System Selection and Design

from <u>Architectural Structures</u>, Wayne Place, Wiley, 2007:

STRUCTURAL DESIGN PROCESS

1.1 Nature of the Process

Architects have a huge array of issues to address in architectural practice. Among these are the following: keeping rain out of a building, getting water off a site, thermal comfort, visual comfort, space planning, fire egress, fire resistance, corrosion and rot resistance, vermin resistance, marketing, client relations, the law, contracts, construction administration, the functional purposes of architecture, the role of the building in the larger cultural context, security, economy, resource management, codes and standards, and how to make a building withstand all the forces to which it will likely be subjected during its lifetime. This last subject area is referred to as architectural structures.

Because of the extraordinary range of demands on an architect's time and skills and the extraordinary number of subjects that architecture students must master, architectural structures are typically addressed in only two or three lecture courses in an accredited architectural curriculum in the United States. These two or three lecture courses must be contrasted with the ten or twelve courses that will normally be taken by a graduate of an accredited structural engineering curriculum. This contrast in level of focus makes it clear why a good structural engineering consultant is a very valuable asset to an architect. However, having a good structural consultant does not relieve the architect of serious responsibility in the structural domain. All architects must be well versed in matters related to structures. The architect has the primary responsibility for establishing the structural concept for a building, as part of the overall design concept, and must be able to speak the language of the structural consultant with sufficient skill and understanding to take full advantage of the consultant's capabilities.

1.2 General Comments Regarding Architectural Education

Structural design is one of the more rigorous aspects of architectural design. Much knowledge has been generated and codified over the centuries that human beings have been practicing in and developing this field. This book gives primary attention to those things that are known, quantified, and codified.

However, very few things in the realm of architecture yield a single solution. To any given design problem, there are many possible solutions, and picking the best solution is often the subject of intense debate. Therefore, no one should come to this subject matter assuming that this text, or any text, is going to serve up a single, optimized solution to any design problem, unless that design problem has been so narrowly defined as to be artificial.

In design, there is always a great deal of latitude for personal expression. Design is purposeful action. The designer must have an attitude to act. Architecture students develop an attitude through a chaotic learning process involving a lot of trial and error. In going through this process, an architecture student must remain aware of a fundamental premise: the process is more important than the product; that is, the student's learning and development are more important than the output. The student has a license to make mistakes. It is actually more efficient to plow forward and make mistakes than to spend too much time trying to figure out how to do it perfectly the first time. To paraphrase the immortal words of Thomas Edison: To have good ideas, you should have many ideas and then throw out the bad ones. Of course, throwing out the bad ones requires a lot of rigorous and critical thinking. No one should ever fall in love with any idea that has not been subjected to intense and prolonged critical evaluation and withstood the test with flying colors. Furthermore, important ideas should be subjected to periodic reevaluation. Times and conditions change. Ideas that once seemed unassailable may outlive their usefulness or, at the very least, need updating in the light of new knowledge and insights.

In pursuing this subject matter, it is valuable to have a frame of reference regarding the roles of the architect, as the leader of the design team, and the structural engineer, as a crucial contributor of expertise and hard work needed to execute the project safely and effectively. The diagram in Figure 1.1 will help provide that frame of reference.

In contemplating the diagram in Figure 1.1, keep in mind that design and analysis are two sides of the same coin and that the skills and points of view of architects and engineers, although distinctive, also overlap and sometimes blur together. The most effective design teams consist of individuals with strong foci who can play their respective roles while having enough overlap in understanding and purpose that they can see each other's point of view and cooperate in working toward mutually understood and shared goals. The most harmful poison to a design team is to have such a separation in points of view and understanding that a rift develops between the members of the team. Cooperation is the watchword in this process, as in all other team efforts.

Structural Design

Predominantly the domain of the Architect

Structural Analysis

Predominantly the domain of the Engineer

Typical questions: What should the form be? What are the structural elements? How do the elements fit and work together?

Characterizations:
Artistic
"Feelable"
Emphasizes "soul"
Intuitive
Learnable
Chaotic
Trial-and-error learning process
Idiosyncratic and individualistic

Typical questions:

How big do the structural elements need to be?

What grade of material do we use?

How strong do the connectors need to be?

Characterizations:
Scientific
Knowable
Emphasizes "efficiency"
Analytic
Teachable
Orderly
Systematized
Generalized and codified

Figure 1.1 Nature of the design process and roles of the design participants.

Design Criteria for the Behavior of the Overall System

Components of a system consist of vertical and horizontal elements. Connections of the vertical to horizontal elements are also necessary. For the structural elements to behave and respond as designed, the system must have the following qualities:

- the components stay together
- the system resists overturning, sliding, twisting and excessive distortion
- the system has internal stability
- the system has overall strength and stiffness



"Order" of Design

There is no set order to design of a structural system. But there are certain stages that can be recognized. These may be referred to as *preliminary*, *revised* and *final*, or more formally as:

<u>First order:</u> which can include determining structural type and organization, design intent, and contextual or programmatic emphasis. Preliminary member size charts are useful at this stage.

<u>Second order:</u> which can include evaluating structural strategies, choice of construction materials, and structural system options with those materials. System selection design aids are useful at this stage.

<u>Third order:</u> which, after the design has been narrowed down, is where analysis and design (shape and size) of individual structural elements (beams, columns, connections, etc.) is performed. The outcome here may direct further first order or second order investigations!!!

from <u>Understanding Structures</u>, Fuller Moore, McGraw-Hill, 1999:

Precast concrete: double tee	Inherently fire-resistive construction	Simple, site-fabricated systems	Systems without beams in roof or floors	Precast-concrete systems without ribs	Short-span, one-way, easily modified	Quickly erected; avoid site-cast concrete	Easily formed or built on site	Highly prefabricated; modular components	Lightweight, easily formed or prefabricated	Precast, site-cast concrete; steel frames	Strong; prefabricated; lightweight	Capable of forming rigid joints	Lightweight, short-span systems	Systems without rigid joints	Multipurpose components	Systems that inherently provide voids	Two-way, long-span systems	Long-span systems
Precast concrete: single tee Precast concrete: single tee	200	-	_	QVI)	900				-						-			
Precast concrete: solid slab					M				\exists	e i						0153		
Site-cast concrete: wattle slab	W			-			W.			W		W						
Site-cast concrete: one-way joists																		
Site-cast concrete: two-way slab																		
Site-cast concrete: two-way plate					Mar angel							Na.						
Site-cast concrete: one-way slab								1000										
Steel space frame Steel decking							-		MAI.			-			\dashv			
Steel open-web joists								1911	8003	9779	N.				-			
Steel frame (rigid connections)												880	RIII.					
Steel frame (hinge connections)												-						
Masonry bearing wall							188								M			
Heavy-frame timber					3/1/									W				
Light-frame timber							W						M			172		
DESIGN CRITERIA	Exposed, fire-resiant construction	Irregular building form	Irregular column placement	Minimize floor thickness	Allow for future renovations	Permit construction in poor weather	Minimize off-site fabrication time	Minimize on-site erection time	Minimize low-rise construction time	Minimize medium-rise construction time	Minimize high-rise construction time	Minimize shear walls or diagonal bracing	Minimize dead load on foundations	Minimize damage due to foundation settlement	Minimize the number of separate trades on job	Provide concealed space for mech. services	Minimize the number of supports	Long spans

Figure 18.6: Framing system selection chart.

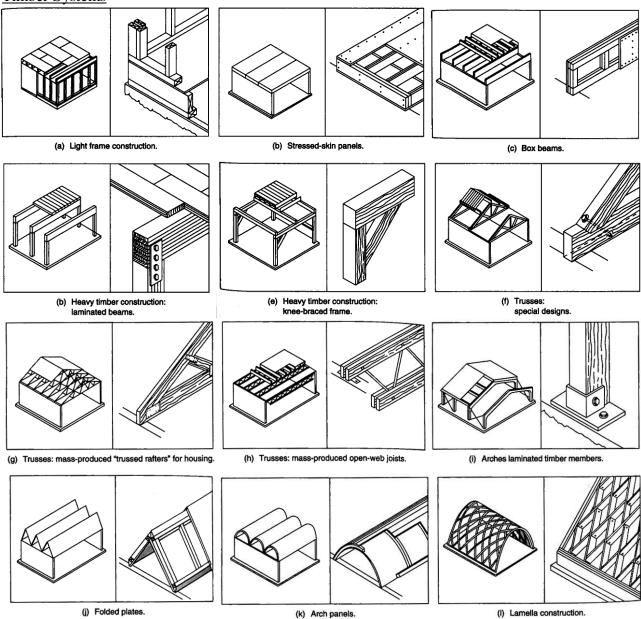
from The Architect's Studio Companion, 3rd ed., Allen & Iano, Wiley, 2002

SIGN CRITERIA: SUMMARY CHART																					
		WOOD AND MASONRY	AND			STEE	ا ر				IIS	SITECAST CONCRETE	CONCR	ETE				PRECZ	PRECAST CONCRETE	NCRE	ы
	Pages 49–65	49–69 49–69	Pages 71–85	Pages 71–85	Pages 88–91	Pages 102–103	87-105 Pages	87-105	Pages	Pages	Pages 116–117	116–117 Pages 118–119	118–119 P ages	120–121 Pages	120–121 Pages	Pages 122–123	Pages 122-123	Pages 132-133	Pages 132–133 Pages	134-135 Pages	134-132
GIVE SPECIAL CONSIDERATION TO THE SYSTEMS INDICATED IF YOU WISH TO:	Platform Frame	9msrT rədmiT	Ordinary Construction	Mill Constroction	Light Gauge Steel Framing	Single-Story Rigid Steel Frame Steel Frame	Hinged Connections Steel Frame—	Rigid Connections One-Way	Solid Slab Postfensioned	One-Way Solid Slab	Posttensioned	One-Way Joist Two-Way Flat Plate	Posttensioned Two-Way Flat Plate	Two-Way Flat Slab	Posttensioned Two-Way Flat Slab	Vaffle 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.	•		•		•																

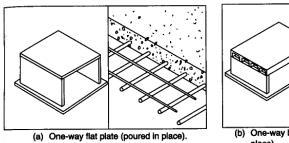
System Types by Material

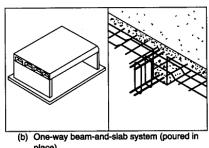
from Structures, Schodek & Bechthold, 6th ed.. Pearson, 2008:

Timber Systems

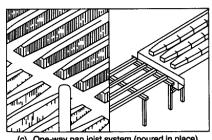


Reinforced Concrete Systems



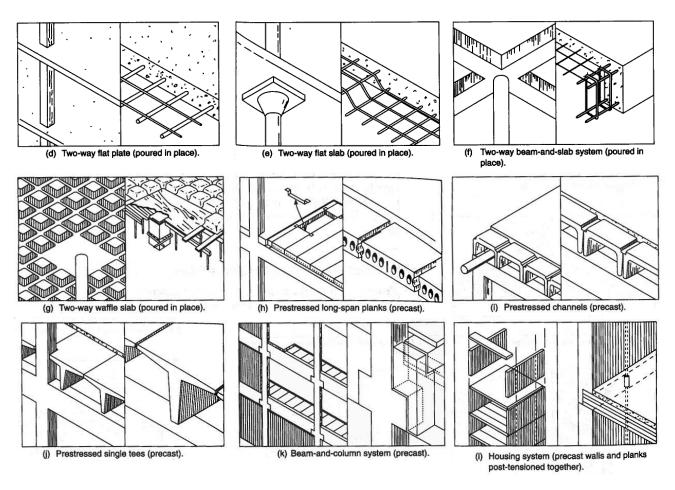


place).

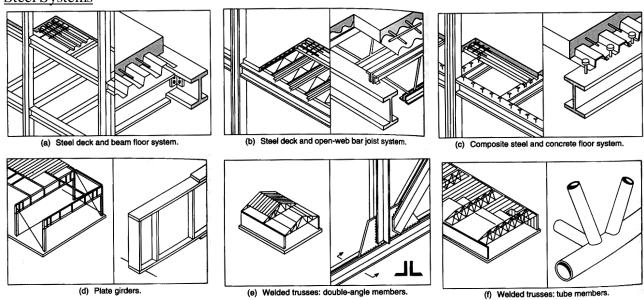


(c) One-way pan joist system (poured in place).

Reinforced Concrete Systems (continued)



Steel Systems



Steel Systems(continued)

