Title: **The Sail at Marina Bay, Singapore**

Authors: Juneid Qureshi, Meinhardt
Alfred A Yee, Precast Design Consultants Pte. Ltd.
Kang Jianhan, Precast Design Consultants Pte. Ltd.
Frederic Perez, Dragages Singapore Pte. Ltd.

Subjects: Architectural/Design
Construction
Structural Engineering

Keyword: Seismic

Publication Date: 2010

Original Publication: Singapore Conference on Structural Marvels 2010

Paper Type:

1. **Book chapter/Part chapter**
2. Journal paper
3. Conference proceeding
4. Unpublished conference paper
5. Magazine article
6. Unpublished

THE SAIL @ MARINA BAY

Alfred A Yee[1], Kang Jianhan[1], Frederic Perez[2] and Juneid Qureshi[3]

[1]Precast Design Consultants Pte. Ltd.
315 Alexandra Road, #04-07 Sime Darby Business Centre, Singapore 159944
[2]Dragages Singapore Pte. Ltd.
19 Keppel Road, #10-00 Jit Poh Building, Singapore 089058
[3]Meinhardt Singapore Pte. Ltd.
168 Jalan Bukit Merah, #09-01 Surbana One, Singapore 150168

ABSTRACT

As the world population continues to grow exponentially, it is anticipated that development of suburban properties will become less popular as it stretches our natural resources, construction materials, and energy supplies to their limits. Suburban developments require more land, roadways, sewer lines, water lines, electrical transmission lines, higher maintenance costs, plus capital expenditures for communication facilities, other utilities, and infrastructure. Urban residential properties, especially in the heart of big cities, are becoming increasingly attractive due to their centralised locations and closer proximities to businesses, commercial establishments, services, employment centers, etc. thus greatly reducing time and expense required for commuting. The stronger demand for urban residential properties will significantly increase land prices, and high-rise building construction will become necessary to maximize land usage and efficiency. Future high-rise buildings will grow to greater, challenging heights in order to accommodate the huge surge of urban residents. At these heights, these extreme structures must be designed to resist the increased natural environmental wind and earthquake forces, and the heavy gravity loads on the foundations. This paper presents solutions to some of the structural challenges encountered in the design and construction of The Sail @ Marina Bay – two tall, slender buildings of high aspect ratios. For safety, serviceability, and occupant comfort, these buildings must resist the increased environmental forces which could cause severe translation, overturning, twisting, and acceleration. The benefits of an innovative coupled shear wall system to improve the performance of these slender, high-rise buildings will be discussed.

KEYWORDS

High-rise, seismic, wind, shear walls, coupling beams, vibration, diaphragm wall, barrette pile, precast construction.

INTRODUCTION

Deriving inspiration from the surrounding sea, the concept of The Sail @ Marina Bay was developed by architects NBBJ of New York. NBBJ envisioned the two high-rise residential towers resembling the tall sails of sailboats. The sculpted shapes of the two soaring towers rising 70 and 63 storeys have created a new icon on the Singapore skyline. The 70-storey tower (Tower One) is 245 meters high and the 63-storey tower (Tower Two) is 215 meters high offering a total of 1,111 residential units.

Tower One features a series of varying floor plan extensions, bowing outward at one end of the building along its height, to form an architectural expression resembling the forward edge of a sail. The varying curved plan dimensions of a typical floor is only 22 meters wide at its maximum (located near the mid-length of the typical floor plate) resulting in a minimum aspect ratio of 11.14 when matched with the building height of 245 meters (see Figures 1 to 3). For Tower Two, the building height is 215 meters high on a structure with typical floors of varying curved plan dimensions and a maximum width of only 21 meters, resulting in a minimum aspect ratio of 10.24.

The podium features an 8-storey structure with the ground floor reserved for retail shops and mechanical equipment rooms, the intermediate floors for parking, and the roof garden level for landscaping, tennis courts, and swimming pools. The podium deck structure is connected to Tower Two at each floor level and a pedestrian bridge links Tower One to the roof top of the podium structure.

Figure 1: Architectural view of The Sail @ Marina Bay

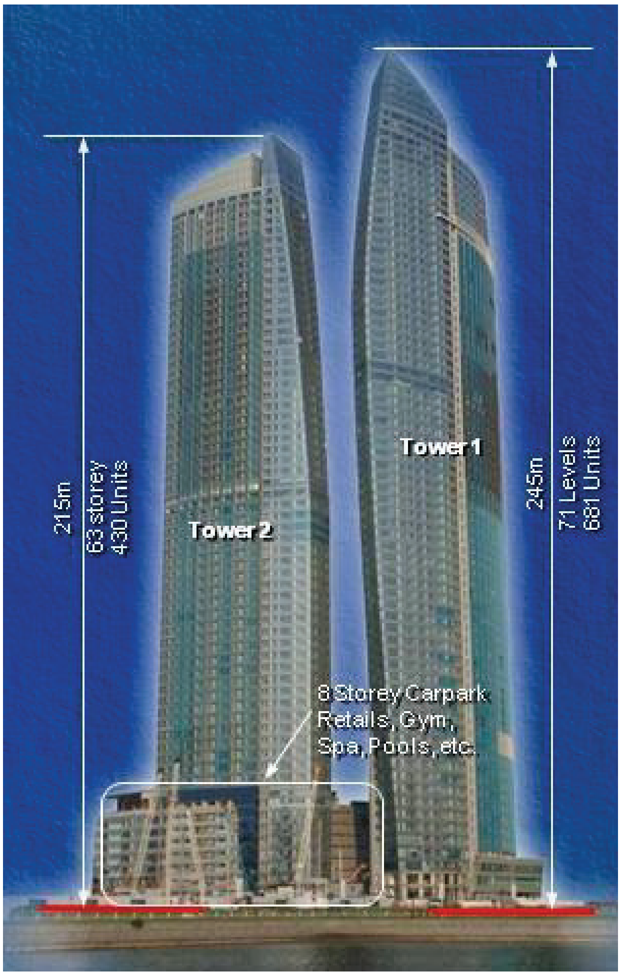


Figure 2: Building elevation

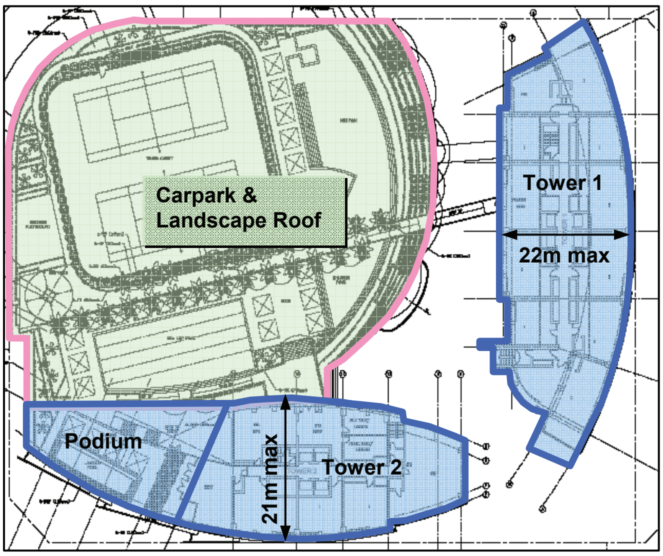


Figure 3: Building layout plan

The combination of height and extreme slenderness of the two towers makes them highly susceptible to dynamic effects and vulnerable to fluttering, vibrations, and accelerations during wind or seismic occurrences. Therefore, it was essential to design the tower structures with sufficient stiffness, strength, and robustness to accommodate both static and dynamic conditions. It is also necessary to ensure that the buildings' responses during these occurrences are within acceptable limits of drift and motion accelerations to provide comfort to the buildings' occupants and to prevent structural and non-structural damage.

During the Sumatra earthquake of 2005, the Singapore buildings that experienced the most shaking were located in the southern and eastern areas of the island where deep underlying soft Kallang clay formations exist. Although Singapore building codes do not include provisions for seismic design, Singapore's soft marine clay formation could create a dangerous amplification effect and increase a building's response to earth tremors originating from distant epicenters. For The Sail @ Marina Bay, the Client emphasized their desire for structural safety and occupant comfort for its tall and slender towers. Therefore, it was necessary that this prestigious development be designed to accommodate higher levels of lateral forces than that which is usually adopted for buildings in Singapore. It was decided by the design team to incorporate seismic design in the structural provisions to enhance the strength and robustness of the towers. A moderate seismic zone corresponding to Zone 2A of the 1997 Uniform Building Code (UBC) published by the International Conference of Building Officials (ICBO) was selected as the basis for the seismic design on this project.

The building site is located at Singapore's Marina Bay – which is on reclaimed land comprised of 20-30 meter thick marine clay deposits. Careful assessment of the area's geotechnical conditions was required to ensure a reliable and efficient foundation system capable of supporting the heavy concentrated static and dynamic tower loads within acceptable limits of overall and differential settlements. In addition to poor soil conditions, a north-south bound MRT tunnel located below and across the site added to the project's challenges. The layout of the project's structures had to be well planned, designed, and constructed to minimize interference to the MRT tunnels and its operations under the buildings' site. During excavation and construction works, monitoring of ground movement adjacent to and at the existing MRT tunnels was performed to prevent damage and limit any movement of the tunnel structure to less than 15 mm.

STRUCTURAL CONCEPT DEVELOPMENT

During the site planning stage, careful consideration was given to the development massing. Placement of the high-rise towers over the MRT tunnel locations would have required very heavy transfer structures and complex foundation systems to bridge the tunnels and support the towers' heavy loads. Instead, the design team oriented the high-rise towers away from MRT tunnel locations and placed the lighter 8-storey carpark and podium structure over the MRT tunnel. A less complex system of deep, rigid transfer post-tensioned girders was utilized to transfer the carpark's lighter loads over and across the MRT tunnel roof at the lower ground level above the tunnel roof (see Figure 4). The adopted layout provides maximum "tunnel free" space for the deep foundations of the high-rise towers and avoided disruptions to subway operations during construction as well as during the operational life of the building.

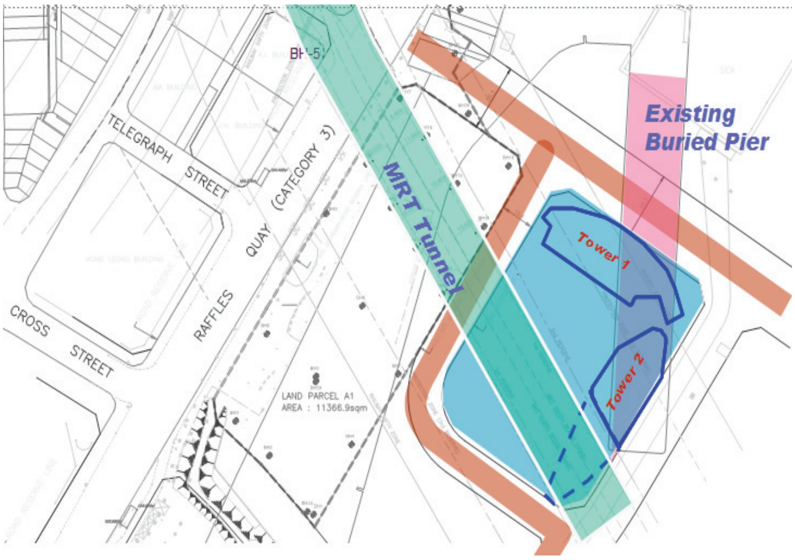


Figure 4: Overall building layout of the high-rise structures over the MRT tunnel structure

COUPLED SHEAR WALL CONCEPT

To meet the design challenges of the tall, slender towers, a relatively rigid framing system that provided adequate stiffness and satisfactory dynamic behaviour under wind and earthquake forces was developed. This framing system provided the optimum levels of structural stiffness strength, ductility, and robustness while maintaining a reasonably comfortable level for the buildings' occupants.

Owing to its high slenderness ratio and structural softness, the obvious first mode of vibration tends to be in the narrow transverse direction of the towers. The residential units are also oriented in this direction, thus, requiring the main dividing party walls between the living units to be located accordingly in this transverse direction. With this ideal orientation, the partition walls between units were designed as reinforced concrete bearing and shear walls to provide the required strength to resist the gravity, wind, and seismic loads of the tower structures. The partition walls also serves as fire proofing, sound proofing, and privacy and security walls between individual units.

In collaboration with the architects, corresponding load bearing partition walls were generally lined up on both sides of the central corridor to maximize the use of effective coupling beams to engage pairs of corresponding shear walls on opposite sides of the central corridor. This allowed efficient integration of the walls to produce maximum interaction and resistance to lateral loadings in the transverse direction of the towers (see Figures 5 and 6).

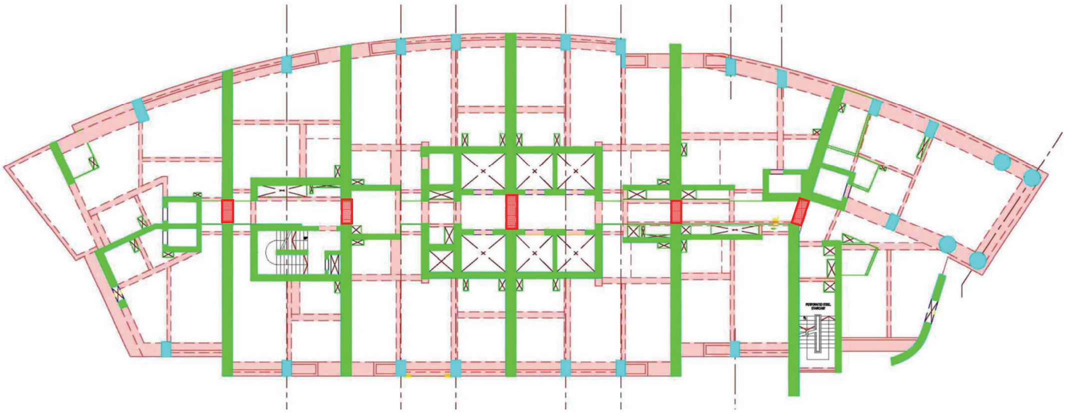


Figure 5: Tower One arrangement of shear walls for efficient interaction through coupling beams to reduce lateral deflection

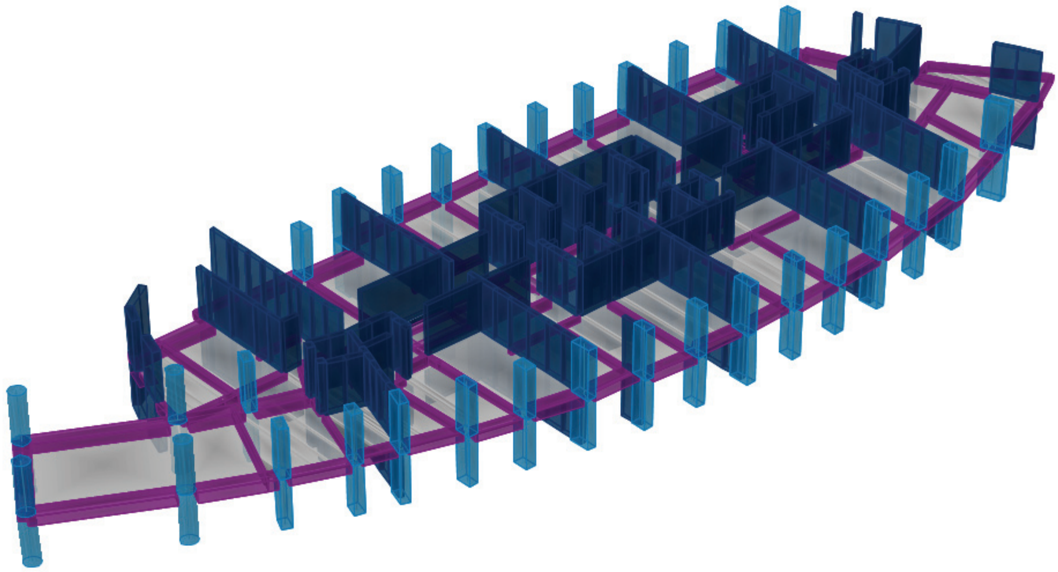


Figure 6: Perspective view of a typical floor layout for Tower One

Lateral drift in the transverse direction is greatly reduced by pairs of shear walls coupled together with 550mm deep beams over the corridor areas at typical floors. Narrow flange steel beams are encased in the coupling beams from the 1^{st} through the 25^{th} floors to accommodate the very large coupling beam shear stresses and restoring moment. In the mechanical floor levels where the floor to ceiling heights are twice that of the typical floors, the coupling beam depths were increased from 550mm to 3000mm deep. The increase in beam depth generated huge contributions to the lateral stiffness integration of the structure in the transverse direction. This mega-coupled shear wall arrangement reduced horizontal sway at the roof level by 46% as compared to a conventional un-coupled shear wall system. Figure 7 demonstrates the effectiveness of coupled shear walls in stiffening the tower structure's most slender transverse structural direction. As a result, the vibration mode for the tower in the slender transverse direction became the second mode of vibration instead of the first mode.

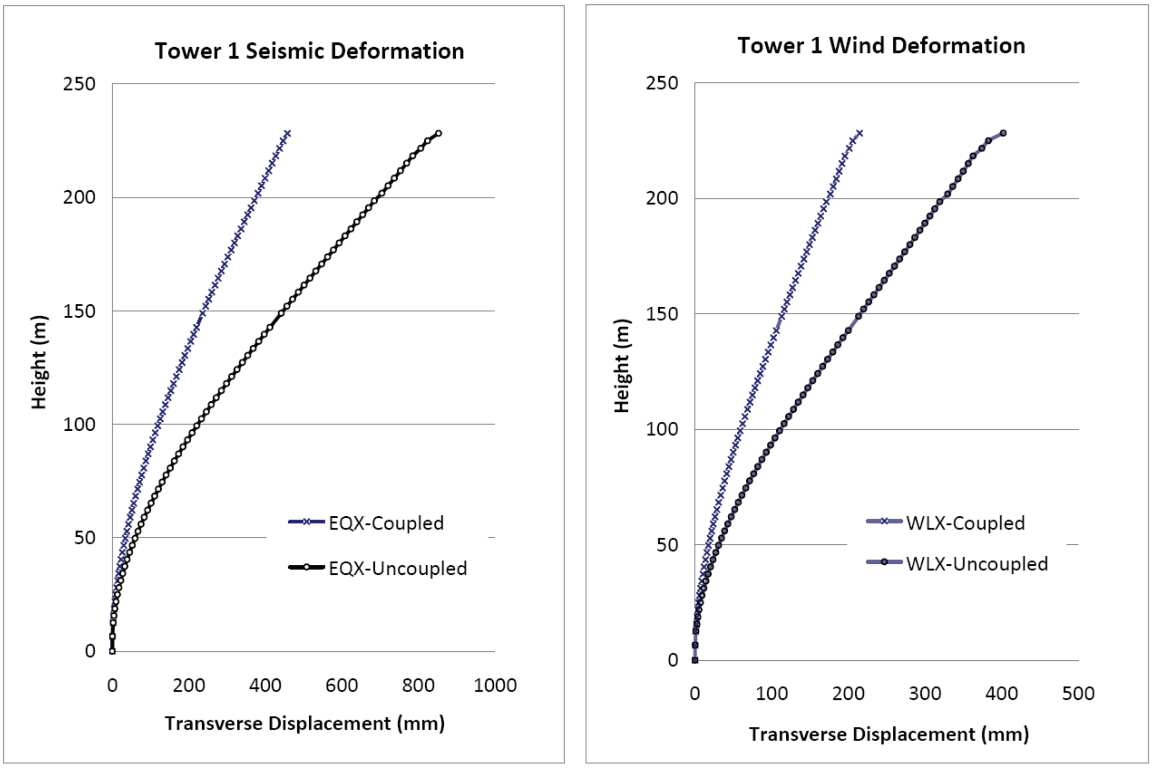


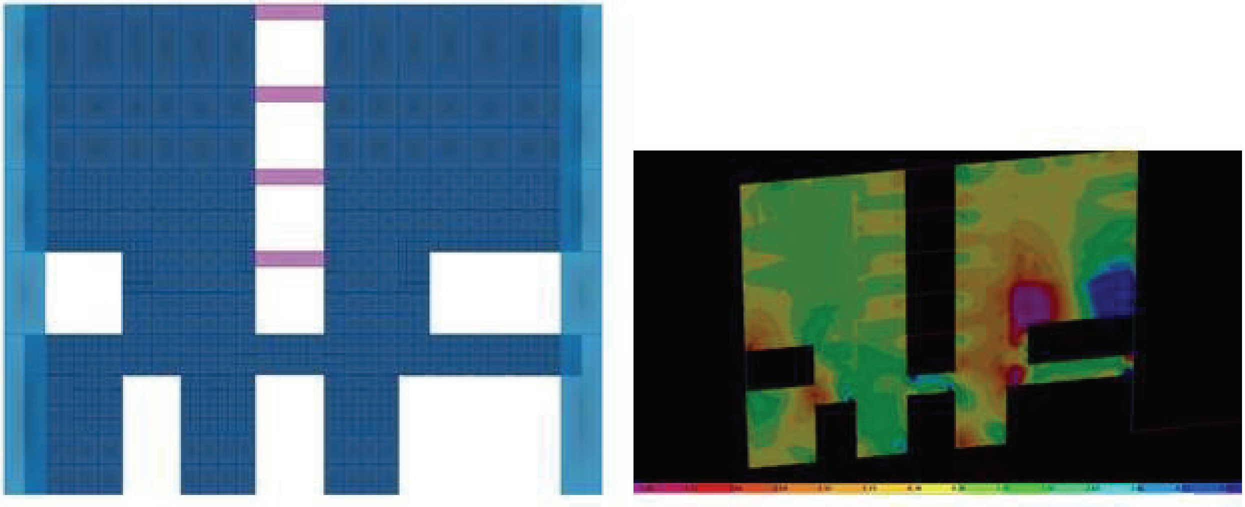
Figure 7: Seismic and wind deformation for coupled and un-coupled shear wall systems

Considering the extreme slenderness of the towers, boundary columns and spandrel beams are provided at the perimeter of the frame tube to increase the peripheral stiffness of the building frame for extra torsional and longitudinal resistance. The boundary columns and spandrel beams prevent undesirable vibration modes and accelerations that affect occupant comfort and tower strength. The wall boundary columns were also designed for reserve strength so that damage due to cracking and bursting of concrete in these critical areas under inelastic seismic loads is prevented.

A typical floor system for both towers consists of semi-precast reinforced composite slabs. The composite slabs are made up of precast concrete slab soffits with in situ structural concrete topping and specially reinforced. This enables development of full diaphragm action, continuity, and monolithic behavior to transfer lateral loads from each floor to the lateral load-resisting frame elements. Frame elements include a combination of perimeter moment frame tubes with columns (spaced at approximately 3.5 meters), interior reinforced concrete partition walls dividing residential units, elevator shafts, walls along the corridor, and staircase walls.

SOFT FLOOR

Owing to the 4-meter wide walkway on the 1st storey, the major shear walls along the grid lines were weakened by 4-meter × 4-meter openings at the ground level. The shear wall loads were then transferred to the mega columns at the ground level and the remaining walls outside of the 4-meter wide openings. This resulted in a “soft” floor condition with associated amplified loads for the exterior line columns and remaining walls due to the stiffness irregularity (see Figure 8).



a) Modeling of Soft Floor b) Shear Stress Distribution
a) Modeling of Soft Floor

Figure 8: Soft floor at 1st floor walkway and 2nd floor

In order to reduce the transfer column size at the soft floor and maximize the usable area in the lower floors, high strength concrete of Grade 80 was used for the first time in a Singapore building. The high strength concrete was used to reduce the size of heavily loaded perimeter columns in the lower floors where the shear wall was partially removed to accommodate the 4 meter × 4 meter walkway access.

For the building's mechanical floors, the perimeter frames were tied to the perimeter beams to ease the stiffness reduction effect as well as reduce the buckling length of the columns. Deeper coupling beams between transverse shear walls at these mechanical floor levels made significant contributions in reducing the drift ratios and the overall lateral displacement at the upper and lower floors.

The architectural features above the penthouse of Tower One required structural steel space trusses to transfer lateral loads from the featured roof parapet wall system to the main concrete tower structure.

HUMAN COMFORT

Owing to its extreme slenderness, the towers are classified as "dynamic structures" in design codes. Existing codes and standards do not comprehensively cover the dynamic behavior of such unusually slender buildings. A force balance wind tunnel test was, therefore, carried out for the project to investigate the effect of static and dynamic wind forces and the serviceability state of the building structure. The test was carried out by Windtech Consultants PTY LTD of Australia.

The structural load study of the wind tunnel testing was used to establish the following design parameters:

- Directional distribution of the mean and peak base moments.
- Shear force distributions along the height of the building.

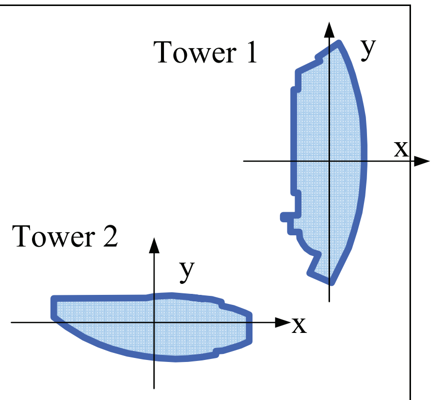
- Mean and peak tip deflections.
- Distribution of equivalent static forces for the design of the structure.
- Directional distribution of the peak tip accelerations and comparison with the relevant occupant comfort criteria.

The wind tunnel tests were performed for two surround model scenarios. The first scenario reflected the current building morphology (referred to as “No Future Surrounds” scenario), while the second scenario included the effects of future developments that may be constructed near the site (referred to as “Future Surrounds” scenario).

By incorporating the 16 load cases from the wind tunnel tests into a computer model, a comparison was made between the wind tunnel testing and the code specified loads. The wind tunnel test load distribution results compared favorably with the recommendations in the British Standard, Wind Loading Code BS6399. In comparing the results with the CP3 code (which preceded the BS 6399 code), the CP3 yielded more conservative results. This was probably due to the limited parameters involved in CP3.

Table 1: Comparison of maximum 50 year return period base moments with CP3 and BS6399 wind loading

Tower 1		
Method	**M_{xx}* (MN-m)**	**M_{yy}* (MN-m)**
Wind Tunnel Modeling	394	1913
CP3 V:1972	437	2744
BS6399 Part 2:1995	485	1423
Tower 2		
Wind Tunnel Modeling	702	317
CP3 V:1972	1173	322
BS6399 Part 2:1995	762	328
*M_{xx} and M_{yy} are the bending moments about the X and Y axes, respectively		



For the design and construction of slender, high-rise buildings, human comfort and reaction to wind vibration becomes a critical component. With increasing height – often accompanied by increased flexibility and low damping – structures become more susceptible to wind action, which governs the design of the lateral system. While a given design may satisfactorily carry all loads, the structure may still suffer from levels of motion that would cause significant discomfort to its occupants. For these two tall and slender towers, limiting the building drift alone did not necessarily satisfy the criteria for occupant comfort. Therefore, in addition to controlling the building drift to at least 1/500 of the building’s height, it was also necessary to control the peak acceleration under strong winds, which directly affects the comfort and motion perception of its occupants.

Wind-induced motions include the sway motion of the first two bending modes (termed along and across wind motions), and a higher mode torsional motion (about the vertical axis and complex combination in the lower modes). Under critical dynamic conditions, these motions can become rather unnerving to the structures’ occupants and may trigger responses analogous to those associated with motion sickness.

In the wind tunnel testing assessment, root mean square accelerations for a 5-year return period and peak accelerations for a 10-year return period are used. The accelerations for the two towers as established from the wind tunnel testing are summarized in Figures 8a to 8d. The threshold accelerations for human comfort range are 4.6-5.1 milli-g for a 5-year return period, and 16.7-18.9 milli-g for a 10 year return period.

As shown in Figures 8a-8d, the maximum 5-year return period acceleration for Tower One and Tower Two occurred at 230° from the north. The maximum 10-year return period acceleration for Tower One and Tower Two occurred at 170° and 230° from the north, respectively. The maximum rotational velocity within the 10-year return period also occurred at 170° and 230° from the north for Tower One and Tower Two, respectively.

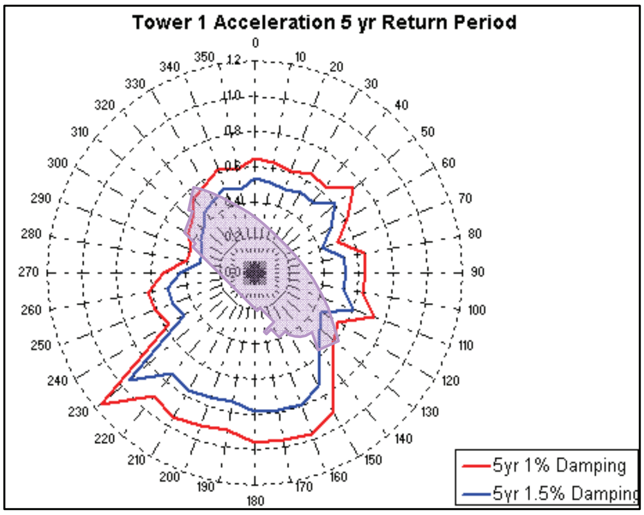


Figure 8a. Tower 1 Acceleration 5 yr Return Period

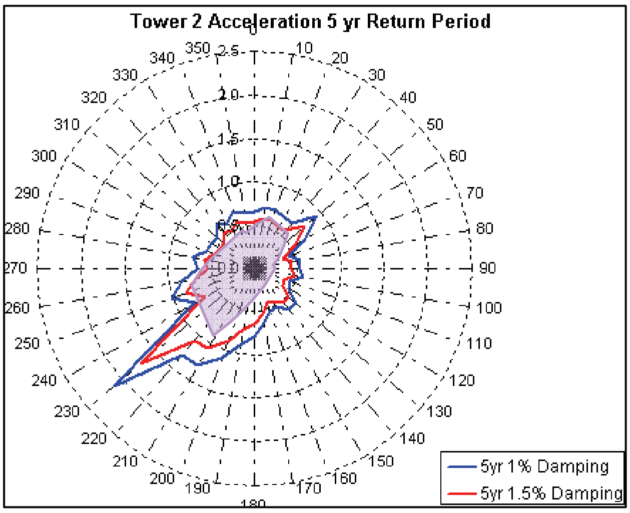


Figure 8b. Tower 2 Acceleration 5 yr Return Period

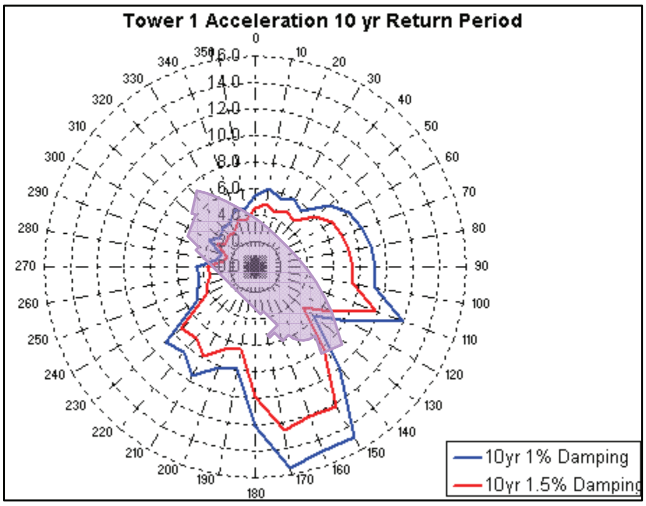


Figure 8c. Tower 1 Acceleration 10 yr Return Period

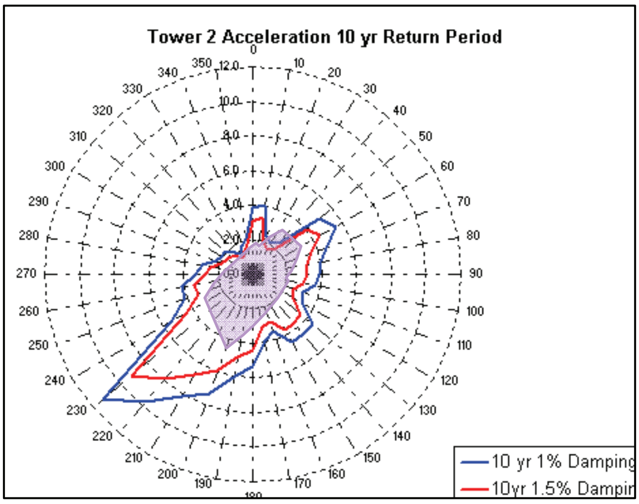


Figure 8d. Tower 2 Acceleration 10 yr Return Period

The wind tunnel test results revealed that the wind response for a 10-year return period wind governs the critical acceleration of 15.5 milli-g for Tower One. This acceleration is within the acceptable criteria recommended in technical publications and demonstrated the towers' satisfactory dynamic performance for occupant comfort. Also, as the buildings are properly cladded and acoustically insulated, significant noise caused by the wind and building motions will not influence the occupants' subjective response to the motion.

BASEMENT EXCAVATION AND FOUNDATION CONSTRUCTION

The project site is covered with hydraulic fill of 6 meters to 10 meters thick and up to 35 meters thick very soft marine clay and fluvial sand underlain by old alluvium or Fort Canning Boulder Bed. Apart from the complicated geotechnical formations, the challenging site constraints posed a very difficult situation for the engineer and contractor. Critical challenges included:

1. The presence of the existing North-East MRT subway line crossing the site as illustrated in Figure 4. The Land and Transportation Authority in Singapore specifies that the subway tunnel movements and stress changes should not exceed 15mm and 15 KPa, respectively, from the proposed sub- and super-structure construction. This was a severe challenge for the basement and foundation construction.

2. The single-level basement for the project required a deep excavation depth of about 9 meters from ground to allow for higher headroom in the retail space as well as a 3 meter thick pile supported raft. The relatively deep basement required a rigid retention system, especially with the adjacent movement sensitive below-ground structures.

3. An old pier in use before the reclamation work was completed crosses one end of the site under Tower One where the basement had been proposed. This created challenges to the installation of the foundation system for Tower One.

4. The excavation and construction of the underground Common Service Tunnel (CST) Phase 1 surrounding the development was occurring at the same time the basement excavation for The Sail was scheduled.

Concurrent construction of movement sensitive below-ground structures presented significant challenges to the excavation and basement construction works for the project. To address these challenges, an extremely rigid yet constructible retention system needed to be adopted. After comparing the options of sheet pile walls, contiguous bore pile walls, secant pile walls, and conventional diaphragm walls, Dragages Singapore and Bachy Soletanche Singapore Pte. Ltd. in conjunction with Meinhardt, proposed an innovative method of using symmetrically arranged triple cellular (32.20m ID each) diaphragm walls with flying beams. This eliminated the cross diaphragm walls which would have obstructed the basement excavation and structural construction (see Figures 9 and 10).

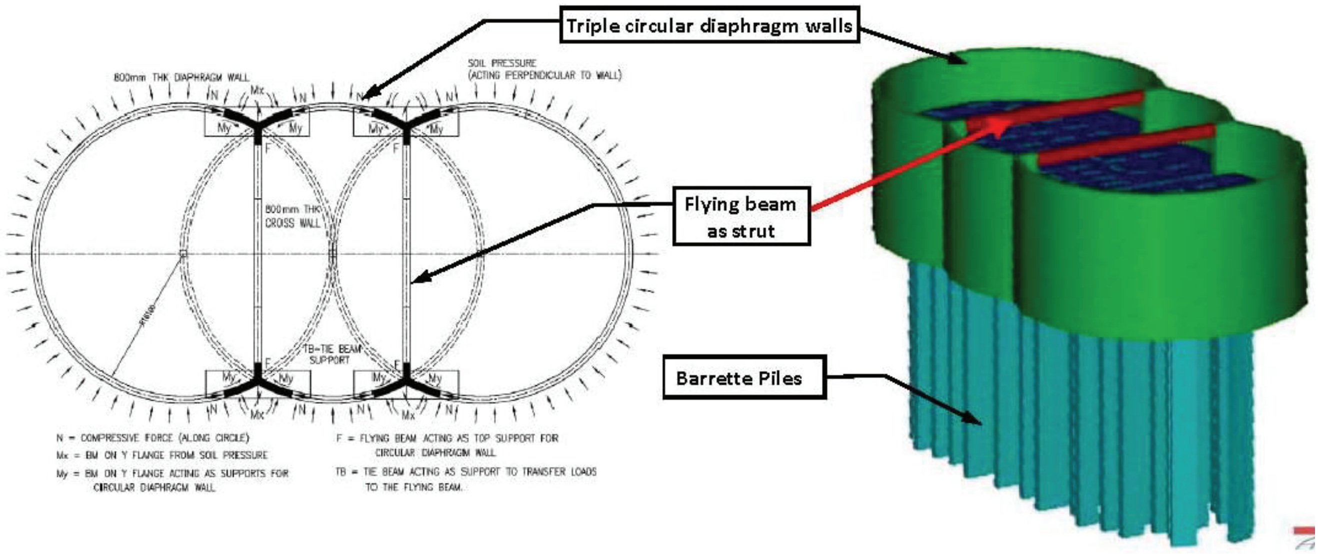


Figure 9: Novel circular diaphragm wall retaining system for excavation

Compared to conventional retention systems, the circular diaphragm wall system has the following clear advantages:

- The wall itself is self supporting and quick to install.
- Produces very small wall and ground movements as required by the project specifications due to its close proximity to existing MRT tunnels and other ongoing adjacent construction activities.
- Enhanced flexibility to handle unexpected geology or features found on the project site (existing pier, varying geology, etc.).
- Being circular, the wall performs primarily as an arch in compression and is therefore, economical.
- The depth of a circular diaphragm wall is reduced as deep socketing is not necessary for mechanical stability as in the case of a strutted cantilevered linear system.
- The need for soil improvement (e.g., Jet Grout Piles (JGP) in the marine clay layers) is completely eliminated.
- A strut free excavation would save time for earth removal as well as rebar placement and concrete pouring. This also avoids installing and removing steel struts.
- Eventually, the wall also acts as a formwork for the 3 meter thick pile raft.

Figure 10: Basement construction

As the site is located next to MRT safety zones, the excavation was monitored for settlement, basal heave, deflection of the wall, and change in pore pressures. Moreover, as this type of retaining wall system was new to Singapore and installed without the conventional JGP slabs and struts, it was decided to place instruments in the wall, barrettes, and the surrounding areas to study the behavior of the new system. Strain gauges were placed to measure the compressive force along the perimeter. The maximum deflection of the circular wall recorded was 9.8mm compared to a predicted value of 11mm from analysis. The maximum tunnel movement recorded was less than 5mm, which was well within the allowable value of 15mm.

With developments increasing in already congested urban environments, construction activity must be carefully controlled to maintain safety and protect neighboring buildings, underground services, and traffic during the construction stage. The results of this project show that cellular diaphragm walls are viable, efficient, and robust structures that can be economically constructed to provide safety and efficiency to construction projects in areas where conditions are often challenging to engineers and builders.

FOUNDATION SYSTEM

Owing to large vertical, horizontal, and overturning forces from gravity, wind, and seismic actions, high capacity foundation elements are required under Tower One. Large capacity barrette piles were utilized for Tower One to ensure the foundation footprint remains within the development boundary. For Tower Two, the foundation demands are less pronounced and, therefore, conventional bore piles were used. As the project site is located on reclaimed land with very poor soil conditions, the high individual pile loads are transferred through the soft marine clay to the deeper Fort Canning Boulder Clay subsoil via skin friction only while end bearing resistance is considered for block shear effects. The bases of all piles were post-grouted to eliminate pile "soft toe" conditions. A heavy concrete mat serving as a monolithic pile cap was designed for all piling to work together as a unit in resisting the severe downward and uplift forces.

To account for pile group interaction effects in resisting vertical and horizontal loads, the analysis incorporated parametric sensitivity studies for varying degrees of additional stiffness for the perimeter piles under the raft. The raft serves as a fixed joint between the foundation piles and the superstructure to uniformly distribute the superstructural loading to all piling without significant differential settlement.

CONSTRUCTION METHODOLOGY

In order to achieve a fast-track construction and reduce construction costs, selected precast elements of the superstructure were fabricated onsite. These precast elements were limited to floor slabs, floor beams, and bay windows that could be fabricated with simple steel moulds that are easily dismantled and shifted. The casting of these structural elements was carried out on the ground floor at the bottom of each tower. With precasting being an integral part of the main contractor's onsite construction process, the schedule and coordination logistics of the precasting and erection activities had to be well managed. The assembly of the precasting floor and corresponding arrangement of precast formwork are shown in Figures 11 and 12.

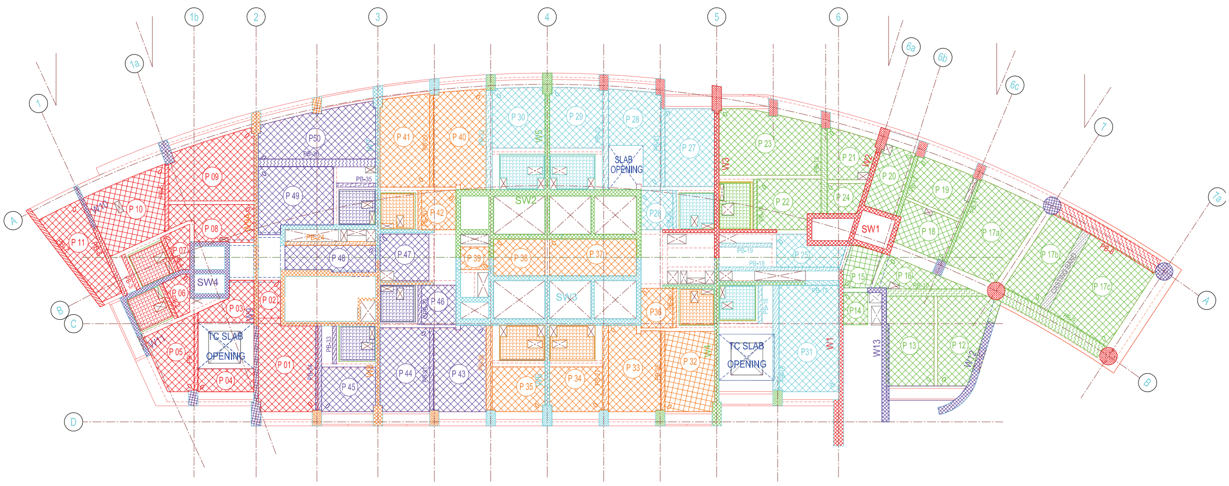


Figure 11: Tower One precast slab layout

The typical floor erection and concreting cycle was planned in three stages ─ precast slab construction, precast beam construction, and in situ shear wall construction (for each floor cycle) – to allow sufficient working spaces so that the different trades did not interfere with each other (see Figure 13). The floor framing system and connection details employed enabled the full integration of all precast and in situ elements to form a monolithic structure that included slabs, beams, columns, and shear walls. The precast slab soffits served as the bottom portion of the composite slabs. They also acted as "stay-in-place" forms to support the in situ concrete topping, thereby, saving labour and time involved in installing formwork, stripping forms, and the temporary storing of forms

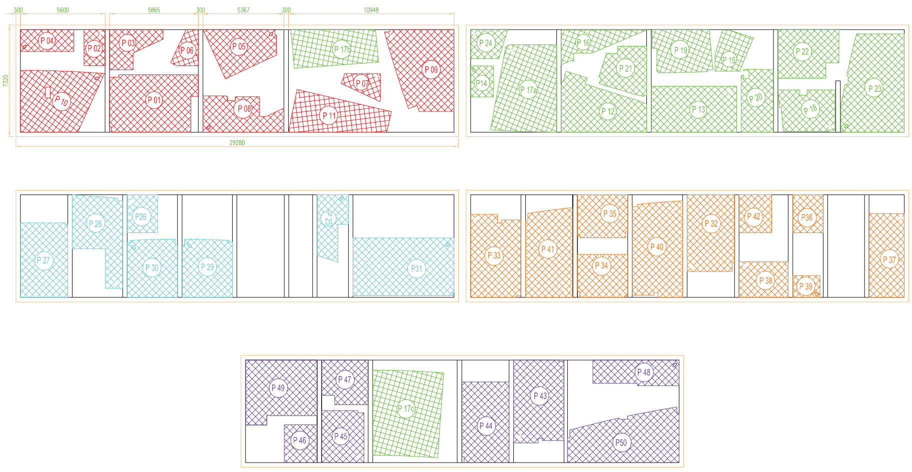


Figure 12: Tower One precast formwork arrangement

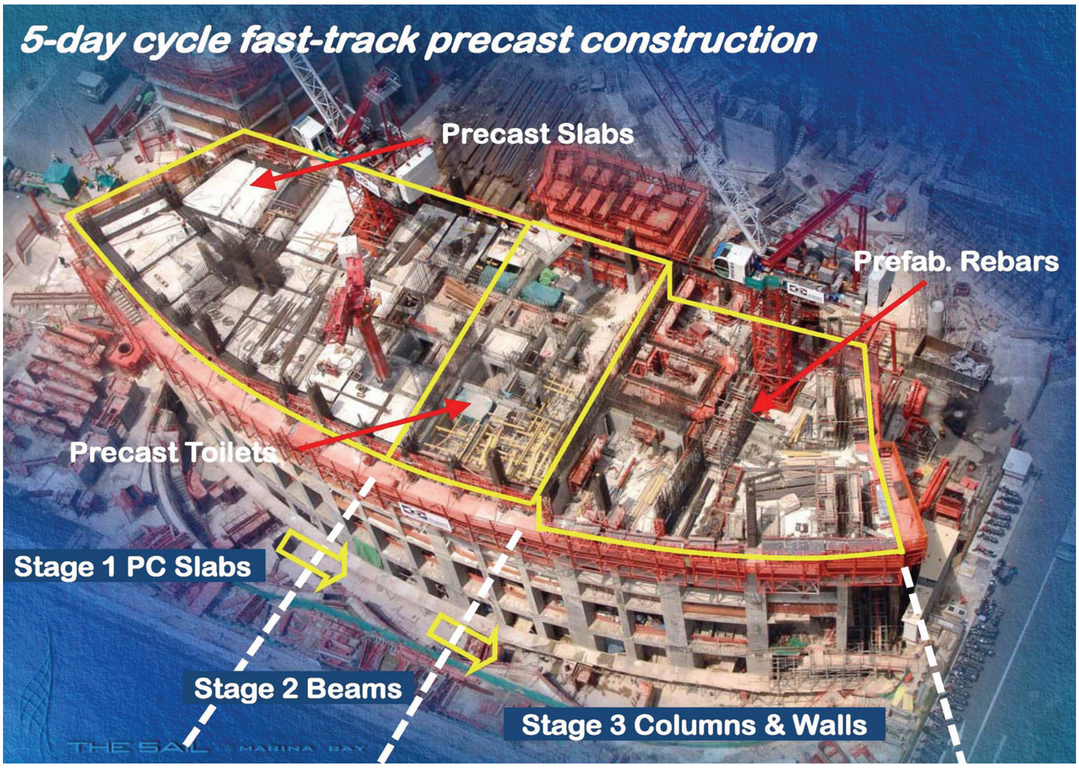


Figure 13: Tower One typical floor precast construction sequence

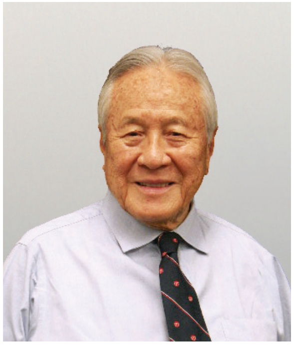
This project was awarded a structural Construction Quality Assessment System (CONQUAS) score of 99.5. This exceptional score was a result of our modular, repetitive structural framing system which reduced typical floor construction cycle time to only five days per floor.

Completed in September 2008, The Sail @ Marina Bay is currently the tallest residential building in Singapore with 1,111 residential units, restaurants, health clubs, recreational areas, and parking facilities. This development has become an iconic landmark boasting panoramic views of the city and Marina Bay.

That same year, The Sail @ Marina Bay was awarded BCA's Design and Engineering Safety

Excellence Award in the Residential Category in recognition of the design and construction team's success in the safe construction of a structurally sound building by creating innovative designs and construction solutions for the project's unique challenges.

ABOUT THE AUTHORS



Dr. Alfred A. Yee
President, Yee Precast Design Group Ltd. (USA)
Director, Precast Design Consultants Pte. Ltd. (Singapore)
BSc, MEng, EngD(Hon)
email: alyee@precastdesign.com

Dr. Alfred A Yee obtained his Bachelor of Science degree in Civil Engineering from Rose-Hulman Institute of Technology and his Masters in Structural Engineering from Yale University. In 1976, the Rose-Hulman Institute of Technology conferred upon him an Honorary Doctor of Engineering degree. That same year, Dr. Yee was made a member of the prestigious National Academy of Engineering (NAE) (USA). He has developed innovative structural concepts, devices, and construction techniques widely used in prestressed/precast concrete construction of mid- and high-rise building structures, hangars, bridges, and wharves. He served on the American Concrete Institute Committee 357, Concrete and Marine Offshore Structures and has designed and supervised construction of ocean-going prestressed concrete barges and prestressed concrete ocean platforms for oil exploration and chemical processing plants.

Dr. Yee is the author of numerous technical articles and has delivered lectures to many international professional organizations and universities on the subject of precast and prestressed concrete. His articles published in the Prestressed and Precast Institute (PCI) received awards for: (a) Excellence in Research and Design, (b) Construction Methodology, and (c) Latest Technology and State-of-the-Art. In 1997, Dr. Yee was awarded the PCI Medal of Honor for his extraordinary contributions to the precast/prestressed concrete construction industry, especially for his innovative design of precast/prestressed concrete high rise buildings along the Pacific Rim which have survived some of the highest intensity earthquakes in the world. In 2004, Dr. Yee was named a Titan of the Precast/Prestressed Concrete Industry in recognition of his outstanding contributions to the Industry; for prominence in industry innovation and change; for positive leadership in industry-altering development and expansion; and for advancing and accelerating the growth of the North American Precast and Prestressed concrete industry.

In 2009, the Hawaii Council of Engineering Societies honored Dr. Yee with the HCES Lifetime Achievement Award in recognition of his significant contributions to the development of engineering in the State of Hawaii and noteworthy impact on the local engineering community.

Er. Kang Jianhan
Precast Design Consultants Pte. Ltd.
MEng, MIES, MIStructE
PE(S) Chartered Engineer (UK)
email: kang@precastdesign.com

Mr. Jianhan Kang is Associate Director of Precast Design Consultants Pte. Ltd. (Singapore), an affiliated office of Yee Precast Design Group Ltd. (USA). He received his Bachelor's Degree from Tong Ji University and graduated from National University of Singapore with his Master's Degree in Civil Engineering in Oct 2002. Mr. Kang is a registered Professional Engineer of Singapore and Chartered Engineer of United Kingdom. He was elected as a member of Institution of Structural Engineers (IStructE) and Institution of Engineers Singapore (IES). He was also appointed the committee member of IES/IStructE Joint Committee Singapore. Mr. Kang has developed his expertise in the area of seismic design and analysis of complex structures ranging from high rise residential and commercial buildings to long-span structures. He participated in the design of Aircraft Maintenance Hangar in Guam with Precast Design Consultants P/L. He was also involved in the conceptual design and design advisory of a super-highrise luxury condominium, The Sail@Marina Bay, in Singapore. Most recently, he was part of the team for the preliminary study and design of offshore concrete barges.

Mr. Frederic Perez
Dragages Singapore Pte Ltd

Frederic Perez is a Construction Director of Bouygues Batiment International. He has 25 years experience in the construction industy. In Singapore for the last 15 years with the subsidiary company, Dragages Singapore Pte Ltd, he was involved in the construction of multi-million dollar projects, such as luxurious condominiums, hotel, office & retail buildings. He oversaw a group of professionals for the successful completion of projects, whilst ensuring that projects are constructed in compliance with statutory and Employer's Requirements and accomplished within the successful project implementation, profitability, cost efficiency and risk minimization. Presently he directs the construction team in the building of the Singapore National Stadium, Singapore SportsHub. He is a Board Member for the Building & Construction Authority (BCA).

Dr. Juneid Qureshi
Group Design Director, Meinhardt (S) Pte Ltd
B.Eng, M.Eng, D.Eng
email:jq@meinhardt.com.sg

Dr. Juneid Qureshi was awarded a Doctor of Engineering degree from The University of Tokyo, Japan, in 1993 for his work on reinforced concrete mechanics. He is Group Design Director of Meinhardt (Singapore) Pte Ltd and his work with the firm has encompassed, from concept design to construction of, a wide range of complex and challenging structural engineering projects in Singapore, the Middle East and South East Asia. He has extensive experience in the design of concrete, steel and composite structural systems for tall buildings as well as long span and large spatial structures. Some of his major and award winning projects include One Raffles Link (Singapore), One Raffles Quay (Singapore), The Sail @ Marina Bay (Singapore), Marina Bay Financial Centre (Singapore), Ocean Heights (Dubai), Signature Towers (Dubai), Capital Plaza (Abu Dhabi) and World Trade Centre (Jakarta). He has published in a number of international journals with his publications covering topics on design and construction of tall buildings, optimum and innovative structural systems and reinforced concrete mechanics. He has received awards for his publications from the Japan Society of Civil Engineers and the Japan Concrete Institute. He is Singapore's Country Representative for the Council of Tall Buildings and Urban Habitats (CTBUH) and is regularly invited to speak at local and regional conferences and seminars.