Volume: 7 | Nomor: 1 | April 2018 | ISSN: 1907-4247 (Print) | ISSN: 2477-4863 (Online) | Website: http://cantilever.unsri.ac.id

Cantilever Jurnal Penelitian dan Kajian Bidang Teknik Sipil

BUILDING INFORMATION MODELING BASED COMPARISON STUDY ON ENERGY INFRASTRUCTURE PROJECT USING INDUSTRIALIZED BUILDING SYSTEM AND CONVENTIONAL METHOD

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Abstract

Construction industry in Malaysia has moved forward into technology-driven where its transition is in progress from conventional method to a more advanced and mechanized system known as the Industrialized Building System (IBS). This paper presents economic aspects of using Interlocking Hollow Brick System (IHBS) in the construction of the Primary Distribution Sub-station (PPU) of energy infrastructure asset development. The main objective is to compare the difference in construction method between IHBS with the conventional method. The study is focused on comparing various aspects of using interlocking block system in terms of time, costs, and utilization of workforce. Building Information Modelling tools in this study are used. From the analysis and modeling of the PPU, it is shown that the implementation of IHBS can reduce construction time, cost, and utilization of workforce up to 40% - 50% as compared to the conventional method. The construction time using IHBS can be reduced up to 48% as compared to the conventional construction method.

Key Words: *industrialized building system, building information modelling, interlocking hollow block system*

1. INTRODUCTION

Industrialized Building System (IBS) is defined as a construction technique where the components are fabricated off-site, consider the environmental impact while optimizing its economic viability by preparing conducive site work, and provide comfort and safety to the occupants (MIDF, 2014, Yunus & Yang, 2011). These systems are used due to several advantages. The IBS system improves the quality of projects, easier to control, reducing rectification work and lowering the total cost of construction. By fabricating the most components in the factory within a controlled environment, delay in construction can be minimized (Bari et.al., 2012, Mydin et. al., 2014 and Farah et. al., 2016).

The need for housing has also catapulting energy demand so thus the energy infrastructure. The Malaysia national energy provider is trying hard to respond to the requirements of electrical power building supply to develop a better option for constructing a sub-station building by utilizing sustainable construction. There are 74,417 distribution sub-stations throughout the Nation in 2016 (Tenaga Nasional Berhad, 2016). However, there are typical problems arise in using the conventional method in the construction industry, those are a delay in construction, a high percentage of wastages and lack of sustainable practice. The conventional construction methods normally generate between 20% - 30% of wastage in terms of production cost (MIDF, 2014). The delay can be furthered prolong due to the weather problem such as rainy season in Malaysia. The use of timber is not environmentally friendly and the use of wet concrete to cast the beam and column need heavy machinery.

This study is aimed to compare the conventional construction method with IBS method by using BIM tools for energy infrastructure building's project. The IBS system in this study using the interlocking hollow block system (IHBS) which also address sustainable construction as an alternative way of speeding up the construction time.

2. LITERATURE REVIEW

Industrialized Building System

One of the main problems faced by Malaysian construction industry is since the 1980s it has relied on foreign workforces about more than 60% from total workforce can be provided by the construction industry (Abdul-Rahman et. al., 2012). The influx of foreign workforce in the society could further aggravate the social problems such as crime and health problems. The introduction of the IBS in the construction industry is a good alternative to reduce the dependency on a foreign workforce. However, penetration and acceptance of the IBS have still infancy in construction industry players, especially in private sectors. The construction industry is normally not easy to embrace into changing regarding initial investment and the cost and/or time drove the objective of the construction projects. Some of the

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undesirable insights specified by the players on the IBS were unprepared for the new concept, inadequate detail of design and has minimum expertise in the new technique. There are 28 issues have highlighted in the implementation of the IBS in Malaysia related to the construction phases (Izatul et. al., 2013).

Construction Industry Development Board (CIDB), Malaysia has enforced the use of IBS by launching IBS Roadmap 2003-2010 and IBS Roadmap 2011-2015 which prearranged the requirements and the needs of Malaysian Construction industry and to reduce construction industry's dependencies on foreigner workforce (Nawi et. al., 2012). The Malaysian government has mandated that government projects will carry 70% IBS content. Under the 9th Malaysia Plan, 291 IBS projects were carried out, constituting a total project value of RM 10 billion. As in Klang Valley in 2013, 46% of 400 construction projects were completed using IBS (MIDF 2014). The next challenge is to convince public sectors to embrace the IBS in their construction projects.

Building Information Modelling

In the construction industry, many projects have become a lot more difficult and complex to carry out (Gerrish et. al. 2017). Because of this necessity, many methods and new functions were established to ease the management and processes. Building Information Modeling (BIM) is one of the advance features utilizing this function. BIM is not software but it is actually the management and dissemination process of holistic information resulting throughout building design development and operation (Park et al. 2017).

Memon et. al. (2014) also define BIM as a process which contains the features of digital representation and serviceable features of any project. This process involves professionals from architecture, engineering, and construction. To ensure an efficient process, these three fields should be able to collaborate with them to ensure correct information and data were delivered systematically. Relatively, BIM is also defined by the collaboration on designing a building facility using a coherent system of computer models which can manage practical data based on parametric projects (Tulenheimo 2015).

BIM is also viewed as a composition of advanced process and technology offering a platform to collaborate between distinct parties in the construction project by exploiting the uses of Information Technology (Zahrizan et al. 2013). Traditionally practice, Park et. al. (2017) state that many application of BIM industry is considered to address the limitation of 2D and paper-based work processes. Encountering this problem, BIM is represented in the 3D visualization of the structure to be constructed, covering all disciplinary design, lifecycle and information of the product (Memon et al. 2014).

Memon et. al. (2014) states that the industry has resulted in poor project performances and very rarely projects are completed within time and estimated cost due to the uncertainties to deal with. In times, firms will struggle to secure work on international projects if they do not have BIM capabilities (Smith, 2014). They also assume the work percentage using BIM will increase by 50% over the next 2 years giving the indications – BIM is essential (Smith 2014). Azhar (2011) in his researches study about a fast track project stated that the biggest challenges were to maintain schedule and ensuring quality using incomplete and uncoordinated design and how to reduce risk and rework. Then, the project manager decided to use BIM in planning and coordinating the project.

Building Information Modelling (BIM) is currently being adopted more serious in the construction industry. The BIM gives many benefits in all stages of life cycle of the construction industry as it promotes reducing in wastages, overlap and cost (Aziz et. al., 2016 and Bui et. al., 2016). The most burden of implementing of BIM in the construction industry in regard to how well streamline the workflow and information flow (Aziz et. al., 2016). In cost management, by implementing the embedded information in BIM system of time and cost as 5D BIM, it shares cost information, so the project team is being able to simulate and explore various design and construction scenarios for the client in real time where the information is linked to the live BIM model (Smith, 2016).

Interlocking Hollow Block System (IHBS)

According to BS 6073-1:1981 clause 3.1.2, brick can be defined as a masonry unit less than 337.5 mm in length, 225 mm in width or 112.5 mm in height. Blocks are the unit width dimensions more than these measurements. Definitions of different types of bricks were applied as in Table I.

Table 1. Type of bricks

Types of brick	Definitions
Solid brick	A brick with small holes than 25% of its volume passing through the brick.
Perforated brick	A brick with small holes more than 25% of its volume passing through the brick
Hollow brick	A brick with small holes more than 25% of its volume passing through the brick and the holes are not small
Cellular brick	A brick with small holes more than 20% of its volume close at one end of the brick.

ASTM C652 classified hollow brick into four types, which are HBS, HBX, HBA, and HBB. The specification in the ASTM C652 covers hollow building brick and hollow facing brick made from clay, shale, fire clay, or a mixture thereof, and fired to incipient fusion. The hollow brick is specified as a hollow clay masonry which net cross-sectional area (solid area) in any plane parallel to the surface, containing the cores, cells, or deep frogs, is less than 75% of its gross cross-sectional area measured in the same plane. The bricks are manufactured from clay, shale or similar naturally occurring substances and subjected to a heat treatment at elevated temperature (firing).

Interlocking blocks are different from conventional bricks since they do not require mortar to be laid. The blocks are just laid dry and locked into place. Because of this characteristic, the process of building a wall is faster and requires less skilled labor. There are three types of interlocking bricks or blocks, namely solid, Perforated or hollow bricks. The differences between perforated and hollow bricks are depending on the surface area of holes less than 25%, if exceeded 25% the bricks were classified as hollow bricks as stated in BS 6073-1:181 clause 3.3. Besides, bricks can be categorized in term of their solidity. The more solidity the brick, the less binder will be required for sufficient brick strength. If the perforations increasing up to 50% in order to achieve sufficient strength, more binder will be needed for thin membranes created onto a hollow block.

3. METHOD

This study is focused on comparing related construction activities factors such as analysis and design, cost of construction, utilization of manpower, and time of construction between both IBS construction method and Conventional construction method. A real geometrical configuration of PPU sub-station of double story building using the conventional construction method and the IHBS are used to study the difference between the two construction methods. A critical observation of the economic aspects in using the conventional method and IHBS is undertaken. This comparison is very important so that it is possible to establish the real benefits of using IHBS. The speed of construction, the use of labor, and the saving in cost of construction are the critical observation that needs to pay attention in the comparison. A meaningful comparison is taken on relevant (time-dependent and quality-dependent) cost components, classified (i.e. labor – direct and indirect; materials; machinery; general expenses; transportation and overhead). As for this study, the method of cost comparison used is standardized identical buildings and functionally similar buildings while the unit is the cost per gross floor area.

For this study, Autodesk Revit 2017 is used in remodeling the Primary Distribution sub-station (PPU) building. Autodesk Revit (Revit) is a design building software especially use to apply building information modeling (BIM) concept. The plan drawing of the building is shown in Figure 1.

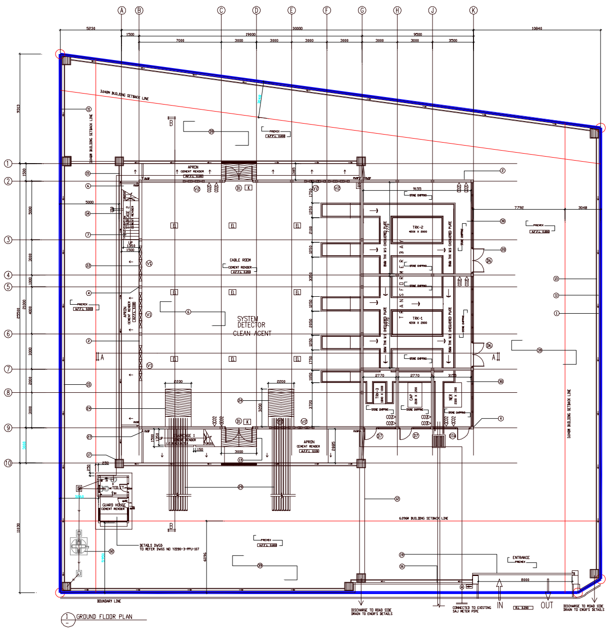

Figure 1. The plan drawing

The expected outcomes from the utilization of Revit in remodeling the existing building are to make a comparison (plan, elevation, and 3D) between conventional and IHBS method. Using Revit, the cost summation on several elements in the building is extracted. It is assisting in generating the total cost of the building easier. Once the 3D model is completed, it is transferred to Autodesk Naviswork Manage 2017 (Naviswork). By using Naviswork software, a 4D time simulation is created to demonstrate the beginning of the PPU construction until it is completed. The sequence stage of the project and the time of the construction to begin and finish is set up first before it can be generated. The complete view angle of the PPU building for conventional method model is shown in Figure 2 and for the IHBS method, it is shown in Figure 3.

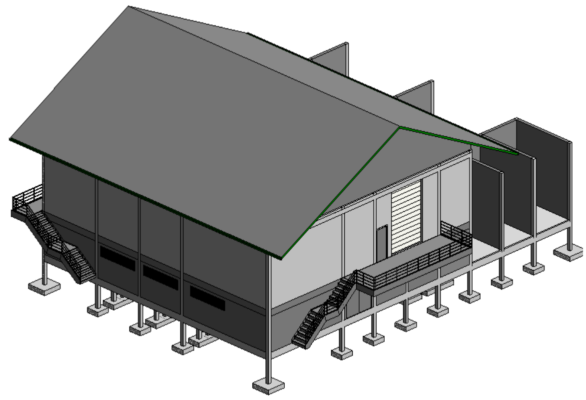

Figure 2. The model of PPU using conventional method.

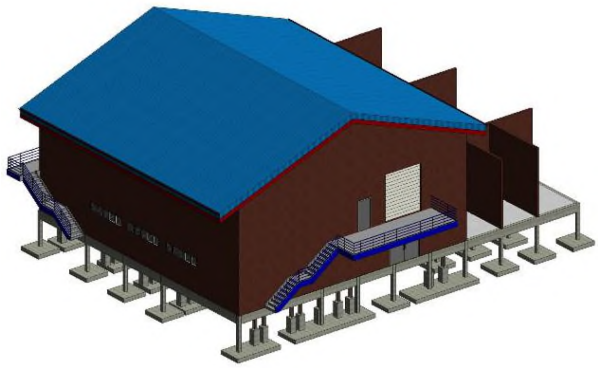

Figure 3. The model of PPU using IHBS.

4. DISCUSSION

Interlocking Hollow Block System (IHBS)

One of the problems facing in energy infrastructure development on constructing the PPU sub-station is the failure of the contractor to deliver construction buildings on time and at a reasonably priced. Poor quality of construction, time-consuming and high-cost material are factors usually associated with the construction industry in Malaysia. It's become a norm either from public or private sector to drag a construction work away from the state of the accomplishment (Nicco-Annan, 2006 as in Kpamma et. al., 2012). The demand for speedy in construction, less waste of materials has led the need for the construction industry to consider construction method that can provide environmentally friendly, speed construction process, and cost saving.

In a building construction, walls are one of the main components in the construction of the building. Walls as partitioning and enveloping of the building play an important role to ensure security, privacy, and comfort to the building. Additionally, walls are very significant to the contribution on the cost of material and labor of building construction. Therefore, the reduction of waste generated from walls can be prevented by using the concept of IHBS technology which functioned as column, beam, and walls.

The use of conventional blocks is largely dominated in the process of building construction wall for the PPU substation. From the observation, this kind of blocks with mortar joints is bringing a lot of generation of waste which needs to be tracked and excluded. The waste generated by the wall can be manifested in the form of over processing, time-consuming, work in progress, material inventories and so on. Therefore, by adopting a drywalling system, like interlocking hollow block system to construct the PPU substation can be a substitute for the construction of wall using conventional method block wall system.

Comparison of IHBS to Conventional Brick Wall System

The standard stages and associated activities involved in the wall construction process in the use of the conventional brick wall system and those involved in the use of the interlocking block were observed and recorded as shown in Table 2. The steps, as observed, were compared to identify which of them was a non-value adding step (or is eliminated in either of the two wall construction systems) and therefore constituted a waste. As shown in Table 2, the use of the interlocking block system led to the elimination of a few construction activities. The step that was eliminated in the laying of the first course was filling and dressing vertical mortar joints. The steps that were eliminated in the subsequent courses included filling and dressing vertical mortar joints, transporting mortar, spreading mortar for a course and leveling. These eliminated steps, also known as non-value adding steps, can be categorized into the various classes of waste.

While some of the eliminated steps are direct manifestations of some category of waste, other steps have a consequential or indirect link to some category of waste. For instance, “filling and dressing vertical mortar joints” directly manifests as “unnecessary processing” but is also indirectly linked to “waiting” since labor had to wait before vertical jointing and dressing is complete for them to either provide more mortar or blocks. “Transporting mortar” is also directly linked to “unnecessary movement” as a form of waste, but indirectly linked to “waiting” since masons had wait for mortar to be supplied to them before they start or continuo vertical or horizontal joining of blocks.

The output of the masons in constructing the walls using the conventional block and the interlocking block including paintwork is 162 m^2/minutes and 18 m^2/minutes respectively. It indicates that the productivity of the masons was higher in the use of the interlocking block in wall construction compared to the use of the conventional block. The output of the masons was about 54% more when the interlocking block was used compared to when the conventional block was used.

Table 2. Activities in masonry works

Stage	Description	Activities (step)	Normal Block	IHBS
A	General Preparation	Setting Out	✓	✓
		Preparation of mortar	✓	✓
B	Laying First Couse	Transporting mortar	✓	✓
		Spreading base mortar	✓	✓
		Transporting block units	✓	✓
		Placing block units in the first course	✓	✓
		Plumbing	✓	✓
		Levelling	✓	✓
		Filling and dressing vertical joint	✓	×
C	Laying Subsequent Course	Transporting mortar	✓	×
		Spreading mortar for the course	✓	×
		Transporting block units	✓	✓
		Placing block units in the course	✓	✓
		Plumbing	✓	✓
		Levelling	✓	×
		Filling and dressing vertical mortar joint	✓	×

✓ Applicable step; × Eliminate/none-value adding steps

The mortar was observed to be an important component in the construction of the walls. The use of mortar was common to the two walling systems even though to varying degrees. The quantity of mortar used for the interlocking block walling was far less than the quantity used for the conventional block walling by 62.2% where conventional wall uses 12.7 kg mortar/m^2 and interlocking block wall use only 4.8 kg mortar/m^2. The cost associated with the process of constructing a wall with the interlocking block is far lower compared to using the conventional block. About 48.8% of the cost that was involved in erecting the wall using the conventional brick wall which can be reduced in building the wall using the interlocking block. Even though a relatively lower cost of labor played a role, a significant portion of the cost savings in the use of the interlocking block came from the significantly low quantity of mortar required.

4D Simulation

The detail task grid of the PPU sub-station building construction is used in the process of scheduling the project by using Microsoft Project. The conventional block wall system consumed a total of 192 days for constructing the building. Whilst, the interlocking block wall system consumed only 137 days. The results of the study indicate that the pace of wall construction using the interlocking hollow blocks is faster than using the conventional block. The elimination of non-value steps like spreading mortar, leveling, vertical mortar jointing and dressing of joints significantly reduces the cycle time of bonding blocks thus increasing the speed of wall construction. Much time is devoted to the interlocking block system for the construction of the first course to ensure near perfect alignment and proper coordination of block units in subsequent courses. Once the first course is properly laid, the building of the subsequent courses simply involves stacking the blocks to interlock. This eliminates the chaos of disjointed stop-and-go production processes associated with the conventional blocks and rather focuses on fast cycle times to ensure reliable and continuous workflow. Generally, less than half the time that was used to erect a wall using the conventional block was required to erect a similar wall using the interlocking block.

5. CONCLUSION

Speedy delivery of value is very important towards ensuring a lean project delivery of construction products. The building construction industry of energy infrastructure, particularly the PPU sub-station, is dominated using the conventional block for wall construction. Various forms of waste have however been observed to be associated with the process of erecting walls using the conventional block. This has led to the need to explore the possibility of adopting other walling systems towards making the wall construction process lean to reduce waste and maximize value.

A comparative study with BIM tools is conducted between the conventional block wall system and the interlocking block wall system in the PPU's building. The focus of the study is to particularly identify some non-value adding steps in wall construction process associated with the use of the conventional block so that those steps could be eliminated with the interlocking block. The study revealed that several non-values adding steps like spreading of base mortar for various courses, vertical mortar jointing, and leveling, which are associated with the use of conventional block, could be eliminated when the interlocking block is used for wall construction. Such various forms of waste as over-production, unnecessary movement, unnecessary processing, inventories and waiting, seen to be associated with the use of the conventional blocks, are minimized when the interlocking block is in use.

There is also a significant reduction in the material required for the interlocking block wall construction process due to the absence of mortar jointing. Reduction in the labor and material requirements in the interlocking block wall construction process makes the cost associated with the process of building walls using the interlocking blocks far less. It can be concluded that the use of IHBS can achieve the cost of construction saving up to 48% as compared with the conventional construction of typical reinforced concrete construction. Most of the savings came from the saving due to the lesser dependency of labor and saving from material cost. It can also be concluded that the use of IBS such as IHBS can be a very good solution to solve the problem of need on both quantity and quality of the housing construction in Malaysia.

ACKNOWLEDGMENT

This project is part of final year project of Muhammad Adam Mahmood and Nur Adibah Jalaluddin in Department of Civil Engineering, Universiti Tenaga Nasional for academic year 2016/2017 and academic year 2017/2018. The authors would like to thank Universiti Tenaga Nasional for the opportunity to publish this paper.

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