THE Borgata ATLANTIC CITY

THESIS PROPOSAL

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Structural Option

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Executive Summary

The Borgata Hotel, located in Atlantic City, New Jersey, is a 43 story tower housing 2,002 guest rooms. These guest rooms combine for a total of 2.2 million square feet and serve the adjoining low rise Casino and Spa resort.

The buildings main structural system is comprised of a concrete frame with post-tensioned slabs. The building resists lateral loads with a network of shear walls in both directions of the building. A core of shear walls exists near the center of the building, as well as multiple shear walls scattered across the plan. The shear walls resist gravity loads as well and replace columns where they exist.

The focus of this thesis will be to refine the gravity and lateral systems of the building. Rather than redesigning the structure in steel, it has been decided to redesign floor systems using a precast filigree system. This redesign using filigree will reduce the overall weight of the building, in turn reducing the size of gravity members as well as seismic forces. In addition to redesigning the floor system, an investigation for the redistribution of shear walls will be done. This investigation will include relocating and resizing shear walls to evenly distribute stiffness throughout the building. With a more symmetric layout of stiffness in the building, torsion can be greatly reduced.

Two different filigree systems will be designed for this thesis. The building's new floor system will be analyzed using the direct design method and checked with computer programs. A filigree design guide provided by The Harman Group will be used for the design of the conventional filigree system. A design guide provided by The BubbleDeck® Group will be used to design the BubbleDeck® floor system. The lateral system will be reanalyzed using a new ETABS model. The members will be redesigned through a combination of hand calculations and the use of PCA programs.

An Architectural breadth study will be included in the relocation of the shear walls. The architectural program and plans will need to be considered while relocating walls for better distribution of stiffness. As well, a study to reduce the size of core will be done. By reducing the size of the core, it could be possible to fit an extra room per floor in the building. This would result in a total of forty or so extra rooms in the hotel. This increase could yield higher revenues for the owner with minimal initial cost increases.

The other breadth study will be in the construction management field. The use of the precast filigree system will greatly reduce the amount of time to erect the building. Every day that can be taken off the schedule can greatly impact not only the overall cost of the project, but also interest on loans for the building and revenue the owner can make by opening earlier.

Table of Contents

Existing Structural System

Floor System

The typical floor is supported by a post-tensioned concrete slab system. The concrete is normal weight (145 pcf dry unit weight) and has a minimum 28 day strength of 5000psi. The slab is 7” thick at the center of the building, and 8 ½” thick at each end where the floor plan is circular in shape. Typical guest floors have a floor to floor height of 8’-9”. The typical bay sizes are 30’-0” X 26’-0” and 30’-0” X 17’-0”. There is variation in span sizes at the ends of the building. Post-tensioned cables are to conform to ASTM A-416 and shall be Grade A or Grade B and are loaded with varying forces from 50 to 900 kips. The non typical floors are a mix of post-tensioned systems with a thicker slab, and two way flat slabs with drop panels.

Roof System

The flat roof slab is similar to the typical floor slab. It is a post-tensioned system, but the slab is 8 ½” thick for the entire slab. The roof slab supports most of the buildings mechanical equipment as well as catwalks used to access the mechanical equipment.

Gravity System:

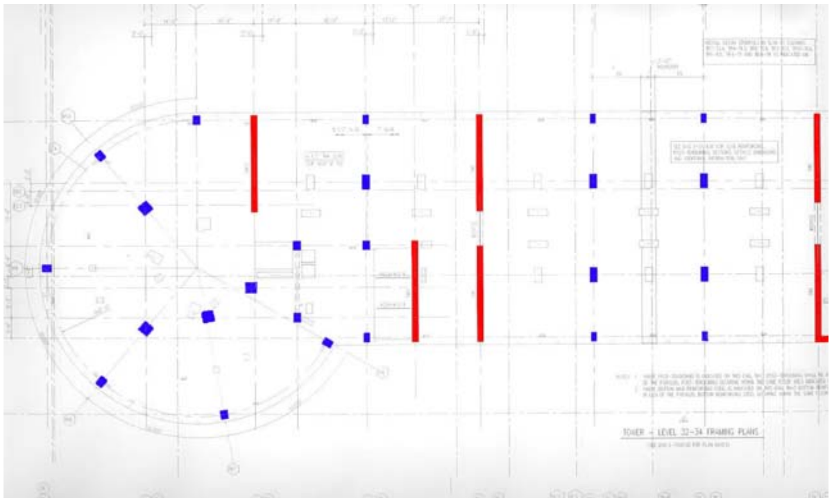
Gravity loads are resisted by a mix of cast-in-place columns and walls. The columns are the main gravity system, but shear walls replace columns where they exist. The concrete columns are typically 18”X30” of 24”x48” in size. Their compressive strength varies with story. At the bottom of the building the concrete strength is 9000psi, in the middle it is 7000psi, and towards the top of the building it is 5000psi.

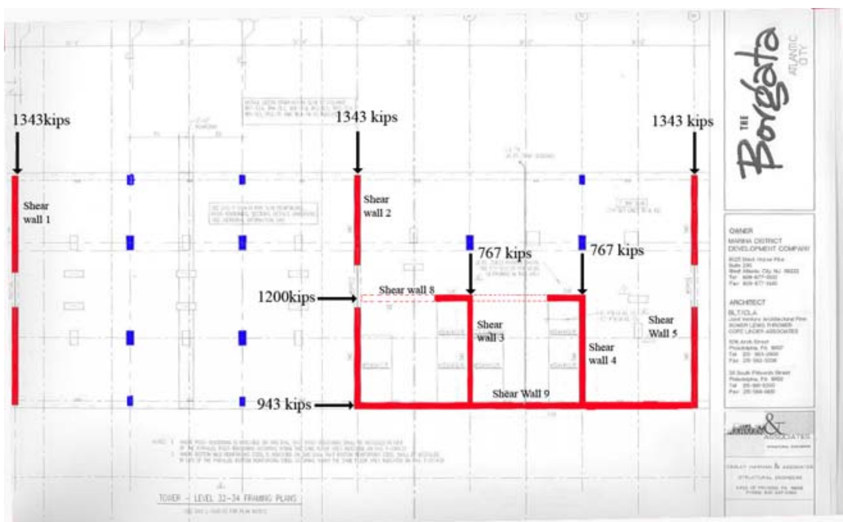
Lateral System: The structure is laterally supported by reinforced high strength concrete shear walls in both the North-South and East-West directions. The shear walls also assume gravity load from the floors. The concrete is normal weight and has a minimum 28-day strength of 9000psi for the entire height of the wall. Most of the shear walls extend the full height of the building, but a few stop at certain stories because of smaller shears towards the top of the building.

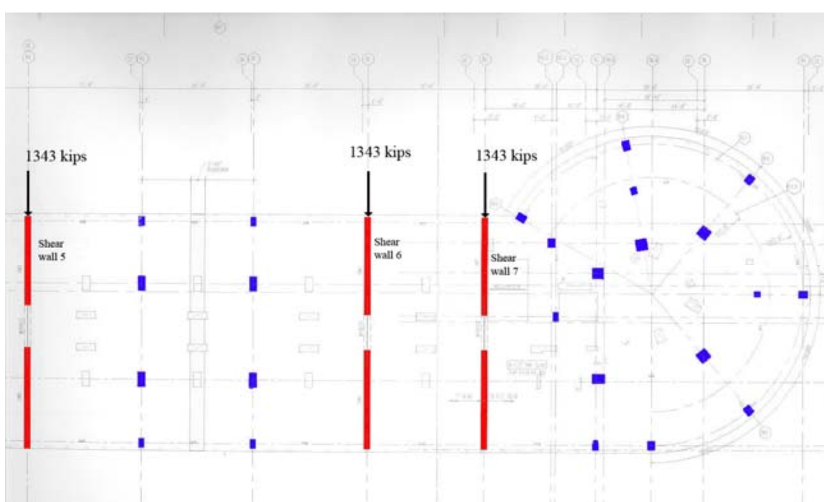
Foundation: The Borgata Hotel is located on the site of a former landfill. The dump was not excavated and the soil below the dump is a combination of marine tidal marsh and clay/sand seams. A deep foundation system was chosen for the building. The transfers gravity and lateral loads to the earth through concrete filled steel tube piles. The piles are 16” in diameter and contain reinforced concrete. Piles are driven to various depths until reaching very dense sand. Columns bear directly on pile caps which vary in size. In some cases at shear walls, the walls and columns bear on 9’-0” concrete pile mats. The slab on grade is a 1’-6” thick structural two-way slab. This slab spans between piles caps since the soil below (landfill) has no bearing capacity.

Existing Structural System

Typical Floor Plan







Problem Background

The Borgata Hotel utilizes a solid post-tensioned slab for its floor system. This slab is 7 inches thick, and in some areas 8.5 inches thick. The slabs contribute a great deal of weight to the building increasing the size of gravity as well as lateral members. In addition to high weights added to the building, a cast-in-place concrete floor system is costly and time consuming to construct. It must allow for the installation of forms, shoring, reinforcing steel and post-tensioning tendons. Proper curing time is also an impacting factor.

The shear wall layout of the Borgata is asymmetric. This dissymmetry in stiffness throughout the building, combined with high lateral loads, introduces high torsion on the structure. This torsion must then be resisted by the lateral system in addition to the initial lateral forces. Were stiffness more evenly and symmetrically laid out across the building plan, torsion could be greatly reduced, in turn reducing the sizes of lateral force resisting members and the foundations.

Problem Statement

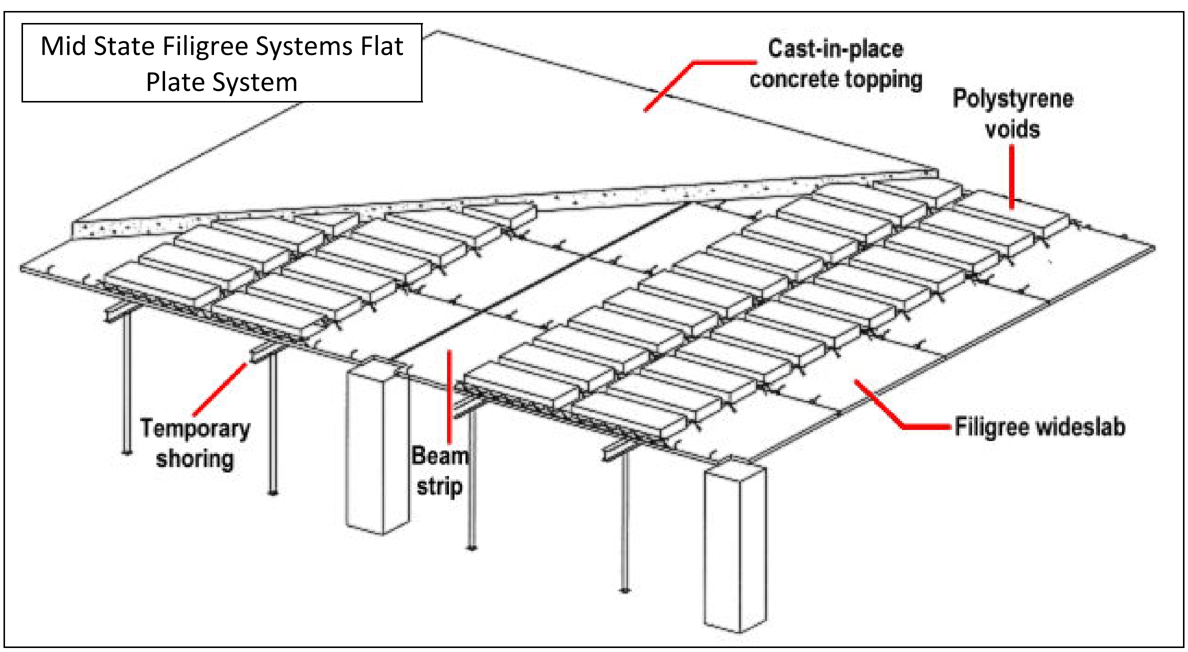
From analysis of the existing structure, the gravity and lateral systems have more than sufficient strength and stiffness to resist design loads and service limitations, respectively. An investigation into the refinement of the gravity and lateral system could yield more economical results. The floor system for the Borgata Hotel Tower is excessively heavy, increasing the size of gravity members and the magnitude of seismic forces. The cast-in-place post-tensioned slab is costly, labor intensive and lengthy to construct. A different system may be more economical to construct. The shear wall layout in the building is erratic. This asymmetric distribution of stiffness introduces large amounts of torsion to the building. A different layout of shear walls could greatly reduce the amount of torsion on the building.

Proposed Problem Solution

Floor Systems

The proposed solution for a redesigned floor system is the implementation of a filigree floor system. A filigree system utilizes prestressed precast panels as forms for a cast-in-place concrete topping. Once the precast planks are placed, reinforcing is installed and a cast-in-place topping is poured. Once this topping cures, the precast plank and cast-in-place topping act as a monolithic slab. In this thesis, two options will be considered for a filigree slab. The first and better known option is a system developed by Mid State Filigree Systems, located in New Jersey. The second option is a system called BubbleDeck®, developed by The BubbleDeck® Group. This system received its break through when implemented in the design of Millennium Tower in Holland. Both of these systems utilize hollow core technology that eliminates non strength performing concrete which drastically reduces the weight of the system.

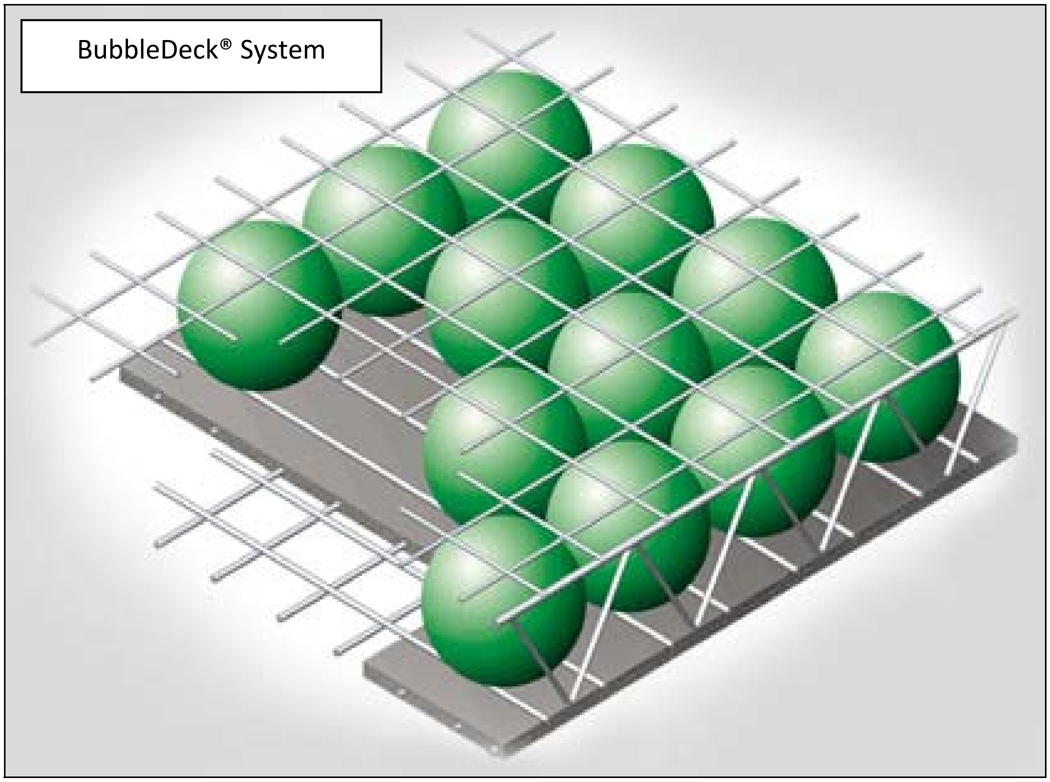
The system developed by Mid State Filigree Systems uses prestressed precast planks for the forms. These planks have polystyrene voids on them, located towards the centers of the spans. These voids reduce the overall dead weight of the slab. Along column lines, foam voids are not used. This solid slab creates the column strips. Mild steel reinforcing or post-tensioning tendons can be used in the cast-in-place topping in the direction perpendicular to the prestressing steel. Small horizontal trusses are also cast into the precast planks. Once the topping is placed on the planks and cures, the trusses create a composite action between the precast plank and the cast-in-place concrete. With this composite action, the slab acts as if it were a single monolithic slab. Below is an image of Mid-State Filigree's flat plate system.



Mid State Filigree Systems Flat Plate System

The system developed by The BubbleDeck® Group uses similar precast planks for forms, but instead of polystyrene voids, it uses hollow recycled plastic balls to create the voids. These balls eliminate concrete in the slab that does not add any strength to the slab. A grid of steel is placed above and below these balls to reinforce the slab. Below is an illustration of the BubbleDeck® system.

BubbleDeck® System



Along with structural advantages, the BubbleDeck system brings architectural advantages as well. The lightweight construction and biaxial behavior allows for long spans. The system can also be manufactured to fit to any shape. This could be especially important for this design because of the circular floor plan at each end of the Borgata. The BubbleDeck system also brings many green design related aspects to the project. The plastic balls are made from recycled material, and they can replace from 35-50% of the total concrete used in the slab. This is a substantial savings in raw material and great use of recycled material, which could help get LEED points for the project.

Lateral System

To resolve the issues concerning asymmetric stiffness distribution, an architectural and structural investigation must be done. In this investigation, new and viable locations for the shear walls will need to be determined. Building codes and the architectural floor plans will ultimately control where the shear walls may be located, and the ultimate and service loads will control their size. The floors plans, for the casino and the hotel will be investigated and possible relocations for shear walls will be chosen. Once new and viable locations are found, a model will be created using ETABS. With loads inputted into the model, the analysis will yield the force distribution in the building. From this analysis the shear walls can be sized and checked for adequate strength and serviceability requirements. Along with these requirements, a check on the overall torsion on the building will be calculated and deemed acceptable or not acceptable.

Columns and Foundations

Once the investigation and redesign of the floor and lateral system is complete, a refinement in the column and foundation design may need to be done. With a filigree floor system, the ultimate loads on the columns should be greatly reduced. This reduction in load could yield significantly column sizes. With a new layout for the shear walls, torsion could be greatly reduced. With both reduced gravity loads and torsion, the foundation design may be able to be adjusted accordingly. An investigation will be carried to determine the effects on the foundation system.

Proposed Solution Process

The analysis and design of the floor systems will be done using both hand calculation and computer aided design. Forces and moments in the slab (for both floor system options) will be found using either The Direct Design Method or The Equivalent Frame Method. The results of these analyses will be compared to results provided from PCA Slab. To design the system by Mid State Filigree Systems, a design guide provided by The Harman Group will be used. The design of the BubbleDeck® system may be carried out with any conventional methods used for designing a solid slab. A design guide provided by The BubbleDeck® Group will be used as well.

To redistribute the shear walls, an in depth analysis of codes, building program, and building floor plan must be done. From this analysis, new locations will determined for shear walls. With these new locations, new sizes can be approximated. Once the new layout and sizes for shear walls are approximated, a model will be creating using ETABS and analyzed to resist the design and service loads. From this analysis, hand calculations and computer aided design will determine the final size and design of the shear walls.

Once the new designs for the slab and shear walls are determined, recalculation of column and footing design will be done. Columns will be design using PCA Column. The method for investigating the foundation design is undetermined at this point. Research will be done to determine the appropriate method to carry out this investigation.

Breadth Studies

Two breadth studies will be conducted for this thesis. The structural investigation for this project has great implications for other areas of the building. A filigree floor system can substantially reduce the amount of labor, the over all cost, and the time to erect the structure. Since this is true, a breadth in the Construction Management Process would contribute to this thesis well. With a redistribution of shear walls in the building, an architectural analysis of the building must be done. Included in this analysis, it will be determined if the core of the building can be reduced in size.

For the breadth in construction management, a new schedule for the erection of the structure will be determined. The expected outcome will be a shorter erection time. Due to this shorter erection time, the building will be able to open sooner. Since the building will open sooner, the owner can begin to collect revenue sooner and make payments on loans sooner. Both of these effects will increase the overall monetary benefits the owner will earn from the building. In addition to a schedule investigation, an in depth cost analysis will be done for the new system. Included in this cost analysis will be the cost of the new floor system and the reduction in cost of other components due to the decrease in gravity loads.

For the architectural breadth, an in depth analysis of codes, building program and floor plans will be done to determine new locations and sizes for shear walls, as well an analysis in the reduction of the size of the core. If the can be reduced in size enough, it could be possible to fit another room per floor in the building. This would result in about 40 extra rooms in the building. With these extra rooms, the owner can collect extra revenue with minimal initial cost increases.

Schedule of Tasks

Time Period	Task
Jan 14 – 20	1. Research alternate slab design methods.
Jan. 21 – 27	1. Design typical bay with both alternative systems. 2. Compare results of alternate floor systems. 3. Square footage cost analysis for both systems. 4. Compare square foot costs of both alternatives to original design. 5. Choose alternative system.
Jan. 27 – Feb. 3	1. Redesign a typical floor with chosen alternative floor system.
Feb. 4 – 11	2. Resize typical columns for new gravity loads. 3. Recalculate effective seismic weight and compare new seismic base shear to wind produced base shears.
Feb. 12 – 18	1. Architectural analysis to decide new shear wall locations and feasibility of a reduction in core size. 2. If extra room is possible, calculate initial costs versus future revenue. 3. Choose new shear wall locations and preliminary sizes.
Feb. 18 – 24	3. Construct and analyze model in ETABS.
Feb. 24 – Mar. 2	1. Redesign shear walls.
Mar. 3 – 9	1. Do detailed cost analyses for alternative floor system, using costs of floor system, and costs affected by reduced weight.
Mar. 10 – 16	1. Create structural system erection schedule. Compare to original erection schedule.
Mar. 17 – 23	1. Write paper. 2. Work on presentation.
Mar. 24 – 30	1. Peer review for paper. 2. Revise and edit report. 3. Work on presentation.
Mar. 31 – Apr. 6	1. Finalize report. 2. Work on presentation.
Apr. 7 – 13	1. Finalize presentation. 2. Practice presentation.
Apr. 13 – 20	Presentations
Apr. 28 – May 4	Awards Jury
May 4 - 11	Relaxation