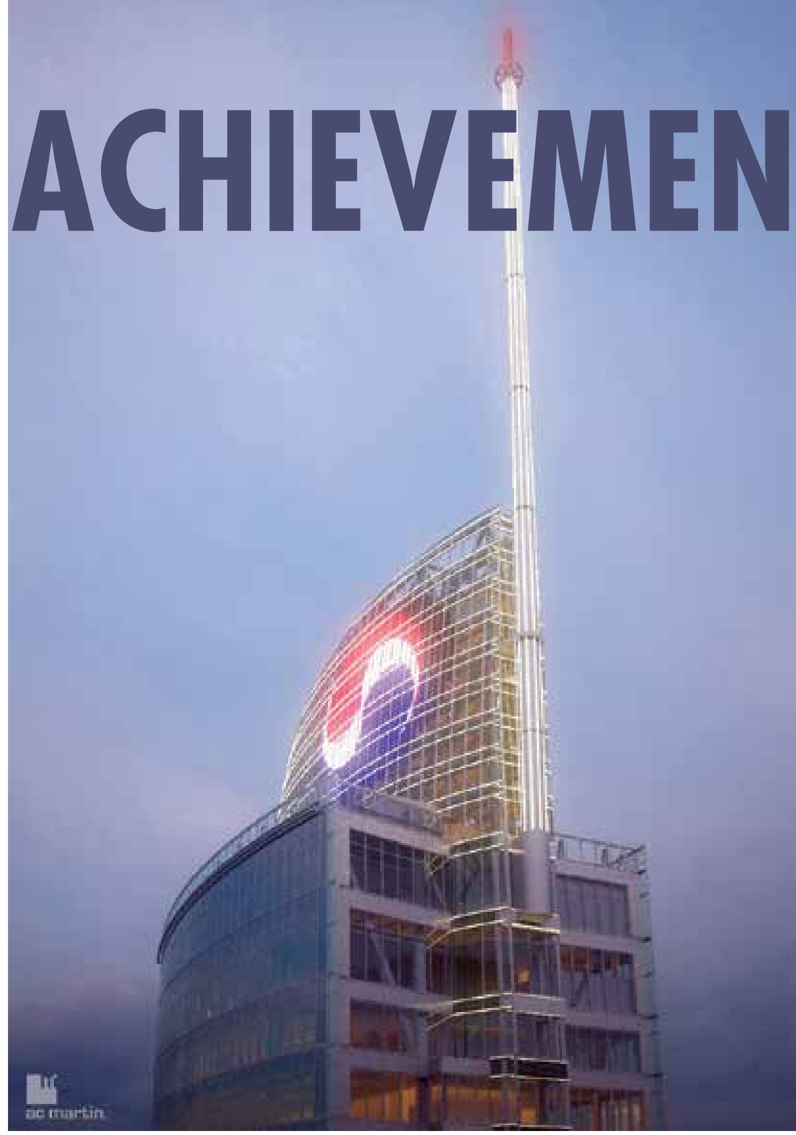
CROWNING ACHIEVEMEN



Sail and Spire with KAL logo. Courtesy of AC Martin.

By Gerard M. Nieblas, S.E., LEED AP, Peter J. Maranian, S.E. and Jeff Lubberts, P.E.

The crowning achievement on the Wilshire Grand project will be the Crown Sail and Spire that set atop the roof of the building. By any measure the crown sail and spire are a building unto themselves.

Typically, engineers place structures over rigid bases that are 10x stiffer than the structure above. This allows the structure to be designed as if on a rigid base. With the Wilshire Grand project, engineers set a stiff structure on top of a flexible one. This resulted in a sail and spire with very high seismic design requirements from upper mode effects produced by the supporting 73-story building.

Project Description

The Wilshire Grand Project is approximately 2,000,000 square feet with 900 hotel rooms, 400,000 square feet of office space and 45,000 square feet of retail space. The 5 level subterranean parking covers the entire site and will accommodate 1,100 vehicles. The structure will have a rooftop pool with ocean views, pressurized double decker elevators, an architectural roof top sail and a 300-foot tall architectural spire.

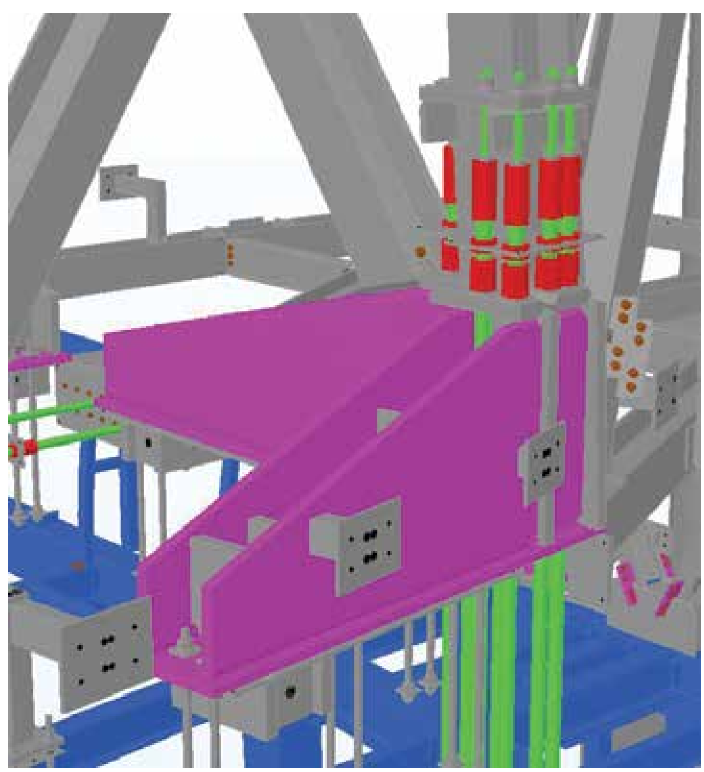
The Tower structure is 73 stories, with the lower floors comprised of office space and the upper 40 floors as hotel rooms. The lateral system for the building is a concrete core wall with concrete-filled steel box columns and structural steel framing outside the footprint of the core. The lateral system of the Tower is extremely slender. In the transverse building direction the core wall is 30 feet wide and nearly 1,000 feet tall.

Along the height of the structure there are buckling restrained braced frames to reduce the overturning demands of the core wall on the mat foundation, and to stiffen the structure for transverse wind and seismic drift.

Sail Structural System

The base of the sail is founded on the 73^{rd} floor with the sky bar and reflective pool. The sail houses the uppermost elevators and elevator machine room along with the tactical approach, building maintenance unit (BMU) #1 on the 75^{th} level, BMU #2 on the 76^{th} level, and catwalks for access to LED lighting.

Lounge at 73^{rd} floor. Courtesy of AC Martin.



Base of sail with DYWIDAG connectors anchors. Courtesy of Schuff Steel.

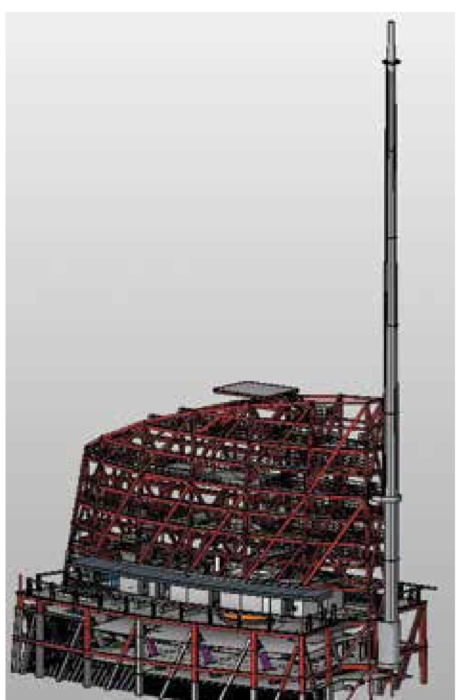
Artist rendering of Sail and Spire. Courtesy of AC Martin.

Top connection of spire to sail. Courtesy of Schuff Steel.

The structural system for the sail is a three dimensional space truss. The sail is approximately 100 feet tall and has a structural steel weight of about 900 tons, with a plan area of about 5,000 square feet.

The lateral forces from the Maximum Considered Earthquake (MCE) are 4.25G in the North-South direction and 5G in the east-west direction. These seismic forces induce uplifts on the wide flange columns as much as 3,800 kips. These high seismic demands are a result of higher mode effects from the supporting tower. These column bases were anchored with what are normally used as rock anchors (DYWIDAGs). These columns have 8 (150ksi), 2½-inch (2.8-inch OD) anchors embedded into the concrete 14 feet.

One of the many design challenges for the support of the sail were the effects of long term creep and shrinkage of the concrete core wall. Portions of the sail are supported directly off the concrete core wall and the edges of the sail extend over the structural steel framing. Over the next 100 years, the concrete core wall will creep and shrink approximately 2 inches more than the elastic shortening of the steel columns. The sail columns at the edges of the steel framing are designed with a 5-inch gap between the bottom of the column and the floor (that would normally support the column). This gap is necessary to keep these columns from pushing down on the steel framing from concrete creep, concrete shrinkage and MCE deflections.



BIM/Revit model of Sail and Spire.

Spire

The total height of the spire is 300 feet. The spire is supported vertically off the 72nd floor and is restrained horizontally from wind and seismic forces at the 75th level in the sail. The spire cantilevers 217 feet, with an 83-foot backspan.

The spire tapers along its height. At the base, the spire is 6½ feet in diameter and 3.33 feet in diameter at the top. The uppermost 17 feet of the spire is a light beacon. It is a tapered stainless steel circular section with perforated holes.

Long term creep and shrinkage of the concrete core wall created support problems for the spire. The lateral restraint of the spire on the 75th level has large steel pins with hinges to allow the sail structure to move downward with creep and shrinkage from the supporting core wall below. From transverse MCE loads, the maximum horizontal reaction is 660 kips per pin. All of the vertical loads of the spire are supported on the 73rd level.

The spire will be erected in 40 sections and bolted together. The bottom sections of the spire are joined together with 144 1⅛-inch A490 bolts.

The spire will be subject to wind loading over many, many years. To compensate for fatigue over the life of the structure, wind stresses were limited to 10ksi for the 50 year wind event. Ancillary welds to the spire for ladders and maintenance were also prohibited to prevent any adverse effects from welding. All ancillary attachments to the spire will be in drilled and tapped holes with rounded edges. The rounded edges reduce stress concentrations and allow for a more uniform layer of galvanization.

After galvanization, the welds will be peened to relieve residual tensile stresses. The process of peening induces residual compressive stresses in the peened surface. These surface compressive stresses provide better resistance to metal fatigue and to corrosion.

BMU's

There are two building maintenance units housed in the sail. BMU #1 is on the 75th level and BMU #2 is on the 76th level. Each of these BMUs fold outward and telescope upward to clear the sail and maintain the exterior of the structure below.

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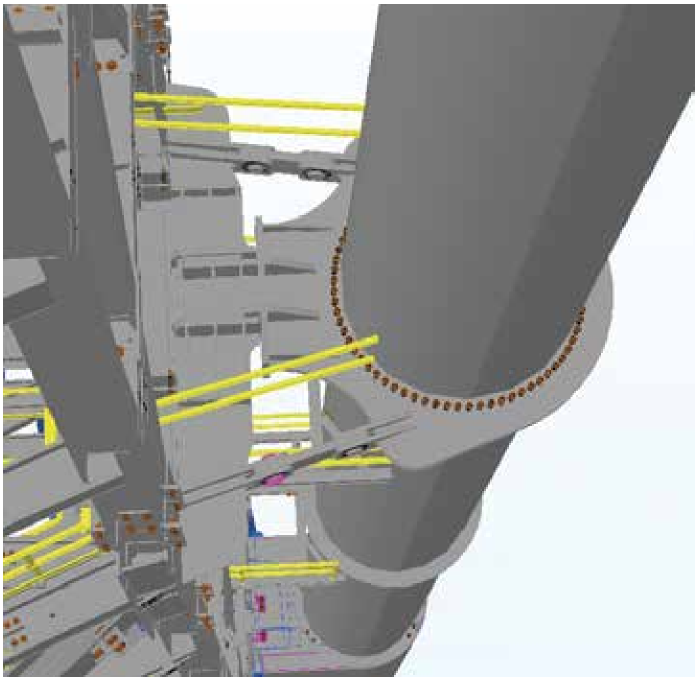
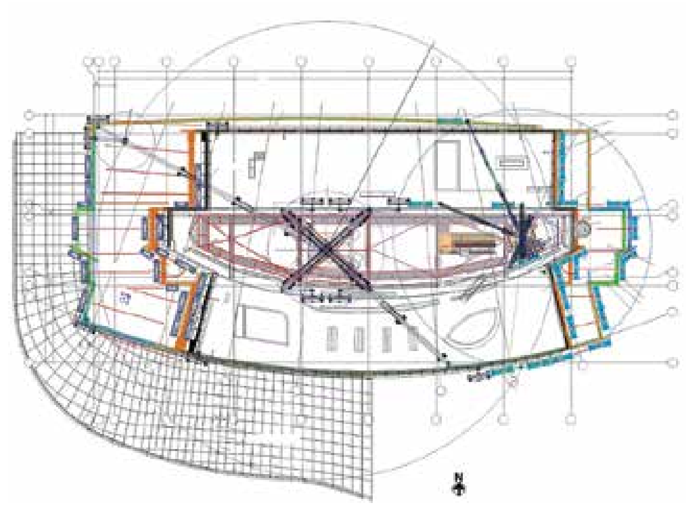
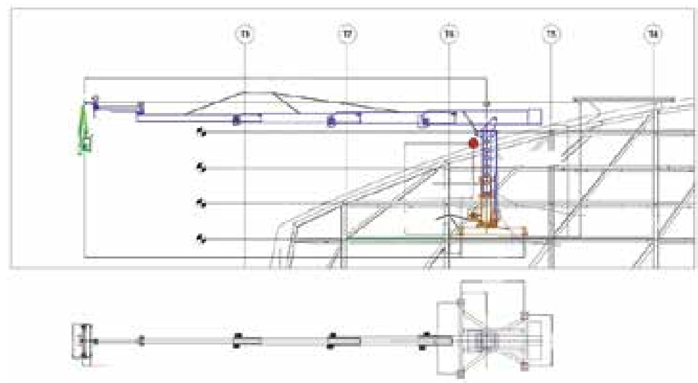


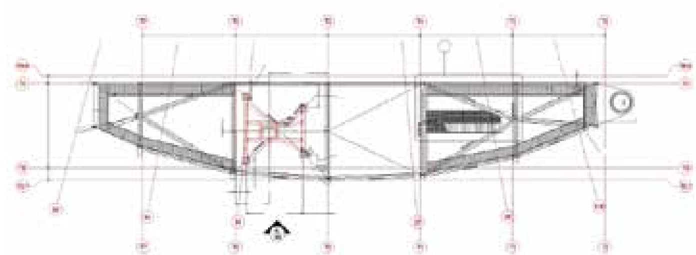
Hinged connection of spire to sail. Courtesy of Schuff Steel.



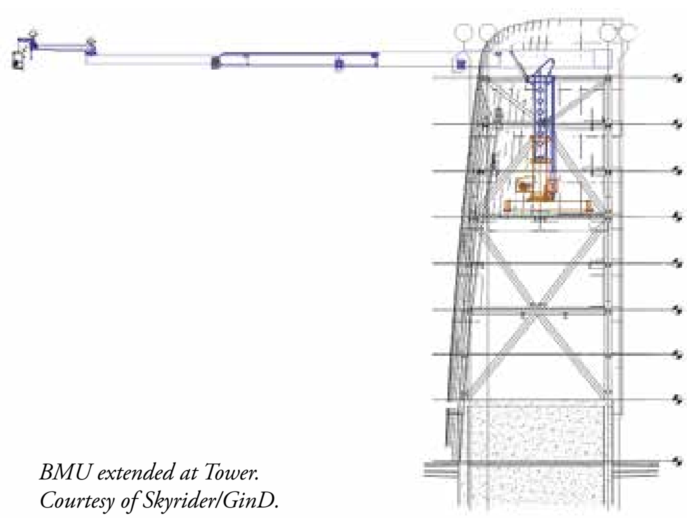
Plan views of BMUs. Courtesy of Skyrider/GinD.



Section of BMU. Courtesy of Skyrider/GinD.



Plan at BMU. Courtesy of Skyrider/GinD.



BMU extended at Tower. Courtesy of Skyrider/GinD.

The building maintenance units for the structure are massive. Their dead weights are approximately 128,000 pounds each. When considering the earthquake response of the BMUs on the sail, they place a 6G demand (700 kip singular reaction) on the sail from 1.5MCE. The BMU arms extend approximately 100 feet to reach the longitudinal edges of the structure. These BMUs need to accommodate a sloping curtainwall. On the north face of the structure, the building skin (and structural columns) slopes 6 feet horizontally in three floors. On the west face of the structure, the building slopes over 45 feet horizontally along its height. On the east face, the upper portions of the structure extend out past the lower cantilevered portions below. The BMUs have to, in effect, reach under an overhang.

Conclusion

The Crown Sail and Spire will be the crowning achievement of the Wilshire Grand Project. This will be the tallest building west of the Mississippi. Outside of New York and Chicago, it will be the tallest building in the United States. This building will redefine the skyline of Los Angeles. With its elegant sail atop the structure, it will be the only building in Los Angeles without a flat top roof.▪

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Structural Consultant for Performance Based Design: Thornton Tomasetti