Comparison of the Structures for two High-rise Buildings in Madrid

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Summary

Four high-rise buildings have been built close together between 2004 and 2008 in Madrid (Spain). The structures of two of these buildings, *Torre Espacio* and *Torre Sacyr-Vallehermoso*, have been designed by *MC-2 Estudio de Ingeniería*, who has been responsible too of the site management. Both buildings have approximately the same height and surface, as well as the same wind exposure conditions. However, the architectural choices imply quite dissimilar external shapes and internal distribution, resulting in a significantly different behaviour under wind loads. The appropriateness of both structural systems, correlated to their speed of construction, cost, facade design and architectural requirements are compared in the paper.

Keywords: High-rise buildings, composite structures, concrete structures, high-strength concrete, pumping, prestressing, wind engineering, foundations.

1. Introduction

Four high-rise buildings (H > 220 m) have been built close together between 2004 and 2008 in Madrid. The structures of two of these buildings have been designed by *MC-2 Estudio de Ingeniería* who has been responsible too of the site management. These buildings are *Torre Espacio* (TEC) and *Torre Sacyr-Vallehermoso* (TSyV). The first has been designed by Pei, Cobb and Freed (New York), whereas the second has been designed by Rubio&Álvarez-Sala (Madrid). Both towers have approximately the same height and surface, and the same wind exposure conditions. However, the architectural choices imply quite dissimilar external shapes and internal distribution, resulting in a significantly different structural behaviour.

2. Structural design

2.1 Torre Espacio

The building consists basically on a combination of reinforced concrete flat slabs with reinforced concrete columns and cores. Main straight columns run along the entire height of the building and are located on circular arches around the cores, receiving most of the gravity loads (Fig. 2). Secondary curved and straight columns that disappear on the upper floors are located on the facades that are straight in plan. Three reinforced concrete cores are responsible of resisting the wind horizontal forces in collaboration with an outrigger that is located at two thirds of the height.

2.2 Torre Sacyr-Vallehermoso

The structure of the standard office and hotel floors of this building is a composite slab supported

by a grid of steel and composite beams and joists. An external ring of columns is located near the facade and a central ring with 15 columns is located by the corridor of the hotel (Fig. 3). Even tough most of the vertical load is resisted by a combination of concrete and reinforcement, a steel profile is embedded in the column in order to simplify the assembly of the steel structure of the floors. A single central core with a constant architectural three-lobed shape runs along the height of the tower and is responsible to stand most of the horizontal wind forces. This reinforced concrete core is combined with an outrigger that connects, at the top of the building, six columns of the intermediate ring with the core, two per lobe.

Fig. 1: General view of TSyV (2nd from the left) and TEC (1st from the right)

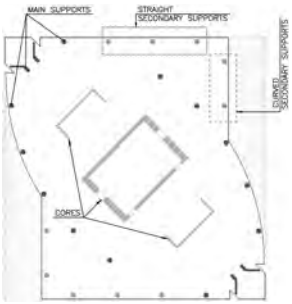

Fig. 2: TEC: Set up of structural elements

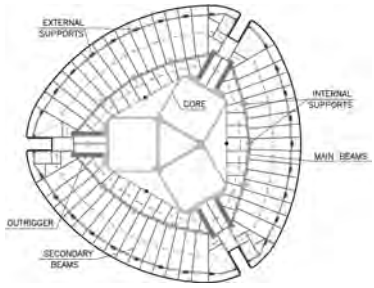

Fig. 3: TSyV: Set up of structural elements

2.3 Comparison between towers

The main results of the comparison between towers are included in the following table:

	Cores			Columns				Slabs				
	H-30 [m^3]	B500 [t]	Cost [M€]	H-30 [m^3]	B500 [t]	S355 [t]	Cost [M€]	H-30 [m^3]	B500 [t]	S275 [t]	Steel deck [t]	Cost [€/m^2]
TEC	11279	1438	2.82	6882	1864	160	2.70	19851	3211	–	–	90
TSyV	16810	3787	5.55	12738	2137	1132	4.84	9810	480	2288	521	115

3. Conclusions

The appropriateness of two structural systems applied to a couple of similar high rise buildings has been studied related to their speed of construction, cost, and architectural requirements:

- Both structures are well adapted to their shape and architectural distribution. The variable shape of TEC is better dealt with a reinforced concrete flat slab, and the composite slab supported by a grid of composite beams can take advantage of the repetitiveness of TSyV.
- The presence of large shafts in the contact between the core and the slabs in TSyV reduces significantly the vertical gravity loads transferred to the core and thus their favourable effect. Besides, these compressive forces must be resisted by the main columns. The core and the columns of TSyV are thus significantly more expensive than those of TEC.
- The use of outriggers must be carefully considered since they influence significantly the design and the construction.
- TSyV has been built 33 % quicker than TEC, mainly because most of the structure could be prefabricated at the workshop, and in spite of the greater complexity of its core and columns.