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Flexural behaviour of interlocking brick system with grout cement mixed with various fibre

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Abstract. Interlocking bricks are usually produced by mixing laterite clay, fine sand, and Portland cement. However, the typical problem with this mixture is the formation of cracks due to the brittle behaviour of the interlocking materials mixture. Therefore, there is a need to add some fibres that could enhance the strength of the production of interlocking bricks. This paper presents the effects on compressive and flexural strength of interlocking bricks produced by mixing with synthetic polypropylene fibre (SPF) and palm oil fibre (POF). Tests were carried out to compare the relative strength between normal interlocking brick and proposed interlocking brick with fibre. Nine interlocking bricks with various mixture were tested for compression. Three beams specimen were prepared and tested until failure. The results showed that the addition of fibre has significantly increased the strength of interlocking bricks in all tests. POF interlocking bricks showed the highest strength, while SPF interlocking bricks showed higher in compression but lower in flexural strength than normal interlocking brick. It was concluded that the addition of POF in the interlocking mixture could be used as an additive mixture to improve the strength of the interlocking brick system.

1. Introduction

1.1 Background

Owning a home in Malaysia is a dream that is slowly becoming expensive to purchase for a growing population. A steady rise in house prices with little sign of slowing down could trigger a greater housing crisis in Malaysia. This situation has been acknowledged by numerous parties such as government agencies and private developers. Both parties from government and private agencies have discussed the difficulties in cost and type of construction faced by prospective first-time homebuyers and factors that have contributed to this dilemma. As a developed country, Malaysia is currently driving for implementing a new modern construction method, the Industrialised Building System (IBS), as an alternative towards enhancing construction performance. Currently, most of the project developments in Malaysia are still conducted by the traditional construction process approach where reinforced concrete with the extensive use of formwork was preferred. This traditional construction process has been widely criticised for its fragmented approach to project delivery and its failure to form effective solutions in construction, thus create several issues such as not environment-friendly, delay in construction time, rising costs, lack of communication, and coordination, and wastages. Therefore, there



is a need to introduce an effective solution that could address the problems in construction for housing development in Malaysia. This paper presents the use of Interlocking Hollow Brick System (IHBS) for housing construction designed as load-bearing construction and categorized as Industrialized Building System (IBS). Interlocking brick is commonly available in various sizes and shapes as shown in Figure 1.

Industrialized Building System (IBS) is a prefabrication concept that is not new in Malaysia construction. The usage of industrialized components for the construction of the building is still very low as compared to the conventional reinforced concrete method. One of the best options of IBS is to use an interlocking hollow brick system (IHBS). This type of load-bearing brick has proposed a new concept of construction where no traditional columns and beams are needed. It is not just reduced the construction time and cost but also reduced material usage. As the method of construction did not require formwork and the production of the IHBS is produced by compression, where no firing is needed, the IHBS can be categorised as green building construction [1, 2]. However, the use of this IHBS in Malaysia has been limited the building construction for up to two to three stories. Some of the problems such as low in compression strength (less than 5 N/mm^2), cracks due to low tensile strength and weight of the brick is too heavy (8kg per brick) have hindered the use of IHBS. The addition of supplementary cementing materials such as fibres (SPF and POF) as proposed in this research came from the waste product which could not only reduce the weight of the brick but also increased the strength of the brick. Therefore, there is a need to investigate the basic details on the strength of the IHBS with the proposed additives fibres [3-5].

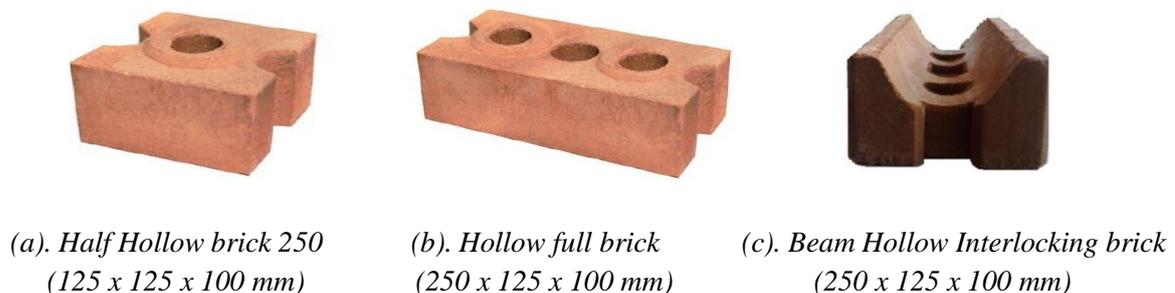


Figure 1. Hollow Interlocking brick characteristic.

1.2 Fibres in IHBS as additives

The use of fibre in concrete is getting popular to enhance flexural and tensile strength. The fibre is considered as a new additive or a new form of binder that can combine effectively with Portland cement. Fibres are most generally discontinuous, randomly distributed throughout the cement matrices. The term 'Fibre reinforced concrete' (FRC) is made up of cement with various sizes of aggregates, which incorporate with discrete, discontinuous fibres (usually 0.5% - 2% by volume) [6, 7]. Generally, fibres bridging the cracks in the matrix and provide resistance to crack propagation and crack opening before being pulled out or stressed to rupture. Fibres are usually used in concrete to control plastic shrinkage cracking and drying shrinkage cracking. They also lower the permeability of concrete thus reduce bleeding of water. Some types of fibres produce a greater impact on abrasion and shatter resistance in concrete. Generally, the strength, ductility and the extent of post-cracking behaviour of concrete depend on the strength characteristics and type and properties of fibres used in the concrete mix [8-10].

Several types of fibres are available in the concrete industry, and each type of fibres have their properties, advantages, and limitations. The selection of fibres is mainly based on the application of the concrete. Among others, the most common fibres used in construction are produced from steel fibres, synthetic fibres, such as nylon and polypropylene, glass fibres, natural fibres and fibres from pre and post-consumer wastes. Since the advent of fibre reinforcing of concrete, a great deal of testing has been led on different fibrous materials to determine the real characteristics and benefits for each product [11]. IHBS is weak in tension and good in compression. The proposed Synthetic Polypropylene Fibre (SPF)

(see Figure 2) and Palm Oil Fibre (POF) (see Figure 3) may act as tensile reinforcement, which could enhance the tensile strength of the IHBS significantly. Fibres also improve significantly in modulus elasticity of a member structure [12, 13]. The use of these fibres is not only cheap but easily available and well blended in IHBS mixture. Although the proposed use of fibre is very good for IHBS, details tests need to be carried out so that the actual properties of the IHBS can be established.



Figure 2. Synthetic Polypropylene Fibre (SPF).



Figure 3. Palm Oil Fibre.

2. Methodology

In this paper, three types of interlocking bricks are prepared and tested for IHBS specimens mixed as normal type, SPF and POF. Sika-215 was used as grout cement to fill in the void of the hollow brick before any compression test and flexural tests are carried out. Grout is a material used in masonry infill. It is prepared as a mortar to fill in the hollow brick void and used together reinforcement bars in the interlocking brick system. The ratio of sika-215 used with water is set at 4kg of water to 25kg of sika so that liquefied mixture can be produced. In order to determine the effect of the sika poured into the void of the interlocking brick, compression test was conducted. The compression tests for IHBS specimens were prepared by staking the bricks in two layers and Sika Grout-215 (with strength of 80.89N/mm²) was poured on the void in the IHBS. Nine interlocking bricks samples were prepared for compression test for the three types of interlocking brick which is mixed as normal type, synthetic fibre type, and oil palm fibre types. A static load was gradually applied to the brick sample. The maximum load was recorded and the failure mode was identified.

In this research, three (3) specimens were prepared with the same parameters but with different material compositions. The three specimens with dimensions of 400mm thick x 125mm width x 3000mm length were prepared and reinforced with three number of 10 mm diameter (Y10) high strength steel bars. Beam brick, half brick, and wall brick were used in the test (see Figure 4(a)). All the specimens are installed with three horizontal reinforcement bars at the upper and lower part hollow voids (doubly reinforced) as shown in Figure 4(b). Vertical reinforcement bars, which are 6mm diameter steel bars (R6) are installed at an interval of 200mm along the span. The specimens were filled by Sika Grout-215 until all void was covered with the grout.

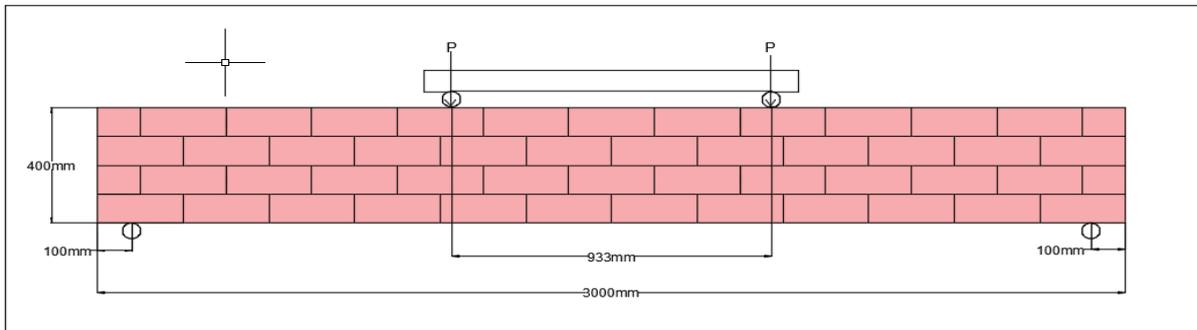


Figure 4(a). Arrangement of the interlocking brick system for flexural tests.

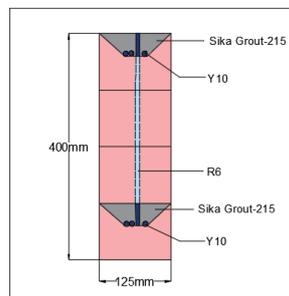


Figure 4(b). Arrangement of reinforcement in the specimens.

A point load was applied from the hydraulic jack to the load cell attached to the spreader beam. A two-point load from the beam spreader measured 933mm between support was applied to the top surface of the beam as shown in Figure 4(a). The supports were fixed to the base and the beam located on the supports as roller supports. The distance of supports from edges was 100mm. The effective length of the beam between the supports was 2800mm. The first and the fourth layers from the bottom of the beams were assembled using bricks, while wall bricks were used at the second and third layers. Three specimens were tested in this study. The simply supported beam with 3000mm length was placed at the frame for testing. Four-point loads bending system was applied to the beam. The LVDT was placed at the bottom of the beam center and both under the applied loads for recording deflection. Data Logger was used to recording the applied load from load cell and deflection from LVDT. The specimens were loaded in an increment of 2kN. The specimen was loaded until the specimen reached maximum load where the applied load tends to reduce. The load continuously applied to the beam, but each increment of load was limited to the deflection of 2mm of the beam. The readings for each load increment were recorded and taken from the logger. Figure 5 shows the preparation for the test and Figure 5 shows the failure mode.



Figure 5. Specimen properties and testing and failure mode due to compression.

3. Results and discussion

3.1 Compressive strength of grouted interlocking brick

The results showed that the maximum compression load for the interlocking brick was 365.14kN, and the minimum was 164.13kN. The surface area contact with the applied load was 250mm x 125mm, which produced the bearing area of 31250 mm². The load applied was then divided with the bearing area surface to establish the compressive stress. The mean compressive stress for normal, synthetic fibre and oil palm fibre type were recorded as 6.72, 7.68 and 10.2 N/mm² respectively as shown in Table 1. The highest compressive strength of the fibre with sika grouted interlocking brick was 10.2 N/mm² recorded from the Oil palm fibre type followed by synthetic fibre type and normal type interlocking brick. The result satisfied the minimum compressive strength required by BS3921:1985 which is 5.2 N/mm² for the conventional concrete blocks. These results showed that the addition of POF has significantly increased the compressive strength of the interlocking brick [14, 15]. This could be due to the contribution of the fibre in the bonding of the materials in the interlocking brick system.

Table 1. Compressive strength for Normal, synthetic and oil palm fibre type of grouted interlocking brick at 28-days

Type	Sample	Max Load (kN)	Area (mm ²)	Compressive Strength (N/mm ²)	Mean Compressive Strength (N/mm ²)
Normal	N1	243.03	31250	7.78	6.72
	N2	164.13	31250	5.25	
	N3	222.52	31250	7.12	
Synthetic Fibber	P1	238.26	31250	7.62	7.68
	P2	228.52	31250	7.31	
	P3	253.29	31250	8.11	
Oil Palm Fibber	O1	275.02	31250	8.80	10.2
	O2	316.19	31250	10.12	
	O3	365.14	31250	11.68	

3.2 Comparison of the flexural testing of normal, synthetic and oil palm fibre type interlocking bricks

Table 2 shows the results of the ultimate flexural load for normal, synthetic fiber and oil palm fiber type interlocking brick recorded as 32.2kN, 25.2kN, and 42kN, respectively. The load-deflection curve for the three types of interlocking brick was plotted in Fig. 6. The initial stiffness of the specimens represented by linear slope of the curve showed that oil palm fiber type has higher slope followed by normal type and lastly synthetic fiber type. The oil palm fiber type interlocking brick beam undergoes reduced deflection with large applied load as compared to normal and synthetic type of IHBS. Normal type of IHBS failed at the deflection of 9.39 mm while synthetic type at 18.27 mm and palm oil fiber at 12.22mm at the mid-span. The oil palm fiber type interlocking brick has shown the ability to sustain higher load followed by normal and synthetic type of IHBS. This shows that synthetic fiber type interlocking brick beam failed earlier than normal and oil palm types while normal type fails earlier than oil palm type. The results showed that palm oil fibre showed the highest value of flexural strength as compared to the SF and the normal interlocking brick system. This could be due the contribution of the fibre in POF that increased the flexural strength of the specimens. The use of POF was also improved in the deflection where the deflection of the specimen was recorded at 6.97mm for maximum ultimate load at 42kN.

Table 2. Flexural test result

Type	Ultimate Load (kN)	Deflection at Ultimate Load (mm)
Normal	32.2	6.14
Synthetic Fibre	25.2	17.45
Palm Oil Fibre	42.0	6.97

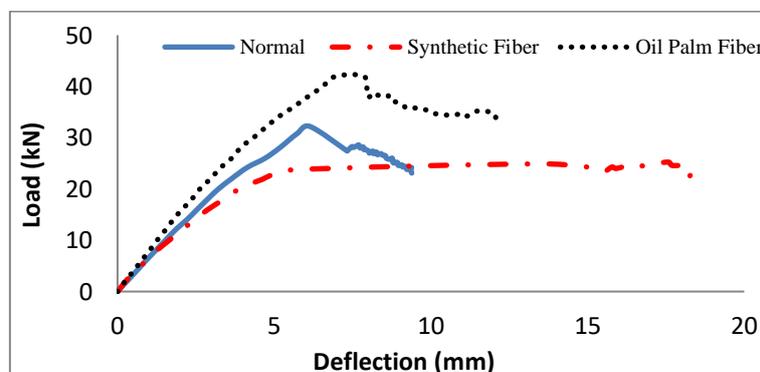


Figure 6. Load-deflection curve for normal, synthetic fibre and oil palm fibre type interlocking brick.

4. Conclusion

The research work presented in this paper was intended to investigate the strength of interlocking bricks in compressive strength and flexural strength. Three types of interlocking bricks were proposed in this study namely normal type interlocking brick, synthetic fibre type interlocking brick, and oil palm fibre type interlocking brick. After concluding the test and analysed the obtained results, it was concluded that oil palm fibre type interlocking brick has better strength for all test results. The results showed that oil palm fibre type of interlocking brick has the highest compression and flexural strength. The synthetic fibre type of interlocking brick also has better compressive and flexural strength as compared to normal type interlocking brick. POF type of interlocking brick was best performed in both flexural and compression because it can sustain higher flexural load and compression load. The addition of palm oil

fibre into the interlocking bricks improved significantly the compression and the flexural strength of the interlocking brick system, which can be used as an additive in IHBS production for better load-bearing brick.

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