Design Challenges for the Tallest Building in Madrid

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Summary

Working closely with Foster and Partners, an astonishing column free base tower was created by supporting the entire weight of the building on only its two end cores. These heavily loaded cores allow the slender tower to efficiently resist wind loads. With a height to width ratio of 11 to 1, this 250 m tower is the ultimate in structural efficiency. To achieve this unique structure, steel trusses at intermediate mechanical levels channel loads from the floors above to the cores and serve as beams in a 'mega-frame' to stiffen the tower. Structural redundancy was achieved in the design by considering a failure of any one of the three truss levels. This load case was considered to ensure that total building collapse would not occur if a local failure of a truss where to occur through an accidental or premeditated event.

Keywords: Tall Buildings in Madrid; Cuatro Torres Business Area; Torre Caja Madrid; Foster and Partners; Halvorson and Partners

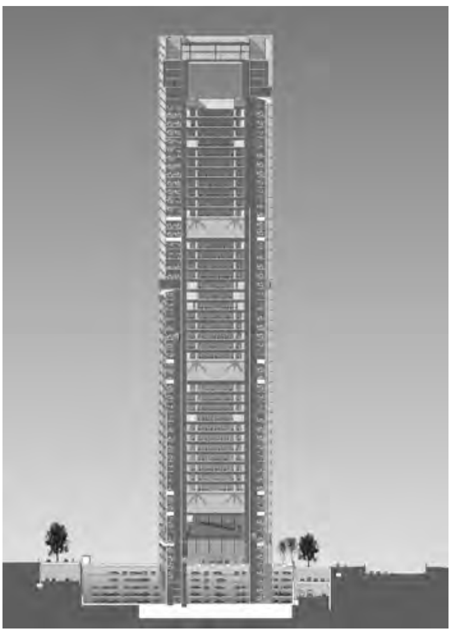

Figure 1: Building section

The project site is located on the North-West corner at the intersection of Paseo de la Castellana and Monforte de Lemos, the existing Ciudad Deportiva del Real Madrid. The development site will consist of four new buildings on parcels P1 through P4, with each building reaching a height of about 250m. Torre Caja Madrid will be located in parcel P1, the southern parcel, and will be the most visible structure on the site when approaching from the South along Paseo de la Castellana**.**

The tower design includes 5 parking levels below grade and 34 office floors (a total of approx. 110,000 sq meters) divided into three distinct office blocks of 11, 12 and 11 floors. Each office block is supported on a set of two-story steel trusses that span between the two reinforced concrete cores. The trusses transfer all of the tower's gravity loads to the two cores which are the only vertical load carrying elements that extend to the foundation. (See Figure 1).

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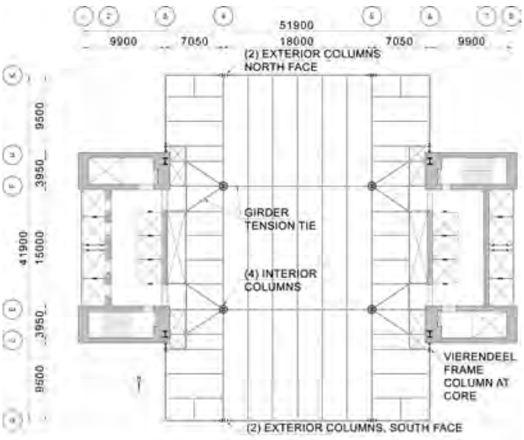
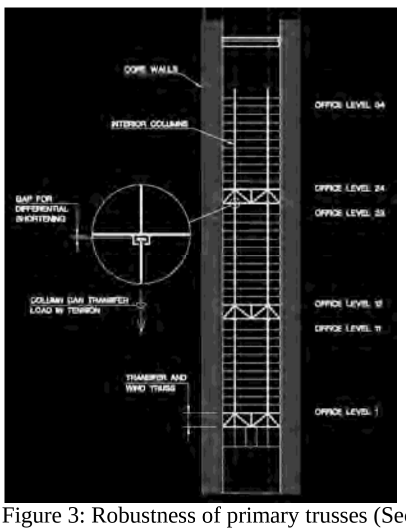


The typical office floor of the building is 32m in the East-West direction by 42m in the North-South direction, and is located between the two cores which are 32m apart. The floor plate cantilevers 9.5m to the North and South of the cores and is supported through the combination of the cantilever trusses at the mechanical levels, and a Vierendeel frame at each floor. The floors are supported on four interior columns and four exterior columns that transfer to the cores through the four trusses at each mechanical level. (See Figure 2).

Figure 2: Typical office plan with columns noted

Each core is 10m in the East-West direction by 23m in the North-South direction. In the North-South direction, each core resists its share of the wind load, while in the East-West direction the primary trusses link the cores and act as a large moment frame to resist the design winds loads. The connection of the top and bottom truss chords to the cores is critical to transfer gravity and wind forces. The connection is made through two built-up steel columns embedded within each core which ensures a strong positive connection between steel members. At each level where the top and bottom truss chords attach to the core, a 1.9m postensioned slab is provided to engage the full cross-section of the core in resisting the truss chord forces

Creep and shrinkage of the concrete cores relative to the steel columns has been accounted for by allowing vertical movement between the two structural components. The Vierendeel frame at the perimeter of every office floor has columns that are located adjacent to the core wall. These steel columns have been detailed to allow for vertical movement at the mid-height between each floor, while still resisting the shear forces from the frame.



Since the building has many critical members supporting multiple floors, it was important to include a level of robustness and redundancy in the design. Each of the 11 or 12 story tiers of the building is independent of the other; with the four interior columns detailed such that the vertical movement of one tier does not load the other. However, to provide a safe level of redundancy in the event that critical members in one truss level are damaged, the other trusses can prevent a complete building failure. The trusses and interior columns are designed to resist service level loads of two 11 or 12 story tiers of the building. If the first level trusses were damaged, the first tier of columns are designed to hang (columns in tension) from the second level trusses. If the second level trusses were damaged, the first tier of columns and the level one truss can support the 12 floors of the second tier or they could hang from truss three. If truss three fails, truss two can support floor loads from tier two and three. (See Figure 3).

Figure 3: Robustness of primary trusses (Section E-W)