Session 1606

"Incorporating Structural Concepts into Beginning Architectural Design"

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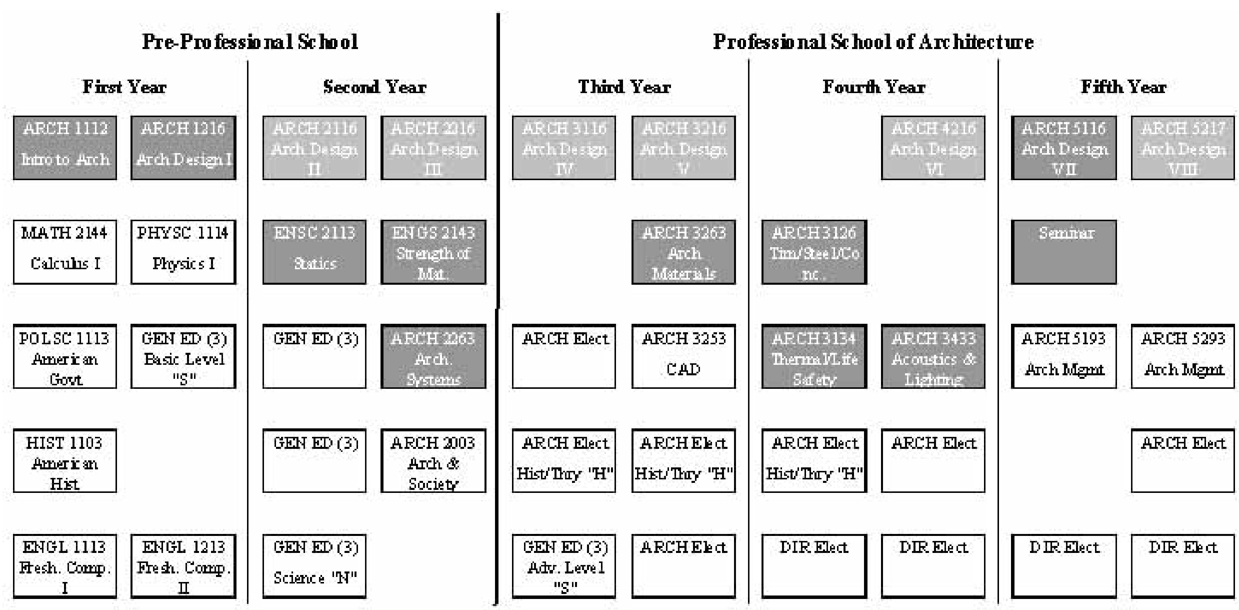
Abstract :

Architecture involves multiple disciplines that must coherently exist within a design. The structural aspects of buildings have significant impacts on the design process, and students must be able to incorporate structures in their design to be successful. It is crucial to a students education that structures be introduced early in the curriculum to expose the students to their effects on the design process.

The study of Architecture at Oklahoma State University is a combination of aesthetic and technical design involving multiple disciplines that must coherently exist within its context. The structural aspects of buildings have significant impact on the design process, and students must be able to incorporate structures in their design to be successful. It is crucial to a student's education that structures be introduced early in the curriculum to expose the students to their effects on the design process. Our belief is that the incorporation of structures into the first design studio is crucial in developing student's awareness of structural limits and effects on the design process of architecture. Once introduced, the student is expected to employ the structural concepts to their future design projects, as well as build on their knowledge of structures.



Architecture : Shading indicates level of Architectural Engineering Faculty contact/emphasis

Oklahoma State University's School of Architecture offers five year professional degrees in Architecture and Architectural Engineering. The first two years of the five year curriculum consist of the pre-professional program, in which architecture and architectural engineering students take primarily the same courses and major courses are taught mainly by faculty who are licensed architects. As the flow chart below illustrates, the curriculum is organized such that structural design courses do not begin until the third year of the program, after acceptance into the professional school.

Application is required for entrance into professional school, and only those students who meet the requirements are accepted. The student would be at a disadvantage if structures was not introduced until the third year of school, thus the incorporation of structures in the early design studios help give the students an understanding of structural issues and resultant effects of structural requirements on the design process.

The first semester freshmen course is titled "Introduction to Architecture", and is a two credit hour class that gives the student a rudimentary understanding of the study of architecture and design studio process. In this course, architecture and architectural engineering students are exposed to several design problems to give them a better understanding of the qualities and complexities of architecture. There are three exercises that involve the architectural engineering faculty and structural design issues. The first is an interview session with practicing professional architects and architectural engineers, and the second is a design problem focusing on architectural engineering design issues. The third is a curricular meeting discussing the requirements of both degree programs.

During the interview sessions, the studio professors arrange for practicing architects and engineers to meet with and be interviewed by the students. This is often the student's first experience with a practicing professional, and the first meeting with the architectural engineers or faculty, who participate in the interviews. The process of architectural engineering is

Arch 1112 Exercise Seven F02

School of Architecture Oklahoma State University

Interview a Professional!!!

Now is your chance! In a seminar setting, you and a group of your classmates will have the opportunity to meet a practicing architect or architectural engineer and learn about the professions from someone who is "in the trenches". Your challenge is to simply listen and ask questions... for example, your questions might be what kind of projects the architect or architectural engineer does, what are the 'highs' and 'lows' of being an architect or architectural engineer, how an architect and an architectural engineer work together, how the educational process prepares students to become architects or architectural engineers, what is it like working in an office, how much time does an architect or architectural engineer spend on a construction site... or any other questions you might have on your mind.

Remember, the professionals have volunteered their time to visit ARCH 1112 and discuss any questions you may have, so don't be shy!

Describe your experience, yes in your design journal, in a minimum of three pages, using architectural lettering. Be sure to record the name of the professional you met with, the the name of the firm he or she works with, and any other interesting facts the architect chose to share with you. Conclude your report with any comments you have on what you learned, and how it has affected your thinking about becoming a professional.

Due Date: beginning of class next week.
Reading Assignment: "State of the Profession"

"Interview a Professional"[1]

Arch 1112 Project Two F 02

School of Architecture Oklahoma State University

Construct "A Tower"

The practice of Architecture is a complex integration of aesthetic and technical systems that typically requires a team of experts in related fields working together to solve a design problem. The primary role of the architect is to work with a client to establish a design direction – a concept – that is a direct result of the project goals, the needs of the user group, and the vision of the architects and architectural engineers. Architectural engineers play an integral role in the creation of architecture, as they are responsible for the design and analysis of the required technical systems.

Imagine that you own an architectural engineering consulting firm, and have just been contacted by the architect of a prestigious international firm. She has hired you to propose a structural concept for a new tower to be built in New York City. The tower will occupy a prominent site on "Times Square", and will support the load of several billboards advertising various events in the city. Site constraints suggest that a high area to one side of the structure will be the most visible location for these advertisements.

The tower may be no taller than forty feet (20" in scale) and no shorter than thirty feet (15" in scale), but it will have to support a load that is cantilevered eight feet (4") outwards from the center of the main structure. The cantilevered load will be located near the upper reaches of the structure, at least thirty feet off the ground. The footprint of the structure must stay within a ten foot (5") diameter area, and pedestrians must be allowed to pass through the base of the tower at the ground level.

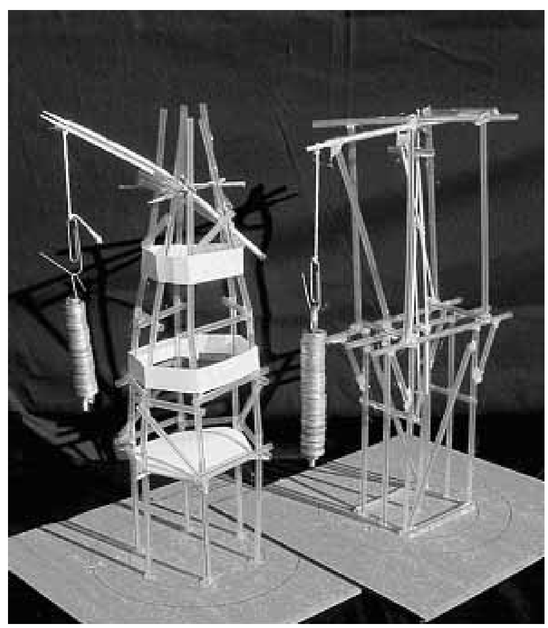
In the next hour, you and your teammates must propose an innovative structural concept to present to the architect. You will do so in model form, at ½"=1'-0" scale. All proposals will be evaluated for aesthetics, strength and durability. Structural soundness will be tested by Professors Steve O'Hara and John Phillips, both faculty of the Architectural Engineering program at OSU. Good Luck!

Project Due: **Structural Testing begins in one hour.... GO!**
Reading Assignment: **"A Museum of Substance"**

"Construct A Tower"[2]

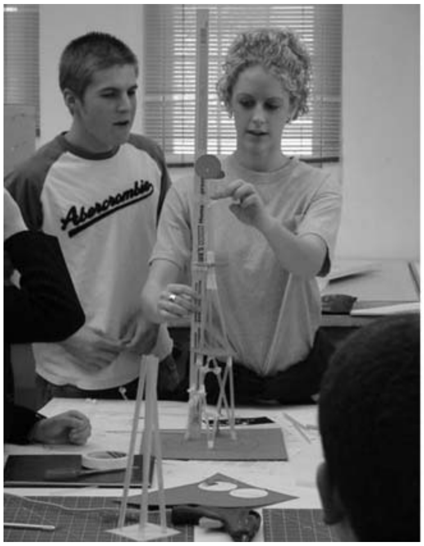
explained to the students, as well as insights into the demands, expectations, and rewards of the profession. Often, example projects are shown to the students to give them a better understanding of the type of work performed by the professional. Questions and discussions arise over topics varying from curriculum expectations, to types of firms available to work for upon graduation, to expected salaries and benefits. The outcome from these interviews is a written exercise performed by the students in which they document the interview and discuss what they have learned from the interview and how it has affected their thought on becoming a professional architect or architectural engineer.

The architectural engineering project for the introductory architecture course is a two hour sketch problem titled "Construct A Tower"[2]. This is a team project that promotes the concepts and ideas of teamwork in the profession while exploring the structural aspects of design. Students are separated into teams of 4 or 5 students, and are given the project requirements. A tower is constructed at the scale of 1/2" = 1'-0" utilizing a limited number of materials given to the student teams, and adhering to constraints set by the program. Constraints for the construction of the tower include tower attachment to a base within a set 5" diameter, the height of the tower being between 15" and 20", and the tower having a cantilever that extends a minimum of 4" outward beyond the base of the tower. Additionally, pedestrians must be able to pass through the base of the tower, and stick figures of pedestrians are given to the teams to test this requirement. The towers are to be built in such a way that a testing weight hung from the end of the cantilever will not cause the tower to collapse, or deflect excessively. The limited amount of building materials given to the students include a cardboard base to which the tower is to be attached, 2 sheets of cardstock, 25 straws, 2 small diameter wood dowels, and a small amount of string from which to hang the testing weights. Connections in the tower are allowed to be made with hot glue and masking tape.



Students work in teams to assemble towers during "Construct A Tower"[2]

The students attempt this project without formal training in structural concepts, but seek advise from the architectural engineering professors. Students utilize intuitive concepts to decide on how to construct the tower. It is intriguing to observe how the students interact within their teams. Some teams appear to start building their towers without much thought, while other teams are meticulous and plan all details before constructing their tower. Some teams are vocal with no discernible team leader, while others are dominated by one or two students. The time frame for the building of the towers is limited to approximately 60 minutes, so decisions are forced upon the teams and they adapt quickly to this situation. The approaches and results of the

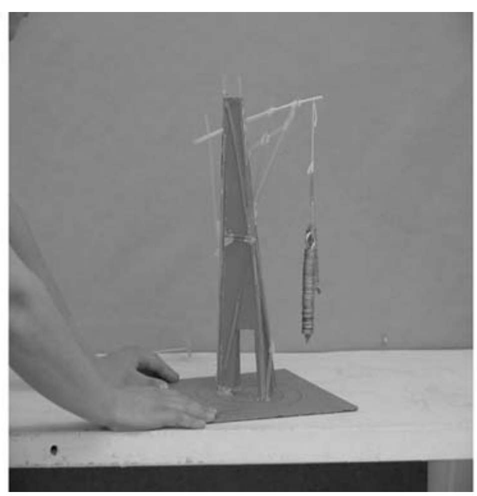


Construction of the tower

Load Testing – Excessive Deflection

teams vary widely, leading to much discussion during the testing phase of the project.
At the end of the construction time, the teams bring their towers to the front of the class to be tested. The students explain their tower, the structural concepts that were used during the planning and construction of the tower, and make a hypothesis on how the tower will react to the testing weights. The testing weights are broken into a lesser and a greater weight, and each are hung from the towers. Once the weights are applied to the tower, the effects of the weights can be discussed. For many, the result is not what they thought it would be, and some indeed fail or deflect excessively.

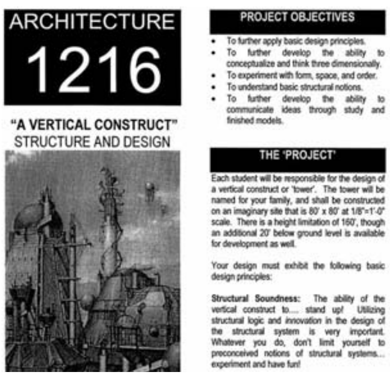
Construction of the tower



Load Testing – Successful Test

The architectural engineering professors discuss the structural concepts with the class during the testing phase of the project. Shearwalls, lateral bracing and rigid frames are discussed as well as torsion and diaphragms within a building system. Suggestions are offered that would make the towers more stable, and insight is given into the types of construction to avoid, such as hinge points along the height of the tower. By organizing the design problem in this way, the students participate well and are eager to learn what did and did not work with their design. This first exposure to structures in design is carried on into the second semester of the curriculum and is incorporated further into the design process.

The first architectural design studio is conducted in the second semester of the first year of study. This course, like all pre-professional design studio courses at Oklahoma State University, is a six credit hour course that meets for sixteen hours a week. Students work on a variety of design problems aimed at increasing their intuitive sense of order and design logic, including structural considerations. The course begins with a series of simple abstract design problems and increases in complexity throughout the semester. The design problems build on each other and are used to demonstrate ordering principles, patterns, and focal points within the designs. These initial problems give the students a background that is used in the design of the final two projects of the semester.


ARCHITECTURE

1216

"A VERTICAL CONSTRUCT"
STRUCTURE AND DESIGN

PROJECT OBJECTIVES

- To further apply basic design principles.
- To further develop the ability to conceptualize and think three dimensionally.
- To experiment with form, space, and order.
- To understand basic structural notions.
- To further develop the ability to communicate ideas through study and finished models.

THE 'PROJECT'

Each student will be responsible for the design of a vertical construct or 'tower'. The tower will be named for your family, and shall be constructed on an imaginary site that is 80' x 80' at 1/8"=1'-0" scale. There is a height limitation of 160', though an additional 20' below ground level is available for development as well.

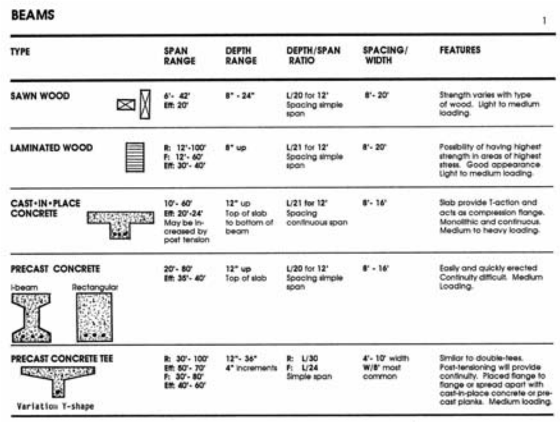
Your design must exhibit the following basic design principles:

Structural Soundness: The ability of the vertical construct to.... stand up! Utilizing structural logic and innovation in the design of the structural system is very important. Whatever you do, don't limit yourself to preconceived notions of structural systems... experiment and have fun!

Program : "A Vertical Construct"[3]   "Rules of Thumb for Preliminary Structural Design"[4]

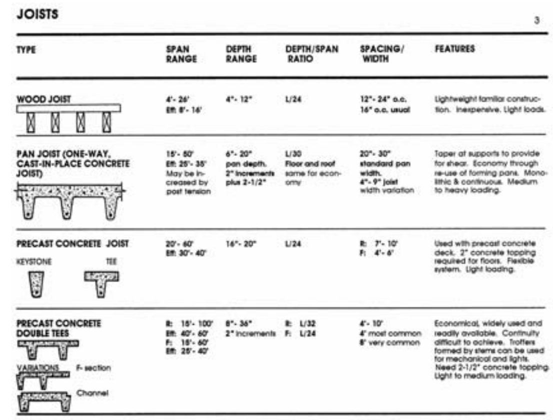
The first of these projects deals with the construction of a tower. The project, titled "A Vertical Construct"[3], is a two week project consisting of the design and construction of a tower utilizing basic design principles with a focus on the structural components of the tower. Architectural engineering faculty act as critics for the students, and offer advice on structural concepts and systems that can be utilized in the design and construction of the student's tower. Structural concepts such as shearwalls, vertical bracing, rigid frames, and cable supports are discussed and examples are shown. A document titled "Rules of Thumb for Preliminary Structural Design"[4] is provided to the students for use in properly representing the structural components of their tower in model form. This information consists of span to depth ratios for many of the structural systems available. The rules of thumb are set up primarily for gravity loads. Effects of combined forces are covered once the student has been admitted to the professional school.

Additionally, the architectural engineering professors discuss the concepts of floor and roof diaphragms, as well as continuity of structures required to ensure the structural stability of the



BEAMS 1

TYPE	SPAN RANGE	DEPTH RANGE	DEPTH/SPAN RATIO	SPACING/ WIDTH	FEATURES
SAWN WOOD	6'- 42' Eff: 20'	8" - 24"	L/20 for 12' Spacing simple span	8'- 20'	Strength varies with type of wood. Light to medium loading.
LAMINATED WOOD	R: 12'-100' F: 12'- 60' Eff: 30'- 40'	8" up	L/21 for 12' Spacing simple span	8'- 20'	Possibility of having highest strength in areas of highest stress. Good appearance Light to medium loading.
CAST•IN•PLACE CONCRETE	10'- 60' Eff: 20'-24' May be increased by post tension	12" up Top of slab to bottom of beam	L/21 for 12' Spacing continuous span	8'- 16'	Slab provide T-action and acts as compression flange. Monolithic and continuous. Medium to heavy loading.
PRECAST CONCRETE (I-beam, Rectangular)	20'- 80' Eff: 35'- 40'	12" up Top of slab	L/20 for 12' Spacing simple span	8' - 16'	Easily and quickly erected Continuity difficult. Medium Loading.
PRECAST CONCRETE TEE (Variation T-shape)	R: 30'- 100' Eff: 50'- 70' F: 30'- 80' Eff: 40'- 60'	12"- 36" 4" increments	R: L/30 F: L/24 Simple span	4'- 10' width W/8' most common	Similar to double-tees. Post-tensioning will provide continuity. Placed flange to flange or spread apart with cast-in-place concrete or precast planks. Medium loading.

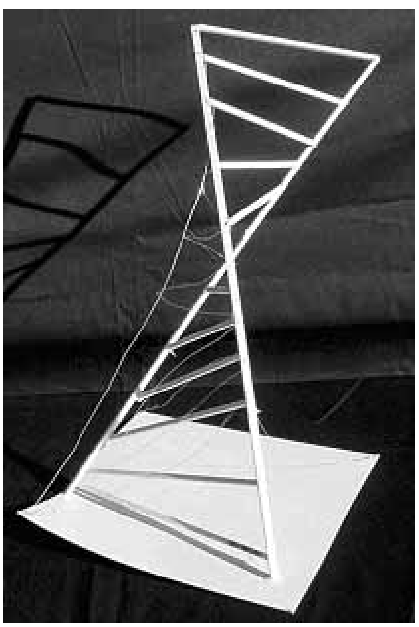


JOISTS 3

TYPE	SPAN RANGE	DEPTH RANGE	DEPTH/SPAN RATIO	SPACING/ WIDTH	FEATURES
WOOD JOIST	4'- 26' Eff: 8'- 16'	4"- 12"	L/24	12"- 24" o.c. 16" o.c. usual	Lightweight familiar construction. Inexpensive. Light loads.
PAN JOIST (ONE-WAY, CAST-IN-PLACE CONCRETE JOIST)	15'- 50' Eff: 25'- 35' May be increased by post tension	6"- 20" pan depth. 2" increments plus 2-1/2"	L/30 Floor and roof same for economy	20"- 30" standard pan width. 4"- 9" joist width variation	Taper at supports to provide for shear. Economy through re-use of forming pans. Monolithic & continuous. Medium to heavy loading.
PRECAST CONCRETE JOIST (KEYSTONE, TEE)	20'- 60' Eff: 30'- 40'	16"- 20"	L/24	R: 7'- 10' F: 4'- 6'	Used with precast concrete deck. 2" concrete topping required for floors. Flexible system. Light loading.
PRECAST CONCRETE DOUBLE TEES (VARIATIONS: F- section, Channel)	R: 15'- 100' Eff: 40'- 60' F: 15'- 60' Eff: 25'- 40'	8"- 36" 2" increments	R: L/32 F: L/24	4'- 10' 4' most common 8' very common	Economical, widely used and readily available. Continuity difficult to achieve. Trotters formed by stems can be used for mechanical and lights. Need 2-1/2" concrete topping. Light to medium loading.

Example pages from “Rules of Thumb for Preliminary Structural Design”[4]

towers. Through the interaction of the architectural engineering faculty with the beginning design studio, the student is exposed to structural concepts that can be used throughout their career.



Rough Study Model and Final Project of a “Twisted Ladder” structural concept.

At the annual Pig Roast celebration held at the end of Architecture Week in the spring semester at Oklahoma State University, the first year studio often has a one week sketch problem that culminates at the Pig Roast. In past years, this project has been titled “Can Buildings Fly?”[5]. The project is to build a kite that will fly, with the kite being modeled after one of a series of well known architectural buildings. This project involves working in teams to solve the problem, building and testing models and structural concepts to arrive at the solution.

ARCH 1216

SKETCH PROBLEM

Can Buildings Fly???

Your challenge for our annual School of Architecture Design Week is to make buildings fly… in the first official 1216 design studio kite flying contest!

PROJECT OBJECTIVES

- To gain an understanding of the basic principles of design evident in a classic work of modern architecture.
- To be able to interpret those same principles in a new way to meet a different set of requirements.
- To further develop design and presentation skills.
- To have fun!

PROJECT REQUIREMENTS

There are only two simple guidelines for this design challenge:

1. You must devise a flying contraption that is based upon the design composition (form/ space/ order) of one of the following famous buildings:
   - Altes Museum By Karl Frederick Shinkel
   - Assembly Bldg, Chandigarh By Le Corbusier
   - Glass House By Philip Johnson
   - Gwathmey House By Gwathmey Seigel Architects
   - Kauffman House "Fallingwater" By Frank Lloyd Wright
   - Kimbell Art Museum By Louis I. Kahn
   - Monastery at La Tourette By Le Corbusier
   - Robie House By Frank Lloyd Wright
   - Schroeder House By Gerrit Reitveld
   - Sydney Opera House By Jorn Utzon

   Consult your textbook, and search for other books in the library to find photos and descriptions of the building you select to interpret. These are all well documented, famous projects.

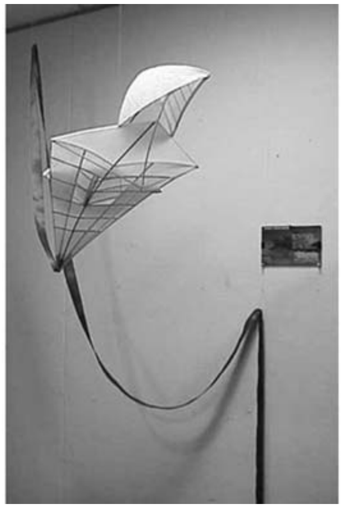
2. The contraption must be capable of being flown - via a string and a fast runner!!! (no motorized kites, please!) The kites will be graded this Friday afternoon, and then tested on Saturday at the annual Pig Roast. Good Luck!

EVALUATION CRITERIA

- Is the kite a beautifully designed interpretation?
- Can it fly (for at least 5 seconds)?
- Is it well crafted?

The kites are due this Friday at **3:00pm** for display in the hallway. The kite flying/testing will begin around 3:00pm Saturday at the Pig Roast – check publicity signs for directions to the picnic .... Go for it!!!

Can Buildings Fly???[5]



Kite : Sydney Opera House

Kite : In Flight

The kites are given the final test flight at the Pig Roast celebration. Some of the more successful kite designs have been based on Falling Water by Frank Lloyd Wright, and the Sydney Opera house by Jorn Utzon. The test flights result in spectacular successes, and spectacular structural failures. In both instances, the students are adding to their intuitive knowledge and experience of incorporating structural aspects into the design process.

The final design project of the first year studio is focused on the creation of a small building, such as a museum or artist studio. In this four-week project, students must apply all that they have learned about fundamental design principles including structural systems. Additionally, students often consult the architectural engineering faculty for advise and critiques of their design. Upon completion of the project, the students present their designs to a jury consisting of faculty members, including architectural engineering faculty. The student explains their structural system and receives feedback from the jury. This jury process is utilized through the five year curriculum, and benefits the student through open dialog with practicing professionals.

In the second year of the pre-professional student experience, students enroll in two consecutive architectural design studios. These studios stress that basic ordering principles be further applied to increasingly complex architectural problems designed to accommodate human activity. Structural system development is further incorporated into the design process, giving the students a better experience of incorporating structures into their designs. The project types include programmatic planning issues, vertical and horizontal circulation, simple structural systems layout, and site design. A listing of typical design problems given would include a golf clubhouse, a library, and a branch bank. Formal teaching is the responsibility of the architectural faculty, and on some projects architectural engineering faculty are available to the students for any questions they may have pertaining to the structural systems they are utilizing in their design.

The architectural engineering components of the curriculum are presented during the first semester of third year for the architectural engineering students and during the first semester of fourth year for architecture students. A six credit hour architectural engineering design studio covering the topics of timber, steel and concrete design is taken during this semester, as well as introduction into environmental controls design. The comprehensive structural course is positioned in the curriculum such that it is considered the studio course for the semester, and students can concentrate on the design of structures during this semester. Upon completion of these courses, the students continue their education while interacting with the architectural engineering faculty both informally and formally. Informally through seminars and critiques given to the fourth year studio design course, and formally through co-teaching the nine credit hour capstone design studio during the fifth year of the curriculum.

The architecture and architectural engineering student at Oklahoma State University are not formally taught structural design until the third year of the curriculum. It is important that the student be exposed to structural concepts and their effects on design from the beginning of their education at Oklahoma State University. With this exposure to structures at the beginning of the student's education, they may become aware of structural issues and maintain a realistic approach to incorporating the effects of structures into their design. As noted by Mario Salvadori, "Even though the functional and structural components of architecture are most often distinct, structure has always had a decisive influence on architecture."[6]. It is our belief that by incorporating structural concepts into the curriculum at the earliest stages, the students benefit from this exposure and adapt to the concepts of structures they can anticipate and celebrate the structure within their design.

1. Bilbeisi, Suzanne: "Interview a Professional", School of Architecture, Oklahoma State University.
2. Bilbeisi, Suzanne: "Construct A Tower", School of Architecture, Oklahoma State University.
3. Bilbeisi, Suzanne: "A Vertical Construct", School of Architecture, Oklahoma State University.
4. Womack, John: "Rules of Thumb for Preliminary Structural Design", School of Architecture, Oklahoma State University.
5. Bilbeisi, Suzanne: "Can Buildings Fly???", School of Architecture, Oklahoma State University.
6. Salvadori, Mario: "Why Buildings Stand Up – The Strength of Architecture", W.W. Norton & Company, Inc., 1980.

JOHN J. PHILLIPS, PE
John Phillips, an assistant professor of architectural engineering, was a volunteer instructor in the first semester "Interview a Professional" and "Construct A Tower" sketch problems, and in the second semester "A Vertical Construct" project. He also teaches Analysis I, Foundations, Timbers, Steel I, Steel II, and Steel III design courses. Professor Phillips is a registered engineer in the state of Texas, and a structural consultant for Brown Engineering.

STEVEN E. O'HARA, PE
Steven O'Hara, the Melvin R. Lohmann Professor in Engineering, teaches fundamental and advanced courses in Concrete and Structural Analysis, and advanced courses in Steel and Masonry. He is a licensed engineer in Oklahoma, with his primary practice in the design and analysis of reinforced concrete buildings.