Design of Reforma 509 with High Strength Niobium Steel

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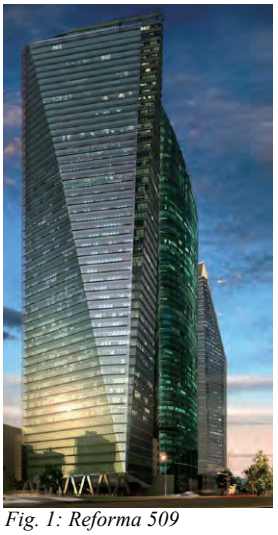

Fig. 1: Reforma 509

Abstract

Reforma 509 is a high-rise building located in the heart of the Central Business District of Mexico City, shown in the render in figure 1. The building is comprised of office, hotel, residential and parking and forms part of a cluster of tall buildings in the area. If completed today, Reforma 509 would be the tallest building in Mexico, at 238m. All of the building's gravity and lateral (wind and seismic) loads are carried by an architecturally expressed perimeter frame that is formed from highly efficient Steel Reinforced Concrete (SRC) columns coupled together by steel tube perimeter bracing.

This paper investigates the implications of substituting grade 50 (f_y=345 MPa) carbon steel with grade 70 (f_y=480 MPa) steel in the design of Reforma 509.

This paper has shown that significant potential savings in material are possible if high strength steel is economically viable and can be competitively tendered.

Keywords: Reforma 509, high strength steel, niobium grain refined steels, high-rise

1. Design criteria

The building has been designed in accordance with the PEER TBI Guidelines, local Mexican codes and where appropriate American AISC, ASTM and ASCE standards. The PEER approach principally requires the designers to demonstrate that the building will:

• be capable of an essentially elastic response and limited damage under a Service Level Earthquake having a return period of 43 years

• respond to Maximum Considered Earthquake (MCE): without loss of gravity-load-carrying capacity, without inelastic straining of important lateral-force resisting elements to a level that will severely degrade their strength; and without experiencing excessive permanent lateral drift or development of global structural instability

2. Tower structure

The building structure is primarily of steel frame construction, with concrete encased structural columns to increase axial capacity and provide stiffness in compression compared to steel only members. The tower's primary structural system consists of the following groups of elements.

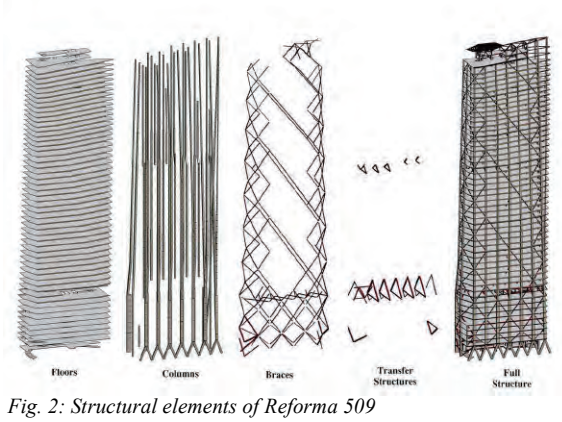

Fig. 2: Structural elements of Reforma 509

- Conventional composite floor structure spanning between internal columns and the perimeter frame.
- Transfer trusses that spread the loads imposed on the internal columns to the perimeter frame.
- Perimeter columns that carry all the gravity loads and over-turning forces to ground. The current design assumes that columns are restrained at nodes floors (typically every third floor).
- Internal and perimeter bracing that provides a shear load path for all the lateral forces imposed on the structure.

These components are shown diagrammatically in figure 2 (above).

It is a fundamental principal of the design that the gravity system of floors, columns and transfer structure remains elastic under a MCE event, but that the bracing elements are able to deform and yield in a ductile manner so that a proportion of the earthquake's energy is safely absorbed and the forces carried by the structure are reduced.

3. Approach for high strength steel design

Initial elemental studies suggest that a significant steel tonnage saving could be realised by changing from grade 50 to grade 70 steel, though a number of secondary effects limit the potential savings. As a result of rationalisation of member sizes, limitations on minimum embedded steel percentages and slenderness effects, the full potential savings are not realised in the final design. The table below highlights the primary elements that have benefitted from use of high strength steel.

Table 1: Steel tonnages by element type

Element Group	Original Design Tonnage	High Strength Design Tonnage	Tonnage Saving	Percentage Saving
SRC Columns	2633	2264	369	14%
Hanging Columns	253	195	58	23%
Other	5981	5912	69	1%
TOTAL	8867	8345	522	6%

It is apparent that there is a significant increase in capacity (and thus reduction in steel tonnage) for the SRC columns between grade 70 and grade 50 and that this saving is increased further when their effective lengths are reduced such that they are assumed to be restrained at every floor.

This paper has shown that potential savings in material are possible if high strength steel is economically viable and can be competitively tendered. Analysis has shown that a 14% saving in steel in the SRC columns can be delivered using the current design approach and that this can be improved to 20% if it is possible to restrain the columns at every floor to reduce the effective lengths.

When completed, Reforma 509 will be an iconic structure of national and international significance, which utilises the latest developments of seismic engineering analysis and design.

4. References

[1] Companhia Brasileira de Metalurgia e Mineração (CBMM) *Singapore Sports Hub* Application of High Strength Niobium Grain Refined Steels to a re-design of the Singapore National Stadium roof