The Cube Tower II

A unique structural concept for another exceptional building

by Luis M. Bozzo

The final cost of a building is the result of varied factors, but the scheme adopted for transmission of loads is particularly significant. In general, a building will be economical if the load paths are clear and well-defined, allowing the analysis to be precise and effective for optimization of sections and members. The selections for the material and structural shapes also influence the final cost. So, function and form must be bound together as far as possible.

The Cube Tower II is a 150 m (492 ft) tall office tower in Guadalajara, Mexico, with 29 above-ground levels and seven underground parking levels. As with the first Cube Tower,[1] this new building was designed to be exceptional. The office levels are configured as two modules (wings) tied to a common core containing the vertical circulation (Fig. 1). Each of the two office wings has a triangular shape and the columns at the apexes of the triangular floor areas lean at 4 degrees (Fig. 2). Thus, the vertices advance away from or toward the vertical core with each additional office level, and every floor plan is unique. In one wing, the triangular area varies from 32 x 20 m (105 x 66 ft) for the bottom office floor to 26 x 15 m (85 x 49 ft) for the top office floor. The parking levels, however, are configured to fully occupy the 42 x 62 m (138 x 203 ft) building site.

Structural Scheme

While the structural concept for the Cube Tower II is obviously unique, it presents well-defined mechanisms for load transmission. The load path is simple and clear: the floor slab is supported on the grid beams, which are in a special "A over A," (A-grid) configuration and are themselves supported on the columns, central core, and lateral walls. Lateral loads are transferred mainly by the central core, freeing the remaining structural elements from the need to transfer seismic loads and allowing the elimination of half of the concrete columns in the office wings (as compared to the original, more conventional structure). In fact, there are just six columns per level. In each of the triangular wings, one column is at the apex and one column is located along each of the two exposed sides (Fig. 3).

For economy, the slabs are one-way elements supported on the "A" grid beams. Where spans exceed 4 m (13 ft), the slab is

Fig. 1: The Cube II is an office tower with 29 above-ground levels and seven underground parking levels. The office levels are configured as two modules (wings) tied to common core containing the vertical circulation. Each of the two office wings has a triangular shape with the column at the apex inclined at 4 degrees to the vertical

300 mm (12 in.) thick and post-tensioned. For irregularly supported areas or for spans less than 4 m (13 ft), the slab is 150 mm (6 in.) thick and conventionally reinforced.

The A-grid beam arrangement maximizes the openness of the office spaces (Fig. 4 and 5). While the beam spans vary because the tributary area is different at each level, the maximum depth was maintained at only 600 mm (24 in.). Widths were varied, however, and longer-span beams were

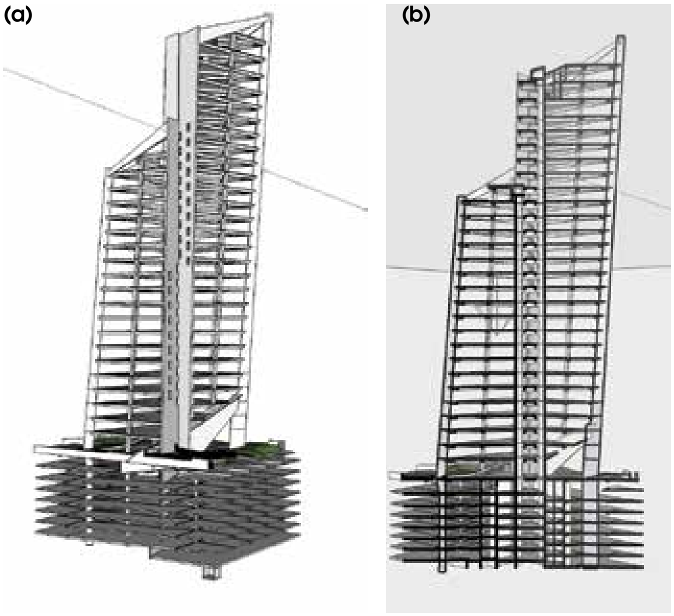


Fig. 2: A 3-D model (created in SketchUp) of the building illustrates the underground parking levels and the 4-degree inclination of the office modules: (a) side view; and (b) section cut through the core and apexes of the office tower floors

also post-tensioned. Because the tower is in a region with high seismicity, the pre-compression level in the beams was kept small, below 10% of the gross cross-sectional compressive capacity. This was done to maintain ductility, even though the office wing beam elements are not considered part of the lateral force-resisting system.

Within the parking levels, the distribution of vertical load supporting elements differs from that in the upper levels. The parking floors are also inclined to avoid the need for a ramp and maximize the number of parking spaces. In the core and region bounded by the A-grid beams, the parking levels consist of cast-in-place slabs and beams. In the surrounding areas, cast-in-place beams support precast prestressed slabs with a field-cast topping course (refer to Fig. 6).

The entrance and reception area of the building includes two inclined transfer beams that carry the loads of the two intermediate side columns (Fig. 7).

Seismic Requirements

The tower is located in Mexico's Seismic Zone 1. The seismic coefficient for this zone is 0.36*g*, which results in large lateral loads. Using a finite element model analysis, the fundamental period for the building was found to be 3.1 and 3.2 seconds in the x- and y-directions, respectively, indicating that the structure is quite symmetric. The height from the street level up to the main roof is 111 m (364 ft). Consequently, the height-period ratio for the building is about 40, which may appear to be quite small.

Using a concentrated mass model, 50 modes were needed to satisfy the minimum 90% mass participation required for a response spectrum analysis. With no reduction in the response spectrum, the maximum inter-story

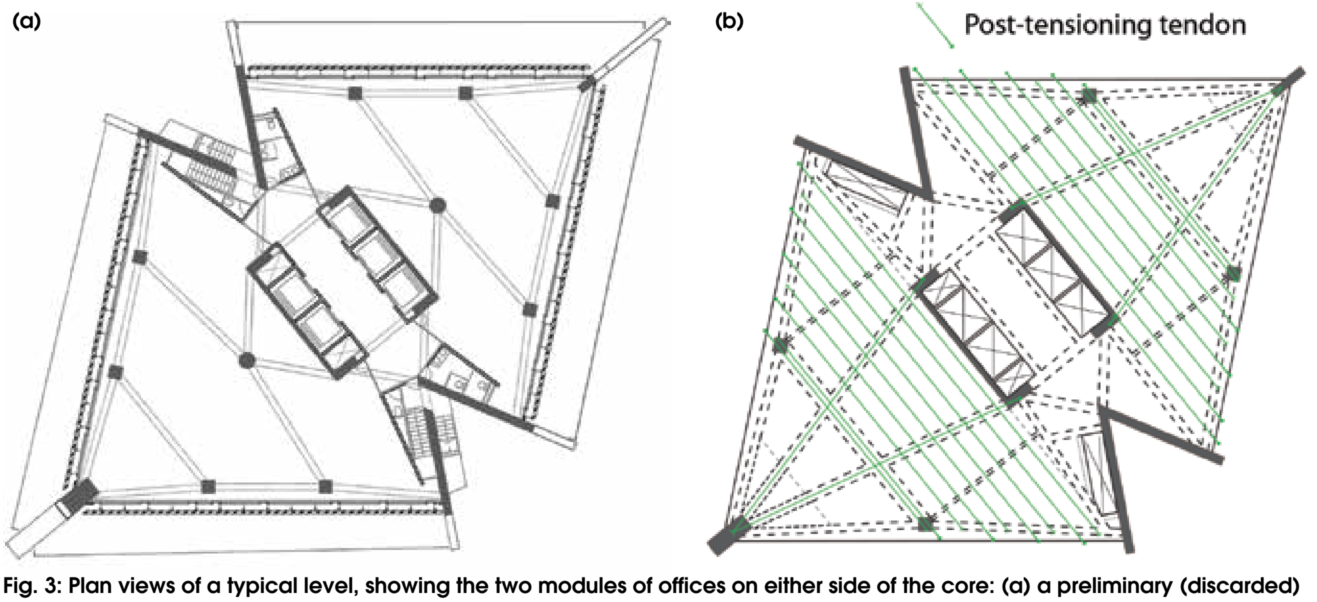


Fig. 3: Plan views of a typical level, showing the two modules of offices on either side of the core: (a) a preliminary (discarded) conventional structure made up of the shear walls and 12 columns (two of which are interior columns); and (b) the final optimized structural system consisting of shear walls, post-tensioned floor slabs, and a unique A-grid distribution of beams that allowed the elimination of half of the columns in the office wings

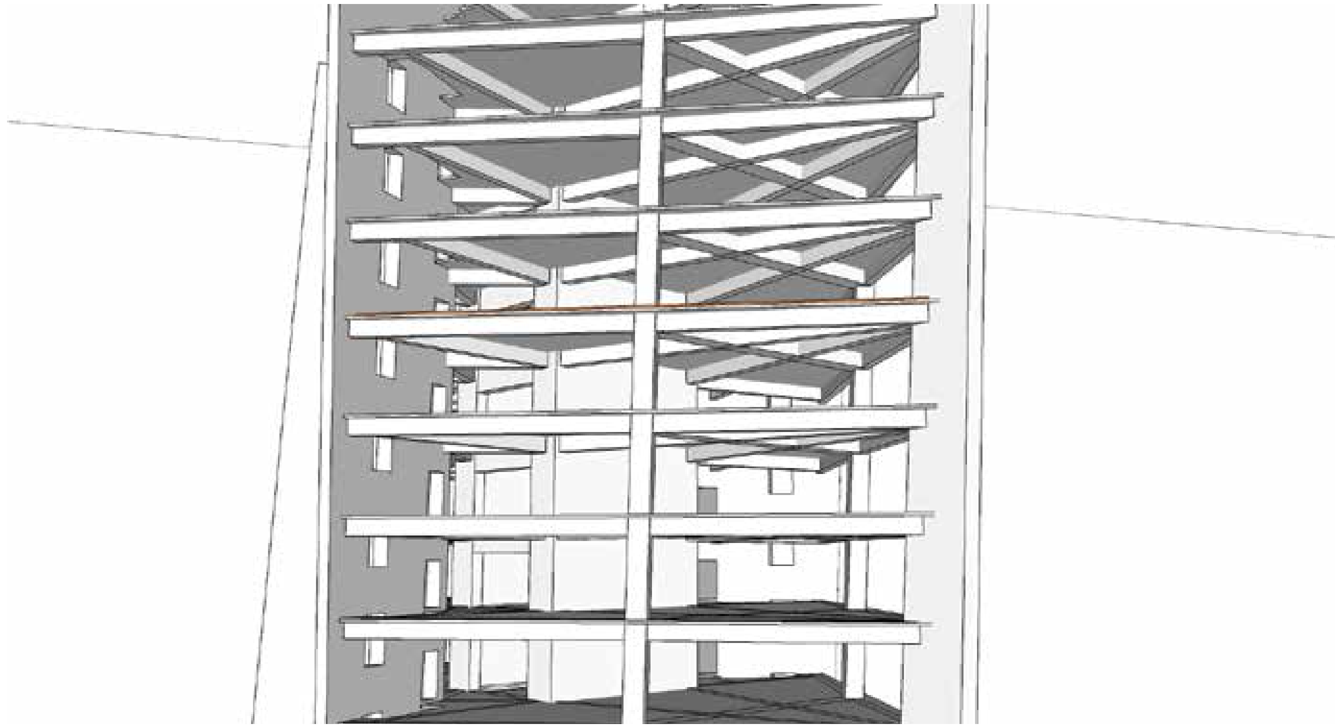
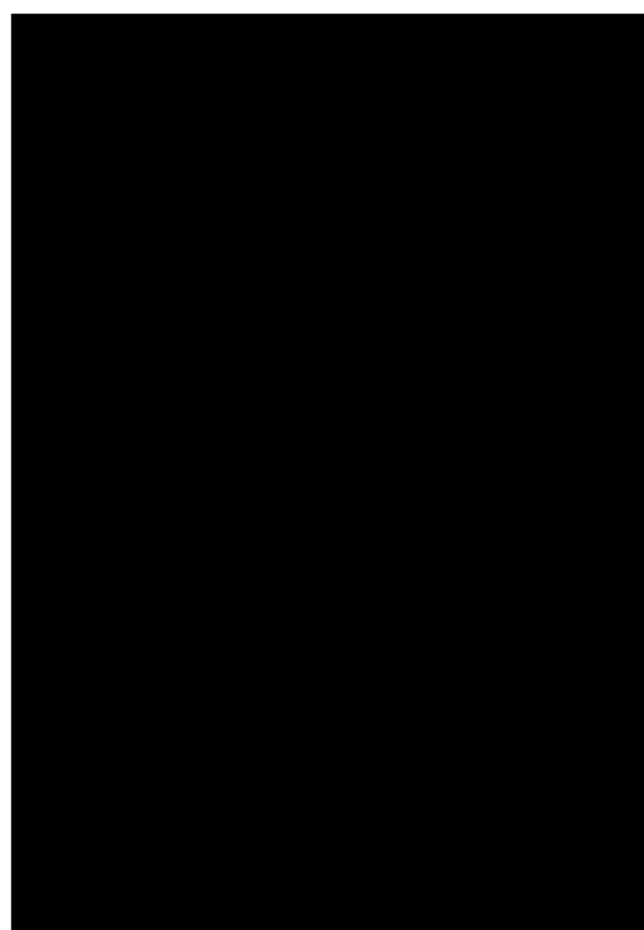


Fig. 4: A view of the 3-D model showing the columns, core walls, and floor beams for an office wing

Fig. 5: View of "back" of tower showing the 30 x 20 m (98 x 66 ft) column-free interior space (for scale, see workers inside). The special A-grid beam arrangement that allowed the elimination of all the interior columns is also visible in the exposed ceiling



drift values were found to be about 0.006 and 0.004 for the x- and y-directions, respectively. These values are clearly below the 0.007 maximum values accepted in many modern building codes.

In high seismic areas of South America, the cross-sectional areas of the shear walls normally total about 2% of the floor area (in the United States, the walls typically total about 0.5% of the floor area). The cross sections of the central core and shear walls in Cube Tower II total 3.6% of the floor area. This increased wall area is required because the 4-degree inclination of the office wings creates lateral displacements, even in the absence of lateral loads. This issue is particularly significant because the elevators require a vertical shaft.

Fig. 6: The parking-level floors were constructed using precast prestressed slabs on cast-in-place beams

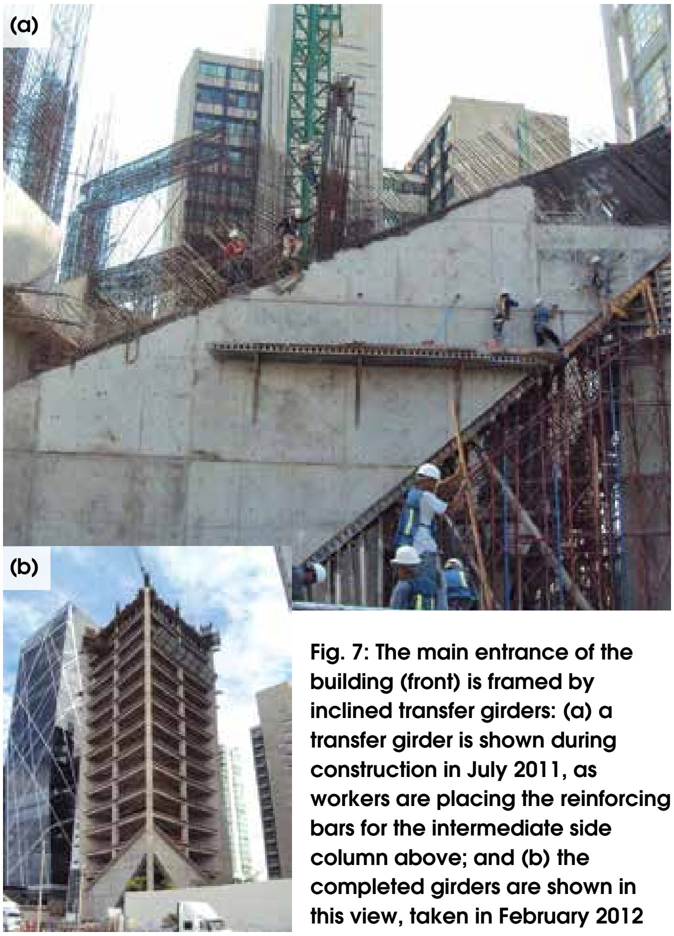


Fig. 7: The main entrance of the building (front) is framed by inclined transfer girders: (a) a transfer girder is shown during construction in July 2011, as workers are placing the reinforcing bars for the intermediate side column above; and (b) the completed girders are shown in this view, taken in February 2012

Summary

The Cube II office tower in Guadalajara, Mexico, consists of 15,265 m^2 (164,311 ft^2) of building space and 21,000 m^2 (226,042 ft^2) of parking area. The building has the following structural subsystems:

- Foundations consisting of a mat foundation at the central core and spread footings at the columns;
- Central core and lateral V-shaped walls totalling 3.6% of the total floor area;
- A-grid floor beams with maximum 600 mm (24 in.) depth allowing a column-free interior space; and
- Post-tensioned one-way slabs with 300 mm (12 in.) thickness, assumed to be simply supported on the aforementioned beams.

Construction began in January 2010, and the structure was completed in January 2013. About half of that period was required to construct the underground levels—work that was complicated by groundwater from about Level 2 down. Also, because each level was unique and sloped, special detailing and formwork were required. The project was completed without a single construction accident, however, and the vertical movement due to dead load was precisely predicted and corrected during construction.

References

1. Bozzo, L.M., "The CUBE Tower," *Concrete International*, V. 27, No. 6, June 2005, pp. 55-60.

Selected for reader interest by the editors.

Project Credits

Owner: CUBE Group
Structural Engineer: Luis Bozzo Structures and Projects SL
Architect: Carmen Pinos Studio
Contractor: Anteus

Luis M. Bozzo is President of Luis Bozzo Estructuras y Proyectos SL, Barcelona, Spain. Born in Lima, Peru, Bozzo attended the Universidad Nacional de Ingenieria and received his MS and PhD from the University of California at Berkeley. He has authored more than 60 articles in international journals and three books about seismic resistance design and mixed reticular slabs. He has designed the largest free-form Catholic church without interior columns and 52- and 62-story central core buildings in Mexico.