

Innovative prefabrication system in Housing Block Construction



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TT3-244

ABSTRACT

Prefabrication is substantially used in housing block construction in Hong Kong to expedite the construction cycle, providing a green construction environment and achieving higher quality construction. Experience on the use of volumetric modules like prefabricate toilet and staircase indicated there are benefits in quality control. However, drawbacks are also identified. The paper overviewed the drawbacks on existing construction method with a view to develop innovative precast system. Conceptual study on alternative precast system indicated the use of lightweight concrete can reduce the weight of precast component, allowing design flexibility to overcome difficult site conditions and significantly shorten the construction time.

KEYWORDS:

lightweight concrete, prefabrication.

INTRODUCTION

Hong Kong is one of the developed cities with the highest density ratio of high rise residential building. The demand for high rise building is great to accommodate the increasing population for limited space. Since 90's prefabrication was used in the housing block construction in Hong Kong in order to expedite the speed of construction, quality of work and for improving environment condition of construction sites. For a standardized housing block, the quantity of precast units is approximately 17% of the total concrete volume. Most of the precast components were used as non-structural element.

Prefabrication provides a solution to expedite the construction process and significantly improve the quality of work. It allows the precast component to manufacture in the precast yard on ground level instead of the on-site concreting work at high level. Moreover, multiple tasks can be scheduled by detail planning so that construction duration can significantly be reduced.

This study is a part of the comprehensive investigation on the development of innovative present system for housing block construction. It overviews the prefabrication method currently adopted in Hong Kong standard housing block construction. Questionnaire survey was carried out to gather the view points on the adoption of prefabrication system. 14 stakeholders including engineering consultants, designers, precast manufacturers and contractor were interviewed. Findings of the questionnaire form the bases of conceptual development of innovative precast system. Opinion on the followings areas was gathered;

- Existing prefabrication industry,
- Strength on current practice,
- Limitations,
- Areas of improvement,
- Ideas towards innovative prefabrication system.

ADVANTAGES OF PREFABRICATION SYSTEM

Standardization construction

Public housing constituted a key portion of construction work in Hong Kong and it has adopted standardized block design. The use of standardize building elements allows the precast components can be mass production. The findings of this study confirmed are advantages of adopting prefabrication in housing block construction. The precast components can be produced under factory condition with re-useable steel mould and achieving a higher degree of precision than the cast in-situ construction. The precasters can set up the production line and allocate a designated crew to monitor the manufacturing process. Table 1 summarized the details of precast modules used in standardized housing block.

Table 1: Details of precast components used in housing block

Type of precast	Length (mm)	Height (mm)	Thickness (mm)	Weight in Tonnes [normal concrete]
Precast Staircase	1650	2650	300	3.15
Precast Semi-slab	4655	2125	65	1.54
Precast Façade (Single storey)	4615	2700	200	3.20

Flexibility

Comparing with the traditional cast in-situ construction method, finding of this study confirmed that the conventional construction method is more labor intensive and relatively low in efficiency than the prefabrication method. The construction activities heavily rely on the site condition (e.g. weather).

Quality & Safety

The factory production of the prefabricated unit eliminated the formwork requirement and allows concreting work to be carried out on ground level; enabling a closer supervision for achieving higher quality products. In case defected work is encountered, it will cause serious delay of the construction progress and the costs of rectification works can be substantial in order to ensure the stability of the entire structure. For the prefabrication construction method, the defective precast components can be identified at the precast yard and the defected work can be rectified before delivered to site.

The use of prefabrication external wall does not require massive scaffolding. It required fewer work process to be performed at the external wall, thus eliminating the potential risk of working at height which is the key factors to foster accidents.

Expedite in construction progress and cost effectiveness

The distinctive characteristic of prefabrication enables multiple construction process to be preceded within the same timeframe. For example, whilst the foundation works proceeding on site, the precastor can start manufacturing precast components and provide steadily supply to the project. This significant reduce the construction time and ease the inflexibility inherited from the traditional cast in-situ construction method. Hong Kong Housing Authority successfully lowering the construction cost after utilizing the prefabrication construction method. The process of typical floor construction can be cycled and benefits from the economic of scale under the standard block design. The consolidated standardized construction cycle contribute to significant reduction in idle time and elimination of possible interruption occurred in the critical path which induced by the varying site condition. High degree of control throughout the project leads to significant decrease in resources, timely program planning, effective budget control and monitoring about the progress of the program.

Environmental Concern

Substantial use of prefabrication leads to less cast in-situ activities and reduce the 'wet work' performed on site. This contributes to less environmental impact (e.g, noise, dust, wastage) being induced to its surrounding area.

Prefabrication offers lower level of wastage in comparison with cast in-situ method. Since the precast components were factory produced, the site environment can be enhanced with significant reduction in material wastage. Stringent control on waste management reduces the adverse effects onto to air, ground and water.

DOUBLE FAÇADE SYSTEM

Precast façade is one of the worth doing precast component used in housing block construction. Five distinguish type of precast facades (A,B,C,D,E as shown in Figure 1) were adopted in a typical floor of housing block with total number of 10 pieces of precast façade installed for each wing. As illustrated in Table 2, the maximum dimension for precast façade is 4.6m width x 2.7m height and with weight 3.2 tonne. It is the external envelop of a building. It is designated as non-structural component whilst its main purpose is to transfer the horizontal wind load to the cast in-situ core walls which taking the load bearing function to support the entire structural. With the adaptation of precast façade, the construction program of the typical floor of 4 wings standard block can be completed within a 6 days construction cycle.

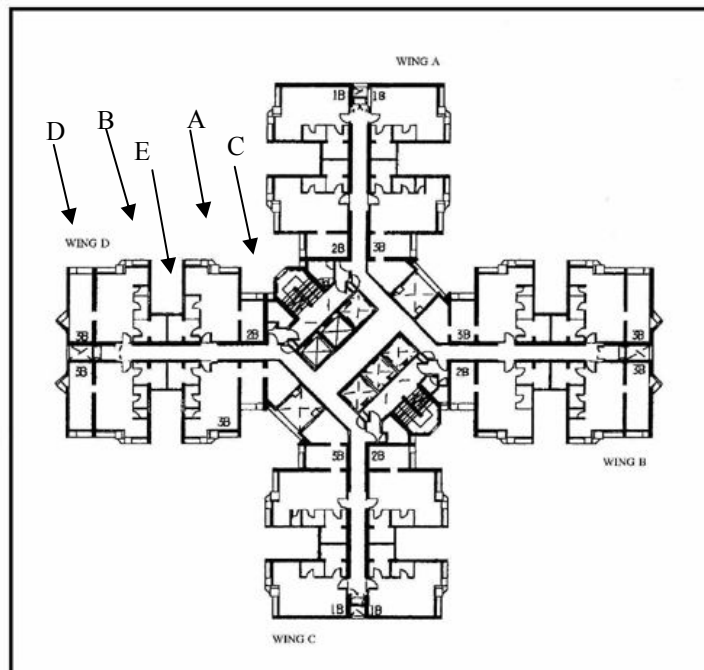


Figure 1: Layout Plan of Harmony Housing Block Type 1

Table 2: 5 types of façade component adopted in a typical housing block

Façade Type	Height (mm)	Length (mm)	Thickness (mm)	Weight using normal weight concrete (tonne)	Weight if constructed with lightweight concrete (tonne)
A	2700	4615	200	3.2	2.3
B	2700	4615	200	3.2	2.3
C	2700	2300	200	1.7	1.2
D	2700	2300	200	1.7	1.2
E	2700	2300	200	1.9	1.4

Merit of double precast façade over single storey precast façade

Conceptual study on alternative precast facade indicated that the use of lightweight double storey facade could reduce the total number of precast components utilized onto the building and contributes to the following advantages;

- Significant reduction in connection joint & effectively eliminate the potential areas of water leakage problems - even though the current design of facade had incorporate a 'boot' shape at base to protect the connection joint and increase the pressure different between internal and external environment. The window frame also fixed to mould of facade before concrete casting, there is a potential of water leakage for the precast unit. The use of double storey facade will significantly reduce the total number of connection joints.
- Combined 2 single storey facade components into one double storey precast facade can reduce of unit weight and the number of hoisting. As illustrated in Figure 2 that the conversion of 2 single precast facade into a double storey facade can effectively reduce the number of boots and therefore reduce the total weight for hoisting. Table 3 compared the weight different between single storey facade and the double storey facade under investigation.
- It is seen that the weight can be further reduced by 30% if lightweight concrete is used, leaving more flexibility in dimension changes to the architecture.
- It's of utmost importance that the double facade approach is made based on the assumption that the existing crane system does not change.
- The fewer crane usage allows for rescheduling of the existing work program and reallocation of resource. The shortening the construction time and expedite in progress implies cost saving with higher productivity and effectiveness.
- Less cast in-situ wet trades and fewer connection joints construction.

Areas of consideration for proposed double storey precast facade

There are several drawbacks for the double facade precast construction, they are:

- the complexity of the new precast system required reschedule of work program for each construction cycle
- a new works sequence based on 2 storey construction cycle is required
- Storage and handling may pose physical constraints of the precast components on site
- The change on the pattern of 'boot' on every floor to alternative floors may raise the aesthetic issue. Additional architectural feature may be required to preserve the consistent outlook for the structure.
- The practical problem of erecting, hoisting and placing the double storey facade onto the designated location at high level may exist. Provision of temporary bracing and supporting strut is required to stabilize the double height facade panel.
- There are space problem for the storage of precast unit during construction.
- The joint for the double facade will be different to the existing single storey facade construction method.

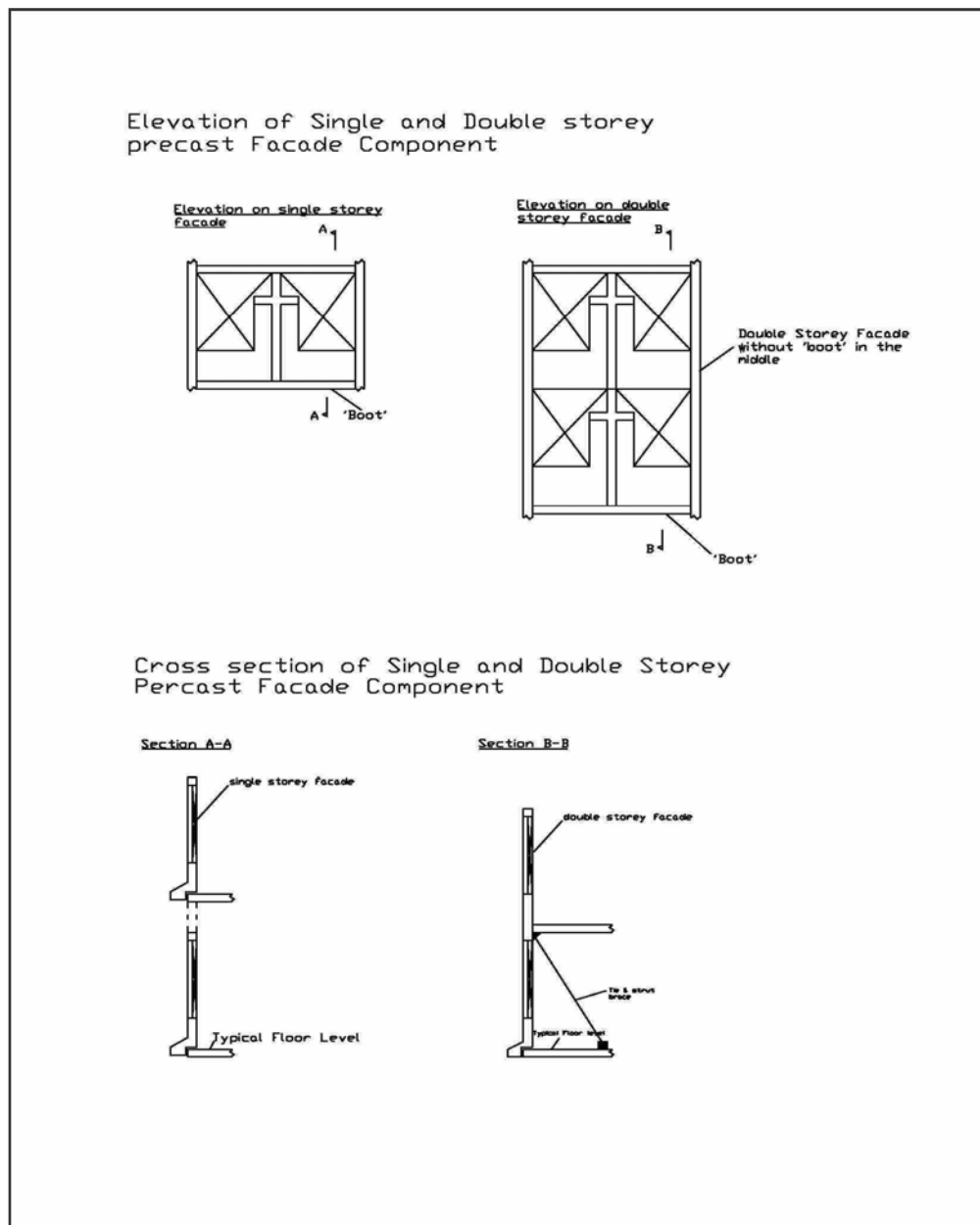


Figure 2: Details of Single Storey façade and Proposed Double Storey Façade

Table 3: Weight comparison between single storey façade & the double storey façade under investigation

	Length	Height	Thickness	Concrete Volume	Unit weight in of Normal Concrete (Tonnes)	Unit weight in Lightweight (Tonnes)
Single storey Façade	4615	2700	200	2.49	3	2.3
Double storey Façade	4615	5400	200	4.98	6	4.4

CONCLUSIONS

It is concluded that the most outstanding merit of prefabrication construction method aligned with expedite of progress and shortening of construction time and multi-tasking. In addition, prefabrication construction method offer environmental friendly and green construction environment by significantly reduce the conventional 'wet work'/ cast in-situ works on site. The proposed double storey façade permits the combination of 2 precast components into one which significantly reduce the totally number of precast components to handle for the entire structure; significant reduce the number of joints and minimizes the risk of water leakage.

Acknowledgements

The research was supported by the Housing Authority Research Fund of Hong Kong Housing Authority.

Reference

1. A M Haas (1983) *Precast Concrete – Design and Applications*. UK: Applied Science Publishers.
2. Robert A Hartland (1975) *Design of Precast Concrete*. London: Surrey University Press in association with International Textbook Company Limited
3. M Levitt (1982) *Precast Concrete -- Materials, Manufacture, Properties and Usage*. UK: Applied Science Publishers.
4. J G Richardson (1973) *Precast Concrete Prouction*. London: Cement and Concrete Assoication.
5. David A Sheppard, William R Phillips (1989) *Plant-Cast Precast & Prestressed Concrete-- A Desgin Guide*. USA: McGraw-Hill Publishing Company.