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.

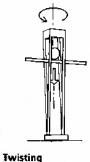
Structural Analysis Structural Design Predominantly the domain Predominantly the domain of the Engineer of the Architect Typical questions: Typical questions: What should the form be? How big do the structural elements need to be? What are the structural elements? What grade of material do we use? How strong do the connectors need to be? How do the elements fit and work together? Characterizations: Characterizations: Scientific Artistic "Feelable" Knowable Emphasizes "soul" Emphasizes "efficiency" Analytic Intuitive Teachable Learnable Orderly Chaotic Systematized Trial-and-error learning process Idiosyncratic and individualistic 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:

RATIONALE	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: double tee											,							15.15
Precast concrete; single tee					2000				_						\vdash	223234		
Precast concrete: hollow-core slab					1353 1574	1825) 1835)	-		-	(1) (1) (1) (1) (1) (1) (1) (1) (1) (1)	-					3/3		
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Site-cast concrete: one-way joists	2000		6000						\exists									
Site-cast concrete: two-way slab					100000													
Site-cast concrete: two-way plate					3//	1												
Site-cast concrete: one-way slab						5			2									
Steel decking																		
Steel space frame					200													
Steel open-web joists																		
Steel frame (rigid connections)														NAME OF TAXABLE PARTY.				
Steel frame (hinge connections)	8111	5115	-				1000					1833		600	2000	-	_	_
Heavy-frame timber Masonry bearing wall	1000 1000	NO.	_			9333	1033	1930	200	-	-		82330	610		_	_	
Light-frame timber	env		-		1277 1277	911	201	2010	NY.	-		-				15123	-	
sodmit emost tdei l		19330	-		10000	8333	2530	\dashv	3333				8113	833	1571	BASS		
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

SSIGN CRITERIA: SUMMARY CHART																					
		WOOD AND	AND			STEEI	н				SIT	SITECAST CONCRETE	CONCR	ETE				PREC	PRECAST CONCRETE	ONCRI	TE
	P ages	Pages	Pages 71–85	71–85	Pages 88–91	Pages 102-103	Pages 87–105 Pages	Pages P2-105	Pages	Pages	116-117	116–117 Pages 118–119	118–119 L 9des	ISO-ISI Pages	120–121 Pages	Pages 122–123	Pages 122–123	Pages 132–133	Pages 132–133	134–132 Bedes	134-132
GIVE SPECIAL CONSIDERATION TO THE SYSTEMS INDICATED IF YOU WISH TO:	Platform Frame	Timber Frame	Ordinazy Construction	Mill Constroction	Light Gauge Steel Framing Single-Story Rigid	Steel Frame—Steel Frame—	Steel Frame— Steel Frame—	Rigid Connections	Solid Slab Postfensioned	One-Way Solid Slab	Postfensioned	One-Way Joist Two-Way Flat Plate	Posttensioned Two-Way Flat Plate	Two-Way Flat Slab	Posttensioned Two-Way Flat Slab	Waffle Slab	Postfensioned Waffle Slab	dal2 bilo2	Hollow Core Slab	Donpje Lee	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.	•		•		•																
			-	1	-	1			-	$\frac{1}{2}$		-			1	1	1	1	1	1]