São Gabriel and São Rafael Buildings, Lisbon


Introduction

The São Gabriel and São Rafael housing towers with 25 upper storeys were built in Lisbon in "Parque das Nações", the former Expo 98 site, and are integrated into the Vasco da Gama Commercial Complex. The names of the towers are those of two of the ships used by Vasco da Gama in the discoveries of the 15th century. The structure of the transition floor looks like the hull of a ship and at the top a sail with a steel triangulated structure is used as a lightning-rod.

Description of the Buildings

The buildings include 5 underground floors and 25 upper storeys and reach a total height of 120 m above ground level (Figs. 1, 2). The upper building structure is composed of steel beams composite with concrete floor slabs supported by steel columns. Resistance to horizontal wind loads and seismic effects is performed by two concrete shear wall cores that surround the lifts and stairs. About 11.0 m above ground level there is a load transition floor, a large prestressed concrete grid-slab that spans between the shear wall cores. The bases of the steel columns are fixed to the upper surface of that slab. The 0.11 m thick concrete floor slab works together with the steel beams; H-sections with a depth of 160 mm spaced 2.10 m apart. The beams are supported at the columns, typically spaced at 6.30 m, by I-sections that are welded to the steel columns and have a variable depth from 0.24 m at the column face to 0.16 m at a distance of 1.00 m from the column. The H-beams are bolted to these cantilevered I-beams. The steel columns have either a hollow circular section, with a diameter of 273 mm, or an H-section (Figs. 3, 4).

The transition grid-slab that supports the steel columns, at level 21.40 m, has an ellipsoidal shape. It is composed of prestressed concrete longitudinal beams of variable depths from 1.50 m to 5.60 m.
with a width of 1,20 m and transverse beams 1,00 m wide also with variable heights. This grid-slab also includes an upper slab and a curved lower slab and is supported only by the two central concrete cores which are spaced 25,20 m apart (Fig. 5).

The central core has a main role; to resist the earthquakes, wind loads and transfer the vertical loads of the upper floors to the foundations. The reinforced concrete walls have a variable thickness of 0,25 m at the top to 0,40 m at the base. Their foundations are prestressed concrete footings 1,00 m wide and 33,00 m long with a depth of 1,30 m to 2,50 m. The use of a prestressed slab avoided reinforcement congestions and allowed for more uniform stresses in the soil (Fig. 6).

The five underground floors are solid reinforced concrete slabs, 0,27 m deep, spanning 8,00 m to 9,30 m and have 0,40 m thick column heads. These slabs are supported at the retaining walls, 0,60 m thick, the reinforced concrete central cores and the interior columns.

Design of the Structure

The structural design included a 3-D finite element model of the whole structure. A commercially available computer program was used in this linear model and the slabs were modelled by shell elements, the beams and columns by linear elements and the shear walls of the central core and of the underground retaining walls were modelled by plate elements.

For the design of the composite floor structures computer models of a grid with linear finite elements were used. Each grid had continuous orthotropic main beams, crossing over the steel columns and secondary beams, typically 2,10 m spaced, simply supported on the main beams.

For the design of the transition grid-slab and the footing slab of the foundation other finite element analyses were performed.

The first modes of vibration have frequencies of 0,5 Hz in the longitudinal direction and 0,61 Hz in the transverse direction. The maximum inter-storey drift for the earthquake action is 0,76 cm, less than the maximum recommended value of 1,5 cm of Eurocode 8.

For a wind speed of 55 km/h (on the average only 1,8 days per year has a wind speed greater than this value) the displacement at the top of the building is 2,73 mm and for a wind speed of 96 km/h the top displacement is 8,20 mm.

For the transition grid-slab the prestressing was applied in stages following the construction of the tower, in height. The composite steel floors were designed according to the Eurocode 4.

Conclusions

The twin towers São Gabriel and São Rafael are interesting high-quality buildings and have been an economic success. The structural design concept has proven to be adequate. The use of a composite steel-concrete floor system reduced the building's dead weight and allowed for the construction to progress more rapidly than with a standard reinforced concrete structure. The use of prestressing in the transition grid-slab was unavoidable and the use of prestressing in the footing slab improved the quality and the economy of the structure and avoided the difficulties in properly placing concrete in extremely dense areas of reinforcement.

SEI Data Block

Structural Design:
JSJ, Lda, Lisbon, Portugal
A2P, Lda, Lisbon, Portugal
Talprojecto, Lda, Lisbon, Portugal

São Gabriel Building
Owner:
Praedium, SA, Lisbon, Portugal
Contractors:
Engil, SA, Oeiras, Portugal
Contacto, SA, Porto, Portugal

São Rafael Building
Owner:
Ferrovial Imobiliária, SA, Lisbon, Portugal
Contractors:
Ferrovial, SA, Lisbon, Portugal