THE ESSENTIAL CHARACTERISTICS OF INDUSTRIALISED BUILDING SYSTEM

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ABSTRACT: In essence, the growing demand for affordable housing, increasing construction costs, lower productivity rate, and heightened concern for energy-efficiency has prompted the Malaysia's construction players to realise the immense benefits of industrialised building system. Despite its advantages, the adoption of industrialised building system has been low in gaining popularity, partly due to lack of awareness and coordination among the relevant parties. Indeed, the need to be competitive in the emerging global market has prompted the local construction players to be more open minded and receptive to novel building technology. In other word, the awareness of current trends and latest innovation in industrialised building system is essential in order to survive in the competitive market. Therefore, this article seeks to enlighten the construction industry players about the characteristics of an industrialised building system as well as its major advantages and disadvantages.

1. INTRODUCTION

In the 7th Malaysia Plan, the country intended to construct about 800,000 units of houses for its population. Indeed, 585,000 units or 73.1% were planned for the low and low medium cost houses. Nevertheless, the achievement are somewhat disappointed with only 20% completed houses reported despite numerous incentives and promotions to encourage housing developers to invest in such housing category (Ismail, 2001).

With the announcement of 8th Malaysia Plan, the country will continue to embark in developing an affordable and sustainable low and medium house. However, the country is facing an uphill task to accomplish the target of 600,000 – 800,000 houses during this period because the conventional building system currently being practiced by the construction industry is unable to cope with the huge demand. Therefore, the former system must be replaced by an industrialised building system (IBS) which has immense inherent advantages in term of productivity, indoor quality, durability and cost (IEM, 2001).

2. DEFINITION OF INDUSTRIALISED BUILDING SYSTEM (IBS)

An industrialised building system (IBS) may be defined in which all building components such as wall, floor slab, beam, column and staircase are mass produced either in factory or at site under strict quality control and minimal on site activities (Rollet, 1986; Trikha, 1999).

Esa and Nuruddin (1998) asserted that an IBS is a continuum beginning from utilising craftsmen for every aspect of construction to a system that make use of manufacturing production in order to minimise resource wastage and enhance value for end users.

Warswaski (1999) expounded that an industrialisation process is an investment in equipment, facilities, and technology with the objective of maximising production output, minimising labour resource, and improving quality while a building system is defined as a set of interconnected element that joint together to enable the designated performance of a building.

Perhaps the most comprehensive definition of IBS was clarified by Junid (1986). He mentioned that an IBS in the construction industry includes the industrialised process by which components of a building are conceived, planned, fabricated, transported and erected on site. The system includes a balanced combination between the software and hardware components. The software elements include system design, which is a complex process of studying the requirement of the end user, market analysis, development of standardised components, establishment of manufacturing and assembly layout and process, allocation of resources and materials and definition of a building designer conceptual framework. The software elements provide a prerequisite to create the conducive environment for industrialised to expand.

Meanwhile, the hardware elements are categorised into three major groups. These includes frame or post and beam system, panel system, and box system. The framed structures are defined as those structure that carry the loads through their beams and girders to columns and to the ground whilst in panel system load are distributed through large floor and wall panels. The box systems include those system that employ three-dimensional modules (or boxes) for fabrication of habitable units are capable of withstand load from various directions due to their internal stability.

3. CLASSIFICATION OF IBS

This section focuses on the classification of IBS published in Malaysia as well as other parts of the world.

Generally, there are four types of building systems currently available in Malaysia according to Badir-Razali building system classification (Badir et al. 1998), namely conventional, cast in-situ, prefabricated and composite building systems is shown in Figure 1.0. Each building system is represented by its respective construction method which is further characterised by its construction technology, functional and geometrical configuration. It is reported that currently at least 22 companies supplying building system in Malaysia (Badir et al.2002). Plate 1.0 – 10 show the various building available in Malaysia.

Warszawski (1999) asserted that the building system could be classified in different ways, depending on the particular interest of their users or producers. Such classification use construction technology as a basis for classifying different building systems. In this manner four major groups can be distinguished namely, system with (1)timber, (2)steel, (3)cast in situ concrete, and (4)precast concrete as their main structural and space enclosing materials. These systems can be further classified according to the geometrical configuration of their main framing components as follows (1)linear or skeleton (beams and columns) system, (2)planar or panel systems, and (3) three dimensional or box systems.

Majzub (1977) expounded that the relative weight of components should be used as a basis for building classification is presented in Table 1.0. The factor of weight has significant impact on the transportability of the components and also has influence on the production method of the components and their erection method on site. The classification by weight also has the advantage of distinguishing between the various basic materials used in the production of component which by itself could determine the characteristic of the system under study. However, Majzub's classification method is found to be inadequate to incorporate other building system flourish recently. One of the distinct example is the interlocking load bearing blocks which was the brainchild of a group of researchers in Universiti Putra Malaysia. This new building system cannot be categorised according to frame, panel or even box system. On the other hand, the composite system that combines two or more construction method cannot also be categorised under the Majzub's classification. Hence, the classification needs to be updated to reflect the current technological advancement.

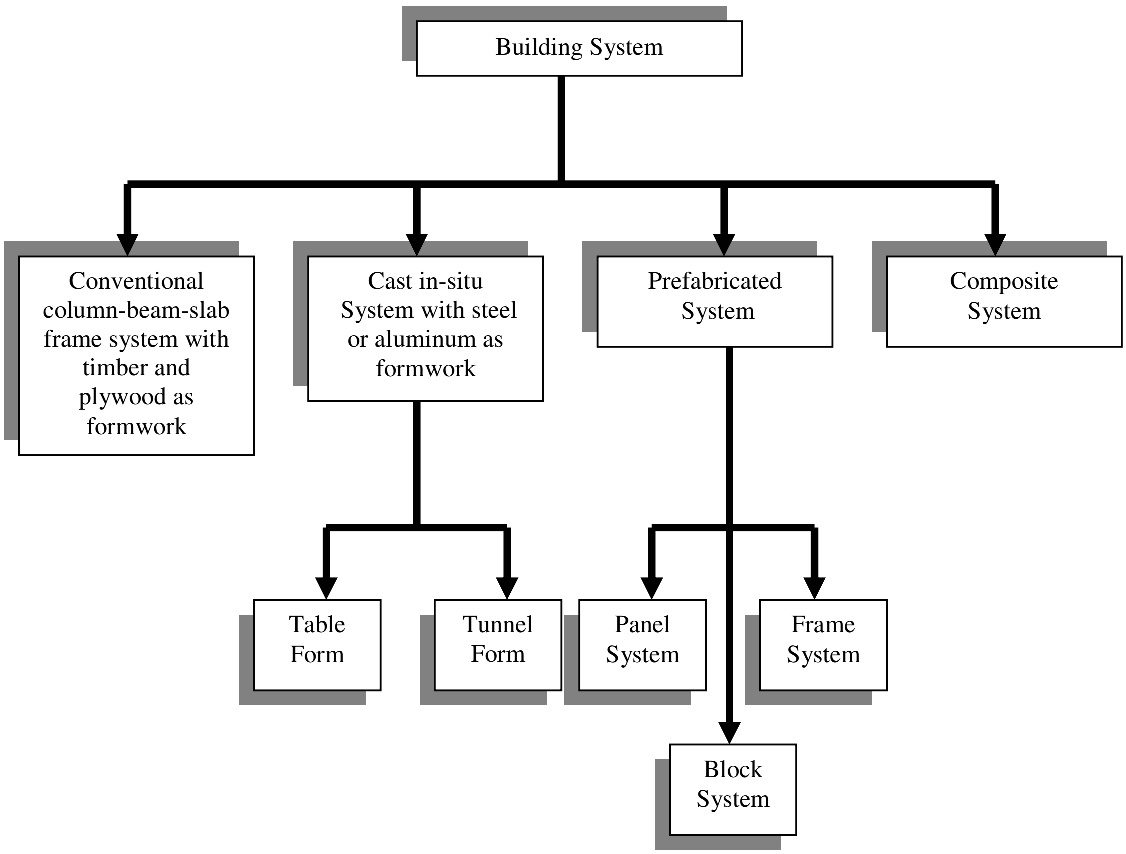

Fig. 1 Type of building system in Malaysia

No	General System	System	Production Material
1	Frame system	Light weight frame	Wood, light gage metals
		Medium light weight frame	Metal, reinforced plastics, laminated wood
		Heavy weight frame	Heavy steel, concrete
2	Panel system	Light and medium weight panel	Wood frame, metal frame, and composite materials
		Heavy weight panel (factory produced)	Concrete
		Heavy weight panel (tilt up – produced on site)	Concrete
3	Box system (modules)	Medium weight box (mobile)	Wood frame, light gage metal, composite
		Medium weight box (sectional)	Wood frame, light gage metal, composite
		Heavy weight box (factory produced)	Concrete
		Heavy box (tunnel produced on site)	Concrete

Table 1.0: Building system classification according to relative weight of component (Majzub, 1977).

4. ESSENTIAL CHARACTERISTICS OF IBS

It is plausible to review the prerequisite characteristics underlining the successful implementation of industrialised building system. Each of them is briefly discussed below.

4.1 Closed System

A closed system can be classified into two categories, namely production based on client's design and production based on precaster's design. The first category is designed to meet a spatial requirement of the client's, that is the spaces required for various functions in the building as well as the specific architectural design. In this instance, the client's needs are paramount and the precaster is always forced to produce a specific component for a building. On the other hand, the production based on precaster's design includes designing and producing a uniform type of building or a group of building variants, which can be produced with a common assortments of component. Such building includes school, parking garage, gas station, low cost housing, etc. Nevertheless these types of building arrangement can be justified economically only when the following circumstances are observed (Warszawski, 1999).

a) The size of project is large enough to allow for distribution of design and production costs over the extra cost per component incur due to the specific design.

b) The architectural design observes large repetitive element and standardisation. In respect to this, a novel prefabrication system can overcome the requirement of many standardised elements by automating the design and production process.

c) There is a sufficient demand for a typical type of building such as school so that a mass production can be obtained.

d) There is an intensive marketing strategy by precaster to enlighten the clients and designer the potential benefit of the system in term of economics and noneconomic aspects.

4.2 Open System

In view of the limitations inherent in the closed system, an open system which allows greater flexibility of design and maximum coordination between the designer and precaster has been proposed. This system is plausible because it allow the precaster to produce a limited number of elements with a predetermined range of product and at the same time maintaining architectural aesthetic value.

In spite of many advantages inherent in an open system, its adoption experiences one major setback. For example, joint and connection problem occur when two elements from different system are fixed together. This is because similar connection technology must be observed in order to achieve greater structural performance.

4.3 Modular Coordination

Modular co-ordination is a co-ordinated unified system for dimensioning spaces, components, fitting, etc. so that all elements fit together without cutting or extending even when the components and fittings are manufactured by different suppliers (Trikha, 1999).

The objectives of modular co-ordination are:

a) to create a basis upon which the variety of types and sizes of building components can be minimized. Through a rationalised method of construction, each component is designed to be interchangeable with other similar ones and hence, provide a maximum degree of freedom and choice offered to the designer. This can also be accomplished by adopting a relatively large basic measurement unit (basic module) and by limiting the dimensions of building components to a recommended preferred sizes (Warszawski, 1999).

b) to allow for easy adoption of prefabricated components to any layout and for their interchangeability within the building. This is achieved by defining the location of each component in the building with reference to a common modular grid rather than with a reference to other components (Warszawski, 1999).

The modular co-ordination for building component apply the basic length unit or module of M=100cm. This allows the designer to apply this size or its multiple in the production of building components. Although this concept seems to be easy for adoption, its application involves a great degree of coordination and adjustment in the manufacturing process and the interfacing aspects of components.

4.4 Standardisation and Tolerances

For accomplishing the requirement of modular co-ordination, all components need to be standardised for production. Such standardisation of space and elements need prescribing tolerances at different construction stages such as manufactured tolerances, setting out tolerances, and erection tolerances, so that the combined tolerance obtained on statistical considerations is within the permitted limits (Trikha, 1999).

Production resources can be used in the most efficient manner if the output is standardised. Then the production process, machinery, and workers' training can be best absorbed to the particular characteristics of the product.

4.5 Mass Production

The investment in equipment, human recourses, and facilities associated with an industrialisation can be justified economically only when large production volume is observed. Such volume provides a distribution of the fixed investment charge over a large number of product units without unduly inflating their ultimate cost (CIDB Singapore, 1992).

4.6 Specialisation

Large production output and standardisation of precast elements allow a high degree of labour specialisation with the production process. The process can be subdivided into a large number of small homogenous tasks. In such working condition, workers are exposed to their work repetitiously with higher productivity level (Warszawski, 1999).

4.7 Good Organisation

High production volume, specialisation of work, and centralisation of production requires a efficient and experiences organisation capable of a high level of planning, organising, coordination and control function with respect to production and distribution of the products (Warszawski, 1999).

4.8 Integration

In order to obtain an optimal result, a high degree of coordination must exist between various relevant parties such as designer, manufacturer, owner, and contractor. This is achieved through an integrated system in which all these functions are performed under a unified authority (Warszawski, 1999)

4.9 Production Facility

The initial capital investment for setting up a permanent factor is relatively experience. Plant, equipment, skilled worker, management resources need to be acquired before production can be commenced. Such huge investment can only be breakeven if there is sufficiently demand for the products. On the other hand, a temporary casting yard or factory can be established at the project site in order to minimise the transportation costs (Peng, 1986).

4.10 Transportation

It is found that casting of large-panel system can reduce labour cost up to 30 percent. However, these cost savings are partially offset by the transportation costs. The transportation of large panels is also subject to the country's road department requirement. These limitations must be taken into consideration when adopting a prefabrication system (Peng, 1986).

4.11 Equipment at Site

For the purpose of erecting and assembling precast panels into their position, heavy crane is required especially for multi-storey building. It is therefore important to incorporate this additional cost when adopting a prefabrication system (warszawski, 1999).

5. BENEFITS OF IBS

Industrialised building system has the following benefits when compared to the conventional construction method.

a) The repetitive use of system formwork made up steel, aluminium, etc and scaffolding provides considerable cost savings (Bing *et al*. 2001).

b) Construction operation is not affected by adverse weather condition because prefabricated component is done in a factory controlled environment (Peng, 1986).

c) Prefabrication takes place at a centralised factory, thus reducing labour requirement at site. This is true especially when high degree of mechanisation involved (Warszawski, 1999).

d) An industrialised building system allows for faster construction time because casting of precast element at factory and foundation work at site can occur simultaneously. This provides earlier occupation of the building, thus reducing interest payment or capital outlays (Peng, 1986).

e) An industrialised building system allows flexibility in architectural design in order to minimise the monotony of repetitive facades (Warszawski, 1999).

f) An industrialised building system provides flexibility in the design of precast element as well as in construction so that different systems may produce their own unique prefabrication construction methods (Zaini, 2000).

g) An industrialised building system component produces higher quality of components attainable through careful selection of materials, use of advanced technology and strict quality assurance control (Din, 1984).

6. SHORTCOMINGS OF IBS

The adoption of IBS is not without its limitations. Below discuss the shortcoming of an IBS system.

a) An IBS system can only be acceptable to practitioners if its major advantageous can supersede the conventional system. However, up to date, there is inadequate corroborative scientific research undertaken to substantiate the benefits if IBS system. It is therefore, arguable that the implementation of IBS is particularly hindered by lack of scientific information (Trikha, 1999).

b) Standardisation of building elements face resistance from the construction industry due to aesthetic reservation and economic reason. One good example of this is when a 300mm thick modular standardised floor slab has to be used although a 260mm thick floor slab can achieve the similar structural performance. This results wastage of material (Kampempool and Suntornpong, 1986).

c) The selection of a new IBS has been hindered by lack of assessment criteria set by the approving authorities. This phenomenon has been even more detrimental to the development of an indigenous IBS. With such reason, absence of assessment criteria has been identified as the most important inhibitor to the introduction of IBS system in the country (Trikha, 1999).

d) Despite an intensive marketing strategy since 1980's in Malaysia to introduce modular co-ordination, its acceptance has received poor responses for the building industry. As a result, even partial introduction of IBS such as lintels, staircase, etc has not been possible (Trikha, 1999).

e) A general decline in demand and volatility of the building market for large public housing projects in most developed countries make an investment in IBS more risky when compared with the conventional labour intensive methods. This reason is substantiated by a cheap imported labour in several European countries (Warszawski, 1999).

f) The industrialisation of building process which emphasis is on the repetitiveness and standardisation cause monotonous "barracklike" complexes that very often turned into dilapidated slums within several years. This shortcoming is further reinforced by production defects in building components which are quite frequent in the initial stages of prefabrication. Such defects resulting from lack of technical expertise and poor quality control cause aesthetic and functional faults, such as cracks, blemishes, moisture penetration, and poor thermal insulation in completed buildings (Warswaski, 1999).

g) Prefabricated elements are considered inflexible with respect to changes which may be required over its life span. This may occur when small span room size prefabrication is used (Warszawski, 1999).

h) At university level, students are less exposed to technology, organisation and design of industrialised building system. The academic curriculum seldom includes courses that incorporate a thorough and methodological manner, the potential and the limitations associated with industrialisation in building. As consequences, there is a natural tendency among practioners to choose conventional methods perhaps with occasional utilisation of single prefabricated elements (Warszawski, 1999).

i) The weakness of existing industrialised building system is still in its cumbersome connections and jointing methods which are very sensitive to errors and sloppy work. Also, standardisation of joint and connection detail may impede the evolution of new technology (Din, 1984).

j) An adaptation of standardisation requires a tremendous education and training effort. Hence, requires an initial immense investment cost. This is cited as one of the greater hindrance to the use of modular coordination (Warsawski, 1999).

7. Potential Growth of IBS

A study was carried out in Israel comparing the economic benefits between the IBS and conventional construction method in 1984. The result findings indicated that the use of IBS components brought considerable savings in site labour up to 70% while the total construction cost amounted to 5-8% of the compared conventional method (Warszawski, 1999). In addition to that, in Singapore, the use of fully prefabricated system provides labour saving of 46.5% as compared to the conventional methods, thus reducing the dependency on foreign (Cheong, 1997). On the hand, the construction of "Bayshore Condominium" in Singapore indicated that the construction cycle time for each floor using the conventional method was 22 days, which is 14 days more than using the prefabricated method based on similar site constraints and management experiences (Cheong, 1996).

Clearly, having described the examples mentioned above, the benefits offered by an IBS are immense and plausible. So, if viewed positively, there is a great potential for IBS to grow in the country. Nevertheless, the commitment and cooperation between the public and private sectors is paramount in ensuring the successful implementation of building industrialisation.

Also, the Malaysia's construction workforce is aging and shrinking as progressively fewer young enter the industry. This phenomenon prompts the industry to rely heavily on foreign workers. If, the demand for labour remains the same and the supply decrease, construction cost will increase and eventually pass on this cost to the home buyers. Hence, the industrialisation of building construction method and the evolution of construction technology are inevitable and plausible.

8. CONCLUSIONS

This paper has focused on some broader issue that could affect the take-up of industrialised building system (IBS) in Malaysia. Despite various economic and non-economic benefits of IBS, its utilisation is not well accepted by the construction players. Therefore, various informative programs such as seminar, colloquiums, and, conferences or perhaps the collaboration with the public universities should be devised to enlighten the private sector as well as the public sector.

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