TOWER 333

Thesis Proposal

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Executive Summary:

Building Description:

Tower 333 is a LEED rated office building located in Bellevue Washington. Each level of the 18 stories above grade has a floor plate of roughly 22,000 square feet, with 8 sublevels of parking below grade. The above grade superstructure is a steel skeleton with poured concrete slabs on composite steel deck, while the sub-grade of the building is post-tensioned concrete slabs with concrete columns. Tower 333's lateral force resisting system is a dual-based concrete core and exterior steel moment frames.

Proposal:

Due to the fact that Tower 333 utilizes a dual lateral system consisting of a concrete core and exterior moment frames, it is proposed to eliminate the moment frames from the system and create a core only lateral system. This proposal, just as does the current Tower 333 construction, will continue to incorporate and utilize the existing foundation and core from a previously abandoned project.

Solution:

To accomplish this proposal, an investigation into the adequacy of the concrete core's ability to resist lateral loads will be executed. From this analysis, it will then be determined what type of structural modification, if any will be needed for the concrete shear wall core to become a core-only lateral system.

Breadth Topics:

In conjunction with the elimination of moment frames in Tower 333's lateral system, it is also proposed that a study on the building's façade and its performance and installation be done. Another secondary study on the scheduling impact and cost savings of changing the dual lateral system to a core-only will be done.

Introduction:

Tower 333 is an 18 story office building located in Bellevue Washington. The total height of Tower 333 is 260 feet with 8 levels of below ground parking that extends 93 below grade. The building is scheduled to be completed by the end of 2007. However, due to the recent tower-crane collapse on the construction site on November 16, 2006 this date could be postponed further, (see additional links on Author's CPEP website for more details.) The code used to design Tower 333 was the IBC 2003 with reference to ASCE-7 02' for load values. For this proposal, ASCE -7 05' will be used as an update. Tower 333 utilizes an existing foundation and concrete core which was built up to Sublevel 5 and abandoned during an earlier project due to financial issues.

Background:

Foundation:

Tower 333 rests on an existing foundation 93 feet below grade, which was abandoned by a previous owner due to financial problems. It consists of spread footings for the concrete columns and a mat foundation supporting the concrete core. Where needed for higher loads, footings were partially demolished and reinforced and an extra 2 feet of concrete were added to the mat foundation for higher capacity. The spread footings have a compressive strength of 4,000 psi while the mat foundation has a compressive strength of 5,000 psi.

Columns:

All columns supporting the 8 levels of parking below grade are constructed of 8,000 psi concrete. The concrete columns range in size from the smallest being 2'-0" x 2'-0"to the largest which have dimensions of 3'-6"x 3'-0". Beginning at the Mezzanine level, the columns change over from concrete to rolled W shapes, which are spliced every other floor and are 27'-8" tall. The smallest size column is a W14x53 and the largest size used is a W14x730, which is used in the moment frames.

Floor System:

The typical 30'x 42' bay of the upper office floors of Tower 333 are supported by 42' long, W18x40 composite beams spaced at a typical 10' on-center, with a camber of 1-1/2". Supporting the beams are 30' long, W18x97 composite girders with a camber of ¾". Both have a strength of 50ksi. These members in turn support a 2-1/2" concrete slab on a 3" deep composite metal deck with the strength of the concrete being 4,000 psi. To control expansion and contraction of the concrete there is WWF 6x6 W3.5xW3.5 reinforcing in the slab. The floor to floor height is 13'-10" and the overall weight of this system is 58 psf with a framing depth of 24”. The finished floor to finished ceiling height is 10’ which allows 3’-10” of plenum clearance space. This plenum space is utilized for the mechanical equipment which incorporates a variety of 12” and 14” deep ducts to transport air to strip diffusers along the perimeter of the building. Refer to Figure 1 for a framing plan of the existing system.

Lateral System:

The lateral system is a dual-resisting system utilizing a special concrete core and perimeter special moment frames. The concrete core consists of 2 foot thick walls, 40 feet in length along the North-South direction and 32 feet in length with 5 foot openings for elevator access in the East-West direction. See Figure 2 for layout of the core and frames.

The concrete shear walls have a bearing capacity of f’c = 9000 psi, with two curtains of #7 rebar at 12 inches on center and #5 hoops and ties at 6 inches on center. The core extends the full height of the building from sub parking level 8 to the roof level, a total of 338 feet. There are a total of four moment frames around the perimeter of Tower 333. One moment frame is on each North and South face, consisting of 3-30 foot bays with columns ranging from W14x730 at the mezzanine level to W14x132 at the penthouse level. The beams on the North and South frames range from W24x176 at floor 1 to W18x86 at the penthouse floor. The other two moment frames are on the East and West face, with one 26 foot bay and one 42 foot bay containing a range of columns from W14x550 at the mezzanine level to W14x132 at the penthouse level and beams ranging in size from W36x256 at floor 1 to W18x86 at the penthouse floor.

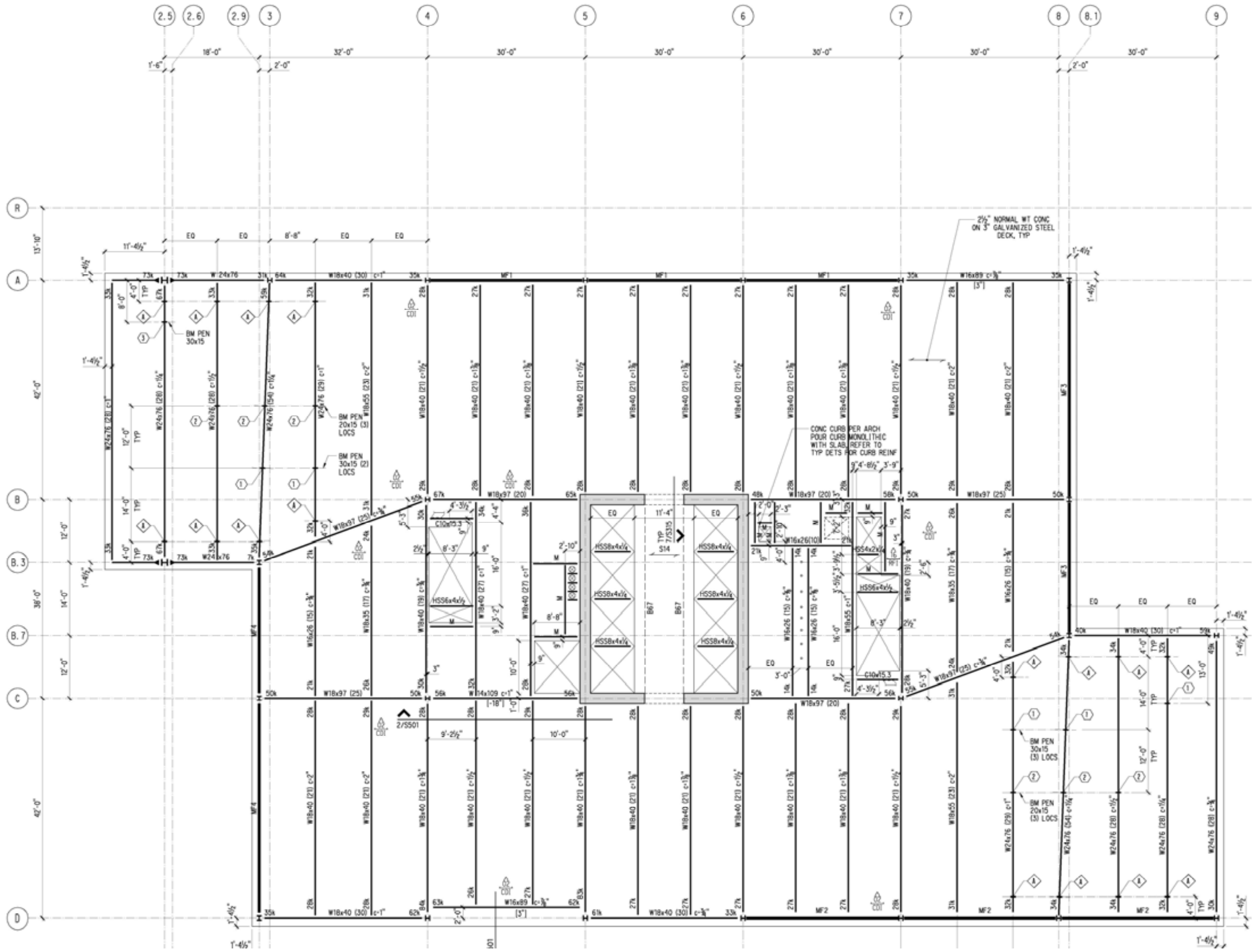

Figure 1:
Existing Structural Steel Floor Framing

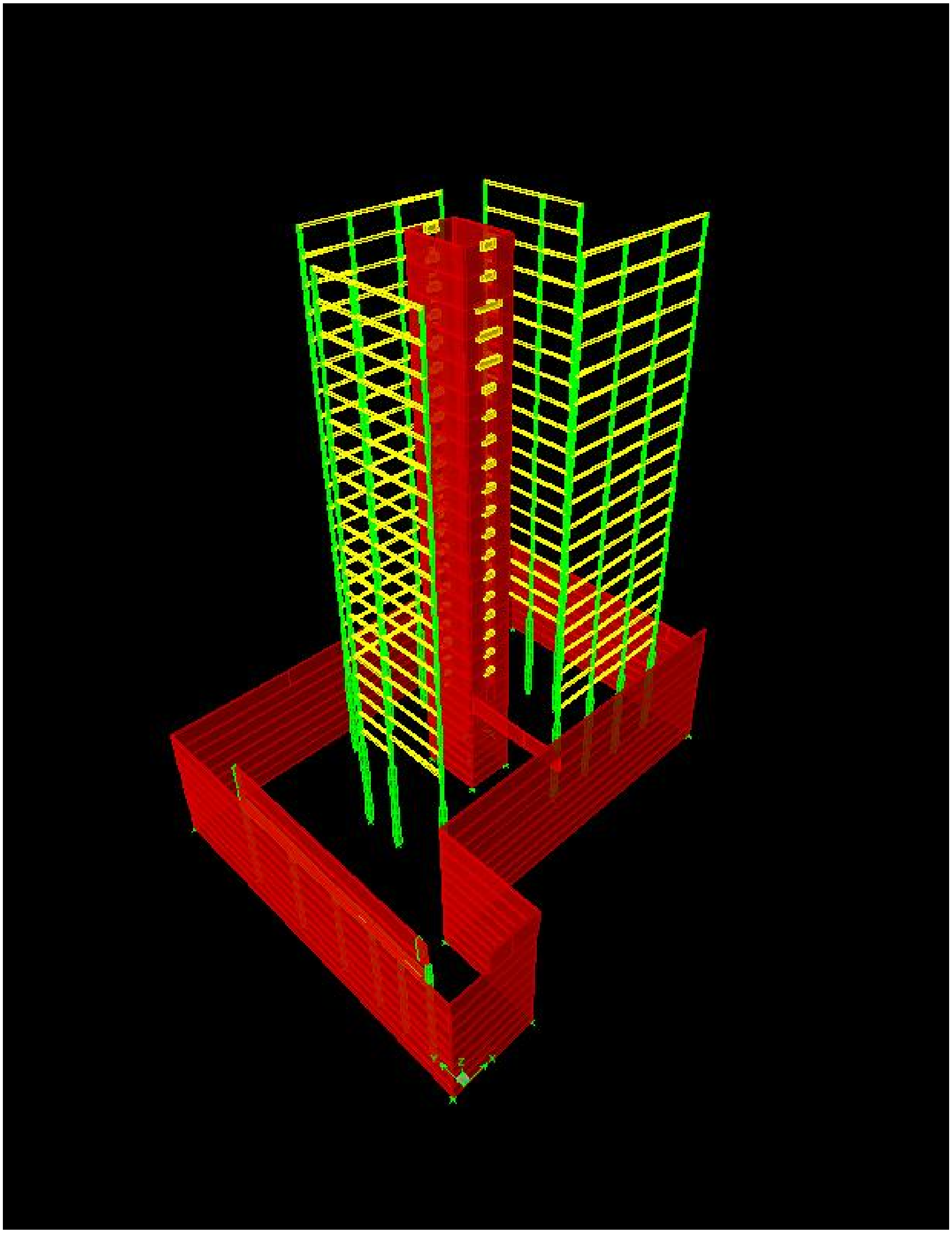

Figure 2
Existing dual core and moment frame lateral system.

Problem Statement:

The main reason for Tower 333 to utilize the existing abandoned foundation is that it saves time and money. However, along with utilizing the existing foundation and core comes the problem of retrofitting these systems to comply with the design of Tower 333.

The original building set to occupy the site was roughly the same height as Tower 333 but the superstructure was to be cast in place concrete with concrete shear walls outside of the core to help resist the lateral load. This allowed the core to be small in comparison to the building's size. Due to the fact that Tower 333 is a steel structure and no shear walls are implemented outside of the concrete core, the existing core is undersized, despite the reduction in weight from concrete to steel. Due to this fact, a dual lateral system of exterior moment frames in combination with the concrete core was designed for Tower 333. This dual system is required by code for any building over 260' in height that does not also have a peer review in the design phase.

In an effort to save construction time and labor costs, it is proposed that the exterior moment frames be eliminated and a core-only lateral system be designed for Tower 333. Using numerous codes including ASCE7-05, ACI, and IBC, along with software such as ETABS, it will be determined whether or not the proposed core-only system is a viable and economic alternative to the existing lateral system.

Problem Solution:

To provide adequate lateral stability, the concrete core will need to be increased in thickness. The coupling beams connecting the two "C" shaped sides of the core will initially be designed in concrete. These coupling beams will be designed to fail plastically and the core walls designed to fail elastically. The fact that the lateral system will be a concrete core-only will reduce the response modification factor to a value of 5, which increases the seismic loads needed to be resisted. The design for an elastic failure of the concrete core creates a more conservative design of the core and provides more redundancy in the lateral system. If the concrete coupling beams are inadequate according to strength and serviceability requirements to implement such a design, steel built-up "I" sections will be used instead.

According to the IBC, a core-only system on a building over 260' in height requires a peer review. To implement the most real-life situation as possible, a peer review for this proposal will also be implemented. A peer review by a Penn State AE faculty member, and or hopefully a professional of the industry on the west coast will be conducted. However, in a real-life scenario, a peer review could result in costly delays in the approval process of Tower 333. Currently certain cities on the west coast, such as San Francisco and Los Angeles are beginning to implement criteria into the building code which will allow for a core-only design above 260' without a peer review. Seattle and the surrounding areas where Tower 333 is located are also looking into a similar modification in the code. This proposal will try and implement those criteria of San Francisco into the design of the core-only system in attempts to expedite the peer review or even eliminate the requirement for one.

Solution Method:

To help eliminate weight, which results in a lower base shear, an option to use lightweight concrete on the floor slabs will be investigated. If this option proves to be uneconomical then normal weight concrete will be used and the core will be designed accordingly for the increased base shear. The modified concrete core will then be designed in accordance with ACI 318-05. Gravity and lateral seismic loads will be determined from ASCE7-05. Using ETABS software, a 3-D model of the proposed core will be created and a dynamic spectral analysis of the seismic loads will be computed. The existing system's ETABS model created for Tech Report 3 will be enhanced to include a flexible diaphragm to better model the seismic response and will also be analyzed. Through a comparison of the two models, it will be determined whether or not the new core-only lateral system proves to be beneficiary.

Breadth Options:

Along with the main study of the core-only system, two individual breadth studies will also be conducted. These include a study of Tower 333's façade system, with emphasis on installation methods, inspection and performance. The second breadth study will focus on the scheduling impact and cost savings involved with eliminating the need for moment frames and implementing a core-only lateral system. It also is hoped that a brief study of the collapse of the tower crane on November 16, 2006 can also be performed. However, this will be dependant on litigation issues that may result and availability of information from all those involved. As of now, information collected on the tower crane collapse is displayed on the Author's thesis CPEP webpage.

The first breadth study will focus on the performance and installation methods of the building façade. In most cases, problems with weatherproofing and poor performance of a façade system are not discovered until after the building is finished. Ultimately, costs involved in resolving these issues turn out to be much higher than if the problem was discovered and fixed during construction. In the case of Tower 333, the type of façade and installation methods described in the specifications will be investigated and a new specification, or an addition to the existing specs, will be written to address how to inspect and deal with problems regarding the façade during the installation process.

The second breadth study will involve the constructability, time and or cost savings regarding the elimination of the exterior moment frames and implementing a core-only lateral system. This study will entail research of the construction schedule and determination of the critical path of the construction process. If the critical path is affected by the core-only design, a determination of whether or not the impact is beneficiary to the construction schedule will be done. In addition to scheduling, a comparison of the cost savings of the proposed design will be studied. Any money saved, or extra money spent through the elimination of the moment frames as well as cost savings due to a change in schedule will be determined.

Tasks & Tools

I. Elimination of Moment Frames

Task 1: Determine Superimposed Loads

- a.) Determine superimposed loads from construction documents
  - i. Investigate lightweight concrete slab option
  - ii. Investigate normal weight concrete slab option (if required)
- b.) Determine superimposed live loads per ASCE7-05

Task 2: Establish Trial Member Sizes

- a.) Establish trial member sizes replacing moment frames
- b.) Establish trial core size

Task 3: Analyze Lateral System

- a.) Create ETABS model of new core-only system
- b.) Analyze effectiveness of new system using ETABS
- c.) Compare ETABS analysis with original design

II. Breadth Studies

Task 1: Façade Inspection & Performance Investigation

- a.) Acquire and study specifications of installation method
- b.) Research possible problems with system
- c.) Develop new specifications for inspection and troubleshooting of facade during installation

Task 2: Façade Inspection of Constructability and Schedule

- a.) Determine critical path of façade installation
- b.) Determine possible critical path change due to new specs
- c.) Compare cost savings of repairs during construction with repairs post construction

III. Possible Tower Crane Investigation

Task 1: Investigate Tower Crane

- a.) Determine Construction Loads
- b.) Determine Base Design
- c.) Investigate Conditions of Collapse

Timetable

	Week -2	Week -1	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9
Task 1: Determine Superimposed Dead Loads			C								S
Task 2: Determine Superimposed Live Loads, ASCE7-05			L								P
Task 3: Establish Trial member sizes			A								R
Task 4: Establish Trial Core Size			S								I
Task 5: Create ETABS model			S								N
Task 6: Analyze and Compare to Original Design			B								B
Task 7: Acquire Specs for Façade & Research Problems			E								R
Task 8: Develop New Specs for Façade			G								E
Task 9: Determine Critical Path &			I								A
Task 10: Compare Cost Savings			N								K
Task 11: Tower Crane Investigation			S								
Task 12: Print and Prepare Presentation											

	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16	Week 17
Task 1: Determine Superimposed Dead Loads					P			F
Task 2: Determine Superimposed Live Loads, ASCE7-05					R			I
Task 3: Establish Trial member sizes					E			N
Task 4: Establish Trial Core Size					S			A
Task 5: Create ETABS model					E			L
Task 6: Analyze and Compare to Original Design					N			S
Task 7: Acquire Specs for Façade & Research Problems					T			W
Task 8: Develop New Specs for Façade Inspection								E
Task 9: Determine Critical Path & Alteration Due To New Specs								E
Task 10: Compare Cost Savings								K
Task 11: Tower Crane Investigation								
Task 12: Print & Prepare Presentation								