International Finance Centre

Phase II

國際金融中心二期

Photo: www.scomposition.com

International Finance Centre, Phase II

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International Finance Centre (IFC) is a commercial, retail and hotel complex located on the harbourfront in Central District and is part of the MTRC's Hong Kong Station Development (photo 1). The office towers are being developed in two phases, with the 38-storey One IFC tower and the IFC Mall shopping centre completed in 1998. Phase II comprises an 88-storey office tower named Two IFC, a 47,000 sq m four-level podium shopping mall, and a five-level basement housing a train station concourse and carpark. Two retail bridges connect the two IFC phases. Construction of Phase II is scheduled to complete in mid-2003, by which time Two IFC will be the third tallest building in the world.

Photo 1: An artist's impression of the fully developed International Finance Centre

Photo 2: An aerial view of the entire International Finance Centre development and MTR Hong Kong Station at the Stage I Central Reclamation in 1997

The project dates back to 1996 when the foundation work contract was awarded to Aoki Corporation, the main contractor for the MTRC's Hong Kong Station, as part of the overall station's contract (photo 2). The contract originally included the foundation works for an 88-storey office tower, in which 72 bored piles with 3 m diameters were to be constructed; as well as the cut-off system using diaphragm walls around the entire site, bored piles for the podium structure and barrettes for a hotel building to the west of the site.

Structural arrangements

The superstructure is an 88-storey composite building with five additional basement levels going down to -32 mPD. The highest point of the tower is 420 mPD. The general footprint of the building is about 57 m by 57 m but at the roof level this area is reduced to 39 m x 39 m. The gross floor area of the Grade-A office building is about 180,000 sq m and the typical floor-to-floor height is 4.2 m. The structure is designed to last for 120 years.

The structural system consists of a central reinforced concrete core wall linked by steel beams and outriggers to eight exterior composite mega-columns.

Two secondary columns are located at each corner of the building to support the gravity load. Composite slabs are used as floor slabs, comprising 460 mm deep steel secondary beams spanning from the core wall to the 900 mm deep primary girders spanning between the mega-columns. Four sets of outrigger and belt truss systems are provided to stabilise and strengthen the external steel frame onto the core wall. The core wall measures 29 m by 27 m at its base with a maximum wall thickness of 1.5 m. The wall is made of Grade 60 reinforced concrete. The core houses the primary building functions, including the elevators, stairs, toilets and mechanical rooms for building services facilities.

Foundation system

As an alternative design, the Aoki team proposed the concept of building a 61.5 m internal diameter cofferdam, lined with 1.5 m thick diaphragm wall panels, to facilitate the excavation and construction of a raft foundation founded on bedrock for the entire office tower (photo 3). The design was accepted by the developer and created what the industry called the biggest hole in Hong Kong.

The majority of the diaphragm wall panels were excavated by the hydrofraise, or the reverse circulation trench cutting machine. The average depth of the panels was about 55 m, with the toe grouted and installed with shear pins to ensure stability.

As the excavation proceeded, a capping beam at the top of the cofferdam and four ring beams were provided as stiffening elements to the diaphragm wall panels (photo 4). By the provision of a compression ring using the cofferdam, the excavation could be extended safely down to bedrock, averaging about 40 m from ground level. The initial excavation was relatively straightforward for merely cutting through reclaimed sand fill layers. However, the later stage of excavation was much more difficult and time consuming for it involved cutting into partially and slightly decomposed granite layers, where a non-explosive demolition agent was used. Meanwhile, a localised depression of the rock level to the south west of the tower base appeared with a maximum depth of rock up to -50 mPD, which was too deep for normal open excavation. In this location, barrettes (rectangular-section piles) were installed to provide support to the building raft. The whole excavation process was carried out down to the formation level at -32 mPD. Including the treatment to the localised bedrock, the work took about 16 months to complete. However, due to economic reasons after 1997, the project was suspended for about two years.

Photo 3: Excavation in progress at the formation level of the 61 m diameter cofferdam

Photo 4: The 61 m diameter cofferdam formed by 1.5 m thick diaphragm wall panels was strengthened by RC ring beams

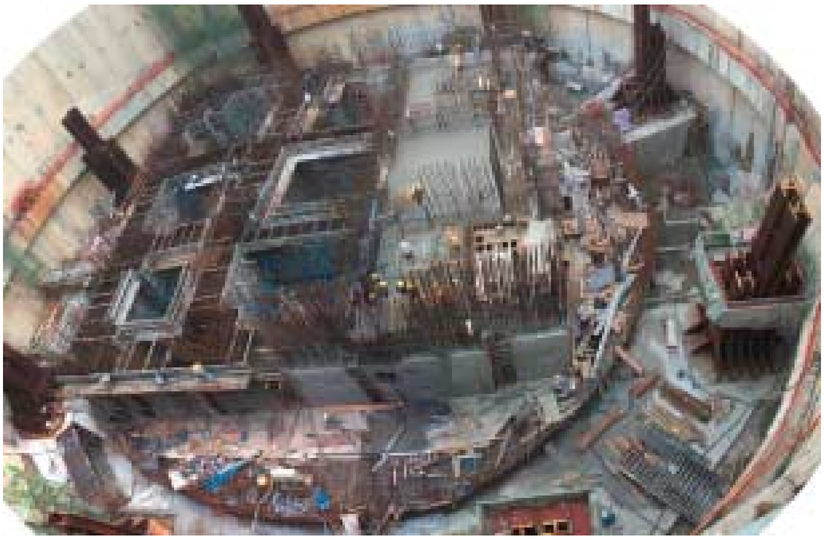

Photo 5: The core wall of the Two IFC tower ascending from the raft at the bottom of the cofferdam. Also note the mega-columns anchored to the plinths by gusset plates

Photo 6: Close-up view of the plinth at a mega-column

Foundation work resumed in early 2000. Immediately from the top of the formation surface, a 6.5 m-deep heavily reinforced slab was constructed to serve as the raft for the entire building tower, with a volume of about 20,000 cu m of concrete (photo 5). Starter provisions for the core wall and gusseted bases for the installation of the mega-columns were also provided here to connect to the construction of the upper structure (photo 6).

The mega-columns

There are eight mega-columns rising from the raft at the base of the cofferdam up to the roof at 420 mPD, supporting the external frame of the entire building (photo 7). The first section of the mega-columns, stretching from basement level 5 to the 6/F level where the transfer truss is located (photos 8 & 9), has six sub-stanchions formed by 90 mm-thick plates with average weights of steel up to 9.7 ton/m (photo 10). Due to the heavy weight, the stanchions were installed in short sections and connected by welding and non-welded bearing splices. Mobile cranes stationed on the ground level around the cofferdam were used to facilitate the installation process (photo 11). In order to speed up the work by allowing the mega-columns to be installed at the earliest float, the contract for structural steel works

Photo 7: A view into the cofferdam with the core wall and mega-columns in position close to ground level

Photo 8: Forming the transfer truss at 6/F at its early stage. Also note the size reduction of the mega-columns at this level

Photo 9: Detail of the south elevation of the transfer truss at 6/F

was subdivided into two stages, for installation of the mega-columns below 6/F and the rest of the works for the superstructure above 6/F, and awarded to two independent nominated sub-contractors, corresponding to approximately 5,000 tons and 19,000 tons of structural steel works respectively.

As construction of the basement slab proceeded in a bottom-up manner, the mega-columns were then encased in concrete, with reinforcing steel bars fixed around the stanchions to increase the strength and stiffness of the columns (photo 12).

Photo 12: Fixing steel bars (50 mm diameter bars at the base section) around the stanchions of a mega-column before encasing it in concrete

Photo 10: Steel sections stacked on the site for forming the mega-columns

Photo 11: Work stations around the sides of the cofferdam on ground level, forming an important base to serve construction activities inside the cofferdam

Photo 13a: Close-up view of the formwork system used for the construction of the core wall at the early stage. Another climb form set would be used to replace this when the core wall reached ground level

Photo 13b: Forming the floor slab inside the cofferdam with a construction joint in place for breaking through to join to the adjoining basement floors later

Photo 14: Erection of the first section of climb form at the ground level

Photo 15: The first section of core wall (western section) being concreted while the erection of the eastern section was in progress

Photo 16: The climb form, composed of two separate climb systems, was used to construct the 780 sq m central core

Construction of the core wall

Construction of the core wall commenced in May 2000, starting from the raft at the bottom of the cofferdam. Due to the non-typical layout and to save time in making modifications to the form in the confined environment inside the cofferdam, a gang form system composed of timber panel-type shutters stiffened by aluminium studs was used (photo 13a). The mobile cranes stationed around the cofferdam on ground level were used for the installation of the formwork. The construction technique followed a bottom-up and floor-by-floor approach, with the vertical wall sections completed first and followed by the floor slabs until reaching ground level. Construction joints were also provided at the sides bounded by the mega-columns to allow separation between the slab and the cofferdam (photo 13b), as well as provide future connection to the basement of the podium portion.

Starting from the ground level, another set of steel shutter formwork was used to replace the original timber panel-type setup up to the 3/F level. From the 4/F level onwards, the form was modified with the addition of a girder frame, hydraulic jack and clamp system, transforming it into a climb form (photos 14 & 15). In order to achieve more effective operation, the core wall was sub-divided into two portions by the use of two independently controllable lifting systems, with construction jointing in the middle where the tie members were located (photos 16, 17 & 18). The floor cycle for typical floors was maintained at four to five days, with certain expected delays at floors where the outrigger system was located, or where the wall started to reduce in size.

Photo 18: The shutter panels, girder support and hydraulic jack arrangement of the climb form, as seen from inside one of the core shafts

The superstructure

The 88-storey tower features an outrigger lateral stability design with a rigid central core wall, eight main mega-columns – two on each face – and secondary columns at the four corners (photo 19) to form the external steel frame. The floor system makes use of 125 mm thick composite slabs supported on steel beams. To allow for unobstructed panoramic views along the

Photo 19: The transfer truss as seen on the 6th floor, supporting two secondary columns at each corner of the building's external frame

Photo 17: A view of the climb form at a building corner when it was in the released position ready for lifting to the next working level

external wall, a deep edge girder spanning up to 24 m is provided to support the floor between the main columns (photo 20).

The mega-columns are of a concrete-encased composite design (photo 21), rectangular in section with the narrow side facing outward to minimise visual obstruction. These columns are composed of six I-section columns (sub-stanchions) arranged in three pairs for the lower floors, and reduced to three, two and one in number for the upper floors. They are used as the main load bearing elements for the building's exterior frame. In order to reduce costs and increase the stiffness of the columns, reinforcement bars ranging from 4 per cent to 2 per cent of the column section (photo 22) are positioned around the perimeter of the stanchions. The encasing concrete used for the columns is of grade 60 (Basement up to 52/F) and grade 45 (53/F and above). One self-climbing form system for each column was used for the encasement works at the mega-columns (photos 23, 24a & 24b).

Other spectacular features in the superstructure are the belt truss and outrigger systems provided in the composite frame to stiffen the entire 88-storey structure.

Photo 20: A 24 m edge beam spanning between the mega-columns at the lower section of the tower. The beam sections were gradually reduced in size for higher levels

Photo 21: Concreting to the composite mega-column

Photo 22: A mega-column with the reinforcing bars fixed in position and ready for the concrete encasement

Photo 23: Two sets of climb forms for the mega-columns on the building exterior


Photo 24a: The climb form in position ready for encasing

The first sets of the belt truss system are located on 6/F and 7/F and serve to provide a transfer arrangement to spread the load of the columns from the upper structure down to the mega-columns (photo 25). Meanwhile, the other three sets of outrigger systems, located on 32/F-33/F, 53/F-54/F and 65/F-66/F respectively (photos 26, 27 & 28), act as strengthening components to improve the rigidity of the structure and to reduce the effect of deflection on the building due to wind load. The outrigger and belt truss systems in general include a built-in inner steel frame serving as an anchor truss, which is embedded in the RC core using a two-stage


Photo 24b: The climb form in its open mold ready for repositioning to an upper floor

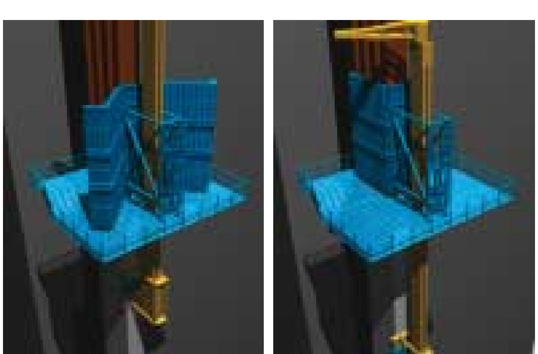
Photos 24c & 24d: Drawing showing the open and shut mold of the climb form for the mega-columns


Photo 25: Building elevation showing the basic configuration of the transfer/belt truss at 6/F


Photo 26: Configuration of the 32/F belt truss before the erection of the floor beams and floor plates


Photo 27: Part-detail of the outrigger/belt truss system at 54/F


Photo 28: Part-detail of the outrigger/belt truss system at 65/F

Photo 29: Installation of the outrigger system at 32/F — anchor frame starting to be installed onto recessed positions on the core wall

Photo 30: Installation of the outrigger system at 32/F — anchor frame being installed onto the core wall recess. The frame was encased in reinforced concrete at a later stage, after completion of the floor system

Photo 31: Close up of the anchor frame before it was encased as part of the retro-installation

casting (retro-installation) process (photos 29, 30, 31, 32a & 32b), and an external frame in the form of belt truss acting as an external stiffening member and taking up the gravity loads from the corner columns.

The outriggers and the belt trusses are connected by semi-rigid joints located inside column slots (photos 33 & 34), which can be made adjustable with a series of packing shims (photo 35). This design is to cater for the differential shortening between the RC core and the perimeter columns during construction of the tower as well as the slight shortening that occurs throughout the life span of the building. This design concept was originally used in the construction of Cheung Kong Center (photos 36 & 37).

Photos 32a & 32b: Encasing of the anchor frame and reinstatement of the core wall

Photo 34: Close-up of the column/outrigger joint with the provision of a slot to control differential shortening

Photo 33: Joining arrangement between the mega-column, outrigger and the belt truss system

Photo 35: Column joint after the column is encased in reinforced concrete

Photo 36: The arrangement of the outrigger system used at Cheung Kong Center (at 59/F)

Photo 37: Close up of the outrigger/belt truss joining arrangement as employed at Cheung Kong Center, bearing similarities in design to the Two IFC arrangement

Photo 38: Commencement of the top-down basement. The work arrangement with steel stanchions supporting the ground floor slab and the basement excavation/construction underneath can clearly be seen

Photo 39: With the ground slab being cast in position, excavation for the basement proceeded in convenient phases. The excavation was initially carried out around the muck-out openings provisioned on the ground slab and gradually extended horizontally and downward in a zigzag manner until basement floors were completed

Photo 40: One of the openings provisioned on the ground slab for mucking-out during the basement excavation process

Basement of the podium

The 38,000 sq m, five-level basement beneath the podium was constructed using a top-down approach. In order to achieve this, steel stanchions were positioned into the bored piles and connected to the foundation by gusset plate. The stanchions were used as supports to the upper basement slabs as the excavation and casting process proceeded (photo 38). A coupling arrangement using couplers welded to the sides of the stanchions was provided at levels where the basement slab was located. Due to the huge size of the basement, the excavation and construction work was sub-divided into nine phases in order to confine the construction to controllable segments (photo 39). The basement work commenced in June 2000 and took about 18 months to complete.

Getting rid of the huge amount of excavated spoil was one of the difficult problems faced in the project. To tackle the problem, three temporary access shafts were formed on the slab of the basement, located at the

Photo 41: Looking into the muck-out opening with the excavation arrangement clearly seen

Photo 42: Spoil removal hoist with the bucket/hopper set-up for unloading at ground level

Photo 43: Operation of the spoil removal hoist inside the muck-out opening

east, middle and west of the podium (photos 40 & 41). The shafts were used to transport the spoil from the excavation point vertically to the ground surface. At the same time, specially designed rack-type lifting devices (material hoists) equipped with 3 cu m tiltable bucket was installed at each shaft to remove spoil efficiently and quickly from the basement (photos 42 & 43). For horizontal transportation, a temporary unloading pier with an elevated linking bridge was provided on the nearby seawall to allow dumping vehicles to remove spoil from the site and unload them onto barges (photo 44).

In order to expedite the excavation and casting works, a double bit method was adopted to construct the basement slab (photo 45). The method was to excavate two basement levels at a time and then cast the slab of the lower basement in an advanced phase. From the completed slab, the slab on top of this was constructed (photo 46). The completed slab in this case facilitated the erection of propping work for the upper slab, and could also be used as a separating plate to allow excavation to continue on the lower basement floors.

The other critical work in the construction of the basement was breaking through between the podium and the main tower portions, as well as part of the basement area linking Phase I and Phase II. The diaphragm wall panels that formed the cut-off wall of the cofferdam under the footprint of the main tower were demolished by pneumatic breakers as the excavation proceeded in a top-down sequence. The panels separating Phase I and Phase II were removed with the saw-cutting method (photo 47), where the concourse of the Mass Transit Railway's Hong Kong Station would be linked.

Photo 44: Temporary pier set-up along the seawall outside the site for dumping purposes

Photo 45: Double-bit arrangement to construct the basement floors. An intermediate basement slab, positioned where the excavating machine was located, was being cast in an advanced phase and also served as a separating plate where the upper slab could be constructed while allowing excavation below to safely proceed at the same time

Photo 46: Another section seen through one of the muck-out openings with the double-bit construction arrangement clearly shown

Photo 47: Breaking through into the existing diaphragm wall panels with the saw-cutting method. After removing the wall, the existing MTR Hong Kong Station concourse could be linked to the new concourse extension inside the Two IFC basement

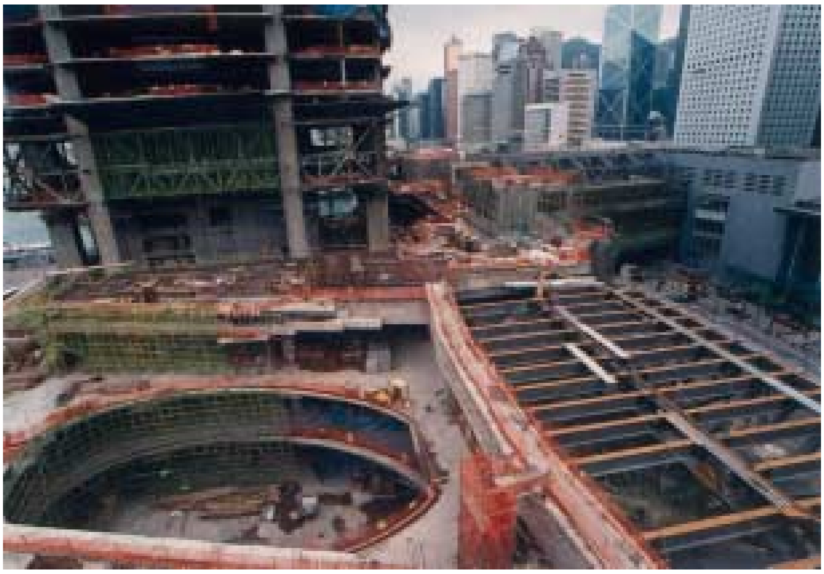

Photo 48: The forming of a 25 m-span oval-shaped atrium with 20 m headroom inside the podium structure

Photo 49: An interior view of the oval-shaped atrium at its final fitting-out stage

Photo 50: An overview of the podium structure before topping-out

The construction of the podium

The five-level 47,000 sq m podium will be used mainly as a high-end retail mall. The podium will be linked to the mall in Phase I by two elevated steel bridges, each three levels high with spans of about 50 m and weights over 3,000 tons. The structure of the podium consists of a number of long-span beams with some up to 30 m, as well as some atrium spaces with headrooms up to 25 m. The biggest space is oval in shape with bow-trusses supporting a semi-glazed roof (photos 48 & 49).

Construction of the podium used a rather traditional formwork system due to the non-typical layout. However, the gigantic size of the building areas as well as the headroom of the podium floors, which averaged up to about 4.5 m, made the formwork erection and casting process have certain difficulties (photos 50, 51a & 51b). The construction of the podium structure commenced in December 2000 and took roughly 15 months to complete.

On completion, there will be a 7,000 sq m landscaped garden on the roof of the retail podium providing public facilities such as sitting-out areas, a cafeteria, water features and plantings (photos 52a & 52b).

Photo 51a: An aerial view of the podium from the Two IFC tower

Photo 51b: A close up look at the podium structure which used rather traditional timber formwork in construction

Photo 52b: A close up look at one of the three glass hoods on the roof deck during its installation

Construction of the vehicular ramp

There is a vehicular ramp on the west side of the site to provide access for vehicles to enter the basement carpark underneath the podium structure. The construction of the ramp employed a bottom-up approach within a 42 m square-shaped cofferdam shaft (photo 53), formed by diaphragm wall on four sides and braced by five layers of 1.2 m diameter steel tubes at the corners (photo 54). A 4 m thick RC raft was constructed on the formation surface at about -28 mPD (photo 55), on which a circular-shaped central core and a spiral

Photo 52a: Elevation of the podium exterior with a series of glass hoods as spectacular roof features

Photo 53: 42 m X 42 m cofferdam formed on the western part of the site for the construction of a vehicular ramp as access into the carpark in the future basement

Photo 54: Ground support with waling beams and a corner bracing arrangement to facilitate excavation to form the 32 m deep cofferdam pit

Photo 55: Fixing the reinforcing bars to form the foundation raft inside the cofferdam. This foundation will support the vehicular ramp as well as part of the superstructure of the future hotel in the IFC Phase 2 development ramp were constructed (photos 56 & 57). This ramp also served as the vehicular outlet through which excavated spoil could be removed using dump trucks during the basement excavation and construction process.

Overall observations

The construction of such a super high-rise project presents a range of practical problems beyond the layman's imagination. For example, at the peak of the construction period, there were more than 1,200 workers from 50 different trades working at the same time on the site. Daily consumption and delivery of materials to the site could be as much as 300 tons per day, with cash flow close to $100 million per month. Some very heavy items, such as components of the outrigger system, were as heavy as 15 tons (there were more than 40 pieces in total, photo 58) and were required to be hoisted to 55/F. There are altogether more than 50,000 structural steel members making up the entire superstructure — a very demanding figure where cranage output is concerned.

The successful running of a project of this scale is a true challenge to the contractor in terms of engineering, construction, safety and overall management. The accomplishment of Two IFC is a masterpiece that sets a milestone showcasing the overall achievement of the Hong Kong's construction industry.

Photo 56: A panoramic view inside the circular ramp during the construction process

Photo 58: Heavy steel components waiting on the ground before hoisting to work spots at high levels of the tower

Photo 57: A detailed look at the gang-form system for the construction of the circular core and the steel bar fixings before the concreting of the ramp

General Information

Components	88-storey Two IFC Twin tower hotel and suite hotel Retail bridges Shopping mall
Companies Involved	<u>Developer</u> The developer is Central Waterfront Property Project Management Co Ltd (CWPPM). It is a joint-venture between Sun Hung Kai Properties Ltd, Henderson Land Development Co Ltd, Hong Kong & China Gas Co Ltd, Bank of China Group Investment Ltd and Mass Transit Railway Corporation (MTRC). <u>Architects</u> The design architect is Cesar Pelli & Associates Architects. The associate architects are Rocco Design Ltd and HBA/Hirsch Bedner Associates. The landscape architect is Urbis Ltd. <u>Structural Engineer</u> Ove Arup & Partners <u>Quantity Surveyor</u> Levett & Bailey Chartered Quantity Surveyors Ltd <u>Facade Engineer</u> Arup Facade Engineering <u>Contractor</u> E Man-Sanfield JV Construction Co Ltd