Bitexco Financial Tower

Ho Chi Minh City, Vietnam

By William J. Faschan, P.E. and Nayan B. Trivedi, P.E.

Bitexco Financial Tower.

Project Team

Developer/Owner

Bitexco Group

Project & Cost Management Consultants

Turner International – *Project & Construction Managers*
DLS – *Quantity Surveyors*

Design Consultants

Carlos Zapata Studio – *Lead Design Architect*
AREP Ville – *Executive Architect*
VNCC – *Local Architects & Engineers*
LERA – *Lead Structural Engineers*
PAEC – *Structural Engineers*
DSA – *Lead MEP Engineers*
VNBT – *Fire Safety Engineers*
Barker Mohandas – *Vertical Transportation Designers*
CTFE – *Foundation Engineers*

Design Sub-Consultants

UWO – *Wind Engineers*
Shannon & Wilson – *Geotechnical Engineers*
Ecart – *Interior Designers*
Meinhardt – *Facade Engineers*

Figure 1: Project Team.

Due to the rapid population growth of Ho Chi Minh City and the dynamic economic development of Vietnam, the need for office space has exceeded supply in Vietnam's largest city. The Bitexco Financial Tower development, currently under construction, will help ease the demand for office space in this thriving Southeast Asian metropolis.

Binh Minh Import-Export Co (Bitexco), a wholly owned Vietnamese company, is the primary investor in this mixed-use development. Designed by the architect Carlos Zapata Studio, the development consists of a high-rise office building, a five-story retail podium, and four levels of below-grade construction, much of which is devoted to parking. The shape of the tower is modeled after a lotus flower bud, the national flower. Standing at 68 stories upon completion, the office tower is destined to become a landmark in the Ho Chi Minh City skyline.

The office tower is essentially an all-concrete structure. Initially, a mixed system comprised of structural steel floor framing, composite perimeter columns and concrete core walls was developed. However, cost comparison demonstrated that the all-concrete structure had a clear cost advantage over the mixed system.

The typical lower office floors are framed with a conventionally reinforced 10-inch (250mm) thick flat plate. The upper executive office floors are smaller in plan and are framed with a thinner 8-inch (200mm) thick flat plate.

Structural Challenges

Poor soil conditions presented a major challenge to the design of this tall tower; Ho Chi Minh City is on the alluvial plain of the Mekong Delta of the Saigon River. The extremely poor soil conditions are further complicated by a high water table since the building site is one block from the Saigon River. An aggressive schedule and tight site constraints provided additional complexities.

The tower is tall and slender, and has a smooth and rounded plan shape that stands almost 50 stories above the surrounding buildings. For these reasons, wind-induced building sway was a major concern for the structural designers. Additionally, the unconventional building shape is such that the perimeter tapers inward at the lower 20 floors, limiting the width of the structure's stance and thereby limiting its inherent resistance to building sway. An innovative structural design using concrete outrigger and belt trusses will stiffen the tower against swaying motion. This innovative structural system, combined with the use of the highest strength concrete that could be supplied in the Vietnamese market, proved to be the most economical and constructible structural system.

As with any landmark project in an emerging market, design and construction challenges have been numerous, requiring the cooperative teamwork of the project's international and local designers and constructors. The project design and construction team is led personally by Mr. Vu Quang Hoi, the Chairman & CEO of Bitexco. Turner International is the program and construction manager and AREP Ville serves as the Executive Architect. Hyundai Engineering and Construction Company is the general contractor for the superstructure. Other primary designers and constructors are listed in *Figure 1*.

Figure 2: Construction Site.

Perimeter Diaphragm Wall

Typically in Ho Chi Minh City, major projects are constructed with two basements. The upper basement is excavated without bracing within a previously constructed diaphragm wall. The first basement slab is cast and the lower basement is constructed top-down.

Since the Bitexco site is small for such a tall tower, four basements were required. Also, the narrow surrounding streets presented a further complication. The time and cost of constructing such a deep basement in such a confined and small site presented a challenge that required the joint efforts of the entire team to solve. After several iterations of architectural layouts, construction sequence plans and diaphragm wall designs, an optimal solution emerged which located the top of the tower mat foundation at the second basement level and not at the fourth basement level, as would be have been expected. This tower mat location, in a sort of split-level basement, minimized the time required to excavate down and to construct the mat, thereby allowing the earliest time for starting the tower construction. The perimeter diaphragm wall was designed to be 32 inches (800mm) thick and was constructed using the slurry method. The wall was constructed to a depth of only 82 feet (25m) below ground to provide a groundwater cutoff for a 46 feet (14m) deep excavation.

Various options were considered for temporarily bracing the diaphragm walls during excavation and basement construction. Tie-backs were deemed infeasible due to the poor soil conditions and the close proximity of surrounding buildings. Rackers and bracing were feasible, but were eliminated because of the constraints that their use would have placed on access to the basements.

Construction Sequence

The final design incorporated a partial top-down approach. In top down construction, the complete ground floor or first basement floor slab is cast before the basements are excavated below. In this partial top down approach, only the perimeter of the ground floor slab was cast and used to stabilize the top of the diaphragm wall before the basement excavation began (*Figure 2*). This permitted the excavation to the level of the tower mat foundation to be performed without temporary bracing. After the tower mat was cast, the tower superstructure construction began with the tower mat serving as a bracing point for temporary supports for the lower excavations of the adjacent basement areas.

The split-level basement design and the partial top-down sequence have proven to be extremely valuable. It was estimated that excavation and construction of the four basements would take one year. With this design, the mat was constructed and the tower construction began several months before the fourth basement was completed.

Foundations

The weight of this tall building required very deep foundations. Comprehensive initial studies and subsurface explorations were performed to form a basis of the foundation design and to estimate foundation settlement. Shannon + Wilson, the international geotechnical consultant, performed a finite element computer analysis of the soil-structure interaction below the tower footprint. The time dependent characteristics of the settlement were studied to understand the ways in which the settlement could be expected to affect the structure and the architectural finishes during and after construction. The maximum predicted settlement was determined to be approximately 4 inches (100 mm).

The tower foundation is a bored pile supported mat. The mat is 13 feet (4m) which effectively distributes the tower loads from the walls of the narrow services core over the extent of the mat. The bored piles are 60 inches (1500mm) in diameter that were drilled to a depth of between 235 feet (75m) and 265 feet (85m). Due to the volume of the mat, the mat was constructed in multiple sections. Also, tubing was embedded in the mat for a temporary cooling system. Insulation was placed on the sides and on top of the mat to limit the potential for cracking from the concrete's heat of hydration.

The foundations for the podium and underlying basements are comprised of 4- inch (1200 mm) diameter bored piles that were drilled to a depth of between 190 feet (58m) and 205 feet (63m). There is one pile for each basement column. The cut-off elevation of these piles is at the fourth basement level. Embedded into the top of each pile is a structural steel wide flange section. The wide flange shape serves to support the perimeter of the ground floor during the top-down excavation and the construction of the basements. Later they will act compositely with the concrete basement columns to support the permanent loads.

Outrigger Truss and Belt Wall Systems

The tower has an aspect ratio (tower height/tower width) of 9, with a core aspect ratio (tower height/core width) of 20. The oval shape of the tower and the absence of surrounding tall buildings, coupled with the high aspect ratio, make the tower susceptible to wind-induced building sway. An innovative cast-in-place outrigger truss system was designed to be used to augment the lateral load resistance of the concrete core and to mitigate the potential for objectionable swaying motions. (*Figure 3* shows locations of outrigger trusses and belt walls).

While many concrete and mixed steel and concrete towers have been constructed with structural steel outrigger systems, few have used a reinforced concrete system. Generally this is because concrete systems cannot provide the comparable strength, or they are too big. Additionally, outrigger systems provide an unintended gravity load pathway between the core and the perimeter columns. For steel outrigger systems without special detailing, gravity load stresses in an outrigger system can exceed the stresses required to achieve the intended wind load resistance. Concrete systems do not lend themselves to the special detailing required to mitigate these unintended gravity load stresses.

However, for this project, the team conceived of a system of reinforced and post-tensioned concrete, detailed as trusswork, that overcame these usual obstacles. The diagonals of the system were detailed to allow their installation only after the superstructure was topped out. To the extent that the outrigger system attracts gravity loads from the perimeter columns, the top chords of the trusswork were designed to be post-tensioned to resist these forces.

At Floors 29 and 30, outrigger trusses and belt walls interconnect the core walls and the perimeter columns. The outrigger truss and belt wall system were designed to function with the concrete core walls to complete the wind load resisting system. The outrigger trusses and belt walls will stabilize the core by resisting a portion of the overturning moments associated with wind-induced east-west movements.

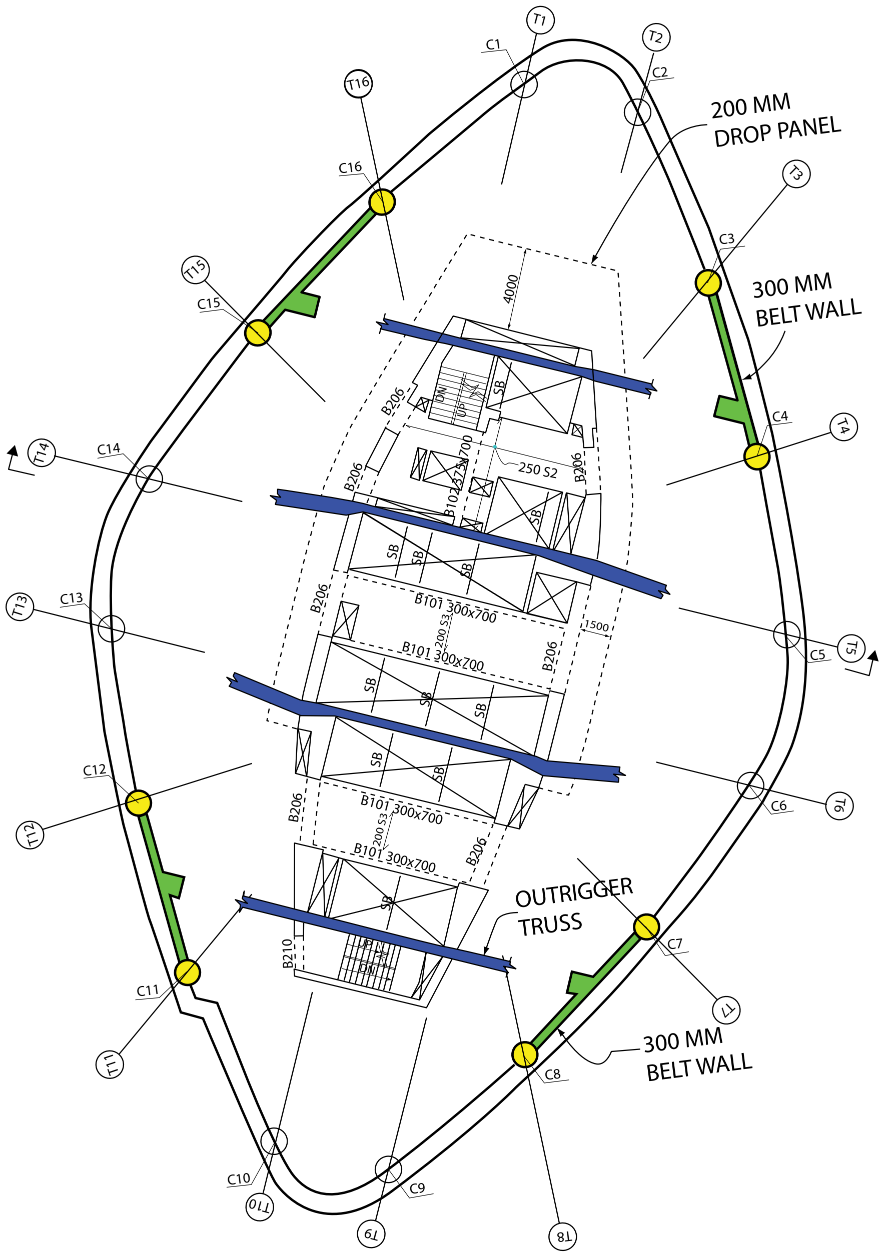

Figure 3: Outrigger Truss and Belt Wall Plan.

There are four sets of double-story outrigger trusses. Two are aligned with the two primary core cross walls and two are aligned with fire stair walls. The connections of the outrigger trusses (40 inches wide, 1000mm wide) to the cross walls (16 inches thick, 400mm) were designed and detailed to transfer the forces effectively. (*Figure 4*) There are four belt walls, two on each side of the tower. The belt walls are one-story tall and interconnect pairs of perimeter columns to each outrigger truss.

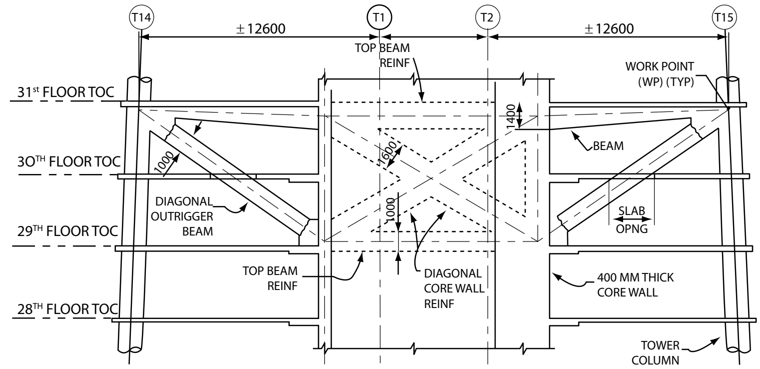

Figure 4: Outrigger Truss Elevation.

Helipad Framing

As part of the tower's lotus flower image, one side of the tower protrudes near Floor 55, taking the shape of a lotus bud. A sky lounge is located on the 55th floor with a helipad and an observation deck directly overhead. The helipad is supported by a pair of 82-foot long (25m) tapered steel cantilever girders. These tapered structural steel girders span from the core walls to the perimeter tower columns and cantilever outward to frame the helipad.

The cross-section of the helipad is framed with secondary tapered structural steel beams, spaced approximately 10.5 feet (3.2m) on center, that are oriented perpendicular to the primary girders. Both ends of the secondary beams cantilever beyond the primary girders to support the circular edge of the helipad. In this instance, the choice of steel resulted in a lighter structure and speedier construction.

Summary

The Bitexco Financial Tower is proceeding with construction despite the global economic crisis. The city, which has an annual growth rate of 12%, is fast becoming an important trade center in the Southeast Asian region. Once construction is finished in 2010, the Financial Tower will offer approximately 1,000,000 square feet (90,000 square meters) of office space. Like the lotus flower it emulates, the Bitexco Financial Tower is an emblem of the emergence of Vietnam into the Global Community of trade, business and commerce.▪

William J. Faschan, P.E. is a Partner at LERA. Mr. Faschan is currently leading the structural design of World Trade Center Tower 4 in New York, as well as projects in India, Europe, the Middle East and Russia. He can be reached at ***william.faschan@lera.com****.*

Nayan B. Trivedi, P.E. is an Associate Partner at LERA. Selected by Building Design and Construction Magazine in their 2007 40-under-40 Competition, Mr. Trivedi is currently Project Manager for the Oberoi Skyz Tower in India, as well as projects in the Middle East and Russia. He can be reached at ***nayan.trivedi@lera.com****.*