SPLIT TENSILE STRENGTH OF INTERLOCKING COMPRESSED EARTH BRICK UNITS

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ABSTRACT

Interlocking compressed earth brick (ICEB) offers environmentally friendly and cost effective material compared to conventional building materials such as clay fired brick, cement brick, and concrete block. Earth soil and concrete is a brittle building material with low tensile strength. However, the tensile strength of the ICEB which combination of soil cement and sand has still remained unknown. This paper presents the experimental investigation of the split tensile strength of ICEB units. Split tensile strength is an important parameter in masonry structures to determine the ultimate load which would be able to split the masonry structures. Several types of ICEB (i.e., wall brick, beam brick, and column brick) was tested under split tensile strength test. In this test, two bearing rods were positioned on the bed and opposite bed surface of the ICEB to provide line load along the bed surface of ICEB unit. From this investigation, wall brick has the highest split tensile strength which is 0.769 N/mm^2 followed by column brick, 0.615 N/mm^2, and the lowest split tensile strength is beam brick which is 0.479 N/mm^2. ICEB units were failed by a tensile crack which parallels to the axis of the loading.

Keywords: Masonry, compressed earth brick, interlocking, mechanical properties, dry stack.

INTRODUCTION

The construction industry is experiencing a rising of cost in building construction due to the high cost of construction materials and slow construction work. Meanwhile, the conventional bricklaying method which is a commonly used method in building construction is costly and time-consuming due to the use of a high quantity of cement for structural work, wall plastering, and bricklaying. Using conventional brick also is costly because needs to use a highly skilled worker to ensure bricklaying is flat and fast. Therefore, the need for new materials that can reduce cost and construction time is required to replace the conventional bricklaying method.

Interlocking compressed earth brick (ICEB) is new materials which can reduce the cost and accelerate the construction. ICEB is an interlocking brick which made from the composition of soil, sand, cement, and water. In a review by Riza et al (2010), cost of construction can be reduced and faster construction work by using ICEB because it used low usage of cement in the construction by eliminating wall plastering and it can be dry stacked. ICEB also can eliminate the use of formwork because ICEB unit itself will be the formwork for the structural member. They also stated that ICEB is more environmentally friendly material compared to conventional building material because it would be able to reduce carbon emission by using less cement in production and curing only by open air instead of by burning process.

Masonry units and structures commonly fail in the tensile mode when it is loaded in compression. This happens because the compressive strength of the brick is higher than the tensile strength of the brick. Brick masonry strength is highly sensitive to the state of stress normal and parallel to the bed joint direction (Drysdale and Hamid, 1982).

A study carried out by Barbosa and Hanai (2009), shows the tensile strength of hollow concrete block are 10% from its compressive strength which is ranged from 1.3 N/mm^2 to 3.1 N/mm^2. Another study by Drysdale and Gazzola (1991), have shown splitting tensile strength of interlocking concrete block of 2.6 N/mm^2 meanwhile 30.4 N/mm^2 is a compressive strength. It shows split tensile strength is approximately 9% of its compressive strength and almost closes to the value stated from Barbosa and Hanai study which is 10%. In another study, Hossain et al (1997), investigated on the properties of the burnt clay brick masonry unit. They discovered that splitting tensile strength of burnt clay masonry is 5% of its compressive strength which is 3.2 N/mm^2 meanwhile its compressive strength is 66.2 N/mm^2. Bahar et al (2004), study about the performance of compacted cement-stabilized soil with different composition of cement to the soil. They found that splitting tensile strength of block has increased with the increase of cement content. They added 4% to 20% of cement by weight of soil in the mixture of the block. The splitting tensile strength using 4% to 10% of cement content increase rapidly. After 10% of cement content, the increase of splitting tensile strength is slow. Meanwhile, Upkata and Ephraim (2012) indicated the tensile strength of concrete increase when laterite sand content increase. Their study shows tensile strength of concrete with 50% laterite sand is 2.91 N/mm^2 meanwhile tensile strength of normal concrete only 1.85 N/mm^2.

Although ICEB is currently used in construction, the physical and mechanical properties of ICEB are remained sparse and not properly documented. This paper will show the result of split tensile strength test of three type of ICEB units to provide rough information about ICEB.

INTERLOCKING COMPRESSED EARTH BRICK (ICEB)

The idea of ICEB was invented is due for the need to the development of low cost building material and also promoting the use of local materials. Interlocking Compressed Earth Brick (ICEB) was developed by Center for Vocational Building Technology (CVBT) (Bales et al, 2009). There are many benefits using ICEB as construction materials such as ICEB can be dry stacked, used less cement, eliminated formwork, and not require highly skilled worker. Without the need for high skilled worker, by saving cement and with the speed of construction, the building costs using ICEB can be reduced compared to conventional building materials.

ICEB consist two holes used for reinforcement, three grout channels commonly filled with a fluid grout, and two interlocking dowels used for aligning the bricks. ICEB allow the bricks to be dry stacked without mortar by creating interlocking joints between layers of bricks. An inexperienced labor can easily build using ICEB because of it easier to connect between brick compared to conventional bricklaying method which is the skilled labor is required to make sure the mortar and bricklaying are flat.

ICEB manufacturing is very simple, hence it just required low skill worker to make it. It only takes three stage of the process to make it, which is soil preparation, mix compression and curing (Riza et al, 2010). In soil preparation, selection of best soil and content mix will give the best result of ICEB. Proper compression is needed to make ICEB have a good strength and curing of the ICEB only by open air.

The size and shape of ICEB are varying according to the application and location which it wants to be placed. The common size of the ICEB brick is 250 mm long, 125 mm wide and 100 mm height. It has the half size brick for the location which requires half of the brick because ICEB no needs to cut.

MATERIALS AND TEST METHOD

ICEB has been manufactured locally by ICEB Trading located at Sungai Petani, Kedah. There are thirteen types of brick in the ICEB, but only three types of brick in ICEB which are commonly used in construction were studied. These three types of ICEB are Wall Brick, Beam Brick, and Column Brick. The others brick are not be commonly used in construction as much as these three type of bricks. Wall Brick and Beam Brick were produced by hydraulic compression machine meanwhile Column Brick was cast by manual compression machine. Figure 1 to 3 shows different types of ICEB to be used in this study.

Figure 1: Wall Brick

Figure 2: Beam Brick

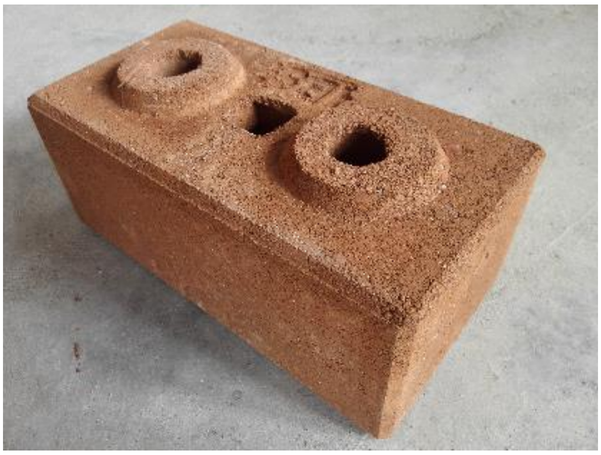


Figure 3: Column Brick

In this study, about 130 units of ICEB were tested to determine the split tensile strength of the ICEB unit. All tested masonry units were sampled at random as prescribed in clause 9 of BS 3921 (British Standard Institute, 1985). From the total of 130 units of ICEB, 50 units are Wall Brick and 40 units from each Beam Brick and Column Brick. The test was carried out in accordance with ASTM C1006 (American Society for Testing and Materials, 2013). This test produces a line load along the bed surface of the ICEB units. Tensile stress occurred on the masonry units resulted from the compressive load applied to the bearing rods. Bearing rod with 10 mm diameter was placed at along the center of the bed and the second bearing rod was placed parallel to the first opposite bed surface as shown in Figure 4. The load rate of 8900 N/min was applied to the bearing rod continuously without any impact. The load was continued until the brick failed and the maximum load was recorded.

The split tensile strength of the ICEB was determined using equation 1.

$$f_t = 2P/\pi LH \quad (1)$$

Where, f_t = splitting tensile strength,
P = maximum load,
L = split length, and
H = distance between rods.

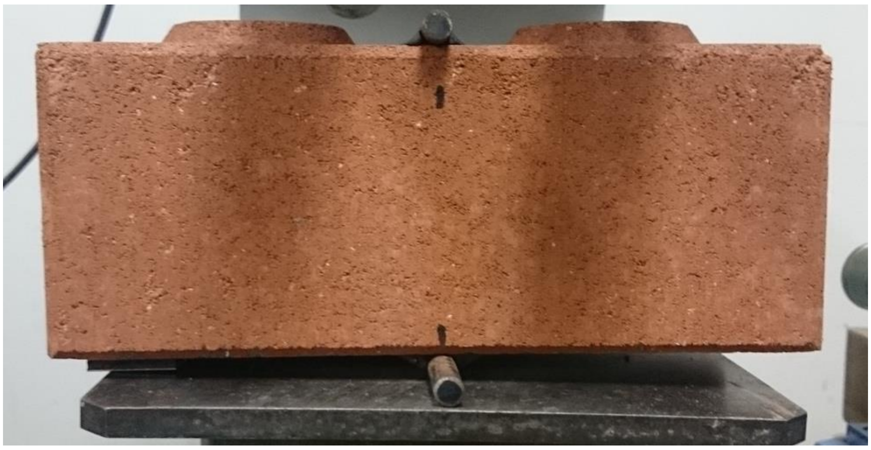
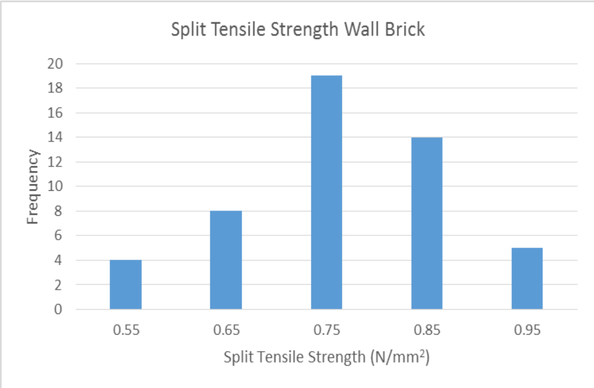


Figure 4: Bearing rods alignment

RESULT AND DISCUSSION

All the experiments conducted to determine the split tensile strength of the ICEBs were performed at the Concrete and Structural Laboratory in Universiti Sains Malaysia. Figure 5 to 7 shows the graph of result from splitting tensile strength test for three types of ICEB. The graph distributions of ICEB split tensile strength are variable. But the average value of split tensile strength is located at the highest frequency in the graph.



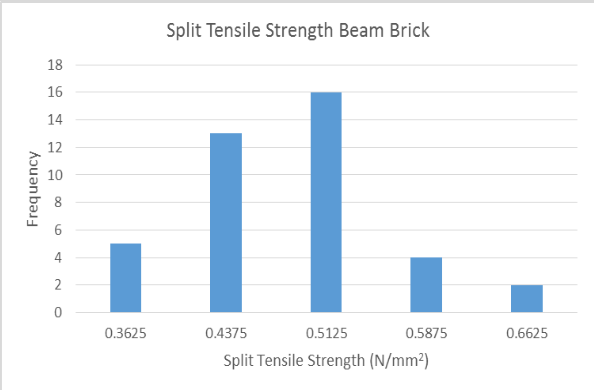


Figure 5: Splitting tensile strength Wall Brick

Figure 6: Splitting tensile strength Beam Brick

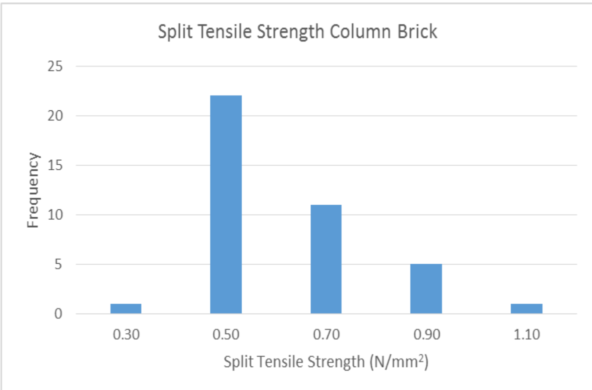


Figure 7: Splitting tensile strength Column Brick

Different of split tensile strength between three types of ICEB were shown in Figure 8 and Table 1. The highest split tensile strength in ICEB is Wall Brick which is 0.769 N/mm^2, followed by Column Brick, 0.615 N/mm^2, and the lowest split tensile strength is Beam Brick which is 0.479 N/mm^2. Beam Brick has the lowest split tensile strength among all three types of ICEB because it has U-shaped of brick. U-shape brick makes beam brick has the deepest groove under the brick. Meanwhile, Column Brick does not have any groove under the brick and Wall Brick has a little groove under the brick. Deep groove under the beam brick makes it has a less surface on the rod bearing during the test. This makes it failed at lower load compared to wall brick and beam brick. Although column brick does not has a groove under the brick, it has lower split tensile strength compared to wall brick which has a little groove under the brick. This because of Wall Brick and Beam Brick were made by hydraulic compression machine. However, Column Brick was made by manual compression machine which has lower compress rate compared to hydraulic compression machine. All types of ICEB is above of minimum tensile strength for masonry according to Hendry et al (2004), which is 0.4 N/mm^2. All wall brick, beam brick and column brick of ICEB units failed by tensile crack at parallel to the axis of the loading as shown in Figure 9.

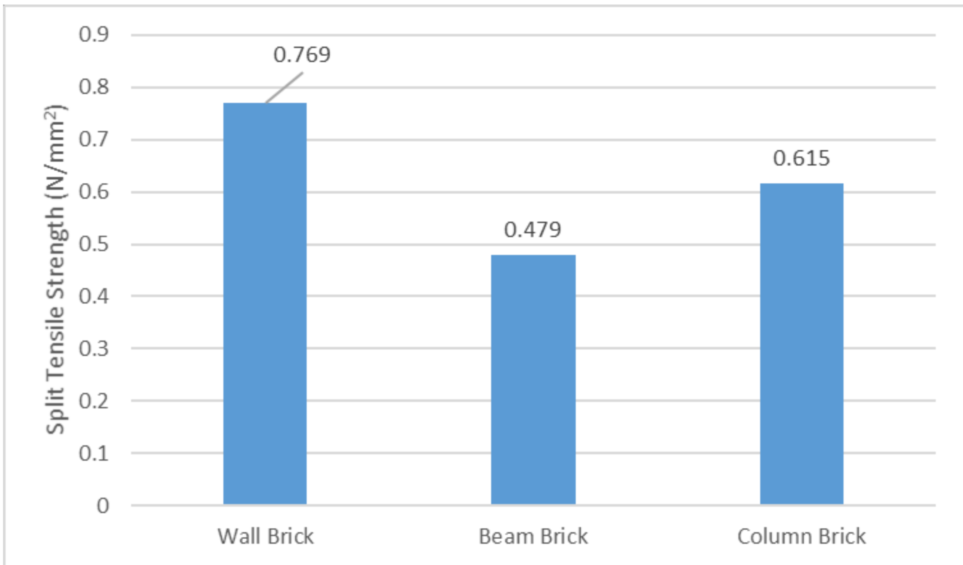


Figure 8: The splitting tensile strength of ICEBs

Table 1: Splitting tensile strength

Brick type	Average strength (N/mm^2)	Standard deviation	COV (%)	Range (N/mm^2)
Wall Brick	0.769	0.106	13.81	0.535 – 0.972
Beam Brick	0.479	0.072	15.05	0.339 – 0.655
Column Brick	0.615	0.156	25.38	0.271 – 1.009

Figure 9: Failure of Splitting Tensile Test

CONCLUSION

This paper shows the result of Interlocking Compressed Earth Brick (ICEB) units splitting tensile strength from laboratory investigation. Only three type of ICEBs were focused in this study despite there are many types of ICEB available in the market with different properties and size.

Among all three types of ICEB units, wall brick has the highest split tensile strength which is 0.769 N/mm^2 followed by Column Brick, 0.615 N/mm^2 and the lowest split tensile strength in ICEB is Beam Brick which is 0.479 N/mm^2. Shape and manufacturing method are the factors which can affect the split tensile strength of ICEB units. Where deep groove under the brick and low compression rate when casting the brick can decrease the split tensile strength of the ICEB units. Although Beam Brick has lowest tensile strength among the other bricks, Beam Brick will be strengthening by steel reinforcement in the construction.

The split tensile strength results from this study can be used as information in the construction industry to calculate and estimate the performance of ICEB units. These can provide knowledge about ICEB and encourage the contractor and other construction players to use ICEB in the construction.

Overall, all ICEB units can be used as masonry units in construction, with greater split tensile strength than minimum tensile strength for masonry.

ACKNOWLEDGMENT
The authors would like to thank ICEB Trading Sdn Bhd for supplying materials used for this study.

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