Introduction

The JW Marriott is a 24 story hotel currently under construction in Grand Rapids. The 376,000 square foot hotel will offer over 300 guest rooms. With multiple accommodations including a business center, restaurant, and 24 hour concierge the JW Marriott will match the service of any hotel in the area. The unique elliptical shape will be a strong presence in the otherwise conservative Grand Rapids skyline. Reflective glass cladding helps to accentuate its place along the Grand River.

The hotel is being constructed under the 2003 Michigan Building Code. The 2003 MBC is an adoption of the 2003 IBC with state amendments. The building rises approximately 256 ft above grade. A helipad, heated driveway and sidewalks, and an adjacent parking deck with Sky Bridge give distinctive touches to the hotel. The architect and structural engineer determined that the absence of perimeter columns would have aesthetic benefits with minimal structural efficiency penalties. Wall-columns were used instead of large circular perimeter columns. These members typically 10 in wide and 11 ft long are concealed within partitions between guest rooms.

Background

Structural Codes:

- *Building Code*
  Michigan Building Code 2003. The 2003 Michigan Building Code is an adoption of the IBC 2003 with state amendments.
- *Structural Concrete*
  ACI 318-2002. Building Code Requirements for Structural Concrete.
- *Concrete Masonry*
  ACI 530-1999. Building Code Requirements for Masonry Structures.
- *Structural Steel*
  LRFD Specification for Structural Steel Buildings, 2nd Edition. AISC.

Foundation:

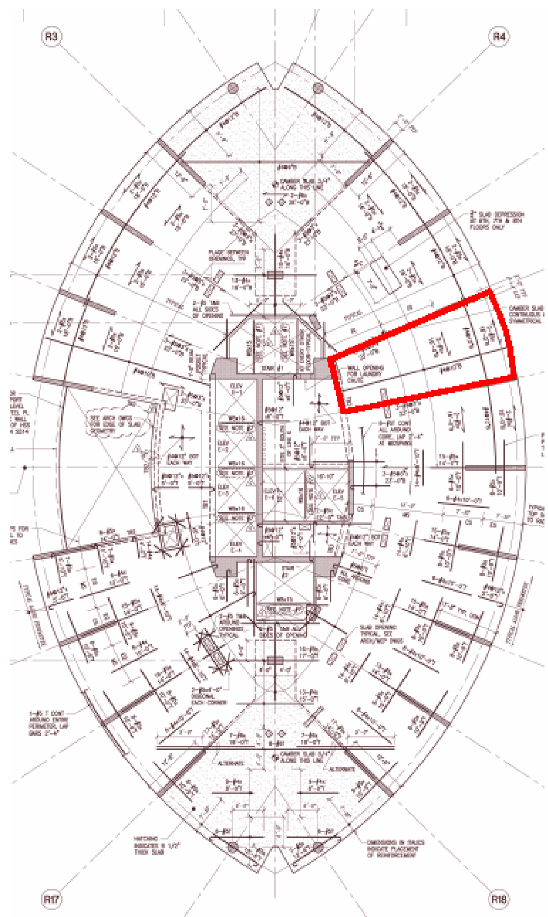
The foundation of the JW Marriott consists of multiple parts. A slab on grade covers the entire basement with 6 inches of 4000 psi concrete reinforced with WWF and 10 inches of 4000 psi concrete reinforced with 4#12 bars each way in the loading dock area. Grade beams span between the building elevator core pile caps. The grade beams range in size from 16-28 inches wide by 42-48 inches in height. All grade beams are 6000 psi concrete reinforced top and bottom. Along the perimeter of the tower there are 21 pile groups that consist of (4-7) 200 ton micropiles. Each micropile is driven 19' into the ground. In the elevator core there is a group of micropiles, (94) 200 ton. Just outside the elevator core there are two groups of 8 micropiles, one on each side of the core in the North-South direction.

Framing System:

The repetitive tower framing plan is advantageous to the structural engineer and general contractor. The typical framing plans take effect from floor 5 through 23. On the first and second floor there are 21 reinforced concrete columns, 24 inches in diameter. The concrete in the columns changes from 10 ksi at the ground level to 8 ksi at the sixth floor, and to 6 ksi at the fourteenth floor. Above the fifth floor the number of circular columns is reduced to four. In the guest rooms, columns are replaced by a series of 10 inch thick wall-columns to maximize views. The elevator core offers support for the interior of the structure.

Floor System:

The existing floor system of the JW Marriott (JWM) is a one-way reinforced concrete flat plate from floors 5 through 22. The slab is 7.5 inches thick and uses 5000 psi strength concrete (unless otherwise noted). Fourteen openings in the slab, located in the main corridor, allow for mechanical duct access. The overall shallow profile of the system permits greater flexibility for the architect's interior design. Throughout the guest levels, the building code specifies 40 psf live load. The size of the typical bay is a trapezoid with sides 10'-7" and increasing to 17'-9" and a skew side length of 35'-3".



Lateral System:

Concrete shear walls serve as the primary lateral force resistance. Located within the elevator core, the walls span from the basement to the helipad. Two major pairs span in each direction (two 25'-6" walls in the East-West direction and in the North-South direction a 35’ and a 10’-7” wall). All shear walls are 12 inches thick. Figure 1. Typical Bay

Additional lateral support is gained from the wall-columns placed along the exterior of the JW. These walls are typically 11’-8” wide and 10” wide. The wall-columns are staggered at angles ranging from approximately 45-78 degrees from vertical. The concrete used in both shear walls and wall-columns vary with height above grade from 6 to 10 ksi.

Problem Statement

The JW Marriott has been designed with great care to optimize all building systems in conjunction with the architect’s difficult plan. The structural system used has proven to be the best choice based on research done in technical reports 2 and 3. In technical report 2, the flat plate framing system proved superior to all alternatives satisfying industry standards for mid rise residential structures. The lateral system proved to be sufficient when analyzed and compared to ASCE7-02 for wind and seismic loading in technical report 3. The JW Marriott performs sufficiently for low seismic activity. However, if the owner wished to use the same unusual building design in Monterey, California, an area of high seismic activity, the structural system would certainly need to be modified.

Problem Solution

Industry standards have proven that the most efficient material for mid rise residential structures is concrete.

Therefore, the floor system should remain a flat plate system to optimize material and labor costs. Attention must be paid to joints and interfaces connecting columns, beams, and slabs together to assure proper rotational capability. The current 7.5 in flat plate system will be redesigned if the current thickness and concrete slab strength (5000 psi) are found to be insufficient for the new loading conditions and code requirements.

Shear wall lateral systems have proven to be reliable under high seismic activity. With this in mind the lateral system will be redesigned to withstand much larger seismic forces in accordance with the appropriate codes.

Solution Method

Floor System:

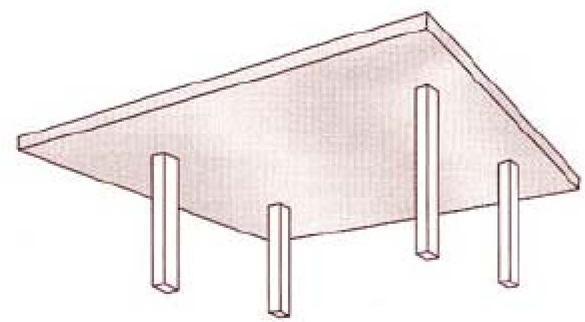


Figure 2. Flat Plate System

The flat plate floor system will be designed in accordance with ACI 318 Chapter 21 Section 21.11 with special checks for deformation capability. Computer modeling with ETABS will be done to simulate the floor system and then compared to manual findings. The live loads shall be in accordance with ASCE7-05. Pattern loadings will be checked for full live load on all spans, full and half live load on adjacent spans, and ¾ full loads and no load on adjacent spans will be investigated.

Lateral System:

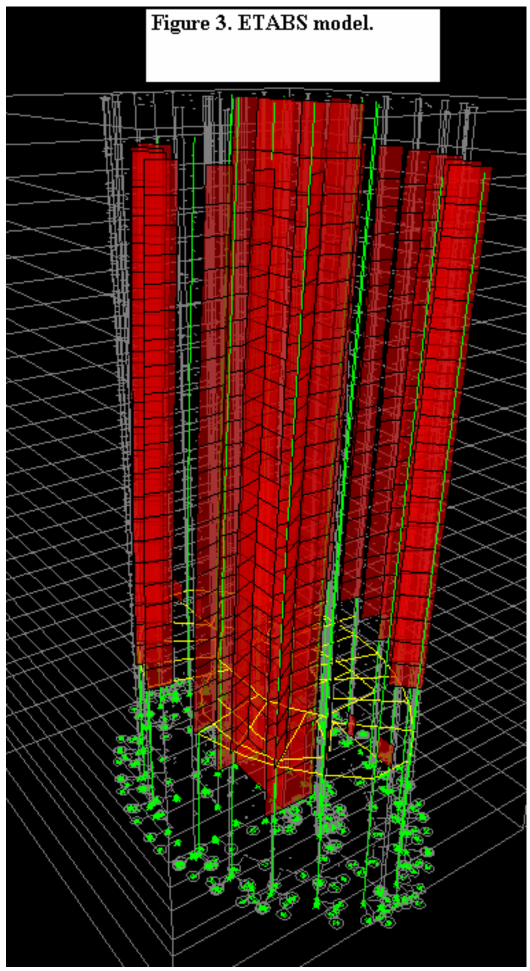


Figure 3. ETABS model.

The lateral system will be analyzed for the wind and seismic loading conditions set forth in ACI 318-05 Chapter 21 Section 21.7 with special checks for deformation capability. All applicable loading combinations will be investigated per ASCE7-05. The loading data will then be placed into ETABS and analyzed to determine the forces within each wall. The computer model forces will be compared to those found by hand analysis. The wall will then be designed based on the worst case loading combination of forces.

Note: For both systems the following topics will also need to be considered.

- *Accidental torsion and amplification*
- *Redundancy Factor*
- *Overstrength Factor*
- *Deflection and amplification Factor*
- *Vertical Earthquake Effects*

Breadth Options

Redesigning the JW Marriott for a high seismic zone, Monterey, California, will offer many opportunities for breadth study. I will focus on two major areas of study, construction management and mechanical systems.

First, construction must be considered because joints connecting building elements are likely to endure rebar congestion. The design must be done in a manner that concrete may be fittingly poured and reach proper consolidation. If necessary I will investigate alternative concrete mix designs to solve any dilemmas. 3-D AutoCad drawings will be made to show examples of critical joints and the rebar inside them.

Second, if the building is to be built in Monterey the mechanical system will be subject to change as well. Higher cooling loads and lower heating loads will warrant a new air handling unit. For instance, average January temperatures differ by 31 degrees between Grand Rapids and Monterey. With this in mind I will determine the current heating loads, new heating loads, and then chose a handler suitable for Monterey.

Tasks and Tools

Phase 1. Flat Plate Floor System.

- Task 1. Determine superimposed loads
  - Determine dead loads from architectural and structural drawings
  - Determine live loads in accordance with ASCE7-05
- Task 2. Establish trial member sizes
  - Determine minimum slab thickness from ACI 318 Ch. 9 Sect 9.5.3 to control deflections
  - Consult PCA Simplified Design publications
- Task 3. Refine Floor System
  - Use SEAOC Seismic Design Manual
  - Verify findings with ACI 318-05 Chapter 21 Sect. 21.11 with special checks for deformation capability
- Sub-Task 7. Determine Constructibility of Members
  - Investigate beam/column/slab/shear wall joints for rebar congestion
  - Determine if alternate concrete mix designs necessary for proper consolidation, if so, design new mix
  - Establish construction procedures

Phase 2. Main Lateral Force Resisting System.

- Task 4. Verify wind and seismic loads
  - Use ASCE7-05 to determine wind and seismic loading
- Task 5. Determine Loads on individual structural members
  - Use ETABS computer modeling with previously determined lateral loads
  - Use manual and spreadsheet analysis (in part from technical report 3) to find loads to individual members

  - Compare computer to manual findings

Task 6. Design Lateral System Members

  - Use SEAOC Seismic Design Manual and PCA notes on ACI 318 to establish trial sizes
  - Design concrete sections in accordance with ACI 318-05 Ch. 21 Sect. 21.7 with special checks for deformation capability
  - Design reinforcement and layout in accordance with ACI 318

Sub-Task 7. Determine constructability of members

  - Investigate beam/column/slab/shear wall joints for rebar congestion
  - Determine if alternate concrete mix designs necessary for proper consolidation, if so design new mix
  - Establish construction procedures

Phase 3. Breath Studies.

Task 7. Determine constructability of members

  - Construct 3-D AutoCad representations of typical joints

Task 8. Design mechanical air handling unit

  - Determine Grand Rapids and Monterey cooling and heating loads
  - Select new air handling unit

Time Table

	Jan. 16	Jan. 22	Jan. 29	Feb. 5	Feb. 12	Feb. 19	Feb. 26	Mar. 5
Task 1								
Task 2								
Task 3								
Task 4								
Task 5								
Task 6								
Task 7								
Task 8								
Compile Final Report								
Create Final Presentation								
Present to Faculty								

	Mar. 19	Mar. 26	Apr. 2	Apr. 9	Apr. 16	Apr. 23	Apr. 30
Task 1							
Task 2							
Task 3							
Task 4							
Task 5							
Task 6							
Task 7							
Task 8							
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