Building Construction Illustrated
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Excerpts
- Topography and Building Form
- Systems: Planar, Linear, Composite
- Wood Frames
- Steel Frames
- Masonry
- Retaining Walls
STEEP SLOPES: structures may

- sit elevated on piers for minimum disturbance of the ground plane
- be terraced or stepped with the slope
- be cut into the slope for minimal building profile

- use of retaining walls required
- amount of cut should approximate the amount of fill
- natural angle of repose for the soil type should not be exceeded

MODERATE SLOPES: structures may

- be elevated on piers
- be cut into the slope

- linear or planar leads

FLAT SLOPES: structures may

- be elevated on piers or pilings
- sit on raised pads
- be dug into earth and bermed

- structures over water supported by flotation or on piles driven to a subsurface support
- piles are used not only to elevate a structure above the ground plane but also to support structures situated above unsuitable bearing soils
- earth pads may aid in draining surface water away from structure
- height of a site's seasonal water table and possible underground streams should be checked to avoid the waterproofing of below grade structures
- earth berms may act as the building's side walls
Systems: Planar, Linear, Composite
A bearing wall structural system utilizes rigid vertical planes to support building loads and transmit them down to its foundation. Using the same plan grid as that of the skeletal structural system, a planar system can be laid out. Giving preferential treatment to one direction, bearing walls can be erected parallel to one another (equally or unequally spaced) with secondary axes for penetrations through the bearing walls perpendicular to the primary axes.

Bearing walls are inherently most effective in resisting and transmitting forces along their planes, and most vulnerable to forces perpendicular to their planes. The lateral stability of bearing walls depends on their mass, rigidity, width to height ratio, and the amount of bracing effective by perpendicular walls, and horizontal roof and floor planes. Care should be taken that penetrations through bearing walls for doors and windows do not destroy the wall's integrity, strength, and rigidity.

Transferring loads horizontally requires rigid horizontal planes which may be of either homogeneous or composite construction.

To the left are diagrams illustrating the variations in form possible through the manipulation of the height, length, spacing, and direction of a series of bearing walls.
The skeletal type of structural system gives a building form through the manipulation of linear structural elements (columns and beams) which in effect form a cage.

In plan the critical points of a skeletal structural system are those at which building loads are transferred vertically along column lines. This gives rise to the use of a column grid where the grid lines represent the horizontal continuity provided by the beams and the intersections of these lines represent the location of columns. The inherent geometric order of a grid, regular or irregular, can be used in the design process to initiate and reinforce a building’s functional and spatial organization.

To ensure lateral stability in a frame system rigid joints and/or shear walls and planes (both vertical and horizontal) are generally required.

To the left are diagrams which illustrate how a single module of space, as defined by four columns supporting four beams, can be seen as a building block that can logically be extended vertically along column lines or horizontally along beam lines.
The composite structural system can be considered a combination of the two preceding structural systems, utilizing both linear columns and beams, and horizontal and vertical bearing planes to define space and provide volumetric enclosure. A plan grid is again useful in organizing and coordinating the functional, spatial, and structural systems for a building.

A building utilizing this type of structural system may appear either as a solid cubical or prismatic form with voids cut out of it or as an additive accumulation of forms.

To the left are diagrams illustrating the flexibility of form possible in the manipulation of linear and planar structural elements.
Wood Frames
- Floor and roof systems are supported by beams, which are in turn supported by posts or columns which then transfer these loads down to the foundation system.

- Together with plank and beam post and floor systems, the post and beam wall system forms a three-dimensional modular grid of spaces which may be expanded both horizontally and vertically.

- The skeleton frame of posts and beams is often left exposed to form a visible framework within which wall panels, doors, and windows should be integrated.

- When the post and beam frame is left exposed, the quality of wood used, the quality of workmanship, and the careful detailing of the joints between the posts and beams are important factors to consider.

- Non-bearing infill wall panels serve to enclose and further define space, act as weather barriers on the exterior, and impart lateral stability to the post and beam frame.

- Lateral stability for the post and beam frame against lateral loads such as wind is achieved through the rigidity of the joints between post, beam, and foundation, and the strength and positive tie of the infill wall panels to the structural frame.
WOOD BEAM/COLUMN CONNECTIONS

CONCEALED CONNECTION
POST or COLUMN CONNECTIONS

6" (152)
mintum bearing
in direction of
beam span

steel 'U' plate,
rail and
bale connections

EXPOSED COLUMN CAP

EXPOSED COLUMN CAP

welded connection

steel column

use steel bearing
plate if post cross-
sectional area is insufficient
to provide bearing for beam
in compression perpendic-ular to grain

EXPOSED 'T' STRAPS

post continuous

spacer blocks

through bolt
connections

SPACED BEAM/SOLID POST

POST or COLUMN CONNECTIONS: COLUMNS CONTINUING VERTICALLY

SOLID BEAM/SPACED POST

POST CONTINUOUS

steel brackets

with web stiffeners

and through bolts

steel straps with

through bolts

shear plates

and pin

additional wood

support ekc-

laminated or bolted
to post as required

BEAM CONTINUOUS

middle post
member
continuous

outer beam
members
continuous

INTERLOCKING POST and BEAM
Above are illustrated the primary ways in which posts and beams may be joined. Steel connections are generally used in post and beam joints to ensure rigidity and the proper transfer of forces. These steel connections may be either concealed or exposed.

The following table is for estimating and preliminary sizing of members only. Column spacing is directly related to the desired bay size and the spanning capability of the wood beams and floor system used.

<table>
<thead>
<tr>
<th>SAFE LOADS FOR WOOD POSTS AND COLUMNS</th>
<th>in kips (1000 lbs) • 1 kip = 483.50 kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>LENGTH</td>
<td>SIZE in inches</td>
</tr>
<tr>
<td>feet (m)</td>
<td>4 x 4 (102 x 102)</td>
</tr>
<tr>
<td>8 (2.44)</td>
<td>6</td>
</tr>
<tr>
<td>10 (3.05)</td>
<td>8</td>
</tr>
<tr>
<td>12 (3.66)</td>
<td>9</td>
</tr>
<tr>
<td>14 (4.27)</td>
<td>10</td>
</tr>
<tr>
<td>16 (4.88)</td>
<td>11</td>
</tr>
<tr>
<td>18 (5.49)</td>
<td>12</td>
</tr>
<tr>
<td>20 (6.09)</td>
<td>14</td>
</tr>
<tr>
<td>22 (6.71)</td>
<td>16</td>
</tr>
<tr>
<td>24 (7.32)</td>
<td>18</td>
</tr>
</tbody>
</table>

- the above assumes the modulus of elasticity (E) for the wood used to be 1,200,000 psi (8.44 x 10^6 kg/m²)
- verify that the allowable unit stress in compression parallel to grain for the wood used is not exceeded
Steel Frames
Structural steel framing may be spanned by:
- composite concrete/steel decking (see 4:25)
- cast-in-place or precast concrete (see 4:27/28)
- in-bearing or curtain walls of metal cladding
- wood or masonry composite sandwich panels
- steel beams may be:
  - wall-supported
  - beam-supported
  - column-supported

Structural steel is essentially a linear system that forms a skeletal frame similar in principle to the wood post-and-beam structural system. (see 4:12 and 5:12)

- Steel frames are normally designed and utilized to carry relatively heavy loads over long spans, and require careful engineering analysis of moment, shear, and tensile stresses, especially at joints and connections.
- Slenderness and depth-to-span ratios of the steel structural members must be checked to ensure rigidity of the frame.
- Lateral and wind forces must be resisted by rigidly braced connections and/or shear walls.
- Since structural steel is difficult to work on-site, it is normally cut, shaped, and drilled by a fabricating shop according to the designer's specifications.
- Structural steel usually requires fire-resistant protection and, if exposed, treatment against corrosion.
- A structural grid should be utilized in laying out the framing system.

- Column or beam support:
  - Beam/column connections usually utilize steel angles and plates which may be welded, bolted, or riveted

- Wall bearing support:
  - Steel bearing plates are required to distribute the concentrated load imposed by the beam so that the resultant unit bearing pressure does not exceed the allowable for the wall material.
  - Beams may be in the form of (W), (S), or (C) channel shapes, structural tubing, or fabricated from channel sections.
  - Columns may be in the form of (W) or (S) shapes, structural tubing, or fabricated from channel or angle sections.
  - Heavy steel lintels for large masonry openings may be fabricated from (W), (S), or (C) channel shapes.
  - Long spans may be framed with built-up plate girders, trusses, arches, or rigid-frame beams.
Masonry
MASONRY WALL SYSTEMS

- Masonry walls are made up of modular building blocks bonded together with mortar to form load bearing walls which are structurally most efficient in compression.

- Concrete block: chemically hardened unit
- Brick: heat hardened clay unit

- Masonry load bearing walls may be used in parallel sets or in conjunction with other wall systems to support most floor or roof systems (joists, beams, structural decking).
- Proper sizing and placement of wall openings critical in maintaining the structural integrity of masonry wall planes.
- Masonry wall openings spanned with lintels or arches.
- Proper placement of expansion and control joints necessary to avoid cracking in the masonry.
- Masonry walls susceptible to water penetration.
- Masonry walls provide strong spatial definition and enclosure, weather protection, an integral and durable wall finish, and fire resistance in one material.
- Masonry walls generally project a heavy image.
- Color, pattern, and texture are important visual properties of masonry walls.

All major dimensions should conform to the modular dimensions of the masonry unit used:

Concrete block: 8" (203) vertical coursing [4" (102) coursing available]
8" (203) multiples for length.

Brick masonry: 2½" (64) vertical coursing [3 courses = 8" (203)]
4" (102) multiples for length.
CONCRETE BLOCK WALL SECTIONS

- Black wall may continue.
- Steel joint floor or roof system.

4" (102) min bearing for standard joint.
* See 4.21

Square ends available for ceiling application.
Solid units or continuous beam beam under joints.

Solid unit:
- Solid unit top course through wall flashing.
- Black parapet condition.
- Wood joint roof system.

Steel anchor straps every 4th joint.
3" (76) min bearing.
Solid units under joint.

Wood stud wall system.
Wood joint floor system.

Header:
2x6 sill plate anchored with 1/2" (13) bolts extending down 2 courses.
Solid units or continuous beam beam.

These wall sections are not intended to be complete. They exclude floor, wall, and ceiling finishes, trim, etc. They attempt to illustrate how various floor and roof systems are supported by a concrete block bearing wall. The above-grade wall is literally an extension of the concrete block foundation wall system. Note that the edges of floor and roof planes are not visible from the exterior except at the top of the concrete block wall. All vertical dimensions should be modular, especially if the block is left exposed as the wall finish.

* See 5.10 for wall flashing.
* See 5.17 for wall insulation.

Precast concrete plank:
- 3" (76) min bearing continuous reinforced beam beam.

Basement space:
Foundation wall:
* See 3.12
Retaining Walls
3.20 RETAINING WALLS

Retaining walls act as cantilevered slabs. They resist the overturning moment caused by lateral ground pressure by transferring the forces onto relatively wide footings. The depth of the lower grade above the footing is important to help stabilize the connection between the retaining wall and its footing.

Retaining walls may be of:
- reinforced concrete
- reinforced masonry
- stone rubble

Factors to consider:
- required expansion joints must be keyed to maintain the lateral stability of the retaining wall
- weep holes must be adequately sized and spaced to drain any ground water from behind the retaining wall and reduce the wall’s surcharge

Below are other means of changing grade. Note that they require greater horizontal distances than do retaining walls for similar drops in grade.

- earth embankment:
  - natural angle of repose for soil may require planted ground cover to prevent soil erosion
  - stone riprap
  - timber or concrete cribbing