Amanda Gerstenberg
Structural Option

Advisor: Dr. Linda Hanagan
The 400: Bremerton, WA
January 16, 2006
AE 481W

Thesis Proposal
Proposal of Research to be Completed Spring of 2006

The bottom two stories of The 400 consist of slab on grade or post-tensioned slab parking (generally 8" normal weight). Four stories of light gage steel residential frame construction are built above the two levels of parking. Wooden trusses are then used to frame the roof. The gross floor area for The 400 is approximately 124,000 square feet.

Depth Work—Blast Redesign:

The mention of the city of Bremerton to anyone in the area means one thing—Navy. Bremerton, Washington is primarily a Navy base, and tourists for the most part do not visit the area unless they are visiting the Navy base. It is proposed that the owner of The 400 is interested in renting the condominiums to military families. A redesign or upgrade of the existing structural system is proposed to develop a design which is considered to be blast resistant for certain attacks deemed important enough to be considered for study in Bremerton, Washington.

Breadth Work—Progressive Collapse:

Because of the proximity of The 400 to the Naval base in Bremerton, Washington, the possibility of a blast will be considered. Ideally, a blast would not occur, but in the event one would take place, the likelihood of a progressive collapse must be evaluated.

Breadth Work—Envelope Study:

The building envelope of The 400 consists of a masonry veneer with rigid insulation and sheathing connecting to the metal studs of the structural system underneath. Each floor's building envelope is supported by a ledger, and the masonry veneer is connected to the metal studs by veneer anchors. Because of the increased precipitation in Bremerton, Washington, special consideration must be taken to ensure that water does not penetrate the building envelope.

Introduction:

The bottom two stories of The 400 consist of slab on grade or post-tensioned slab parking (generally 8" normal weight). Four stories of light gage steel residential frame construction are built above the two levels of parking. Wooden trusses are then used to frame the roof. The gross floor area for The 400 is approximately 124,000 square feet. Ground has recently been broken for construction of The 400, and updated plans are in the process of being developed. No Mechanical, Electrical, or Plumbing designs are readily available.

The mention of the city of Bremerton to anyone in the area means one thing—Navy. Bremerton, Washington is primarily a Navy base, and tourists for the most part do not visit the area unless they are visiting the Navy base. While Bremerton is not by any means the United States' largest Navy base, it is a substantial population of military personnel.

The building envelope of The 400 consists of a masonry veneer with rigid insulation and sheathing connecting to the metal studs of the structural system underneath. Each floor's building envelope is supported by a ledger, and the masonry veneer is connected to the metal studs by veneer anchors.

Background:

Twelve concrete shear walls are located throughout The 400, each 12" thick. Most reinforcing for the shear walls is one #5 at 18" on center each way, each face. At critical points, reinforcement can reach up to nine #6 at 3" on center, each face, and the lap splices range from 16" to 132", depending on bar size and concrete strength.

Three foot wide square spread footings typically one foot deep are located throughout the lower parking level. The depth, however, can reach up to three feet, depending on their location. Eight inch concrete walls (not shear) are located throughout the lower parking level.

A four inch slab-on-grade with one #4 for reinforcement at 18 inches on center each way is the primary slab of the lower parking level, while a 6 inch slab with an f'c of 4000 psf is used at the exterior edge on this 25,844 gross square feet level. This level is supported by 7'6" square pilecaps 48 inches deep and is connected with standard hooks on both top and bottom, and the footings reach a height of 51'0". Control joints must be spaced so as to not exceed 225 square feet, and the areas should be approximately square with no acute angles.

Of the 13,685 gross square feet upper parking level, approximately half of the level contains a 4” slab-on-grade just like the lower level, and the other half contains an 8 ½” post-tensioned slab. The post-tensioned slab contains 9’4” square drop panels 4 ¼” deep at each column, and four #4 are used continuously on the top and bottom; this is general reinforcement requirements for the upper parking level.

The upper parking level contains 8” concrete walls. One corner contains a 3’9”x3’9”x4 ¼” drop cap. This is because of the poor soil which is located in the southeast building corner, requiring additional load distribution. Unique to this level, however, is a three foot closure/pour strip and an extra stair well for access to the upper parking level.

Each residential floor is approximately 21,000 gross square feet. The wall framing consists of metal studs spaced typically 2 feet on center. The typical deck slab is made up of ½” metal form deck with 2 ½” concrete. The floor joists used are generally 10TDW16 steel joists 24” on center, supported by W10x15 girders.

Summary of Completed Technical Assignments:

Technical Assignment 1:

The first technical assignment towards this thesis project consisted of an analysis of the existing structural system. Many aspects must be taken into consideration while designing a structural system, many of which were included in the first technical assignment. The loading (dead, live, snow, wind and earthquake) were calculated to be used for analysis. These calculations were followed by detailed explanations of the structural and foundation system as well as lateral system. To complete the assignment, typical members were verified.

The 400 consists of four stories of residential metal frame construction (condominiums) above two stories of structural concrete parking. The metal construction is a non-composite system of steel floor joists supported by girders; steel studs are used for the walls. The parking consists of slab on grade wherever possible and a post-tensioned slab wherever slab on grades are not possible.

Technical Assignment 2:

The second technical assignment towards this thesis project consisted of evaluating possible alternate structural systems. The four alternate systems considered were engineered lumber, hollow core planks, two-way flat slab, and waffle slab systems. The most important considerations are site limitations for construction and soil properties which do not accommodate to large loads very well. In addition, height requirements are also a concern because The 400 is already designed to the maximum possible height.

Many aspects, including vibration, foundation and column load implications, and depth of system, were compared and contrasted. The Engineered Lumber system was chosen to be the best candidate for re-design, for many reasons including lighter and cheaper overall system.

Local design members shared concern for a wood structural system as compared to a steel structural system because of local problems with mold. Especially due to the amount of precipitation in the Bremerton, Washington area, mold has the potential to be a serious concern for a wood structural system.

Technical Assignment 3:

The third technical assignment towards this thesis project consisted of evaluating the lateral system in more depth. The lateral system of The 400 consists of two clusters of shear walls surrounding the stair wells and elevator shafts. The rigid diaphragm of the floor transfers the load to the lateral shear walls, which run the entire height of the building. As concluded in the first technical assignment, The 400's lateral system was adequately designed.

Depth Work—Structural:

The Problem:

Suppose that the owner is intending to rent the condominium spaces to the families of the military stationed in Bremerton or with Bremerton as their United States home base. Because The 400 is intended to house families of the military and because of the proximity of The 400 to the military base in general, there is a possibility of a terrorist attack of The 400.

The Solution:

The 400 will be designed to withstand a terrorist attack on the building. The same structural system will be used for the new design: non-composite system of steel floor joists supported by girders with steel studs for the walls. While some of the existing structure may not need to change because of the increased strength of the current design, other parts of the structure may show to increase in member size.

A possible problem this new proposed solution could result in is an increased weight of the overall system due to increased steel member sizes and additional strengthening materials. The additional weight of the increased steel members would then, in turn, add more load to the foundation, resulting in increased design of the foundation. The increased weight of the entire structure may result in a problem, such as a new or improved foundation, because the soil is relatively weak, especially in the southeast corner.

Steps used to accomplish this blast redesign are as follows:

1. Determination of the possible blasts to be encountered and the probability of each blast to occur. These will then be evaluated to identify the blast cases to be designed for.
2. Determination of the loads and locations of potential attack to be considered for the blast redesign. This includes research of the loads of the potential blasts themselves and loads upon impact.
3. Determination of the critical load cases to be considered for the blast redesign. This includes the locations within the building where the blast is most likely to occur and the factored load combination which is most critical.
4. Redesign the structure for the blast loading. This includes both the steel non-composite system, joists and studs as well as the foundation with the increased loading which is transferred to the foundation. The interior and exterior walls will also most likely need to be redesigned for the lateral loading created by the potential blast loading on the structure. As a result, the shear walls or the lateral system in general may need to be redesigned or have an increase in reinforcement.
5. Determination of a cost comparison for the new design as compared to the old design. While this need not be to the penny, if time allows, quoted cost from a manufacturer will be used for comparison. While the design load of the blast redesign will only increase, which will then increase the total cost of the building, the approximate increase in cost per unit will be determined. This percentage increase will then be proposed through a survey to determine the percentage of Americans that would be willing to pay the increased cost to know that their building was designed to withstand the given terrorist blast(s).
6. Summary of the results and problems encountered throughout the blast redesign.

Breadth Work—Progressive Collapse

The Problem:

Because of the proximity of The 400 to the Naval base in Bremerton, Washington, the possibility of a blast will be considered. Ideally, a blast would not occur, but in the event one would take place, the likelihood of a progressive collapse must be evaluated.

The Solution:

First, the most common progressive collapses will be researched and evaluated. Second, the causes of these collapses will be identified. Lastly, possibilities to prevent this progressive collapse from occurring will be determined and evaluated.

Breadth Work—Envelope Study

The Problem:

The 400 is to be built in Bremerton, Washington. As shown in the following precipitation charts of rainfall, Bremerton typically has more rainfall than even Seattle! In addition, when compared to State College, PA, the highest amount of precipitation in Bremerton is more than double the highest amount of precipitation in State College.

In any location, it is possible for water to seep through the envelope of the building inside the structure, deteriorating the structural support of the building. In an area of increased precipitation, such as Bremerton, special consideration must be taken to make sure water does not penetrate the envelope and deteriorate the building.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. High	44°	48°	54°	58°	64°	70°	75°	75°	68°	60°	50°	44°
Avg. Low	34°	35°	36°	40°	45°	50°	54°	54°	50°	44°	38°	34°
Mean	38°	42°	45°	48°	55°	60°	64°	65°	60°	52°	45°	40°
Avg. Precip.	7.7 in	6.3 in	5.8 in	3.0 in	2.3 in	1.5 in	0.8 in	1.0 in	2.1 in	4.3 in	8.3 in	8.9 in

Bremerton, WA

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. High	45°	48°	52°	57°	64°	68°	75°	75°	68°	58°	50°	45°
Avg. Low	35°	37°	38°	41°	46°	51°	55°	55°	51°	45°	40°	35°
Mean	40°	44°	46°	48°	55°	61°	65°	66°	61°	54°	45°	41°
Avg. Precip.	5.4 in	4.0 in	3.5 in	2.3 in	1.7 in	1.5 in	0.8 in	1.1 in	1.9 in	3.3 in	5.8 in	5.9 in

Seattle, WA

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. High	32°	35°	46°	58°	68°	78°	82°	80°	72°	61°	48°	37°
Avg. Low	16°	18°	26°	37°	47°	56°	60°	58°	51°	40°	32°	22°
Mean	25°	27°	37°	48°	58°	67°	71°	70°	62°	51°	41°	30°
Avg. Precip.	2.4 in	2.6 in	3.3 in	2.9 in	3.6 in	4.0 in	3.6 in	3.3 in	3.3 in	2.8 in	3.3 in	2.7 in

State College, PA

The Solution:

The envelope of The 400 will be evaluated to determine possible areas of consideration for seepage into the structure. Research will be conducted on failure modes of building envelopes. Updates to the current envelope system or a proposed new envelope will then be completed to determine an ideal design with the smallest chance for building envelope failure.

If time permits, an additional building envelope study dealing with feasibility will be conducted. The reality of construction proves that no matter how well-designed the structure, the design means nothing unless it is constructed properly. Site investigations will be performed to determine if construction procedures are actually followed. Ideally, observations will occur on sites in which building envelopes are being constructed. In the event that access is not granted or local building sites at this stage do not exist, general field procedures will be compared to expected and designed procedures.

Steps used to accomplish this goal are as follows:

1. Determination of possible local sites to survey for proper construction of building envelope or field procedures in general. This will include receiving permission to observe the site(s) and various stages of construction.
2. Research most common failures of building envelope. This will include studies from various locations nationwide, as local problems vary drastically. The most in depth study will, however, be performed for the area of Bremerton, Washington.

3. Determination of possible and most probable problem areas with the building envelope of The 400. This will include considering alternate building envelopes which may not have the problem areas of the current building envelope.
4. Develop a quality assurance check to determine that a building envelop failure does not occur. This will include steps which the design team could follow to ensure the building envelope is constructed properly and will not fail. Regular inspections of various design team members and/or authorities will be considered when developing this quality assurance check.
5. Determination of the reality of the quality assurance check to be implemented during construction. This will include interaction with companies specializing in Building Technology to receive an experienced opinion from the field.
6. Observation of local sites to observe their quality assurance procedures. This will include evaluation of the proposed design of the building and determination on if that design is actually completed during construction.

Proposed schedule of Thesis research for Spring of 2006:

Week of:		Task:
January	*9*	***Determine possible blasts for Bremerton, WA/Common progressive collapse failures***
	16	***Research common building envelope failures***
	23	***Determine loads and locations for potential attack***
	30	***Determine critical load cases/Determine causes of progressive collapse failures***
February	*6*	***Determine possible / probable building envelope failures***
	13	***Redesign structure for blast loading***
	20	***Redesign structure for blast loading/Steps to prevent progressive collapse from occurring***
	27	***Determine cost comparison for old and new designs***
March	*6*	***Spring Break - NO CLASS***
	13	***Develop quality assurance check***
	20	***Determine reality of quality assurance check***
	27	***Prepare final thesis report***
April	*3*	***Prepare presentation / print final thesis***
	10	***Final thesis presentations***

NOTE: *Determination of sites to perform observation for building envelope breadth study and actual observation of sites will be completed throughout the entire schedule as construction allows. Preparation of written reports at each stage will be completed; the final thesis report preparation the week of March 27 is solely to compile all smaller reports into one comprehensive report.*

[blue] = ***Blast redesign depth study/Progressive collapse***

[green] = ***Building envelope breadth study***