DESIGN CRITERIA FOR THE SELECTION OF STRUCTURAL SYSTEMS

If you wish to create a building with a highly irregular form:

Choose systems with simple floor and roof framing that are fabricated mostly on site, such as

- Sitecast concrete using any slab system without beams or ribs (pages 105–121)
- Light gauge steel framing (pages 86–89)
- Platform frame (pages 47–63)
- Masonry construction with either concrete slab or wood light floor framing (pages 69–83)

If you wish to leave the structure exposed while retaining a high fire-resistance rating:

Choose structural systems that are inherently resistant to fire and heat, including

- All concrete systems (although ribbed systems may require added thickness in the ribs or slab, or an applied fireproofing) (pages 105–133)
- Heavy timber frame (pages 47–67)
- Mill construction (pages 69–83)

Structural steel is extremely susceptible to loss of strength in a fire and usually must be protected with a fire-resistive finishing system. For further information on the fire resistance of various structural systems and uses for which they are permitted, see pages 435–447.

If you wish to allow column placements that deviate from a regular grid:

Use systems that do not include beams or joists in the floor and roof structure, such as

- Sitecast concrete two-way flat plate or flat slab (pages 116–119)
- Metal space frame

If you wish to minimize floor thickness to reduce total building height or to reduce floor spandrel depth on the building facade:

The thinnest floor systems are concrete slabs without ribs, preferably prestressed, such as

- Sitecast concrete two-way flat plate or flat slab, especially when post-tensioned (pages 116–119)
- Precast prestressed hollow core or solid slab (pages 130–131)
- Posttensioned one-way solid slab (pages 112–113)

If you wish to minimize the area occupied by columns or bearing walls:

Consider long-span structural systems, such as

- Heavy wood trusses (pages 64–65)
- Glue laminated wood beams (pages 60–61)
- Glue laminated wood arches (pages 66–67)
- Conventional steel frame (pages 85–103)
- Open-web steel joists (pages 98–99)
- Single-story rigid steel frame (pages 100–101)
- Steel trusses (pages 102–103)
- Sitecast concrete waffle slab, particularly when posttensioned (pages 120–121)
- Precast concrete single or double tees (pages 132–133)

You may also wish to consider other long-span systems, such as specially fabricated steel beams, suspended systems, arches, vaults, and shells.

DESIGN CRITERIA FOR THE SELECTION OF STRUCTURAL SYSTEMS

If you wish to allow for changes to the building over time:

Consider short-span one-way systems that permit easy structural modification, such as

- Light gauge or conventional steel frame (pages 85–103)
- Any wood system, including those incorporating masonry construction (pages 47–77)
- Sitecast concrete one-way solid slab or one-way joist construction, excluding posttensioned (pages 112–115)
- Precast concrete solid or hollow core slab (pages 130–131)

If you wish to permit construction under adverse weather conditions:

Select a system that does not depend on on-site chemical processes (such as the curing of concrete or mortar) and that can be erected quickly, such as

- Any steel system (pages 85–103)
- Any wood system (pages 47–67)
- Precast concrete systems, particularly those that minimize the use of sitecast concrete toppings and grouting (pages 123–133)

If you wish to minimize off-site fabrication time:

Consider systems in which the building is constructed on site from easily formed, relatively unprocessed materials, such as

- Any sitecast concrete system (pages 105–121)
- Light gauge steel framing (pages 86–89)
- Platform frame (pages 47–63)
- Any masonry system (pages 70–77)

If you wish to minimize on-site erection time:

Consider systems using highly preprocessed, prefabricated or modular components, such as

- Single-story rigid steel frame (pages 100–101)
- Conventional steel frame, particularly with hinge connections (pages 85–103)
- Any precast concrete system (pages 123–133)
- Heavy timber frame (pages 47–67)

If you wish to minimize construction time for a one- or two-story building:

Consider systems that are lightweight and easy to form, or prefabricated and easy to assemble, such as

- Any steel system (pages 85–103)
- Heavy timber frame (pages 47–67)
- Platform frame (pages 47–63)

(continued)

If you wish to minimize construction time for a 4- to 20-story building:

Choose from the following systems

Precast concrete (pages 123–133)

Conventional steel frame (pages 85–103)

Once the structural components for either of the above systems are prefabricated, on-site erection proceeds quickly

Any sitecast concrete system (pages 105–121)

The absence of lead time for the prefabrication of components in these systems allows construction of the building to begin on-site at the earliest time.

If you wish to minimize construction time for a building 30 stories or more in height:

Choose a system that is strong, lightweight, prefabricated, and easy to assemble

Steel frame (pages 85–103)

Systems of precast and sitecast concrete are also becoming an economical alternative to steel frame construction in some regions.

The structural design of high-rise buildings is a specialized task, and the necessary consultants should be sought out as early as possible in the design process.

If you wish to minimize the need for diagonal bracing or shear walls:

Choose a system that is capable of forming rigid joints, such as

Any sitecast concrete system, particularly those with beams or deepened slabs around the columns (pages 105–121)

Steel frame with welded rigid connections (pages 85–103)

Single-story rigid steel frame (pages 100–101)

When depending on a rigid frame for lateral stiffness, the sizes of the framing members often must be increased to resist the added bending stresses produced in such systems.

If you wish to minimize the dead load on the building foundation.

Consider lightweight or short span systems, such as

Any steel system (pages 85–103)

Any wood system (pages 47–67)

If you wish to minimize structural distress due to unstable foundation conditions:

Frame systems without rigid joints are recommended, such as

Steel frame, with bolted connections (pages 85–103)

Heavy timber frame (pages 58–61)

Precast concrete systems (pages 123–133)

Platform framing (pages 47–63)

Welded steel frame, masonry bearing wall, and sitecast concrete frame are particularly to be avoided.

DESIGN CRITERIA FOR THE SELECTION OF STRUCTURAL SYSTEMS

If you wish to minimize the number of separate trades and contracts required to complete the building:

Consider systems that incorporate many of the functions of a complete wall system in one operation, such as

Masonry construction including Mill or Ordinary construction (pages 70–83)

Precast concrete loadbearing wall panel systems (pages 126–127)

If you wish to provide concealed spaces within the structure itself for ducts, pipes, wires, and other building mechanical systems:

Consider systems that naturally provide convenient hollow spaces, such as

Truss and open-web joist systems (pages 62–65, 98–99, 102–103)

Light gauge steel framing (pages 86–89)

Platform frame (pages 47–63)

Light gauge steel framing and platform frame construction are often applied as finish or infill systems in combination with other types of building structure to provide such spaces. For more information on the integration of building services and the structural system, see pages 168–183 and 196–215.

DESIGN CRITERIA: SUMMARY CHART

GIVE SPECIAL CONSIDERATION TO THE SYSTEMS INDICATED IF YOU WISH TO:	WOOD AND MASONRY				STEEL			
	Pages 47–63	Pages 47–67	Pages 69–83	Pages 69–83	Pages 86–89	Pages 100–101	Pages 85–103	Pages 85–103
	Platform Frame	Timber Frame	Ordinary Construction	Mill Construction	Light Gauge Steel Framing	Single-Story Rigid Steel Frame	Steel Frame—Hinged Connections	Steel Frame—Rigid Connections
Create a highly irregular building form	●		●		●			
Expose the structure while retaining a high fire-resistance rating		●		●				
Allow column placements that deviate from a regular grid								
Minimize floor thickness								
Minimize the area occupied by columns or bearing walls						●	●	●
Allow for changes in the building over time	●	●	●	●	●		●	●
Permit construction under adverse weather conditions	●	●			●	●	●	●
Minimize off-site fabrication time	●		●	●	●			
Minimize on-site erection time		●				●	●	●
Minimize construction time for a one- or two-story building	●	●			●	●	●	●
Minimize construction time for a 4- to 20-story building							●	●
Minimize construction time for a building 30 stories or more in height							●	●
Avoid the need for diagonal bracing or shear walls						●		●
Minimize the dead load on a foundation	●	●			●	●	●	●
Minimize structural distress due to unstable foundation conditions	●	●					●	
Minimize the number of separate trades needed to complete a building			●	●				
Provide concealed spaces for ducts, pipes, etc.	●		●		●			

DESIGN CRITERIA: SUMMARY CHART

GIVE SPECIAL CONSIDERATION TO THE SYSTEMS INDICATED IF YOU WISH TO:	SITECAST CONCRETE										PRECAST CONCRETE			
	Pages 112–113	Pages 112–113	Pages 114–115	Pages 114–115	Pages 116–117	Pages 116–117	Pages 118–119	Pages 118–119	Pages 120–121	Pages 120–121	Pages 130–131	Pages 130–131	Pages 132–133	Pages 132–133
	One-Way Solid Slab	Posttensioned One-Way Solid Slab	One-Way Joist	Posttensioned One-Way Joist	Two-Way Flat Plate	Posttensioned Two-Way Flat Plate	Two-Way Flat Slab	Posttensioned Two-Way Flat Slab	Waffle Slab	Posttensioned Waffle Slab	Solid Slab	Hollow Core Slab	Double Tee	Single Tee
Create a highly irregular building form	●	●			●	●	●	●						
Expose the structure while retaining a high fire-resistance rating	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Allow column placements that deviate from a regular grid					●	●	●	●	●	●				
Minimize floor thickness		●			●	●	●	●			●	●		
Minimize the area occupied by columns or bearing walls									●	●			●	●
Allow for changes in the building over time	●		●								●	●		
Permit construction under adverse weather conditions											●	●	●	●
Minimize off-site fabrication time	●	●	●	●	●	●	●	●	●	●				
Minimize on-site erection time											●	●	●	●
Minimize construction time for a one- or two-story building														
Minimize construction time for a 4- to 20-story building	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Minimize construction time for a building 30 stories or more in height														
Avoid the need for diagonal bracing or shear walls	●	●	●	●	●	●	●	●	●	●				
Minimize the dead load on a foundation														
Minimize structural distress due to unstable foundation conditions											●	●	●	●
Minimize the number of separate trades needed to complete a building														
Provide concealed spaces for ducts, pipes, etc.														

PRACTICAL SPAN RANGES FOR STRUCTURAL SYSTEMS

This chart gives practical span ranges for various structural systems. Greater or lesser spans may be possible in some circumstances. Page references are included where a system is covered in greater detail elsewhere in this book.

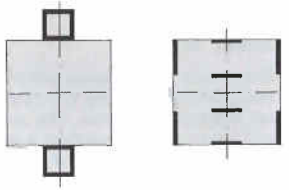
STRUCTURAL SYSTEM		Pages	Span Range: 10′ 3 m · 20′ 6 m · 30′ 9 m · 50′ 15 m · 100′ 30 m · 200′ 60 m · 300′ 90 m · 500′ 150 m
WOOD	Joists	54–55	
	Decking	52–53	
	Solid Beams	58–59	
	Rafter Pairs	56–57	
	Light Floor Trusses	62–63	
	Light Roof Trusses	62–63	
	Glue Laminated Beams	60–61	
	Heavy Trusses	64–65	
	Glue Laminated Arches	66–67	
	Domes		
BRICK & CONCRETE MASONRY	Lintels	74–75	
		82–83	
	Arches	77	
STEEL	Corrugated Decking	94–95	
	Light Gauge Joists	88–89	
	Beams	96–97	
	Open-Web Joists	98–99	
	Single-Story Rigid Frame	100–101	
	Heavy Trusses	102–103	
	Arches and Vaults		
	Space Frame		
	Domes		
	Cable-Stayed		
	Suspension		
SITECAST CONCRETE	One-Way Slabs	112–113	
	Two-Way Slabs	116–119	
	One-Way Joists	114–115	
	Waffle Slab	120–121	
	Beams	110–111	
	Folded Plates and Shells		
	Domes		
	Arches		
PRECAST CONCRETE	Slabs	130–131	
	Beams	128–129	
	Double Tees	132–133	
	Single Tees	132–133	
PNEUMATIC	Air Inflated		
	Air Supported		

CONFIGURING STABILIZING ELEMENTS

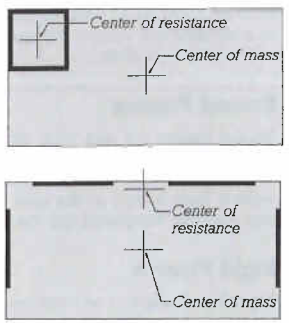
The proper arrangement of shear walls, diagonal braces, or rigid joints in a structure is crucial to their effectiveness in resisting lateral forces acting on the building. As illustrated in the adjacent schematic floor plans, these elements may be placed within the interior of the building or at the perimeter, and they may be combined in a variety of ways. However, they must be arranged so as to resist lateral forces acting from all directions. This is usually accomplished by aligning one set of stabilizing elements along each of the two perpendicular plan axes of a building. Stabilizing elements must also be arranged in as balanced a fashion as possible in relation to the mass of the building. Unbalanced arrangements of these elements result in the displacement of the center of resistance of the building away from its center of mass. Such a condition causes unusual building movements under lateral loads that may be difficult or impossible to control.

In general, considerations of lateral stability become increasingly important as the height of the building increases. The configuration of stabilizing elements is discussed in more detail on the following pages.

Stabilizing elements may be placed within the interior or at the perimeter of a building.



Stabilizing elements should be arranged in a balanced fashion.



Unbalanced arrangements of stabilizing elements result in the displacement of the center of resistance of the building away from its center of mass. Such arrangements should be avoided.

This chart indicates the methods of resisting lateral forces most appropriate to each structural system. More detailed information on the individual systems can be found on the pages noted in the chart.

STRUCTURAL SYSTEM		Pages	Rigid Frame	Semi-Rigid Joints w/Supplemental Braced Frames or Shear Walls	Braced Frame	Shear Walls
WOOD	Platform Frame	47–63			● Let-in bracing	● Panel sheathing
	Timber Frame	47–67			● Timber bracing	● Diagonal or panel sheathing
MASONRY	Ordinary Construction	69–83				● Masonry walls
	Mill Construction	69–83				● Masonry walls
STEEL	Light Gauge Steel Framing	86–89			● Strap bracing	● Panel sheathing
	Single-Story Rigid Steel Frame	100–101	● Parallel to frames only		● Perpendicular to frames	
	Conventional Steel Frame	85–103	● Requires welded connections	●	●	● Sitecast concrete
SITECAST CONCRETE	One-Way Solid Slab	112–113	○ May require added structure	●		
	One-Way Beam and Slab	112–113	●	●		
	One-Way Joist	114–115	●	●		
	Two-Way Flat Plate	116–117	○ May require added structure	●		
	Two-Way Flat Slab	118–119	○ May require added structure	●		
	Waffle Slab	120–121	●	●		
	Two-Way Beam and Slab	116–117	●	●		
PRECAST CONCRETE	Solid Slab	130–131	○		○ Uncommon	●
	Hollow Core Slab	130–131	○		○ Uncommon	●
	Double Tee	132–133	○		○ Uncommon	●
	Single Tee	132–133	○		○ Uncommon	●

● Recommended
○ Possible in some circumstances