Thesis Proposal

SMILOW CANCER CENTER – YALE-NEW HAVEN HOSPITAL

20 York Street, New Haven, Connecticut

Pennsylvania State University

Department of Architectural Engineering

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EXECUTIVE SUMMARY

For the purposes of upcoming thesis reports, this proposal outlines the student's ideas and plans for his design of the Smilow Cancer Center. Aside from informing consultants and faculty of thesis intentions, this proposal is meant to be a guideline for the student as to the type of progress to be achieved and when.

For the depth study, the student has decided to investigate the idea of progressive collapse and its effects on different types of structural systems. Hence, the current steel structural system of Smilow Cancer Center is to be redesigned into a reinforced concrete structure, with both existing and alternate systems being analyzed for progressive and disproportionate collapse failures. Relevant to the field of building failures, the student will also study the possibility of implementing a blast-resistant wall system in certain areas of the building. This will account for the breadth portion of the thesis. Also, a full three dimensional computer model will be generated for both structural systems as a part of the M.A.E. requirement.

To ensure the thesis is progressing smoothly, a general timeline of tasks and activities has been generated. Although it is preliminary, the timeline will hopefully give a good idea of the student's plan for completing his own design for Smilow Cancer Center.

INTRODUCTION

Given the high profile and high importance nature of the Smilow Cancer Center project, it is crucial that the effects of progressive collapse be investigated for both cases of the existing steel frame structure and the proposed concrete frame alternative. This proposal details the student's plan for substituting an entirely concrete structural system for the existing steel frame and concrete shear wall combination. The consequences of progressive collapse will be considered for both structural systems. Also, in relation to the field of building failures, the feasibility of implementing a blast-resistant curtain wall system will be studied.

BACKGROUND: Smilow Cancer Center

GENERAL BUILDING DATA

- Smilow Cancer Center
- 20 York Street, New Haven, CT 06510-3202
- Yale-New Haven Hospital
- 497,000 sq. ft.
- 14 patient floors + 2 mechanical floors
- Primary Project Team
    - *Owner:* Yale-New Haven Hospital // New Haven, CT // www.ynhh.org
    - *Construction Manager:* Turner Construction Company // Milford, CT // www.turnerconstruction.com
    - *Architect:* Shepley Bulfinch Richardson & Abbott // Boston, MA // www.sbra.com
    - *Structural Engineer:* Spiegel Zamecnik & Shah // New Haven, CT // www.szsdc.com
    - *Mechanical/Electrical Engineer:* BR+A Consulting Engineers, Inc. // Boston, MA // www.brplusa.com
    - *Plumbing/Fire Protection Engineer, Code Consultant:* R.W. Sullivan Consulting Engineers, Inc. // Boston, MA // www.rwsullivan.com
    - *Civil Engineer:* Tighe & Bond Consulting Engineers // Norwalk, CT // www.tighebond.com
- Dates of Construction: September 2006 – February 2010
- Overall Project Cost: $253M
- Delivery Method: Design-Bid-Build with Guaranteed Maximum Price

Located in the middle of New Haven, the addition of the Smilow Cancer Hospital to the Yale-New Haven Hospital complex will feature a state-of-the-art building with the latest equipment for the treatment of the disease. The several areas of specialization are separated among the sixteen stories of the building, with the larger equipment (i.e. MRIs, ultrasound, operating rooms) housed primarily on the lower floors and the 112 inpatient rooms—all single rooms—

starting on the eleventh floor. As for the exterior, the façade emulates that of the surrounding buildings in the complex with its glass and terra cotta curtain walls. For ease of installation, a unitized curtain wall panel system was used: the glass and terra cotta come in pre-installed panels ready to be attached to the structure.

Being one of the most comprehensive cancer facilities in the New England region, the city of New Haven extended its Medical Zone to allow the construction of the Smilow Cancer Hospital back in 2006, despite some opposition from a few local residents. Those opposed to the new building were mostly concerned about issues such as traffic, parking, and “architectural integration with the neighborhood.” The design of the building follows the 2005 Connecticut State Building Code which adopts mostly from BOCA National Building Code.

BACKGROUND: Existing Structural System

SUMMARY

The structural system of Smilow Cancer Center consists of a concrete slab on metal deck floor system supported on a steel framing system (moment, lateral braced, and regular gravity frames) and four reinforced concrete (RC) shear walls. On the first level, concrete beams of varying sizes run along three edges of the building. The floor slab and steel beams act in composite action with each other, while the moment frames and shear walls share the lateral load. The whole structure rests on a 4-foot thick mat slab foundation (the slab is 8 feet thick at shear wall locations). A relatively simple structure, the footprint of the building through the first five levels is almost square (210 ft. x 176 ft.). At the beginning of the seventh floor[1], however, the northeast “corner” of the building ends in a rooftop garden, and the rest of the building rises to the roof as an L-shape.

Normal weight concrete is used for the shear walls and the foundation, while lightweight concrete is used for the floor slabs. Concrete strength ranges from 3000 psi to 8000 psi depending on the location and use. All reinforcement is A615 Grade 60 steel. A range of steel W-shapes are used for the framing system, but all are of the standard A992 grade steel (F_y = 50 ksi). Additionally, Hollow Structural Shapes (HSS) conform to ASTM A500 Grade B, while all other steel shapes (i.e. plates, channels, etc.) conform to ASTM A36 (F_y = 36 ksi).

FOUNDATION + COLUMNS

As mentioned above, the foundation for Smilow Cancer Center is a 4-foot thick mat slab with different types of column base plates down at the basement level. These columns vary from W-shapes, HSS, and even cruciform columns consisting of a wide flange plus two T-shapes—all of which are encased in concrete. Some columns are regular reinforced concrete columns. Starting on the first floor, the columns continue up the structure as regular steel columns.

[1] Smilow Cancer Center does not have floors labeled 6th or 13th for superstition purposes.

FLOOR SLABS + BEAMS

The typical floor slab for Smilow Cancer Center is a 4-1/2" thick lightweight concrete slab on a 3" deep, galvanized, 18 gage composite steel floor deck with a 3 span minimum. Reinforcement consists of one layer of 6 x 6 – D4 x D4 welded bar mesh and top reinforcing bars. The slab is supported on steel framing and concrete shear walls at some locations. As per ASCE 05, the floor slabs are considered as rigid diaphragms when taking into account lateral loads.

The hospital's typical bay is a 30 ft. x 30 ft. square with W-shape columns at the corners, W24 girders along the perimeter, and two W18/21/24 beams spaced evenly at 10 ft. on-center. As discussed in the following section, most of the beams frame into simple gravity columns, while moment frames and shear walls are dispersed throughout the structure to effectively resist lateral loads.

LATERAL RESISTING SYSTEM

Smilow Cancer Center's lateral resisting system is a combination of six primary moment frames, several smaller lateral braced frames on the roof, and four C-shaped RC shear walls. Four of the six main moment frames are located at the edges of the building, while the remaining two run along the east-west direction at approximately one-third points of the building's length. The four shear walls are all located towards the southeast quadrant of the building, strategically placed around central elevator and mechanical openings. All four shear walls rise up to either the sixteenth or seventeenth floor, ending where the lateral braced frames of the roof begin.

BACKGROUND: Progressive Collapse

The concept of progressive collapse can be likened to a chain reaction in the failure of critical structural components of a building. Picture a simple three-bay, one-story frame where each member has sufficient capacity under gravity loads. But suppose a local failure occurs in one of the interior columns: the remaining members are suddenly carrying the additional load of the failed member. Without considering this effect during the design process, the remaining members would most likely fail as well, leading to a "progressive collapse" of the building.

One of the more infamous instances of this type of failure was the Ronan Point Apartment Tower collapse in England in 1968. A gas explosion near the corner of the 18th floor knocked out some load-bearing precast concrete panels supporting the above floors. The loss of these few critical members resulted in the collapse of the entire corner of the building, from the 22nd (top) floor all the way to the ground. Thus, the disproportionate nature of a progressive collapse is evident in the catastrophic failure of a large part of a building caused by a relatively small event.

PROPOSAL: Problem and Solution

As mentioned before, the highly critical nature of a hospital warrants an investigation into designing structural members against progressive collapse. In the case of Smilow Cancer Center, failure of even a few critical members on the ground level could easily lead to very catastrophic results. Damage to the hospital could cost up to the millions of dollars, not to mention the tragic and severe loss of life that could ensue. For this reason, the upcoming reports for the thesis will explore the feasibility of replacing the steel framing system with a reinforced concrete frame system. Both systems will be considered for progressive collapse focusing on typical corner, exterior, and interior columns on the first floor. Existing and proposed systems will be analyzed and compared for gravity and lateral loads primarily through 3-D computer programs learned in AE 597A: Computer Modeling of Building Structures. Some hand calculations for typical members will also be performed.

For the breadth topic of the thesis, the pros and cons of installing a blast-resistant curtain wall system—at least at ground level—will be analyzed. Hopefully, this type of curtain wall would partially alleviate the effects of any destructive events that may occur. Of course, this system would have to be compared to the existing unitized curtain wall panel system in terms of blast-resistance, thermal performance, cost, et cetera.

PROPOSAL: Methodologies and Research

In order to efficiently analyze each structural system and the consequences of progressive collapse on each, a more in-depth understanding of building failure modes is needed. Basically, representative frames of each structural system will be analyzed with and without critical columns. From the student's basic knowledge of progressive collapse so far, the two main methods for reducing the chances of this type of collapse are redundancy (alternate load paths) and improved capacity in critical members (over-design of members basically). The following sources should help in the further study of the subject:

- Nair, R. Shankar. "Progressive Collapse Basics."
- Longinow, Anatol. "Blast Basics."
- American Society of Civil Engineers, ASCE 7-08.
- American Concrete Institute, ACI 318-05.
- American Institute of Steel Construction Manual, 13th Edition.
- RS Means Catalogue

These references should give a better insight into the efficient design of a structural system with a reduced risk of progressive collapse.

TASKS AND SCHEDULE

The following is an outline of the tasks that need to be completed and the approximate time-frame of each. Note that this schedule is only *preliminary* and may be subject to unforeseen changes. Also, some tasks may overlap into other time-frames.

- *Weeks 1-2*

  TOPIC RESEARCH

  Collection of sources and recording of background information regarding progressive collapse

  ALTERNATE SYSTEM CONCEPTUAL DESIGN

  Preliminary sizing of typical members for alternate concrete structural system

  COMPUTER MODELING

- *Weeks 3-4*

  EXISTING SYSTEM ANALYSIS

  Analysis of the existing system for deletion of critical columns: corner, exterior, interior

  ALTERNATE SYSTEM DESIGN DEVELOPMENT / COMPLETION

  Continued sizing of members for alternate concrete structural system

  COMPUTER MODELING

- *Weeks 5-6*

  ALTERNATE SYSTEM DESIGN DEVELOPMENT / COMPLETION

  Continued sizing of members for alternate concrete structural system

  PROGRESSIVE COLLAPSE ANALYSIS

  Continued analysis of both systems for deletion of critical columns

TOPIC RESEARCH

Research of blast forces and blast-resistant wall systems

COMPUTER MODELING

- *Weeks 7-8*

COMPARISON OF STRUCTURAL SYSTEMS

Calculation of costs and discussion of pros and cons of each structural system

INVESTIGATION OF CURTAIN WALL SYSTEMS

Study of alternate blast-resistant curtain wall system and comparison of existing and proposed systems

- *Weeks 9-11*

ORGANIZATION / FINE TUNING OF MATERIAL

PREPARATION OF FINAL PRESENTATION/REPORT

	WEEK										
TASK	1	2	3	4	5	6	7	8	9*	10	11
Topic Research	■	■			■	■					
Existing System Analysis			■	■	■	■					
Alternate System Design	■	■	■	■	■	■					
Structural System Comparison					■	■	■	■			
Computer Modeling	■	■	■	■	■	■					
Presentation Development									■	■	■

**Week 9 is the week of Spring Break.*

CONCLUSION

Smilow Cancer Center, the latest addition to the Yale-New Haven Hospital complex, is regarded as “the most comprehensive cancer care facility between Boston and New York City.” As such, it is a high-profile and not to mention very important building. Needless to say, the structural integrity of a hospital, even after some catastrophic events, is of the utmost importance. So, the student proposes the design of Smilow Cancer Center’s structural system as a reinforced concrete frame system with critical members at the first floor resistant to progressive collapse. As related to the building failures field, the prospect of a blast-resistant curtain wall system at ground level will be investigated as a part of a breadth study. In addition, the practical criteria such as cost, constructability, et cetera will be considered for all existing and alternate systems.