Industrialised Building Systems (IBS): It's attribute towards enhancing sustainability in construction

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Abstract

Greater Cairo Region (GCR) is the largest metropolitan area on the African continent and the Arab world. It accommodates 16.1 million inhabitants representing 19% of Egypt's total population. Today, critical urban issues arise from the sheer size of the metropolis GCR and from its population density. Traffic congestion is on the top of these issues. This research focuses on the significant role that hubs (Multi Modal Platforms) can play in enhancing the GCR transportation infrastructure. Ramses square area in Cairo is selected to demonstrate a systematic solution to solve the problems resulted from the interference of multi uses activities and transportation modes in central areas of capital cities.

Keyword: Greater Cairo Region (GCR); Hubs; Urban Dynamics; Transportation

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1.0 Introduction

There are now clear signs that sustainability issues are increasingly of central concern to business. Once regarded as radical thinking, it is now fast becoming main stream and is increasingly recognized as beneficial to humankind, business and the environment. While the construction industry is an economically strategic sector, it is also regarded as labour intensive and a huge contributor to pollution. Thus, in this era of rapid urbanization and population growth, intensive competition for scarce resources in an increasingly competitive market, the construction industry's efforts at addressing these challenges and improving its reputation requires innovative thinking that goes "beyond the fence". Essentially, it has to minimize the use of natural resources and emissions of waste so as not to jeopardize the needs of future generations.

Sustainable construction is defined as the creation and responsible maintenance of a healthy built-environment based on resource efficiency and ecological principles. These principles include reusing, reducing and recycling resources, protecting the environment, applying life cycle economies and creating quality built-environment.

IBS is a construction process that utilizes techniques, products, components or building systems involving prefabricated components and on-site installation (CIDB, 2003). The adoption of IBS is strongly advocated in the Malaysian construction industry to reduce construction time as well as the industry's dependence on foreign labour. The Construction Industry Master Plan 2006-2015 (CIMP, 2006) highlighted one of the challenges facing the Malaysian construction industry as the availability of cheap foreign labour which encourages labour-intensive construction methods over the use of more innovative methods.

This hampers the industry's efforts to increase productivity and quality in the long run. Accordingly, the CIMP has recommended the industry to extend the use of modern construction methods and information technology. The wider adoption of IBS is also encouraged as a means to overcome environmental issues associated with conventional methods.

2.0 Literature Review

The benefits attributed to IBS adoption are numerous and well documented, providing impetus for its implementation in the industry. Interlocking blocks and prefabricated systems are among the various types of IBS used. Thanoon*et al*. (2004) developed interlocking load bearing blocks and demonstrated that its application reduced the overall construction cost because it required minimum labour. From the showcased residential building, it showed that the walls can be constructed using minimal unskilled labour. The reasonable weight and the simple shape of the blocks make the system worker-friendly. No formwork was used in the construction of the entire house. Nasly and Yassin (2009) developed interlocking blocks using sustainable raw materials i.e. rice husk ash (RHA) as cement replacement, palm oil fly ash (POFA) and recycled construction waste aggregates. Applying these to a pilot house resulted in cheaper building costs due to faster completion time, fewer skilled workers and lesser wastage. Thus, sustainability can be achieved by using RHA as cement replacement and the use of POFA as aggregates.

Tam *et al.* (2007a), Jaillon*et al*. (2009) and Jaillon& Poon (2010) made it clear that prefabrication provides an effective solution to problems of on-site waste generation. Specifically, it has the potential of reducing long term construction cost even if the initial construction cost may be higher.Prefabrication is an effective waste minimization model for general projects, public housing, private residential and commercial projects in the construction industry.The adoption of prefabrication may also enhance environmental awareness through education and training undertaken by the government.

Jaillon*et al.* (2009)'s study on the waste reduction potential of using prefabrication in building construction in Hong Kong revealed that construction waste reduction was one of the major benefits when using prefabrication compared to conventional construction. With average waste reduction reaching 52%, this implies that a wider use of prefabrication could considerably reduce waste generation, thus alleviating the burdens associated with its management. Other researches on IBS show that it enhances productivity, improves quality, and employs fewer skilled workers (Gibb, 1999; Warszawski, 1999).

The focus of the literature in this area has concentrated largely on reviews of the benefits of the interlocking block system or prefabrication techniques in residential buildings.Yet, it has left the broader question of how both methods differ from more conventional methods of construction relatively unexplored. The conventional building methodis defined as components of the building that are pre-fabricated on site through timber or plywood formwork installation, steel reinforcement and cast in-situ. Conventional buildings are mostly built of reinforced concrete frame**s** with the traditional construction method using wooden formwork.

By responding to this gap, this study intends to investigate and report on the benefits gained from the application of interlocking blocks systems and prefabrication in residential building compared to the conventional method. It provides a comparative study between the application of IBS and conventional methods of construction. The overall objectives are to review the construction techniques of interlocking blocks and prefabricated systems, and to assess their benefits attributed in terms of time, cost, quality, waste minimization and labour requirement.

3.0 Methodology

The two dominant research methods in the social sciences involve qualitative and quantitative study. As quantitative research focuses on generalizing findings to a wider population, it usually involves the design of highly structure questionnaires which are then circulated to a large group of respondents. In this study, mainly qualitative methods were used.

Firstly, four case studies were carried out on completed residential building projects aimed at analyzing their cost, time and quality. Next, face-to-face interviews were conducted with the engineers and project managers involved in all the four selected case studies. This was done on site to capture and validate some of the information that could not be found in the content analysis of documents from the contractors in terms of quality, labour usage and the duration of specified work packages. Additionally, on-site observations were also conducted to evaluate the site environment and determine the type of waste generated from the application of the construction techniques studied.

The case studies for interlocking blocks were based on two low-rise residential projects built on campus. Project 1 is a 5-storey female residential hostel using interlocking block system with a Gross Floor Area (GFA) of 6840m^2 commanding a contract sum of RM8, 072,810.34 within a construction period of 9 months. Project 2 is a 4-storey male residential hostel with a GFA of 6843.14m^2 using conventional construction methods, commanding a contract sum of RM8, 998,557.80 within a construction period of 14 months.

The case studies for the prefabricated buildings were based on the construction of two packages of 70 units of 2-storey semi-detached houses. One package was constructed using conventional methods while the other used prefabricated components. Initially, both packages were designed for conventional construction. When the contract was awarded, the contractor proposed to construct Package 1 (34 units) using the prefabricated system and Package 2 (36 units) using the conventional method. This was agreed by the client. No design changes were made to accommodate the change in construction method. The Gross floor Area (GFA) for each unit was 348.39m^2. The total contract sum for both packages was RM24, 637.00; the construction cost for Package 1 was RM12, 551,472.21 and Package 2 was RM12, 085,527.79. The interview with the contractor revealed that the preparation and pre-casting of the panel system for the entire units took three (3) months.

4.0 Results and Discussion

Based on the methodology that had been chosen, the result of the analysis revealed the following findings.

4.1 Construction Techniques

Interlocking blocks are different from conventional bricks in that they do not require mortar during bricklaying. This speeds up the process of building walls and requires fewer skilled labours as the blocks are laid dry and locked into place.Interlocking blocks are produced with hollow centres to reduce weight, avoid seepage and improve insulation. The holes inside the concrete blocks allow reinforcement bars and concreting to run vertically through the blocks to compensate for the lack of tensile strength.Once a section of the wall was built, grout holes were filled with a lean cement mixture to seal the wall and making it permanent.The amount of grout used was calculated to be less than 7.5% of the mortar used in conventional masonry (Nasly& Yassin, 2009).The floor slab and roof beams are of conventional construction.

The prefabricated system used precast concrete wall panels manufactured at the pre-casting yard or factory where quality control is monitored and deemed more efficient than the conventional method. The floor slab and roof beams were of conventional construction. The use of precast wall panels reduces material storage on site and site labour requirements due to the simplified construction method. Further, the pre-casting work can be carried out at any time since it is not influenced by weather. Thus, the quality and progress of the works can be monitored and controlled appropriately.

4.2 Utilization of Manpower and Equipments

Tables 1 and 2 list the labour and plant needed for both construction methods. The findings revealed that the construction method with interlocking block and prefabricated elements engaged six (6) to ten (10) workers per day, while the conventional method employed ten (10) to fifteen (15) workers per day including bricklayers, plasterers, painters, bar-benders, carpenters and concretors. The prefabricated system utilized minimum labour due to the elimination of major elements such as columns and beams, while the conventional method is labour intensive for superstructure works such as formwork, rebar fabrication and installation, concrete placement, and dismantling formwork to columns and beams. The findings demonstrated that conventional methods require more labour and plant for construction than the interlocking blocks. The IBS was able to reduce the number and types of labour employed, thus resulting in the reduction of the overall construction cost. Once excessive labour is reduced, this can ultimately lead to reducing the nation's dependence on foreign labour.

Table 1: Comparison between the type of labour and plant used for Interlocking Blocks and the Conventional Method

Items	Interlocking block Method	Conventional Method	Comments
Type of labour	Semi-skilled, supervisor	Concretor , bricklayer, plasterer, painter, carpenter, bar bender, tiler, plumber, drain layer , general labour	**Interlocking block:** superstructure and walls only involved semi-skilled workers **Conventional method:** more skilled workers such as barbender, carpenter, bricklayers, plasterer, painter and concreter.
Labour per day	2 or 3 teams in one day, a supervisor, and six or seven semi-skilled workers for laying blocks.	3 skilled workers, 4 general workers for each work/trades on site	**Interlocking block:** The same team is involved for each element from start to finish **Conventional method:** needed a variety of traders and teams for each element from start to finish
Type of plant & equipment	crane	Concrete mixer, bar bending, bar cutting, vibrator set, crane	**Interlocking block**: less number of plants, only for constructing load bearing walls for the superstructure **Conventional method:** More plant is needed for the construction of each building element

Table 2: Comparison on type of labour and plant for Prefabricated Elements and the Conventional Method

Items	Prefabricated	Conventional Method	Differences
Type of labour	Semi-skilled, crane operator, supervisor	Concretor, bricklayer, plasterer, carpenter, bar bender, general labour	**Prefabricated elements**: Semi-skilled workers **Conventional method:** involves skilled workers such as barbender, carpenter, bricklayers, plasterer, painter and concreter
Labour per day	2 or 3 teams in one day: a supervisor, a crane operator and two or three semi-skilled workers for erection.	3 skilled workers, 4 general workers for each work/ trade on site.	**Prefabricated elements:** The same teams for the major construction process **Conventional method:** A variety of traders and teams for each element from start to finish
Type of plant & equipment	Crane	Concrete mixer, bar bending, bar cutting, vibrator set, crane.	**Prefabricated elements:** Less number of plants due to only constructing load bearing walls **Conventional method**: More plant is needed for each building element

4.3 Cost Savings

It is commonly acknowledged that the use of precast concrete systems enable lowering of overall project cost. Polat (2008) noted that 93% of the contractors interviewed claimed they achieved cost savings when they used the precast concrete system, and only 7% did not. This finding is promising as Arditi*et al.* (2000) had earlier found that only 42% of contractors claimed they achieved cost savings with the precast concrete system.

Tables 3 and 4 show the comparisons of the construction costs for interlocking blocks, the prefabricated system, and the conventional method. As shown in Table 3, the cost/m^2 for interlocking blocks is RM 1,180.24 while that of the conventional method is RM1, 314.97. Evidently, the cost/m^2 for interlocking blocks is reasonably lower than that of the conventional method – a savings of 10%. This stems from the fact that the interlocking blocks double as load bearing walls, thus doing away with the construction of the structural frame work. This results in the reduction of employment of labour, overall completion time and building materials, hence reducing overall construction cost.

Table 4 shows the construction cost/m^2 of prefabricated and conventional methods, indicating that the cost/m^2 of the prefabricated building is slightly higher than that of the conventional method. The cost/ m^2 difference is RM 96.02 (10%). This may be attributed to the need for piling works to support the precast panels. Nevertheless, the prefabricated panel proved to be better in quality, strength, and finish.

Table 3: Comparison of Cost/m2 GFA for Interlocking Blocks and the Conventional Method

ITEM DESCRIPTION	CONVENTIONAL METHOD (RM/m2)	INTERLOCKING BLOCK (RM/m2)
Preliminaries	77.89	77.92
Piling	72.15	72.19
Building Works	821.86	761.36
External & Infra Works	15.32	159.39
Mechanical Works & Electrical Works	168.05	206.07
Provisional Sum	15.03	19.22
TOTAL	**1,314.97**	**1,180.24**

Table 4: Comparison Cost/m2GFA for Prefabricated Systems and the Conventional Method

DESCRIPTION	CONVENTIONAL METHOD (RM)	PREFABRICATED (RM)
Preliminaries	36.47	78.12
Piling	-	23.61
Building Works	688.71	703.99
External & Infra Works	64.74	71.17
Mechanical Works	53.78	54.69
Electrical Works	49.58	49.33
Provisional Sum	21.58	22.88
SKB Works	48.68	55.84
TOTAL	**963.60**	**1,059.62**

4.4 Time Saving

Table 5 shows the comparison in construction periods for interlocking blocks, prefabricated systems and the conventional method. The construction period required to construct a 5-storey hostel building using interlocking blocks was nine (9) months compared to 14 months using the conventional method – a shorter period by five months. Thus, with the interlocking block system, the overall construction period can be potentially reduced by 35%.

A comparison on the construction period between prefabricated systems and the conventional system shows no significant improvement in time. This was partly due to late decision making to use the prefabricated system – it was made after the contract was awarded and on the initiation of the contractor himself. Upon deciding, the contractor required three (3) months slag time to prepare and pre-cast the wall components. Despite the set-back on start time, the prefabricated system was able to complete the job on time according to the original contract. These findings suggest IBS offers savings in the overall construction completion time.

Table 5: Duration of Project Completion for

Type of construction	Construction period (month)	D.L.P. (month)	S.O.M.G.D. (day)	C.C.M.G.D. (month)
Conventional Method	14	12	14	3

Interlocking Blocks	9	12	14	3

Type of Construction	Construction period (month)	D.L.P. (month)	S.O.M.G.D. (day)	C.C.M.G.D. (month)
Conventional Method	18	18	14	3
Prefabrication	18	18	14	3

Legend:
D.L.P - Defect Liability Period
S.O.M.G.D – Schedule of Making Good Defect
C.C.M.G.D – Certificate Completion Making Good Defect

The findings suggest that the use of IBS for low-rise residential buildings offers shorter construction time. Prior researches have arrived at similar conclusions: the use of interlocking blocks and prefabrication reduces overall construction period (Nasly and Yassin, 2009; Jaillon and Poon, 2009; Thanoon*et al.,* 2004).

4.5 Improved Productivity and Quality

Interlocking blocks and prefabricated systems are produced in special moulds. The compaction is done mechanically, depending on the type of block, materials used, required quality and available resources. The blocks and prefabricated components are manufactured at the building site or on a larger scale in a production yard. The mixing, placing and curing are carried out under factory-controlled conditions, resulting in higher quality products through the process of controlled prefabrication. This is in contrast to the conventional method where the production is exposed to uncertain weather and consequent damage.The blocks and prefabricated components also tested and have better fire resistance than conventionally constructed building.

4.6 Waste Minimization and Reduction

The highest waste-producing building work components are formwork, packaging and protection, finish work, masonry work, scaffolding, concrete work, material handling and hoarding. This indicates that waste generation on sites may mostly be related to the construction method, the availability of on-site sorting and recycling facilities for construction waste, and the level of education and training of the workers (Jaillon*et al.,* 2009). From observation on the majority of construction sites in Malaysia, it was found that temporary works generated the highest amount of waste on construction sites. This is due to the adoption of traditional cast in-situ concrete, using timber formwork works.

The finished surfaces of interlocking blocks and prefabricated systems are smooth and even ready to receive tiles or other finishes. This totally eliminates plastering. Wet trades such as concreting, masonry, plastering and tiling on site were considered as the second major waste generation activities. A study by Osmani*et al.* (2006) demonstrated that the waste generated from cutting materials were the major cause of wastage during the construction phase. This corresponds with the findings of Tam *et al.,* (2007a, 2007b) that concluded the use of standardized building components such as prefabrication reduces waste generation. Tam *et al.,* (2007a) confirmed that waste reduction from plastering can be achieved by almost 100% after adoption of prefabrication. It was also argued that tiling can be directly applied to concrete surfaces after formwork striking and for painting; only a layer of 1-2mm thick skim coat is required instead of 15-20mm thick plastering.

According to Jaillon*et al.,* (2009), waste also arises as a result of design concepts and decisions. Previous researches showed that last minute changes due to client requirements and design changes were the major causes of waste during design stages (Poon *et al.,* 2004; Osmani*et al.,* 2006). In view of this, prefabrication appears to be an advantageous solution to tackle the major causes of waste during both design and construction stages.

4.7 Savings in Construction Materials and Energy

Saving construction materials on site will result not only in savings of natural resources, but also saving energy resources, fossil fuels, nuclear and hydroelectric facilities, all used in the mining, manufacturing, transportation and installation of construction materials. The need for timber, largely consumable in the conventional in-situ construction process for temporary staging, bracing, forming, etc will be reduced substantially and thus contribute to the preservation of our forest and wildlife.

Furthermore, using less construction materials will lessen building dead loads, save structural framing and foundation support materials as well as the overall construction cost. Material reduction will also have a positive impact on traffic on the highways during the construction process and thus reducing highway maintenance cost and the associated material and energy for repairs. Savings in materials can be observed in the adoption of prefabrication and interlocking block systems where the construction of structural framing can be eliminated. This will lead to the reduction in the usage of cement, sand, steel and timber for structural framing and finishes, thus reducing the overall construction time and cost.

5.0 Conclusion

The study assesses the use of prefabrication and load bearing interlocking blocks in building and its impact on time, cost, quality, waste minimization and labour usage compared to the conventional cast in-situ construction method. The case studies showed that the use of interlocking blocks and prefabrication system provides significant advantages such as reduction in construction time by 35%, less skilled labour requirement and construction cost savings of more than 10%, and improved quality control. Early decisions on the use of IBS can bring in the said benefits.

The use of IBS in the form of prefabrication systems and interlocking blocks can provide better solutions to on-site waste generation. Long term costs can be reduced even if the initial cost is higher. A wider application of interlocking blocks and prefabrication techniques in building construction could significantly reduce the use of construction materials such as cement, sand, timber, steel, and formwork due to fewer amounts of framing and foundation works. Their adoption was also capable of reducing energy consumption and construction waste generation, hence alleviating the burdens associated with its management and disposal. The results of the case studies provide positive views in the application of prefabrication systems and interlocking blocks for future projects. It was also suggested that the adoption of prefabrication and load bearing interlocking blocks systems should be integrated at the earliest design stage to optimize the benefits of its adoption.

The findings of the research has also provided data that confirm the advancement of IBS can contribute to significant economic and environmental benefits, particularly in housing development. Further studies should be conducted to assess a wider range of building types and evaluate the quantities of various building materials saved by adopting IBS related building systems. Fundamentally, the evidence suggests that sustainable production involves businesses contributing to environmental quality through the efficient use of natural resources, the minimization of waste and the optimization of products and services. The construction industry can take a leadership role in promoting sustainable patterns of production and creating environmental awareness through IBS adoption. The industry can also work towards these goals through education and training.

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