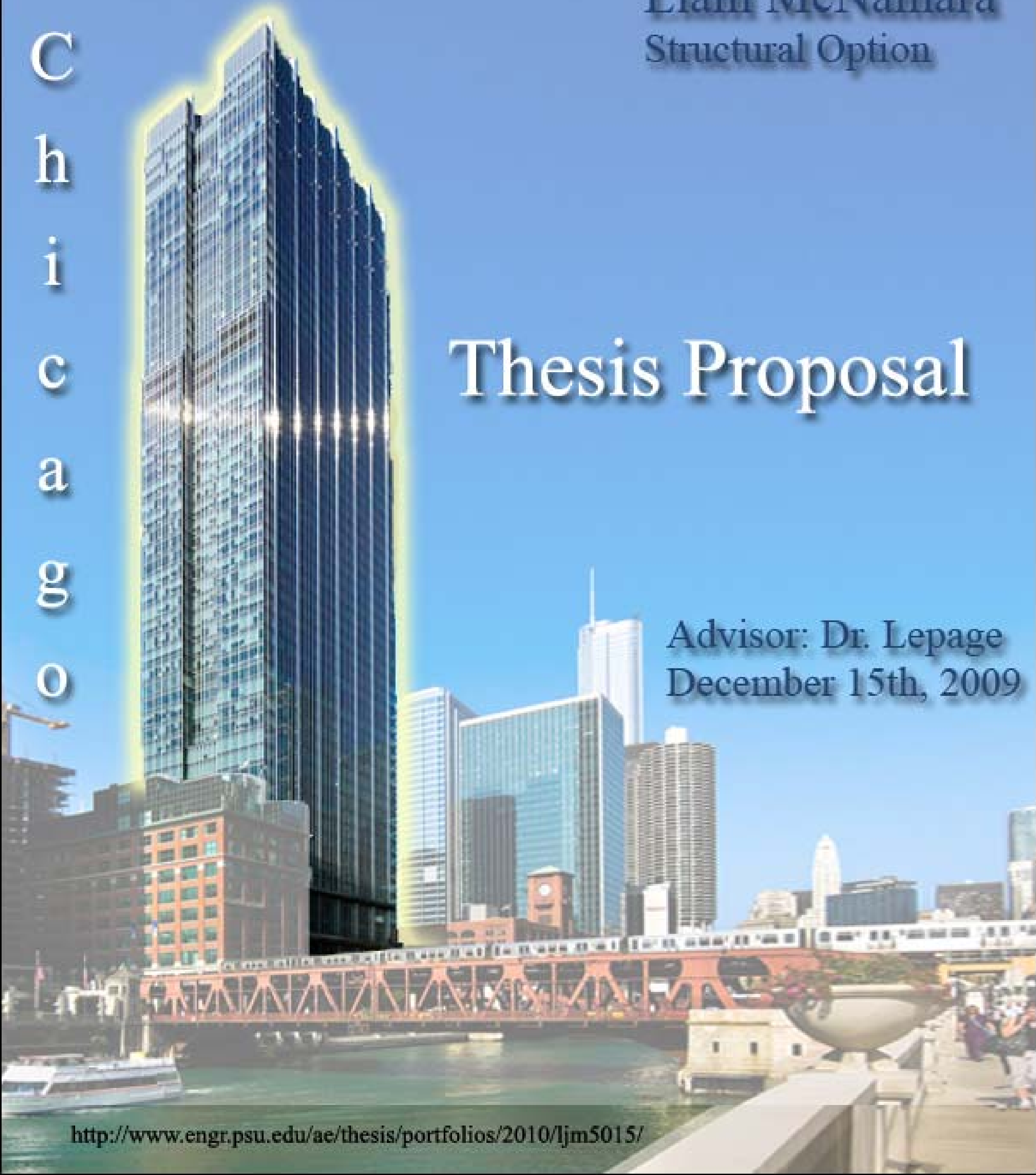
300 North La Salle

Liam McNamara
Structural Option

Chicago



Thesis Proposal

Advisor: Dr. Lepage
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http://www.engr.psu.edu/ae/thesis/portfolios/2010/ljm5015/

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Executive Summary

The following is a proposed depth study for the redesign of the structural system of 300 North La Salle. 300 North La Salle is a 60-story high rise office building located on the north bank of the Chicago River in Chicago Illinois. It offers 25,000 gsf of rentable, column free floor space per level, with a total square footage of 1.3 million. 300 North La Salle's current structural system consists of a large reinforced concrete core with exterior steel W-shape columns. The floor system consists of composite steel beams with 3" metal decking topped with an additional 3" concrete slab. The lateral loads are primarily resisted by the shear wall core which is stiffened by a series of 3 outrigger trusses, spanning north to south, and two exterior belt trusses, spanning east to west, located between floors 41 & 43.

300 North La Salle is a rentable office building, and the owner's profits are dependent on the amount of rentable floor space that can be sold. After analyzing the shear wall core in Technical Report 3 as well alternative floor systems in Technical Report 2, it was decided that if the floor system could be designed to act as a series of deep beam outriggers, the thickness of the shear walls could be reduced and the need for the trusses may be eliminated. This redesign will be performed with the intention of increasing the rentable floor space that the owner can make profit from when leasing.

The report will include the redesign of the floor system, and shear walls, as well as strength checks and necessary redesign of the exterior columns. The report will explore various changes to the truss system and corresponding evaluations.

Breadth studies will explore constructability and architectural impacts. The constructability could be an issue with respect to the new ceiling to floor "sandwich" of Mechanical, Electrical, and Plumbing systems through the castellations in the deep steel beams. This will be examined through Revit models and Navisworks clash detection. The architectural impact will occur with respect to changes at the truss levels. If the trusses can be removed or reduced and additional floors added the glazing will need to be reexamined on these levels as well as the location of the setback above the 43rd floor. These evaluations will be performed with sketches and Adobe Photoshop to explore effects on the overall building appearance.

Introduction

300 North La Salle is a 60-story high rise office building located on the north bank of the Chicago River in Chicago Illinois. It offers 25,000 gsf of rentable, column free floor space per level, with a total square footage of 1.3 million. Construction on the building began in 2006 and was completed in February of 2009 at a cost of $230 million. It is owned and managed by Hines developers and was designed by Pickard Chilton Architects. The primary tenant is Kirkland & Ellis, Chicago's largest law firm, occupying between 24 and 28 floors.

300 North La Salle rises elegantly above the Chicago River with a subtle set back above the 42nd floor. Its "fin-like" steel outriggers and aluminum mullions emphasize verticality. The appearance of structural members on the façade as well as the large open floor plans allude to Mies van der Rohe and the international style he helped make famous in Chicago. His international style incorporated open "universal" spaces that were easily adaptable with clearly arranged structural framework and a "less is more" motto.

The structural engineers for the design were Magnusson Klemencic Associates. The superstructure is composed of a bearing concrete core and six steel W-shape outrigger trusses spanning north-south, three on both cardinal sides, and two belt trusses spanning east-west on the north and south faces of the building. The trusses are all located between floors 41 and 43. The bearing concrete core wall also acts as a shear wall core to carry lateral forces to the foundation. The "belt" of trusses spanning from the 41st to 43rd floors aides in controlling lateral deflection of the structure and rotation within the shear wall core. The concrete strength of the core varies between 6,000 and 10,000 psi and the wall thicknesses vary between 1'6" and 2'3".

The typical floor system is composite beam with steel decking. It is composed of a 3" cast-in-place concrete slab on a 3" steel deck, and W-shape steel beams. The composite decking is typically 4,000 psi lightweight concrete. The steel members are Fy = 50 Ksi except for select columns on the lower level that are high strength Fy = 65 Ksi steel. The typical bay size is 28.5' x 45'. The system was chosen to efficiently span the 45' length creating a column free floor plan between the core and exterior of the building.

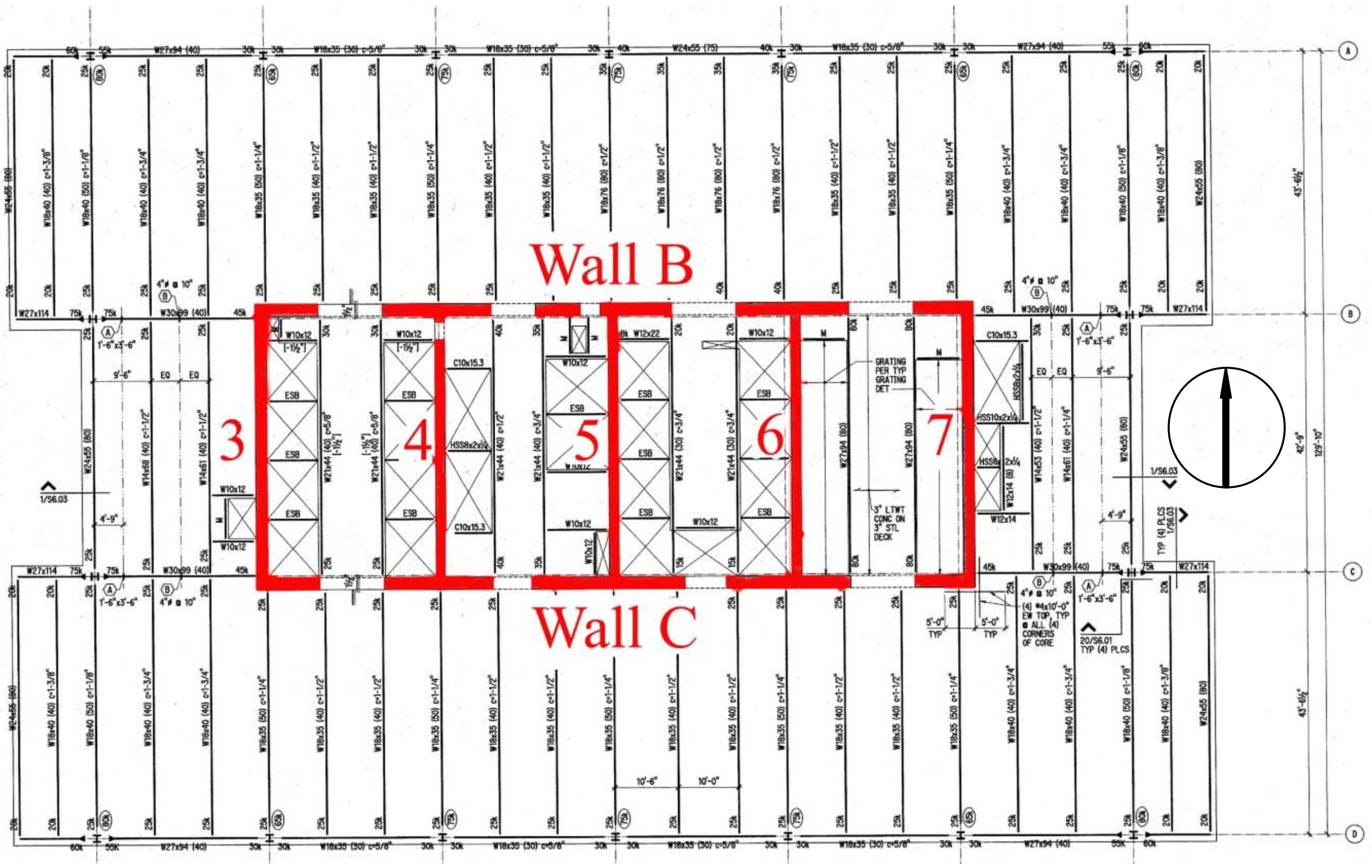

Figure 1 : Core Layout and Wall Designation

This report will be a depth proposal for a redesign of parts of the structural system of 300 North La Salle. The proposal will include a proposed redesign of the existing floor system, shear wall core, and outrigger and belt trusses. It will also pose other strength and serviceability issues that will arise from these changes which must be evaluated. The proposal also includes a breadth study of the architectural and constructability impacts of the redesign.

Existing Structural System

Foundations:

The foundation of the building is a combination of poured concrete piers and driven steel H-Piles with a 12" concrete slab sloping away from the core. The foundation slab is 28'-3" below grade and the foundation walls are 18" thick cast-in-place concrete around 3 levels of sub grade parking. The piers are drilled to approximately 72' below grade from top depths of 27'-41' below grade and have a bearing pressure of 40ksf. The piles are driven to refusal in bedrock at approximately 110' below grade and have a design bearing strength of 270 tons.

Gravity System:

The main gravity-load is carried to the ground by exterior steel columns and an interior concrete core wall. The floor system on every floor is poured concrete slab over composite decking. While the slab varies from 3" lightweight concrete, on the office floors, to as thick as 8" normal weight concrete in the mechanical area, the deck is a consistent 3" Type W minimum 20 gage galvanized steel. The composite decking transfers its loads onto 50ksi steel Wide flange beams typically spanning between 42'-9" and 43'-6½" spaced at 9.5' o.c. Below the elevator pits and Com Ed rooms on Lower Levels 1-4 the slab changes to normal weight 2-way flat concrete slab between 12" and 14" deep. The thickened two way flat slab is used to more readily carry the large live loads in these areas to the core. The roof system is also a lightweight concrete slab on 3" decking, however the beam size is increased to carry the additional weight from the green roof around the core of the building.

Lateral System:

Wind and seismic forces are resisted by a concrete shear wall core, strengthened by a series of outrigger and belt trusses between the 41st and 43rd floors. The shear wall core is cast-in-place normal weight concrete of 6,000; 8,000; and 10,000 psi strength depending on location. The wall reduces in thickness and plan as it rises through the building. The thickness reduces from 2'-3" to 2'-0" and then to 18" on the north and south walls at levels 9 and 43 respectively. The core has four 28'-6" bays running east-west as it rises from Lower Level 4 to Level 42, at Level 43 the core drops its outer two bays and continues through the penthouse with the inner two bays. The shear walls' step back to two bays corresponds to a 10' reduction in east-west width, at the top of the two story "belt" truss system. The floor and roof diaphragms carry the lateral loads to the shear wall core. The shear walls in the core then transfer the base shear, overturning moment, and rotational forces to the foundation.

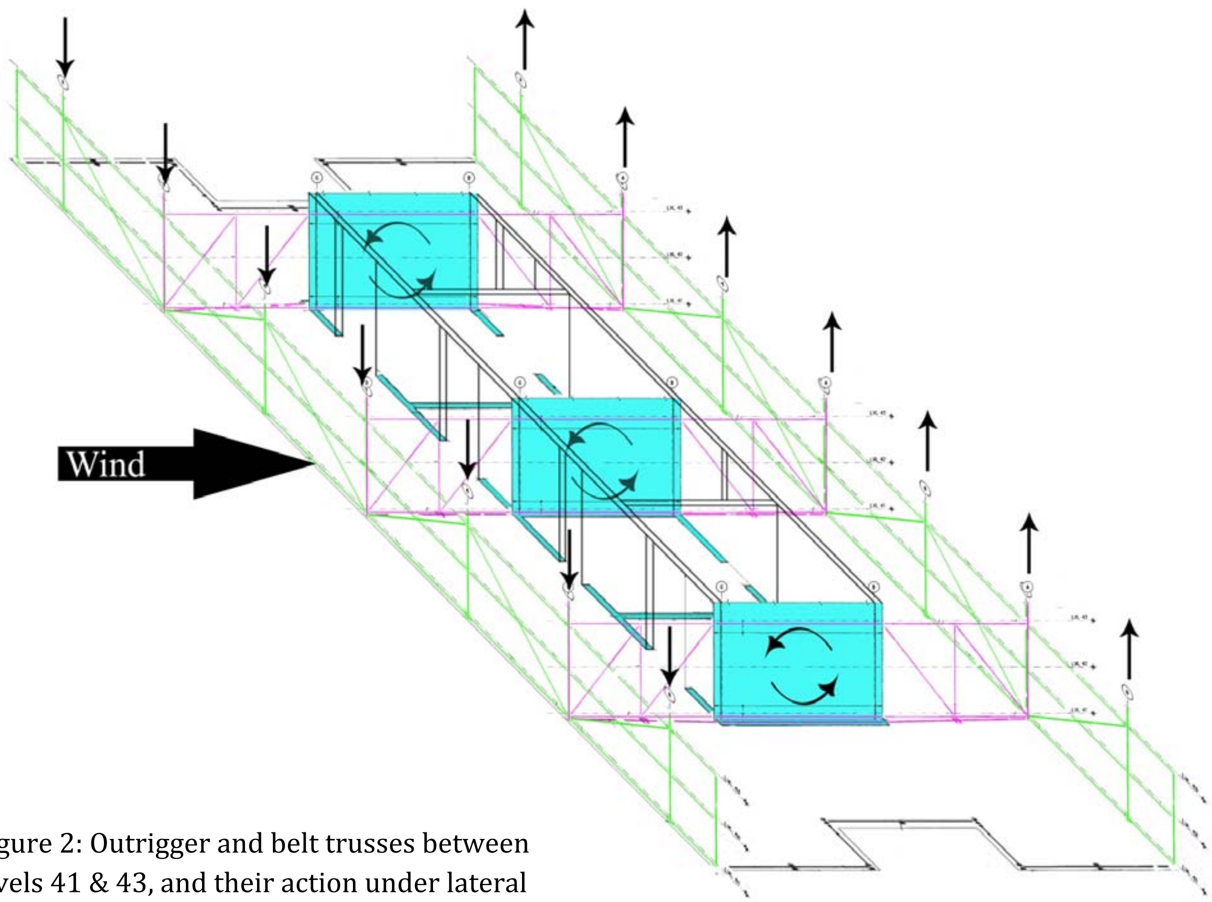

Figure 2: Outrigger and belt trusses between levels 41 & 43, and their action under lateral loads.

The belt truss system is comprised of two multi-bay braced frames running east-west on the north and south exteriors, and three braced frames spanning north-south to the concrete shear wall on the interior of the building. The truss members are varying sizes of steel Wide flanges. The purpose of this "belt" truss system is to create a couple moment, from the outrigger steel columns in the event of lateral loading. This couple moment is applied on the shear wall core to fight rotation within the core, and therefore reduce the deflection of the building.

Problem Statement

300 North La Salle's current lateral system is a reinforced concrete shear wall core with a series of 2-story tall outrigger and belt trusses between the 41st and 43rd floors. The shear walls are currently made of 6-10ksi concrete varying in thickness from 18-27 inches. The thicknesses are controlled by the drift of the building under lateral wind loads. The current composite beam floor system assembly typically consists of 3" of light weight concrete on top of 3" metal decking. The deck bears its gravity load on the exterior steel columns and the reinforced concrete core wall and also works as a diaphragm to transfer the lateral loads to the shear walls.

300 North La Salle consists of rentable office space; an increase in open floor space could return larger profits for the owner. The goal of this thesis is to increase rentable floor space by reducing the size of the shear wall core, and possibly adding an additional floor level.

Problem Solution

The building will achieve more net rentable floor space from a reduction in the size of the shear wall core. Upon early inspection it is proposed that reducing the core from 5 N-S walls to 3 thicker N-S walls could reduce the length of the core by up to 28'. Reducing the core to three N-S walls, will also require the outriggers to be moved and re-evaluated.

The shear wall thicknesses can initially be estimated by summing together the thickness of all 5 walls, and dividing it among the three new walls. By keeping the total area of the walls close to the original design, it will ensure that the core can carry the shear loads close to the ground as effectively as the original design. Other than shear checks, the flexural strength of the slimmed down core must be re-evaluated, it is anticipated that the thicknesses of the two walls running East-West will need to be increased. This is because along with carrying the shear in the EW direction, the walls act like flanges for the NS walls, and are imperative to resist flexure when loads are applied in the NS directions.

After studying how the outrigger trusses from levels 41-43 stiffen the shear wall core and transfer lateral loads into axial forces in the columns in Technical Reports 1 and 3 it was decided that if some form of outriggers were located on every floor it would reduce the loads on the shear walls. In an attempt to do this it is being proposed that the floor system be redesigned with deep castellated beams spanning from the core to the exterior colonnade.

The new proposed floor system would be up to 3' deep castellated steel W-shape beams. These beams would support long span composite metal decking and an additional concrete slab. The beams would need to be castellated, meaning that they would have large hexagonal holes cut through their webs, to run the mechanical and electrical systems through the beams and maintain the current floor to ceiling "sandwich" depth. The deep beams would then be connected to the columns and deep girders with moment connections. These connections would transfer lateral loads into axial loads on the columns, and reduce the amount of flexural loads being carried by the shear wall core.

This proposal would require a redesign of the floor system for gravity loads using the loads calculated in Technical Report 2. The columns would also have to be reevaluated and possibly redesigned under their new axial loading. The shear walls will then be resized based on their new loading and relative stiffness.

The changes to 300 North La Salle will then be made to the current ETABS model from Technical Report 3. Various models will be run analyzing the building without the belt trusses, without all of the trusses, and with smaller height trusses and an additional floor. These models will be used to investigate the building under design wind and seismic loads and check its deflection and drift against code.

Breadth Issues

The change of the floor system to deep castellated beams from the relatively shallow composite steel beam system will produce various construction management issues. The biggest effect will be during the scheduling of construction. While advantages will be gained by having to transport fewer structural elements since there will be less castellated beams the original design, difficulties will arise in scheduling the electrical and mechanical contractors. The mechanical and electrical systems must now be run through the castellated beams, and this could require longer installation times as well as cause conflicts between the MEP contractors. As a construction management breadth, a cost and scheduling evaluation will be performed to investigate the feasibility of using castellated beams.

The reduction of the shear wall core to 3 walls from 5 walls will affect the vertical circulation of people through the building. A study will be performed on the number of elevators necessary, to efficiently service all the floors. As an architectural breadth 5-10 typical floor plans for different levels will be redesigned to try and maintain the flow of people through the building. The results of this breadth will reflect the feasibility of reducing the shear wall core and provide details on how much floor space can actually be gained by the reduction.

Figure 3: Noticeable change in façade at truss levels.

MAE Course Related Issues

The MAE requirement for this course will be met by the ETABS computer model of this building. The computer model is reflective of the information taught in AE 597A. The model will be used to evaluate the building under lateral wind and seismic loads. The connections of the castellated beams to the columns will be done with methods taught in AE 534.

Problem Solution Method

The redesign of 300 North La Salle will be performed using the following codes and resources; IBC 2006, ACI 318-08, ASCE 7-05, AISC Design Guides, ETABS, RAM Structural System, and Revit Architecture. The new floor system will be designed with the aid of AISC Design Guides for castellated steel beams. The new gravity loads will then be used to evaluate the columns using RAM Structural System. Based upon the new design of the deep outrigger beams, the shear walls will be redesigned with requirements from ACI 318-08. The ETABS model of 300 North La Salle will then be updated and analysis of the building without alterations to the outrigger and belt trusses will be performed. Based on the results of this model, additional models may be made studying the buildings performance under various changes to the trusses as well as removal of the trusses completely. The ETABS models will be compared and confirmed or rejected based on ASCE 7-05 and IBC 2006 requirements. Select portions of the building will then be modeled in Revit Architecture to study changes to the façade, as well as the BIM study of the new floor composition.

Tasks

1. **Redesign Shear walls**
    a. Design thicknesses of 3 walls in place of the 5 walls running N-S
    b. Calculate relative stiffness of shear walls
    c. Distribute lateral loads from Technical Report 3 according to walls new relative stiffness
2. **Evaluate new design under lateral loading**
    a. Update ETABS model
    b. Run analysis of new design checking seismic loads if there is an increase in building weight
    c. Check serviceability under story drift and deflection
3. **Design of the new floor system**
    a. Determine design loads
    b. Research long span decking & castellated steel beams
    c. Determine structural floor plan layout
    d. Design deep castellated beams
    e. Design entire floor system including decking and girders
4. **Redesign Columns**
    a. Re-evaluate columns under new gravity loads
    b. Redesign columns if necessary
    c. Design deep beam to column moment connection
5. **Investigate various alterations to outrigger and belt trusses**
    a. Propose alternatives to existing trusses
    b. Build ETABS models with new alternatives
    c. Run analysis of new designs
    d. Check serviceability under story drift and deflection
6. **Construction Management investigation of new floor "sandwich"**
    a. Model existing mechanical, and electrical systems for a select floor in Revit Architecture
    b. Design new castellated beam in Revit Architecture

   c. Model new structural floor system in Revit Architecture integrating the previously modeled MEP systems.
   d. Import model into Navisworks and run clash detection
   e. Evaluate feasibility of new floor design

7. **Architectural façade design at truss levels**
   a. Evaluate effect of changes at truss levels on exterior
   b. Sketch proposed glazing changes
   c. Photoshop changes onto existing building renderings
   d. Evaluate aesthetics of alteration

8. **Final Presentation preparation**
   a. Organize, format and finalize presentation
   b. Prepare for final presentation

Proposed Schedule

January 2010

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
					1 New Year's Day	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24 / 31	25	26	27	28	29	30

January 5–16: Research / design deep beam floor system

January 17–23: Spot check / redesign columns

January 24–31: Redesign shear walls

February 2010

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	1	2	3	4	5	6
7					12	13
14	15	16	17	18	19	
21	22	23			26	27

Update and Analyze ETABs model

Design/ run alternate truss designs via ETABs

March 2010

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	1	2	3	4	5	6
7	8	9	10	11	12	13
14					19	20
21	22	23	24	25	26	27
28	29	30	31			

Alt. trusses continued

Constructability check via Navisworks

Architecture breadth

Final report prep.

April 2010

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
				1 Final	2 report	3 prep.
4	5 Final report prep.	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22 Earth Day	23	24
25	26	27	28	29	30	