Executive Summary

The Macallen building is a 14-story mid-rise residential structure with a maximum height of 169 feet. It consists of three parking levels and eleven residential floors. The parking levels are constructed of cast-in-place concrete and the residential levels utilize steel framing with composite deck. Additionally, the building contains a number of occupiable green roofs, the most prominent being the publically-accessible, 20,000 square foot green terrace on the first residential floor. It is the first residential building in Boston to receive LEED certification, earning a LEED gold rating.

Largely due to the unique architecture and amenities provided by the Macallen Building, only 20 of the building's 140 units are currently available, even though the doors weren't open to occupants until June 2007. However, the height of the building had to be negotiated with building officials due to Macallen's relative height with regard to surrounding buildings. In light of the building's popularity, this proposal includes the addition of another residential level to accommodate more condo units by placing one of the parking levels below grade. This floor addition would require attention to the building's foundation, parking capacity, and gravity supporting elements below the added story. Additionally, the parking garage layout would need to be looked at since cars would now enter the garage on level "P2" instead of "P1".

Furthermore, this proposed depth study includes a seismic analysis of the building in the seismically active zone of San Diego, California. San Diego was chosen based on its seismic activity and because it is foreseeable that the residents of the city would embrace the high-end, environmentally friendly condominium. This depth study also addresses the idea of the Macallen Building as a model for residential, environmentally safe buildings in America. If the structure can withstand the seismic forces in California, it can be built almost anywhere in the continental United States.

The building will be redesigned keeping the same structural type and layout wherever possible because it was determined in Technical Assignment #2 that the design was cost and strength efficient. The AISC Steel Construction Manual, 13th Edition and ACI 318-05 will be used as a basis for design. To supplement hand calculations, an ETABS model will be created to analyze the building in its entirety and compare design values.

A breadth study will be conducted on the construction-related issues involved in redesign of the building. Included in this will be an evaluation of increased revenue that could be expected by adding an additional story. Another breadth study will be performed on the building envelope to help ensure the longevity of building systems and save on repair costs over the building's lifetime.

Existing Structural System

Floor System

The floor system on the parking levels is a two-way, 1'-0" thick, reinforced concrete slab. Some areas of the floor are thickened to 1'-4". Slab reinforcement varies in both size and spacing depending on location.

The typical residential floor system consists of a 3-¼" lightweight concrete slab (with a maximum density of 120 pcf) reinforced with #4 rebar spaced at 12" on center in each direction. The slab is cast on a 2", 18 gage, galvanized steel deck. The composite system is completed with ¾" diameter, 4" long shear studs. This is supported by rolled steel W-shapes with typical nominal depths of 16" on interior spans and 24" along the exterior. Typical spans are 36'-0" and typical spacing is 8'-9½".

Roof System

The roof terrace on the first floor is supported by a 5" lightweight concrete slab cast compositely on a 2", 18 gage, galvanized steel deck. The slab is reinforced with #4 rebar spaced at 12" on center in each direction. Rolled steel W-shapes of varying size are used to support the composite roof system. Typical beam spacing is 8'-0" and 9'-0" and typical beam spans are 29'-6" and 36'-0".

The other roofing system found on the Macallen Building is a composite roof with a 17° slope. The slab is a 3-¼" lightweight concrete slab cast on a 2", 18 gage, galvanized steel deck. Slab reinforcement is #3 rebar spaced at 15" on center. The composite system is supported by W-shape steel members.

Lateral System

The lateral resistance system on parking levels is comprised of a series of cast-in-place reinforced concrete shear walls. The walls that run North-South are 1'-6" thick, 35'-0" long, and spaced at 72'-0" on center. The East-West shear walls are 1'-0" thick, 36'-0" long, and are located along the building's exterior walls.

The lateral resistance system on the residential levels in the North-South direction is achieved through a prefabricated, staggered steel truss system. The top and bottom chords of the trusses are W14 shapes with rectangular HSS (hollow structural steel) members running in between them, acting as web members. The web elements are fillet welded to gusset plates. The gusset plates are fastened to the bottom chord member and the slab is placed around the plate and reinforced with 180° hook bars. All truss chord-to-column connections are designed for an axial load of 60 kips.

Lateral forces in the East-West direction are resisted by steel moment frames. The beam to column moment connections are detailed with 5/16" fillet welds on the beam flanges and 4 x

4 x 3/8 angles attaching the beam webs to the supporting column with ¾" diameter, A-325X bolts. The column-to-column moment connections utilize steel channels of minimum size C9 x 15 to attach column webs. The channels are attached using A-325 slip critical bolts with a minimum 7/8" diameter.

Foundation

The foundation is slab on grade with piles. The slab is 1'-2" to 1'-6" thick depending on loading conditions. The piles are prestressed, precast concrete piles with minimum widths of 1'-2". The design load on each pile is 120 tons. The pile caps are reinforced concrete with thicknesses ranging from 3'-0"-4'-6". Due to grade changes around the site, some areas also required exterior, below grade concrete foundation walls (non-shear). These walls are 1'-0" thick with f'c = 4,000 psi.

Columns

The vertical supporting elements on parking garage levels are reinforced rectangular concrete columns with widths ranging from 1'-0" to 3'-0" and typical spacing at 36'-0" in the east-west direction. Vertical reinforcement ranges in size from #6 to #10 rebar and horizontal ties are either #3 or #4 bars, with varying geometry specific to the different column types.

The columns on residential floors are a combination of W14 steel shapes and rectangular HSS steel shapes. The typical floor-to-floor height on these levels is 11'-1". The W14 members are used in the moment frames whereas the HSS members are used as gravity columns. Typical gravity columns range in size from HSS 5 x 5 x 3/16 to HSS 10 x 10 x 5/8. Seismic frame columns are typically a W14 x 159 to W14 x 342. Column splices to both frame types occur every 22'-2" (or every other floor) at mid-floor height. The columns are braced by the floor system so the maximum unbraced length of any column is 11'-1".

Problem Statement

Previous technical assignments found that the current structure is suitable to resist calculated gravity and lateral loads. However, the design in most cases was efficient so it can be inferred that the increase in building weight and seismic zone change will warrant a partial redesign of building columns and complete redesign of moment frames, staggered trusses, and shear walls.

Solution

Although it was determined that the gravity load carrying system was adequate for the building's original design, the addition of another floor will warrant a redesign of all columns located beneath the additional floors. That is, the columns of the first, or lobby, floor and all parking levels will need to be redesigned. The steel columns on the lobby floor will be sized using AISC Steel Construction Manual, 13th Edition.

The concrete columns in the parking levels will be designed under the new loads with ACI 318-05 and the CRSI Handbook. The CRSI Handbook will be used to determine the sizes of irregular, non-critical column conditions. ACI 318-05 will establish column sizes for all other concrete columns.

The change in building weight and seismic zone will necessitate a new design for the lateral force resisting structure. Each moment frame, staggered steel truss, and shear wall will need to re-examined under the new seismic loads. It is anticipated that the depths of truss chords and moment frame beams will need to be increased. Any changes in floor-to-floor heights will be monitored and considered when analyzing the feasibility of the particular system. Additionally, changing the web members of the trusses from HSS to W-shapes will be evaluated for strength and feasibility. These changes to steel members will be made under the provisions of AISC Steel Construction Manual, 13th Edition.

To compensate for the additional lateral loading on parking levels, a thickening of shear walls will first be considered. If lateral forces cannot be resisted by shear walls of reasonable thickness, three alternative methods will be evaluated. The first is to decrease the spacing of the walls in the North-South direction and running shear walls in all bays in the East-West direction (as opposed to every other bay). The second option is extending the footprint of the lateral structure to other areas of the building. *Figure 1* shows that the lateral structure only exists in part of the overall building area. Lastly, concrete with higher compressive strength could be used. The parking structure uses 5 ksi concrete, however, concrete with higher compressive strength is commonly available on the west coast.

To supplement the aforementioned calculations, two ETABS model will be created. The first will implement the calculated design members and the other will utilize the same layout but allow ETABS to design the members. This will either confirm or deny the design and show how the gravity and lateral systems function together.

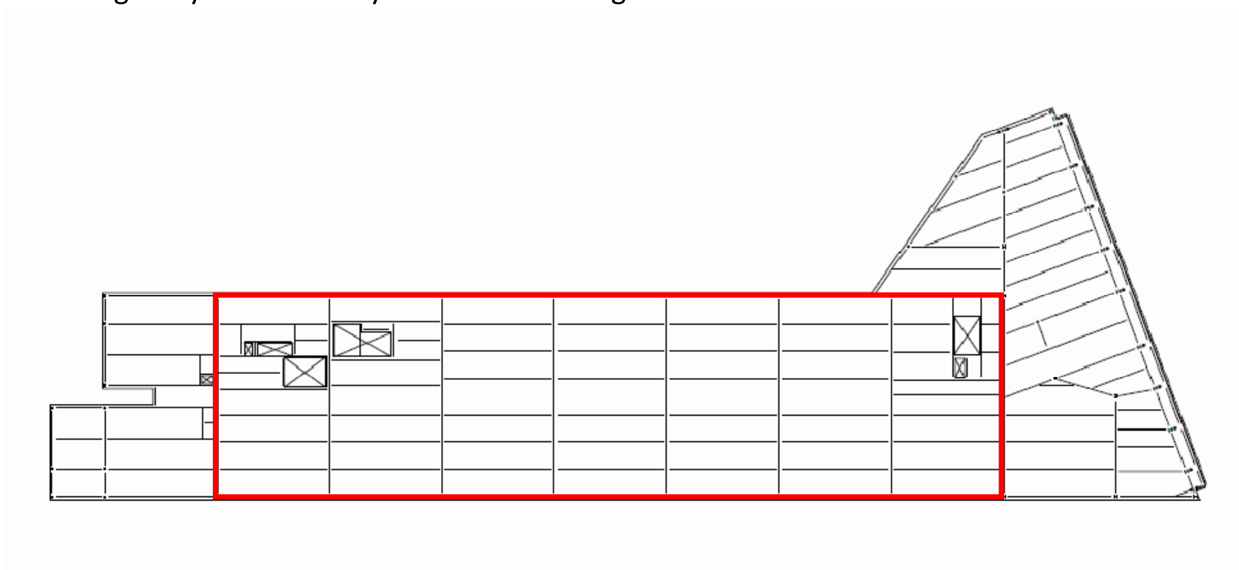

Figure 1: Extent of Lateral Structure on Typical Floor Plan

Breadth Options

Construction Management

This breadth study will focus on the scheduling impact and cost-related issues that will be impacted by the proposed structural changes. If a similar structural layout is practical to maintain, the only notable scheduling changes would involve the additional time needed excavate down to build the sub-grade parking level and to construct the extra residential story.

Cost analyses will be conducted separately for the increased revenue and the additional cost of labor and materials to implement the proposed building alterations. Additionally, the increased construction time will be considered before directly comparing revenue to cost. The owner is unable to profit from a condominium until construction is complete so small revenue gains may not outweigh scheduling delays.

Building Envelope

An analysis and possible redesign of the building envelope will be studied. Problems in building façades are often found after construction and the associated costs exceed those of the construction and design costs to install efficient systems. Additionally, fixing these problems after the building is constructed interferes with normal building operation.

The building façade materials, installation methods, and maintenance routine outlined in the specifications will be analyzed to find possible sources of water and sediment intrusion into the building envelope. Addendums will be added to the current specs in an effort to produce a more complete building envelope with the least chance of failure in either the short or long term.

The current and redesigned building envelopes will also be looked at to examine thermal losses. From this analysis, time forgiving, a cost savings could be determined based savings in operational costs of mechanical equipment.

Depth-Related Study

A brief study will be performed to ensure that it is possible for the building to house and supply the additional mechanical and electrical load induced by the additional floor.

Tasks

1. Structural Changes – Addition of Residential Floor
    a.) Redesign of columns beneath added floor using AISC Steel Construction Manual, 13^{th} Edition and ACI 318-05 for the steel and concrete columns, respectively
    b.) Address possible affects that this change will have on column splices. Column splice locations help determine column sizes so additional column alterations may be necessary.
    c.) Rearrange the second parking level to facilitate the parking garage entrance. Also, investigate options to increase the parking capacity to accommodate the additional building capacity.

2. Structural Changes – Change in Seismic Zone
    a.) Using the same framing layout, design the lateral force resisting system to resist new seismic loads using ASCE 7-05 to calculate loads and a combination of ETABS, AISC Steel Construction Manual, 13^{th} Edition, and ACI 318-05 to design the framing elements.
    b.) Compare ETABS design sizes to those obtained by hand and adjust members accordingly.
    c.) If supporting the new lateral loads proves to be impossible or impractical using the same layout, experiment with alternate layouts as outlined in the body of this report.

3. Building Envelope Breadth Study
    a.) Analyze the current building envelope specifications.
    b.) Determine possible weaknesses in the system and develop new or modified specifications that limit the opportunity for façade failure.

4. Construction Management Breadth Study
    a.) Compare the added cost to added revenue that could be expected from adding the additional residential level using R.S. Means Building Construction Cost Data to determine construction costs and correspondence with the developer for condo revenue information.
    b.) Create a revised construction schedule outlining the impact of the story addition. This will be used to further compare the benefit of increasing the number of residential floors.
    c.) Compare the short term vs. long term cost impact of the proposed building envelope changes.

5. Miscellaneous
    a.) Organize and format final report
    b.) Prepare final presentation

Schedule

Task	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
	Jan. 14-18	Jan. 21-25	Jan. 28-Feb.1	Feb. 4-8	Feb. 11-15	Feb. 18-22	Feb. 25-29	Mar. 3-7
1-a.) Redesign Gravity Elements to Support Additional Story								
1-b.) Address Column Splices and Make Changes where Necessary								
1-c.) Redesign Parking Levels to Accommodate New Building Arrangement and Capacity								
2-a.) Calculate New Seismic Forces and Re-Design Structure to Support the New Loads								
2-b.) Compare Design Values Between ETABS and Hand Calculations								
2-c.) Investigate Alternate Lateral Structure Layouts								
3-a.) Analyze Existing Building Envelope Specifications								
3-b.) Develop New Specifications for the Building Façade								
4-a.) Create Cost Comparison to Evaluate the Benefit of Adding an Extra Residential Level								
4-b.) Consider the Scheduling Impact of Adding an Extra Residential Level								
4-c.) Compare Short Term and Long Term Cost Savings Associated with Building Envelope Breadth Study								
5-a.) Organize and format final report								
5-b.) Prepare Final Presentation								

Task	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16	Week 17
	Mar. 10-14	Mar. 17-21	Mar. 24-28	Mar. 31-Apr. 4	Apr. 7-11	Apr. 14-18	Apr. 21-25	Apr. 28-May 2	May 5-9
1-a.) Redesign Gravity Elements to Support Additional Story	No Classes - Spring Break					Present to Faculty Jury			Final Exams
1-b.) Address Column Splices and Make Changes where Necessary									
1-c.) Redesign Parking Levels to Accommodate New Building Arrangement and Capacity									
2-a.) Calculate New Seismic Forces and Re-Design Structure to Support the New Loads									
2-b.) Compare Design Values Between ETABS and Hand Calculations									
2-c.) Investigate Alternate Lateral Structure Layouts									
3-a.) Analyze Existing Building Envelope Specifications									
3-b.) Develop New Specifications for the Building Façade									
4-a.) Create Cost Comparison to Evaluate the Benefit of Adding an Extra Residential Level									
4-b.) Consider the Scheduling Impact of Adding an Extra Residential Level									
4-c.) Compare Short Term and Long Term Cost Savings Associated with Building Envelope Breadth Study									
5-a.) Organize and format final report									
5-b.) Prepare Final Presentation									