Perception on Innovation for Pre-cast Toilet

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Abstract

The Hybrid construction method with in-situ concrete used for a toilet in a predominantly pre-cast concrete (PC) structure is a hindrance towards full adoption of Industrialised Building System (IBS). Improved knowledge on a leaking problem can lead to innovative toilet construction. Research objectives are to gauge stakeholders' awareness on leaking problems in PC structure and perception on innovative toilet construction. Research methodology is through case study and structured interviews. The study concludes that improved development of Pre-fabricated Toilet Unit (PTU) is a good solution for the leaking problem in PC structure but it requires consolidated efforts from stakeholders to improve construction industry acceptance.

Keywords: leaking problem; pre-cast concrete structure; acceptance on new technology; prefabricated toilet units.

https://doi.org/10.21834/jabs.v3i8.284

1.0 Introduction

In recent year, the usage of pre-cast concrete (PC) components for building structural framing system is widely adopted in Malaysia away from the conventional in-situ reinforced concrete (IRC) method in response to the growing global approach of off-site fabrication. In Malaysia, the off-site approach is known as industrialized building system (IBS). The original objectives of IBS roadmap are to achieve a better quality of work, faster completion period and reduce the site workers (CIDB, 2010a). Malaysian government mandated the use of 70% of IBS components in all government projects has achieved reasonable success. However, the acceptance by the private sectors towards IBS is still unsatisfactory. In-situ method of construction is still preferred due to a limited supply of IBS products in local construction industry. Construction Industry Development Board (CIDB) had carried out a survey on 85 completed government projects constructed under the period of IBS roadmap 2003-2010 to gauge the success rate in achieving the original objectives. The survey shows that quality of work had improved, whereby 90.7% of stakeholder satisfied that IBS offers better quality compared to conventional method. The survey also stated that objectives of faster construction time and reduction of site worker are achieved (CIDB, 2012b).

According to IBS-One Stop Centre of CIDB, among many categories of IBS in Malaysia, PC is the most popular. Unfortunately, IRC is preferred compared to PC due to its rigidity and monolithic casting. Unlike IRC, PC structure is less rigid and not monolithically cast. The joints between PC components and the cold joints between PC and IRC topping are prone to cracks due to the building movement from the live load, dead load, and lateral force. Leaking occurs as water seep through the cracks on the floor surface of PC slab. For toilets constructed on PC slab, the leaking problem is more severe due to constant contact with water. Previous attempts with the use of IRC topping on top of PC slab or PC half slab as a floor for toilets did not guarantee water tightness and failed to give long term solution to leaking problem. Therefore, the hybrid method of construction in which toilet floor uses IRC while the remaining building structure remains as PC is commonly practiced. This approach will reduce the IBS contents and defeat the whole exercise of maximizing IBS adoption in Malaysian construction industry. Industry players including CIDB recommend conventional in-situ toilet to be used in PC frame buildings. According to stakeholder, traditionally built in-situ toilet offers a better solution to the leaking problem, design flexibility, and better accessibility during construction than PTU. Therefore, The objectives of this research are to gauge stakeholders' awareness of the leaking problem in PC and to ascertain stakeholders' perception towards innovative toilet construction.

2.0 Literature Review

A literature review of existing research materials is to establish variables related to the research topics by exploring issues on the leaking problem in PC, a comparison between in-situ toilet & pre-fab toilet and innovation in toilet construction.

2.1 Leaking Problem in Pre-cast Concrete

Stakeholder identified that water tightness and leakage is the main concern with PC. A study

by CIDB in August 2010 shows the leakage defects in PC structure has the highest percentage of occurrence at 11.2% compared to other defects which are in the range of 1.9% - 3.7%. (Neville, 1989) (Li. K et al, 2009). Leaking is defined as the process by which liquid leaks through a porous substance (Wiktionary, 2012). PC like any concrete is a porous material of low permeability. Even minor crack in concrete can cause water leaking due to capillary action of water. Water leaking is a common occurrence in wet areas due to direct contact with water and such problems always pose a challenge during maintenance. Research by (Chew et al, 2004) indicates three (3) common types of water leakage defects in toilets. They are leakage through cracks, leakage through pipe penetration and leakage through joints. Causes of water leakage in toilets are inferior workmanship, incorrect application of waterproofing, poor maintenance, water ponding, joint failure and formation of excessive shrinkage cracks in concrete. Water leakage if not tackle properly can lead to excessive defects such as spoiling of concrete and corrosion of pipe, and corrosion of steel concrete reinforcement.

2.2 In-situ Toilet against Prefabricated (Prefab) Toilet

Two (2) common approaches to toilet construction in PC buildings are in-situ toilet and prefab toilet. An in-situ toilet is a conventional construction method by using raw materials. It is more labor intensive with the involvement of many trades that follow the building construction sequence and therefore takes a longer period to construct. The raw materials are cheap, the design is flexible and adaptable during construction. Prefab toilet is an off-site approach. Fabrication of components done in factory and assembly is at the site. This method offers faster construction period with the manufacturing done concurrently with the work on the site. Cost saving is possible with mass production of factory made products. The fully assembled prefab toilet is designed, coordinated and tested in advance under controlled factory environment. Therefore, it is more reliable and rigid but inflexible for modification during construction. Table 1 below summarized the advantages and disadvantages of in-situ toilet and prefab toilet.

Table 1: Advantages and disadvantages of in-situ and prefab toilets

In-situ toilet: Advantages	Prefab toilet: Advantages
a. The Monolithic casting of concrete and pipe penetration. b. Flexible design c. Rely on readily available trades. d. Suitable for any size and shape of the toilet. e. Easy to renovate. f. Open system and competitive tendering.	a. Standard modular design. b. Works are done in the factory. c. Reduce site activities and construction period. d. Less trade involves. e. Better quality control. f. Better testing method in factory. g. Sustainable construction improved material management and reduce wastages. h. Coordinated design and services in the factory. i. Reduced error
In-situ toilet: Disadvantages	Prefab toilet: Disadvantages

a. All works are done on site. b. Involves many trades c. The quality of work depends on workmanship. d. Need proper supervision to reduce error. e. Longer construction period to follow work sequence. f. Accessible for maintenance. g. Testing on site. h. Wastage of material	a. Rigid design and inflexible for renovation. b. Restriction in size to suit manufacturing and transportation. c. The proprietary system is less competitive during tendering. d. Costly repair work. e. Pre-formed opening for services. Not monolithic.

Low adoption of prefabricated toilets in Malaysia is due to limited products available in the local market. Readily available products often associated with portable toilets. Local prefab toilet industry needs to learn from developed countries. For example, the Housing & Development Board (HDB) of Singapore had developed and implemented its own fully prefabricated PC construction system including the prefabricated toilet units for their public housing projects. Since its inception in mid 90's the PC components had increased from just 15% in 1988 to 71% in 2007. (Kian S. W., 2009). In United Kingdom (UK), 20-30% of new-build commercial office projects used off-site toilet module. (Gardiner and Theobald, 2005).

2.3 Innovation in Toilet Construction

In some developed countries, their research and development on the innovation of prefab toilet explore the design beyond basic sanitation to project an aesthetic image of comfort and luxury. The application is not only limited to buildings but also for ship industry and aerospace industry. The off-site toilet is seen as a revolutionary approach to toilet construction to replace the conventional in-situ toilet construction method that is perceived as labour intensive and time-consuming. There are two (2) common types of prefab toilets available in the market. The first type is a lightweight panel system which panels can be assembled and disassembled on site. The second type is a pre-assembled system in which a complete box with fittings and accessories are assembled in the factory and delivered to site for installation. Both systems can be further categorized based on the material used. The floor materials normally use pre-cast concrete or moulded fiberglass while the wall materials use fibre cement board, Ferro cement board or pre-cast concrete panel. (Lau J. M. et al, 2009). A study by Pan.W. et al, (2009) also suggests that maintenance cost of an off-site toilet is cheaper than an in-situ toilet. Toilets are identified as critical areas for maintenance and a lot of defects occur in these wet areas even though toilets only represent 5-10% out of build up area of buildings (Nadim. W. et al, 2010). These factors motivate stakeholders to seek the best solution for off-site toilet construction that can produce good design, high-quality product and low maintenance and most importantly, acceptance by end users (Ramly et all, 2006). For example, Singapore had successfully developed their own prefabricated bathroom units (PBUs) for use at their HDB's flats. Their PBU industry has evolved from two pilot projects in 1995 using lightweight panel system and pre-assembled box system respectively to the current system using a more durable prefabricated Ferro-cement toilet system. During an oral interview with IBS Centre, a body under Construction Industry Development Board

(CIDB), they informed that their research suggests that perception towards pre-cast concrete structure has improved. However, perception towards Prefabricated Toilet Unit (PTU) among the industry players in this country is still not favourable. PTU industry in Malaysia is still at the infancy stage and the production is limited to small to medium size portable toilets. As such, PTU is perceived as only unsuitable for use inside buildings. IBS Centre also elaborated that based on their interviews with industry players, the negative perception towards PTU is attributed to many factors such as 1) designers are not familiar with PTU, 2) limited number of manufacturers who produce high-quality PTU, 3) PTU is suitable for compact size toilet and difficulty to produce PTU for larger size toilets, 4) High initial capital investment for production of PTU. 5) Economic of scale and need large a volume of production of PTU to reduce cost, 6) building owners dissatisfaction on the hollowness feel of PTU floor and wall panels and etc. Due to the negative perception towards PTU, most industry players including CIDB recommend conventional in-situ toilet to be used in pre-cast concrete frame buildings. According to stakeholders, traditionally built in-situ toilets offer a better solution to the leaking problem, design flexibility, and better accessibility during construction than PTU.

3.0 Methodology

This research adopted mixed methods; qualitative and quantitative. The qualitative approach adopted oral interviews, literature review, and case studies to establish variables related to the research objectives. A quantitative method was a simulation of collected data from online and oral interviews using prepared standard set of questionnaires. For Better and clear answers for topics outside the standard questions, oral interviews with selected groups of respondents experts on this topics were conducted.

3.1 Method 1 – Case Study

Case study method of toilet construction in PC buildings done on three (3) completed projects which share common features namely, all are multi levels residential buildings, adopts pre-cast concrete framing system and used a different approach for toilet construction.

3.1.1 Case Study One (CS1)

CS1 is a four (4) levels teacher quarters in Gombak, Selangor built by Leighton Group Malaysia through a Design and Build (D&B) Contract for the Ministry of Education Malaysia (KPM). The structural system based on pre-cast concrete frames with pre-cast lightweight internal and external infill wall panels. The toilet construction is pre-cast concrete floor slab and pre-cast wall panel with in-situ floor and wall finishes. Interview with tenants indicates that leaking problem occurs at the pre-cast panel joint at toilet area. Leaking defects still persisted after making good of the defects.

3.1.2 Case Study two (CS2)

CS2 is multi levels apartment buildings, a public housing project constructed in 1995 in Hougang neighborhood, Singapore developed by the country Housing Development Board

(HDB). The buildings adopted full a pre-cast system for structural framing, internal partition, facades system and prefab toilet. As a pilot project, two (2) prefab toilet systems had been adopted namely lightweight panel system and pre-assembled box system. A survey by HDB conducted in 1998 indicated that 85% of tenants has strong acceptance for prefab toilet construction. A higher case of the leaking problem was reported for the lightweight panel system than the preassembled box system. The severity of some cases forced HDB to replace some of the prefab toilet using a conventional in-situ method.

3.1.3 Case study three (CS3)

CS3 is a recently completed student hostel complex at the new campus of Universiti Teknologi Mara (UiTM) in Tapah, Perak. The project was built by Crest Builder holdings Bhd. using a Design, Build, Operate and Transfer Contract with Ministry of Education Malaysia and UiTM. The eight (8) blocks of four (4) levels buildings were originally designed based on full IRC structure. However, the framing system was subsequently changed to PC as part of government's IBS compliance policy. Internal walls and external walls use conventional masonry units. The toilet construction is in a full in-situ method as recommended by the PC manufacturer in order to achieve monolithic casting of concrete together with pipes penetration to optimize water tightness. This method is the most common approach in local construction industry.

3.2 Method 2 – Interviews with standard set of Questionnaires

A total number of 75 representatives from building owners (clients), developers, consultants, contractors, sub- contractors and end users related to the three (3) case study projects have been interviewed which breakdown are as shown in table 2. The interview questions are based on prepared questionnaires. The data obtained from the interviews were tabulated in table 3 to gauge their awareness of leaking problems in PC structure and tabulated in table 4 to gauge their perception on innovative in toilet construction.

Table 2: Number of respondents

Respondents	***Number of respondents***
Clients / developers	6
Consultants	12
Contractors	12
Sub-contractors related to toilet construction	15
End user	30

Table 3: Awareness on leaking problems in pre-cast concrete

Factors	***A***	***B***	***C***	***D***
Leaking in pre-cast concrete	100%	100%	100%	100%
Leaking in in-situ concrete	33%	58%	41%	33%
Leakage problems through cracks	16%	83%	16%	60%
Leaking problem through pipe penetration	100%	100%	83%	86

Leaking problems through joint	83%	75%	75%	76%	
Leaking due to water ponding and poor drainage	100%	100%	100%	100%	
Leakage due to poor water-proofing	100%	100%	100%	100%	
Leaking problem due to poor maintenance	83%	58%	74%	10%	

Note: A: Client/Developer, B: Consultants, C: Contractors/Sub-con, D: End Users

Table 4: Perception on innovative toilet construction (Prefab toilet unit-PTU)

Factors	***A***	***B***	***C***	***D***
Incentive by Government for R&D on PTU	50%	25%	18%	n/c
Knowledge and exposure on PTU technology	50%	50%	48%	33%
Availability of PTU products in market	33%	50%	33%	33%
Design flexibility of PTU	33%	25%	0%	6%
Aesthetic outlook of PTU	66%	16%	51%	83%
Flexibility in size of PTU	0%	0%	0%	0%
Design flexibility of PTU	0%	0%	0%	0%
High capital investment of PTU	100%	100%	100%	n/c
Lower cost of mass production PTU products	100%	100%	100%	75%
Low maintenance cost of PTU	100%	100%	100%	80%
Market-driven factors of PTU	33%	50%	37%	40%
PTU as proprietary system	100%	100%	100%	33%
Better quality control of PTU product.	100%	100%	100%	100%
Reduced construction period	100%	83%	100%	100%
Adaptability for future changes	0%	0%	0%	0%
Post construction service and guarantee	83%	83%	100%	23%

**n/c – no comment.*

Note: A: Client/Developer, B: Consultants, C: Contractors/Sub-con, D: End Users

4.0 Results and Discussion

4.1 Stakeholders' Awareness of leaking problem in PC structure

From Table 3, it can be concluded that the majority of stakeholders share similar views that leaking problem is more prevalent in PC structure compare to IRC structure. The major cause of leaking is water ponding due to poor drainage and poor workmanship of waterproofing system. This is not surprising since these two (2) factors are interrelated. Water ponding can cause prolongation of stagnant water in which consequently the water will slowly seep through to the waterproofing layers. Poor workmanship of the waterproofing system will expedite the process of leaking. The next cause is leaking at pipe penetration and followed by leakage through joint. Poor maintenance also contributes to the leaking problems.

Surprisingly, leaking through cracks is considered as the least cause of leaking problem. Client, developer, and contractor seemed to put the blame on poor maintenance by end users on the cause of leaking. On the other hand, the end users put the blame on poor workmanship by contractors for the cause of leaking. Consultants seemed to agree with contractors whereby poor maintenance will lead to the leaking problem.

4.2 Stakeholders' Perception towards Innovative Toilet Construction PTU

From Table 4, the findings revealed that majority of stakeholders agreed that initial production of PTU requires high capital investment however lower cost can be achieved through mass production. PTU is often associated with a proprietary system and therefore more durable with lower maintenance cost. PTU also contributes to shorter construction period. Perceptions on PTU by expert groups of respondents not captured in Table 4, but captured during oral interview are as follows;

4.3 Client / Developers

The developers are moderately familiar with PTU. They often rely on consultants to advise on the design aspect, cost implication and method of construction for PTU. However they are fairly receptive towards PTU provided that it meets their budget allocation, meets buyers' or end-users' expectation and offers good immediate and long-term return on investment. The PTU must be good of a high-quality product and easy to maintain.

4.4 Consultants / Designers

Most designers are moderately familiar with PTU and are aware on the limited availability of PTU for usage inside building in the local market. Their knowledge on PTU is often based on the reference of other developed countries. Designers' concern is mainly on design and aesthetic outlook of the toilet. When enquired by clients, designers often advised against adopting PTU perceived to have limitations in term of design, size and adaptability for future changes. Consultants prefer the concept of PTU to be preconceived during the early design stage and not as a counter-proposal during tender stage. However, PTU manufacturers must incorporate their design concept, guarantee good quality final product, provide pre-construction technical support, provide proper assisting supervision during construction stage including testing and commissioning and most importantly provide post-construction support service during defect liability period.

4.5 Contractors

Contractors are moderately familiar with PTU technology. They are also receptive towards PTU provided that it gives them good quality products that offer reasonable profit margin, meets their construction schedule and suits their work sequences. Their acceptance for PTU is influenced by the reduced number of skilled trades for toilet construction on site with the fabrication and the testing is done in the factory. However, contractors feel that PTU manufacturers should provide complete PTU proprietary system and offer full services during the pre-construction stage, construction stage and post-construction stage including maintenance during defect liability period and during product warranty period.

4.6 End users

Except for end users for case study two, the rest are not familiar with PTU and need an explanation on the concept of PTU during interviews. They are not aware of PTU application in local construction industry. Their negative perception of PTUs is due to lack of understanding of the products that are often associated with non-permanent portable toilets. However, they are exposed to latest trend in toilet design from on-line and printed media which increase their expectation in term of aesthetic on the PTU end products. End users initial concern is on the aesthetic outlook rather than on the quality. In newly constructed projects, end users usually are not involved during the construction process. Only after they move into their respective premises that they become more aware of the importance of good workmanship, serviceability, and maintenance.

5.0 Conclusion

The study proves that stakeholders are aware of the cause of leaking at toilet area in PC buildings. PTU is perceived as a good solution for leaking problem at toilet area despite the limited supply of PTU in the local market. However, limitations of PTU regarded as rigid, limit design flexibility and not suitable for large size toilet need to be overcome to improve their perception. Thus, the promotion of PTU should not just come from policy makers but also to include manufacturers of PTU. The PTU industry needs a holistic approach to improving peoples' perception. PTU products should be flexible, adaptable, projects exclusiveness without compromising on the maintainability. As financier and owner of projects, clients need to play a bigger role in promoting PTU because consultants and contractors response to their demands. Direct collaboration between clients and PTU manufacturer can lead to innovative PTU technology and develop effective products. Using Singapore HDB as a benchmark, equivalent local government agencies such as Syarikat Perumahan Negara (SPN) can play a catalyst role for the adoption of PTU. A policy that mandated full adoption of PTU in PC building for all future public housing should be introduced. CIDB can play the role of a regulatory body for PTU as components of IBS products.

Acknowledgements

We would like to thank Kementerian Pengajian Tinggi (KPT) for providing us the research grant and to Universiti Teknologi MARA (UiTM) (600-RMI/ERGS 5/3 (44/2012)).

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