Drexel University Race Street Dormitory

THESIS PROPOSAL

Doug Tower

Structural

Advisor: Kevin Parfitt

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I. Executive Summary

Drexel University's Race Street Dormitory project began with Drexel requesting a 10 story suite-style residence hall. The original architectural design consists of an L-shaped building, 12 stories and approximately 120 ft high, with 10 stories of 12 student suites, each with 4 students and 1 resident assistant suite per floor. The ground floor and first floor are much smaller in plan than the upper floors and house public and service spaces such as the lobby, mail room, common rooms, resident assistant room, mechanical rooms, etc.

The building has been designed structurally with speed of construction and floor height in mind. The original design is a steel frame with pre-cast pre-stressed hollow core planks with concrete topping for a depth of 10", as well as brace frames and moment frames for lateral load resistance.

This thesis will be to find the best concrete structure as a replacement for this building. Three alternatives will be studied- 1) concrete columns in the original column grid with post-tensioned cast-in-place flat slab and shear heads 2) an altered concrete column grid into two smaller square bays and a very narrow rectangular middle bay with a cast-in-place filigree system flat slab and 3) concrete walls and slabs using Tunnel Form construction. Shear walls will also be designed for the lateral system of the flat slab systems. The ADOSS program will be used to find sizing, and initial comparison will be done based on a typical bay. Each system will be evaluated based on slab thickness, column or wall size and interference, and cost before the best one is chosen for comparison with the existing steel design.

Two breadth studies will be done on the chosen system in comparison to the existing design. The first will be a cost estimate and time schedule. The second will be an acoustic analysis, comparison, and improvement between suite and suites/hallway interfaces.

II. Introduction

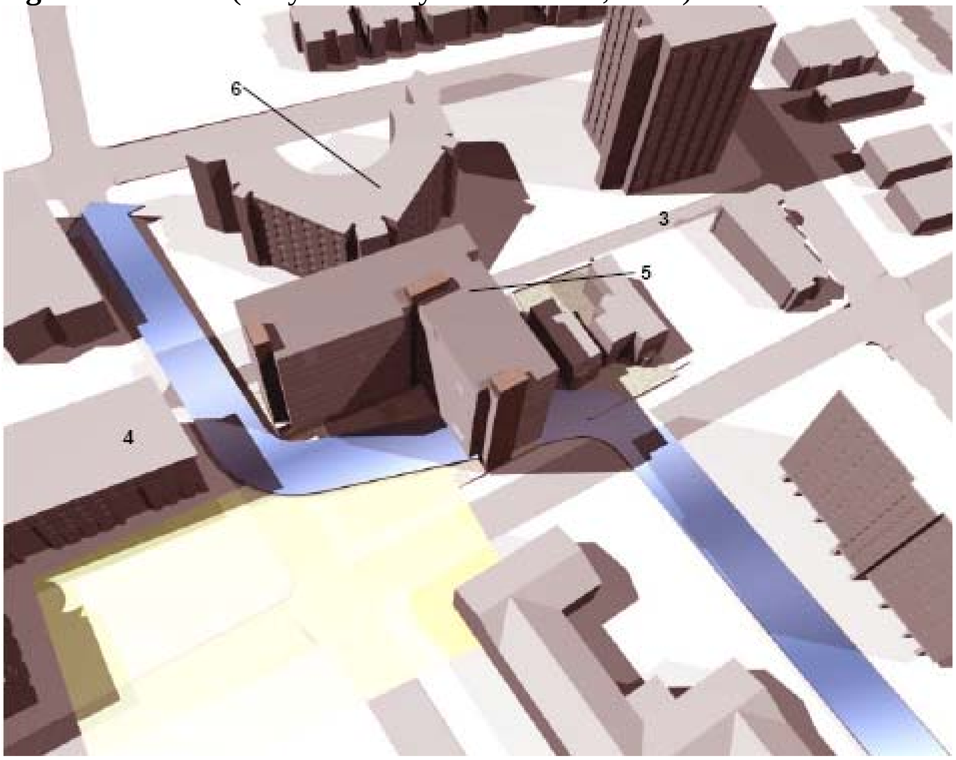
The existing steel structure is well designed, both in terms of quality, cost, and speed of construction. The intent of this thesis redesign is to explore concrete options more thoroughly, find benefits within an alternative structural system and side effects. Technical report 2 was limited to studying alternative floors in a general sense; the first part of the spring semester will be dedicated to more detail and the impact of an alternative structural system on construction of other aspects of the building.

III. Background

i. Design

This dormitory was designed in order to accommodate the needs of Drexel University, who planned a design-build project in order to fast track construction. The university requested a residence hall with 10 stories of suites with 11 to 13 suites per floor and 4 students per suite. The building also needed to accommodate Resident Assistants and other space needs, including a lobby, mail room, etc. The original architect designed the building in an L-shape in order to architecturally respond to another residence hall, North Hall, and accommodate future circulation patterns of the university. A major factor that influenced the structural design was speed, and fast tracking and prefabricated members were used. Floor to floor heights were especially critical to keep building height to a minimum. See figure below:

Figure: *Site Plan* (Erdy McHenry Architecture, 2006)



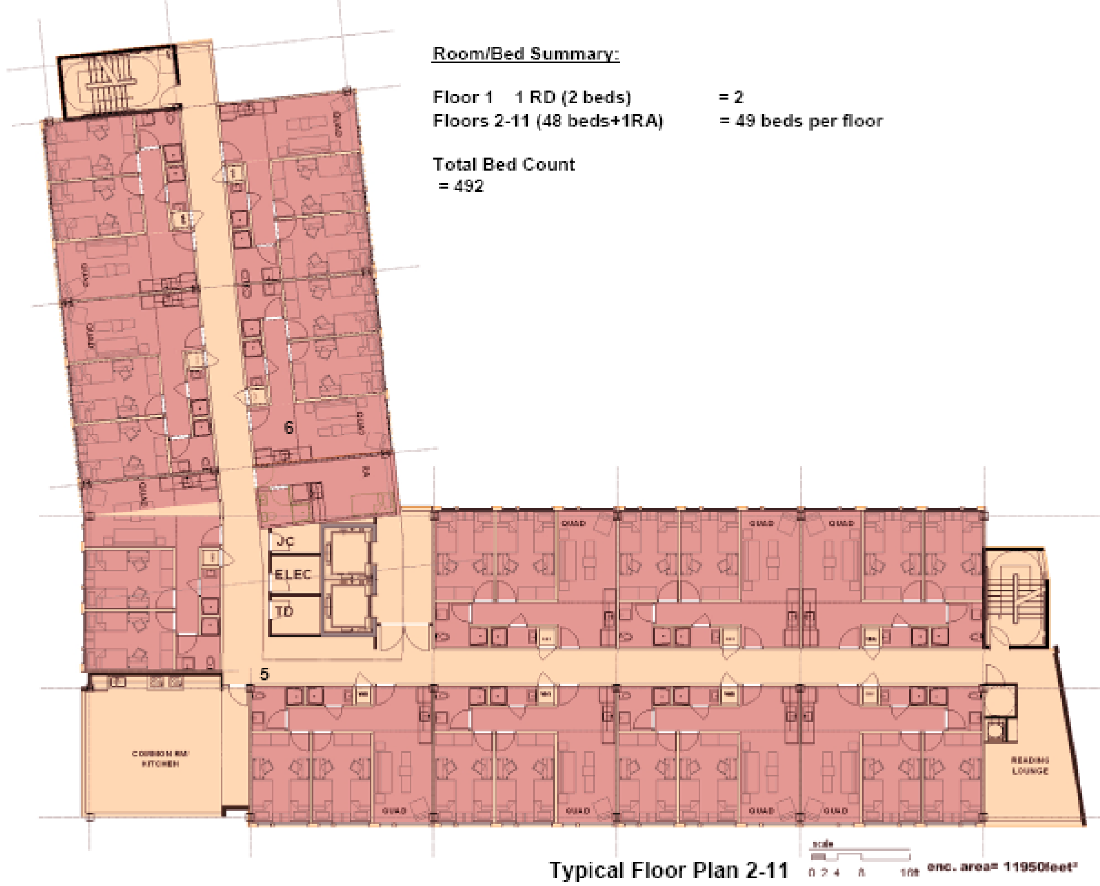
Legend:
North Hall = #4,
Race Street Dormitory = #5,
Blue line is future circulation pattern.

ii. Existing Building

The Race Street Dormitory is a twelve story, 120 ft high steel framed building with wind and seismic loading corresponding to Philadelphia, PA. As discussed earlier, the dormitory is an ‘L’ shaped building with legs roughly 116 ft and 165 ft long that veer 4 degrees off a right angle at one point. At its lowest level above grade, the building consists of only part of one leg of the ‘L’ shape- a roughly rectangular length running east-west. This ground level consists of mechanical rooms, an electrical room, and maintenance rooms as well as a shop and bicycle room. This floor is abutted against a higher grade (one story higher) on which sits the shorter wing of the building on free standing columns. Figure 1 shows some of the flooring at this level and the piers for the free standing columns. An enclosed first floor lies on the footprint of the ground floor and contains the main entrance lobby, a security entrance, a mailroom, a Resident Assistant suite, and a large common room. The second floor and consecutive floors form the main “L” shape of the building. These floors have a central hallway with rows of suites on either side. Suites have two bedrooms, common room, two showers, two baths, and kitchenette. There are three elevators at the south-east corner (bend) in the building, two of which begin at the ground story level. There are two stairways at the far north and east ends of the building. (See figures below)

Figure: *First Floor Architectural Plan* (Erdy McHenry Architecture, 2006)

Figure: *Typical Architectural Floor Plan* (Erdy McHenry Architecture, 2006)



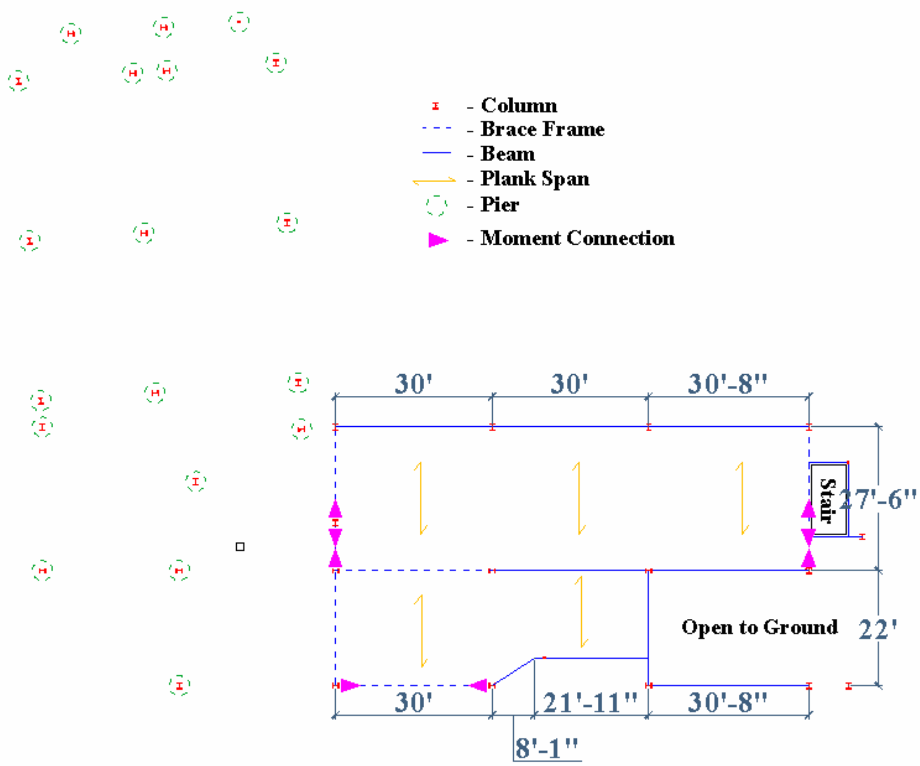
iii. Existing Structural System

The residence hall is mainly a steel W-shaped column and beam frame with moment connections, moment frames, braced frames. The floor to floor heights are 9’4” for floors two through eleven, 14’ for level one, and 10’ for ground level. (See figure 5 for height layout) Beams run predominately longitudinally along the building, as floor planks span two horizontal bays. (See figures 1-3) Beam sizes are mainly W12 or W18, and span up to 30’8”. The third through eleventh floors have identical beam systems, while the beams at the first and second floors are unique and generally larger.

The roof is flat and consists of mainly W12 purlins spaced 6’ on center and Grade 33 structural galvanized steel decking supporting EPDM single-ply membrane roofing over rigid insulation.

Each floor consists of pre-stressed pre-cast hollow core concrete planks 8” deep, typically 8’ wide with 2” cast-in-place concrete topping. (See figures 1-3) The planks are typically 22’8 or 28’2” long (8” overhang typical). The maximum depth of the floors is about 28” (roughly 18” beams, 8” decking, and 2” leveling slab), but, as noted before, beams do not frame each bay of the system, and are not intermediately placed within bays. This allows for up to 90’ expanses of 10” deep flooring uninterrupted by beams (see fig. 3).

Figure 1 - First Floor Framing Plan



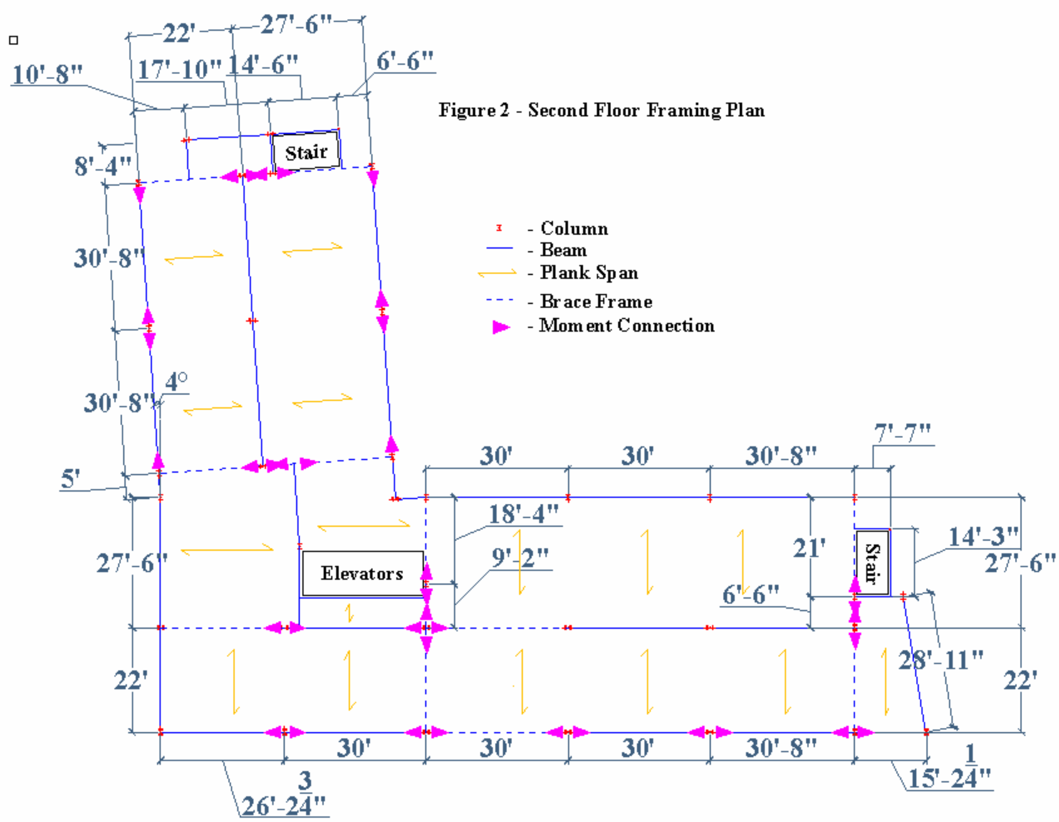


Figure 2 - Second Floor Framing Plan

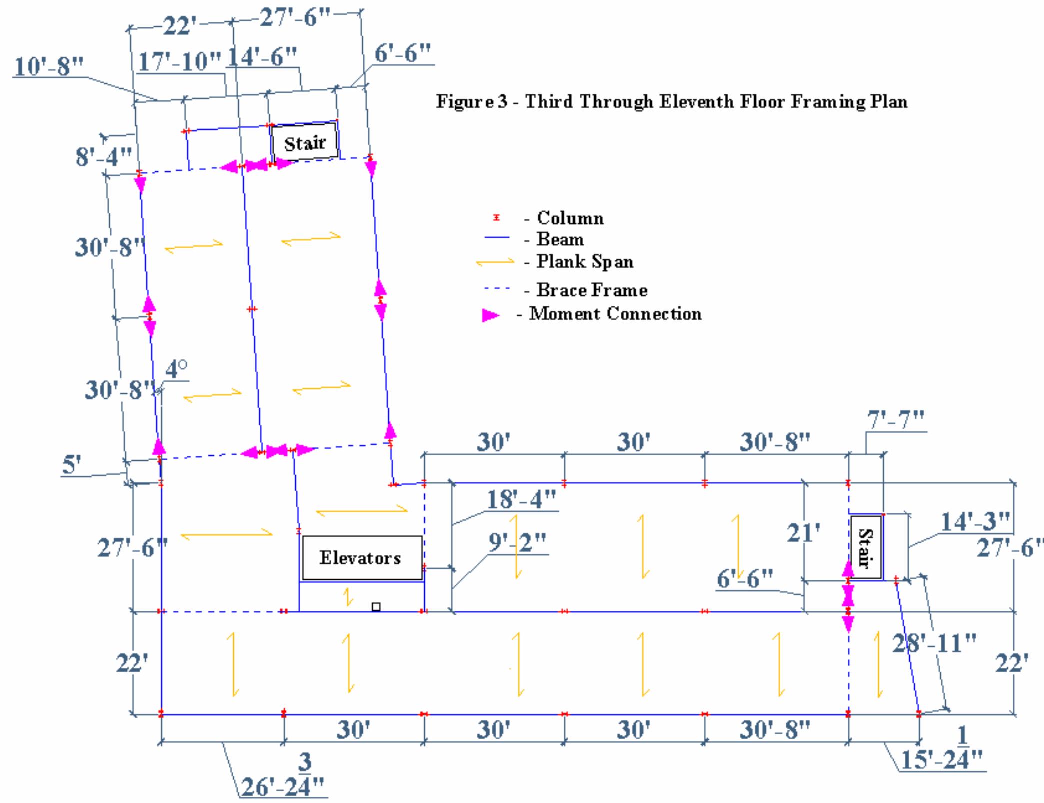


Figure 3 - Third Through Eleventh Floor Framing Plan

iv. Lateral Load Resisting System

The lateral load resisting system is a series of diagonally braced frames with moment connections and moment frames. The two wings of the building were designed with separate lateral systems. The moment frames were used when brace frames would not work for architectural reasons (along exterior walls). Brace frames were designed to accommodate hallways down the center of the building, and lobbies and other open spaces. (See figures 4-9)

There is strong seismic factor that played into the design of the structure. BF1 and BF2 are highly rigid at one end of the building and BF5 is highly rigid at the other reduce torsion, while BF3 strengthens the connection between the wings.

Figure 6 - Brace Frame 4 with Wind Loading

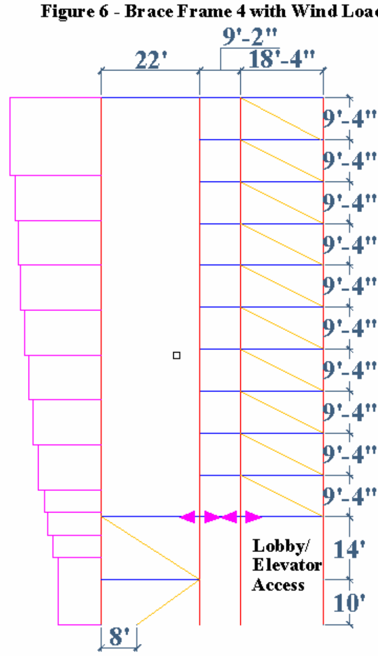


Figure 9 - Moment Frames 1 and 2

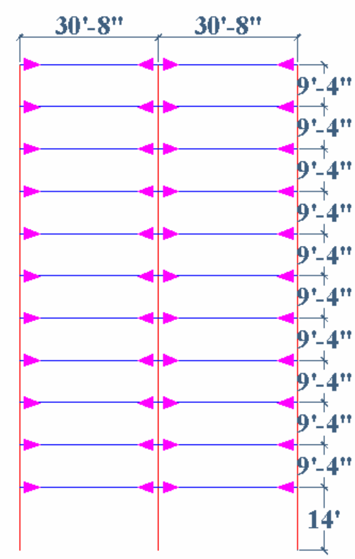


Figure 4 - Brace Frames 1 and 2 with Wind Loading

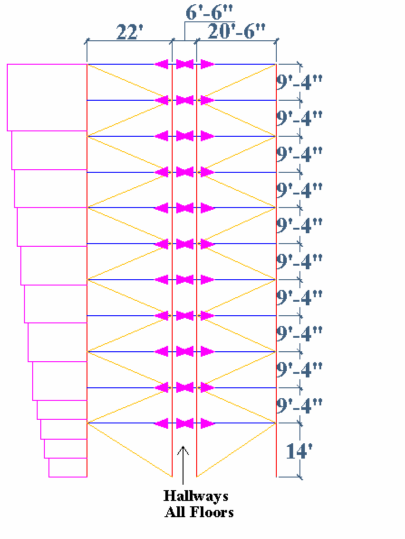


Figure 5 - Brace Frame 3 with Wind Loading

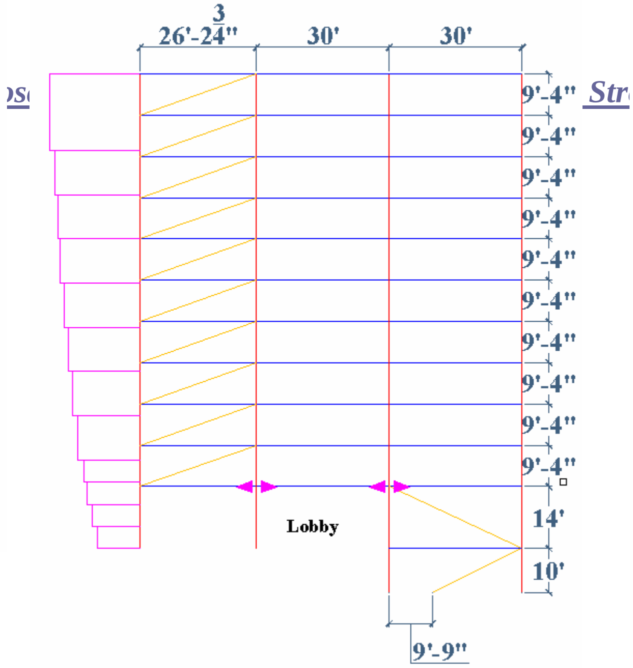


Figure 7 - Brace Frame 5 with Wind Loading

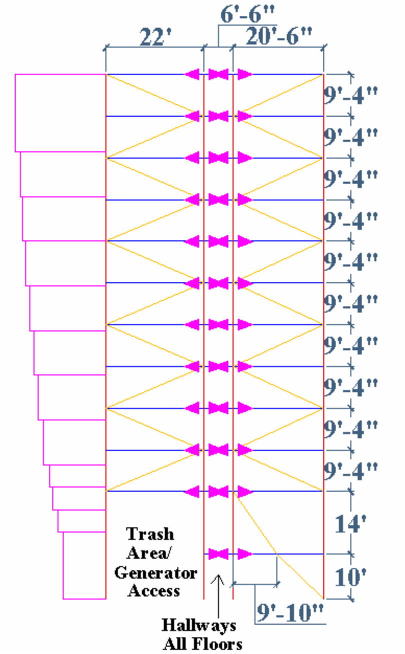
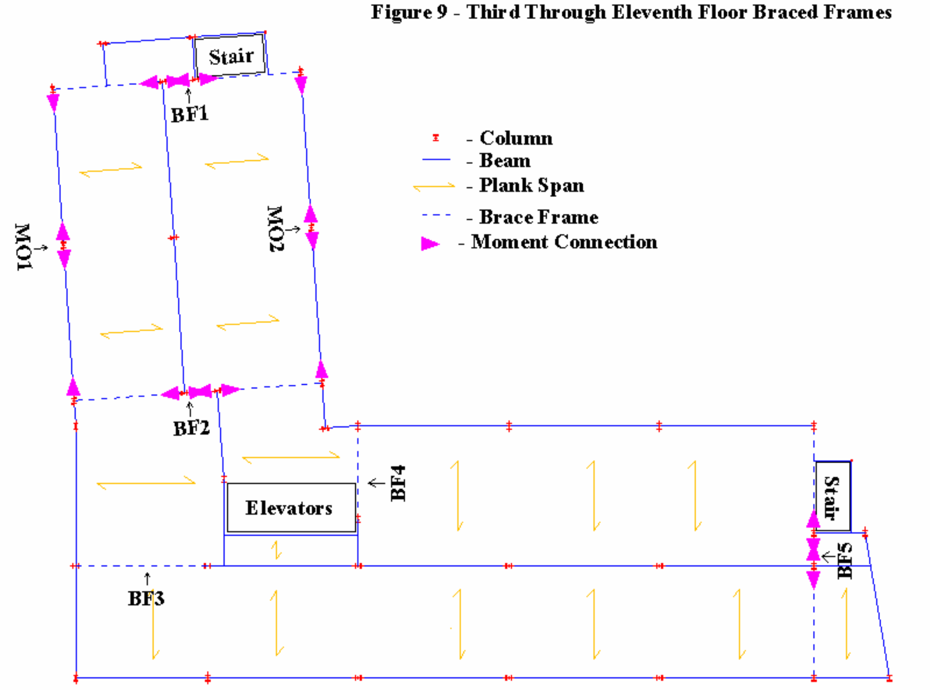


Figure 9 - Third Through Eleventh Floor Braced Frames



IV. The Problem

The problem is to find the most economical and feasible concrete redesign of the structure, and compare it to the existing system. Floor thickness, clear span, and speed of construction were critical deciding factors in the original structural system and will be considered heavily in this redesign. Furthermore, a lateral system of shear walls will be designed to accommodate the change to concrete. This system could work more efficient than the existing lateral system, but offers challenges in design. Restrictive issues of this structural redesign include keeping the suites identical and avoiding impact on public and service spaces, which will be left unchanged as much as possible. Architectural changes will be noted.

V. Proposed Solutions

Through research of the dormitory's architecture, structure, and the capabilities of concrete alternatives, this thesis study will look into three possible alternative structural systems of varying degrees of change extremity. As information showing a relatively ineffective design comes to light through the design process, this thesis will disregard an alternative as seems fit. If all of the alternatives seem feasible, the final report will discuss all of them and breadth studies will be carried out on one of choice.

Alternative #1: Keep the existing column grid with maximum sized bays of 30'8" by 27'6," and minimum sized bays of 30' by 22'. Design the building with cast in place columns, shear heads, and post-tensioned two way slabs. Design a lateral system of cast-in-place concrete shear walls. In comparison to the existing system, there should be a slight reduction in slab thickness, and a large increase in column size. Shear heads will limit the need for drop panels, which means timelier construction and possibly cut down on column size to keep them from impacting critical spaces, such as the suites and hallway width.

Alternative #2: Change the existing column grid into three longitudinal bays with two roughly 20' by 20' square bays and one roughly 7' by 20' bay in the center for the hallway. Design with a filigree two way slab system for speed in construction. Design a lateral system of cast-in-place concrete shear walls. Column sizes should be significantly smaller and the slab thinner than Alternative #1, but many more columns are needed which could slow construction significantly, and possibly add cost.

Alternative #3: Tunnel Form System (concrete floors and walls) (http://www.highriseconcrete.com/apts.htm). This system consists of cast in place walls (not spaced at each partition) poured in unison with a flat slab by the means of one piece volume frames in bays. The system means shear wall design will not be an issue because the high volume of concrete walls will probably be sufficient for rigidity. Some extra reinforcement may be required.

Two breadth studies will be performed on a chosen alternative to the existing design.

Breadth Study 1 – Construction

A critical issue in evaluating an alternative structural system is construction. This study will involve a detailed cost estimate of the existing structural system and the proposed structural system, and comparison. If non structural elements are eliminated or changed due to an alternate structural system a cost evaluation will be studied. Furthermore, the building construction schedule will be altered for the proposed system and the impact on all aspects of construction will be analyzed.

Breadth Study 2 - Acoustics

University residence halls are inherently very loud places to live and study. Most likely sound issues were not considered in this building due to the university's tight budget. This study will evaluate any discrepancies in the acoustical properties of the existing structural system versus the proposed structural system, as well as propose non-structural improvements to improve quality of life in the dorm. It will focus on hallway and suite sound issues. Criteria will include sound absorption, reverberation time, and sound transmission between suites and hallway/suite interfaces. These values will be compared to recommended values, and this study will further examine materials and possibilities of improving the sound characteristics of these spaces.

VI. Solution Method

To design the system, each alternative will be accounted for in each phase to help in comparison with each other.

Alternative #1 will first be analyzed based on Chapter 13 of ACI 318.95 *Building Code Requirements for Reinforced Concrete*, Equivalent Frame Method, through the ADOSS program. Post-tensioning loads will be imputed using load balancing method. Live and Super imposed Dead loads will be used based on those in Table 1. For moment distribution, Live load patterns of full live load on all spans, full and half live load on adjacent spans, and three-quarter full load and no load on adjacent spans will be used. Shear head reinforcement will be designed.

Alternative #2 will be analyzed as Alternative #1 without post-tensioning. Slab size will be determined by deflection based on ACI 318.

Alternative #3 will studied separately.

Table 1 - LOADING	Existing Design	This Design (IBC 2003)
Service Level Live Loads (psf)		
All floors, u.n.o.	40	40
Lobbies	100	100
Mechanical Rooms	250	250
Mechanical Penthouse Floor	250	250
Storage Rooms	200	250
Roof	20	20
Corridors	None	100
Elevator Machine Room Floor	125 + Machine Reactions	250
Dead Loads (psf)		
Partitions	15	15
Finish	Not noted	4
Mechanical	Not noted	5
Concrete Plank Weight	Not noted	82.5
Steel Member Weight	Not noted	10

VII. Tasks and Tools

Phase 1

Layout

1. Determine column layout for Alternative #2 within architectural requirements
2. Determine Tunnel Form feasibility and grid layout

Phase 2

Two way floor system analysis

3. Establish trial member sizes
    a. Minimum slab thickness from ACI 318
    b. Column sizes from CRSI design tables
4. Refine floor systems for typical bays
    a. ADOSS program analysis
5. Cost analysis

Post-Tensioned two way floor system analysis

6. Establish trial member sizes
    a. Minimum slab thickness from ACI 318
    b. Column sizes from CRSI design tables
7. Refine floor systems for typical bays
    a. Calculate load balancing due to Post-tensioning
    b. ADOSS program analysis
8. Cost analysis

Tunnel Form

9. Design system- further research is necessary
10. Cost analysis

Phase 3

Lateral Force Resisting System

11. Determine Lateral loads
12. Determine Sizing
    a. Determine required concrete sections
    b. Layout rebar using hand calculations
13. Cost analysis

Phase 4

14. Determine most effective system based on structural criteria

Phase 5

Breadth Studies

15. Construction
    a. Cost analysis using RS. Means and manufacturer costs
    b. Cost works comparison of schedule

16. Acoustical
    a. Determine recommended sound levels
    b. Estimate sound levels and evaluate transmission/reverberation in existing and new system
    c. Research acoustical materials and cost
    d. Evaluate best option for improving acoustics

IX. Concluding Remarks

In order to explore concrete alternatives more thoroughly, this report proposes and open ended thesis project exploring three structural system alternatives. Each system will be evaluated based on slab thickness, column or wall size and interference, and cost before the best alternative is decided upon, then compared to the existing system. The inherent flaw in this comparison is that construction costs and time issues will not be taken into account until after one is chosen, due to time constraints. When an alternative is chosen, construction and acoustics breadth studies will performed in relation to the two structural systems- existing and proposed – as well as the building as a whole.

X. References

1) Tower, Douglas (2006), *'Drexel University Race Street Dormitory,'* Technical Reports 1-3.

2) Drexel University (2005), *'Project Summary and Scope Components'* RFP. June 6

3) Erdy McHenry Architecture (2006), *'Drexel University New Residence Hall,'* presentation by Chris Boskey, Nov. 29

4) Highrise Concrete Systems, Inc. http://www.highriseconcrete.com/apts.htm)