Mechanisation in Construction – A Malaysian Perspective

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Abstract

Many developing countries have suggested policies to increase mechanisation or prefabrication in their respective construction industries to improve on quality and to increase construction productivity. Mechanisation is widely acknowledged to significantly reduce the reliance of the construction industry on labour; a problem particularly acute in developed economies where skilled labour is increasingly scarce, expensive or both. The trade-off between capital and labour in the production function is clearly illustrated by investments in plant and machinery to produce precast concrete components as compared to employing labour to manually carry out the concreting works in-situ. There is evidence that the low wages of migrant construction labour may preclude the use of the more capital intensive precast concrete technology in developing countries. This paper examines a number of precast systems currently in use in Malaysia and attempts to characterize the factor inputs to support the decision for a semi-mechanised approach. Various constraints against the adoption of precast concrete technology is exposed and discussed. The impact of current labour policy, employment of migrant labour, training, and technology is discussed to identify appropriate policies and incentives that could increase the adoption of mechanised construction systems into the building industry. The current financial incentive for the adoption of mechanised construction system in Malaysia is clearly deficient.

Keywords: Mechanisation, Precast concrete, Malaysia

1. Introduction to Mechanisation

The primary objective of mechanisation or prefabrication in general is to enhance productivity at project, company and industry level, reduce construction time, reduce wastage and improve quality. In many developing countries, it may be proposed as one of a suite of strategies for the construction industry to adopt advanced systems and technologies to enable construction companies to penetrate global markets and export professional services and construction expertise. The introduction of greater mechanisation and prefabrication was also proposed in developed countries to improve the performance of their respective construction industries (NAO, 2001)

In 1999, the Malaysian government initiated a program to introduce prefabrication methods into the construction industry with the aim of improving productivity, quality and safety. An

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eight-year road map to drive the adoption of industrialised building systems (IBS) in order to reduce cost, improve quality and reduce the dependence on migrant labour was introduced in 2003 (CIDB 2003). The main IBS systems proposed include pre-cast concrete, advanced formwork system, steel framing systems, prefabricated timber frames, and block work systems (such as interlocking concrete masonry units). Key targets to be achieved include a gradual reduction of the percentage of migrant workers in the construction industry from the existing level of 75% in 2003 to 15% in 2009, and to increase utilisation of IBS from 30% of total public housing in 2004 to 70% in 2008.

A survey carried out in 2003 indicated that the utilisation of IBS in building construction was extremely low at approximately 15% (Shaari, 2003). Earlier efforts by the government to encourage greater mechanisation in the industry have not gained traction as the construction companies continue to practice conventional methods of in-situ construction. It was reported by Hamid et al. (2008) that only 10% of the completed building projects utilised IBS in 2006; less than 35% of total construction projects used at least one IBS product, compared with the projection of utilising IBS 50% of all building projects by 2006 and 70% by 2008, as recommended in the IBS road map.

Financial incentives such as the abolition of a 0.25% levy on low, and medium cost houses, and a 50% levy reduction for building incorporating more than 50% IBS components were announced in 2003. In 2005, buildings with at least 50% IBS components were exempted from this levy altogether to further encourage adoption of IBS components. In October 2008, the government (Ministry of Finance, 2008) further advanced the full utilisation of IBS in government projects by stipulating that the use of IBS components in public projects must not be less than 70% and that the IBS had to be specified for all public building works.

The aim of this study is to characterise the cost structure of the mechanised and conventional methods of concrete construction in Malaysia to enable construction managers and cost engineers to gain a deeper understanding of the drivers behind the adoption of mechanised building systems in Malaysia. Material and labour costs, as inputs to these forms of construction, are estimated and analysed to identify and recommend appropriate policies and reforms that could promote the greater use of mechanisation in Malaysia or in developing economies in general. The main focus of this paper is to review the extent to which a semi-precast panelised wall system may be utilised for residential construction to replace the conventional reinforced concrete frame with brick infill walls. This semi-precast wall panels may be produced with simple flat moulds and hence a smaller capital investment in plant and machinery. The ability to cater for complex shapes and designs with the use of a cast in-situ column or section is an added advantage for designers and builders who are not well versed with the methods of installing fully precast components. This semi-precast system may allow for the numerous benefits of precast construction such as greater productivity, shorter construction programmes, and improved quality to be achieved at a lower cost compared to a fully precast system.

2. Literature Review

Many developing economies have been reported to be looking towards improving the quality of the products of construction and increasing the productivity of the sector with greater use of mechanisation, prefabrication technology and upgrading the skill of workers. Various precast concrete building systems were created in the early 1970s by construction companies in Europe and the US to cope with increasing demand for housing. High levels of precast utilisation were reported in Denmark, Netherlands, Sweden and Germany in the 1990s (Construction 21 Steering Committee, 1999).

In many countries, prefabrication is applied in the building sector to enhance productivity, improve quality, and cope with a shortage of skilled labour. However, in land scarce Hong Kong, the Housing Authority had advocated the usage of precast concrete methods since the mid-1980s and contributed to major precasting innovations in the industry. Although the Hong Kong Construction Industry Review Committee (CIRC) recommended a wider adoption of prefabrication to improve the quality and to reduce the generation of construction waste, Jaillon and Poon (2009) reported that the private sector still relies heavily on cast in-situ methods of construction involving the use of timber formwork, in-situ concreting, substantial amount of wet trades and bamboo scaffolding. In the same article, Jaillon and Poon reported major advances in precast construction techniques involving volumetric and modular precast elements, and large increases in number of precast elements used in public housing projects. It is interesting to note that incentive schemes were required to encourage the private sector to promote the use of prefabrication such as prefabricated non-structural external wall in the Joint Practice Note 2 (Government of Hong Kong, 2002).

Similarly, precast concrete was introduced in the early 1980s in Singapore, and have resulted in volumetric precast elements being used to provide additional space to existing high rise apartment blocks for the Public Housing Upgrading Program. The main driver for adopting prefabrication technology was to reduce Singapore’s dependence on foreign labour and technology through increased construction productivity. Given the many technical and social constraints of operating in a highly built-up environment, Lau and Tay (1996) reported that prefabrication has improved the efficiency and cost effectiveness of concrete construction while at the same time minimise disruptions for their upgrading programs.

A survey on the use of precast concrete systems in Turkey and the US (Polat, 2010) indicated that American respondents considered restrictions on transportation, poor communication, and the lack of qualified specialised contractors as the three most important barriers to the extensive use of precast concrete systems in the US market. On the other hand, Turkish respondents ranked poor communications amongst parties and the lack structural engineers and specialised contractors as the most important factors in Turkey. Polat suggested that the cost of exploiting labour-intensive methods of construction may be much lower than the cost of implementing advanced technologies such as precast concrete systems in a developing country.

Precast concrete construction in Australia took off in the 1990s when designers and building owners realised that the economics and speed of construction of precast walls and floors were favourable compared to conventional in-situ systems. Benefits of precast flooring such as the long-spanning ability to eliminate conventional concrete beams and therefore the need for formwork during construction was recognised early (National Precast Concrete Association Australia, 2009). Reports of cost savings of 10% of the structure costs by using precast walling and flooring were common.

More recent studies by Lou and Kamar (2012) identified a series of critical success factors for the adoption of mechanisation in construction but had not fully considered the economics of the precast versus cast in-situ option in detail. Elliott (2002) had previously pointed out that precast cannot compete with cast in-situ concrete where the ratio of labour-to-materials or plant is low, say one man-hour pay is less than 1/50 tonne of cut-and-bent rebar, or one man-hour pay is less than 1/500 daily hire of a large mobile crane. This observation clearly lends weight to the discussion on the two opposing policies of greater mechanisation and the continued employment of cheap migrant labour by the construction industry in Malaysia.

3. Methodology

Based on the review presented above, the case for promoting pre-cast technology as a means of mechanisation in a developing country is obvious and has been proven in many instances to bring about immediate gains in productivity, shorter construction periods, improved quality and safety performance, and in specific cases a reduction in overall construction cost. There is clear evidence to indicate that the concept of greater productivity with large-scale precast buildings can be achieved in Malaysia (Lai, 2005).

The relative cost of the cast in-situ, precast and semi-precast systems was examined by either studying the precast manufacturer's bid submitted to the builders or by estimating the cost of each system from published cost guides. The cost comparisons for cast in-situ and precast construction systems were previously conducted by Yong (2010) to assess the effects of wages and material costs on the price of each system. The cost for the semi-precast system was obtained from a precast manufacturer and was valid for projects in the states of Selangor, Perak and the Federal Territory of Kuala Lumpur.

4. Comparison of Construction Costs

Conventional building construction in Malaysia consists of reinforced concrete frames with brick in-fill walls, timber or cold formed metal trussed roof with either clay or concrete tiles, or sheet metal roofs. Concrete is cast in-situ into timber moulds while steel reinforcement is generally fabricated off-site but may still be bent on-site in less developed areas. This method of construction is very labour intensive, involving many wet trades on the work site: carpenters to fabricate the moulds and scaffolding, bar benders to cut, bend and place steel reinforcements, concreters to place, vibrate and finish the concrete, and brick layers to build the walls.

A case study was conducted by Yong (2010) on proposed hostel blocks for an institution of higher learning in the state of Perak, Malaysia where the builder was obligated to construct 4 blocks with the use of precast components while the remaining blocks were to be constructed with conventional in-situ technology. Each hostel block provided a total area of 3,088 square metres of floor space. As both precast and in-situ construction methods were to be employed, it was possible to obtain construction drawings and cost estimates for both these modes of construction. A reinforced concrete structural frame was the proposed structural form with a slab and beam arrangement. The walls were all in clay brick with cement render on both faces. In comparison, the proposed prefabricated system was precast columns, precast inverted-T beams supporting hollow core precast prestressed planks. The hollow core planks were eventually topped up with an 80 mm structural screed.

4.1 Material and Labour Costs for In-situ Construction

A close examination of the builder's cost for cast in-situ slabs indicated that the supply and installation of sawn timber formwork cost approximately RM 7 (12%) whereas the materials (supply and fix concrete and steel reinforcements) cost RM 47, or 88% of the of the total cost of a suspended reinforce concrete slab.

The concrete structure complete with reinforced concrete slabs, beams and columns worked out to a cost of RM 250 per square metre for the cast in-situ option. This conventional construction method necessitated the deployment of a large number of workers to fabricate and install sawn timber formwork and timber props to support the fresh in-situ concrete. Materials now constitute 70% of the total cost with site labour and machinery accounting for 24% and 6%, respectively, as shown in Table 1.

Table 1: Comparison of concrete structure cost

Case Study Items	MALAYSIA Unit Cost (RM, %) (per sq.m)
In-situ Suspended Slab and Beam	RM 250 (100%)
- Supply of Materials and Forms	RM 175 (70%)
- Site Labour	RM 59 (24%)
- Crane Rental	RM 16 (6%)
Precast System (Slab and Beam)	RM 411 (100%)
- Manufacture & Supply of Materials	RM 360 (88%)
- Site Labour	RM 23 (6%)
- Crane Rental	RM 28 (7%)

4.2 Manufacturing and Labour Cost for Precast Construction

In comparison, a fully precast solution with hollow-core slabs and planks, beams and columns, cost RM 411 per square metre, an increase of more than 60% over the cost of the cast in-situ concrete. The supply cost of the manufactured precast components was more than double the supply cost of materials and forms for the cast in-situ option as shown in Table 1. The reduction in site labour from RM59 to RM23 per square metre did little to mitigate this large increase in material supply cost. There was also a significant increase in the cost of crane rental as larger capacity cranes were required for the heavier precast components.

These results indicate two important observations in the cost structure: (a) the supply of precast components is clearly more expensive than the supply and fixing of concrete, steel reinforcement and forms, and (b) the cost of site labour for cast in-situ construction is double that of precast construction. It is clear that the saving in site labour costs cannot compensate for the higher material cost incurred by adopting a fully precast solution. Construction labour in Malaysia consists of migrant workers from neighbouring countries, often working illegally and unregistered, and earning RM 50 and RM 100 per day as unskilled and skilled workers, respectively (CIDB 2009). The presence of these migrant workers in large numbers naturally put downward pressure on the wages for local workers in the same industry leading to a situation where local workers shun working as skilled workers in the construction industry. This observation confirms the assertions by Shaari (2003) that construction firms in Malaysia have continued to adopt labour intensive practices due to the availability of cheap migrant labour instead of investing in plant and equipment for the manufacture of prefabricated components.

5. Semi-Precast Construction

A semi-precast system comprising of a series of precast wall panels that are interconnected with cast in-situ joints or columns were developed in 2002 for residential construction. This method of construction was particularly suited for detached, semi-detached or multi-storey commercial buildings with complex architectural designs. The semi precast system allowed various sizes of wall panels to be erected and fully adaptable to most existing designs and provides sufficient versatility for architect’s design intent to be expressed. The cast in-situ joints or columns are reinforced with conventional reinforcements, provide stability to the building, and eliminate the possibility of ingress of water. These in-situ columns can also act as load carrying members to support heavily loaded beams and allow a hybrid system of conventional and precast systems to be achieved.

Figure 1 shows typical wall panels being cast flat with openings for windows and doors predetermined. The edges of the precast wall panels are cast with a shear key joint providing a strong interlock with the in-situ concrete. This method of casting allows wall panels of various thicknesses to be easily cast. Figure 2 shows the shear keys and continuity bars at the edge of each wall panel. Figure 3 illustrates how a plastic tube is used as backing for the sealant between the wall panel and floor slab. Figure 4 shows a partially completed double storey house built using this semi-precast system. The entire semi-precast panelised system can be demonstrated by the model shown in Figure 5 where the wall panels are shown in grey and the cast in-situ sections are shown in white. The model shown here has a revised shear key for improved vertical shear resistance. The size of the in-situ columns can be easily increased or reduced depending on the structural requirements.

5.1 Manufacturing and Labour Costs

The precast panel walls were generally 100mm or 120mm thick with a layer of mesh reinforcement placed mid-thickness. A local precast manufacturer quoted a price of RM 110 per square metre to supply and install these panels with approximately 30 pieces 3 metre by 3 metre panels to construct a double storey townhouse. These wall panels were 40% more expensive compared to the cost of a conventional 260mm brick wall which comprises RM 38 per square metre for the brick wall and an additional RM 40 for the cement render on both faces (total brick wall = RM 78 per sq.m). The proposed floor slab was a half slab (80mm thick semi-precast slab with an additional 70mm in-situ concrete) supported on the edges of the wall panels. When compared on a per unit basis, the estimated cost for the panel wall system worked out to be RM 42,460 whereas the conventional RC framed with brick wall was costs RM 23,917. The panel wall system was 78% more expensive as tabulated in Table 3.

Figure 1: Precast wall panels at the casting yard

The installation rate of 40 panels per day for a team of installers indicate that the construction schedule can be shortened considerably with the associated cost savings making up for the marginally higher cost of these panels. This semi-precast system has several advantages over a fully precast construction: the panels are connected with wet cast in-situ joints providing full structural connection at a low cost, wet-joints for all floor slabs to prevent water ingress or leakages, ability to allow for large tolerances due to wide cast in-situ joints, able to create complex shapes and configurations to comply with architect's design intents, adaptable to last minute design changes, and excellent quality finishes.

These large prefabricated panels create potential for transportation, handling and temporary stability hazards which must be adequately addressed. Suitable braces must be installed to provide stability during installation. These additional items combine to increase the total cost of the semi-precast system but the overall productivity, quality and schedule benefits far outweigh these costs.

Figure 2: Shear key at the edge of the precast wall panel

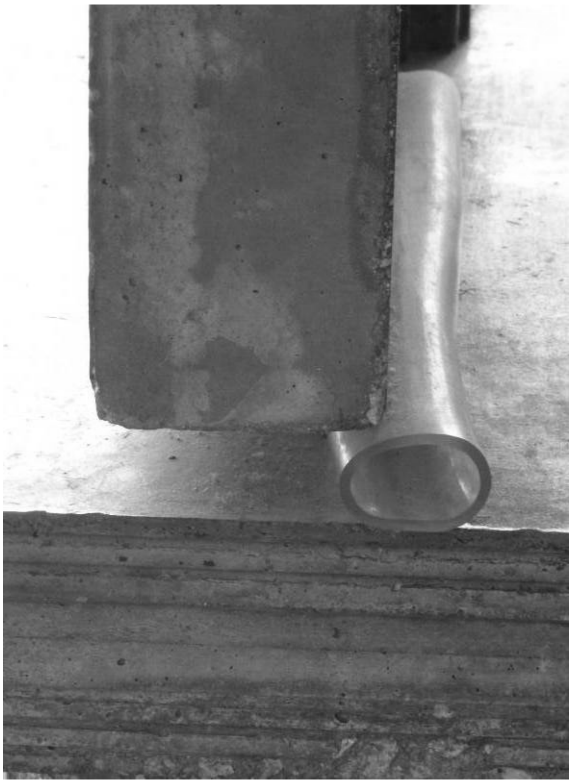

Figure 3: Plastic tube to act as backing for the sealant

6. Discussion

The cost comparison of the semi-precast panelised wall system indicates that it may be feasible for large scale residential housing construction in Malaysia. This system, although not fully mechanised and require substantial labour input to construct the in-situ joints may bridge the path between a conventional cast in-situ construction and the more capital intensive fully pre-fabricated precast slab, beam and column system.

The comparison between conventional cast in-situ against a fully precast solution indicates that the availability of cheap migrant labour in Malaysia generates an artificially low cast in-situ cost that is hard to beat. The cost of precast components is generally higher to cater for the additional capital investment in plant and machinery. If one considers the additional financial risk involved with investing in a precasting plant whilst having to compete for projects on a continuing basis, the total financial viability of the investment may not be feasible.

Table 3: Comparison of Panel Wall and RC Frame with Brick In-fill Wall

Item	Description	Unit	Qty	Rate	Amount
	Double Storey House – Panel Wall System				
1	Panel Wall (external & internal)	cu.m	29.37	1,100.00	32,307.00
2	Column – Car Porch	cu.m	0.08	1,100.00	88.00
3	Beam – Car Porch	cu.m	0.55	1,100.00	605.00
4	Floor Slab (150mm thick)	cu.m	8.60	1,100.00	9,460.00
	Total per unit				42,460.00
	Total gross floor area	sq.m	136.94		310.06
	Double Storey House – RC Frame & Brick Wall				
1	Brick walls	sq.m	244.78	38.00	9301.64
2	Plastering	sq.m	489.56	20.00	9,791.20
3	Column – Car Porch	sq.m	0.08	280.00	22.40
4	Beam – Car Porch	sq.m	0.55	280.00	154.00
5	Floor Slab	sq.m	8.60	280.00	2,408.00
6	Structural Frame	sq.m	8.00	280.00	2,240
	Total per unit				23,917.24
	Total gross floor area	sq.m	136.94		174.65

Figure 4: Completed precast wall panel with in-situ columns

Pan et al. (2007) identified through their survey of the UK's leading house builders that significant barriers against the use of off-site and other modern methods of construction in the house-building industry were considered to be higher capital cost, difficult-to-achieve economies of scale, complex interfacing between systems, lack of ability to freeze the design early on, and the nature of the UK planning system. Sadafi et al (2012), on the other hand, reported that factors preventing the wider application of IBS components in Malaysia were skill shortages and design conflicts were the two most challenging categories for the respondents, followed by installation issues, manufacturing and cost difficulties and lack of knowledge. The disadvantages pointed out by participants included prohibitive cost and maintenance issues and limitations in architectural and detail design.

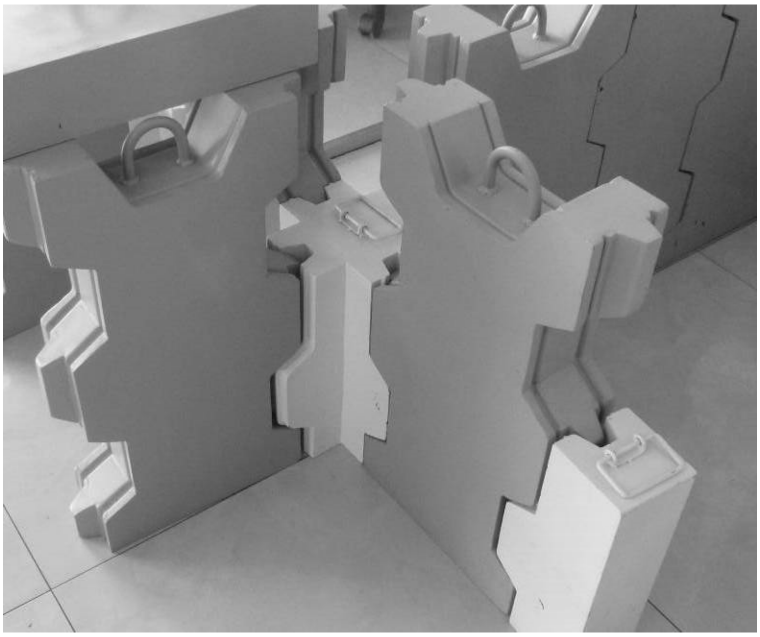

Figure 5: Model showing the precast wall panels (grey) and cast in-situ column sections (white)

Lou and Kamar (2012) also reported that barriers to a greater IBS adoption in Malaysia include the following points: not popular among design consultants; lack of knowledge among designers; the need for mind-set change; the chicken-and-egg dilemma; lack of support and slow adoption from the private sector; lack of push factor from responsible bodies; volume and economy of production in scale to IBS components; monopoly of big boys, limiting opportunities to other contractors; low IBS construction components available in the market; IBS requires on-site specialized skills for assembly of components; lack of special equipment and machinery; lack of local R&D on technologies and testing facilities; mismatch between readiness of industry with IBS targets; insufficient capacity for contractors to secure project; and a sustainability issue, with the government to lead during a downturn.

With the prevailing conditions in Malaysia, it may be worthwhile considering the lower investment in a semi-precast panelised wall system combined with increased utilisation of labour to complete the in-situ connections. This semi-precast system seem to require little specialised skills for the assembly of the wall panels, fully adaptable to complex designs and shapes, and may be able to address many of the concerns mentioned above.

If mechanisation or off-site construction is to make a sustained positive contribution in the marketplace, research is needed to identify the pervading issues that constrain the uptake of this, or conversely, can promote this in a more reasoned and defendable way, especially taking into consideration the existing societal, cultural, and current business models associated with conventional thinking and practice (Arif et.al. 2012). The core finding here is that as far as mechanisation is concerned, the semi-precast system seem to be the logical way forward for Malaysia at this stage of its development and taking into account the large number of migrant workers in the country at this point in time. Once a clearer policy with regards to the reduction of these migrant workers is outlined, the economics of the various systems of construction may evolve leading to a different system being optimal once the number of migrant workers is substantially reduced.

7. Conclusion

The case studies presented here have illustrated the trade-off between capital and labour in the production of reinforced concrete buildings. Construction firms in a developing economy like Malaysia with access to cheap migrant labour can choose to keep construction costs down by utilising greater labour inputs. On the other hand, construction firms in a developed economy, e.g. Australia, with high labour wage rates can easily opt to increase capital input and decrease labour input to minimise costs.

The cost comparisons clearly indicate that the choice of inputs for construction is market driven, and that financial incentives to increase mechanisation in construction must be coupled with a reduction in the supply of cheap migrant labour.

The semi-precast system seem to be the logical way forward for Malaysia at this stage of its development and taking into account the large number of migrant workers in the country at this point in time. Once a clearer policy with regards to the reduction of these migrant workers is outlined, the economics of the various systems of construction may evolve leading to a different system being optimal once the number of migrant workers is substantially reduced.

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