A review on past and present development on the interlocking loadbearing hollow block (ILHB) system

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Abstract. Massive migration and increasing population in Malaysia has contributed to the increasing demand of quality and affordable housing. Over the past 50 years, the Malaysian housing industry has seen the growth of using conventional construction system such as reinforced concrete frame structures and bricks. The conventional system, as agreed by many researchers, causes delays and other disadvantages in some of the construction projects. Thus, the utilization of interlocking loadbearing hollow block (ILHB) system is needed to address these issues. This system has been identified as an alternative and sustainable building system for the construction industry in Malaysia which the PUTRA block system is the latest example of the ILHB developed. The system offers various advantages in terms of speed and cost in construction, strength, environmentally friendly and aesthetic qualities. Despite these advantages, this system has not been practically applied and develop in Malaysia. Therefore, this paper aims to review the past and present development of the interlocking loadbearing hollow block (ILHB) system that available locally and globally.

1. Introduction

In the 11th Malaysia Plan (2016-2020) [1], it was stated that the construction industry will expand by 10.3% percent per annum over the next five-year period. This growth was expected to come from the increasing demand for affordable and quality housing, especially from the low and middle-income group. The 11th Malaysia Plan (11MP) was targeting to build about 50,000 units of low cost housing under the Program Perumahan Rakyat (PPR) compared to only 38,000 units targeted in previous 10th Malaysia Plan (2010-2015) [2]. Unfortunately, due to the increasing material prices, shortage of building materials and lack of skilled laborers causes the delay in the construction of the housing projects [3]. Therefore, the delays of the housing projects since the 10th MP is an important issue which has to be addressed in the 11th MP which has already been launched since May 2015.

Because of these reasons, alternative construction methods need to be introduced to overcome the above problem, hence such as the adoption of the innovative Interlocking Loadbearing Hollow Block (ILHB) system. The ILHB system is one of the newest masonry structural inventions in the world nowadays. Historically the masonry structural system was originated since the ancient time of sun-dried clay bricks (about 8000 B.C) and through the years the masonry structures has great potential but requires further studies and development. Due to changes in design concept and the development of codes of practices, many developed countries nowadays have shown their interest in transforming the masonry structures into a variety of structural application through innovation of the design to improve

its serviceability and performance of the masonry system [4][5][6]. Masonry structures has many advantages as widely discussed in the literature [7][8][9][10][11][12][13][14]. Furthermore, the need to accelerate the masonry construction processes besides reducing its construction time and costs which resulted in a desire to develop a new efficient interlocking loadbearing hollow block system (ILHB) [5].

This paper review the past and present development of masonry structures and several existing ILHB systems that has been developed in the world. The reviews in this paper is an important subject to support future research and development of the ILHB system in Malaysia. Salient observation on the latest invention of Putra Block in Malaysia will be further discussed in this paper as the adoption rate of Industrialized Building System (IBS) in Malaysia is lower than other developed countries [1]. Hence, these review papers will assist the future development of interlocking loadbearing hollow block.

2. History of masonry development

Masonry structures has been extensively used since ancient times where the applications are not limited to building construction only, but is also widely used in construction from the smallest to huge buildings, monuments and other infrastructures. With the combination of art and great architectural work, masonry building technique will result a heritage building.

In ancient Mesopotamia, there are many types of materials used for masonry unit. One of the example of masonry material used is the sun-dried mud bricks as shown in Figure 1. It is the oldest brick in the world taken from archaeological digs at the site of ancient Jericho. The brick resembles long loaves of bread, with some bold patterns of a Neolithic thumb print impression on their rounded tops. It was used by the people of Mesopotamia for their shelter [3].

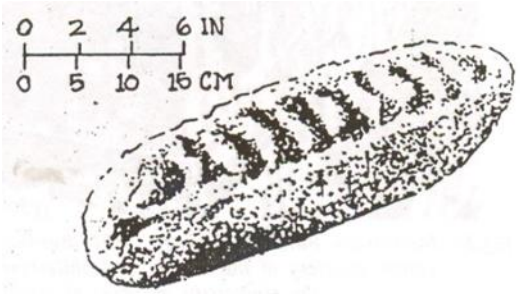

Figure 1. BSun-dried brick (about8000 B.B) [39]

Until 1950's, there were no engineering methods of designing masonry for buildings [15]. The masonry building is built based on graphical methods or simple calculation as cantilever wall, without shear wall and lead to the increased thickness of wall from top to bottom [3]. Hence, the masonry structures built is considered very uneconomical beyond 3 or 4 storeys [16]. At the early 20th century, masonry was relegated to secondary usage as facing, land infills and fire proofing purposes. It is because, building exceeding 3 or 4 storeys had to be constructed with steel frame or reinforced concrete frames. An example of the final masonry structure that was constructed as method mentioned above is the Monadnock Building, built in the year 1981 (see Figure 2). It was designed by John Root in Chicago, comprises of 16-storey high with 1.82 m thick walls at the base [16][17][18][19]. The Monadnock Building was designed based on the considerations from 'Rule-of-Thumb' tables given in building codes and regulations at that time [15]. The thick unreinforced masonry walls at the base of the building provided the required stability against wind loads. Such structures made it clear at the turn of the century that a size limit had been reached on masonry and construction techniques.

Figure 2. Monadnock building in Chicago (1981) [18].

3. History of masonry development in Malaysia

The first historical masonry building structure constructed in Malaysia is the A Famosa heritage building that was built by the Portuguese after successfully capturing Malacca in 1511. Due to the quality of the design, the remains of the A Famosa building still stays strong and stand firm until today. Later, more masonry structures were introduced during the British colonial era with the construction of various official and middle class residential buildings. The existing buildings were found located at the Harvard Estate at Gurun and the TUDM quarters at Tok Jalai, Jitra in the state of Kedah [20][21]. However after the independence of Malaya in 1957, many of these masonry buildings have been demolished to make way for new development by the Malaysian government. The application of hollow block units was further introduced mainly for the housing construction. Examples of housing construction using these hollow blocks are the low cost housing located at Taman Sri Kemuning, Jitra in the 1970's, Setapak Jaya Housing Estate in Setapak in 1978 and the Selayang Utara and Selayang Selatan in 1979 [20][21].

At the present time, some of the buildings using the traditional masonry system in Malaysia are still around and has been gazetted as a national heritage. Some of these national heritage buildings are the Sultan Abdul Samad complex in Kuala Lumpur (which was built in 1894), the Sultanah Aminah's hospital in Johor Bharu and the Federated Malay States Railway's (FMSR) building. Due to their excellent performance by overseas and local standards, this system had been approved and gazetted under the Uniform Building by- Laws in 1989. In 1994, the low-cost housing project at Chembong, Negeri Sembilan uses an innovative masonry structural system which eventually won the prestigious Prime Minister's award. From there, it was reported that a number of housing projects started using a comparable masonry system for its construction method. Unfortunately, the usage of any masonry structural system are less popular in Malaysia despite the associated advantages to this method.

4. Interlocking Loadbearing Hollow Block (ILHB) system

Interlocking loadbearing hollow block (ILHB) system is different from traditional concrete blocks and brick. The mortar layer is eliminated and the block unit was interconnected through natural interlocking mechanisms provided on sides or top-bottom surface such as protrusion and grooves. The elimination of the mortar layer increases the rate of construction significantly. It has been reported by [22] that the efficiency factor of dry-stacked (mortarless) brick masonry is around 0.90. The mortar layers are also the weakest part of a masonry wall as the substitution of lime for aggregate reduces the overall strength of the joint [23].

There has been several attempts to develop innovative ILHB system in different parts of the world in the recent past. In 1994, Juan Haener developed the Haener block system located at Canada [24]. The block was made from concrete and it was used for the construction of loadbearing walls [31]. The system comprises of three types of block units as in Figure 3. The horizontal alignment of the blocks is ensured

by interlocking keys provided at the sides while the vertical alignment between the block is achieved by small projection key at the top of the blocks. In addition, the inside web is inclined at the bottom to act as a support to the top key to interlock the blocks. This type of interlocking mechanism is very efficient to ensure the self-alignment and easy construction [25]. Furthermore, the block also allows both horizontal and vertical reinforcement embedded in grout to be placed at suitable intervals for load bearing walls.

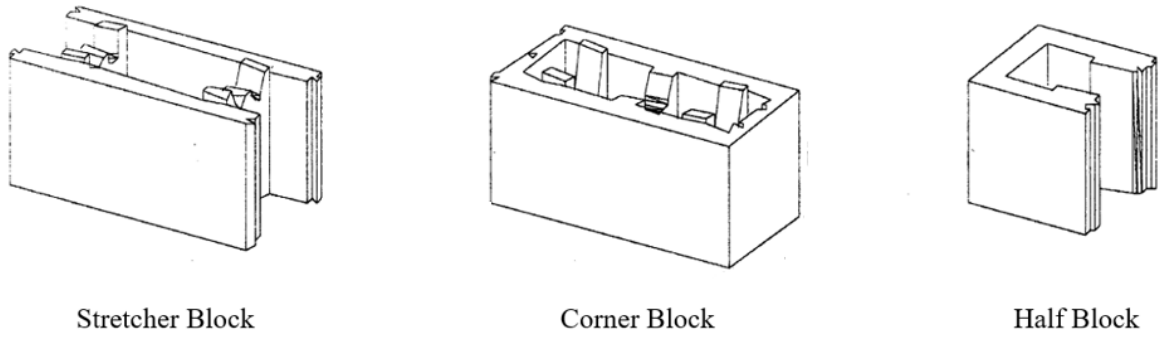

Figure 3. Haener block system [24].

Further development on an ILHB system was proceeded by the innovative Mecano block in Peru. The block system was invented by Cetholic in 1988 which has no interlocking mechanism as shown in Figure 4 [26]. The blocks were made from sand-lime [32] and simply stacked on top of each other to construct a wall. The hollow cores of the block allow horizontal and vertical reinforcement with help from grouting to interlock between the block unit. The block unit must have accurate dimensions and smoothness with an allowable tolerance of 0.5 mm obtained through molding under pressure [25]. Furthermore, it is requiring concrete grout and must have a high degree of workability to combined each block unit.

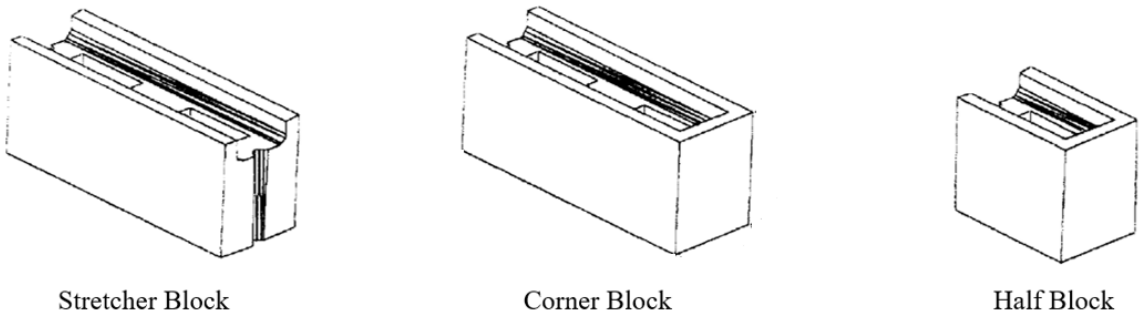

Figure 4. Mecano block system [26].

In 1992, the modified “H” and “W” block made up of concrete was invented by Drexel University, USA [27][33]. It was used mainly for reinforced masonry construction purposes and can resist earthquake. The first of the two systems is a simple modified H-block as shown in Figure 5 (a). It consists of tongue and groove as the interlocking mechanisms on both the bed and head joints. The block system is reinforced in both vertical and horizontal directions. Partial grouting is required to ensure the stability of the wall during construction prior to full grouting. The second system is the W-block interlocking system as shown in Figure 5 (b) which also shows the possible horizontal and vertical reinforcement and the stacking of the units. The horizontal joints between the courses are staggered by using different height unit and dovetail arrangement in the head joint. Three different types of W-block is required to construct the walls. However, the vertical joints are made continuously along the height of the wall.

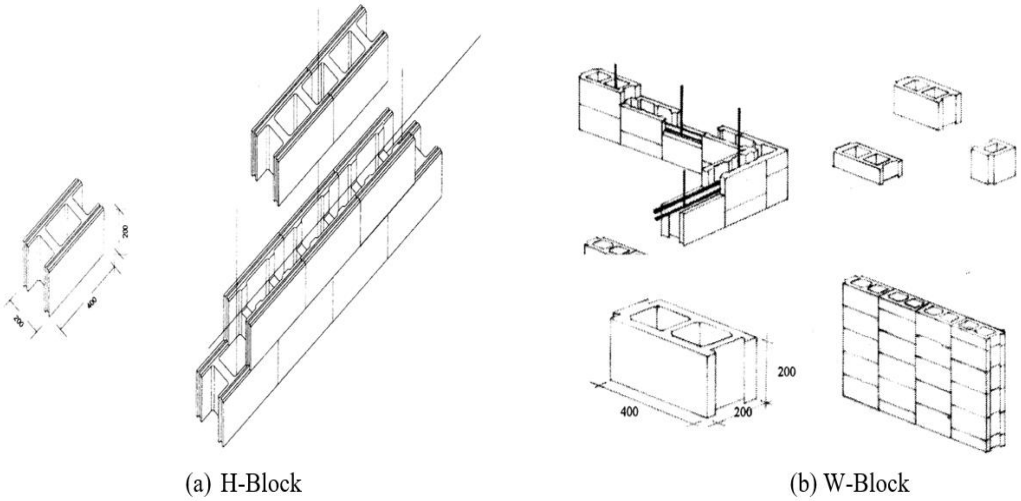

Figure 5. (a) Modified H-Block and (b) W-Block block system [27].

By 2000 the Solid Interlocking Block (or Sillblock) system made from concrete was developed by the Indian Institute of Technology, Madras [28][36]. The development of the blocks was aimed to accelerated mortarless masonry construction. The system consists of two types of block system with three basic shapes for each type which is called a stretcher, jamb and corner blocks as in Figure 6. The interlocking mechanism is achieved through the dovetail design of the block for both top and side locking mechanism. Both horizontal and vertical is interlocked by means of meticulous skill which the horizontal reinforcement is only allowed at the end of the corner and the hollow cores of the corner block unit can be grouted if needed [38]. To ensure stability during erection, mortar slurry was sprayed by using a spray gun and dipping the bottom of each block in mortar slurry for uniform and very thin mortar bedding [37].

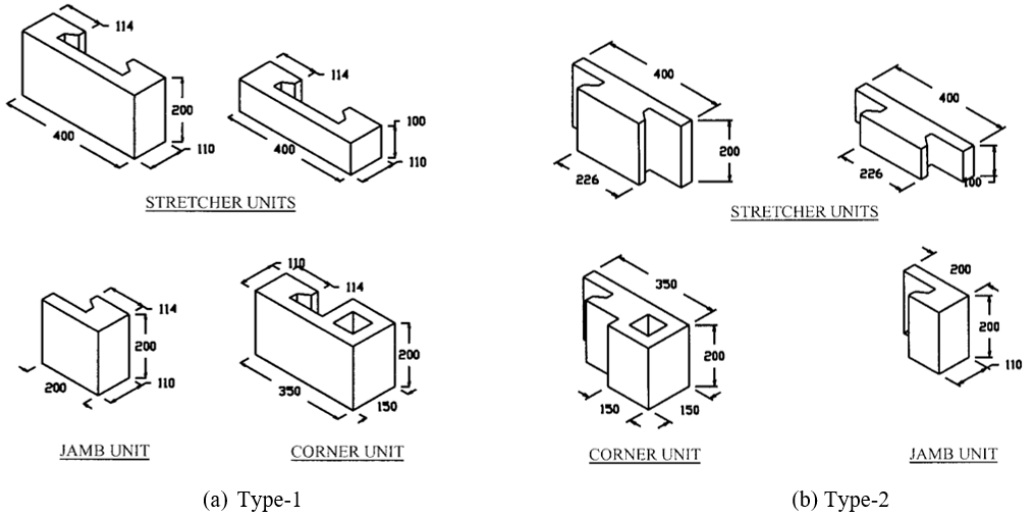

Figure 6. (a) Type-1 Sillblock and (b) Type-2 Sillblock, (2000) [28].

In Malaysia, the latest development of the ILHB system was developed in 2004. Putra Block is a loadbearing hollow concrete block and has been developed by the Housing Research Centre (HRC) of Universiti Putra Malaysia (UPM) [25]. The block system consists of three units which comprises of the stretcher block, corner block and half block [34] as shown in Figure 7. Each block has different geometrical configuration and its function was to facilitate better masonry structures construction.

Generally, the stretcher block was the main unit used in the construction of the walls. It was functioned to resist the load acting on the wall. The corner block unit was to be used to connect between junctions and at the end of the walls while the half block unit was to be used to complete the courses of the wall so that the vertical joint would be staggered [25]. The block also has been manufactured with hollow section allowing vertical reinforcement and grouting mortar at intervals necessary to complete the wall construction [35].

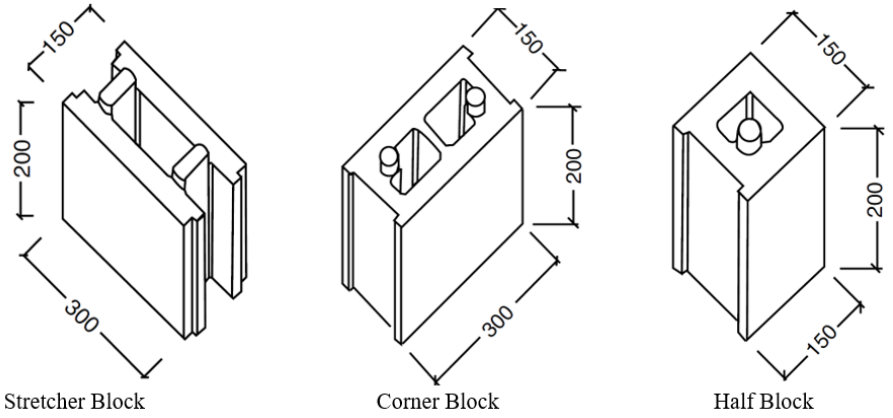

Figure 7. Putra Block system, (2004) [30].

The development of Putra block is the latest invention of masonry structural units for the construction industry in Malaysia. It is used as an alternative to Industrialized Building System (IBS) and numerous in-depth investigations has been conducted on these block systems. It also offers various advantages in term of its design, construction cost and time and especially towards modern construction method. Experimental work done by [29] shows the experimental work conducted to investigate the structural behaviour of every single unit of the Putra block as in Figure 8. The characteristic strength in Table 1 shows excellent properties which fulfils the requirements of standard specifications for the loadbearing concrete masonry units [30]. From further experimental studies, it was also observed that the behaviour of the ILHB wall was primarily dominated by a large lateral displacement and the dry joint opening at approximately the mid height of the wall (at the maximum moment location). Besides that, the mode of deformation and dry joint opening in the wall are affected highly by grout, reinforcement and pre-compressive load. Hence, further investigations of masonry unit such as the Putra Block needs to be conducted to meet the demand of the construction industry in the 11th MP and beyond.

Table 1. Compressive strength test of individual Putra block units [30].

Types of specimens	Density, P (kg/m^3)	Compressive strength (N/mm^2)	Tensile strength, f_t (N/mm^2)
Stretcher	2042.24	18.62	2.06
Corner block	2014.8	18.02	2.79
Half block	1936.66	17.03	2.16
Grout	2035.00	15.00	2.09
Reinforcement	-	-	$f'_y = 275$

5. Summary and conclusion

This paper highlighted past and present reviews on the development of various masonry structural system available locally and globally. It was obvious that the masonry structural system is not a popular system in Malaysia as it was slowly ceased to be adopted as a construction method by the mid 90's. It is acknowledge that the construction industry in Malaysia uses reinforced concrete and steel structures with bricks or panels as in-fills. Hence, as the need for more quality houses in Malaysia rises especially for the low and middle income groups in the 11th MP, the introduction of an interlocking loadbearing

hollow block, which is an alternative building system, is in greater demand. Therefore, the development of the Putra Block system was timely and with its interlocking mechanism, will be mortar-less and has self-alignment capabilities which reduces the demand for skilled labourers, reduces mistakes and any wastage. Future work on using green concrete, which utilizes agricultural and construction waste as cement and aggregate replacement, will enhanced its sustainable properties and reduces the carbon foot prints as specified by the Construction Industry Transformation Plan (2016-2020).

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