SECOND CONSTRUCTION TECHNOLOGY FORUM
CONSTRUCTION FOR SUSTAINABILITY

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Strategic Implementation of Prefabrication and Modular Construction &
Some Experience Sharing of Hong Kong Housing Authority

Joseph Y.W. Mak
Chief Structural Engineer
Hong Kong Housing Authority

Strategic Implementation of Prefabrication & Modular Construction

- Committee on Environment & Technology of CIC forms a working group on the captioned in Dec. 2011.
- The objective is to explore the feasibility of wider application of prefabrication.
- A draft report is being prepared on this subject and some of the findings are extracted for deliberation.

Precast Construction Development in Hong Kong

a) Public Housing Works

- Precast construction has become mandatory since 1997.
- Scope include facades, staircase, partition walls, beams and refuse chutes.
- Recently, scope has been extended to semi-precast slab plus fabric reinforcement, and ground water tanks.
- In near future, scope will further include volumetric bathroom.

Precast Construction Development in Hong Kong (cont'd)

b) Private Sector Buildings

- Private sector developers adopted precast concrete construction around 2002 when the gross floor area (GFA) concession was included.
- Recent measures implemented by the Government, however, control the misuse of GFA concession and the attractiveness of using precast facades might be decreased.
- Some developers are switching from using precast facades to curtain wall. Nonetheless, more use of curtain wall would increase greenhouse gas emission due to thermal insulation.

Drivers for use of Prefabrication

a) Project Schedule

- Prefabrication might not significantly shorten the construction time. In HA construction, 6-days cycle has been an optimum.
- Nonetheless, prefabrication can ascertain the stability of project progress as the construction will not be affected by adverse weather conditions or other site constraints.

Drivers for use of Prefabrication (cont'd)

b) Reduction in Manpower Demand

- Prefabrication can help reduce the demand for manpower since works can be done by specially trained labourers supported with machinery in precast factories
- This can help alleviate the shortage of local skilled labourers, particularly in the trades of formwork and bar bending, and the acute aging of the construction workforce.

Drivers for use of Prefabrication (cont'd)

c) Cost

- Due to less reliance on increasingly scarce skilled labourers, the use of prefabricated components can reduce labour cost.
- Due to the use of standardized precast products, it helps generate economic of scale
- Recycling and reuse of moulds can reduce cost and minimize material waste.

Drivers for use of Prefabrication (cont'd)

d) Quality Assurance

- The use of robust steel moulds and in a well controlled work environment can better guarantee the quality and workmanship of the end products.
- The method of construction, such as casting in windows into façades can resist water penetration and leakage through exterior walls.
- Proper workmanship and least maintenance can much extend the service life of buildings.

Drivers for use of Prefabrication (cont'd)

e) Site Safety

- Reduction in accident rate is attributed to the reducing need for workers to conduct work-at-height activities such as scaffolding works.
- Labourers can be trained and work at precast factories and on ground under an environment of high familiarity.

Drivers for use of Prefabrication (cont'd)

f) Transportation and Storage

- Due to the close proximity between Hong Kong and the Pearl River Region where many precast factories are located, the highly efficient road network can facilitate transportation of precast components.
- Storage area of precast products on site are often minimal because majority of transportation are planned to be just in time and products stacked on detachable truck trailers.

Drivers for use of Prefabrication (cont'd)

g) Government and Industry Support

- After the support of government through GFA concessions over the years, some private developers have realized the benefits on prefabrication and will continue to follow this approach.
- Another effective way to encourage prefabrication is through extra credits given to innovative design/construction method by the industry. HA has been adopting the three envelope system and will extend to more upcoming projects.
- Another positive catalyst is given by the industry under BEAM PLUS assessment to projects using off-site prefabrication.

Prerequisites of Wider Implementation of Prefabrication

a) Design Approach

- Prefabrication is better included in contracts through engineer's design and cleared with BD's submission well before building tender. The design period could be absorbed in the foundation construction period. Contractor's design after building contract award may be critical because lead time has to be allowed for fabricating steel moulds prior to manufacture of precast units.
- Collaboration and freezing of design layout has to be achieved amongst project team to enable engineer's design to proceed.

Prerequisites of Wider Implementation of Prefabrication (cont'd)

b) Buildability Considerations

- Even at the design stage, consideration of tower crane disposition, circulation of trucks/trailers around the perimeter of the footprint, weights of precast components, connections of precast vs precast and precast vs insitu elements all need to be addressed.
- Standardization and/or minimizing the precast types all help ease the manufacture and erection processes.

Prerequisites of Wider Implementation of Prefabrication (cont'd)

c) Quality Assurance

- Since most precast factories are located in Mainland, local employers and developers need to engage consultants to full time supervise the workmanship and production of precast concrete products. This is however not uncommon because nowadays many prestigious projects with prefabrication in Mainland such as steelwork adopt the same approach. For developers with continuous precasting works, they can engage consultants for the same on a longer term basis.

Prerequisites of Wider Implementation of Prefabrication (cont'd)

c) Quality Assurance (cont'd)

- HA has been employing consultants for full time supervision on a two-year term consultancy basis. In addition, a scoring system has been established which is used for reference for tendering eligibility.
- Other assurance measures, such as laboratory tests in HK, factory audits and breaking up upon delivery to sites have also been used.

Characteristics of Public Housing Construction in Hong Kong

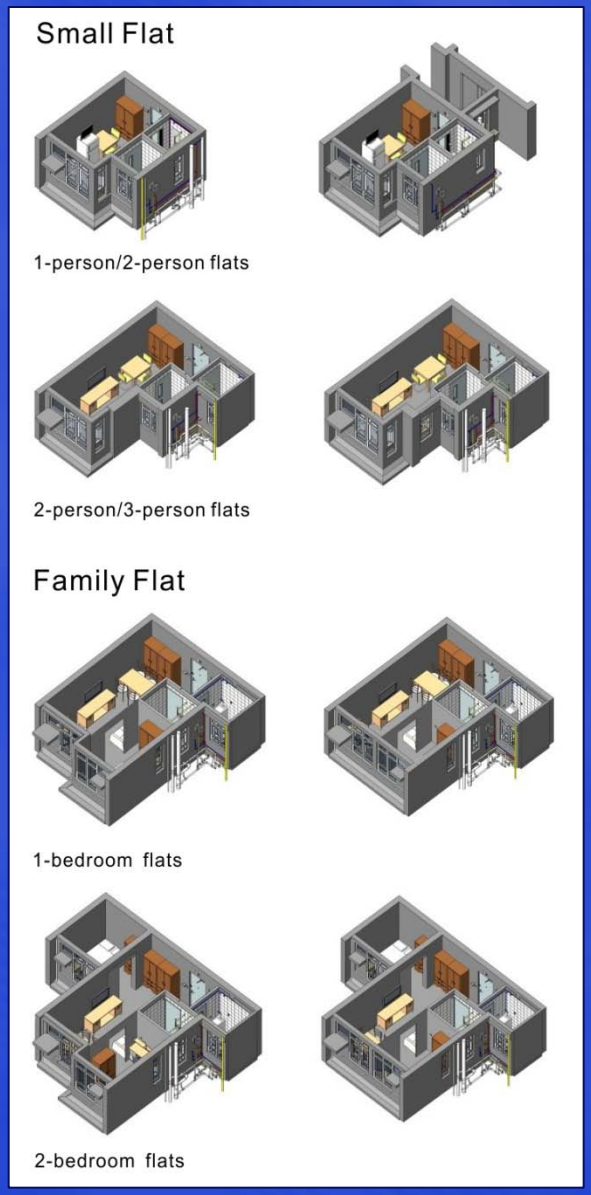
A. Standardization

B. Prefabrication

C. Mechanized Construction

Standardization to Modular Flat Designs

- Taking the benefit of mass flat production, but bearing in mind the impact of prototype blocks, we target for standardization of flat units only.
- This has replaced the standard block designs which we have adopted in the past three decades.



Standardization to Modular Flat Designs (cont'd)

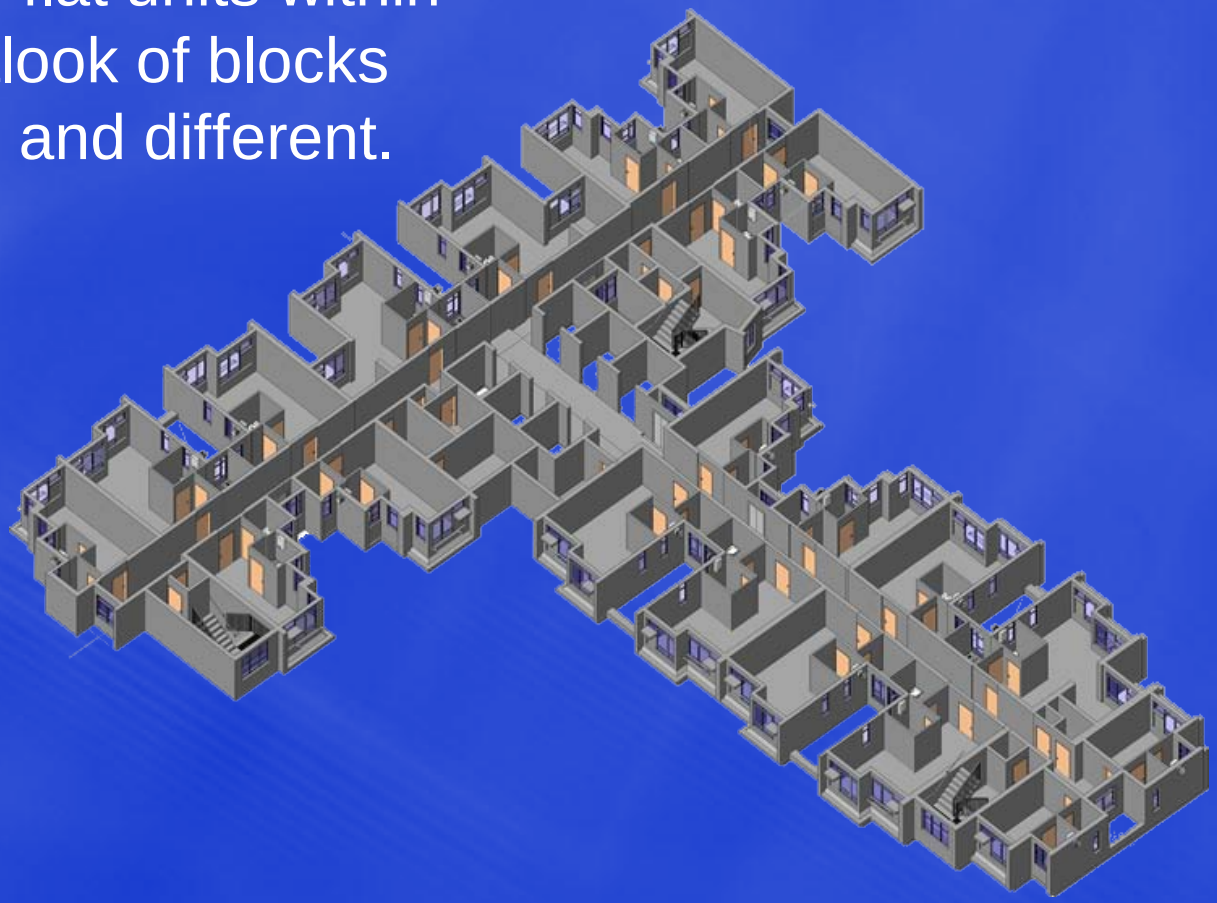
- Building skeleton components such as facades, slabs, staircases, partition walls and beams are standardized to form modular flat units.

Standardization to Modular Flat Designs (cont'd)

- Building fabric components such as windows, bathroom and kitchen fittings, doors, metal gatesets are standardized for factory manufacture.

Standardization to Modular Flat Designs (cont'd)

- Blocks are assembled using these modular flat units within layout, but outlook of blocks can be unique and different.



Prefabrication

- Prefabrication of concrete components is essentially the construction method which transfers some of the difficult insitu reinforced concrete construction from working floor to factory.

- The transfer is also from elevated construction on site to construction on ground in factory.

Prefabrication (cont'd)

- For elevated construction, it is often difficult to handle complicated component profiles or locations which are difficult to access. Substantial falsework and working platforms may be required. In case timber formwork is used, the workmanship may be deteriorated after repetitive construction.

Prefabrication (cont'd)

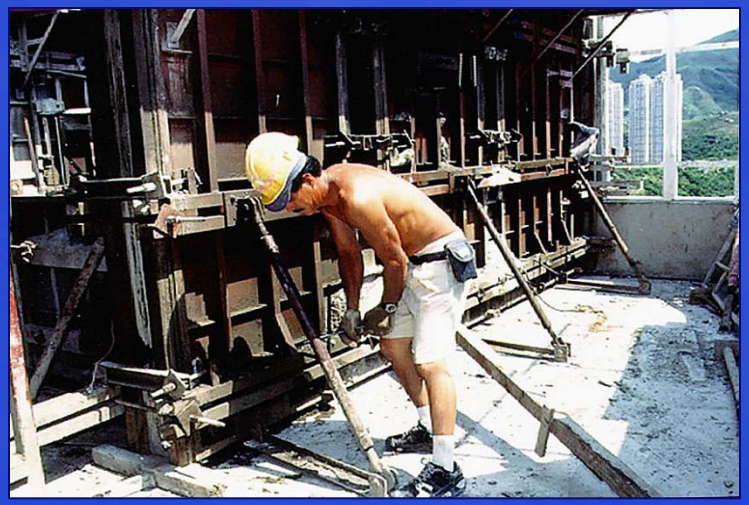
- For factory fabrication on ground, steel moulds can be used which facilitates horizontal casting of concrete and steel fixing.

Mechanized Construction

- Mechanized construction comprise primarily the use of tower crane to move around steel formwork, concrete skips and precast components. The transportation is between ground and working floor and between different wings of working floors. The HA has adopted this approach early in the 80's.

Mechanized Construction (cont'd)

- Large panel steel wallforms are used which replace timber formwork.
- Large panel formwork was mandatorily introduced in the mid 80's.
- It was a pioneer environmental initiative to reduce the use of timber.



Mechanized Construction (cont'd)

- Precast components are transferred from ground to working floor upon delivery to site.

Prefabrication to Slash Construction Time and Save Cost

Using Prefabrication to Slash Construction Time

- The HA domestic block construction is currently adopting 6 days cycle for structural frame construction.
- The application of finishes, both external and internal, will follow a few floors behind.
- The overall construction of superstructure is around two years for a typical forty-storey building.

Using Prefabrication to Slash Construction Time (cont'd)

- The relatively fast rate of construction is facilitated by the following :-

  a) Standardized modular flat with prefabricated components.

  b) Rotational use of large panel steel formwork.

Using Prefabrication to Slash Construction Time (cont'd)

c) Fair face off-form finishes with paint to exterior and tiles/paint to interior.

Using Prefabrication to Slash Construction Time (cont'd)

d) Minimization of wet trade on site through:-

(i) prefabrication and pre-installation at factory (i.e. tiling to bathroom, utilities installation, etc.).

(ii) use of precast partition walls instead of blockwork partition.

Using Prefabrication to Save Cost

- Prefabrication could lead to saving of both construction cost and long term maintenance cost.

- Saving in construction cost :-
  a) Fair face off-form finishes minimizes touching up and repair, which is very frequent for timber construction. (e.g. slab soffit and wall finishes)
  b) Labour cost in precast factory is much lower than that for insitu construction, first because cost is cheaper in Mainland China and second semi-skilled labour in factory instead of skilled labour at working floor is required.

Using Prefabrication to Save Cost (cont'd)

c) Insitu architectural wet trade, such as block works partitioning, tiling, plastering, etc. are substantially reduced, mostly transferred to factory or eliminated through off form.

d) Mechanized construction demands much less labour than those of conventional timber construction, particularly in terms of carpentry and temporary works.

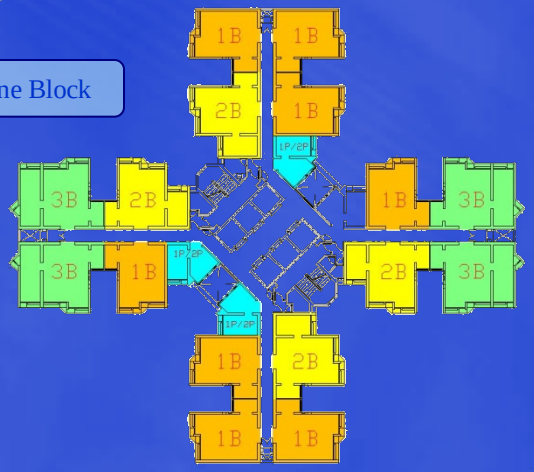
Using Prefabrication to Save Cost (cont'd)

- Saving in maintenance cost :-

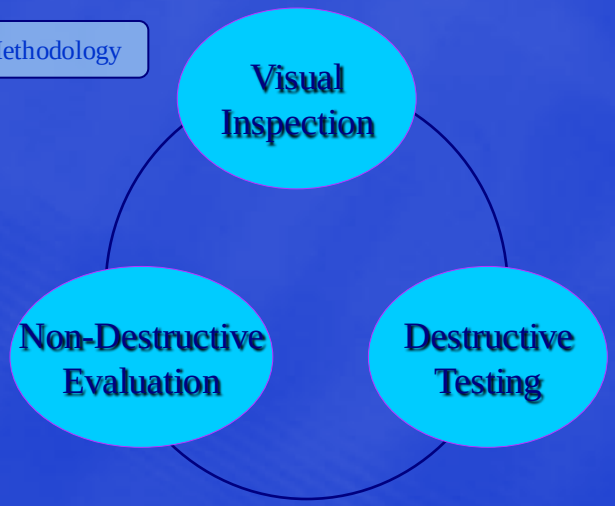
  a) In 2010, we have commissioned the Hong Kong Polytechnic University to assess the expected working life of our public housing blocks.

  b) We have selected eight standard prototype blocks, out of 250 blocks we have constructed in the past 15 years, some near the coast and some up the hills.

Harmony One Block

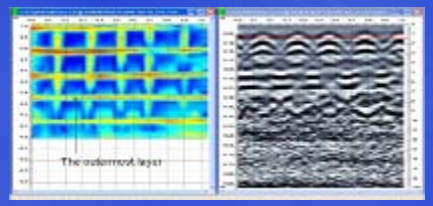


Methodology

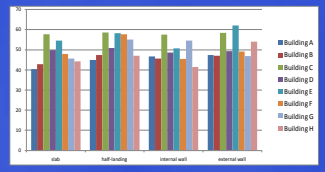


Using Prefabrication to Save Cost (cont'd)

c) It was established that the working life could be over 100 years, without the need for major repairs. (NOTE : In normal international design codes, the design life is 50 years for domestic buildings).



Test Results



Findings

With appropriate maintenance and monitoring regime, working life for housing buildings built after 1992 is at least 100 years or more …

Using Prefabrication to Save Cost (cont'd)

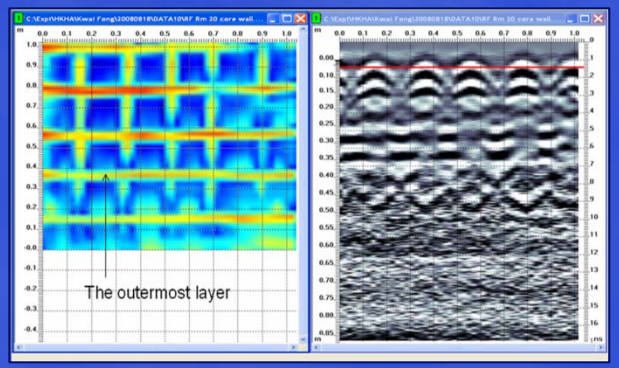
d) The main reasons contributing to a long working life are :-

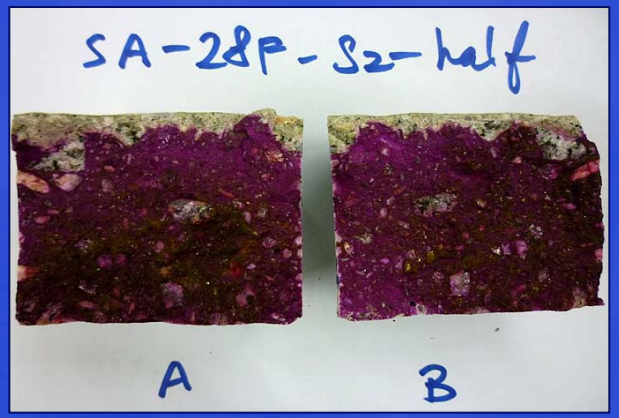
(i) Mechanization using steel formwork, ready mix concrete and tower crane can largely reduce the amount of 'labour intensive' type of construction, thus minimizing human workmanship errors.

(ii) Prefabrication in factory can change the mode of construction from elevated positions to ground floor line production. The construction difficulty is hence substantially reduced and better workmanship can be assured.

Using Prefabrication to Save Cost (cont'd)

(iii) Workmanship contributes significantly to the quality of built products, such as the maintaining of consistent concrete cover to reinforcement. Corrosion to reinforcement is the major factor which leads to deterioration of reinforced concrete structures and substantially reduces the working life of buildings.





Using Prefabrication to Save Cost (cont'd)

e) Another major maintenance cost is on the serviceability maintenance :-

(i) window leakage – through precast construction, windows are cast into the facades which eliminate regular maintenance.

Using Prefabrication to Save Cost (cont'd)

(ii) water seepage at toilet floor – waterproofing is installed at factory in volumetric precast, which greatly enhance the workmanship.

(iii) plumbing and drainage – again through volumetric precast whereby pipes and ductings are cast in factory.

Prefabricated Systems

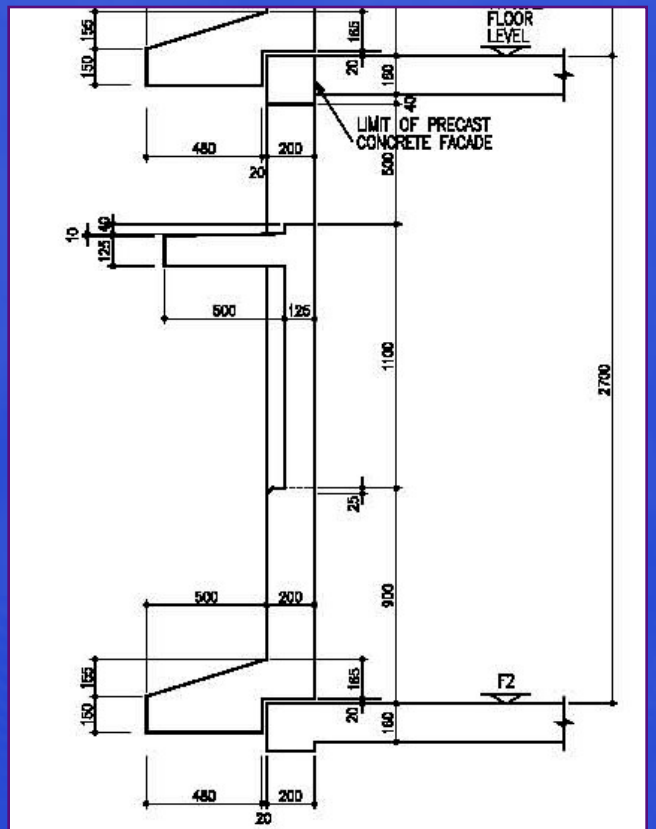
Prefabricated Components

A. Precast Facades

- To tackle the complicated profile by casting on ground.
- To cast-in windows to prevent water seepage.

Prefabricated Components (cont'd)

- Horizontal cast (wall as slab)
- Design to be supported on either side by structural walls; not to accumulate the loadings to lower floors.



Sectional Elevation of Precast Facade

Prefabricated Components (cont'd)

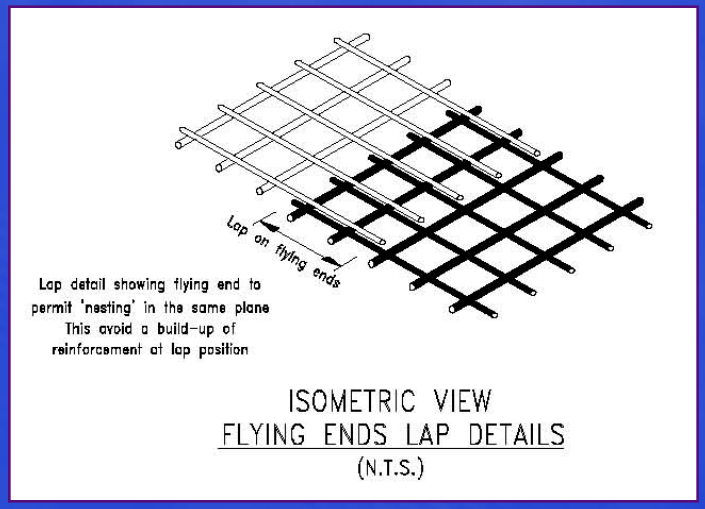
B. Semi-precast Slab

- To avoid using substantial insitu formwork and falsework, hence neater construction.
- To provide quality surface finish at soffit of slab.
- To house concealed conduits within slab thickness.

Prefabricated Components (cont'd)

C. Fabric Reinforcement for Insitu Slab

- Fabric reinforcement could be laid in the insitu portion of concrete above semi-precast slab.
- Basically minimal fixing of reinforcement on site for slab, hence significant labour saving.
- Flying ends are adopted so that no double layers of fabric reinforcement at laps.



Prefabricated Components (cont'd)

D. Precast Staircase

- Staircase is normally confined in a limited space within the staircore. Insitu construction is difficult and sometimes dangerous due to possible movement of falsework.
- Precast staircase is simple to produce in factory and easy to install on site.

Prefabricated Components (cont'd)

E. Precast Partitions

- Two types of precast partitions :-

  (i) Lightweight partitions

  (ii) R.C. partitions

Prefabricated Components (cont'd)

- Lightweight partitions are either by aerated concrete or hollow tube panel.
- Lightweight partitions are to be erected after construction of structural frame, to serve as partitions but eliminate wet trade (previously by blockworks).

Prefabricated Components (cont'd)

- R.C. partitions are thin partitions which is difficult to construct vertically by insitu method.
- R.C. partitions often for FRP reasons or for sound insulation, are better cast in factory and horizontally.

Prefabricated Components (cont'd)

F. Precast Tie Beams

- These tie beams are located in elevated positions unsupported by floor slabs. Construction is difficult in terms of erection of falsework.
- Precast tie beams are easier to install, mainly to make the connections at supports.

Prefabricated Components (cont'd)

G. Precast Ground Water Tank

- Ground water tank precast on site and hoist into position instead of insitu casting within confined space.
- It enhances buildability and quality of concrete and saves time in critical path.

Prefabricated Components (cont'd)

H. Volumetric precast bathroom/kitchen

- To precast a box-type structure to embody numerous pipe ducts, fittings, tiles, waterproofing membranes etc.
- A lot of wet trade could be transferred to the factory which is a better controlled working environment.

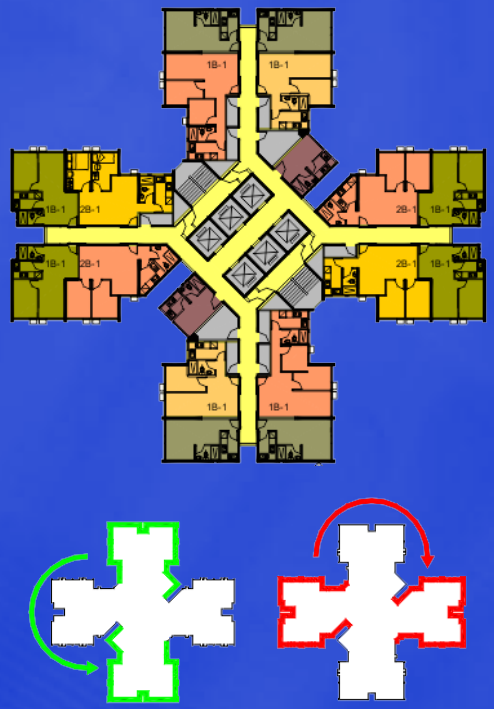
Prefabricated Components (cont'd)

- From past experience, bathrooms and kitchen areas are locations which call for frequent maintenance throughout their life spans.

Precast in High Rise Buildings

Prefabrication for High Rise Construction

- There are several important considerations to facilitate use of prefabrication in high rise construction:-
- Symmetry in Layout Design
  a) If the layout can be designed to be symmetric, or as far as possible symmetric, the prefabricated steel formwork can be rotated from one wing to another, thus avoiding the transfer of formwork to ground level.
  b) The no. of types of precast elements could also be largely reduced, hence more repetitive use of steel moulds and simplify logistics.



Prefabrication for High Rise Construction (cont'd)

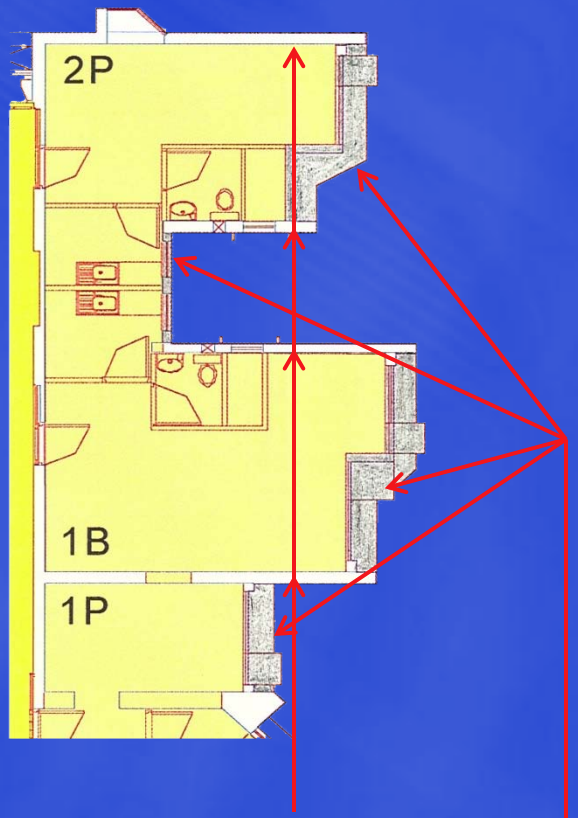
- Use of Tower Crane
  a) Tower crane contributes a significant cost to construction. If the crane capacity could be reduced, it saves the overall construction cost.
  b) If the weight of precast components could be minimized, such as the use of planar facades or facades with less complicated profiles, the capacity of tower cranes could be smaller.

Prefabrication for High Rise Construction (cont'd)

c) Symmetry of layout could also greatly enhance the tower crane capacity as the reach of the crane can be optimized. Sometimes, if the block is very asymmetric, two instead of one tower crane may be required.

Prefabrication for High Rise Construction (cont'd)

- Dimensional Accuracy of precast elements
  a) Precast construction calls for high precision; otherwise it cannot fit into and interface with insitu construction as formwork is also prefabricated.
  b) Where precast is connecting to precast, such as non-wind resisting elements, accuracy is also vital.
  c) Generally, a maximum of 4mm tolerance between each connection is allowed.



Insitu concrete walls

Precast Façade (Dimensional accuracies are very important as very tight tolerances could be allowed)

Prefabrication for High Rise Construction (cont'd)

- Transportation from Factory to Site
  a) Width of precast element has to be limited to less than 2.5m for truck transportation.
  b) Transportation is preferably by road, and 'just in time' to minimize storage on site.

The End

Thank You