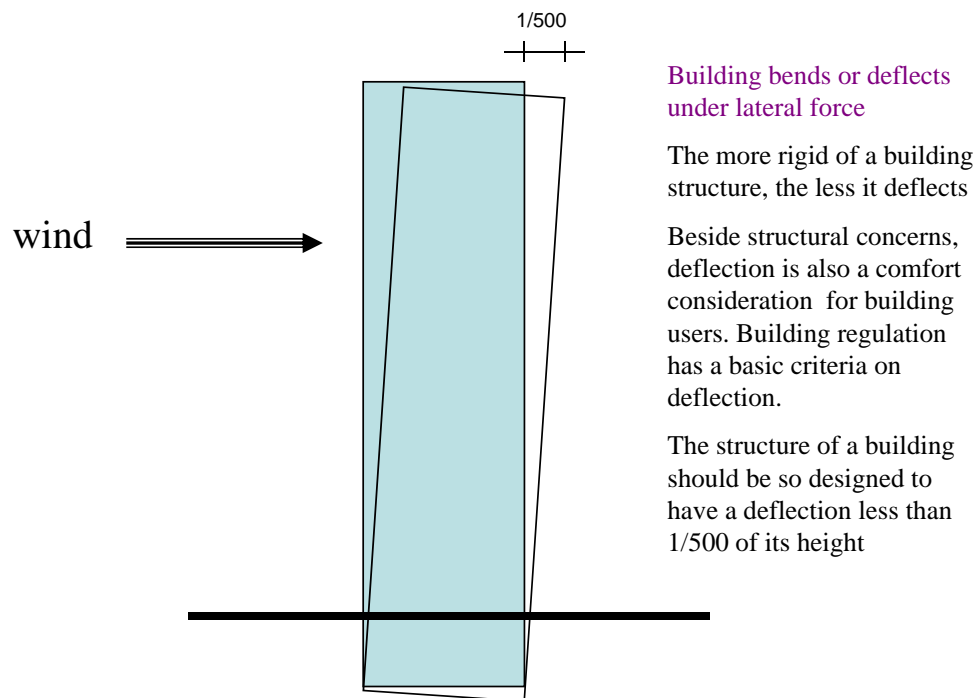


# Experience of Hong Kong in the Construction of Super High-Rise Structures

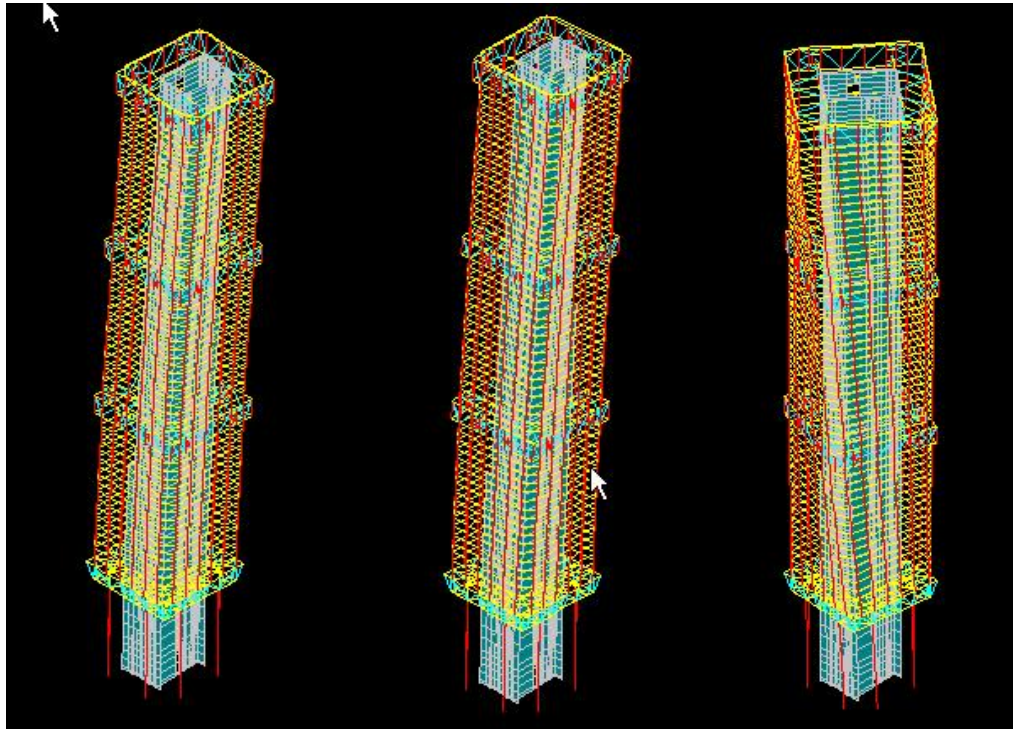
Presented by Raymond Wong

City University of Hong Kong

February 2013



The main challenge for super high-rise slim buildings



Various deflection modes under wind tunnel test  
(Cheung Kong Centre)

To achieve these requirements, super high-rise structure should have the following strengthening designs in common:

1. Provision of lateral stiffening members to make the structure more rigid to take up wind load. These members can be in the form of outrigger, bracing members, belt truss, vertical truss, tensioned members etc.
2. Provision to accommodate some differential deflections/shortening between different structural materials (RC and structural steel for hybrid structures)



Manulift Tower, 1994 - 1997



Office Tower of Langham Place  
1999 - 2004



Nina Plaza 2004 - 2008

Construction of  
the Cheung Kong Centre

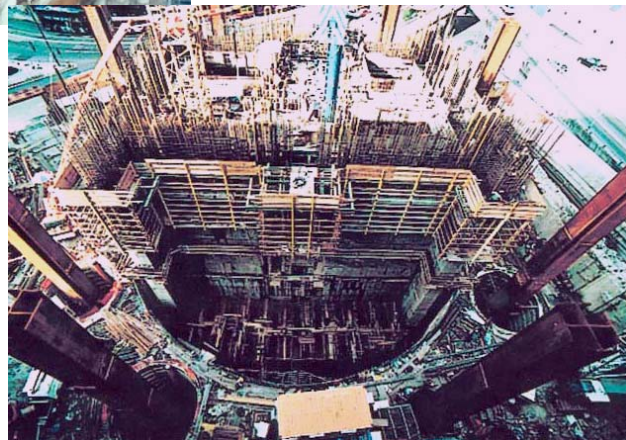


Rising of the main structure





Forming the RC core wall using a set of self-climbing formwork operated by screw jacks (Jump Form)





Construction of the transfer truss



Detail of the transfer truss



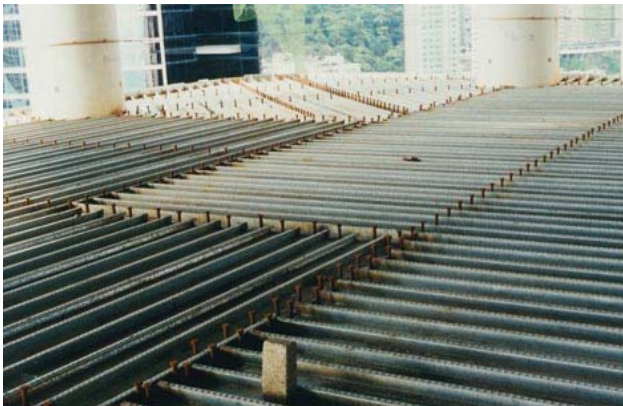


Composite column in the form of reinforced concrete filled tube





Connecting the steel joist to the core wall



The RC topping forming the floor slab

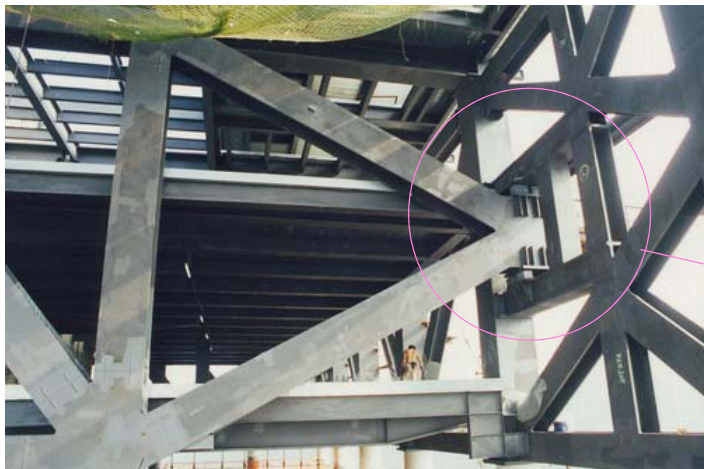


Outrigger/belt truss as a stiffening provision in the building design





The adjusting device to cater for the differential shortening of the external frame using shim plate and hydraulic lifting action



Close up view of the shimming device





The set of outrigger/belt truss located on the roof level

Construction of the  
International Finance Centre

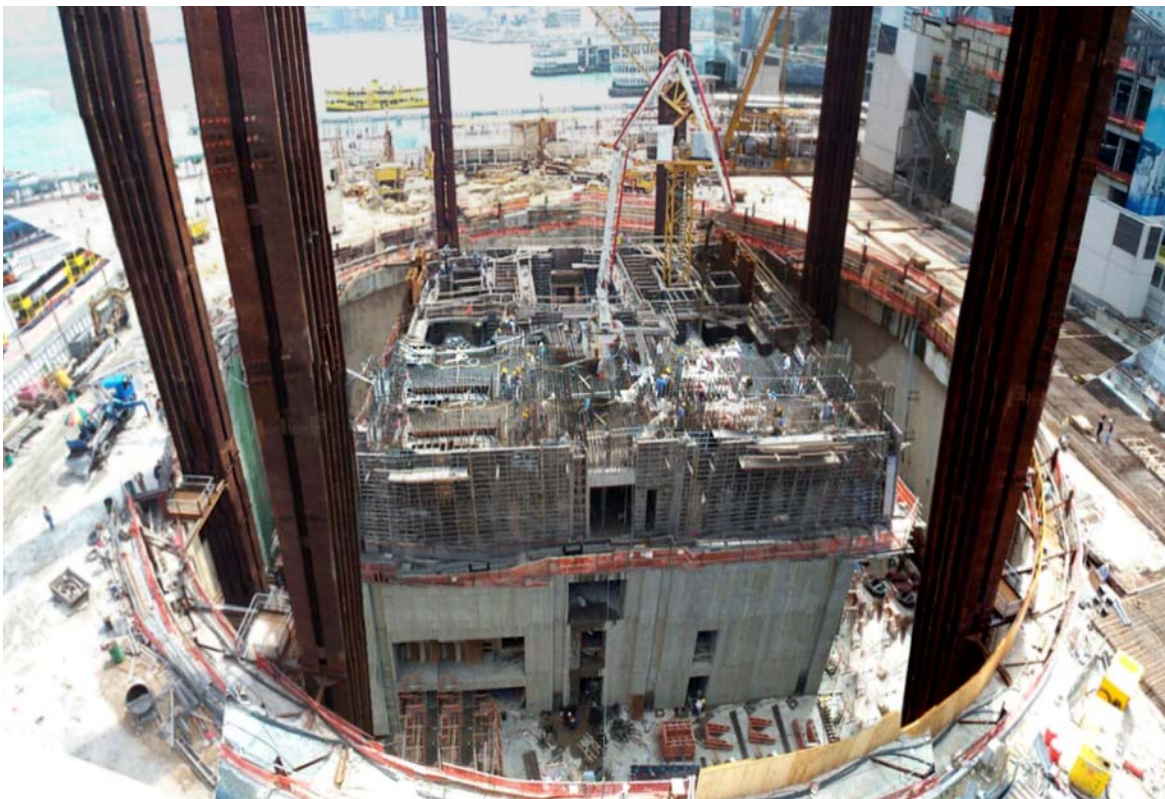
a) Construction of the core wall within  
the 62m cofferdam



Construction of the core wall inside the cofferdam as seen in July 2000



Construction of the core wall inside the cofferdam as seen in August 2000



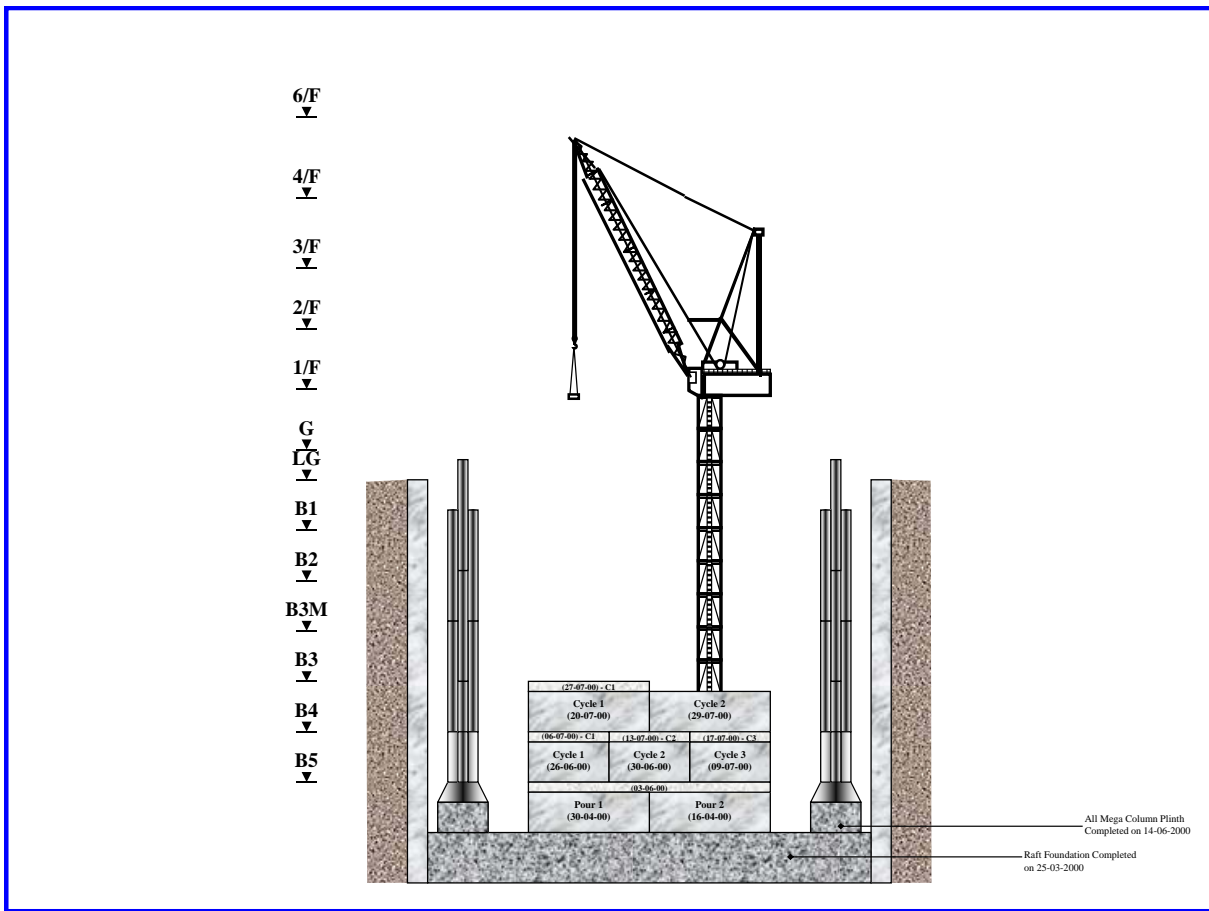
Construction of the core wall inside the cofferdam as seen in October 2000



Forming the slab around  
the core wall inside the  
cofferdam shaft



## b) The mega columns



The plinth and the base plate for the mega column



Erection of the column  
from the base

c) Using the Climb Form to construct  
the core wall



Erecting the Climb Form from the Ground level as seen in February 2001



Operation of the Climb Form  
from the Ground level to the  
1/F as seen in March 2001





Formwork detail as seen from  
an elevated position



General Formwork layout showing the various shaft positions



Formwork operation detail as  
seen on the deck



Formwork operation detail – the external  
and internal jack systems



Inside structure inside the core wall to be formed using in-situ method by the using of timber form and aluminium form



Detail formwork arrangement to form the interior wall and slab inside the core wall



d) Construction of the outrigger system on 6-7/F





Detail of the completed outrigger system on 6/F and the building frame on top

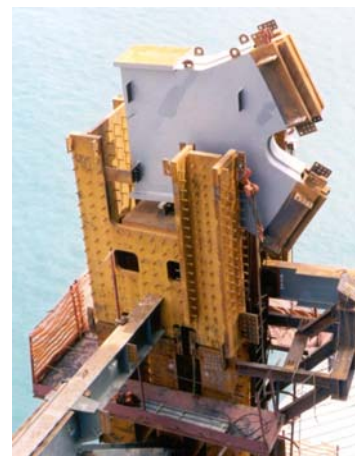


e) Construction of the outrigger system on 32/F

Junction detail of the column head and the outrigger bearing-support

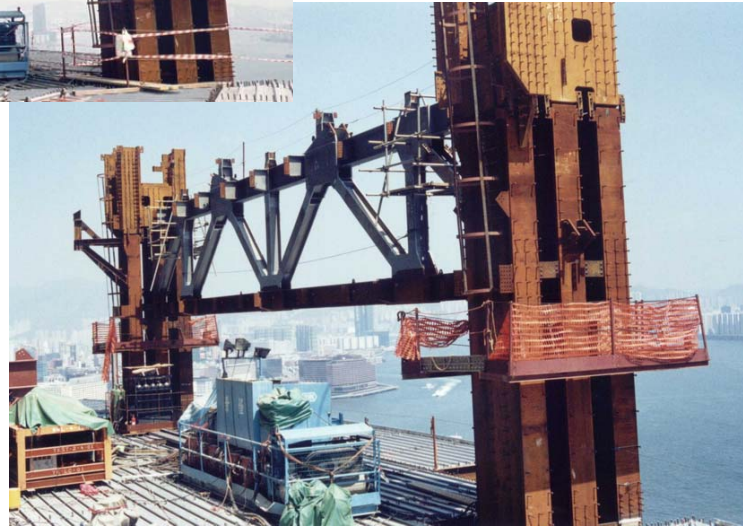


Deck on 32/F before the erection of the outrigger





Gradual extending of the belt truss and outrigger



Column head junction with the bearing-support in position



The anchor framing  
embedded into the  
core wall



Gradual completion of the outrigger systems



Anchor frame before embedding with outer layer of reinforced concrete



Embedment of the anchor frame concrete on the core wall soon to complete

The completed outrigger and belt truss system on 32/F



The bearing support of the outrigger and the column articulation detail

## f) Construction of the building frame



Erection of the floor beams  
to form the building frame





Forming the composite slab

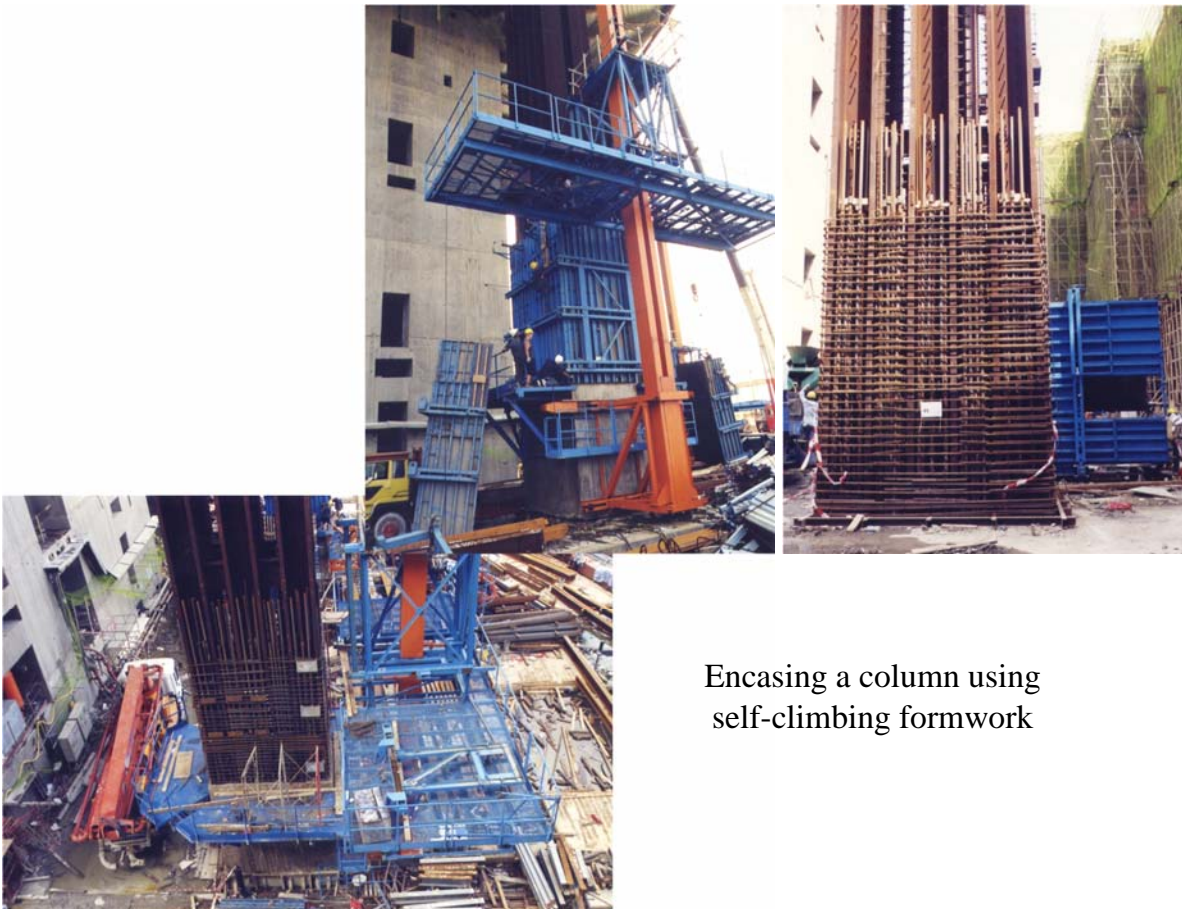
Connecting shear  
stud to the floor  
beams to provide  
bonding between  
beams and RC slab



g) Forming the Mega Columns using  
the Climb Form



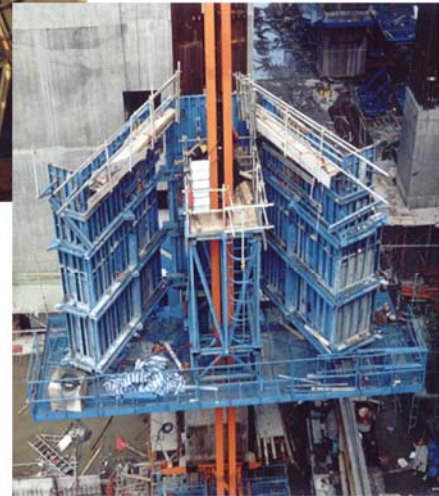
Junction detail of the mega column and the slab



Encasing a column using self-climbing formwork



Erection of the Climb Form specially designed for the forming of the composite column



The column form in a closed position





Operati The column form in an opened  
for the position ready for lifting PC2

## A Construction Highlight for the International Commerce Centre at Kowloon Station, West Kowloon

### **Construction features of the ICC Tower**

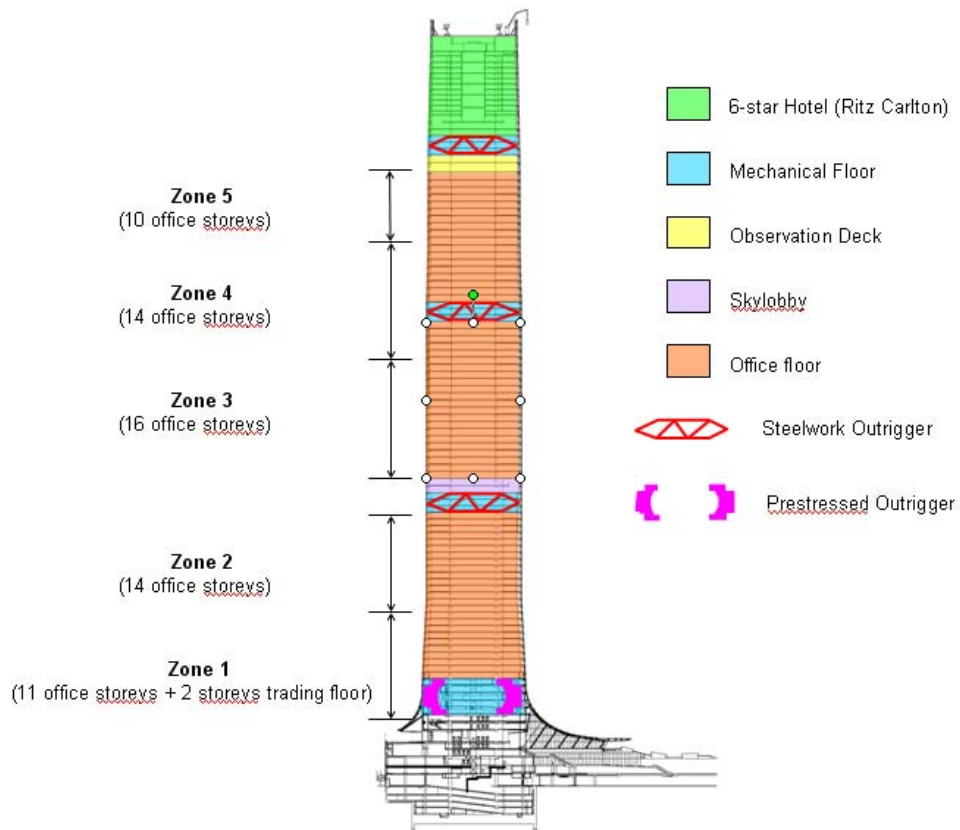
Height of tower structure – 490m  
Average floor plate area – 3000m<sup>2</sup>  
Total floor area – 280,000 m<sup>2</sup>

#### **Key dates**

Procession of site – June 2003  
Obtaining of Temporary Occupation Permit – December 2007  
Expected Full Occupation – February 2010  
Opening of the hotel – end of 2010

#### **Use of floor spaces** (floor number is for reference only)

Office spaces from 8/F to 98/F.  
Hotel apartment from 101/F to roof, total 14 floors.  
Sky Lobby and Observation Deck located on 43/F and 99/F  
respectively.  
Outrigger spaces are used as mechanical floors.



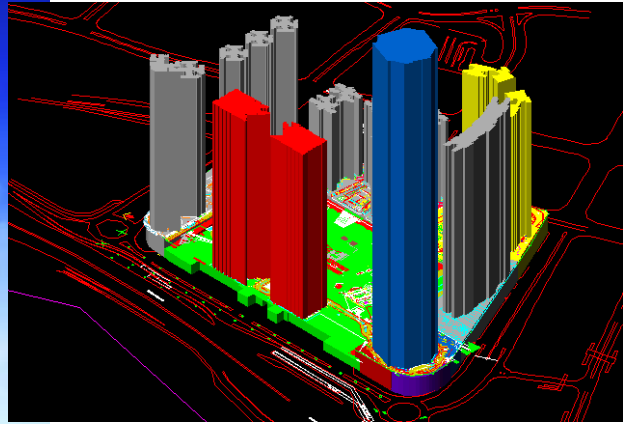
### Construction/structural features

- A 76m diameter cofferdam lined with 1.5m-thick diaphragm wall panels was formed to facilitate the construction of the 9m-deep foundation raft and core wall structure of tower using bottom up arrangement.
- Basement in 2 levels is constructed using semi bottom-up arrangement due to limited space and the existence of the MTR tunnel tube crossing within 6m on the side of the tower foot-print.
- Grade 90 concrete is used up to 60/F. The other portion of tower structure uses mainly Grade 45 and Grade 60 concrete.
- Four sets of outrigger are provided at 6/F, 42/F, 78/F and 100/F. Except for the one on 6/F which is constructed in in-situ prestressed design, the upper ones are in fabricated structural steel with an inner frame embedded in the core wall.

- Two sets of jump-form were used (in stepped operating mode) for the construction of the core wall from 2/F up to 100/F with some dimension re-alignment at a few floor locations with the outrigger frame or where thickness of core wall reduced.
- Connecting joint between the outrigger and mega column is provided with design to cater for the differential deflection similar to the IFC2 project.
- General composite frame structure is used for the tower up to 100/F, with the central core, an external steel frame rested onto 8 mega columns which span about 16m.
- Hotel floors from 101/F upward are constructed in in-situ method using Grade 60 reinforced concrete and traditional large panel form, with a transfer structure at 101/F.
- Total amount of structural material consumed:  
Concrete 240,000 m<sup>3</sup>, Reinforcing bar 98,000 tons,  
Structural steel 27,000 tons

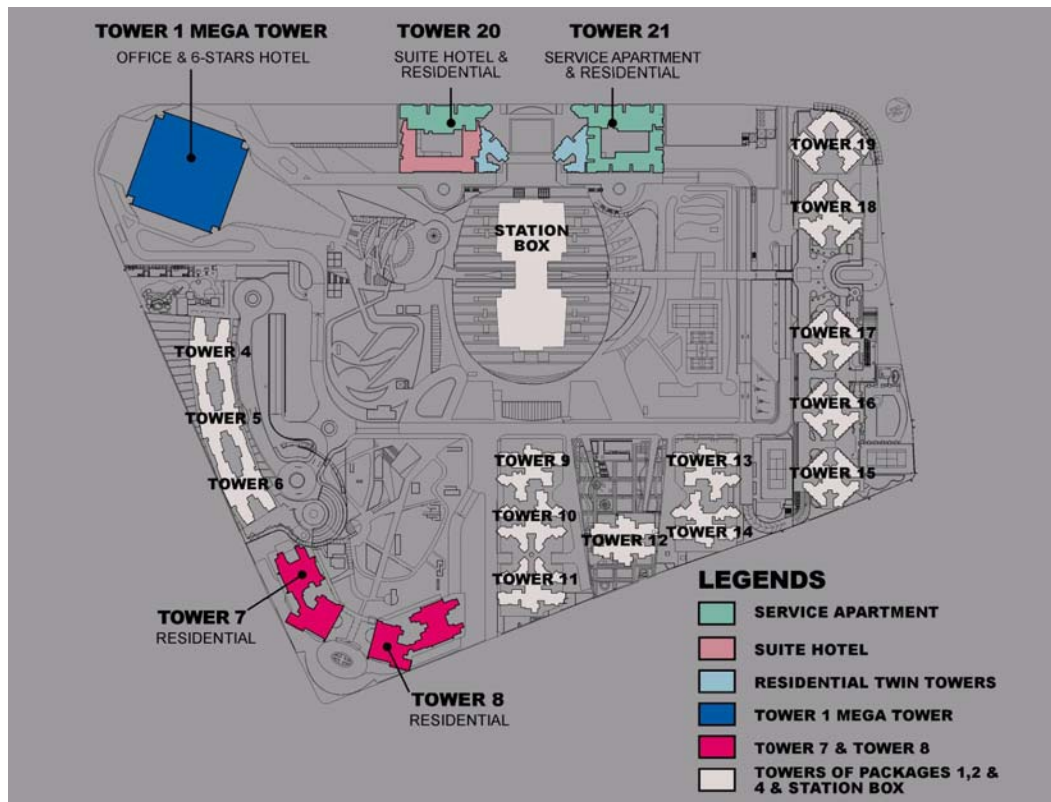
Artistic view of the ICC tower and the Kowloon Station Development as seen from Hong Kong side





Artistic view of the ICC tower and the Kowloon Station Development as seen from Hong Kong side





Master Plan for the MTR Kowloon Station Development



Photo 1



Photo 2

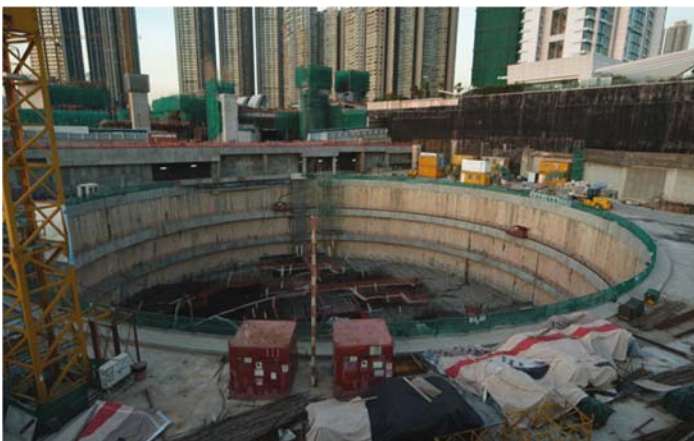
Early stage of work as seen in 2002 showing the layout of site and the facilities that equipped for the forming of diaphragm wall panels which would be used as the lining of the 76m cofferdam



Standard equipments for the construction of diaphragm wall as seen on site, including the desanding plant (above) for the removal of excavated spoil through the circulating bentonite slurry and the reverse circulation trench cutting



Commencement of excavation for the 76m-diameter cofferdam as seen in late 2003



Completion of the foundation raft up to the third layer. The total depth of the raft is 9m. The concreting process is arranged to be placed in 5 layers as a means to control temperature generated from concrete as well as to ease the handling of large amount of concrete during work.

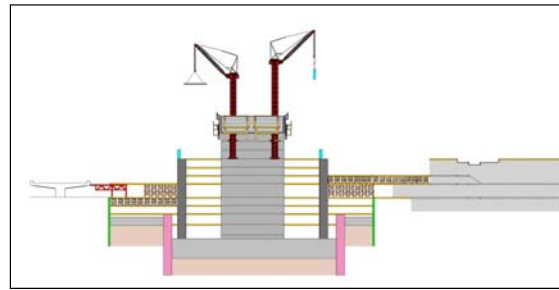


Excavation of the cofferdam down to the formation at about -20mpd



Casting the 9m deep foundation raft in various portion  
(total in 18 pour and concrete volume 36,286m<sup>3</sup>)

Building section showing the construction arrangement from the foundation raft up to the first outrigger set on 6/F.



Core wall and the mega columns constructed within the cofferdam close to the ground level. Usual large-panel steel form was used up to 4/F before the erection of the jump form.



Construction of the floor system from ground to 1/F spanning from the core wall to the mega columns using traditional timber panel formwork.



Commencement of excavation on the side of the cofferdam to form the remaining portion of basement structure



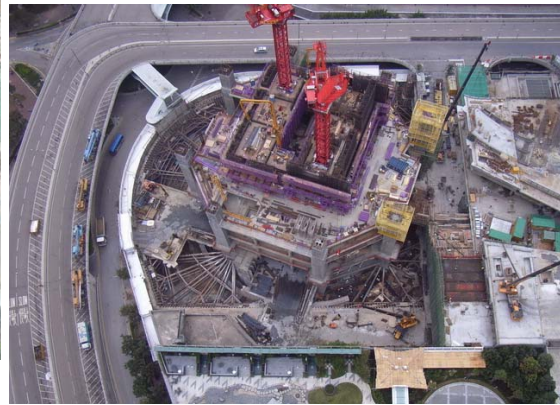
Main building structure constructed up to 4/F. The jump form was erected on the 2/F for the onward construction of the core wall.



Main building structure as seen in February 2006 with the jump form for the core wall and the climb form for the mega columns in full operation.

Overview seeing the construction of the basement using typical bottom-up arrangement with shoring support counter-act onto the completed main tower structure. The diaphragm wall panel as side to the previous cofferdam was demolished as the excavation proceeds.

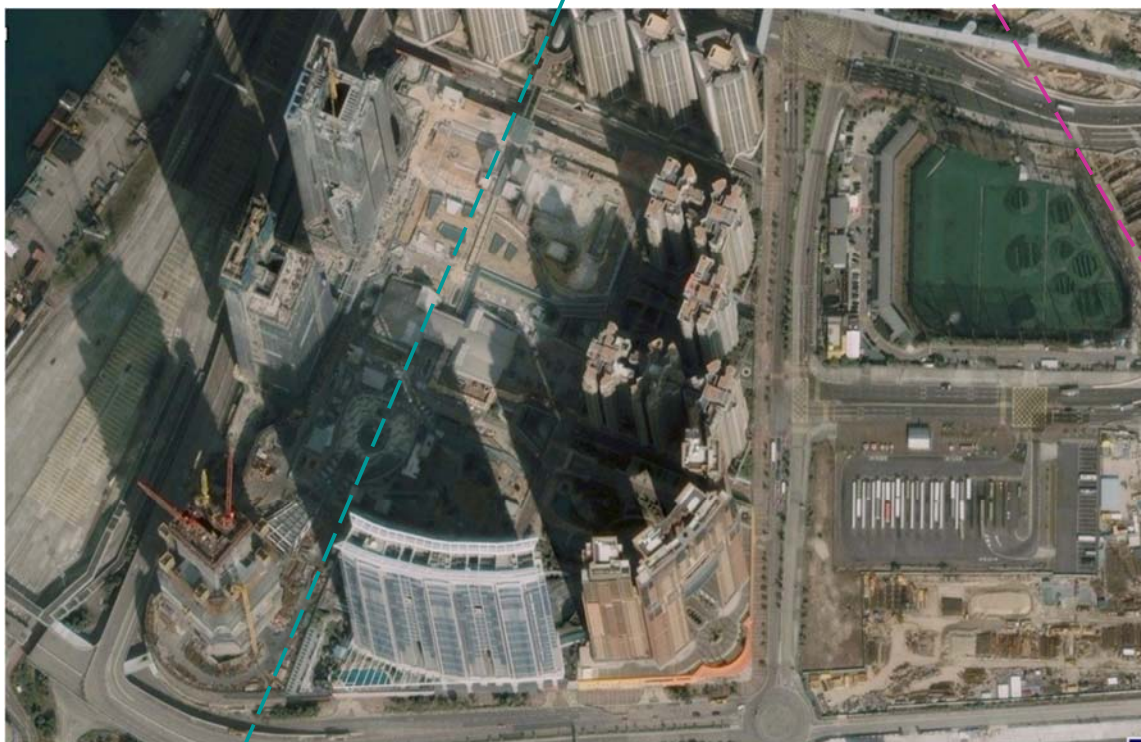




Construction of the tower before entered onto the typical cycle. By the time the jump form for the core wall was being erected and the basement construction on the side commenced.



The core wall and mega columns of the main tower structure ascending from the cofferdam. The tunnel tube of the MTR Tung Chung Line is located on the strip of land on the lower side of the cofferdam.



Tunnel tube of existing MTR Tung Chung Line and Airport Express

Tunnel tube of future Kowloon Southern Link (2009)

Aerial view of the Kowloon Station Development and the nearby facilities



Close up of the gigantic jump-form system for the core wall construction

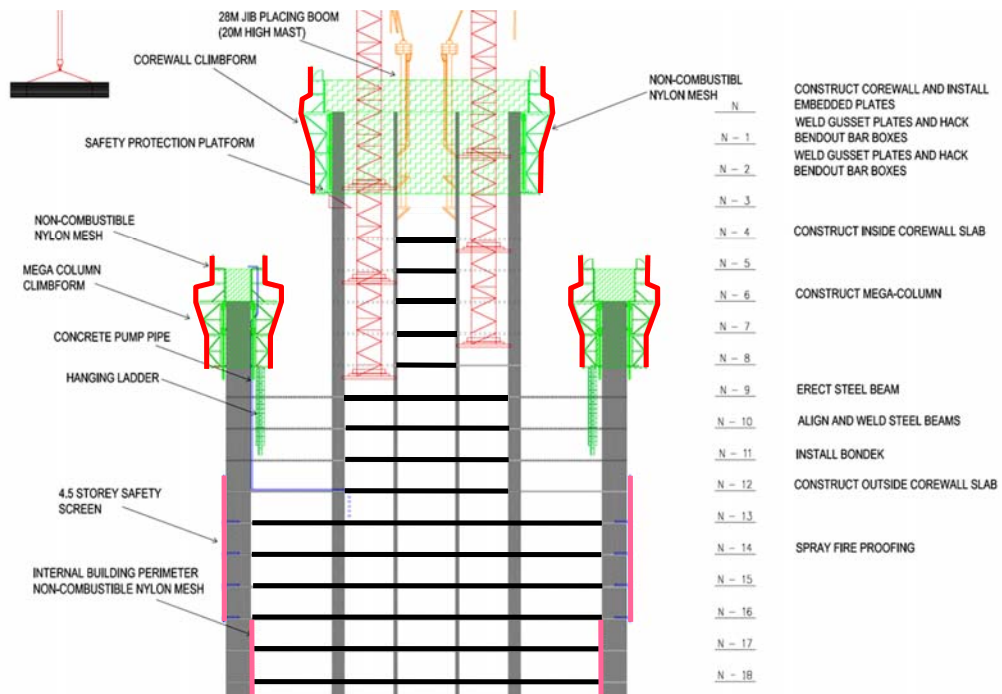


Overview of the tower structure with the jump-form for the core wall, climb-form for the mega columns and a set of lift-form for an appended wall (the finger wall, at the right side of core, orange in colour) in operating position.



Close up of the lower portion of the main tower with the structural layout and floor system clearly seen.

## Typical Construction Sequence and safety provisions



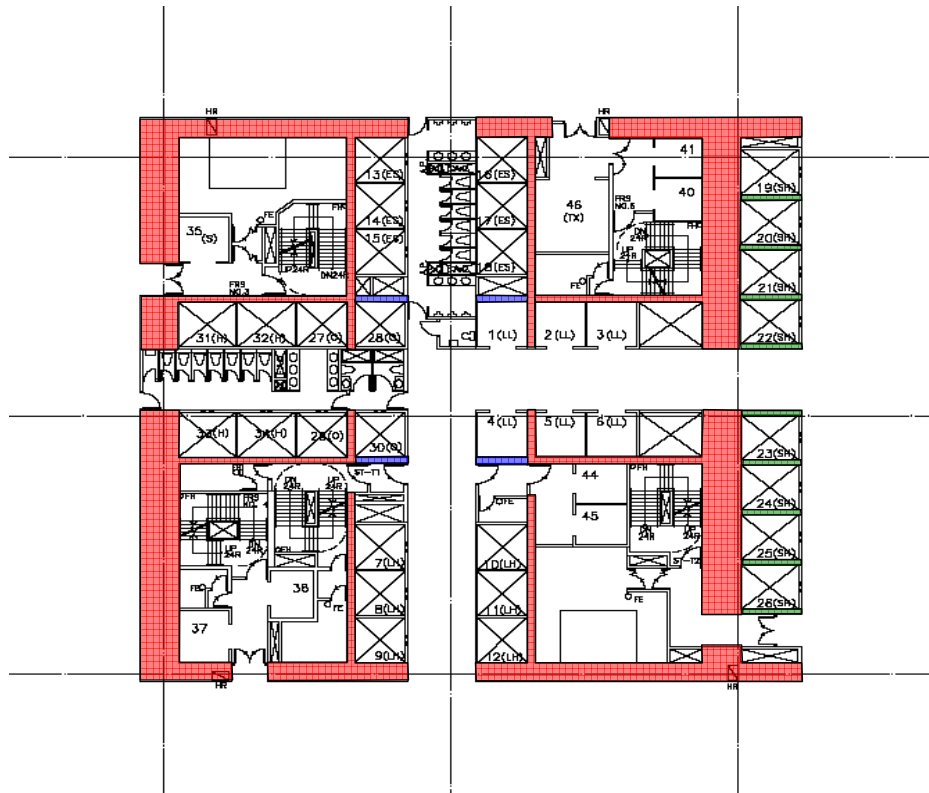
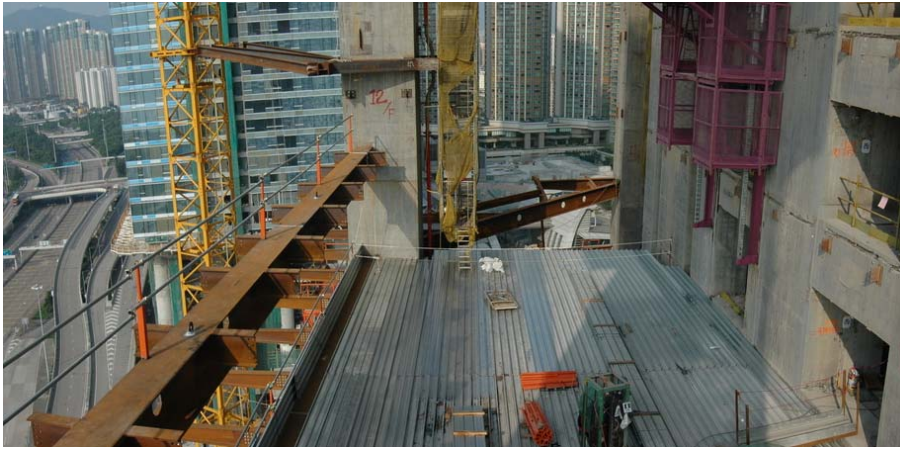


Figure 3 – Typical layout of core wall



Close up of the core wall structure with a set of self-climbing loading platform being erected for the lifting of materials and equipments.



Typical view of floor deck spanning between the core wall and the external frame before concreting

Typical floor layout detail at the building corner on 15/F.  
The set-up of climb-form for a mega column can also be observed.





Installing the climb-form for the mega column as seen from the side . The steel shutter panel was not fixed onto the main frame of form at this stage.



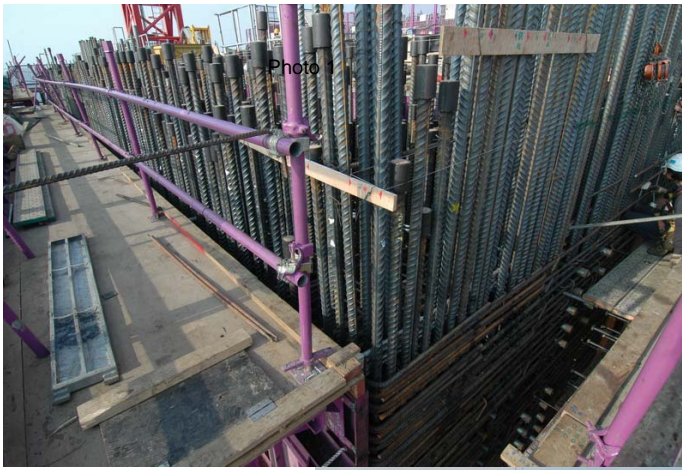
Setting-up of the climb-form mounted on top of the mega column with the enclosing safe screen and work platform already in place.

Two sets of climb-form in szconized operating phase.



Reinforcing bar of the mega column being fixed with lapping coupler as seen on the work platform ready for concreting.





Reinforcement detail for the core wall (measured 38m x 38m), as seen on the work platform. In order to reduce the thickness of wall, Grade 90 high strength concrete was used for the core wall and the mega columns from the basement up to 60/F.

General view of the jump-form for the core wall as seen on the platform deck. Due to the large size of the core wall, two separated sets of jump-form were installed and operated in stepped sequence to make each lifting more easy to handle.

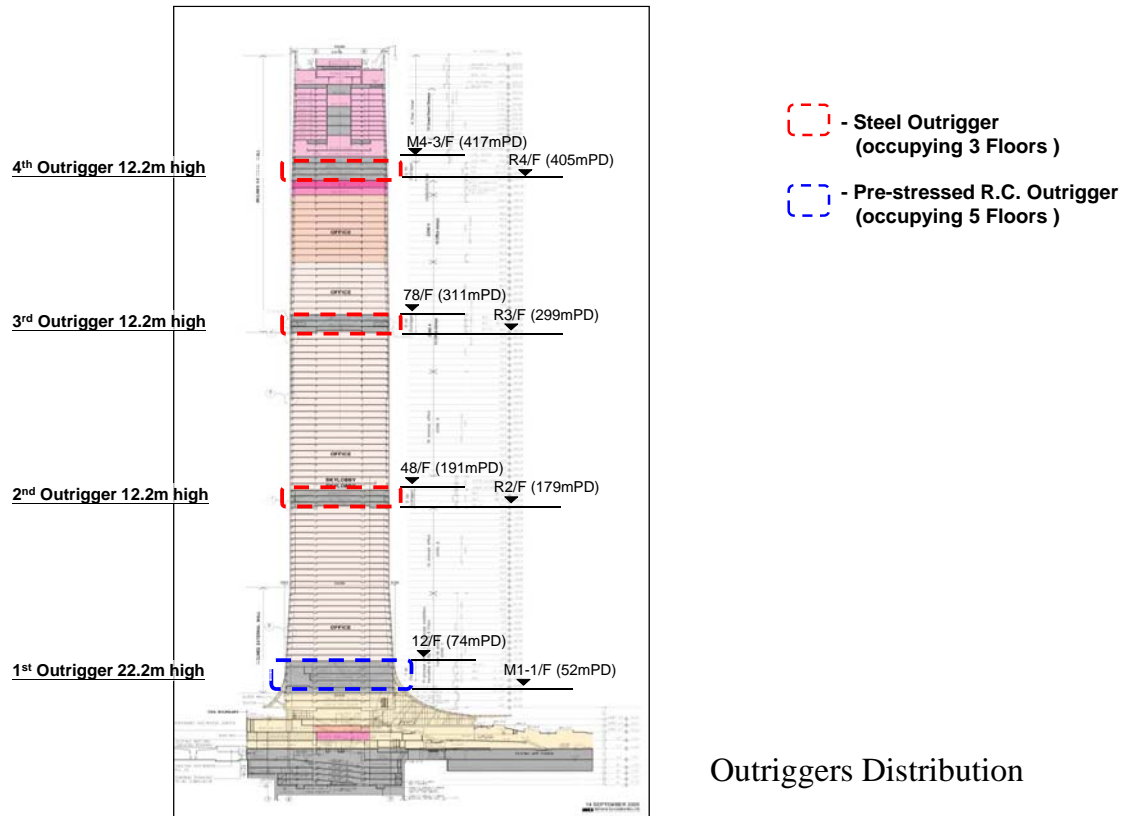


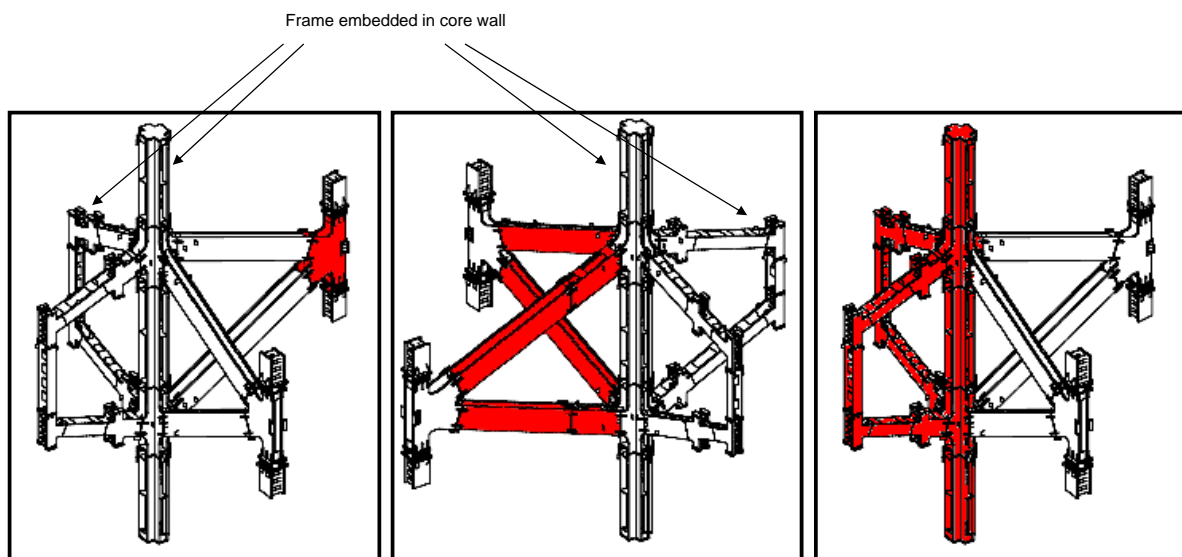
The jump form for the construction of the core wall in two operating phases. Note also the set of lift-form (orange in colour) on the right side of core wall for the construction of the finger wall.



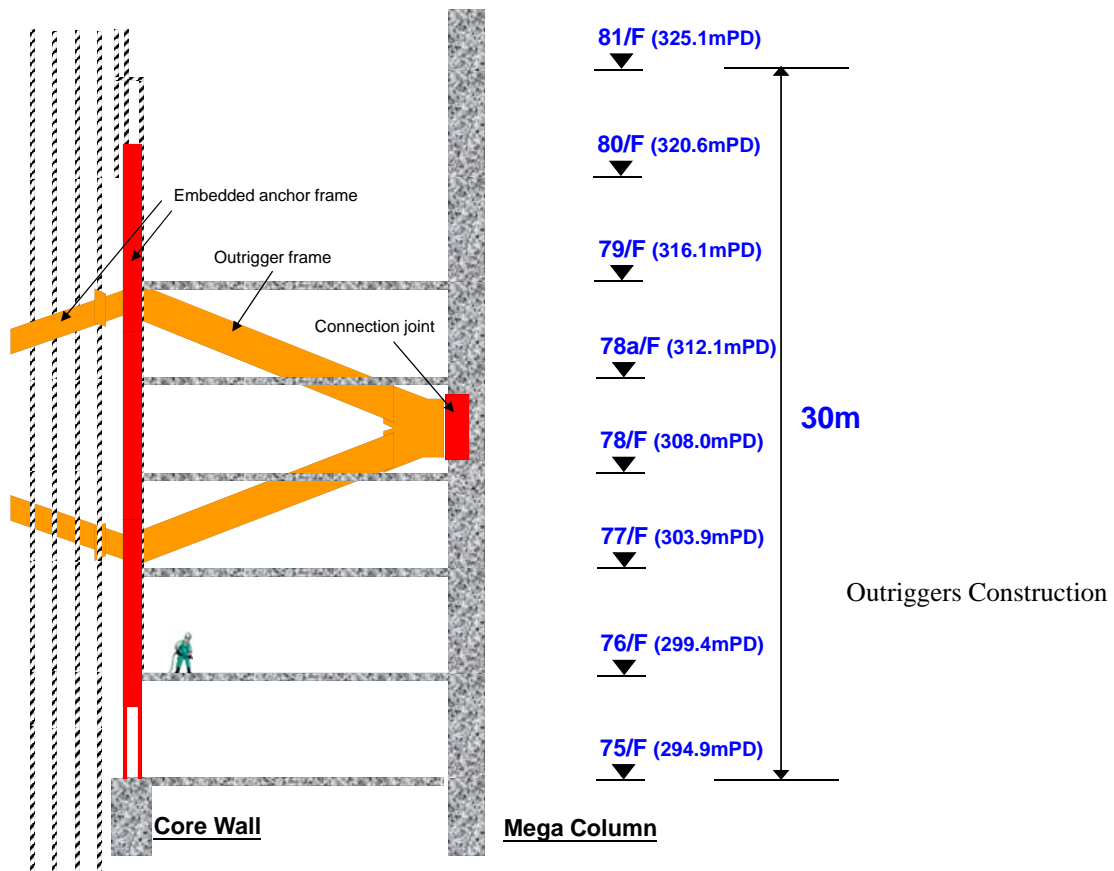


lift-form (orange in colour) used for the construction of the finger wall appended to the core wall.





composition of a set of typical Outrigger





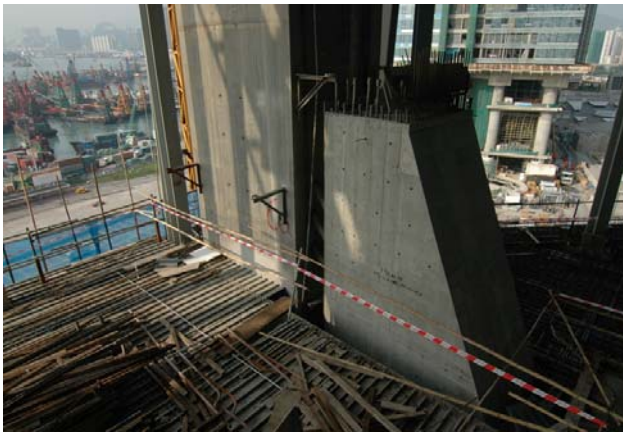
Anchor frame to be embedded in the core wall for the tightening of the outrigger member



installing the jointing member (K-knot) of the outrigger onto the slot provided in the mega column.



outrigger member in initial connected position before final adjustment and welding.



Unlike other outrigger system used to stiffen the structural frame for highrise tower, ICC employed a set of cast-in-situ RC outrigger system,, tensioned in various stages. This design was employed to gain time in the planning and fabrication of the structural members. Photo 29a shows a set of anchor block on the side of the mega column. Photo 29b is another set situated inside the core wall.



External view of the tower as seen in October 2006 showing all the major structural parts of the tower were under construction at its typical cycle. This included the core wall structure, the finger wall (wall appended to the core wall up to 50/F, the mega columns and the floor deck). Note also the spacious entrance canopy with about 25m headroom on the lower right corner of photo.



Gradual progress of the tower structure as seen in early to mid 2007 with the installation of curtain wall for the lower floors which scheduled for the obtaining of the temporary operation permit by November 2007.



External view of the ICC Tower from the roof of Sorrento in September 2007, January and April 2008.