NEW WILSHIRE GRAND CENTER (LOS ANGELES, CALIFORNIA) – **Where Innovation Meets Resilience**

The Wilshire Grand Center, a prominent 73 storey structure, situated in downtown Los Angeles, has reshaped the western skyline of downtown Los Angeles and stands as a testament to engineering marvel and finesse. Encompassing around 2 million square feet, this structure seamlessly integrates hotel and office spaces. While the top of the structure features restaurants and a sky lobby overlooking the skyline, the surrounding podium structure include additional commercial spaces for a burgeoning resurgence of the surrounding area. The building was the brainchild of Architect AC Martin Partners Inc while M/s Brandow and Johnson were bestowed to fortify the structure against all natural hazards. M/s Thornton Tomasetti was involved in the performance based analysis and design and M/s Turner Construction Company was responsible to breathe life into the structure.

Details

The precise architectural details including its 100 feet crown sail designed to emulate the Half Dome in Yosemite National Park and a 30 feet tall LED-laced spire it dramatically redefines the Los Angeles skyline as the city's only building without a flat top roof. It was built into a thick foundation made from the largest continuous concrete pour in history dumping 82 million pounds. It was then supplemented with buckle-resistant braces (BRBs) at levels 70-73, that would act as shock absorbers in the case of an earthquake or strong wind. The structure was built with almost 19000 tons of structural steel.

The structural steel-framed tower is geometrically complex, with many of the steel columns sloping over the height of the building to ensure the curved periphery. Between the 28th and 30th floors, the exterior building columns slope inward 6 feet over the three floors to transition the floor plate configuration

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from office to hotel space. The columns are embedded the full depth of the 18-ft-thick concrete mat foundation to anchor seismic uplift forces. The design team implemented a performance-based design methodology to accommodate the utility requirement.

A conventional code-prescribed lateral design would have required a perimeter lateral system on the structure in addition to the concrete core wall, resulting in deep perimeter beams. This would have either increased the storey heights or reduced the heights of the window opening size. This would have increased the overall project duration. The building is designed to be linearly elastic for a service-level earthquake with a 43-year return period, and for collapse prevention for the extremely rare 2,475-year return period earthquake. To achieve this performance, the design team created three buckling-restrained brace (BRB) regions over the height of the structure. A total of 170 BRBs distribute lateral overturning forces to the exterior concrete-filled steel box columns.

Structural Analysis and simulation:

Before commencement of construction, AMEC who was the geotechnical consultant for the project, simulated earthquakes to validate the performance under extreme conditions. Working with data prepared by the California Geological Survey and the Southern California Earthquake Center, the analysis began by cataloging nearly 100 local faults, poring over analyses of their geometry, their type, their slip rate and maximum possible magnitude. The engineers studied how waves of energy, generated by earthquakes ranging from magnitude 4 to the low 8s, moved through the earth across Southern California and extrapolated how the earth movements would translate into shaking. With the help of an independent review board, they culled through 3,551 recordings of 173 earthquakes taken by 1,456 monitoring stations around the world and came up with 11, the best representation of the most severe earthquakes the building would experience, based on historic data.

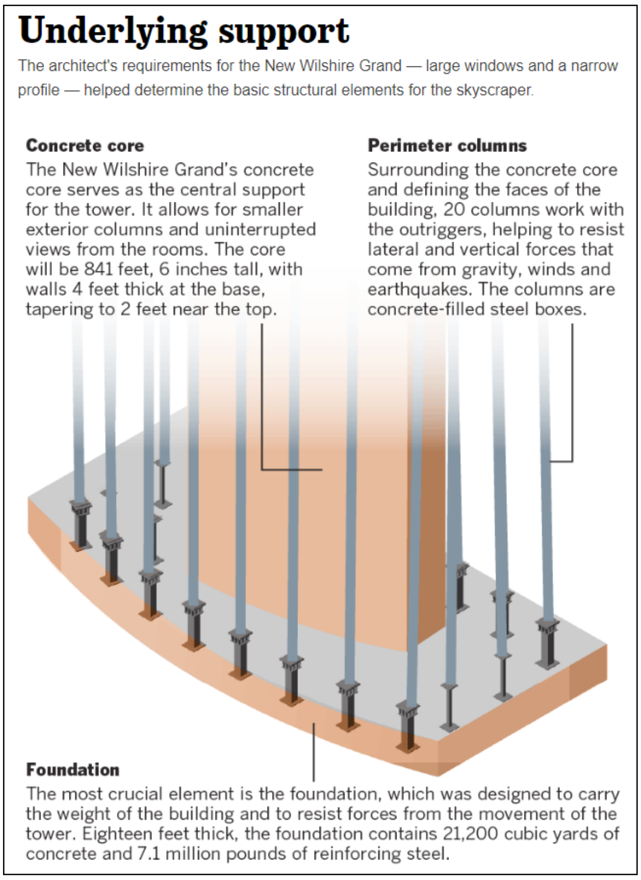

Fig. 1

With the data in hand, the next step was to test the information against the New Wilshire Grand's specifications. The tower was built around a concrete core that rises 841 feet and 6 inches thick. Its walls are 4 feet thick at the base and 2 feet near the top. The entire building weighs 300 million pounds. This required the engineers to work upon multiple data points (112,500 lines of information) that included information like the size and location of the beams, columns and walls, along with their strength, stiffness and behavior when overloaded. The team thoroughly scrutinized the data.

Based on the results of the tests, the engineers redesigned the size and depth of the foundation to resist a much as 13.2 million pounds of force pulling up and 25 million pounds of force pushing down on each of the 20 perimeter columns as the tower swayed during an earthquake.

The Wilshire Grand significantly features a seismic joint between the base and the tower that allows for 1.5 feet of sway without causing damage to partitions or pipework.

Outriggers

The concrete core is supported with a series of structural elements known as outriggers. These braces form giant triangles extending from the core to the exterior columns.

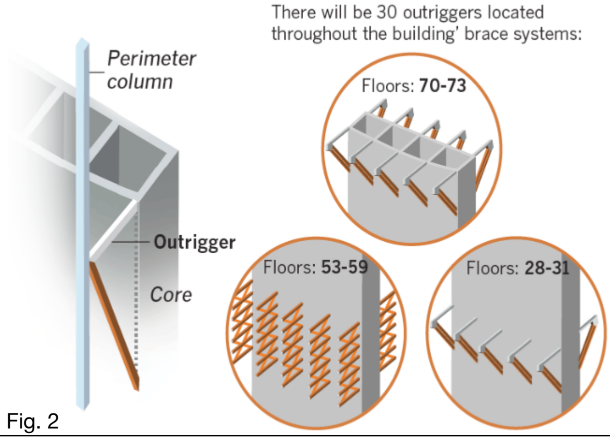

Fig. 2

Physics 101

For every force in nature, there is an equal and opposite reaction. In the design of skyscrapers, gravity, winds and earthquakes are the greatest forces that the building reacts to.

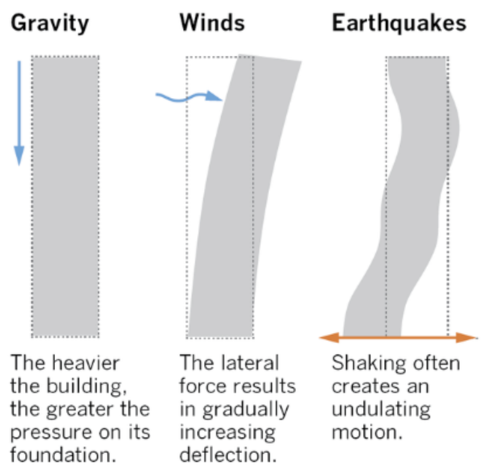

Fig. 3

The numbers pointed out a major problem. Strained by the force of earthquakes, the outriggers jammed into the core, delivering more stress than the concrete could absorb. The inside walls between the elevators and stairwells were failing. And this could lead to wide cracks forming in the core. Initially the intent was to add more concrete to the walls, but that would crowd the elevator shafts. Placing steel plates inside the walls would slow the construction and raise costs. And this led to the recommendation to add BRBs. These devices are long steel bars encased in a steel box filled with grout that allows the bars to compress or stretch as the building moves. There are 170 of the BRBs used in the construction of the building. At the top of the structure there exist ten 2,200-kip BRBs extending from floors 70 to 73. Between floors 53 and 59 are 120 800-kip BRBs, with each spanning only one floor and hidden in the hotel room demising walls—a unique configuration that allowed the developer to maximize the hotel room count. Closer to the bottom of the structure, between floors 28 to 31, are 40 2,200-kip BRBs. Bundled in groups of four at ten locations, they span three floors and are capable of resisting 8,800 kips at each location. The extensive system of BRBs is complemented by perimeter belt trusses around the exterior between levels 28 and 31 and levels 70 and 73. These elements all work together to provide torsional resistance and load path redundancy.

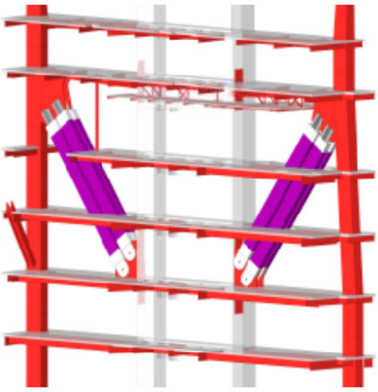

Fig. 4: Lower Outriggers with Double - Double BRBs

Fig. 5: Embed plate for lower

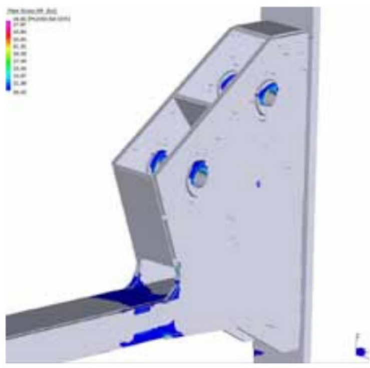

Fig. 6: FEA model for connection at core Courtesy of SIE, Inc.

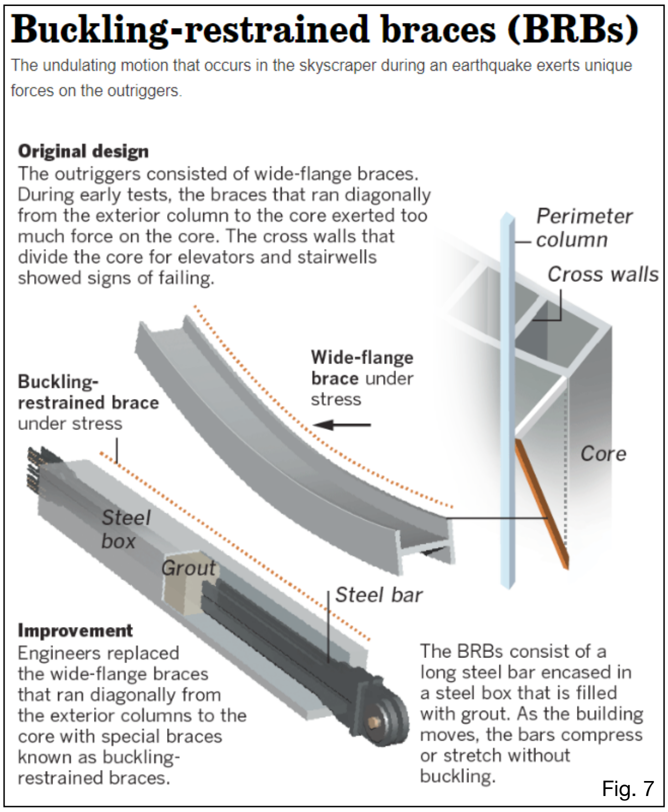

Fig. 7

The lower and the upper outriggers were connected to the core wall with steel embed plates. Shear studs and half-couplers were welded to the back of the embed plates to meet the desired force demands. The embed plates were up to 4 inches thick, stand over 34 feet tall. Gusset plates were welded to the embed plates to receive the double-pinned connections for the double BRBs. The sensitivity of concrete to heat from the welding of the gusset plates led to the use of electroslag welding with tight tolerances of 3/8 inch for horizontal control of the embedment plate.

One of the challenges in designing the Middle Outriggers was the need to accommodate a large “notch” in the outrigger girders adjacent to the core wall for mechanical, electrical and plumbing utilities. Due to the short floor-to-floor height, the notches were required to provide a path for ducts, conduits and pipes. The outrigger girders at these locations were heavy members connected to an embedded plate with a gusset plate and pin. Each girder was reinforced with plates to provide the required strength at the notch.

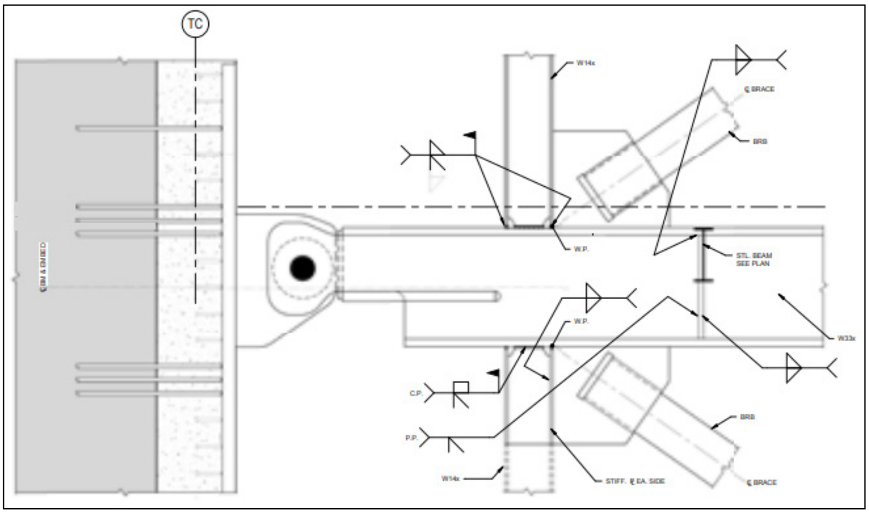
Fig. 8: Middle Outrigger girder connection to embed plate.

It was assumed that after completion of the structure, the elastic shortening of the steel would be complete except for that associated with occupant live loads. Due to the thickness of the concrete core walls, it would take approximately 50 years for 75% of the concrete shrinkage to occur. With shrinkage and creep of the core wall, the BRBs would go into tension. The Upper Outrigger BRBs were single 2,200-kip braces, sensitive to the differential movement between the shrinkage, creep and elastic shortening of the core wall and the elastic shortening of the structural steel box columns. A pre-compression force of 1,000 kips was used for each of the upper BRBs on alternate sides of the build to reduce tensile force between braces. Once the compressive strains reached approximately a 1/2 inch, the BRB was bolted off. A total of 500 tons of compression was jacked into the braces creating tension in the exterior building columns with each brace pushing upwards on the building’s perimeter.

Movement at the base of the tower could amplify into a roller coaster ride at the top. With possible accelerations of 4g, engineers worried that the crown and spire might buckle. However, removing those architectural elements was not an option. Luminous by day, illuminated by night, the sail-like crown was the building’s hood ornament, a distinctive mark in the city’s skyline.

Engineers considered anchoring the sail to the building with long cables that would allow a gentle rocking. But further tests showed that the sail would rock so violently that it would damage the concrete core. A redesign of the sail into a shorter feature offered no advantage. The sail had to be made sturdier, less light and airy.

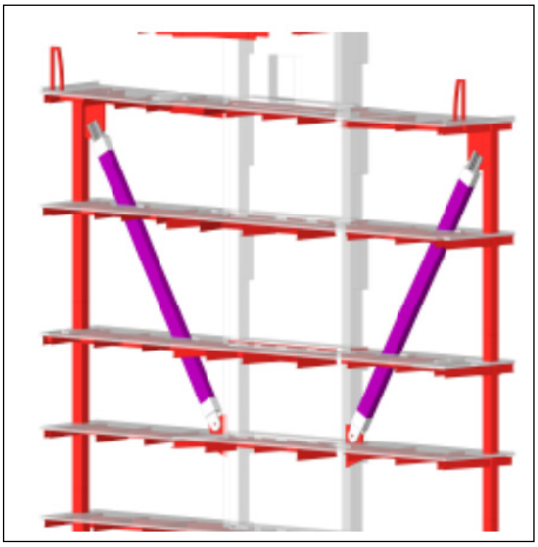

Fig. 9: Upper outrigger BRB

Conclusion

As the Wilshire Grand Center graces Los Angeles with its imposing presence, it sets a precedent for the seamless integration of technological sophistication with architectural splendour. This skyscraper stands tall, not just in height but as a symbol of cutting-edge design that prioritizes safety, particularly in regions prone to seismic activity.

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