Trump Taj Mahal Hotel

Atlantic City, New Jersey

Thesis Proposal

Prepared By: Stephen Reichwein, Structural Option

Faculty Advisor: Dr. Andres Lepage

The Pennsylvania State University

Department of Architectural Engineering

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Executive Summary

The Trump Taj Mahal Hotel is a 40 story hotel tower being built along the boardwalk in Atlantic City, New Jersey. It serves mainly as an expansion to the existing hotel on the adjacent lot. The tower's main lateral force resisting system is a massive concrete shear wall core. The floor system is comprised of both a filigree flat plate system in the main area of the floor plan and a conventionally reinforced concrete flat plate located in the core of the tower.

In order to open the Trump Taj Mahal Hotel in a more timely manner, a steel redesign will be conducted on the tower. This redesign will include both the lateral force resisting system and the gravity system. Special care must be taken in the design of each in order to avoid too many impacts to the architecture of the tower.

The lateral force resisting system will be designed as a core of steel braced frames. Adequate stiffness must be provided by the braced frames in order to effectively handle the design wind loads provided by the wind tunnel report issued by DFA. The strength requirements of AISC Manual of Steel Construction 13th Edition LRFD and the drift limitation of H/400 must be met or exceeded.

The current filigree gravity system will be redesigned as a steel frame with pre-cast planks. This system will be oriented in such a way that does not change the current floor to floor height of the tower. Some areas of the tower's plan may be too complex in order to utilize planks; therefore a slab on metal deck may need to be used in those areas.

By redesigning the Trump Taj Mahal Hotel in steel, various opportunities will arise for breadth studies. Two studies will be conducted; the architectural impacts resulting from the newly designed braced frame core and the construction management impacts of a steel structural system with comparison to the current concrete system.

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Introduction

The Trump Taj Mahal Hotel is currently under construction on the boardwalk in Atlantic City, New Jersey. It is scheduled for completion by the end of summer 2008. The tower rises 40 stories to a height of 434 feet from the base to the top of the large trump sign above the roof. The New Jersey State Uniform Building Code, parent code IBC 2000, was the code used in the design of the tower. The code references ASCE 7-02 for the determination of design loads. For the remainder of this project ASCE 7-05 as an update.

Background

Foundation

The entire tower rest on a reinforced concrete mat foundation, typically 9' thick around the core area; 6' thick elsewhere. The specified concrete compressive strength of the mat foundation is 5000psi. A geotechnical report prepared by Geotech, Inc., dated April 25, 1996, specifies the allowable bearing capacity of the soil on site as 4TSF and recommends that the site be classified as Site Class “D”.

Columns

Square, rectangular, and round reinforced concrete columns with standard ties are used throughout the hotel tower, with a wide range of sizes and reinforcing arrangements. Columns taper in size, decreasing in depth at the higher levels of the tower. Specified concrete compressive strengths also vary from 9000psi at the base to 5000psi at the higher levels.

Floor System

Two types of floor systems are used on a typical floor of the hotel tower. A one-way pre-stressed filigree flat plate system is utilized in the areas outside of the central core. Inside of the core, a conventionally reinforced flat plate system is utilized. 5000psi is the specified compressive strength of both systems.

A filigree flat plate floor slab acts as a composite system, utilizing both pre-cast and cast-in-place components. 8’-0” wide 2 ¼” thick pre-stressed planks form the base of the system.

Foam voids are cast on top of the planks, lowering the dead weight of the system. However, some floors of the tower with higher loads may have solid slabs instead of voided slabs. A layer of concrete is poured on top of the planks and 2 ¼" on top of the voids, if present. 10x10 W4xW4 Welded Wire Fabric is used as temperature reinforcing for the cast –in-place concrete.

The gravity loads of the filigree flat slab floors are transferred to the columns via 8'-0" wide conventionally reinforced in-slab beams that run 32'-0" x 16'-0" bays, typically. The filigree flat slabs are connected to the in-slab beams by reinforcing dowels, typically #7 bars on the top layer. The base of the beams are formed using the filigree planks, however the planks are not utilized in the strength of the beam.

Filigree Flat Slab System (Non-Core)

The proceeding diagram describes the various filigree flat slabs, by level number.

Level Number	Solid or Voided	Total Depth (inches)
2, 3	Voided	12
4	Solid	10
5 thru 39	Voided	10
40	Solid	12
41	Solid	10

Conventionally Reinforced Flat Plate System (Core)

The proceeding diagram describes the various conventionally reinforced flat plate slabs, by level number.

Level	Reinforcing	Thickness (inches)
2, 3	#6 @ 12" Bottom, Each Way	12
4	#7 @ 12" Bottom, Each Way	10
5 thru 39	#6 @ 12" Bottom, Each Way	10
40	#6 @ 12" Bottom, Each Way	12
41	#7 @ 12" Bottom, Each Way	10

Lateral System

Four ordinary reinforced concrete shear walls, spanning from the base of the tower to level 41, are the primary lateral force resisting system of the Trump Taj Mahal Hotel. Two 58' long walls resist the forces in the east/west direction, as well as the north/south direction. These four walls form the core that lies in the geometric center of the tower.

The shear walls decrease in thickness, 24" from levels 1 through 4 and 16" from levels 4 through 41. Because numerous openings exist, link (coupling) beams provide load transfer across the openings, providing added stiffness for the entire system. Specified compressive strength of the concrete used for the shear walls varies by level, matching that of the columns.

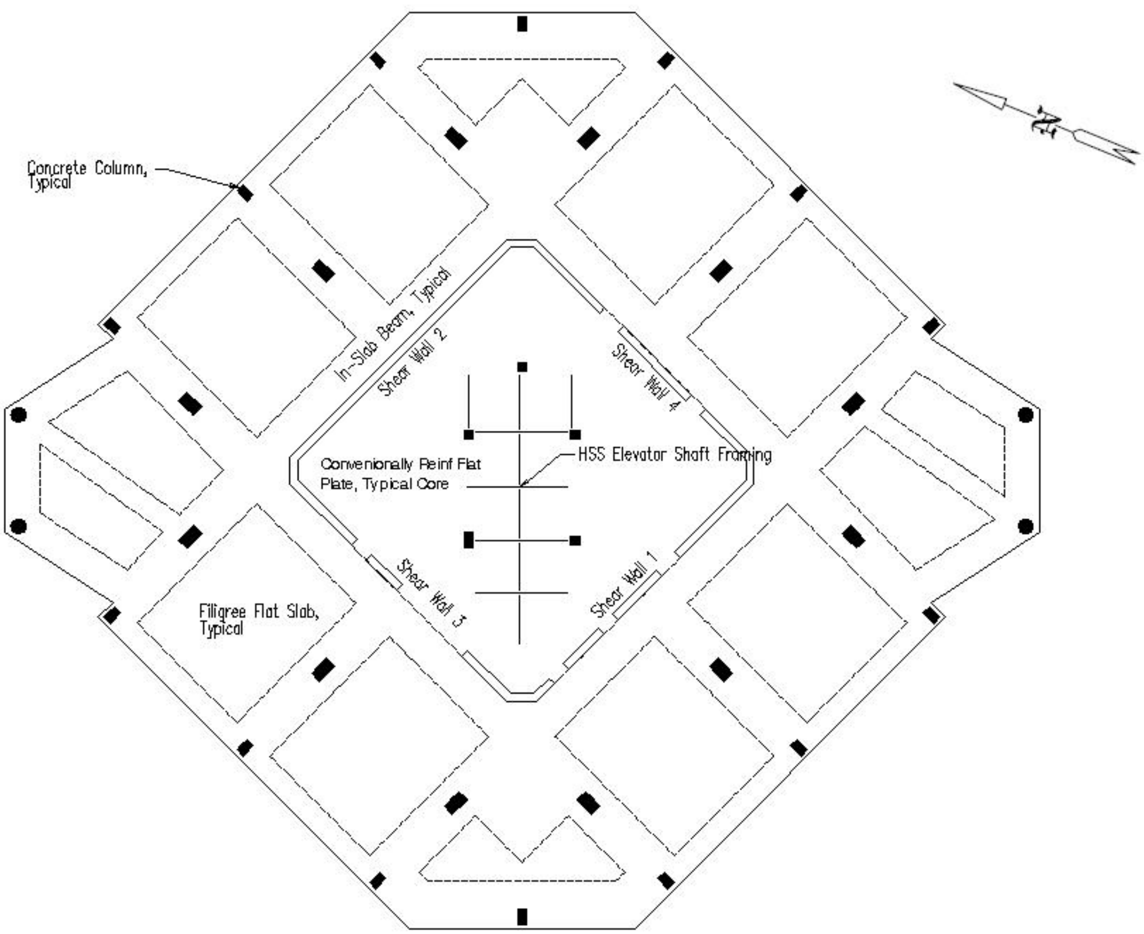

Figure 1: Typical Framing Plan

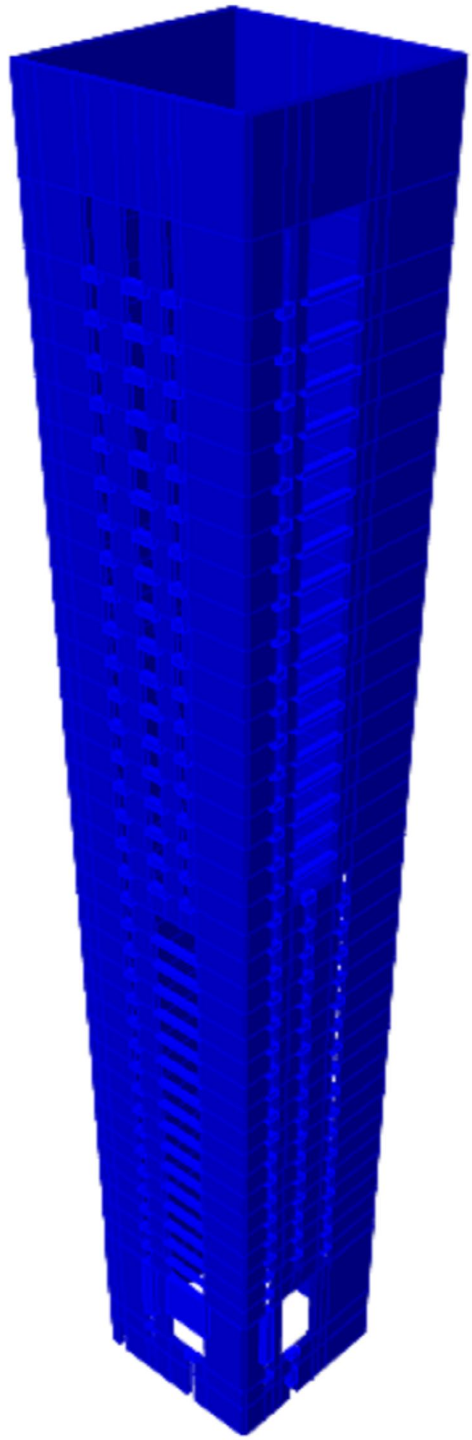

Figure 2: Ordinary Reinforced Concrete Shear Wall Core

Problem Statement

Concrete structural floor systems require a long erection time because they are labor intensive and require curing. However, what if Donald Trump wanted his hotel to open as soon as possible in order to generate revenue? Steel structural floor systems require much less time for erection compared to that of concrete systems. However, it was found in Technical Report Number Two (Reichwein, 2007) that the structural depth of a steel system is often larger, requiring an increase in the building height to retain the same area of rentable space. The increase in building height will also conflict with the wind tunnel test issued by DFA because it was performed using a scale model. Can such a steel system be devised in order to retain the current height of the building?

While investigating the effectiveness of the current concrete shear wall core with the use of ETABS in Technical Report Number Three (Reichwein, 2007), large inherent torsions were present under the wind loading specified by the wind tunnel test performed by DFA. This inherent torsion exists because the center of pressure of the wind and the center of rigidity of the building do not coincide. This happens because each wall has a different stiffness, caused by the unsymmetrical layout of the core openings. The perimeter of the building is also not restrained torsionally.

Despite its inherent torsion, the stiffness of a concrete core shear wall was able to effectively handle the wind forces of Atlantic City, New Jersey. However, the long erection time of a concrete shear wall will delay the opening of Donald Trump's hotel. In order to reduce the construction time of the lateral force resisting system, a steel system should be considered. But, could a steel system provide adequate stiffness in order to meet the drift requirements in a hurricane prone region?

Problem Solution

In an effort to reduce the erection time of the structure, a steel redesign of the Trump Taj Mahal Hotel is being proposed for farther study. This redesign includes both the floor system and lateral force resisting system of the building. All steel framing will be designed in conformance with AISC Manual of Steel Construction, 13th Edition.

A core of braced steel frames will be considered as the first alternative of the lateral force resisting system. An ETABS model will be constructed in order to distribute the lateral forces to each frame accordingly. The braced frames will be designed for strength using AISC 13th Edition LRFD and must meet the drift limitation of H/400 (for this particular project, 13 ½”). In order to provide the braced frames with adequate stiffness, built-up column sections may be needed at the lower levels of the hotel. If the braced frames alone cannot provide the adequate strength or stiffness, a hat truss or perimeter moment frames may need to be considered. However, perimeter moment frames will be avoided as much as possible. Moment frames are costly in terms of construction, as well as inefficient structurally.

The filigree floor system will be redesigned as a steel frame with pre-cast concrete planks. A steel frame with pre-cast concrete planks offers superior erection time. However, it was found in Technical Report Number Two (Reichwein, 2007) that this type of system would be the deepest structurally. A deep structure will possibly require a rise in building height. However, a new framing scheme has been developed in order to retain the current floor-to-floor height. Actual steel frame designs will be determined utilizing RAM Steel Frame according to AISC 13th Edition LRFD. Some depth restrictions may need to be imposed. Some areas of the hotel tower may impose geometric constraints that do not fully agree with pre-cast plank design. These areas may need to be designed using a slab on metal deck.

Breadth Proposals

By redesigning the Trump Taj Mahal Hotel in steel, various opportunities will arise for breadth studies. Two studies will be conducted; the architectural impacts resulting from the newly designed braced frame core and the construction management impacts of a steel structural system with comparison to the current concrete system.

The redesign of the tower in steel will impose various effects on the architecture of the tower. Because of the significant amount of changes being made to the core of the tower, a study will be conducted on the architectural impacts resulting from the newly designed brace frame core. The impacts to the architectural layout of the core will include alterations of the core openings, stairs, elevators, and service areas. A significant amount of changes are also being made to the floor system of the tower. In order to properly conceal the newly designed steel frame at the perimeter of the building, the addition of soffits above the window of each hotel room may be required. The partitions in between each hotel room may need to be widened in order to conceal the steel frame running on column lines in between rooms. A Revit model with each structural system will be constructed in order to illustrate the key architectural impacts; Both floor plans and interior renderings will be utilized.

There is a substantial difference between the construction management of a steel structure and concrete structure. Such differences include cost, scheduling, sequencing, and site conditions. Cost and scheduling of each system will be estimated utilizing the 2007 RS Means reference. Sequencing will be conducted using Primavera Schedule; a schedule of both structural systems will be compiled. Site conditions, including the tower crane size and place, of the newly designed steel system will be analyzed and compared to the current site. Finally, both the steel and concrete systems will be compared, illustrating key advantages and disadvantages of each.

Tasks and Tools

I. Redesign of Lateral Force Resisting System as a Steel Braced Frame Core

1. Task 1: Determine Design Loads
    a) Determine the superimposed live and dead loads from design documents and ASCE 7-05
    b) Determine wind loads based Wind Tunnel Report issued by DFA
    c) Determine seismic loads per ASCE 7-05, Equivalent Lateral Force Procedure
2. Task 2: Determine a symmetrical/asymmetrical layout scheme to accommodate openings
    a) Sketch various options
    b) Note architectural impacts for breadth study later on
3. Task 3: Set up a 3D model using ETABS
    a) Select trial steel member sizes
    b) Perform iterations until most efficient member and core sizes are found
    c) Check lateral drift and story drift against criteria set forth in ASCE 7-05
4. Task 4: Design and spot check critical members
    a) Verify strength of steel members per AISC 13th Edition LRFD
    b) Perform spot checks using hand calculations

II. Redesign of Gravity Floor System as Steel Frame and Pre-cast Concrete Plank

1. Task 5: Set up framing plan model using RAM Structural System Steel Module

    a) Determine framing plan

    b) Size members for loads determined in Task 1

    c) Spot check members to verify computer design

    d) Superimpose gravity loads and lateral loads to verify braced frame design

III. Breadth Studies

1. Task 6: Discuss architectural impacts of a structural steel system

    a) Redesign the core area to fit the needs of the occupants and services of the tower, but also the structural needs of the core based on Task 1

    b) Complete Revit Architecture model in order to compare the architectural differences between the structural steel system and the current concrete system

2. Task 7: Construction management impacts

    a) Complete a cost and time analysis of each system utilizing RS Means 2007

    b) Determine the sequencing of each system

    c) Complete a construction schedule of each system utilizing Primavera

    d) Analyze any changes that may need to be imposed on the site in order to accommodate the construction of the steel frame

    e) Compare both the steel and concrete systems and not key differences

Proposed Work Schedule

January, 2008

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
30	31	1 Winter Break	2	3	4	5
6 Winter Break	7	8	9	10	11	12
13 Winter Break	14 Task 1 - Determine Design Loads Classes Begin	15	16	17	18	19
20	21 Task 2/Task 6 - Determine a symmetrical/asymmetrical layout scheme to accommodate openings	22	23	24	25	26
27	28 Task 3 - Setup 3D Model of Braced Frame Core	29	30	31	1	2

February, 2008

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
27	28 Task 3 - Setup 3D Model of Braced Frame Core	29	30	31	1	2
3	4 Task 4 - Design and Spot Check Critical Members of Braced Frame Core	5	6	7	8	9
10	11 Task 4 - Design and Spot Check Critical Members of Braced Frame Core	12	13	14	15	16
17	18 Task 5 - Steel Gravity Frame and Precast Plank Design	19	20	21	22	23
24	25 Task 5 - Steel Gravity Frame and Precast Plank Design	26	27	28	29	1

March, 2008

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
24	25 Task 5 - Steel Gravity Frame and Precast Plank Design	26	27	28	29	1
2	3 Task 6 - Discussion of Architectural Impacts	4	5	6	7	8
9	10 Spring Break	11	12	13	14	15
16	17 Task 7 - Construction Management Issues	18	19	20	21	22
23	24 Task 7 - Construction Management Issues	25	26	27	28	29
30	31 Work on Written Report; Work on Presentation	1	2	3	4	5

April, 2008

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
30	31 Work on Written Report; Work on Presentation	1	2	3	4	5
6	7 Work on Presentation; Work on Written Report	8	9	10	11 Written Report Due	12 Rehearse Presentation
13 Rehearse Presentation	14 Present to Faculty Jury	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	1	2	3