EARTH AND ENGINEERING SCIENCES BUILDING

Justin Strauser – Structural option
Advisor: Professor Parfitt
Thesis Proposal
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Executive Summary

The Earth and Engineering Sciences building at University Park, Pennsylvania is a four story educational and laboratory facility. It was designed by Herbert Beckhard and was intended to be a part of his architecture legacy. The building itself is a pleasant site to the eye as it mixes the traditional Penn State brick theme with precast concrete panels and glass. A total floor area of 106,000 square feet is provided for multiple uses and is utilized primarily as an educational facility. The building features several class room spaces, computer and research labs, as well as a small auditorium. One of the signature points in the design is a lobby that ties the East and West wings of the building together.

The purpose of this thesis will be an attempt at correcting a flaw in the initial planning of the structure. The building was originally scheduled to house all mechanical equipment at the roof level and mask this equipment with parapets that would give an appearance of an added floor. However, as the planning stages progressed it was determined that the overall height needed to accomplish this feat would impose on restrictions set forth by local zoning authorities. This problem was corrected by adding extra basement space and moving the equipment into this additional space. An alternate floor system will be designed to correct this issue and allow the mechanical equipment to remain on the roof.

RAM and ETABS are two structural design software packages that will be utilized in the redesign of the structural system of the EES building. Three systems are under review as alternatives for the existing system. Multiple systems could be selected, but for this study a hollowcore plank floor, flat plate slab, and an A992 steel composite system will all be investigated. In order to complete the necessary analysis several references will need to be used. The AISC Manual for Steel Construction, ACI 318-05, IBC 2003, and ASCE7-02 will all be employed as guidelines for proper design of the aforementioned alternate systems. R.S. Means will also be referenced, as it will be needed to perform a detailed cost estimate of the alternative systems.

Two breadth topics will be researched and reported as part of the final solution to the problem being approached. The first will be to look at each floor system from the viewpoint of a construction manager. Each system will be rated on its' ease of constructability and overall cost of materials and labor. From this a comparison can be made on another level than strictly structural performance. Secondly, each system will be analyzed as to its' effects on architectural acoustics. Moving mechanical equipment will bring into play issues with noise and vibrations that will need to be considered when selecting a suitable floor and structural system.

Background

The Earth and Engineering Sciences building at University Park, is a four story educational and laboratory facility. It was designed by architect Herbert Beckhard, and was intended to be one of his monumental buildings. The building left a suitable legacy to Beckhard as it expressed his style through the use of mutlitone brick, precast panels, punch out windows and a beautiful lobby space. Most of the laboratory and educational spaces are located in the four above ground stories; with an additional basement level located below grade. The basement level provides the foundational elements of the structure and houses various mechanical equipment. The EES building encompasses a total of 106,000 square feet of usable space. The engineering and planning was performed on the most part by L. Robert Kimball and Associates as they took on a joint venture with Herbert Beckhard and Frank Richlan. The construction was contracted out to Leonard S. Fiore.

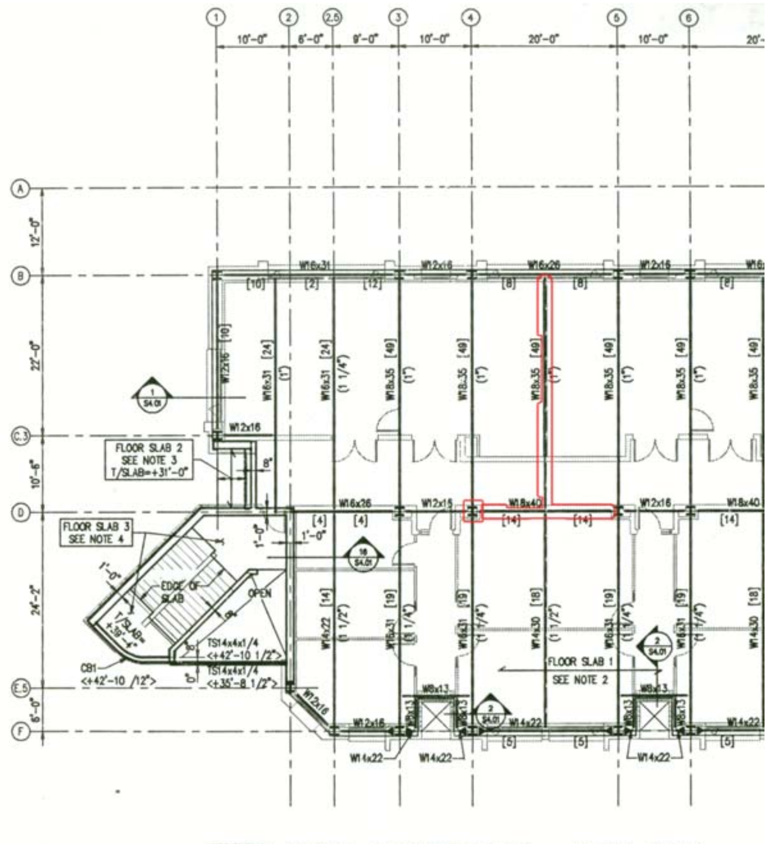
The structure consists of several types of materials and uses a composite design scheme. Steel is the primary design material, but it is employed integrally with various reinforced concrete elements. The structural steel and reinforced steel are either A36 or A572 grade, depending on the location and use.

The exterior walls are reinforced concrete, while some CMU does exist. Precast concrete panels on granite are used in conjunction with a brick veneer to complete the envelope of the structure. These envelope elements do not provide significant strength benefits however as they are anchored to the main structural system.

To fully describe the structural outlay of the EES building, it must be broken down by floors. While most floors are similar in design several variations do exist. The foundation is

primarily below grade and encompasses 16,535 square feet of usable area. This basement level is approximately 16 feet in height and houses most of the mechanical systems for the entire building. Two types of slabs are used in the basement: a slab on grade and a slab used in the stairwell. The slab on grade is 5 inches in depth and reinforced with welded wire fabric, while the slab used in the stair well is 8 inches in depth and reinforced with #4 rebar spaced at 12 inches. Both slabs are composed of concrete at 4,000 ksi compressive strength. To support columns and walls a plethora of spread footings and column piers are utilized. The size of the footings and piers varies according to the size of the element supported and the intensity if the load seen. All piers and footings are composed of concrete and reinforced with steel rebar. Included in the basement level are steel columns and reinforced concrete foundation walls. The steel columns are all A36 grade steel and range in size from W10 X 33's to W10 X 68's. The foundation walls, with the exception of the CMU walls used for the auditorium wing, are a concrete with #5 bars spaced at 8" in each direction.

The first floor becomes more spread out and the usable floor space increases to 25,922 square feet. The floor height at this level is 17 feet and 4 inches. This floor uses slabs similar to that of the foundation, as it was required to continue the stairwell and provide part of the foundation. Additional slabs were exploited in order to provide a workable floor system. These slabs were composed of lightweight concrete poured on top of 20 gauge galvanized steel decking. The two slabs vary in depth as different depth decking and pours were incorporated. Each slab was reinforced with welded wire fabric in the concrete pour. At the first level concrete beams and grade beams needed to be installed in order to support and tie in the concrete screen and veneer to the main structural elements. Steel columns for this floor are again A36 grade steel and span the entire length from the basement to the second floor or from a few concrete piers to the



THIRD FLOOR FRAMING PLAN – WEST WING

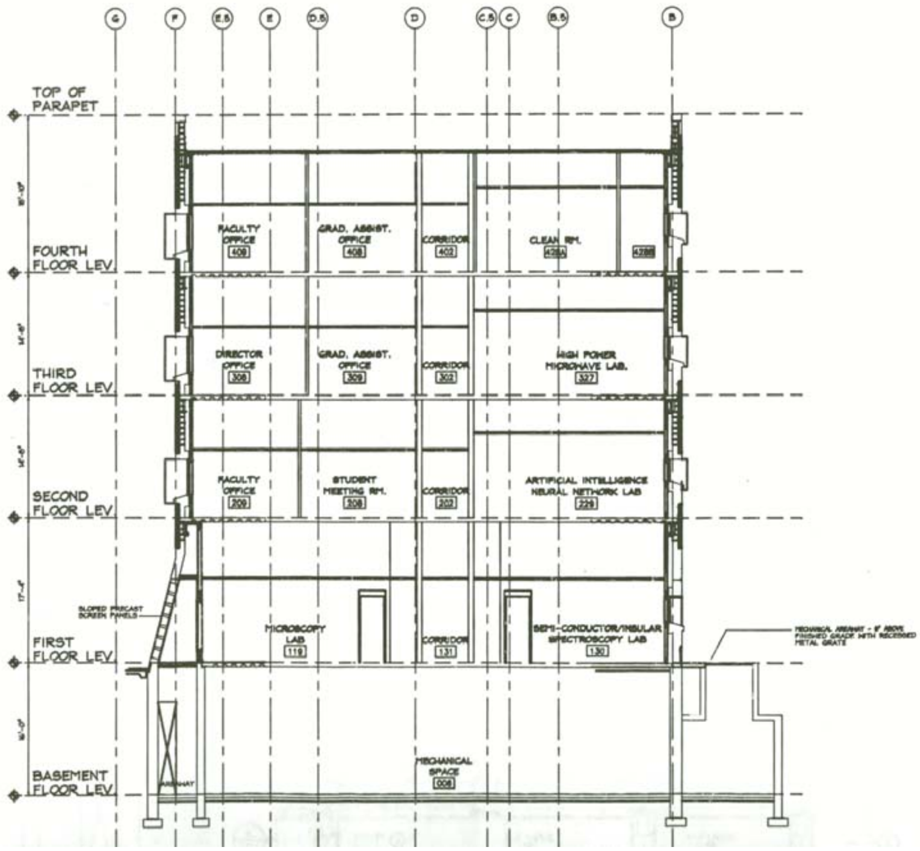
second floor. Sizes for these columns range from W10 X 33's to W10 X 60's. The primary element of the floor system is the steel beams. These beams are predominantly A36 grade steel and range from W8's to W21's with various sizes and weights in between. Span lengths are typically one of two lengths: 27 feet 4 inches or 32 feet 6 inches. All beams are spaced at 10 feet on center throughout this floor. To ensure composite action in the floor system, the steel beams are connected to the slabs by shear studs that are welded to the beam and extend into the slab. Finally, exterior walls are located around the perimeter of the building and are the same makeup as the foundation walls.

The second through fourth floors are very similar in layout and have few significant differences. The second and third floors both include around 19,410 square feet of open space while the fourth floor features 19,784 square feet. The height of these three floors is each 14 feet 8 inches. The two floor slabs present on the first level are again used on these upper floors with the addition of a 6 inch normal weight concrete slab reinforced each direction with #4's at 12 inch on center spacing. At the second level the steel columns from the basement and first floor are spliced to continue to the top. From the splice the new columns are sizes of W10 x 33, W10 x 39, or W10 x 45. Beams at these levels are mostly A36 grade steel, but there are a few cases where A572 grade steel is used at a size of W24 x 84. The remaining beams range from sizes of W8 x 13 to W21 x 50, again with various depths and weights being employed. The same exterior walls are used at these levels as are used throughout the rest of the EES building.

The roof of the structure is composed of several steel joist sizes used in conjunction with steel beams. Only one type of roof decking is present, a 1 ½ ", 20 gauge galvanized metal roof deck, type "B". The primary loading the roof will see is small live loads and snow.

Lateral loads in the Earth and Engineering Sciences Building are resisted by a number of concrete shear walls. These shear walls are located around the central core of the building around elevator shafts and stairwells. Additional shear walls are also located at the outermost Eastern-Western points of the building around two more stairwells.

Statement of the Problem:



The EES building faced several design issues on its' way to completion. One consideration was how to handle the mechanical equipment that would be needed to maintain the building. Air handling units, chillers, and water heaters would all need to be placed in an area that would not impose on the visible appearance of the structure. It was originally planned to place these elements on the roof and hide them with pseudo walls and screens. However, the height restrictions for this particular zoning area would not allow this and the mechanical equipment was moved to another location. The basement was expanded in order to make room for some of these items. This seemed to be an expensive solution to the problem, but was an effective and quick solution. If a structural system was designed to allow this equipment to remain on the roof and not expand the basement it could prove to save a great deal of time and money. In order to accomplish this feat a new alternative structural system must be designed in order to maintain the original design. The new system must allow the mechanical equipment to remain on the roof without altering the floor to floor height of the interior spaces. The system selected will need to support this additional weight and limit vibration issues. It may be possible not to alter the lateral resisting system as it is only present in sections of the building that were including in the original design. Whatever solution is selected it must be able to correct the problem and save money when compared to what was originally done.

Proposed Solution of the Problem

Alternative #1 will be a prestressed hollow core plank floor with 2” of topping, illustrated in Figure 1. The floor will be supported by 12RB36 rectangular prestressed beams. The beams will tie into reinforced concrete columns that will change per location as needed. The floor to floor height will be maintained as shown in the above sections regarding the structural system. The lateral load resisting system will remain unchanged. It will consist of a number of reinforced concrete shear walls throughout the central core of the building, stairwells, elevator and mechanical shafts. Floor loads will be calculated by live loads provided in the IBC 2003 code, these are illustrated in the figures in Appendix A.

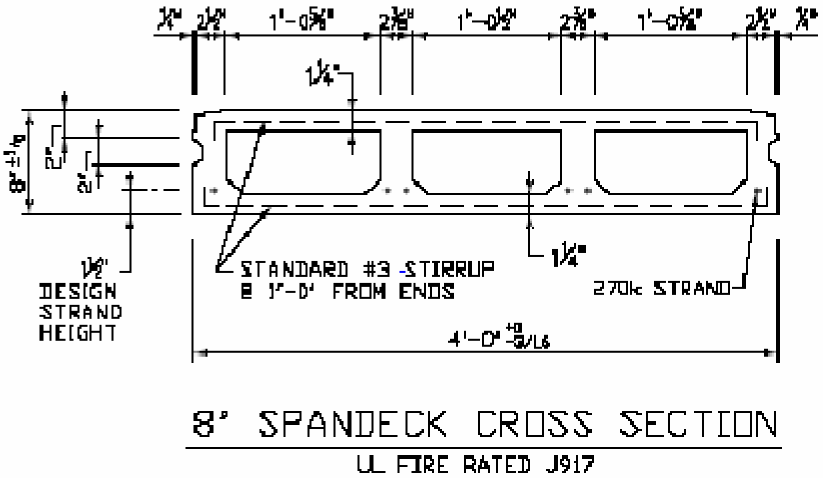


Figure 1

The second alternative solution is to employ a flat plate concrete slab system. This alternative was not investigated as a possibility in Technical Assignment 2, but may be a suitable choice for what is hoped to be accomplished in the problem solution. If a slab can be designed to support the loads of the entire structure and reduce the floor system height as well it must be considered.

Additional alternatives will need to be investigated for consideration. One such possibility will be to use a stronger grade steel to try to reduce beam depth and in turn reduce the floor depth.

Solution Method

The prestressed hollowcore and supporting beam members will be selected in accordance with PCI handbook. From the handbook trail members will be selected for the various loading conditions. These selections will be inputted into ETABS in order to perform a full analysis. If steel beams are used as opposed to prestressed concrete an alternate analysis program may need to be considered. Loads will be altered to include investigations of fully and partially loaded bays under various live load patterns. Further analysis will be performed to determine vibration qualities of the structural system.

The flat plate slab will be designed in accordance to the current ACI 318-05 code and the equivalent frame method. The analysis for this system will again be done in ETABS in the same manner as the prestressed hollowcore.

Lastly, the higher grade steel alternative will be investigated and analyzed in RAM similar to what was performed in Technical Assignment 2. The analysis will be more thorough and will encompass the entire building as a 3d model instead of just a two bay simplification of the structure. This will be performed in accordance with the LRFD and AISC Manual for Steel Construction.

These alternatives will all be compared on the basis of their performance versus cost and depth issues. The system that proves to be the most efficient option will then be completely designed and presented. The structural system then will be laid out in a way to ensure the positioning of the mechanical equipment on the roof level. As a result some changes to the architectural appearance of the building at this level will need to be adjusted to tie in closer to that of the original design.

Breadth Studies

Throughout the redesign of the EES building two breadth topics will be considered. The first of these topics is that of a construction management aspect of the architectural engineering practice. Construction management among other things considers cost of construction and erection times. These two topics will be investigated in this study as the alternative system is designed. A detailed cost estimate for both the original and alternate system will be completed and contrasted. Constructability and scheduling issues for each system will be looked at to see how much of an influence they would have on the selection of an efficient structural system.

The second breadth topic will be that of architectural acoustics. As building materials change the overall effect that is felt from an acoustical standpoint will be drastically altered. The alternate system being considered will change from a predominant steel structure to a concrete structure, having a direct effect on the acoustics of each space. Also, reducing floor depths will decrease the amount of buffer zone that is available to absorb noise between floors. The most probable cause for acoustical problems may be moving the mechanical equipment to the roof where vibrations can be more easily felt throughout the building if not properly dealt with.

Tasks and Tools

I. Hollowcore and Prestressed Beam Alternative

Task 1. Establish Trial Member Sizes
  a) Determine beam sizes based on PCI handbook
  b) Determine Hollowcore plank sizes based on PCI handbook
  c) Determine beam sizes based on LRFD and AISC manual
  d) Evaluate most efficient beam and hollowcore configuration based on R.S. Means
Task 2. Determine initial loading
  a) Find self weight based on above member sizes
  b) Find superimposed dead loads based on existing plans
  c) Find live loads on the Basis of IBC 2003
  d) Find wind loads based on IBC 2003 in conjunction with ASCE7-02
  e) Find snow loads based on IBC 2003 in conjunction with ASCE7-02
Task 3. Complete frame analysis by means of ETABS

II. Concrete Beam and Flat Plate Slab Alternative

Task 1. Establish Trial Member Sizes
  a) Determine beam sizes based on ceiling height and ACI 318-05
  b) Determine slab thickness based on ACI 318-05
  c) Determine most efficient beam and slab configuration based on R.S. Means
Task 2. Determine initial loading
  a) Find self weight based on above member sizes
  b) Find superimposed dead loads based on existing plans
  c) Find live loads on the Basis of IBC 2003

d) Find wind loads based on IBC 2003 in conjunction with ASCE7-02
e) Find snow loads based on IBC 2003 in conjunction with ASCE7-02

Task 3. Complete frame analysis by means of ETABS

III. A992 Steel Beams with Composite Concrete Slab

Task 1. Establish Trial Member Sizes
a) Determine beam sizes based on AISC Manual for Steel Construction
b) Determine slab characteristics based on AISC Manual for Steel Construction
c) Determine most efficient beam and slab configuration based on R.S. Means

Task 2. Determine initial loading
a) Find self weight based on above member sizes
b) Find superimposed dead loads based on existing plans
c) Find live loads on the Basis of IBC 2003
d) Find wind loads based on IBC 2003 in conjunction with ASCE7-02
e) Find snow loads based on IBC 2003 in conjunction with ASCE7-02

Task 3. Complete frame analysis by means of RAM

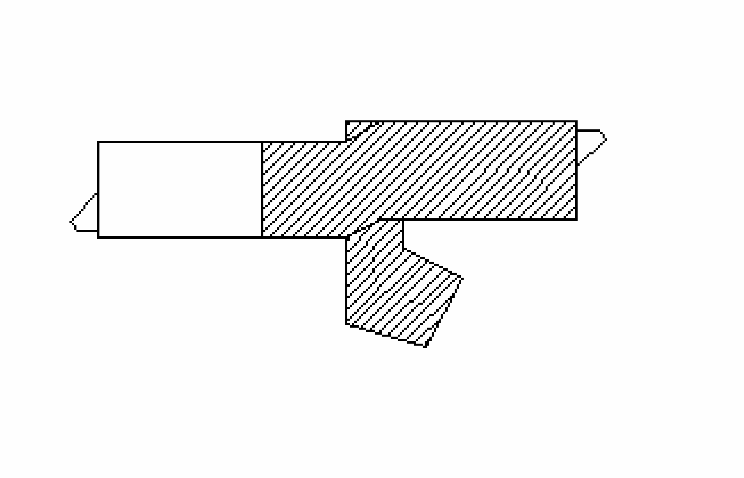
IV. Compare each System on Performance, Efficiency, and Acoustical Value

Thesis Timetable

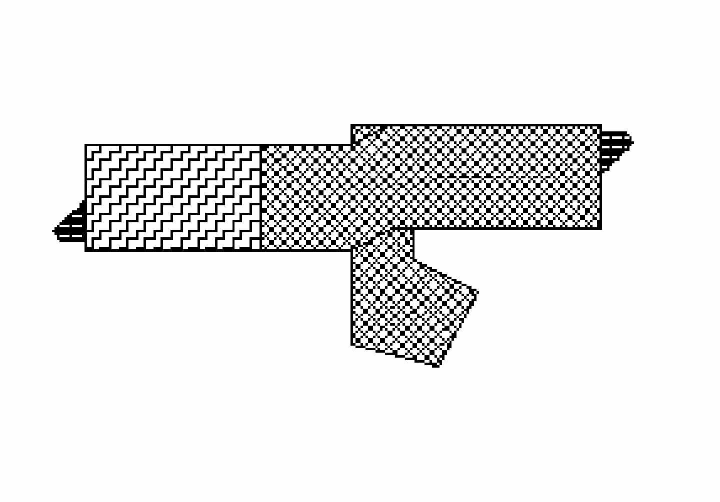
Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Loads Selected	🟥															
Alterntive 1 Trial Sizes		🟥														
ETABS Model Complete	🟥	🟥	🟥	🟥												
Alternative 1 Analyzed					🟥											
Alternative 2 Trial Sizes						🟥										
Alternative 2 Analyzed						🟥										
Alternative 3 Trial Sizes							🟥									
Alternative 3 Analyzed							🟥									
Systems Compared								🟥		🟥						
Breadth Topics Investigated										🟥	🟥					
Presentation Prepared											🟥	🟥	🟥	🟥		
Presentation														🟥		
Review															🟥	🟥

APPENDIX A
Drawings not to scale
Live Loads

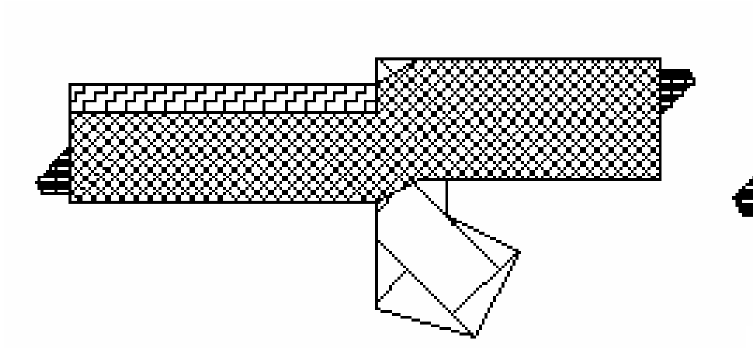
Basement



1st Floor



2nd Floor



3rd – 4th Floor