Application of Formwork for High-rise and Complex Building Structures – the Hong Kong Cases

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1. Introduction

• Formwork system is the key factor determining the success of a construction project in terms of:
  - speed
  - quality
  - cost
  - safety of works
2. Classification of Formwork

- Sizes
- Location of use
- Materials of construction
- Nature of operation
- Brand name of the products.
2.1 Classification according to sizes

small-sized formwork

- operation by workers manually
- timber and aluminium

large-sized formwork

- crane facilities are required in the operation
- reduce the number of jointing and to minimize the number of lift.
- stiffening components - studs and soldier.
2.2 Classification according to location of use

- Different elements in the structure have different design and performance requirements in the use of formwork.

- Some systems are more adaptive for specific location of use, such as
  - Irregular frame structure – traditional timber form or aluminium form
  - Cross Wall – gang form, climb form or jump form
  - Floor – table form
  - Repeated regular section – tunnel form
Aluminium formwork system for residential housing block

Timber formwork for irregular-grid podium structure
Steel panel form (Gang form) for constructing a core wall

Table form for the flat slab structure
Gantry form/tunnel form system for the construction of station facilities
Jump form system used in public housing project

Climb form in the construction of the 50-storey Manulife Tower
2.3 Classification according to materials of construction

- Timber  - most popular formwork material
- low initial cost
- high adaptability to complicated shape
- labour intensive and environmental unfriendly

- steel  - hot-rolled or cold-formed sections
- heavy weight
- suitable for large-sized panels

- Aluminium  - stiff and light weight
- higher material and labour cost
- excellent finish
Detail of wall formwork using manual operable timber panels

The Festival Walk, a super-sized shopping mall constructed in traditional timber formwork system
Examples of steel form in the form of large panel shutters
Detail of a typical aluminium formwork system for apartment-type building
2.4 Classification according to nature of operation

- Manually operated formwork
- Self-lifted formwork
- Crane-lifted formwork
- Gantry, traveling and tunnel type formwork system
Climb form operated by the use of a series of synchronized hydraulic jack systems
Jump form for the construction of a high-rise residential tower – lifting action is done by a series of screw jack systems
• Construction of the 600m-long elevated expressway for the Lantau Link using a type of traveling gantry form

• Structure of the Shui Hong Station of the West Rail projects
2.5 Classification according to brand name of the product

Some common names in the market

- RMD
- PERI
- SGB
- Thyssen
- VSL
- MiVan
3. Considerations when using formwork

3.1 Design related considerations

- shape of the building
- Architectural features on building exterior
- Internal layout
- Structural form
- Consistence in building dimensions
- Span and Headroom
- Repetitive nature
- Finishing standard
3. Considerations when using formwork

3.2 Construction related considerations

- Complexity of the built environment
- Speed of work
- No. of possible reuses
- Construction planning and arrangement
- Area or volume of cast per pour
- Involvement of other construction technique
- Dependence of work
- Provision of construction joint
- Accessibility to work
- Feasibility of introducing alternative design
Examples of some crucial built situations

very large site

Sloped site

very crowded site
Phasing arrangement to be considered
Examples where special techniques are involved in the construction

Incorporation of precast elements

Incorporation of tensioning and complicated phasing arrangement
Examples where complicated construction jointing requirement are involved
Accessibility problems in formwork process
Accessibility problems in formwork process– more examples
4 Examples of Application

4.1 Festival Walk – using traditional manual-type timber formwork

- 21,000 sq m site.
- 4-level basement and 7-level upper structure.

Features:
- A 48m-span void constructed of 8 numbers of cast-in-situ and post-tensioned beams, supported on the sides by bearers.
• large span structures up to 32m in length, cast-in-situ, some are post-tensioned.

• 3 atrium spaces, averaged 35m in span, and with 25m headroom

• Average headroom for each floor is about 4.5m.
• Basement -- top-down approach.

• non-repeated layout

• structure subdivided into 6 main phases.

• great number of construction jointing
Other complication/features of the formwork system as shown in the project.

Using the ground surface as formwork soffit.

Formwork forming the shape of the drop panel of the flat slab using blinding concrete.
Other complication/features of the formwork system

Provision of complicated construction jointing in the formwork
4.2 Belcher’s Garden – using traditional manual-type timber form

• situates on sloped site with area around 24,000 sq m.

• level difference about 65m.
Forming the sloped beams on the formed slope
Construction of the podium structure
Other features:

- 10-level podium, used as carpark, shopping mall and recreational facilities
- Six 48-storey residential towers built on top of podium
- Huge size of podium and sophisticated typographic environment of site, demands complicated phasing and sectioning arrangements
Falsework to support the transfer plate
Detail of transfer plate before concreting
Superstructure

- irregularity in layout
- complicated architectural features in external envelops
- large amount of short-span slabs
- large amount of shear walls in the structure
- use of manually operated timber panel forms
Detail of the floor form layout from an elevated position
Detail of the wall formwork
Detail of wall and floor formwork arrangement as seen from the floor interior
4.3 Lee Garden Hotel Redevelopment – Climb form for core, composite slab and structural steel outer frame

- 50-storey office building
- Inner core constructed in reinforced concrete
- Outer frame in structural steel
- RC core constructed using the VSL climb form -- self-lifting formwork system using hydraulic jacks
Assembling of the climb form on the ground slab level
The climb form at its trial operation
Details of the Climb-form system

Gantry frame, shutters, rail tracks, and scaffold detail
More detail on the rail track for the panel shutters
Detail of the guide wheel and locking pin
Resizing the form where the section of the core wall changed
4.4 Cheung Kong Center –

• 62-storey office building

• Jump form system for core

• Composite slab and concrete-filled steel tube as the outer frame
Layout of the Jump Form rising from the foundation raft
Overall layout arrangement of the Jump Form as seen from an elevated position
Formwork arrangement as viewed from the side

Screw jack detail
The gantry frame that mounted the panel shutters rigidly within the core wall layout
Steel fixing inside the form
Detail seeing the arrangement of the formwork system with the panel shutters in position.
Form system as seen from the inner shaft
4.5 Gateway – Climb form for core and table form for slab

- 3 detached building towers each of 38-storey high
- Structure of towers –
  - Central core with averaged 12m span RC columns around
  - Post-tensioned flat slab system,
  - Core wall - VSL climb form, partially in large panel gang forms
  - Slab – aluminium strutted flying form system
External view of the climb form for the construction of the core wall

Some sections at the sides of the core wall are formed using large panel shutter
Floor slab as seen from various elevations
Wall section of the core before the enclosing with panel shutters.
Other Features

- slab is cast in two separated sections in a staggered manner with a lapse of 2 to 3 storeys to convenient tensioning works, as well as to obtain better operation arrangement in the handling of the formwork
Flat slab and post-tensioning arrangement
Dropped panel at the column head and detail for slab joining to the core wall
4.6 Harbourfront Landmark
   – Steel panel form for shear walls & table form for slab

• 62-storey residential development with 3 attached towers on a 6,500 sq m site.
• Shear walls to form compartment units, centered with a core structure.
• Walls -- steel form system
• Slabs -- aluminium-strutted flying form system
General detail of the steel form for wall
Detail of large panel wall formwork
The rear elevation with ellipse-shaped core wall serving as kitchen and store room
The rear section with slab constructed using manual timber formwork
- central cores -- constructed in form of vertical shaft.
- inner structures – slab, lift walls & landings are cast-in-situ using timber forms
- stair flights -- prefabricated
Releasing the table form
Placing the table form
Forming the inner walls and stair landing within the core shaft
4.7 Park Avenue – Aluminium form

• four 46-storey high residential towers on transfer plate
• aluminium formwork - MIVAN system
• structure consist of a large number of shear wall
Mock up of the Aluminium Form before installation in full scale
General detail of the aluminium form – walls and beams
General detail of the aluminium form – walls and beams
General detail of the aluminium form – walls and beams
General detail of the aluminium form – wall (view from interior)
General detail of the aluminium form – Floor
General detail of the aluminium form – stair
General detail of the aluminium form – stair
General detail of the aluminium form – Plant box and external features
General detail of the aluminium form – Plant box and external features
General detail of the aluminium form – Plant box and external features
Close up detail
Close up detail
Close up detail
Problems encountered in the using of the Aluminium Form

• Too many formwork accessories that make installation very difficult

• Complicated external wall and spatial design magnify the installation problem

• Inconsistent in the major structural elements require frequent amendment to the formwork

• Resulted to a very long learning curve
Problem of too many insistently sized components
4.8 Nina Plaza

- Climb form for the core wall (3 isolated cores)
- Modified steel table form for floor slab
- Traditional timber form for podium structure
Arrangement of the climb form for one of the building cores
The form in its opened mold

Side view of the form seeing the platform and the jacking rod
Overview of the formwork arrangement for the core and the floor
Floor formed in staggered manner
Propping arrangement and the layout of the table form as seen from the underside
4.9 Some advanced self-climbing systems used in various forms of development - IFCII
Building frame and core wall layout
Formwork at its opened mold
Close up view of the hydraulic jack

Jack for external panels

Jack for inner panels
Operation of the Climb Form (Panels in the inner shaft)
Operation of the Jack System
Setting up of the climb form at the deck level

Deck at the topping out level
Gantry frame, scaffold and Panel shutters as seen in the form interior
Linking the core and the inner wall/slab construction
4.10 Some advanced self-climbing systems used in various forms of development – Residential Development at Repulse Bay

Formwork Features

- A curved apartment-type tower structure of 28-storey high
- 5 stair-core in parabolic-shape elevation, constructed using climb form
- Modified steel table form for the floors
Detail of the staircase core
Junction detail between core and the floor slab
The table form for the casting of floor
The hydraulic jack mounted on the external face for the lifting of the climb-form system.
4.11 Some advanced self-climbing systems used in various forms of development – Residential Development at Stubb Road
External view of the Jump form
The form system as seen on the deck level
Detail of the screw jack and the motor gear
Detail of the shuttering arrangement
Panel shutters inside the form system
Panel shutters inside the form system
4.12 Some advanced self-climbing systems used in various forms of development – Chartered House
Large panel formwork for the ground floor core wall
Modifying the large panel form into the climb form by adding in the gantry frame and jack system
Overview of the climb form
Arrangement between the core wall and the floor
Layout of the core wall and the gantry/jack system within the core wall shaft
Placing a section of the table form onto the floor slab
Material hoist for the lifting of the table form units
The floor slab and the tensioning arrangement
4.13 Some advanced self-climbing systems used in various forms of development – Urban Renewal Authority Mong Kong Redevelopment
Forming the transfer plate and the lower section of core wall using manual timber form.

The lower section of core wall below the transfer plate.
Erection and trial operation of the slip form system
Erection of the slip form on top of the transfer plate
Arrangement for the core wall and floor formwork
Layout/gantry frame arrangement above and below the deck level
Close up detail of the hydraulic jack system
4.14 Some advanced self-climbing systems used in various forms of development – Concord Project in Fanling Wah Ming Estate
Detail of the jump form for constructing the core wall
Detail and layout of the jump form for constructing a typical wing
Close up seeing the operation detail of the jump form and the guide rail for the panel shutters
4.15.1 Formwork Systems used in Civil Jobs – Ma Wan Elevated Expressway
Complicated falsework is required in the forming of the elevated expressway section
Gantry-type traveling formwork for the casting of the repeated expressway section
4.15.2 Formwork Systems used in Civil Jobs – West Rail Sui Hong Station
Setting-up of the gantry form for the construction of the station structure
A suspended soffit supported by hangers from the gantries. The soffit will be used to cast the suspended slab of the station structure.
Detailed view of the gantry system and the suspended station slab
The construction of the station’s superstructure using usual large-panel gang form from the suspended slab.
4.15.3 Formwork Systems used in Civil Jobs – West Rail Depot at Pat Sheung
Traveling form for the casting of the repeated station structure/deck
4.15.4 Formwork Systems used in Civil Jobs – Airport Ground Transportation Centre
Traveling form for the forming of the passenger access linking the Airport Terminal Building and the Ground Transportation Center
Detail of the double-decked passageway – waffle floor for the upper deck
Forming the hollow-section curved roof of the GTC
Gantry supporting the roof soffit that formed the underside of the roof structure
The roof portion above column head that formed using normal soffit panel supported by props
Comparing some formwork cases for circular structures

Circular ramp in Festival Walk
Comparing some formwork cases for circular structures

Circular ramp in IFC-I
Comparing some formwork cases for circular structures

Circular ramp in IFC-II
Comparing some formwork cases for circular structures

Circular ramp in Festival Walk
A spiral-shaped stair
Formwork Collapse Cases – The Festival Walk
Formwork Collapse Cases – a portal beam in the Ma On Shan Station of the KCR East Rail Extension
A portal beam formwork similar to the one collapsed
Formwork Collapse Cases -
Industrial Building in Kwai Fook Rord, Kwai Chung, 1995
Summary

The structural form of the building is one of the critical factors to determine the choice of formwork.

System products contribute much in the success of formwork application.

The choice and arrangement of utilizing formwork is highly depended on individual site/project environment.

More collaboration between client, design teams and contractor can help in the effective use of more advance formwork systems.