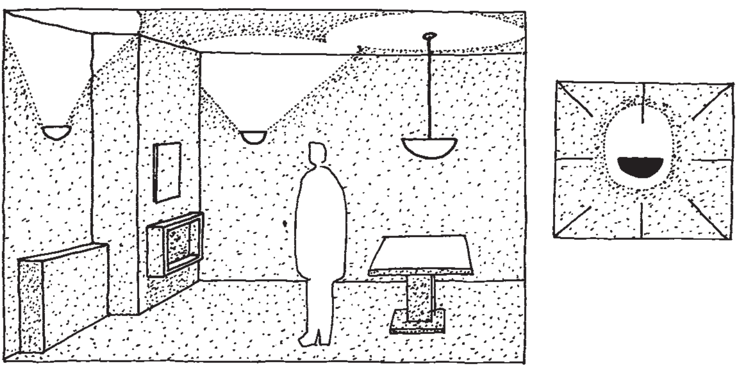
DIRECT - INDIRECT

A direct-indirect will tend to equally emphasize the upper and lower horizontal planes in a space (i.e., the ceiling and floor).

Typical fixture: same as semidirect

Costs: Same as Semidirect.

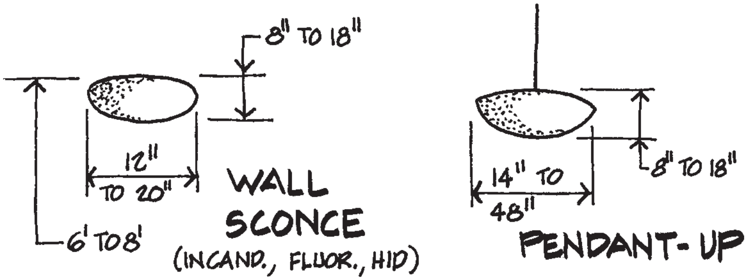
___ (*e*) *Semi-indirect lighting*



SEMI - INDIRECT

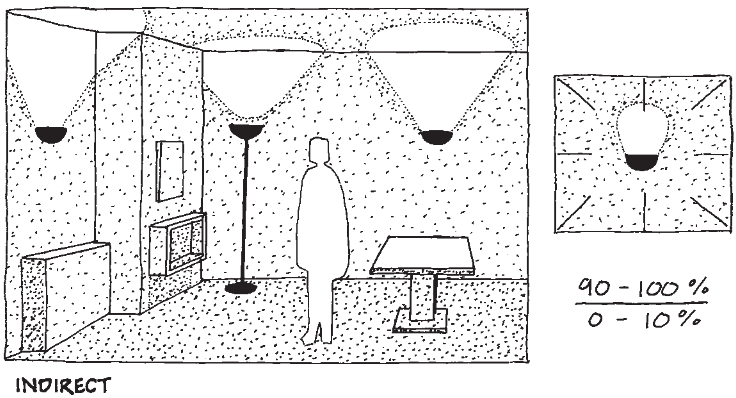
A semi-indirect system will place the emphasis on the ceiling, with some downward or outward-directed light.

Typical fixture:



Costs: Wall sconce: $215 to $920 (90% M and 10% L)
Pendant: $425 to $2695 (85% M and 15% L)

___ (*f*) *Indirect lighting*



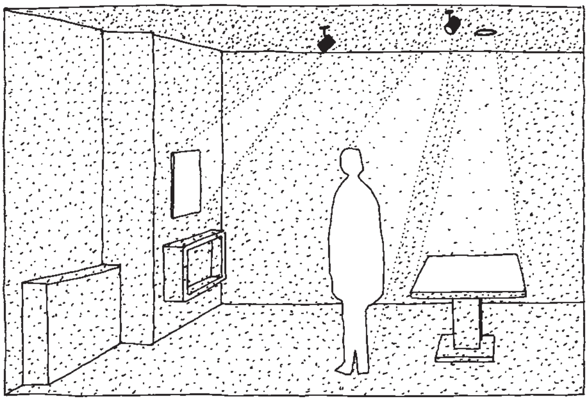
A fully indirect system will bounce all the light off the ceiling, resulting in a low-contrast environment with little shadow.

Typical fixture: Same as Direct-Indirect.

Costs: Same as Direct-Indirect.

Note: ADA requires that, along accessible routes, *wall-mounted* fixtures protrude no more than *4″* when mounted lower than *6′8″* AFF.

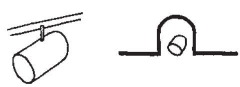
___ (*g*) *Accent or specialty lighting*



ACCENT

Used for special effects or spot lighting, such as lighting art objects or products on display.

Typical fixtures:



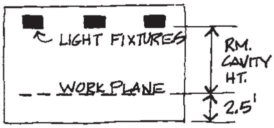
Costs: Track: $100 to $550 (90% M and 10%L)
Recessed accent: $180 to $1225 (80% M and 20% L)

___ *d.* Simplified calculations

___ (1) For estimating light from one source (such as a painting on a wall lit by a ceiling mounted spot) use the *Cosine Method* shown on p. 565.

___ (2) For general room lighting use the *Zonal Cavity Method*.

ZONAL CAVITY CALCULATIONS METHOD FOR GENERAL LIGHTING



$$\text{ROOM CAVITY RATIO (RCR)} = \frac{(5)(H)(\text{LENGTH} + \text{WIDTH})}{\text{LENGTH} \times \text{WIDTH}}$$

H = HEIGHT FROM THE WORK PLAN (2.5 FT. ABOVE FLOOR) TO BOTTOM OF LIGHT FIXTURES.

LENGTH & WIDTH = ROOM DIMENSIONS

$$\text{NUMBER OF FIXTURES} = \frac{(\text{FOOTCANDLES}) \times (\text{AREA OF ROOM})}{(\text{LUMENS PER FIXTURE}) \times (\text{CU}) \times (\text{MAINT. FACTOR})}$$

FOOTCANDLES = THE DESIRED ILLUMINATION ON THE WORK PLANE. SEE PART 1.

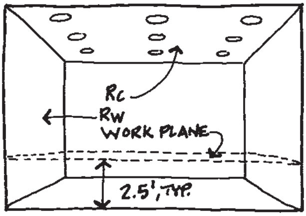
LUMENS PER FIXTURE = (LUMENS PER LAMP) × (NUMBER OF LAMPS IN THE FIXTURE).

CU = COEFFICIENT OF UTILIZATION

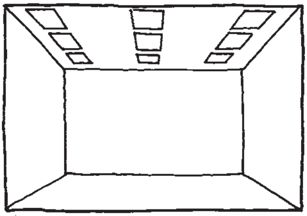
THE COEFFICIENT OF UTILIZATION EXPRESSES THE EFFICIENCY OF THE LIGHT FIXTURE ROOM COMBINATION. IT IS DEPENDENT ON FIXTURE EFFICIENCY, DISTRIBUTION OF LIGHT FROM THE FIXTURE, ROOM SHAPE, AND ROOM SURFACE REFLECTANCES. LIGHT FIXTURE MANUFACTURERS PRINT TABLES LISTING THE CU AS A FUNCTION OF ROOM CAVITY RATIO AND ROOM SURFACE REFLECTANCES FOR EACH INDIVIDUAL LIGHT FIXTURE. SEE NEXT PAGE.

MAINTENANCE FACTOR = VARIES FROM <u>0.85 TO 0.65</u>. THE MAINT. FACTOR ADJUSTS THE CALCULATION FOR THE FACT THAT LAMPS PRODUCE LESS LIGHT AS THEY GET OLDER AND FIXTURES GET DIRTY AND REFLECT LESS LIGHT OUT OF THE FIXTURE.

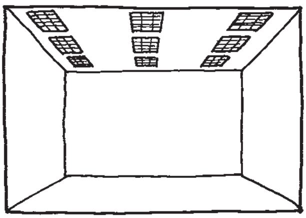
TYPICAL COEFFICIENTS OF UTILIZATION



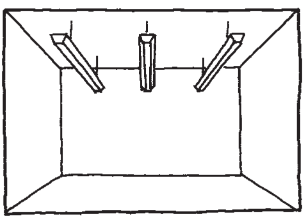
INCANDESCENT PATTERN DOWNLIGHT		
ROOM TYPE	HIGH REFL. FIN.	LOW REFL. FIN.
TYP. SMALLER RMS. (MOD. LOW CL'G.)	0.70 TO 0.80	0.60 TO 0.70
TYP. LARGER RMS.		
RELATIVELY HIGH CL'G.	0.85 TO 0.90	0.80 TO 0.85
RELATIVELY LOW CL'G.	0.90 TO 0.95	0.85 TO 0.90



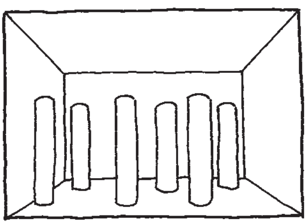
FLUORESCENT, 2×4, (PRISMATIC LENS)		
ROOM TYPE	HIGH REFL. FIN.	LOW REFL. FIN.
TYP. SMALLER RMS (MOD. LOW CL'G.)	0.35 TO 0.45	0.30 TO 0.40
TYP. LARGER RMS.		
RELATIVELY HIGH CL'G.	0.50 TO 0.60	0.45 TO 0.50
RELATIVELY LOW CL'G.	0.60 TO 0.70	0.55 TO 0.60



FLUORESCENT, 2×4, (PARABOLIC LOUVER)		
ROOM TYPE	HIGH REFL. FIN.	LOW REFL. FIN.
TYP. SMALLER RMS (MOD. LOW CL'GS.)	0.30 TO 0.45	0.25 TO 0.35
TYP. LARGER RMS.		
RELATIVELY HIGH CL'G.	0.55 TO 0.65	0.45 TO 0.55
RELATIVELY LOW CL'G.	0.65 TO 0.75	0.55 TO 0.65



FLUORESCENT PATTERN OF INDIRECT LIGHTING		
ROOM TYPE	HIGH REFL. FIN.	LOW REFL. FIN.
TYP. SMALLER RMS. (MOD. LOW CL'GS.)	0.35 TO 0.50	0.15 TO 0.20
TYP. LARGER RMS		
RELATIVELY HIGH CL'G.	0.40 TO 0.65	0.20 TO 0.30
RELATIVELY LOW CL'G.	0.50 TO 0.75	0.30 TO 0.40

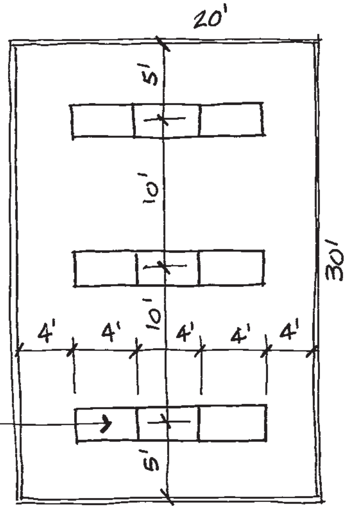


H.I.D. PATTERN OF INDIRECT LIGHTING		
ROOM TYPE	HIGH REFL. FIN.	LOW REFL. FIN.
TYP. SMALLER RMS. (MOD. LOW CL'GS)	0.28 TO 0.38	0.05 TO 0.15
TYP. LARGER RMS.		
RELATIVELY HIGH CL'GS	0.40 TO 0.55	0.10 TO 0.20
RELATIVELY LOW CL.	0.50 TO 0.65	0.10 TO 0.25

EXAMPLE:

PROBLEM:

DO A PRELM. DESIGN OF A 20' × 30' CLASS ROOM W/ DESK HEIGHT OF 2.5' AND CEILING HEIGHT OF 9'. USE 2 × 4 LAY IN FLUOR. LIGHTS WITH 4 - 32 WATT LAMPS. ASSUME REFLECTANCE OF: CEILINGS = 80%; WALLS = 50%; AND FLOORS = 40%



2×4 FLUOR. FIXTURE

SOLUTION:

1. NO. OF FIXTURES = $\frac{FC \times A}{LUM/FIX \times CU \times MF}$

WHERE: FC = DESIRED LIGHT LEVEL, SELECT 75 FC (P. 566)
A = AREA OF ROOM = 20' × 30' = 600 SF
LUM./FIX. = ASSUME 80 LUM/WATT (SEE P. 589) × 32 WATTS × 4 LAMPS = 10 240 LUM./FIX.

CU = COEF. OF UTILIZATION. FROM TYPICAL CU'S ON P. 602, AT FLUOR., 2×4, SELECT 0.6
MF = MAINT. FACTOR (P. 601), SELECT 0.8

$$= \frac{75 \times 600}{10240 \times 0.6 \times 0.8} = 9.15$$

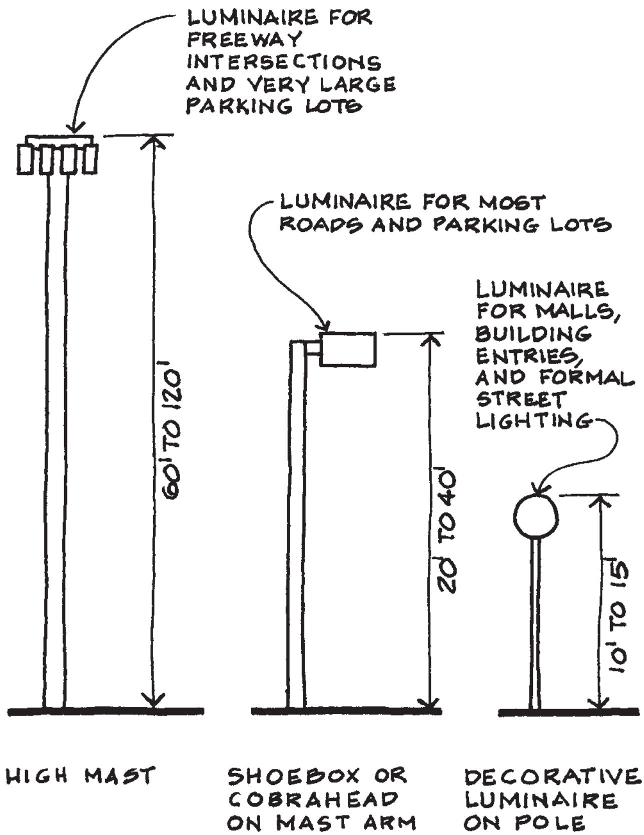
SAY 9 FIX.

2. SPACING (P. 594) FOR DIRECT FLUOR = S/MH = 1.5
SPACING = (1.5)(9 − 2.5) = 9.75' SAY 10'

3. LAYOUT AS SHOWN ABOVE.

___ *e.* Exterior lighting: As with all exterior lighting, avoid light spill onto adjacent property and night-sky pollution.

___ (1) Parking lot lighting: Space 4 times pole height for range of 0.8 fc to 3.6 fc.

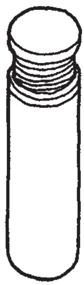


___ (2) Landmark lighting is the lighting of building facades, monuments, or other prominent objects. This is most effective if the object is light in color, rough, or varied in texture, and has a dark surround. Possibilities are scalloping (10–20° angles) or grazing (1–5° angles).

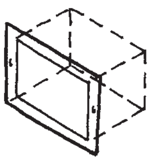
___ (3) <u>*Landscape and pathway lighting:*</u> For public plazas, space short poles or bollard lights at about 4 times their height. At walkways in landscaping, place lights at terminals such as walk corners, steps, landings, overlooks, and transitions. Place pathway lights at 15′ to 30′ along walking surface, using narrow cone downlight. Place lights within landscape area for best visual effect.

COMMON EXTERIOR LIGHTING

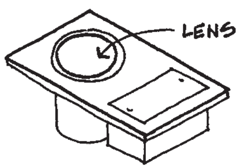
TYPE	USE
BOLLARDS	WALKWAY AND PATHWAY LIGHTING. A TYPICAL BOLLARD IS 42" – 48" HIGH & USES A LAMP RANGING FROM ABOUT 35 WATT TO 100 WATT HID.



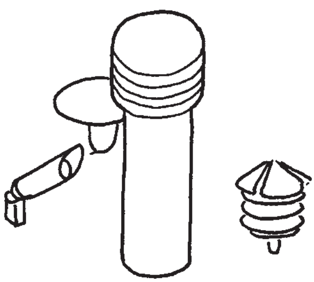
TYPE	USE
STEP LIGHTS	WALKWAY AND STAIRWAY LIGHTING FROM ADJACENT SIDE WALLS. THE LIGHT IS MOUNTED AT OR BELOW THE RAIL HEIGHT.

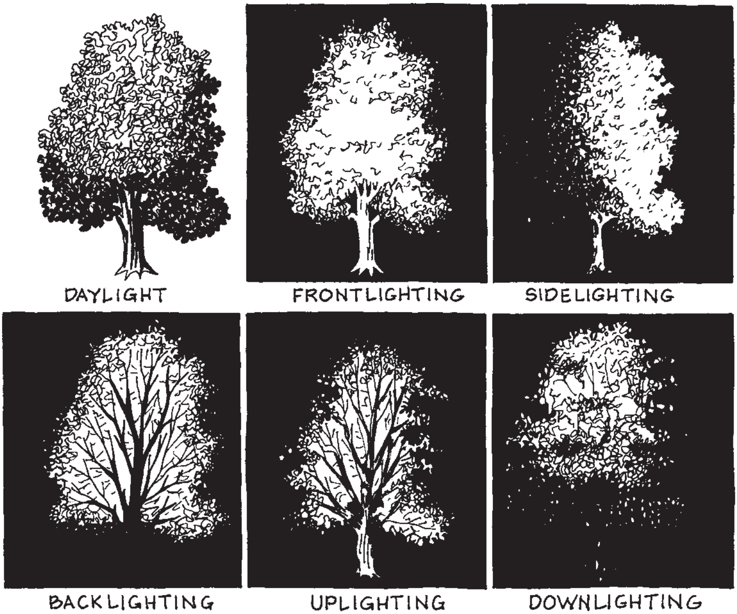


TYPE	USE
WELL LIGHTS, DIRECT BURIAL LIGHTS	ILLUMINATION OF TREES & STRUCTURES FROM BELOW FROM CONCEALED UPLIGHTS.



TYPE	USE
LANDSCAPE LIGHTS	A WIDE VARIETY OF LOW LEVEL LIGHTS, SUCH AS PATH, PLANTER BED, AND WALLWASH LIGHTS AND UPLIGHTS IN SEVERAL STYLES. FOR RESIDENTIAL LANDSCAPES, MOST LIGHTING SYSTEMS ARE LOW VOLTAGE (TYP. 12 V).





LANDSCAPE LIGHTING AT NIGHT

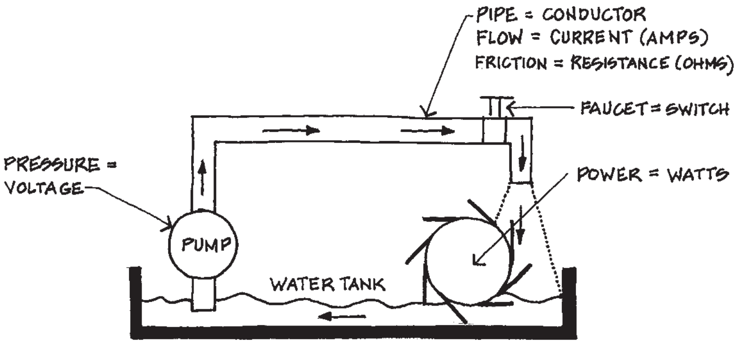
NOTES

___ B. POWER AND TELEPHONE

(B) (I) (O) (1) (16) (27)

For Energy Conservation, see p. 193. For ***Costs,*** see App. A, item K. The architect needs to contact the utilities early to verify power availability and type.

___ 1. Electrical Power



___ *a.* Water analogy (an electrical circuit)

1 volt = Force needed to drive a current of 1 amp through a resistance of 1 ohm.

1 watt = Rate at which electrical energy is consumed in a circuit with a force of 1 volt in a current of 1 amp.

___ *b.* Basic formulas

___ Power formula: Watts = volts × amps

Used to convert wattage ratings of devices to amps. Wires and circuits are rated by amps.

___ Ohm's law:

$$\text{Amps} = \frac{\text{volts}}{\text{ohms}}$$

Devices may draw different amperage even though connected to the same voltage.

___ *c.* Modern electronics and computers are increasingly having an impact on building design, requiring more space than ever.

___ *d.* A building's electrical system has three general parts: *service* (where the power enters and is regulated), *distribution* (the network of wires that carry power to all parts of the building), and *circuits* (where the energy is utilized). An electrical system may be classified as small, medium, or large. As a rule, provide 20% to 30% of breaker space for future expansion.

___ *e.* <u>Building power systems</u> consist of:

- ___ *Transformer* to reduce voltage from utility power grid. Exterior ones should ideally be 20′ away from the building.
- ___ *Main switchboard* (sometimes called *service entrance section* or *switchgear*) with main disconnect and distribution through circuit breakers or fused switches.
- ___ *Subpanels and branch circuits* to distribute power throughout building.

More detailed description based on building size:

___ (1) <u>*Residential and small commercial buildings*</u> typically use *120/240 volt, single-phase* power, at 60 to 200 amps and one or two panel boxes.

- ___ (*a*) <u>*Transformers*</u> are pole mounted (oil cooled, *18″ dia.* × *3′ H*) or for underground system, oil or dry type pad mounted on ground. Both outside building.
- ___ (*b*) <u>*Main switchboard*</u> usually located at power entry to building and typically sized at *20″ W* × *5″D* × *30″ H*.
- ___ (*c*) <u>*Branch circuits*</u> should not extend more than *100′* from panel. Panel boards are approx. *20″ W* × *5″ D* × *30″ to 60″ H*. The max. no. of breakers per panel is *42*.
- ___ (*d*) <u>*Clearance*</u> in front of panels and switch boards is usually *3′ to 6′*.

___ (2) <u>*Medium-sized commercial buildings*</u> typically use *120/208 V, 3-phase* power to operate large motors used for HVAC, etc., as well as to provide 120 V for lights and outlets. Service is typically 800 to 1200 amps.

- ___ (*a*) *Transformer* is typically liquid-cooled, pad-mounted outside building and should have *4′* clearance around and be within *30′* of a drive.

The size can be approximated by area served:

Area	No. res. units	Pad size
18,000 SF	50	4′ × 4′
60,000 SF	160	4.5′ × 4.5′
180,000 SF		8′ × 8′

___ (*b*) Main switchboard for lower voltage is approx. *6′ W × 2′D × 7′H* (for 2000 amps or less or up to 70,000 SF bld'g.). Provide *3′ to 6′* space in front for access. Higher voltage require access from both sides. *3000 amps* is usually the largest switchboard possible.

___ (*c*) Branch panels: For *general* lighting and outlets is same as for residential and small commercial except there are more panels and at least *one per floor.* The panel boards are generally related to the functional groupings of the building.

For *motor* panels, see large buildings.

___ (3) *Large commercial buildings* often use *277/480 V, 3-phase* power. They typically purchase power at higher voltage and step down within the building system. Typically, electrical rooms are required, ideally with two exits (one to the outside). All large electrical components require 3.5′ in front and side, 2.5′ at rear, and 3′ above, for clear access.

___ (*a*) *Transformer* is typically owned by the building and located in a vault inside or outside (underground). Vault should be located adjacent to exterior wall, ventilated, fire-rated, and have two exits. Smaller dry transformers located throughout the building will step the 480 V down to 120 V. See below for size.

___ (*b*) *Main switchboard* is approx. *10 to 15′ W × 5′D × 7′H* with *4′ to 6′* maintenance space on all sides. Typical sizes of transformer vaults and switchgear rooms:

Commercial building	Residential building	Transformer vault	Switchgear room
100,000 SF	200,000 SF	20′ × 20′ × 11′	30′ × 20′ × 11′
150,000 SF	300,000 SF	(30′ × 30′ × 11′ combination)	
300,000 SF	600,000 SF	20′ × 40′ × 11′	30′ × 40′ × 11′
1,000,000 SF	2,000,000 SF	20′ × 80′ × 11′	30′ × 80′ × 11′

Over *3000 amp,* go to multiple services. XFMR vaults need to be separated from rest of the building by at least *2-hr.* walls.

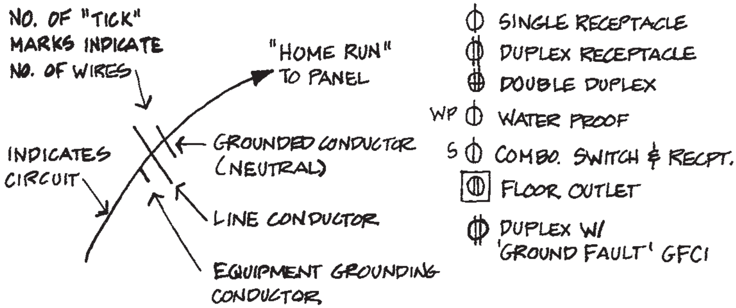
___ (*c*) Branch panels

- ___ Panels for lighting and outlets will be same as for medium-sized buildings except that they are often located in closets with telephone equip. The area needed is approx. *0.005* × the building area served.
- ___ Motor controller panel boards for HVAC equip., elev's., and other large equipment are often in (or next to) mechanical room, against a wall. A basic panel module is approx. *1′W × 1.5′D × 7′H.* One module can accommodate 2- to 4-motor control units stacked on top of one another. Smaller motors in isolated locations require individual motor control units approx. *1′W × 6″D × 1.5′H.*

___ (*d*) Other: In many buildings an emergency generator is required. Best location is outside near switchgear room. If inside, plan on a room 12′W × 18′ to 22′L. If emergency power is other than for life safety, size requirements can go up greatly. In any case, the generator needs combustion air and possibly cooling.

___ *f.* Miscellaneous items on electrical

___ (1) Circuit symbols on electrical plans



___ (2) Lightning protection: As a rule, a tall building should have at least 2 lightning rods on its roof, with special conductors down to ground terminals.

___ (3) For fire alarms, see p. 524.

___ (4) Residential

___ (*a*) Service drops (overhead lines) must be:

___ *10′* above ground or sidewalk

___ *15′* above driveways

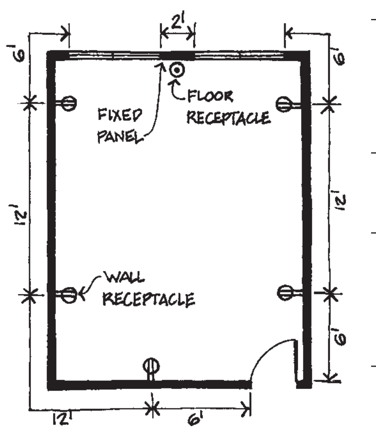
___ *18′* above streets

___ (*b*) A min. of *1 wall switch* controlling lighting outlets required in all rooms (but convenience outlets may apply in main rooms).

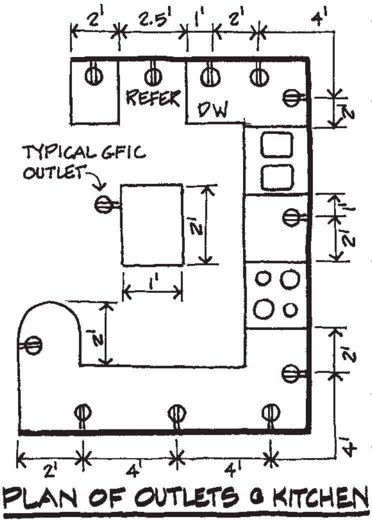
___ (*c*) All rooms require a convenience outlet every 12′ along walls, 2′ or longer.

___ (*d*) Provide sufficient 15- and 20-amp circuits for min. of *3 watts of power/SF. One* circuit for every *500 to 600 SF.*

___ (*e*) A min. of *two* #12 wire (copper), *20-amp* small appliance circuits required pantry, dining, family, extended to kitchen.



PLAN OF OUTLETS IN A TYP. ROOM



__ (*f*) A min. of *one* #12 wire, 20-amp circuit required for *laundry* receptacle.

__ (*g*) A min. of *one* receptacle per *bathroom* with ground fault circuit interrupter protection (GFCI, required within *6′* of water outlet and at exteriors).

__ (*h*) A min. of *one 20-amp* outlet (GFCI) required in *basement, garage, patios, kitchen counters, wet bars, and crawl spaces.*

__ (*i*) Provide *smoke detector*. See p. 84.

__ (*j*) Mounting heights:
Switches, counter receptacles, bath outlets: *4′* AFF
Laundry: *3′6″* AFF
Wall convenience outlets: *12″* AFF

__ (3) For outlets and controls required to be *HC accessible,* per ADA, place between *18″ and 4′* AFF.

__ (4) Always check room switches against *door swings.*

__ (5) Check flush-mounted wall panels against *wall depth.*

__ (6) Building must always be *bonded and grounded* by connecting all metal piping to electrical system, and by connecting electrical system into the ground by either a buried rod or plate outside the building or by a wire in the footing (UFER).

__ (7) Consider *lightning protection* by a system of rods or masts on roof connected to a separate ground and into the building elect. ground system.

Costs (30% M and 70% L):
Outlets including wiring:
Residential: $50–$80/ea.
Commercial: $60–$90/ea.
Hospital: $70–$100/ea.

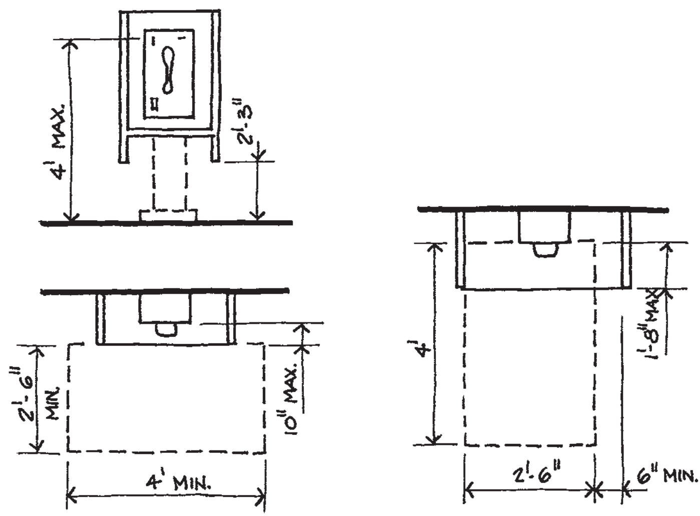
___ 2. <u>Building Telephone and Signal Systems</u>

___ *a.* Small buildings often have a telephone mounting board (TMB) of ¾″ plywood with size up to *4′* × *4′*.

___ *b.* Medium-size buildings often need a telephone closet of *4′ to 6′*.

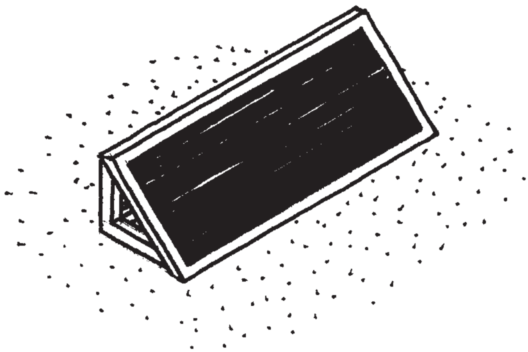
___ *c.* Large buildings typically have a *400-SF* telephone terminal room. Secondary distribution points typical throughout building (one per area or floor) usually combined with electrical distribution closets (approx. *0.005* × area served).

___ *d.* ADA requires that where public phones are provided, at least *one* must be HC-accessible (1 per floor, 1 per bank of phones). See ADA for special requirements.



___ *e.* ADA/ANSI now has requirements on emergency signals (called "appliances") in buildings. Where required by code, wall-mounted appliances must be either 6′8″ to 8′ above floor or 4″ to 12″ below ceiling. For very high rooms, ceiling-mounted appliances must be suspended to be no higher than 30′. Corridors must have appliances every 50′ to 100′ and 15′ from ends. Rooms must have one appliance unless it is not visible everywhere, limited to two, but 80′ square rooms or larger may require more.

___ **3. Solar Electric** (Photovoltaics)



___ *a.* Photovoltaics produce electrical energy from *sunlight* via solar electric *panels* facing sunlight (direct or reflected). Although it is most desirable to face these panels into direct sun, they can operate in any sky type of light. *Batteries* store the energy until needed, unless supplying the power grid.

___ *b.* About 10% are presently being used for *remote locations,* such as rural houses away from the power grid. The other 90% are being used on grid, usually due to government or utility subsidies.

___ *c.* **The off-grid houses cost about *20% to 30%* above conventional houses. Of the extra cost, about *55% to 60%* is due to photovoltaics and the rest for added energy conservation features to reduce the electric load.**

___ *d.* For off-grids, size collector area at about *10%* of floor area served (*7 to 12 watts/SF* of panel). For *retrofits* of less efficient homes, *double or triple* this. If the house is also tied into the *power grid,* then this can all be reduced.

___ *e.* Size battery and converter *storage area* at about *1 SF for every 12 SF* of collector area.

___ *f.* Collector area is made up of the PV *modules* and in turn assembled into *arrays.* This should face south *with* a tilt angle within the range of ±*15 deg.* of the site latitude, and be roof- or ground-mounted. PV can also be building-integrated as part of wall or roof systems. A typical PV module range *is 3′ × 5′*.

___ *g.* Presently there are two types of PV being made:

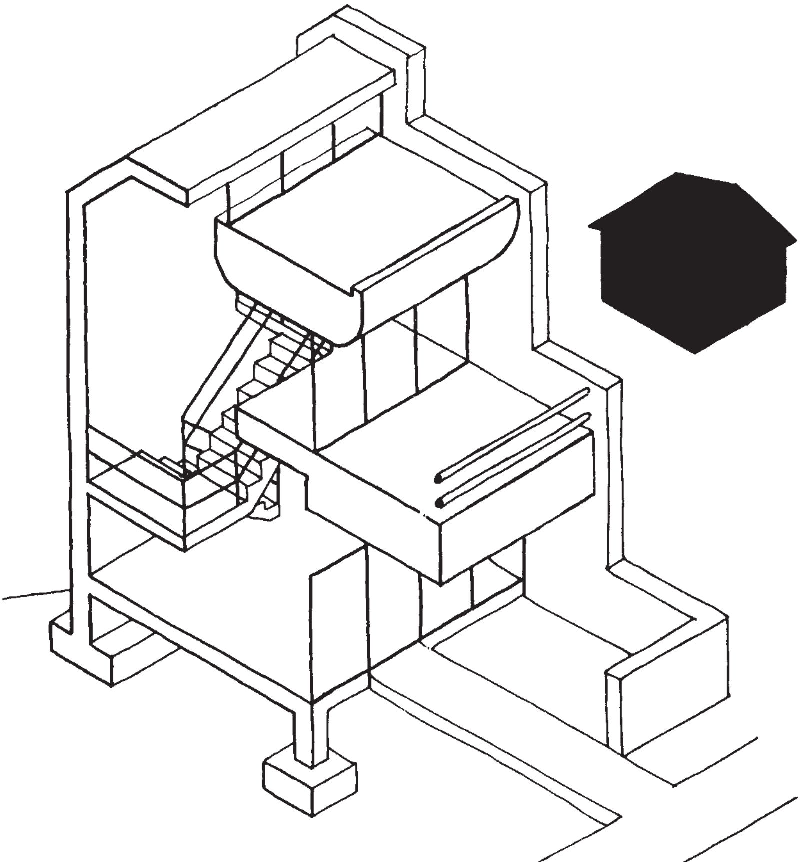
___ (1) Crystalline modules require glass protection in steel frames.

___ (2) The newer thin films are glass modules or lightweight flexible laminates that are more durable but sometimes only 50% the efficiency of crystalline (or about 7 watts/SF of panel).

___ *h.* Other concerns are no year-around *shadows* on panels; keep collector undersides *cool;* steel-frame mounting for *wind* resistance and, if roof-mounted, prevention of *leaks.* Be sure battery storage is well ventilated.

Costs: PV presently costs about $9/watt (95% M and 5% L), for off-grid situations. About half is the cost of the electronics and half the cost of structural support. The actual PV system for a house costs about *$6 to 7/SF* of the house area. About *10%* of this is for the storage batteries, which must be replaced about every *6* years. On-grid costs are presently at $6 to 7/watt.

NOTES



A APPENDIXES

NOTES

___ APPENDIX A: BUILDING-TYPE DATA

Entries A through L in the tables on pp. 622–635 provide rough costs and other useful information, as described below, for the various listed types of buildings.

___ A. *Occupancy type* per IBC. See p. 93. (34)

___ B. *Efficiency ratio:* Average net-to-gross ratio as a percentage of total. Also see p. 37.

___ C. *Areas* (*SF*): Give typical building areas. (15) (22) (43) (55)

___ D. *Costs* (*$/SF*): Typical SF costs based on areas in item C above. The projects do not include any site work or furniture, fixture, and equipment costs. See p. 227 for site work costs. (15) (22) (43) (55)

___ E. *A/E* (*Architectural/Engineering)* fees (% of item D): Low figure equals minimal work, whereas high equals comprehensive, detailed services. A highest quality job may often go up another 5% from the high shown. In any case, these are rough numbers to begin an estimate of fees. See p. 3. (30)

___ F. *FF&E* (*Furniture, Fixture, and Equipment*) *costs* (*$/SF*) are over and above costs given in item D above, and are for items not generally provided by the general contractor. These numbers are for rough beginning planning. See pp. 456 and 462.

___ G. *Parking:* Although local zoning ordinances will give exact requirements, these numbers are national standards that can be used for beginning planning. See p. 227.

___ H. The average *partition density* (length of partition based on floor area) is on the left. The average *door density* (floor area per door) is on the right.

___ I. *Fire protection classification* designates what type of sprinklers to use, when required. See p. 521. (B) (15)

___ J. *A/C* (*Air Conditioning*) *loads* are a range, given in SF/Ton. See p. 546. (10)

___ K. Average *mechanical* (HVAC and plumbing) costs to left and *electrical* costs to right. Both are given as % of total costs (D, above). (B) (11)

___ L. *Typical power* requirements are given in watts/SF. Typically, lighting takes 20 to 25% of total power. See p. 609. (B)

APARTMENT (100000 SF –)	Low	Ave.	High
__A. Occupancy Type		R-2	
__B. Efficiency Ratio		65	
__C. Area (SF)	24000	42000	71500
__D. Costs ($/SF)	66	87	100
__E. A/E Fees (% of D)	5	6	8
__F. FF&E Costs ($/SF)	12	18	24
__G. Parking (CAR/D.U.)	0.3	1.0	1.5
__H. Partition/Door	8-9 SF/LF		80-90 SF/DR.
__I. Fire Prot. Class		LIGHT	
__J. A/C (SF/Ton)	400		500
__K. Mech./Elect. Costs (% of D)	14% M		6.5% E
__L. Power (Watts/SF)	20		25
__M. Other			

AUDITORIUMS	Low	Ave.	High
__A. Occupancy Type		A-1	
__B. Efficiency Ratio		70	
__C. Area (SF)	13500	26000	101500
__D. Costs ($/SF)	135	185	215
__E. A/E Fees (% of D)	6	7	9
__F. FF&E Costs ($/SF)		42	
__G. Parking			
__H. Partition/Door			
__I. Fire Prot. Class		LIGHT	
__J. A/C (SF/Ton)	150		200
__K. Mech./Elect. Costs (% of D)	7% M		8% E
__L. Power (Watts/SF)	20		25
__M. Other			

APARTMENT (100000 SF +)	Low	Ave.	High
__A. Occupancy Type		R-2	
__B. Efficiency Ratio		65	
__C. Area (SF)	114000	213000	456000
__D. Costs ($/SF)	80	105	124
__E. A/E Fees (% of D)	5	6	8
__F. FF&E Costs ($/SF)	12	18	24
__G. Parking (CAR / D.U.)	0.3	1.0	1.5
__H. Partition/Door	8-9 SF/LF		80-90 SF/DR
__I. Fire Prot. Class		LIGHT	
__J. A/C (SF/Ton)	400		500
__K. Mech./Elect. Costs (% of D)	15.5% M		7.5% E
__L. Power (Watts/SF)	20		25
__M. Other			

AUTO SALES	Low	Ave.	High
__A. Occupancy Type		B	
__B. Efficiency Ratio			
__C. Area (SF)	11000	20500	27000
__D. Costs ($/SF)	63	82	98
__E. A/E Fees (% of D)			
__F. FF&E Costs ($/SF)		6	
__G. Parking			
__H. Partition/Door			
__I. Fire Prot. Class		ORDINARY	
__J. A/C (SF/Ton)	250		300
__K. Mech./Elect. Costs (% of D)	17% M		11% E
__L. Power (Watts/SF)	15		25
__M. Other			

BANKS	Low	Ave.	High
__A. Occupancy Type		B	
__B. Efficiency Ratio		70	
__C. Area (SF)	5500	8000	20500
__D. Costs ($/SF)	140	179	233
__E. A/E Fees (% of D)	6	10	12
__F. FF&E Costs ($/SF)	12	18	24
__G. Parking (PER 1000 SF)	2.5	3	3.5
__H. Partition/Door	15-20 SF/LF		150-200 SF/DR
__I. Fire Prot. Class		LIGHT	
__J. A/C (SF/Ton)	250		300
__K. Mech./Elect. Costs (% of D)	12% M		12% E
__L. Power (Watts/SF)	15		20
__M. Other			

CAR WASH	Low	Ave.	High
__A. Occupancy Type		B	
__B. Efficiency Ratio			
__C. Area (SF)		2500	
__D. Costs ($/SF)		89.70	
__E. A/E Fees (% of D)			
__F. FF&E Costs ($/SF)			
__G. Parking			
__H. Partition/Door			
__I. Fire Prot. Class			
__J. A/C (SF/Ton)			
__K. Mech./Elect. Costs (% of D)			
__L. Power (Watts/SF)			
__M. Other			

BOWLING ALLEY	Low	Ave.	High
__A. Occupancy Type		A-3	
__B. Efficiency Ratio			
__C. Area (SF)		20 000	
__D. Costs ($/SF)		98.40	
__E. A/E Fees (% of D)			
__F. FF&E Costs ($/SF)			
__G. Parking			
__H. Partition/Door			
__I. Fire Prot. Class			
__J. A/C (SF/Ton)	200		300
__K. Mech./Elect. Costs (% of D)			
__L. Power (Watts/SF)	20		25
__M. Other			

CHURCHES	Low	Ave.	High
__A. Occupancy Type		A-3	
__B. Efficiency Ratio		70	
__C. Area (SF)	87000	14000	17300
__D. Costs ($/SF)	105	145	162
__E. A/E Fees (% of D)	4	7	9
__F. FF&E Costs ($/SF)	6	12	24
__G. Parking (PER 1000 SF)		0.4	
__H. Partition/Door			
__I. Fire Prot. Class		LIGHT	
__J. A/C (SF/Ton)	100		200
__K. Mech./Elect. Costs (% of D)	15% M		9% E
__L. Power (Watts/SF)	20		25
__M. Other			

CONVENIENCE MARKET	Low	Ave.	High
__A. Occupancy Type		M	
__B. Efficiency Ratio			
__C. Area (SF)		5000	
__D. Costs ($/SF)		99.60	
__E. A/E Fees (% of D)			
__F. FF&E Costs ($/SF)			
__G. Parking			
__H. Partition/Door			
__I. Fire Prot. Class			
__J. A/C (SF/Ton)			
__K. Mech./Elect. Costs (% of D)			
__L. Power (Watts/SF)	15		25
__M. Other			

CLUB, HEALTH	Low	Ave.	High
__A. Occupancy Type		A-3	
__B. Efficiency Ratio			
__C. Area (SF)	19000	27000	44500
__D. Costs ($/SF)	85	127	148
__E. A/E Fees (% of D)			
__F. FF&E Costs ($/SF)			
__G. Parking			
__H. Partition/Door			
__I. Fire Prot. Class		LIGHT	
__J. A/C (SF/Ton)	100		250
__K. Mech./Elect. Costs (% of D)	16% M		10.5% E
__L. Power (Watts/SF)	20		30
__M. Other			

CLUB, COUNTRY	Low	Ave.	High
__A. Occupancy Type		A-2,3,4,5	
__B. Efficiency Ratio			
__C. Area (SF)	4500	9500	15000
__D. Costs ($/SF)	88	130	138
__E. A/E Fees (% of D)	4	7	9
__F. FF&E Costs ($/SF)	18		90
__G. Parking (PER 1000SF)		0.4	
__H. Partition/Door			
__I. Fire Prot. Class		LIGHT	
__J. A/C (SF/Ton)	100		200
__K. Mech./Elect. Costs (% of D)	9% M		9.5% E
__L. Power (Watts/SF)	20		25
__M. Other			

CLUB, SOCIAL	Low	Ave.	High
__A. Occupancy Type	A-2		A-3
__B. Efficiency Ratio			
__C. Area (SF)	6000	15000	20000
__D. Costs ($/SF)	70	130	137
__E. A/E Fees (% of D)			
__F. FF&E Costs ($/SF)			
__G. Parking			
__H. Partition/Door			
__I. Fire Prot. Class		LIGHT	
__J. A/C (SF/Ton)	150		300
__K. Mech./Elect. Costs (% of D)	18% M		9.5% E
__L. Power (Watts/SF)	20		30
__M. Other			

COLLEGE, CLASS RM. & ADM.	Low	Ave.	High
A. Occupancy Type		B	
B. Efficiency Ratio		65	
C. Area (SF)	50000	58000	155000
D. Costs ($/SF)	125	157	200
E. A/E Fees (% of D)	4	6.5	9
F. FF&E Costs ($/SF)	7		20
G. Parking (PER STUDENT)		0.45	
H. Partition/Door			
I. Fire Prot. Class		LIGHT	
J. A/C (SF/Ton)	150		200
K. Mech./Elect. Costs (% of D)	14.5% M		10% E
L. Power (Watts/SF)	15		25
M. Other			

COLLEGE, STUDENT UNION	Low	Ave.	High
A. Occupancy Type	A-2		A-3
B. Efficiency Ratio		60	
C. Area (SF)	44400	82000	123800
D. Costs ($/SF)	121	164	185
E. A/E Fees (% of D)			
F. FF&E Costs ($/SF)	7		21
G. Parking			
H. Partition/Door			
I. Fire Prot. Class		LIGHT	
J. A/C (SF/Ton)	200		300
K. Mech./Elect. Costs (% of D)	20.5% M		9% E
L. Power (Watts/SF)	20		25
M. Other			

COLLEGE, LABORATORY	Low	Ave.	High
A. Occupancy Type		B	
B. Efficiency Ratio			
C. Area (SF)	13000	40500	80000
D. Costs ($/SF)	207	234	276
E. A/E Fees (% of D)			
F. FF&E Costs ($/SF)	12		30
G. Parking			
H. Partition/Door			
I. Fire Prot. Class			
J. A/C (SF/Ton)	150		200
K. Mech./Elect. Costs (% of D)	27% M		10% E
L. Power (Watts/SF)	15		20
M. Other			

COMMUNITY CENTER	Low	Ave.	High
A. Occupancy Type		A-3	
B. Efficiency Ratio			
C. Area (SF)	11900	18800	32600
D. Costs ($/SF)	106	167	185
E. A/E Fees (% of D)	6	8	12
F. FF&E Costs ($/SF)		18	
G. Parking (PER 1000 SF)	3	4	5
H. Partition/Door			
I. Fire Prot. Class		LIGHT	
J. A/C (SF/Ton)	150		200
K. Mech./Elect. Costs (% of D)	18% M		9.5% E
L. Power (Watts/SF)	20		25
M. Other			

COURT HOUSE	Low	Ave.	High
__A. Occupancy Type		A-3	
__B. Efficiency Ratio		60	
__C. Area (SF)	17800	32400	106 000
__D. Costs ($/SF)	129	157	172
__E. A/E Fees (% of D)			
__F. FF&E Costs ($/SF)		36	
__G. Parking			
__H. Partition/Door			
__I. Fire Prot. Class		LIGHT	
__J. A/C (SF/Ton)	150		200
__K. Mech./Elect. Costs (% of D)	14% M		10% E
__L. Power (Watts/SF)	20		25
__M. Other			

DEPARTMENT STORE	Low	Ave.	High
__A. Occupancy Type		M	
__B. Efficiency Ratio		80	
__C. Area (SF)	54000	111500	196500
__D. Costs ($/SF)	59	89.50	105.50
__E. A/E Fees (% of D)	4	6.5	8
__F. FF&E Costs ($/SF)			
__G. Parking (PER 1000 SF)	4	5	5.5
__H. Partition/Door	60 SF/LF		175 SF/DR
__I. Fire Prot. Class		ORDINARY	
__J. A/C (SF/Ton)	200		300
__K. Mech./Elect. Costs (% of D)	16.5% M		12.5% E
__L. Power (Watts/SF)	10		15
__M. Other SEE PART 14 ON ADA ELEV. REQMTS.			

DAY CARE CENTER	Low	Ave.	High
__A. Occupancy Type	R-3		I-4
__B. Efficiency Ratio			
__C. Area (SF)		6000	
__D. Costs ($/SF)		107	
__E. A/E Fees (% of D)			
__F. FF&E Costs ($/SF)		18	
__G. Parking			
__H. Partition/Door			
__I. Fire Prot. Class			
__J. A/C (SF/Ton)	200		300
__K. Mech./Elect. Costs (% of D)			
__L. Power (Watts/SF)	15		25
__M. Other			

DORMITORY	Low	Ave.	High
__A. Occupancy Type		R-2	
__B. Efficiency Ratio		65	
__C. Area (SF)	25000	50500	130000
__D. Costs ($/SF)	96.50	139	158
__E. A/E Fees (% of D)	4	6	8
__F. FF&E Costs ($/SF)		24	
__G. Parking			
__H. Partition/Door	9 SF/LF		90 SF/DR
__I. Fire Prot. Class		LIGHT	
__J. A/C (SF/Ton)	400		500
__K. Mech./Elect. Costs (% of D)	14% M		9% E
__L. Power (Watts/SF)	10		15
__M. Other			

FACTORIES	Low	Ave.	High
__A. Occupancy Type	F-2		F-1
__B. Efficiency Ratio			
__C. Area (SF)	31000	54500	109500
__D. Costs ($/SF)	54.50	83	101
__E. A/E Fees (% of D)	4	8	12
__F. FF&E Costs ($/SF)			
__G. Parking (PER 1000SF)	0.75	1.5	2.5
__H. Partition/Door			
__I. Fire Prot. Class	ORDINARY		EXTRA
__J. A/C (SF/Ton)	100		150
__K. Mech./Elect. Costs (% of D)	14.5% M		10.5% E
__L. Power (Watts/SF)	25		40
__M. Other			

FUNERAL HOME	Low	Ave.	High
__A. Occupancy Type		A-3	
__B. Efficiency Ratio			
__C. Area (SF)	3000	12000	20500
__D. Costs ($/SF)	78.50	110	174
__E. A/E Fees (% of D)			
__F. FF&E Costs ($/SF)			
__G. Parking			
__H. Partition/Door	14-15 SF/LF		140-150 SF/DR
__I. Fire Prot. Class		LIGHT	
__J. A/C (SF/Ton)	200		300
__K. Mech./Elect. Costs (% of D)	13.5% M		4.5% E
__L. Power (Watts/SF)	20		25
__M. Other			

FIRE STATIONS	Low	Ave.	High
__A. Occupancy Type		B	
__B. Efficiency Ratio			
__C. Area (SF)	5500	6500	8800
__D. Costs ($/SF)	130.50	151.50	171
__E. A/E Fees (% of D)			
__F. FF&E Costs ($/SF)		18	
__G. Parking			
__H. Partition/Door			
__I. Fire Prot. Class			
__J. A/C (SF/Ton)	200		300
__K. Mech./Elect. Costs (% of D)	17% M		9% E
__L. Power (Watts/SF)	10		15
__M. Other			

GARAGE, PARKING	Low	Ave.	High
__A. Occupancy Type		S-2	
__B. Efficiency Ratio		85	
__C. Area (SF)	121000	176000	320000
__D. Costs ($/SF)	29	45	57
__E. A/E Fees (% of D)			
__F. FF&E Costs ($/SF)			
__G. Parking			
__H. Partition/Door	30-60 SF/LF		300-600 SF/DR
__I. Fire Prot. Class		ORDINARY	
__J. A/C (SF/Ton)			
__K. Mech./Elect. Costs (% of D)	4% M		5% E
__L. Power (Watts/SF)	3		5
__M. Other			

GARAGE, SERVICE	Low	Ave.	High
__A. Occupancy Type		S-1	
__B. Efficiency Ratio		85	
__C. Area (SF)	3500	9000	22000
__D. Costs ($/SF)	35	70	78.50
__E. A/E Fees (% of D)	3	5.5	8
__F. FF&E Costs ($/SF)			
__G. Parking			
__H. Partition/Door	30 SF/LF		300 SF/DR
__I. Fire Prot. Class		ORDINARY	
__J. A/C (SF/Ton)			
__K. Mech./Elect. Costs (% of D)	14.5% M		9% E
__L. Power (Watts/SF)	10		15
__M. Other			

HOSPITAL	Low	Ave.	High
__A. Occupancy Type		I-2	
__B. Efficiency Ratio		55	
__C. Area (SF)	65000	128500	303000
__D. Costs ($/SF)	185	245	320
__E. A/E Fees (% of D)	4	6.5	9
__F. FF&E Costs ($/SF)	40		66
__G. Parking (PER BED)	0.75	1.8	3
__H. Partition/Door			
__I. Fire Prot. Class		LIGHT	
__J. A/C (SF/Ton)	150		250
__K. Mech./Elect. Costs (% of D)	24% M		12% E
__L. Power (Watts/SF)	25		35
__M. Other			

GYMNASIUMS	Low	Ave.	High
__A. Occupancy Type		A-3	
__B. Efficiency Ratio		70	
__C. Area (SF)	56000	71000	136500
__D. Costs ($/SF)	110	142	158
__E. A/E Fees (% of D)	6	6.5	9
__F. FF&E Costs ($/SF)			
__G. Parking (PER 1000 SF)		5	
__H. Partition/Door			
__I. Fire Prot. Class			
__J. A/C (SF/Ton)	200		250
__K. Mech./Elect. Costs (% of D)	18.5% M		8.5% E
__L. Power (Watts/SF)	15		25
__M. Other			

HOTEL	Low	Ave.	High
__A. Occupancy Type		R-1	
__B. Efficiency Ratio			
__C. Area (SF)	87000	166000	222500
__D. Costs ($/SF)	128	158	175
__E. A/E Fees (% of D)			
__F. FF&E Costs ($/SF)		25	
__G. Parking			
__H. Partition/Door			
__I. Fire Prot. Class			
__J. A/C (SF/Ton)	300		400
__K. Mech./Elect. Costs (% of D)	17.5% M		10.5% E
__L. Power (Watts/SF)	20		30
__M. Other			

JAILS / PRISONS	Low	Ave.	High
__A. Occupancy Type		I-3	
__B. Efficiency Ratio		75	
__C. Area (SF)	60500	64000	14950
__D. Costs ($/SF)	165	218	244
__E. A/E Fees (% of D)			
__F. FF&E Costs ($/SF)			
__G. Parking			
__H. Partition/Door			
__I. Fire Prot. Class		LIGHT	
__J. A/C (SF/Ton)	250		300
__K. Mech./Elect. Costs (% of D)	18% M		11.5% E
__L. Power (Watts/SF)	15		25
__M. Other			

MEDICAL/DENTAL, CLINICS/OFF.	Low	Ave.	High
__A. Occupancy Type		B	
__B. Efficiency Ratio			
__C. Area (SF)	9000	15000	33000
__D. Costs ($/SF)	103.50	146.50	159
__E. A/E Fees (% of D)	6	8	9
__F. FF&E Costs ($/SF)	12	18	30
__G. Parking (PER 1000 SF)	1.5	3	5
__H. Partition/Door			
__I. Fire Prot. Class		LIGHT	
__J. A/C (SF/Ton)	250		300
__K. Mech./Elect. Costs (% of D)	17.5% M		10% E
__L. Power (Watts/SF)	15		20
__M. Other SEE PART 14 ON ADA ELEV. REQMTS			

LIBRARIES	Low	Ave.	High
__A. Occupancy Type		A-3	
__B. Efficiency Ratio			
__C. Area (SF)	16500	24500	71000
__D. Costs ($/SF)	78.50	147	137
__E. A/E Fees (% of D)			
__F. FF&E Costs ($/SF)	24	72	120
__G. Parking			
__H. Partition/Door			
__I. Fire Prot. Class	LIGHT		ORDINARY*
__J. A/C (SF/Ton)	250		300
__K. Mech./Elect. Costs (% of D)	16% M		11% E
__L. Power (Watts/SF)	15		25
__M. Other * AT STACKS			

MOTELS	Low	Ave.	High
__A. Occupancy Type		R-1	
__B. Efficiency Ratio		60	
__C. Area (SF)	55500	68500	128000
__D. Costs ($/SF)	73	98.50	109
__E. A/E Fees (% of D)	3	4	6
__F. FF&E Costs ($/SF)		24	
__G. Parking (PER D.U.)	0.4	0.8	1.6
__H. Partition/Door	7-8/SF/LF		70-80 SF/DR
__I. Fire Prot. Class		LIGHT	
__J. A/C (SF/Ton)	400		500
__K. Mech./Elect. Costs (% of D)	16% M		8% E
__L. Power (Watts/SF)	15		20
__M. Other			

MUSEUMS	Low	Ave.	High
__A. Occupancy Type		A-3	
__B. Efficiency Ratio			
__C. Area (SF)	27600	31250	63000
__D. Costs ($/SF)	175	190.50	201.50
__E. A/E Fees (% of D)			
__F. FF&E Costs ($/SF)			
__G. Parking			
__H. Partition/Door			
__I. Fire Prot. Class		LIGHT	
__J. A/C (SF/Ton)	250		300
__K. Mech./Elect. Costs (% of D)	14% M		12% E
__L. Power (Watts/SF)	20		25
__M. Other			

OFFICE (LESS THAN 50 000 SF)	Low	Ave.	High
__A. Occupancy Type		B	
__B. Efficiency Ratio		75	
__C. Area (SF)	8500	17000	25000
__D. Costs ($/SF)	87	113	150
__E. A/E Fees (% of D)*	3	6.5	10
__F. FF&E Costs ($/SF)	12	24	36
__G. Parking (PER 1000 SF)	1.66	2.6	3.5
__H. Partition/Door	20 SF/LF		200-500 SF/DR
__I. Fire Prot. Class		LIGHT	
__J. A/C (SF/Ton)	250		300
__K. Mech./Elect. Costs (% of D)	15% M		9.5% E
__L. Power (Watts/SF)	15		20
__M. Other	*INCLUDES T.I., SEE P. 41		

NURSING HOMES	Low	Ave.	High
__A. Occupancy Type		I-2	
__B. Efficiency Ratio			
__C. Area (SF)	24500	38000	82500
__D. Costs ($/SF)	123.50	146.50	188
__E. A/E Fees (% of D)	5	8	11.5
__F. FF&E Costs ($/SF)			
__G. Parking (PER D.U.)	0.25	0.3	0.35
__H. Partition/Door	8 SF/LF		50 SF/DR
__I. Fire Prot. Class		LIGHT	
__J. A/C (SF/Ton)	200		250
__K. Mech./Elect. Costs (% of D)	22% M		11% E
__L. Power (Watts/SF)	15		25
__M. Other			

OFFICE (50 000 SF +)	Low	Ave.	High
__A. Occupancy Type		B	
__B. Efficiency Ratio		75	
__C. Area (SF)	77500	87500	428000
__D. Costs ($/SF)*	94.50	138	168
__E. A/E Fees (% of D)	3	6.5	10
__F. FF&E Costs ($/SF)	18	42	60
__G. Parking (PER 1000 SF)	1.66	2.6	3.5
__H. Partition/Door	20 SF/LF		200-500 SF/DR
__I. Fire Prot. Class		LIGHT	
__J. A/C (SF/Ton)	250		300
__K. Mech./Elect. Costs (% of D)	13% M		8% E
__L. Power (Watts/SF)	15		20
__M. Other	*INCLUDES T.I., SEE P. 49		

POLICE STATION	Low	Ave.	High
—A. Occupancy Type		B	
—B. Efficiency Ratio			
—C. Area (SF)	4000	10500	19000
—D. Costs ($/SF)	120	157	198.50
—E. A/E Fees (% of D)			
—F. FF&E Costs ($/SF)			
—G. Parking			
—H. Partition/Door			
—I. Fire Prot. Class		LIGHT	
—J. A/C (SF/Ton)	250		300
—K. Mech./Elect. Costs (% of D)	17.5% M		12% E
—L. Power (Watts/SF)	15		20
—M. Other			

RELIGIOUS EDUCATION	Low	Ave.	High
—A. Occupancy Type		A-3	
—B. Efficiency Ratio			
—C. Area (SF)	6700	9800	13500
—D. Costs ($/SF)	102.50	130	150
—E. A/E Fees (% of D)			
—F. FF&E Costs ($/SF)			
—G. Parking			
—H. Partition/Door			
—I. Fire Prot. Class		LIGHT	
—J. A/C (SF/Ton)	150		200
—K. Mech./Elect. Costs (% of D)	15% M		9% E
—L. Power (Watts/SF)	15		20
—M. Other			

POST OFFICE	Low	Ave.	High
—A. Occupancy Type		B	
—B. Efficiency Ratio			
—C. Area (SF)	7000	12500	30000
—D. Costs ($/SF)	93.50	135	146
—E. A/E Fees (% of D)			
—F. FF&E Costs ($/SF)			
—G. Parking			
—H. Partition/Door			
—I. Fire Prot. Class		LIGHT	
—J. A/C (SF/Ton)	200		275
—K. Mech./Elect. Costs (% of D)	14% M		9.5% E
—L. Power (Watts/SF)	15		25
—M. Other			

RESEARCH LABORATORY	Low	Ave.	High
—A. Occupancy Type		B	
—B. Efficiency Ratio		60	
—C. Area (SF)	54000	64500	86000
—D. Costs ($/SF)	132.50	175	220
—E. A/E Fees (% of D)			
—F. FF&E Costs ($/SF)			
—G. Parking			
—H. Partition/Door			
—I. Fire Prot. Class		LIGHT	
—J. A/C (SF/Ton)	100		250
—K. Mech./Elect. Costs (% of D)	25.5% M		12% E
—L. Power (Watts/SF)	15		25
—M. Other			

RESIDENTIAL/SINGLE FAM.	Low	Ave.	High
—A. Occupancy Type		R-3	
—B. Efficiency Ratio			
—C. Area (SF)	1800	2900	3900
—D. Costs ($/SF) *	91	114.50	154
—E. A/E Fees (% of D)			
—F. FF&E Costs ($/SF)	6	18	60
—G. Parking			
—H. Partition/Door			
—I. Fire Prot. Class			
—J. A/C (SF/Ton)	300	400	450
—K. Mech./Elect. Costs (% of D)	12% M		5% E
—L. Power (Watts/SF)	5		10
—M. Other			

RETAIL STORES	Low	Ave.	High
—A. Occupancy Type		M	
—B. Efficiency Ratio		60	
—C. Area (SF)	20500	46500	65500
—D. Costs ($/SF)	70	98	125
—E. A/E Fees (% of D)	4	6	9
—F. FF&E Costs ($/SF)			
—G. Parking (PER 1000 SF)	3.5	4.5	5.5
—H. Partition/Door	10-60 SF/LF		300-600 SF/DR
—I. Fire Prot. Class		ORDINARY	
—J. A/C (SF/Ton)	250		300
—K. Mech./Elect. Costs (% of D)	13.5% M		10% E
—L. Power (Watts/SF)	10		15
—M. Other			

RESTAURANTS	Low	Ave.	High
—A. Occupancy Type	B		A-3
—B. Efficiency Ratio		70	
—C. Area (SF)	4000	5500	9000
—D. Costs ($/SF)	118	151	173
—E. A/E Fees (% of D)	3.5	6	8
—F. FF&E Costs ($/SF)	36	60	120
—G. Parking (PER 1000SF)	10	15	21.5
—H. Partition/Door	20-25 SF/LF		150-250 SF/DR
—I. Fire Prot. Class	LIGHT		ORDINARY *
—J. A/C (SF/Ton)	150		200
—K. Mech./Elect. Costs (% of D)	20.5% M		11% E
—L. Power (Watts/SF)	15		30
—M. Other * KITCHEN AREAS			

SCHOOL, ELEMENTARY	Low	Ave.	High
—A. Occupancy Type		E	
—B. Efficiency Ratio			
—C. Area (SF)	28000	43500	62000
—D. Costs ($/SF)	98	160.50	132.50
—E. A/E Fees (% of D)	6	7.5	9
—F. FF&E Costs ($/SF)	6		12
—G. Parking			
—H. Partition/Door			
—I. Fire Prot. Class		LIGHT	
—J. A/C (SF/Ton)	150		250
—K. Mech./Elect. Costs (% of D)	18% M		10% E
—L. Power (Watts/SF)	15		25
—M. Other			

SCHOOLS, JR. HIGH	Low	Ave.	High
__A. Occupancy Type		E	
__B. Efficiency Ratio			
__C. Area (SF)	48500	85500	106500
__D. Costs ($/SF)	104.50	135.50	140
__E. A/E Fees (% of D)	6	7.5	9
__F. FF&E Costs ($/SF)	6		12
__G. Parking			
__H. Partition/Door			
__I. Fire Prot. Class		LIGHT	
__J. A/C (SF/Ton)	150		250
__K. Mech./Elect. Costs (% of D)	19.5% M	9.5% E	
__L. Power (Watts/SF)	15		25
__M. Other			

SCHOOLS, VOCATIONAL	Low	Ave.	High
__A. Occupancy Type		B	
__B. Efficiency Ratio			
__C. Area (SF)		43500	
__D. Costs ($/SF)		136	
__E. A/E Fees (% of D)			
__F. FF&E Costs ($/SF)	6		12
__G. Parking			
__H. Partition/Door			
__I. Fire Prot. Class			
__J. A/C (SF/Ton)	100		250
__K. Mech./Elect. Costs (% of D)	19% M		11% E
__L. Power (Watts/SF)			
__M. Other			

SCHOOLS, SR. HIGH	Low	Ave.	High
__A. Occupancy Type		E	
__B. Efficiency Ratio			
__C. Area (SF)	50000	139000	249500
__D. Costs ($/SF)	112.50	139	161.50
__E. A/E Fees (% of D)	6	7.5	9
__F. FF&E Costs ($/SF)	6		12
__G. Parking (PER STUDENT)		0.5	
__H. Partition/Door			
__I. Fire Prot. Class		LIGHT	
__J. A/C (SF/Ton)	150		250
__K. Mech./Elect. Costs (% of D)	18% M		10% E
__L. Power (Watts/SF)	15		25
__M. Other			

SERVICE STATION	Low	Ave.	High
__A. Occupancy Type		B	
__B. Efficiency Ratio			
__C. Area (SF)	1000	1500	1700
__D. Costs ($/SF)	105	111.50	136.50
__E. A/E Fees (% of D)			
__F. FF&E Costs ($/SF)			
__G. Parking			
__H. Partition/Door	15 SF/LF		150 SF/DR
__I. Fire Prot. Class			
__J. A/C (SF/Ton)			
__K. Mech./Elect. Costs (% of D)			
__L. Power (Watts/SF)	10		20
__M. Other			

SPORTS ARENA	Low	Ave.	High
—A. Occupancy Type		A-4	
—B. Efficiency Ratio			
—C. Area (SF)	235000	173500	320500
—D. Costs ($/SF)	124	144	192
—E. A/E Fees (% of D)			
—F. FF&E Costs ($/SF)			
—G. Parking			
—H. Partition/Door			
—I. Fire Prot. Class		LIGHT	
—J. A/C (SF/Ton)	100		200
—K. Mech./Elect. Costs (% of D)	16.5% M	10% E	
—L. Power (Watts/SF)	25		35
—M. Other			

THEATER	Low	Ave.	High
—A. Occupancy Type		A-1	
—B. Efficiency Ratio			
—C. Area (SF)	10000	14500	20500
—D. Costs ($/SF)	85	117.50	138
—E. A/E Fees (% of D)			
—F. FF&E Costs ($/SF)			
—G. Parking (PER SEAT)	0.1	0.25	0.5
—H. Partition/Door			
—I. Fire Prot. Class		LIGHT *	
—J. A/C (SF/Ton)	150		200
—K. Mech./Elect. Costs (% of D)	17% M		10% E
—L. Power (Watts/SF)	20		25
—M. Other * EXCLUDING STAGE AREAS			

SUPERMARKETS	Low	Ave.	High
—A. Occupancy Type		M	
—B. Efficiency Ratio			
—C. Area (SF)	8500	22500	40000
—D. Costs ($/SF)	41	82	95
—E. A/E Fees (% of D)	3	7	7.5
—F. FF&E Costs ($/SF)			
—G. Parking			
—H. Partition/Door	30 - 40 SF/LF		300-400 SF/DR
—I. Fire Prot. Class		ORDINARY	
—J. A/C (SF/Ton)	100		250
—K. Mech./Elect. Costs (% of D)	14.5% M		12.5% E
—L. Power (Watts/SF)	20		25
—M. Other			

TOWN HALL	Low	Ave.	High
—A. Occupancy Type		B	
—B. Efficiency Ratio			
—C. Area (SF)	30500	47500	90000
—D. Costs ($/SF)	120	149	192
—E. A/E Fees (% of D)			
—F. FF&E Costs ($/SF)			
—G. Parking (PER 1000 SF)	1.0	3.5	8
—H. Partition/Door			
—I. Fire Prot. Class		LIGHT	
—J. A/C (SF/Ton)	200		300
—K. Mech./Elect. Costs (% of D)	15% M		9.5% E
—L. Power (Watts/SF)	15		25
—M. Other			

TRANSPORTATION	Low	Ave.	High
__A. Occupancy Type		A-3	
__B. Efficiency Ratio			
__C. Area (SF)		175000	
__D. Costs ($/SF)	167	176	263
__E. A/E Fees (% of D)			
__F. FF&E Costs ($/SF)			
__G. Parking			
__H. Partition/Door			
__I. Fire Prot. Class		LIGHT	
__J. A/C (SF/Ton)	150		250
__K. Mech./Elect. Costs (% of D)	15% M		13% E
__L. Power (Watts/SF)	15		25
__M. Other			

VETERINARY CLINIC	Low	Ave.	High
__A. Occupancy Type		B	
__B. Efficiency Ratio			
__C. Area (SF)		20000	
__D. Costs ($/SF)		189	
__E. A/E Fees (% of D)			
__F. FF&E Costs ($/SF)			
__G. Parking			
__H. Partition/Door			
__I. Fire Prot. Class			
__J. A/C (SF/Ton)	100		300
__K. Mech./Elect. Costs (% of D)	17% M		5.5% E
__L. Power (Watts/SF)	20		30
__M. Other			

WAREHOUSE	Low	Ave.	High
__A. Occupancy Type	S-1		S-2
__B. Efficiency Ratio		95	
__C. Area (SF)	36000	67000	157500
__D. Costs ($/SF)	40	56	70
__E. A/E Fees (% of D)	4	5.5	8
__F. FF&E Costs ($/SF)			
__G. Parking (PER 1000 SF)	1.5	2	2.5
__H. Partition/Door			
__I. Fire Prot. Class	LIGHT		ORDINARY
__J. A/C (SF/Ton)			
__K. Mech./Elect. Costs (% of D)	10% M		7.5% E
__L. Power (Watts/SF)	10		15
__M. Other			

	Low	Ave.	High
__A. Occupancy Type			
__B. Efficiency Ratio			
__C. Area (SF)			
__D. Costs ($/SF)			
__E. A/E Fees (% of D)			
__F. FF&E Costs ($/SF)			
__G. Parking			
__H. Partition/Door			
__I. Fire Prot. Class			
__J. A/C (SF/Ton)			
__K. Mech./Elect. Costs (% of D)			
__L. Power (Watts/SF)			
__M. Other			

NOTES

___ APPENDIX B: LOCATION DATA

Entries A through V in the tables on pp. 640–653 provide useful architecturally related data, as described below, for various U.S. cities and nearby areas.

___ A. *Latitude* is given in degrees and minutes. (10)

___ B. *Elevation* is in feet above sea level. See p. 180. (10)

___ C. *Frost line* is inches below top of ground to frost line. See p. 255 and p. 283. (5)

___ D. *Ground temperature* is the constant year-round temperature (in degrees F) at about 20 to 30 feet below the surface. See p. 182. (5)

___ E. *Seismic* is UBC earthquake zones. See p. 155. (34)

___ F. *Termite* lists zones of degree of infestation (with 1 being worst). See p. 256. (5)

___ G. *Soils* are the predominant soils for the location. See p. 245. No data available at this publication.

___ H. *Plant zone* is for plant hardiness. See p. 268. (5)

___ I. *Rain, average* in inches per year. (46)

___ J. *Rain, intensity* is hourly intensity in inches/hour for 5-minute periods to be expected once in 10 years. Some storms have twice as much in some zones. See pp. 239 and 519. (5)

___ K. *Percent sun* is yearly average of clear days. See p. 172. (46)

___ L. *Heating degree days* (*HDD*), base 65°F. See p. 172. (46)

___ M. *Cooling degree days* (*CDD*), base 65°F. See p. 172. (46)

___ N. *Percent idity* (*% RH*) *AM* is yearly average in mornings. See p. 172. (46)

___ O. *Percent humidity* (*% RH*) *PM* is yearly average in afternoon/evenings. See p. 172. (46)

___ P. *Winter temperature* is design winter dry-bulb temperature (99%) as recommended by ASHRAE. See p. 172. (10)

___ Q. *Summer temperature* is design summer dry-bulb temperature (1%) as recommended by ASHRAE. See p. 172. (10)

___ R. *Wind speed (mph), average* is yearly average. See p. 172. (46)

___ S. *Wind, intensity* is design wind speed per 97 UBC. See p. 154. (24)

___ T. *Snow* is the ground snow load in LB/SF per 97 UBC. See p. 149 where not given, establish from local authority.

___ U. *Insulation* is the recommended zone for minimum R value. See p. 368. (10) (36)

___ V. *Costs* are the city cost indexes to adjust cost given in this book. See p. 45. (C) (11)*

___ *Other:* (1) Possible radon-producing area. See p. 255. (60)

*Data courtesy of BNI Building News. See latest BNI for current data.

NOTES

LOCATION

Line No.	LOCATION	A LAT.	B ELEV.	C FROST LINE	D GD. TEMP.	E SEISMIC	F TERMITE	G SOILS	H PLANT ZONE	I RAIN AVE.	J RAIN INT.	K % SUN
1	AK ANCHORAGE	61-1	90			4	0		9	15		34
2												
3	AL BIRMINGHAM	33-3	610	3	64	1	1		8	52	7.2	58
4	HUNTSVILLE	34-4	619	3	62	1	1		7	55	6.3	55
5	MOBILE	30-4	211	0	70	0	1		9	65	7.8	60
6	MONTGOMERY	32-2	195	2	67	0	1		8	49	7.5	59
7												
8	AR FT. SMITH	35-2	449	7	64	1	2		7	40	7.4	60
9	LITTLE ROCK	34-4	257	4.5	64	1	2		7	49	7.2	60
10												
11	AZ PHOENIX	33-3	1117	0	72	1	2		8	7	4	81
12	TUCSON	32-1	2584	0	72	1	2		8	11	4	78
13												
14	CA BAKERSFIELD	35-2	495	0	64	4	2		9	6	3.6	75
15	FRESNO	36-5	326	0	64	3	2		9	11	3.6	73
16	LOS ANGELES	34-0	99	0	68	4	2		10	12	3.6	72
17	RIVERSIDE	33-5	1511	0	72	4	2		9		3.6	
18	SACRAMENTO	38-3	17	0	64	3	2		9	17	3.6	73
19	SANTA BARB.	33-4	33	0	64	4	2		10	16	3.6	
20	SAN DIEGO	32-4	19	0	72	4	2		10	9	3.6	72
21	SAN FRANCISCO	37-4	8	0	64	4	2		9	20	3.6	72
22	STOCKTON	37-5	28	0	64	3	2		9	14	3.6	
23												
24	CO COLO. SPRINGS	38-5	6173	10	54	1	3		5	15	4.8	68
25	DENVER	39-5	5283	10	54	1	3		5	15	4.8	67
26												
27	CT BRIDGEPORT	41-1	7	18	52	2A	2		6	42	6.3	56
28	HARTFORD	41-5	15	18	52	2A	2		6	44	6.3	52
29	NEW HAVEN	41-2	6	18	52	2A	2		6		6.3	
30												
31	DE WILMINGTON	39-4	78	6	56	1	2		7	41	6.6	
32												

DATA

L HDD	M CDD	N % RH AM	O % RH PM	P WINT TEMP	Q SUM TEMP	R WIND AVE.	S WIND INT.	T SNOW	U INSUL.	V COST*	OTHER	Line No.
10816	0	73	63	−23	71	7	90		6	130		1
												2
2943	1891	84	57	17	96	7	70	5	3	79		3
3279	1708	85	58	11	95	8	70	10	3	77	(1)	4
1695	2643	86	57	25	95	9	100	0	2	81		5
2277	2274	87	56	22	96	7	80	5	3	75		6
												7
3477	1969	85	56	12	101	8	70		3	74	(1)	8
3152	2045	84	57	15	99	8	70	5	3	78		9
												10
1442	3746	51	23	31	109	6	75	0	3	89	(1)	11
1734	2840	53	25	28	104	8	75	0	3	89		12
												13
2128	2347	65	38	30	104	6	70	0	3	97	(1)	14
2647	1769	78	40	28	102	6	70	0	3	98		15
1595	728	79	64	41	83	8	70	0	1	107	(1)	16
				29	100		70	0	2	97	(1)	17
2772	1198	83	45	30	101	8	70	0	4	100	(1)	18
2487	269	80	59			6	70	0	1	107		19
1284	842	76	62	42	83	7	70	0	1	102		20
3161	115	84	61	35	82	11	70	0	1	112		21
2674	1448	78	44	28	100	8	70	0	4	108	(1)	22
												23
6346	501	63	40	−3	91	10	75		5	92	(1)	24
6014	680	68	40	−5	93	9	75		5	95	(1)	25
												26
5501	746	76	60	6	84	12	85	25	4	103	(1)	27
6174	666			3	91	9	85	25	4	101	(1)	28
				3	88					102	(1)	29
												30
4986	1015	78	55	10	92	9	75	15	4	91		31
												32

*Data courtesy of BNI Building News. See latest BNI for current data.

LOCATION

Line No.	LOCATION	A LAT.	B ELEV.	C FROST LINE	D GD. TEMP.	E SEISMIC	F TERMITE	G SOILS	H PLANT ZONE	I RAIN AVE.	J RAIN INT.	K % SUN
1	DC WASHINGTON	38-5	14	8	58	1	2		7	40	6.6	54
2												
3	FL JACKSONVILLE	30-3	24	0	73	0	1		9	53	7.8+	61
4	MIAMI	25-5	7	0	76	0	1		10	58	7.8+	69
5	ORLANDO	28-3	106	0	74	0	1		9	48	7.8+	65
6	TAMPA	28-0	19	0	76	0	1		10	47	7.8+	67
7												
8	GA ATLANTA	33-4	1005	4	64	2A	1		7	49	7	59
9	COLUMBUS	33-2	242	3	66	1	1		8	51	7.5	59
10	SAVANNAH	32-1	52	0	68	2A	1		9	50	7.5	59
11												
12	HI HONOLULU	21-2	7							23		74
13												
14	IA DES MOINES	41-3	948	30	53	0	2		5	31	7	55
15	DAVENPORT	41-3		30	55	0	2		5		6.6	
16	SIOUX CITY	42-2	1095	35	52	1	3		4	25	7	57
17												
18	ID BOISE	43-3	2842	6	55	2B	3		5	12	3	58
19	POCATELLO	43-0	4444	20	53	2B	3		5	11	3.8	56
20												
21	IL CHICAGO	41-5	610	35	54	0	2		4	33	6.3	52
22	PEORIA	40-4	652	25	54	1	2		5		6.3	
23	ROCKFORD	42-1	724	35	54	0	2		5	37	6.3	53
24	SPRINGFIELD	39-5	587	18	56	1	2		5	34	6.3	54
25												
26	IN EVANSVILLE	38-0	381	7	58	1	2		6	42	6.5	55
27	FT. WAYNE	41-0	791	23	55	1	2		5	34	6.2	50
28	INDIANAPOLIS	39-4	793	20	56	1	2		6	39	6.3	51
29	SOUTH BEND	41-4	773	30	54	1	2		5	38	6.3	47
30	TERRE HAUTE	39-3	601	15	56	2A	2		6		6.3	
31												
32												

DATA

L HDD	M CDD	N % RH AM	O % RH PM	P WINT TEMP	Q SUM TEMP	R WIND AVE.	S WIND INT.	T SNOW	U INSUL.	V COST*	OTHER	Line No.
5004	970	83	55	14	93	7	75	20	4	95		1
												2
1402	2520	88	56	29	96	8	95	0	2	80		3
199	4095	84	61	44	91	9	110	0	2	86		4
656	3401	89	55	35	94	9	95	0	2	80		5
739	3324	88	58	36	92	8	100	0	2	82		6
												7
3021	1670	82	56	17	94	9	75	5	3	83	(1)	8
2356	2152	87	54	21	95	7	70	5	3	75	(1)	9
1921	2290	86	53	24	96	8	100	0	2	79		10
												11
0	4389	72	56	62	87	11				125		12
												13
6554	1019	80	60	−10	94	11	80	25	5	89		14
							75	25	5	87		15
6947	940	82	60	−11	95	11	85	35	5	85		16
												17
5802	742	69	43	3	96	9	70		4	92		18
7123	445	72	44	−8	94	10	70		4	88	(1)	19
												20
6455	740	80	60	−5	94	10	75	25	5	103		21
6226	948			−8	91	10	75	20	5	92		22
6952	714	83	61	−9	91	10	75	25	5	92		23
5654	1165	83	61	−3	94	11	75	20	4	89		24
												25
4729	1378	82	59	4	95	11	70	15	4	88	(1)	26
6320	786	82	62	−4	92	10	75		5	88	(1)	27
5650	988	84	62	−2	92	10	75	20	4	95		28
6377	710	82	62	−3	91	10	75	20	4			29
				−2	95		70	20	4	86	(1)	30
												31
												32

*Data courtesy of BNI Building News. See latest BNI for current data.

LOCATION

Line No.	LOCATION	A LAT.	B ELEV.	C FROST LINE	D GD. TEMP.	E SEISMIC	F TERMITE	G SOILS	H PLANT ZONE	I RAIN AVE.	J RAIN INT.	K % SUN
1	KS TOPEKA	39-0	877	15	58	2A	2		6	33	7.3	58
2	WICHITA	37-4	1321	12	60	1	2		6	29	7.3	62
3												
4	KY LEXINGTON	38-0	979	7	59	1	2		6	46	6.4	52
5	LOUISVILLE	38-1	474	6	58	1	2		6	44	6.4	53
6												
7	LA BATON ROUGE	30-3	64	0	70	0	1		9	56	7.8	60
8	LAKE CHARLES	30-1	14	0	72	0	1		9	53	7.8+	58
9	NEW ORLEANS	30-0	3	0	72	0	1		9	60	7.8+	60
10	SHREVEPORT	32-3	252	18	68	1	1		8	44	7.6	59
11												
12	MA BOSTON	42.2	15	30+	52	2A	2		6	44	5.7	55
13	LOWELL	42.3	90	35	48	2A	1		5		5.7	
14	NEW BEDFORD	41-4	70	18	54	2A	2		6		6.2	
15	SPRINGFIELD	42-1	247	25	52	2A	1		5		6.0	
16	WORCESTER	42-2	986	30	52	2A	2		5	48	5.7	54
17												
18	MD BALTIMORE	38-8	14	8	58	1	2		7	42	6.6	59
19												
20	ME LEWISTON	44-0	182	50	50	2A	3		5		5.2	
21	PORTLAND	43-4	61	48	50	2A	3		6	44	5.4	55
22												
23	MI DETROIT	42-2	633	30	50	1	3		5	31	5.8	50
24	FLINT	40-0	766	30	49	1	3		5	29	6.0	47
25	GRAND RAPIDS	42-5	681	20	50	0	3		5	34	6.0	44
26	KALAMAZOO	42-1	930	20	52	1	3		5		6.2	
27	LANSING	42-5	852	25	50	1	3		5	30	6.0	48
28												
29	MN DULUTH	46-5	1426	50	48	0	3		3	30	6.2	49
30	MINNEAPOLIS	44-5	822	50	46	0	3		4	26	6.4	54
31	ROCHESTER	44.0	1297	38	49	0	3		4	28	6.4	50
32												

DATA

L HDD	M CDD	N % RH AM	O % RH PM	P WINT TEMP	Q SUM TEMP	R WIND AVE.	S WIND INT.	T SNOW	U INSUL.	V COST*	OTHER	Line No.
5319	1380	83	59	0	99	10	80	20	4	83		1
4787	1684	80	55	3	101	12	80	15	4	81		2
												3
4814	1170	82	60	3	93	9	70	15	4	85	(1)	4
4525	1342	81	58	5	95	8	70	15	4	89	(1)	5
												6
1673	2605	88	59	25	95	8	90	0	2	84		7
1579	2682	91	63	27	95	9	100	0	2	82		8
1490	2686	88	63	29	93	8	100	0	2	86		9
2269	2444	88	58	20	99	8	70	0	3	78		10
												11
5593	699	72	58	6	91	13	85	30	5	101	(1)	12
				-4	91		80	35	5	94	(1)	13
				5	85		85	20	5	91	(1)	14
				-5	90		80	30	5	94	(1)	15
6950	359	74	57	0	89	10	80	30	5	96	(1)	16
												17
4706	1138	77	54	14	93	9	75	20	4	90		18
												19
				-7	88		80	70	6	87	(1)	20
7501	254	79	59	-6	87	9	85	60	5	89	(1)	21
												22
6563	615	81	60	3	91	10	75	25	5	95	(1)	23
7068	456	81	62	-4	90	10	75	30	5	91	(1)	24
6927	570	83	63	1	91	10	75	30	5	88	(1)	25
				1	92		75	30	5	86	(1)	26
8298	530	85	64	-3	90	10	75	30	5	88	(1)	27
												28
9901	150	81	63	-21	85	11	75		6	93	(1)	29
8007	662	79	60	-16	92	11	75		6	98		30
8277	479	83	65	-17	90	13	80		6	93		31
												32

*Data courtesy of BNI Building News. See latest BNI for current data.

LOCATION

Line No.	LOCATION	A LAT.	B ELEV.	C FROST LINE	D GD. TEMP.	E SEISMIC	F TERMITE	G SOILS	H PLANT ZONE	I RAIN AVE.	J RAIN INT.	K % SUN
1	MO KANSAS CITY	39-1	742	15	58	2A	2		6	35	7.4	60
2	ST. JOSEPH	39-5	809	20	55	2A	2		5		7.4	
3	ST. LOUIS	38-5	535	12	58	2A	2		6	34	6.6	55
4	SPRINGFIELD	37-1		8	59	1	2		6	39	7.4	58
5												
6	MS BILOXI	30-2	25	0	70	0	1		9		7.8	
7	JACKSON	32-2	330	1	67	1	1		8	53	7.5	59
8												
9	MT BILLINGS	45-5	3567	25	50	1	3		5	15	4.2	55
10	GREAT FALLS	47-3	3664	60	50	2B	3		5	15	3.6	51
11												
12	NC CHARLOTTE	35-0	735	5	62	2A	2		7	43	7.4	59
13	RALEIGH	35-5	433	3	62	2A	2		7	42	7.4	59
14	WINSTON-SALEM	36-1	967	4	62	2A	2		7	42	7.4	59
15												
16	ND FARGO	46-5	900	55	46	0	3		3	20	6.4	54
17												
18	NE LINCOLN	40-5	1150	28	54	1	2		5	27	7.2	59
19	OMAHA	41-2	978	30	53	1	2		5	30	7.2	60
20												
21	NH MANCHESTER	43-0	253	45	46	2A	3		5		5.6	
22												
23	NJ NEWARK	40-5	132	15	54	2A	2		6	44	6.3	64
24	TRENTON	40-1	144	12	55	2A	2		6		6.3	
25												
26	NM ALBUQUERQUE	35-0	5310	6	60	2B	2		5	8	4.6	76
27												
28	NV LAS VEGAS	36-1	2162	0	70	2B	2		8	5	3.8	80
29	RENO	39-3	4404	20	58	3	2		5	7	3.2	80
30												
31												
32												

DATA

L HDD	M CDD	N % RH AM	O % RH PM	P WINT TEMP	Q SUM TEMP	R WIND AVE.	S WIND INT.	T SNOW	U INSUL.	V COST*	OTHER	Line No.
5283	1333	81	59	2	99	11	75	20	4	86		1
				-3	96		75	25	4	84		2
4938	1468	83	59	2	97	10	70	20	4	90		3
4660	1374	82	58	3	96	11	70	15	4	84		4
												5
				28	31				2			6
2389	2320	91	58	21	97	7	80	5	3	81		7
												8
7212	553	66	44	-15	94	11	80		5	87		9
7766	391	67	45	-21	91	13			6	87		10
												11
3342	1546	82	54	18	95	7	70	10	3	79	(1)	12
3531	1394	85	54	16	94	8	75	15	3	77	(1)	13
3874	1303	83	55	16	94	8	75	15	3		(1)	14
												15
9343	476	81	62	-22	92	12	85	35	6	90		16
												17
6375	1124	82	58	-5	99	10	80	25	5	85		18
6194	1166	81	59	-8	94	11	80	25	5	87		19
												20
				-8	91		75		5	88		21
												22
4972	1091	73	53	11	92	9	80	20	4	102	(1)	23
				11	91		75	30	4	97	(1)	24
												25
4414	1254	60	29	12	96	9	70	10	4	86	(1)	26
												27
2532	3029	40	21	25	108	9	80	5	3	97		28
6030	357	70	31	5	95	7			3	100		29
												30
												31
												32

*Data courtesy of BNI Building News. See latest BNI for current data.

LOCATION

Line No.	LOCATION	A LAT.	B ELEV.	C FROST LINE	D GD. TEMP.	E SEISMIC	F TERMITE	G SOILS	H PLANT ZONE	I RAIN AVE.	J RAIN INT.	K % SUN
1	NY ALBANY	42-5	277	30+	46	2A	3		5	36	5.7	49
2	BINGHAMTON	42-1	1590	30+	51	1	2		5	37	5.8	42
3	BUFFALO	43-0	705	30+	51	1	3		6	38	5.7	43
4	NEW YORK	40-5	132	15	54	2A	2		6	44	6.3	64
5	ROCHESTER	43-1	543	30+	50	1	3		6	31	5.4	46
6	SYRACUSE	43-1	424	30+	50	1	3		6	39	5.4	44
7												
8	OH AKRON	40-1	1210	15	54	1	2		5	36	6.0	46
9	CINCINNATI	39-1	761	10	58	1	2		6		6.3	
10	CLEVELAND	41-2	777	23	54	1	2		5	35	6.0	45
11	COLUMBUS	40-0	812	10	56	1	2		5	37	6.2	48
12	DAYTON	39-5	997	10	54	1	2		5	35	6.2	49
13	TOLEDO	41-4	676	20	54	1	2		5	32	6.0	50
14	YOUNGSTOWN	41-2	1178	15	53	1	2		5	37	6.0	44
15												
16	OK LAWTON	34-3	1108	8	62	1	2		5/6		7.2	
17	OKLA. CITY	35-2	1280	8	64	2A	2		5/6	31	7.4	64
18	TULSA	36-1	650	8	62	1	2		5/6	39	7.5	63
19												
20	OR EUGENE	44-1	364	13	56	2B	3		7	46	3.4	43
21	PORTLAND	45-4	21	13	54	2B	3		8	37	3.4	39
22												
23	PA ALLENTOWN	40-4	376	15	53	2A	2		6	44	6.3	56
24	ERIE	42-1	732	25	51	1	2		6	39	5.7	44
25	HARRISBURG	40-1	335	18	52	1	2		6	39	6.3	54
26	PHILADELPHIA	39-5	7	12	54	2A	2		7	41	6.4	56
27	PITTSBURGH	40-3	1137	15	54	1	2		6	36	6.2	44
28	SCRANTON	41-2	940	25	51	2A	2		5		6.0	
29												
30	RI PROVIDENCE	41-4	55	18	54	2A	2		6	45	6.2	55
31												
32												

DATA

L HDD	M CDD	N % RH AM	O % RH PM	P WINT TEMP	Q SUM TEMP	R WIND AVE.	S WIND INT.	T SNOW	U INSUL.	V COST*	OTHER	Line No.
6927	494	80	57	-6	91	9	70	30	5	87		1
7344	330	82	63	-2	86	10			5	83		2
6798	476	80	63	2	88	12			5	90	(1)	3
4868	1089	72	56	11	92	9	80	20	4	115	(1)	4
6713	531	81	61	1	91	10	70	40	5	90		5
6768	506	81	61	-3	90	9	70	35	5	87		6
												7
6241	625	80	61	1	89	10	75	15	5		(1)	8
5069	1080			1	92			15	4	83		9
6178	625	79	62	1	91	11			5	91	(1)	10
5686	862	80	59	0	92	8	70	20	4	89		11
5689	947	80	60	-1	91	10	70	20	4			12
6570	622	84	60	-3	90	9		15	5	89	(1)	13
6560	485	82	62	-1	88	10	75	25	5	85	(1)	14
												15
				12	101		80	5	3	77		16
3735	1914	80	54	9	100	12	75	10	3	83		17
3731	2043	81	56	8	101	10	70	10	3	81	(1)	18
												19
4799	261	91	60	17	92	8	80		4	90		20
4691	332	86	60	17	89	8	85		1	95		21
												22
5815	751	80	56	4	92	9	70	30	5	91	(1)	23
6768	402	78	66	4	88	11			5		(1)	24
5335	1006	76	54	7	94	7	70	25	4	85	(1)	25
4947	1075	76	55	10	93	10	75	25	4	98	(1)	26
5950	645	79	57	1	89	9	70	30	4	89		27
				1	90		70		5	87		28
												29
5908	574	75	55	5	89	11	90	20	4	98	(1)	30
												31
												32

*Data courtesy of BNI Building News. See latest BNI for current data.

LOCATION

Line No.	LOCATION	A LAT.	B ELEV.	C FROST LINE	D GD. TEMP.	E SEISMIC	F TERMITE	G SOILS	H PLANT ZONE	I RAIN AVE.	J RAIN INT.	K % SUN
1	SC CHARLESTON	32-5	9	0	67	2A	1		9	52	7.6	58
2	COLUMBIA	34-0	217	3	65	2A	1		8	49	7.4	60
3												
4	SD RAPID CITY	44-0	3165	28	50	1	3		4	16	5.4	62
5	SIOUX FALLS	43-4	1420	38	50	0	3		4	24	6.8	57
6												
7	TN CHATTANOOGA	35-0	670	5	63	2A	2		7	53	6.8	58
8	KNOXVILLE	35-5	980	8	60	2A	2		7	47	6.6	56
9	MEMPHIS	35-0	263	3	63	3	2		7	52	6.8	59
10	NASHVILLE	36-1	577	5	60	1	2		7	48	6.5	57
11												
12	TX ABILENE	32-3	1759	4	68	0	2		7	23	7.2	67
13	AMARILLO	35-1	3607	6	61	1	2		6	19	6.0	72
14	AUSTIN	30-2	597	3	73	0	1		8	32	7.4	63
15	BEAUMONT	30-0	18	0	70	0	1		9		8	
16	CORPUS CHRISTI	27-5	43	0	76	0	1		9	30	8	61
17	DALLAS	32-5	481	4	69	0	1		8	29	7.5	70
18	EL PASO	31-5	3918	2	68	1	2		6	8	4.8	80
19	HOUSTON	29-4	50	0	76	0	1		9	45	8	56
20	LUBBOCK	33-4	3243	5	64	0	2		7	18	6	72
21	SAN ANTONIO	29-3	792	1	76	0	1		9	29	7.8	62
22	WACO	31-4	500	4	71	0	1		8	31	7.6	63
23	WICHITA FALLS	34-0	994	8	66	1	2		7	27	7.2	67
24												
25	UT OGDEN	41-1	4455	18	55	3	3		5		4.5	
26	SALT LAKE	40-5	4220	16	55	3	3		5	15	4.5	62
27												
28	VA NORFOLK	36-5	26	2	60	1	1		8	45	7.2	58
29	ROANOKE	37-2	1174	15	57	1	2		7	39	6.6	59
30	RICHMOND	37-3	162	4	57	1	2		7/8	44	7.0	56
31												
32												

DATA

L HDD	M CDD	N % RH AM	O % RH PM	P WINT TEMP	Q SUM TEMP	R WIND AVE.	S WIND INT.	T SNOW	U INSUL.	V COST*	OTHER	Line No.
2147	2093	86	56	25	94	9	110	0	2	79		1
2629	2033	87	51	20	97	7	75	10	3	81	(1)	2
												3
7301	667	71	50	−11	95	11	80	15	5	81	(1)	4
7885	749	81	60	−15	94	11	80	40	5	83		5
												6
3583	1578	86	56	13	96	6	70	5	3	77	(1)	7
3658	1449	86	59	13	94	7	70	10	3	79	(1)	8
3207	2067	81	57	13	98	9	70	10	3	81		9
3756	1661	84	57	9	97	8	70	10	3	83	(1)	10
												11
2621	2467	74	50	15	101	12	80	5	3			12
4231	1428	73	45	6	98	14	80	15	4			13
1760	2914	84	57	24	100	9	70	5	2	80		14
				27	95		95	0	2			15
970	3574	90	62	31	95	12	100	5	2			16
2407	2809	82	56	18	102	11	70		3	82	(1)	17
2664	2096	57	28	20	100	9	70	5	3			18
1549	2761	90	60	27	96	8	100	0	2	86		19
3516	1676	75	47	10	98	12	80	10	3	78		20
1606	2983	84	55	25	99	9	80	0	2	80		21
2126	2891	84	57	21	101	11	70	5	3			22
3011	2506	82	51	14	103	12	80	5	3			23
												24
				1	93		70		5	85	(1)	25
5802	981	67	43	3	97	9	70		5	87	(1)	26
												27
3446	1458	78	57	20	93	11	90	10	3	83		28
4315	1085	78	53	12	93	8	70	25	4	81		29
3960	1336	78	57	14	95	8	75	15	3	85	(1)	30
												31
												32

*Data courtesy of BNI Building News. See latest BNI for current data.

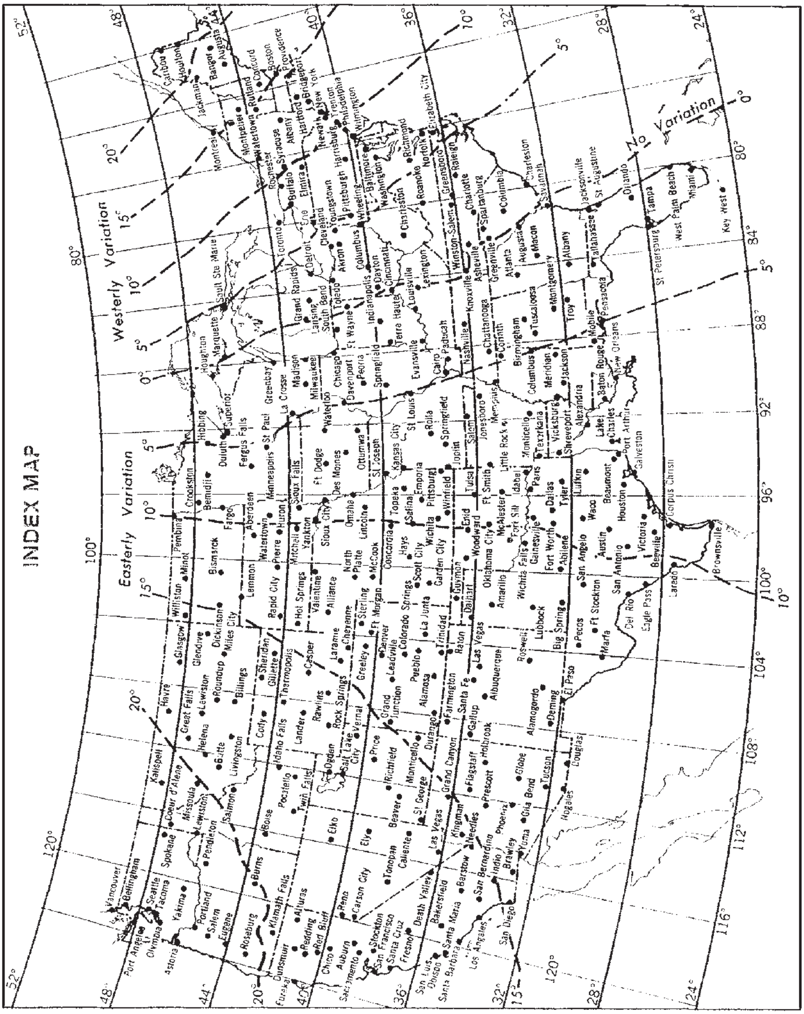
LOCATION

Line No.	LOCATION	A LAT.	B ELEV.	C FROST LINE	D GD. TEMP.	E SEISMIC	F TERMITE	G SOILS	H PLANT ZONE	I RAIN AVE.	J RAIN INT.	K % SUN
1	VT BURLINGTON	44-3	331	50	46	2A	3		4/5	34	5.0	44
2	RUTLAND	43-3	620	50	46	2A	3		4/5		5.4	
3												
4	WA SPOKANE	47-4	2357	25	50	2B	3		6	17	3.0	47
5	SEATTLE	47-3	386	5	52	3	3		8	39	3.2	38
6												
7	WI GREEN BAY	44-3	683	50	49	0	3		4/5	28	6.0	52
8	MADISON	43-1	858	50	50	0	3		4/5	31	6.3	51
9	MILWAUKEE	43-0	672	50	50	0	3		5	31	6.2	52
10												
11	WV CHARLESTON	38-2	939	15	60	1	2		6	42	6.3	48
12	HUNTINGTON	38-2	565	15	60	1	2		6	41	6.3	44
13												
14	WY CHEYENNE	41-1	6126	24	52	1	3		4/5	13	4.8	64
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
32												

DATA

L HDD	M CDD	N % RH AM	O % RH PM	P WINT TEMP	Q SUM TEMP	R WIND AVE.	S WIND INT.	T SNOW	U INSUL.	V COST*	OTHER	Line No.
7953	379	77	59	-12	88	9	75		6	94	(1)	1
				-13	87		75		5	87	(1)	2
												3
6882	411	78	52	-6	93	9	75		5	99	(1)	4
5121	184	83	62	21	84	9	80		1	106	(1)	5
												6
8143	381	82	63	-13	88	10	90	40	6	92		7
7642	467	84	61	-11	91	10	80	40	5	90		8
7326	470	80	64	-8	90	12		40	5	97		9
												10
4697	1007	83	56	7	92	6	70		4	87	(1)	11
4676	1121	83	58	5	94	7	70		4	89	(1)	12
												13
7310	309	65	44	-9	89	13	80		5	91		14
												15
												16
												17
												18
												19
												20
												21
												22
												23
												24
												25
												26
												27
												28
												29
												30
												31
												32

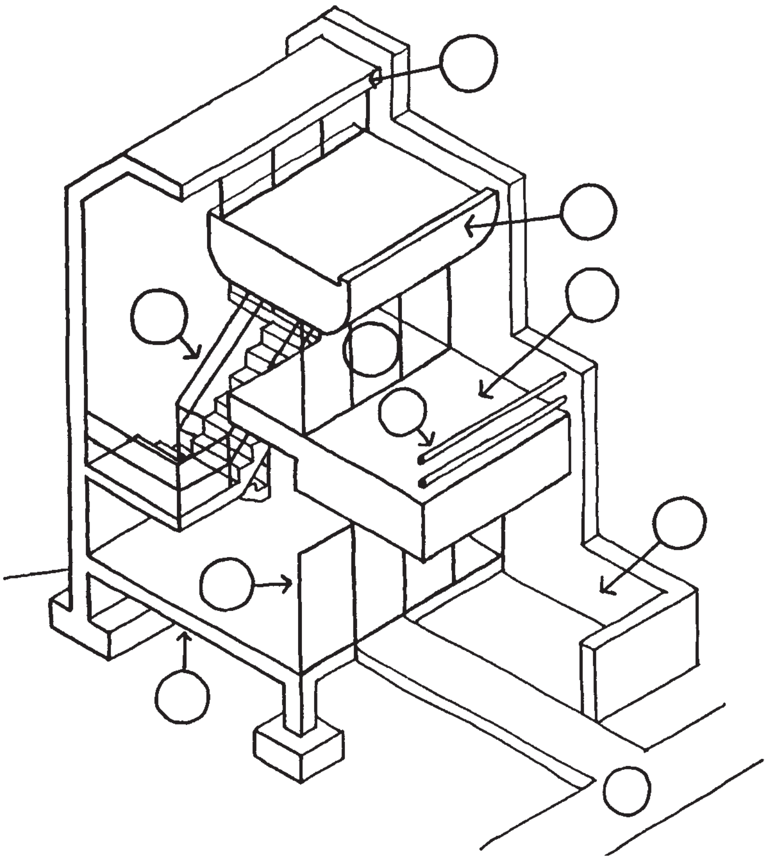
*Data courtesy of BNI Building News. See latest BNI for current data.



MAGNETIC VARIATION

The magnetic compass points to magnetic north rather than true north. In most localities magnetic north does not coincide with true north but is toward the east ("easterly variation") or toward the west ("westerly variation") from it

The heavy broken lines on this map connect points of equal magnetic variation, and present a generalized picture of magnetic variation in the United States. Due to "local attraction" it may be quite different in your locality. For more exact information consult your local surveyor.



R REFERENCES / ACKNOWLEDGMENTS / INDEX

NOTES

___ REFERENCES

This book was put together from a myriad of sources including the help of consultants listed on p. 663. References shown at the front of a section indicate general background information. A reference shown at a specific item indicates a copy from the reference. The major book references are listed as follows, and many are recommended for architects' libraries:

— (1) Allen, Edward, and Iano, Joseph, 2002. *The Architect's Studio Companion: Rules of Thumb for Preliminary Design,* 3d ed. New York: John Wiley & Sons.

— (2) Ambrose, James, 1981. *Simplified Design of Building Foundations.* New York: John Wiley & Sons.

— (3) Ambrose, James, 1995. *Simplified Design for Building Sound Control.* New York: John Wiley & Sons.

— (4) American Institute of Architects, 1970. *Architectural Graphic Standards,* 6th ed. New York: John Wiley & Sons.

— (5) American Institute of Architects, 2000. *Architectural Graphic Standards,* 10th ed. New York: John Wiley & Sons.

— (6) American Institute of Architects, 1988. *The Architect's Handbook of Professional Practice,* David Haviland, ed.

— (7) American Institute of Architects, 1982. *Architect's Handbook of Energy Practice—Daylighting.*

— (8) American Institute of Architects, 1981. *Energy in Architecture.*

— (9) *Architect's, Contractor's, Engineer's Guide to Construction Costs,* 2002, Don Roth, ed.

— (10) Ballast, David Kent, 1988. *Architect's Handbook of Formulas, Tables, and Mathematical Calculations.* Englewood Cliffs, NJ: Prentice-Hall.

— (11) Ballast, David Kent, 1990. *Architect's Handbook of Construction Detailing.* Englewood Cliffs, NJ: Prentice-Hall.

— (12) Better Homes and Gardens, 1975. *Decorating Book.*

— (13) Bovill, Carl, 1991. *Architectural Design: Integration of Structural and Environmental Systems.* New York: Van Nostrand Reinhold.

— (14) Building Green, Inc., 2001. *Green Spec Directory: Product Directory with Guideline Specifications, 1999–2001*, Environmental Building News, eds.

— (15) Building News, 2002. *Facilities Manager's 2002 Cost Book,* William D. Mahoney, ed.-in-chief.

16 Butler, Robert Brown, 1989. *Standard Handbook of Architectural Engineering.* New York: McGraw-Hill.

17 Ching, Francis, 1975. *Building Construction Illustrated.* New York: Van Nostrand Reinhold.

18 Ching, Francis, 1990. *Drawing: A Creative Process.* New York: Van Nostrand Reinhold.

19 Clayton, George T., 1973. *The Site Plan in Architectural Working Drawings.* Chicago: Stipes Publishing.

20 Construction Specifications Institute, 1995. *Master-Format: Master List of Section Titles and Numbers.* The numbers and titles used in this product are from *MasterFormat*™ (1995 edition) and *UniFormat*™ (1998 edition) and are published by the Construction Specifications Institute (CSI) and Construction Specifications Canada (CSC), and are used with permission from CSI, 2002.

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21 Craftsman Book Co., 2002. *1997 National Construction Estimator*, Martin D. Kiley and William M. Moselle, eds.

22 Craftsman Book Co., 2002. *2002 Building Assembly Costs*, Martin D. Kiley and Michael L. Kiley, eds.

23 Dell'Isola, Alphonse, 1974. *Value Engineering in the Construction Industry.* New York: Construction Publishing Co.

24 Dept. of the Air Force, AFM 88-54. *Air Force Civil Engineer Handbook.*

25 Dept. of the Army, 1969. *FM-34 Engineer Field Data.*

26 Elliott, H. M., 1979. *How Structures Work: A Structural Engineering Primer,* unpublished.

27 Federal Register, 1991. *Americans with Disabilities Act* (ADA).

28 Foote, Rosslynn F., 1978. *Running an Office for Fun and Profit: Business Techniques for Small Design Firms.* Pennsylvania: Dowden, Hutchinson & Ross.

29 Flynn, Kremers, Segil, and Steffy, *Architectural Interior Systems,* 3d ed.

30 Guidelines Publications, 1990. *Design Services Appraiser.*

31 Guidelines Publications, 1975. *Architectural Rules of Thumb.*

32 International Association of Plumbing and Mechanical Officials, 2000. *2009 Uniform Plumbing Code,* Walnut, CA.

33 International Conference of Building Officials, 2009. *2000 IBC Handbook—Fire and Safety Provisions.*

34 International Code Council, 2009. *2009 International Building Code.* Copyright 2009 International Code Council, Inc., Falls Church, Virginia. 2009 International Building Code. All rights reserved.

35 International Code Council, 2009. *2009 International Plumbing Code*. Copyright 2009 International Code Council, Inc., Falls Church, Virginia. 2009 International Building Code. All rights reserved.

36 International Code Council, 2000. *2000 International Residential Code for One and Two Family Dwellings.*

37 Libbey-Owens-Ford Co., 1974. *Sun Angle Calculator.*

38 Lockard, William K., 1968. *Drawing as a Means to Architecture.* New York: Van Nostrand Reinhold.

39 Lockard, William K., 1982. *Design Drawing.* New York: Van Nostrand Reinhold.

40 Lynch, Kevin, 1962. *Site Planning.* Boston: MIT Press.

41 McGraw-Hill Book Co., 1993. *Sweet's Catalog File.* New York: McGraw-Hill.

42 McGraw-Hill Book Co., 1966. *Time Saver Standards,* John H. Callender, ed.-in-chief. New York: McGraw-Hill.

43 Means, R. S. Co. Inc., 2002. *Means Building Construction Cost Data.*

44 Means, R. S. Co. Inc., 2002. *Means Assemblies Cost Data.*

45 Munsell, A. H., 1946. *A Color Notation.* Munsell Color Co., Inc.

46 National Oceanic and Atmospheric Administration, 1992. *Comparative Climatic Data for the U.S.*

— 47 National Roofing Contractors Association, 1983. *Handbook of Accepted Roofing Knowledge.*

— 48 National Roofing Contractors Association, 1981. *The NRCA Roofing and Waterproofing Manual.*

— 49 National Fire Protection Association. *NFPA 5000 Building Construction and Safety Code,* National Fire Protection Association, Quincy, MA 02269.

— 50 Parker, Harry, and MacGuire, John, 1967. *Simplified Engineering for Architects and Engineers.* New York: John Wiley & Sons.

— 51 Parker, Harry, and MacGuire, John, 1954. *Simplified Site Engineering for Architects and Engineers.* New York: John Wiley & Sons.

— 52 Peña, William, with Parshall and Kelley, 1977. *Problem Seeking.* Washington, DC: A.I.A. Press.

— 53 Rosen, Harold, and Bennett, Philip, 1979. *Construction Materials Evaluation and Selection.* New York: John Wiley & Sons.

— 54 Running Press, 1995. *Cyclopedia: The Portable Visual Encyclopedia.* Philadelphia: Running Press.

— 55 Saylor Publications, Inc., 2002. *2002 Current Construction Costs.*

— 56 Schiler, Marc, 1992. *Simplified Design of Building Lighting.* New York: John Wiley & Sons.

— 57 Stasiowski, Frank A., 1991. *Staying Small Successfully.* New York: John Wiley & Sons.

— 58 U.S. Navy, 1972. *Basic Construction Techniques for Houses and Small Buildings.* New York: Dover Publications.

— 59 Watson, Donald, and Labs, Kenneth, 1983. *Climatic Design.* New York: McGraw-Hill.

— 60 Wing, Charlie, 1990. *The Visual Handbook of Building and Remodeling.* Emmaus, PA: Rodale Press.

— 61 Wood, R. S., and Co., 1985. *The Pocket Size Carpenter's Helper.*

NOTES

NOTES

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