Drexel University Race Street Dormitory

REVISED THESIS PROPOSAL

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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 a complete redesign of the building utilizing concrete and tunnel form construction, with minimal architectural changes. An altered architectural plan and structural layout of concrete bearing walls, flat slabs, and some columns will be designed, with columns only where larger open spaces are necessary. The ADOSS program will be used to find initial sizing, then ETABs and hand calculations will be used to design the entire building structure based on gravity and lateral loads.

Two breadth studies will be examined as part of the project. The first will be an ongoing architectural change of the building as the structure is designed in an attempt to keep as much of the existing spaces intact and fulfill the space and code requirements of the building. The second will be a cost estimate and time schedule.

II. Introduction

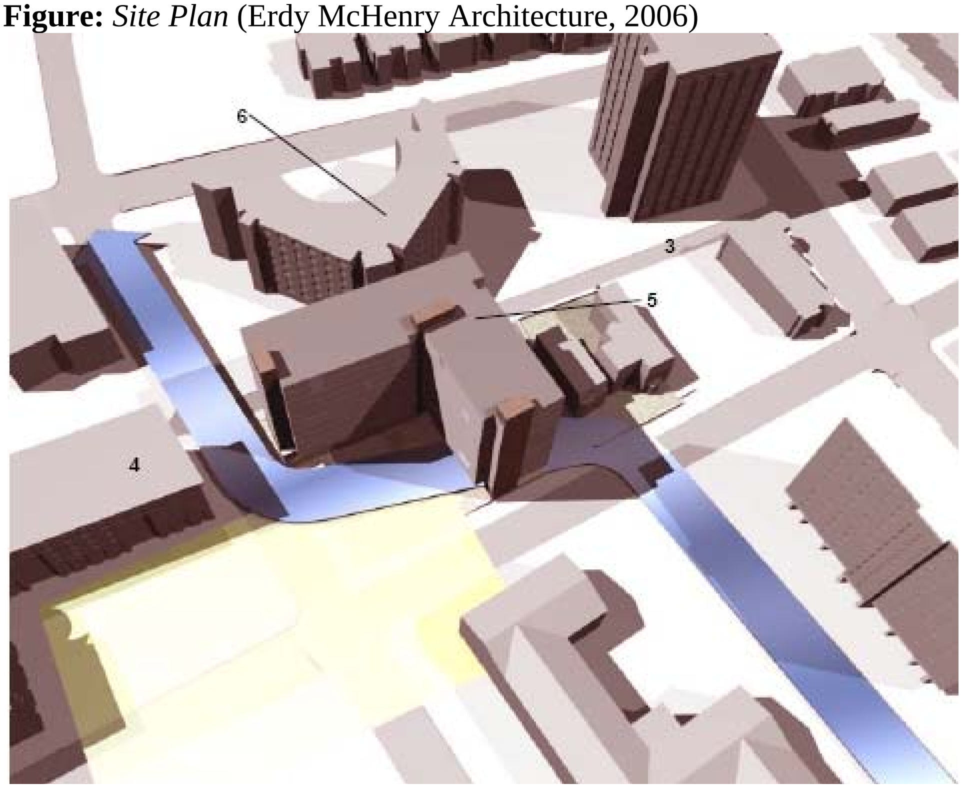
The existing steel structure of the Drexel University Race Street Dormitory is well designed, both in terms of quality, cost, and speed of construction. This thesis will redesign the building with mainly concrete walls and slabs as an attempt to explore and utilize the benefits of tunnel form construction and concrete itself. Alternative concrete structural systems were explored, such as two way slabs, and post-tensioned slabs, but they are too generic and less viable alternatives in terms of speed of construction, cost, and large column interference in building spaces. It is likely that the original designers considered and disregarded these alternatives, but possibly not tunnel forms.

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:

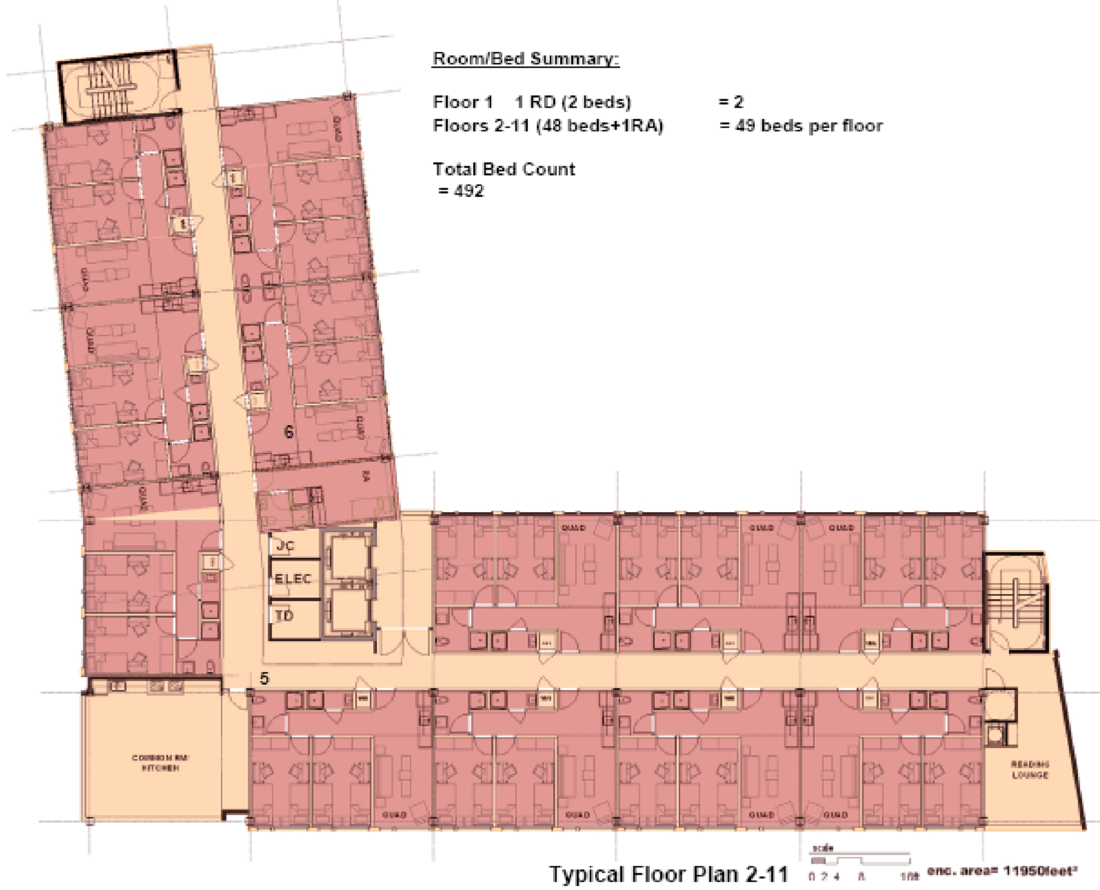
North Hall = #4, Race Street Dormitory = #5, Blue line is future circulation pattern.

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 in length of 10” deep flooring uninterrupted by beams (see fig. 3).

Figure 1 - First Floor Framing Plan

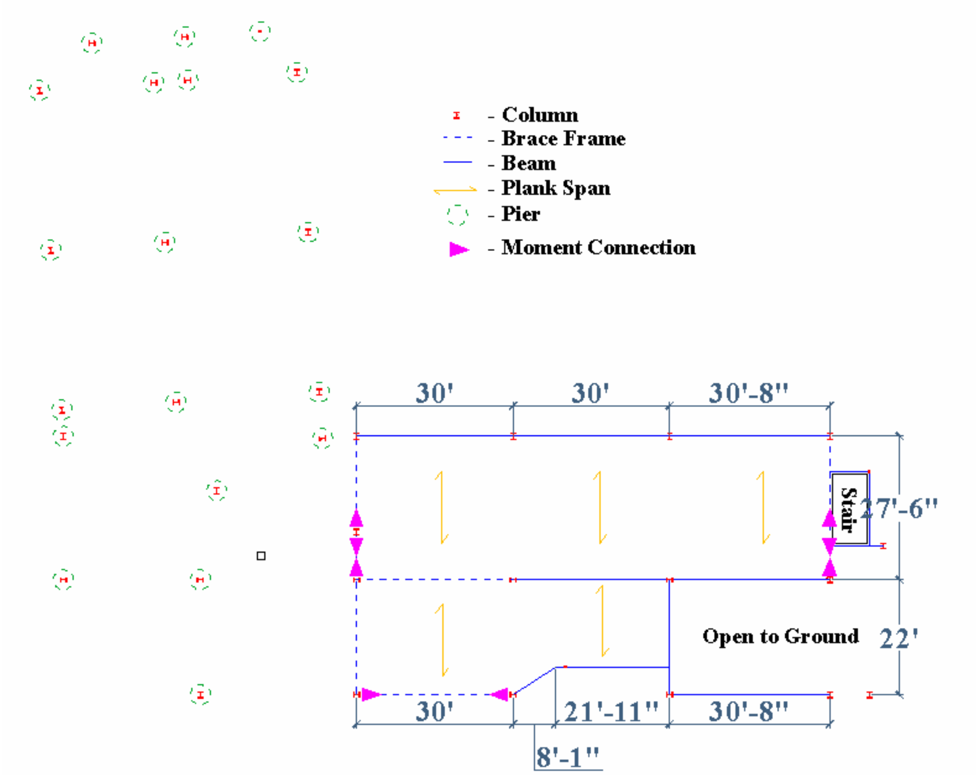
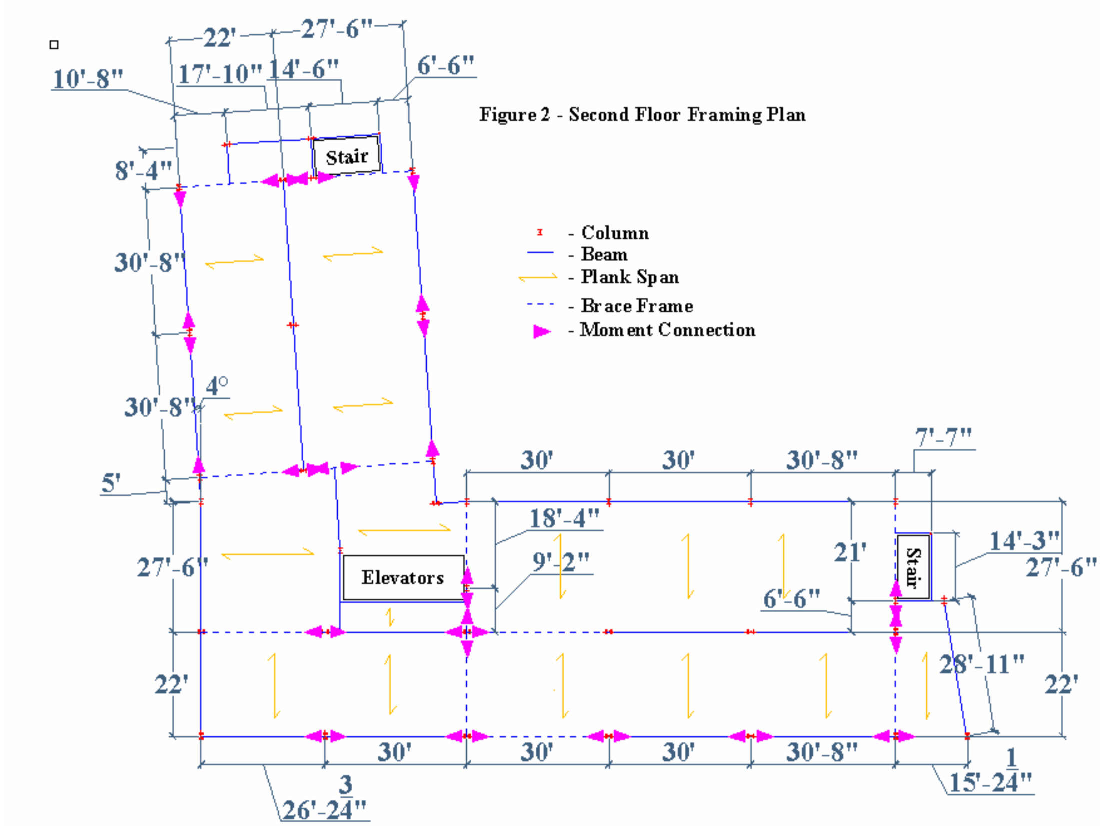


Figure 2 - Second Floor Framing Plan



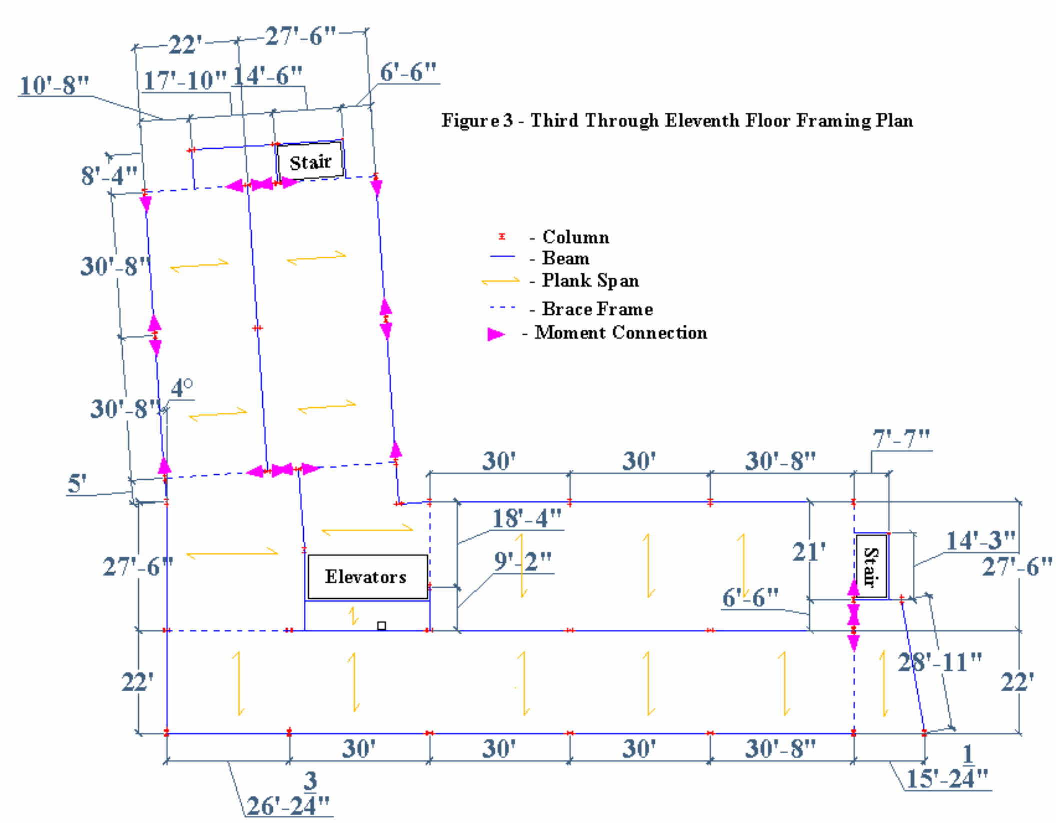


Figure 3 - Third Through Eleventh Floor Framing Plan

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 component 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

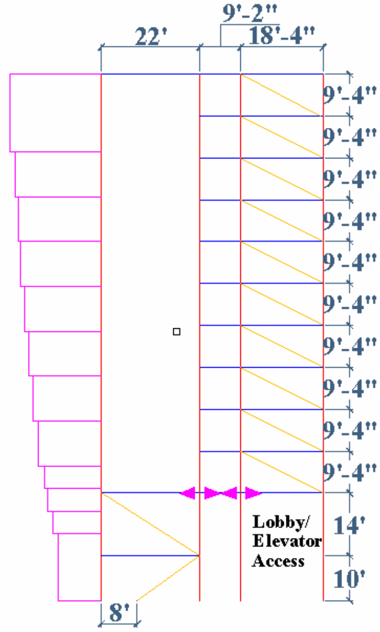


Figure 9 - Moment Frames 1 and 2

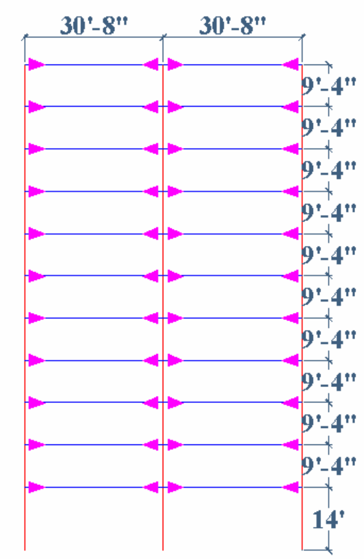


Figure 4 - Brace Frames 1 and 2 with Wind Loading

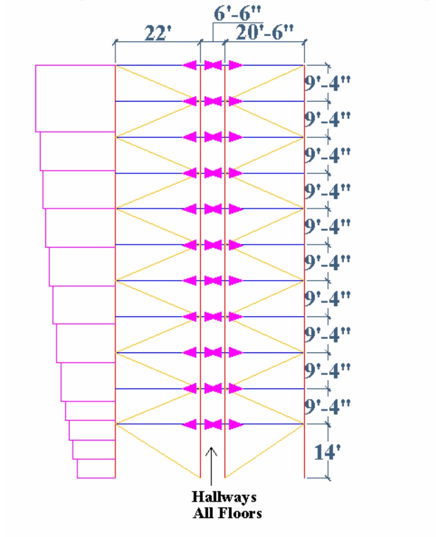


Figure 5 - Brace Frame 3 with Wind Loading

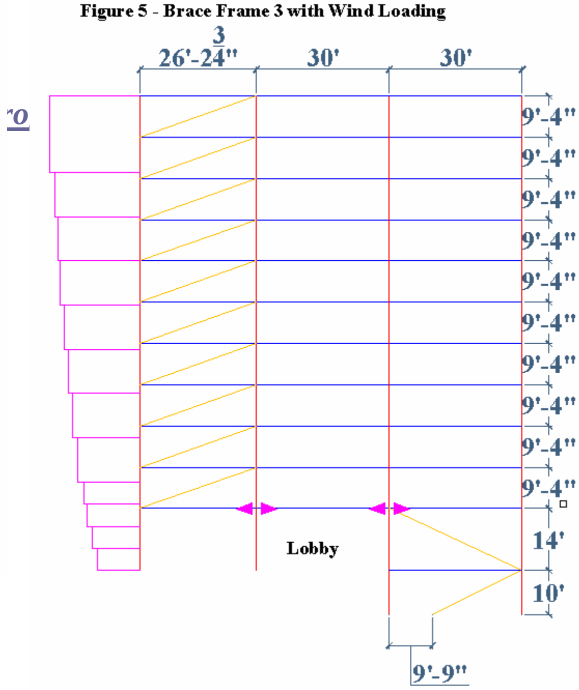


Figure 7 - Brace Frame 5 with Wind Loading

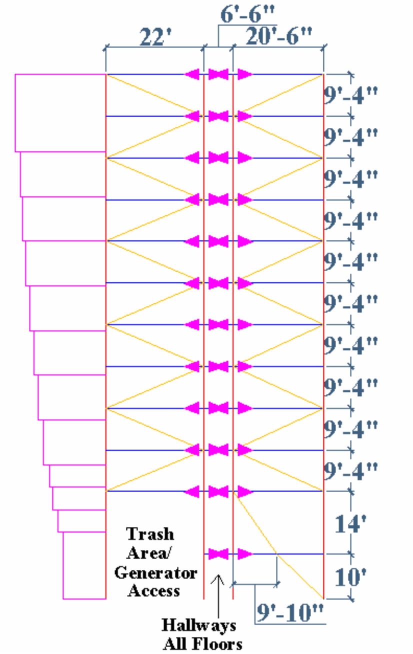
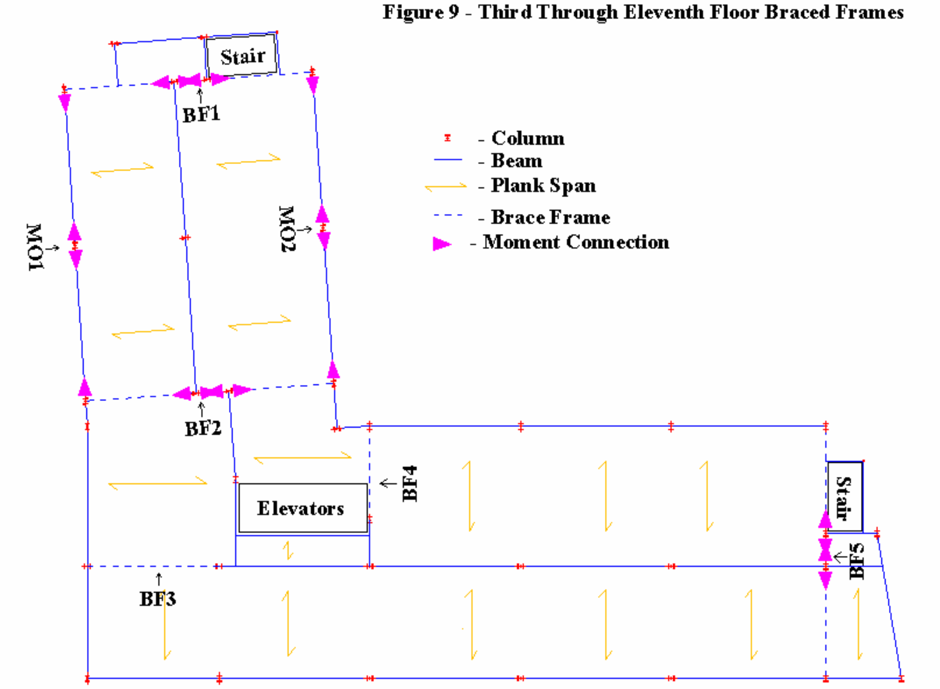


Figure 9 - Third Through Eleventh Floor Braced Frames



IV. Tunnel Form Construction

Tunnel form construction is a simple, viable method of building a concrete structure in a timely manner, and without the large columns associated with two way slabs, the next best alternative to this building. The method uses large, pre-built, angled forms that form the entire wall and part of the slab above. Forms are slid in from the exterior by crane, two per bay, forming the walls and floor above. The method is highly efficient in pouring because forms are pre-built, reused, easily moved, and easily partitioned if there are holes in the load bearing wall. The system is more cost effective the more uniform bays that are constructed, and could be bought by Drexel University and used on future projects.

IV. The Problem

The proposed thesis problem is to apply a concrete structure to the existing building that utilizes tunnel form construction. Because of the inherent limitations of this construction, flat slabs and columns will be used to open up areas that require larger uninterrupted space. Minimal architectural change, reuse of forms, floor thickness, clear span, and acoustics must be considered in this redesign. Suites must remain identical for legal reasons. Floor thickness must be kept to a minimum for cost reasons. Clear span will be limited by the span capabilities of one way slabs on bearing walls and/or minimum column sizes without drop panels. Concrete has strong acoustic properties, so layout of bearing walls could be done in such a way to separate private and semipublic areas acoustically without added cost.

V. Proposed Solution

In order to utilize tunnel form construction, the structure will be designed using cast-in-place concrete walls and flat slabs in such a way to accommodate the forms. Furthermore, the uniformity of the formwork will be kept in mind during the design to make the system cost effective. Bearing walls will mainly be perpendicular to the edge of the building as borders to typical bays (the exterior wall cannot be bearing, so tunnel forms can be place in the building and then removed).

A major problem with the bearing wall, flat slab system is the span limitations. Tunnel form designers typically span up to 28’ between walls, but a 20’ bay would better fit the existing architectural layout of the building and desired slab thickness (under 10”- the existing building floor thickness). The original building, however, has a variety of larger open spaces that must be accommodated. To do this, this thesis will try to cluster larger spaces together and design an alternate two-way flat plate with columns system for these areas. This results in a building that incorporates tunnel form design as much as possible, with the most economical integration of columns and typical flat plate formed construction.

Breadth Study 1 - Architectural

The building will have to be changed architecturally to implement the new structural system. This breadth study will simply be an in depth rearrangement and alteration of spaces in the building, attempting to maintain the same spaces and/or work them around the new structural system. The first floor plan will likely change to accommodate new load bearing walls on the 10 floors above. This breadth study will be integrated with the design of the structural system to optimize each.

Breadth Study 2 - 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.

VI. Solution Method

To design the system, preliminary alternative structural floor plans will be drawn to accommodate the architectural needs of the building as much as possible. Typical structural grids will be sized and designed based on Chapter 13 of ACI 318.95 *Building Code Requirements for Reinforced Concrete*, Equivalent Frame Method, through the ADOSS program. 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. A computer model will be designed to evaluate the building as a whole for gravity and lateral loads. Hand calculations will evaluate much of the building for gravity and lateral loads as well as per IBC 2003.

Breadth study 1- Architecture - will be an ongoing process as the structural system is laid out and its needs to maintain slender columns, walls, and floors are accommodated as much as possible. Discretion will be used as to evaluate whether or not spaces are changed for structural needs or cost considerations. After a structural system is finalized, the architectural layout will be finalized.

Breadth study 2 – Construction - will be an analysis and comparison of cost and construction speed with the existing building. It will be evaluated after a structural and architectural redesign, and will be considered during all aspects of design.

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 Concrete Slab Weight	Not noted Not noted	10 12.5 per inch depth

VII. Tasks and Tools

Phase 1

Layout

1. Research tunnel form systems
2. Determine possible alternative building shape and structural layout

Phase 2

Floor and Wall system analysis

3. Establish trial member sizes
   a. Minimum slab thickness from ACI 318
   b. Column sizes from CRSI design tables
   c. Establish trial wall thicknesses
4. Refine floor systems for typical bays
   a. ADOSS program analysis
5. Create ETABs model and detail structural system

Phase 3

Lateral force resisting system check

6. Determine Lateral loads using ASCE 7- 05
7. Check building using ETABs model

Phase 4

Hand Design/Check

8. Design typical wing by hand according to ACI 318
9. Hand check building for deflection/torsion/overturning

Phase 5

Foundation design

10. Redesign foundation to accommodate new system

Phase 6

Breadth Studies

11. Architecture
    a. Finalize architecture layout
12. Construction
    a. Cost analysis using R.S. Means and manufacturer costs
    b. Cost works comparison of schedule

Phase 7

Finalize Project

IX. Concluding Remarks

This thesis will attempt to apply tunnel form construction for an existing architectural layout with minimal changes. The purpose of the change is to design a viable alternative structural system that utilizes the advantages of concrete, high construction speed, and low cost. There will be many challenges in applying this system to the existing building, and the process should be dynamic and fully integrated in terms of structure, architecture, and construction.

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)