Architecture, Engineering and Construction, The Dataflux Tower, in Monterrey, Mexico

Pablo CORTINA
Ingeniero Civil
POSTENSA
Mexico D.F. Mexico

Jose Antonio LLOMBART
Ingeniero de Caminos
EIPSA
Madrid, Spain

Eduardo Jose PIÑA
Ingeniero Civil
POSTENSA
Mexico D.F. Mexico

Summary

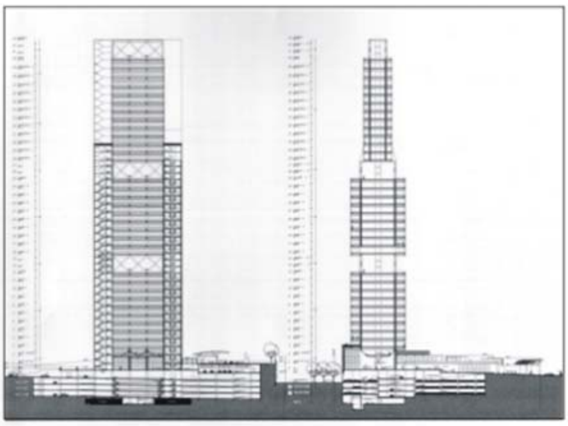
This article describes the main characteristics and construction system of the structure of the "Dataflux" Tower, in Monterrey (Mexico). The resulting project is an original global solution in good agreement with the architectural project, the construction schedule needed and the economic requirements. The full height of the building is 182 meters. It is made up of two large concrete cores, connected by three steel bridge structures, located at different levels, supporting a suspension system for the floors at lower levels. All the floors are post-tensioned concrete slabs using un-bonded tendons. Homogenized stays, made of concrete and high-strength strands encased in structural steel pipes, form the suspension elements. The construction system has brought a singular solution, which has made it possible to carry out the work in a short period of time.

Keywords: Tall building, structural design, post-tensioned concrete slabs, white Portland cement, innovative association of materials.

1. Introduction

The work involved in the structural design, analysis and determination of the construction process of the building known as the "Dataflux" Tower, in the city of Monterrey (Mexico), is a cooperative project carried out by POSTENSA and EIPSA. The structure project required the intense participation of a large team of technicians and engineers.

The building, designed by Mexican architect Agustin Landa, is 182 meters high, measured from the lowest underground level to the top. Its height, from street level, is 166 meters. The structure is characterized by the fact that it is formed by two large concrete cores, between which there are three structural elements formed by large steel trusses working as bridges from which the slabs situated at lower levels hang (*Fig.1*).



All the floors are post-tensioned concrete slabs using unbonded tendons. Thanks to its conception, its height and the exceptional nature of the structural solution requested by the Architect, it is destined to become the most important building in Monterrey, and one of the most notable buildings in the country. It allows for the structure to be part of the image of the building and guarantees recognition of the structural project thanks to the architectural project.

Fig. 1 Elevation views of the building

2. General description

The building offered interesting challenges during the conception stage of the structural project: The solution had to be aesthetically pleasing to the eye, with a strict deadline for the completion of the construction works and, of course, economic considerations also played an important part. It was concluded that the structural project should allow for a construction procedure that enabled several different fronts to be open simultaneously and to minimize the time devoted to each of them.

Fig. 2 Construction of the first Bridge Structure

The building has four underground sloped parking floors, a plaza (ground floor), a mezzanine and 40 floors above ground, with a story height of 4.10 m. Two thirds of these floors will be destined for offices, and the rest for apartments. The general layout corresponds to three blocks of floors suspended from the same number of bridge structures, formed by large steel open web girders 8.20 meters high (*Fig. 2*), which are fixed to the two reinforced concrete cores, inside of which the lifts and services are located.

3. The structure

3.1. General scheme

The structure consists of four sloped parking floors, in which the different levels form a spiral with story heights of 3.06 m, a plaza (ground floor), maximum size 114 m by 71.68 m, a mezzanine, two blocks of 12 levels each, designed for offices with maximum sizes in plan view of 43.50 m by 28.20 m, and a set of 14 levels designed for apartments, roof and heliport, with maximum sizes in plan view of 43.50 m, by 17.40 m, all of them with story heights of 4.10 m.

3.2. Lower floors Slabs

The structure of the parking levels and the plaza is made up of cast in place concrete joist slabs, 30 cm high with an 80 cm separation between joists' axis, post-tensioned with unbonded tendons, supported on flat post-tensioned beams of the same height, running perpendicular to the joists. In this area there is a span modulation of 8.70 m.

3.3. Tower Slabs

Fig 3 Typical tower floor

In the tower, the structure of the office and apartment floors is divided into three blocks and is formed by a monolithic groups made up of concrete joist slabs, 30 cm high, post-tensioned using unbonded tendons. They have a maximum span of 8.70 m and are supported on two post-tensioned beams 40 cm wide by 70 cm high, with an internal span of 17 m and two 4.85 m overhangs at the ends (*Fig. 3*). Each of these beams is suspended from 2 stays, the characteristics of which require a special description.

3.4. Steel trusses

All the slabs are supported at two of their sides by the concrete cores and suspended in their central area from four stays, which hang from two, 25.50 m long and 8.20 m high, steel trusses made of pipes (*Fig. 4*). These trusses are a bridge between the two concrete cores to which they are fixed using post-tensioning systems of thirty-six 36 mm diameter, 1245 KN load capacity Dywidag bars

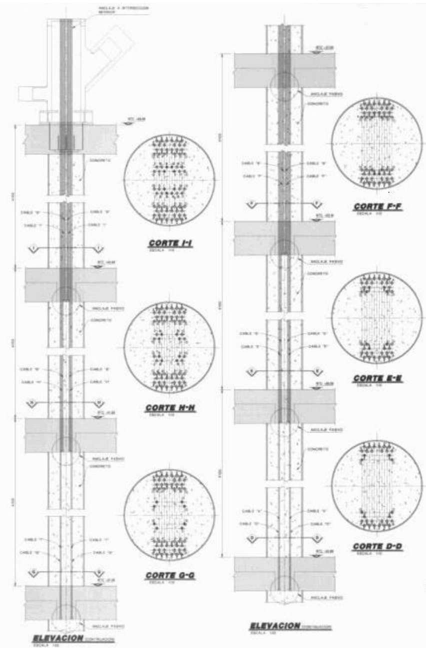
The steel structures are formed of A-50 steel pipes and plates. The upper horizontal cord is a tube 32” in diameter and 7/8” thickness. The other truss members are 24” in diameter with thickness varying from ½” to 7/8”. Plates designed to complement the steel section are used, as needed, inside the pipes in the zones of greater stress.

Fig. 4 Typical Steel truss

In the diagonal truss members, where the greatest tension stresses occur, the complementary plates are set out as a prolongation of the stiffeners of the upper knot of the steel girder and, in the lower knot, of the inside walls of the support piece of the anchor system of the stays, from which the block of slabs located under the trusses hang.

3.5. Stays

The slab suspension system is made up of homogenized stays. Each stay is formed by an exterior steel pipe (*Fig. 5*) filled with concrete and two “families” of 0.6” high strength steel strands.



In the construction stage, the slabs are suspended from the first family of 0.6” bare strands located inside the pipes. Each slab is built, in its final position, using a formwork system supported on the slab immediately below it. After the slab’s concrete is poured and it reaches the project strength, the joist’s unbonded tendons are stressed, in the usual way for any post-tensioned slab. Next the suspension of the slab is begun, by tensioning the corresponding vertical strands of the first family, lodged inside the stays. These strands are pre-stressed strictly to support the slab’s self-weight, and the force applied on jacks is adjusted and stopped when the slab is first raised from the formwork used to support it. The stress of these strands is no greater than 55% of the rupture load during the construction stage. Unbonded tendons form the second family; these tendons remain inactive during the slab construction process.

Fig. 5 Typical Stay configuration

Each slab is poured at the same time as the fraction of stay corresponding to the inside of the steel pipes located between the slab and the one located immediately below, in an upward direction. The strands belonging to the first family (subjected to stress produced by the action of the slab’s self-weight) are encapsulated in concrete and permanently bonded. When all the slabs and stays of each block suspended from a bridge structure are poured, the unbonded tendons are pre-stressed, compressing the concrete inside the pipes making it able to contribute structurally to support the action of service loads, without suffering states of decompression.

The stays, now homogenized, work as if they were real "columns", with the singularity that the compression stresses decrease under the action of the service loads.

The amount of high strength steel of the stays is determined in accordance with the stresses calculated for each of the three structural blocks. In the stays under the greatest stress, the active reinforcement is formed by forty-four bare 0.6" diameter strands (first family), which are permanently bonded to the concrete, and 46 unbonded strands of the same diameter (second family).

3.6. Concrete cores

The cores are two reinforced concrete structures with a hollow rectangular section. Their exterior size at the base is 9.30 m x 18.00 m (*Fig. 6*), with variable thickness and concrete strength. The concrete is made with white cement and selected marble aggregates. The exposed outside faces have been hand-granulated.

The walls of the service cores are 50 cm thick and made of 45 MPa concrete from the foundations to the ground floor. From the ground floor to the level of the first open-web girders bridge, they are 30 cm thick with four headers at the ends in the form of a 2 m x 2 m angle, 50 cm thick with 35 MPa concrete. From that level up to the flat roof, the walls are 25 and 30 cm thick, using 25 MPa concrete. From the level of the second trusses system, the exterior transversal section of the core gradually decreases until it becomes a smaller core in the apartment area.

Fig. 6 Concrete Cores

Fig. 7 Tower footing

3.7. Foundation

The building is supported directly on a very strong rock bed (*Fig. 7*). The foundation of the tower is made up of two large "double T" shaped footings, in plan view, 18.40 m x 27.10 m and 3 m high.

4. Structural analysis

The specifications of the Mexican "Reglamento para las Construcciones del Distrito Federal" (RCDF Regulations for Constructions in the Federal District) and its "Normas Tecnicas Complementarias" (NTC Complementary Technical Regulations) were followed both for the analysis and design. The effects of wind and earthquakes were taken into consideration in accordance with the "Manual de Obras Civiles de la Comision Federal de Electricidad" (Federal Electricity Committee (CFE) Civil Works Manual). The structural concrete elements were verified in accordance with the ACI 318-95 American Standard.

5. Construction process

The structural project was carried out so as to make it possible to have different fronts open simultaneously, minimizing execution time and enabling the construction process to be performed without any problems.

1 Lot at the beginning of construction work.

2. Excavation. Construction of foundation, columns and slabs of underground parking floors. Begins construction of concrete cores.

3. Begins construction of concrete cores using sliding forms, the process continues uninterrupted until the top of the building is reached.

4. Construction of the first bridge structure begins on the ground floor.

5. The first bridge structure is lifted to its final position using four jacks and prestress strands.

6. The bridge structure is fixed to the cores using Dywidag bars. Simultaneously the construction of the second bridge structure, over the first one, and the slabs belonging to the first block begins.

7. The second bridge is lifted to its final position and the building process is repeated

8. The third bridge is built over the second, construction of the cores reaches top of the building**.**

9. The third bridge structure is lifted to its final position and is fixed to the concrete cores using the same dywidag bars anchor system**.**

10. Construction of floors belonging to the third block.

11. The construction of the slabs is finished; the stay's strands are stressed to their final state.

12. Construction of the project is finished including architectural details, curtain walls, building equipment, etc..

6. Final discussion and future considerations

The Dataflux Tower was conceived using for the first time the **"S/S/S"** system (Structural Section System) designed by Postensa, in which the total weight of the building is divided into sections according to the number of blocks into which the height of the building is divided.

The **"S/S/S"** building is sustained by two or more pairs of large concrete homogenized stays, making use of the walls of the service cores, with a high load capacity. These cores form part of the building superstructure and the horizontal elements that complete the frames are steel bridge structures every 10 or more levels in accordance with the demands of the project. From each of these bridge structures are suspended ten or more floors supported by columns-stays and by the cores. The total load of this structural section is channeled through the concrete cores to the foundation.

The columns-stays have a structural "steel-concrete-pre-stressing" section, and are subjected to permanent compression stresses to create low-strain homogenized stays. The floors are made of post-tensioned concrete in order to ease their connection to the cores and to clear large spans keeping the slabs light and thin. The **"S/S/S"** system can be repeated as many times as are suitable for the height of the building, and results in the following positive qualities:

a. The columns-stays are composed of high strength steel, concrete and structural steel, and their behavior is that of a homogenized column with a small transversal section, over the whole height of the building.

b. Thanks to the construction system used, there is one floor completely free of columns in each sector, which can be used as a lobby, auditorium or for any other use requiring open spaces.

c. The area occupied by the columns is no more than 0.28% of the area of the floors, compared with the 3% to 4% that a tower would require for its columns.

d. The spans between columns (homogenized stays) can be from 8 to 17 m, using post-tensioned slabs.

e. The underground parking floors are built using small columns, since they do not have to support the loads of the tower. The modulation of these columns can be different from that of the tower to provide maximum functional efficiency for the parking spaces.

f. The vertical supports of the building are the large service cores, allowing for an important saving in structuring, with no negative effects on the architectural needs. The cores can be reduced gradually in size in the tower height, as vertical communications needs decrease.

g. The construction procedure is repetitive, extraordinarily fast and economic, compared to usual procedures.