Partnering for Success – the Development of Precast Bathroom for Public Housing

Professor J.M. KO

Associate Vice President and Dean
Faculty of Construction & Land Use
the Hong Kong Polytechnic University

Ir SO Yau Chi

Director and General Manager
Yau Lee Construction Co., Ltd.

Basis of Development

In recent years, the Housing Authority has adopted modular flat concept in the design of high-rise residential buildings. As the shape, size and layout within a flat is highly standardized, this creates opportunities for the implementation of prefabricated bathroom units in the construction process. Instigated by Yau Lee, the prefabricated bathroom was developed with the initiatives to enhance waterproofing performance of the bathroom and to reduce wet trades on site such as plastering and tiling works.

The traditional way in constructing a bathroom involves several trades on site, i.e. formworkers, steelfixers, and concretors for the concrete frame, bricklayers for the partitions, waterproofers for the water proofing layers, installers for aluminium windows, plasterers and tillers for the finishing works together with plumbers for the plumbing and drainage works. The large number of different trades requires careful co-ordination and supervision to ensure quality of the works. The presence of wet trades not only creates messy working condition, packaging and wastage of material also causes environmental problems in their disposal.

In order to minimize the impact of these factors, Yau Lee Construction Co. Ltd. (Yau Lee) had team up with the Hong Kong Polytechnic University (PolyU) in 1998 to develop precast bathroom. The productions of these precast bathrooms can thus be carried out in the factory where the workmanship can be easily ensured. Through systematic control of the material, wastage can be kept to a minimum and disposal of the waste material can also be processed and controlled.
Design Concepts

The design was based on the following fundamental concepts :-

(a) Design with end-users in mind
The precast bathroom shall follow the design of the flat. Primarily, this requires optimization of the usable space with minimum change on the existing design. To achieve this objective, thickness of the walls, ceiling and base slab of the precast bathroom is limited to 50-75 mm.

(b) Environmental friendly
Wet trades, such as plastering and tiling works, shall be minimized on site to reduce the generation of construction wastes. As a result, all the finishes are completed in the factory.

(c) Buildability
The precast bathroom shall be installed in place with accurate setting out and leveling. The installation method shall be simple and easy to handle by semi-skilled workers. The installation time shall not adversely affect the construction program.

(d) Durability
The precast bathroom shall be designed to withstand possible impact loading during lifting and transportation.

(e) Future Maintenance
Details of waterproofing and material selection shall play an important role in the design of precast bathroom. Potential problems in water leakage and tile debonding shall be alleviated.
Development Stages

In November 1998, a research team in Yau Lee was set up with top management, design engineer and precast factory engineer to launch the design of the prefabricated bathroom unit. The New Harmony Standard Block was selected as a basis of the study. The Hong Kong Polytechnic University was invited to carry out the development, design and testing of the prefabricated bathroom unit.

**Scheme development and selection**

The adjacent figure shows the floor plan of a typical bathroom unit. In the original design, the bathroom is constructed after completion of the in-site structural wall next to the bathroom. Three sides of the bathroom are made from drywalls in the form of partitions. To develop the precast bathroom unit, three different design schemes have been considered.

The immediate consideration was to adopt the semi-precast concept where the precast elements would be installed prior to the construction of the in-situ concrete structure, i.e. the structural walls. A composite system using steel plates and precast concrete was then considered. Precast concrete walls are used to form three sides of the bathroom. The fourth side next to the in-situ structural wall was to be made of a stiffened steel plate. It would act as an internal formwork for the concreting work of the in-situ structural wall. However, the use of steel plates would be very costly and would create a compatibility problem with the finishing. An alternative scheme was needed.

The second design scheme is based on a hybrid system using a combination of drywalls, cold-formed steel connections and precast slabs. The drywalls are erected to form the three sides of the bathroom and are connected to the precast roof and precast floor using specially designed cold-formed steel brackets. The precast unit is installed and integrated with the in-situ structural wall. It was anticipated that the drywall system could lead to possible problem in the process of prefabrication and installation. The scheme was not pursued.
To use the side-wall of the bathroom a formwork for the concreting of the structural wall would require strong material or a thicker concrete section. However, in order not to make a major revision to the layout of the bathroom, it was decided that the bathroom unit would need to be standalone to make use of thinner wall sections. The present precast concrete solution is adopted. Lightweight concrete is use to form the precast bathroom unit and the precast bathroom is installed after the construction of in-situ structural wall.

Material and Detail Design

By the mid-1999, different mixes of lightweight concrete were tested by casting 50mm thick samples of partition wall. Performance and quality of the mixes were assessed. Of prime concerns were the workability and strength of the lightweight concrete, and the consistency achieved in batching process. Having selected the optimal mix for lightweight concrete, detail design of the precast bathroom unit was carried out. This included design of the production process, moulds, lifting method and installation method.

Prototype and Tests

Several specimens were manufactured in the factory. In January 2000, lifting test and loading test were carried out in the factory by staff of the Hong Kong Polytechnic University. The purpose of the tests was to examine whether the precast bathroom unit has adequate strength and stiffness to resist the processes of lifting and installation, and subsequent concreting work above the unit. Strain gauges were installed to verify the design. Performance of the precast bathroom unit under various lifting and loading conditions was found to be satisfactory. Trials for various methods of installation were conducted in the factory. The tests are informative and invaluable. Diagonal bracings were installed in the precast bathroom unit to temporary strengthen the unit during transportation. The transportation process was tested to satisfaction by placing two precast bathroom units on a moving truck.
Mock up for comments

In May 2000, technical submissions were presented to the Housing Department for comments. A mock up sample was set up on site in August 2000. The sample flat was completed with the precast bathroom together with on site installation of window, pipes, sanitary fittings and door. Demonstrations on the installation method were arranged for architects, engineers, site supervising officers, construction teams and subcontractors in order to gather comments from all concerning parties. Revisions and amendments were made to incorporate all the comments.

Pilot Project Application

The prefabricated bathroom has been successfully implemented to the construction work in Tseung Kwan O Area 73A Phase 2 of the Housing Department. It has been well proved that the precast bathroom units can be easily integrated with fast track construction. As in this case, the installation method is very efficient and the current 6-day cycle programme can be easily maintained without considerable modifications to the existing programme.
Product Description

The precast bathroom is a box-type structure composed of lightweight concrete with galvanized mesh reinforcement and concealed conduits embedded inside. Density of the lightweight concrete is 1900 kg/m³. In considering lifting capacity of tower cranes, self-weight of the precast bathroom unit is limited to 3 tons. The precast bathroom unit is completed with conceal conduits, pipe sleeves, waterproofing and tiling before delivery to site.

Installation

The precast bathroom is installed after removing the steel wall-form of the in-situ walls and before the placement of precast slab panels of the floor above. The following table illustrates how the installation of the precast bathroom is incorporated into the original 6-day cycle programme.
6-day Cycle Programme

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Technical Considerations

**Architectural Aspects**

(a) Limitations of size (height, width and length) due to transportation
(b) Limits in dimensions to allow maximum flat areas to tenants
(c) Limits in floor level difference between living room and bathroom
Requirements in waterproofing

The arrangement of waterproofing work is basically same as the in-situ bathroom. Cold applied waterproof membrane is applied to floor slab and wall to a height of 500 mm from base slab. An additional liquid applied waterproof membrane is also applied to 1.6m above floor level. As the walls and slabs of the precast bathroom are cast together to form monolithic joint, its waterproofing performance will be much better. To ensure consistency in water-tightness performance, water-tightness test would be carried out before delivery to site.

Structural Aspects

(a) Limits in dead weight due to floor loading and foundation margins

Lightweight concrete (LWC) is adopted for the production of precast bathroom. The LWC consists of cement, sand, water and foam. The foam is generated by an admixture, called Microcell. After mixing the components together, the density of the lightweight concrete is approximate 1900 kg/m³. The corresponding self-weight of the precast bathroom is about 3 tons. The following table shows the mix-proportion of the lightweight concrete.

The precast bathroom is expected to be lifted at an age of 7 days and the corresponding design strength is 5 MPa.

(b) Avoid extra stiffening to the whole building structure

A 10mm gap is provided between the precast bathroom and the in-situ wall to allow for construction tolerances. The precast bathroom is not in direct contact with the structural wall. At the same time, a 10mm thick polystyrene sheet is placed on top of the precast bathroom such that the in-situ floor slab is cast in separation with the precast bathroom. The whole precast box is isolated from the structural frame of the building. There is adequate room allowed for the deflection of the structural floor slab. Hence, the precast box will not share loadings from floor slab above.
Building Services Aspects

Requirements in conduits, junction boxes, connection details, bonding details, pipe sleeves for gas, plumbing & drainage

(a) Pipe Installation

To ensure the openings at precast bathroom match with that at structural wall, the size of openings preformed at structural wall is 10 mm larger than that at precast bathroom. Subsequent to bathroom installation, sealant is applied at one wall end. Expandable foam is then applied to fill void to ensure water-tightness. Lastly, sealant is applied on the other wall end.

(b) Floor Drain Installation

An UPVC adaptor is cast in the precast bathroom and recesses are preformed at the end of the adaptor to facilitate floor drain installation. Subsequent to the placement of precast bathroom, a vertical floor drain is installed with extension beyond the gap. In this case, the floor drain is post-installed rather than cast in with the in-situ wall. The flange of the floor drain becomes unnecessary. The omission of the flange would also facilitate the filling of waterproof cement sand at the box-out.

(c) Earthing

-Metal Railing

Earthing is essential at the location of metal railing. A metal strip is fixed onto the wall of precast bathroom at the designated location. One end of the metal strip is attached to the metal railing. On the other end, it is in connection with a wire junction box. A conduit is connected to this junction box with extension to the top slab. Wiring is provided inside the conduit to connect with the earthing system.

-Window

Earthing is essential for window installation. One end of metal strip is bent as shown in the following diagram. On the other end, the strip is connected to a junction box fixed on the roof slab of precast bathroom. Wiring is provided inside the conduit to connect with the global earthing system.
Others

(a) **Requirements in durability and maintenance**

Since the wall thickness of the precast bathroom is 50 to 75mm, all concealed conduits and junction boxes in the precast bathroom are to be galvanized iron to prevent damages from nailing. Moreover, in the light of the thin wall structure of the precast bathroom and the adoption of lightweight concrete which has lower density, galvanized reinforcement is used to enhance the cover protection and long term durability.

(b) **Tight tolerances between precast bathroom and in-situ wall**

Tolerances must be allowed for the production of precast bathroom, the construction of cast in-situ wall in particular the openings for pipes together with that for the installation operation. This imposes extra requirements in the design of the formwork system in factory and those for in-situ wall. Guiding angle brackets are fixed on the floor slab to facilitate the installation of the precast bathroom.

Partnering

It is the joint efforts among the Housing Authority (HA), the Hong Kong Polytechnic University (PolyU), Yau Lee Construction Co., Ltd. (Yau Lee) and the Yau Lee Wah Precast Factory (YLW), a subsidiary of Yau Lee Holdings Ltd.

HA takes a leading role to change to the modular design concept to foster precast construction. During the development of the precast bathroom, the Housing Department’s Design and Standards Sections was closely involved in the evolution of the design work. During the process towards the acceptance of the new concept, the Housing Department’s project team had worked closely with Yau Lee to crystallize the concept.

In order to get sound and solid theoretical support, PolyU as a academic researcher accepted to provide consultancy and to prepare design and testing scheme. PolyU also accepted the basic perception of the project and committed to share information and ideas to strive for the excellence of the product.
For the construction part, Yau Lee carried out market searching for materials, formulated installation method and co-ordinated requirements for site operations. YLW was focusing on the production and tests in the factory.

Conclusion

The success is the collaboration among the building developer, academic researcher, builder and manufacturer. The essence of the successful implementation was the partnering approach where everyone involved worked towards the single target of “making it work”. Partnering are established among all parties to share information and ideas, to work co-operatively, to set common goals, to address and resolve problems, to achieve better alignment of the respective requirements, and, to achieve acceptable solutions.

The main features of partnering of mutual trust, common objectives and effective communication are the key issues to ensure a success.

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