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

Presented by Raymond Wong
City University of Hong Kong
February 2013

Building bends or deflects under lateral force

The more rigid of a building structure, the less it deflects

Beside structural concerns, deflection is also a comfort consideration for building users. Building regulation has a basic criteria on deflection.

The structure of a building should be so designed to have a deflection less than 1/500 of its height

The main challenge for super high-rise slim buildings
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
Raft Foundation Completed on 25-03-2000
All Mega Column Plinth Completed on 14-06-2000

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

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
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
Operation of the self-climbing form for the composite column in IFC2.

The column form in an opened position ready for lifting.
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 – 3000m²
Total floor area – 280,000 m²

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 m³, 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.
Master Plan for the MTR Kowloon Station Development

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 36,286m3)
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.

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

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.

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

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.

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

Two sets of climb-form in synchronized operating phase.
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.

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.

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.

Outriggers Distribution

- Steel Outrigger (occupying 3 Floors )
- Pre-stressed R.C. Outrigger (occupying 5 Floors )
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.