Effect Of Groove Infill To The Compressive Strength Of Multiple Groove Concrete Block Masonry Unit Under Uniformly Distributed Load

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Abstract. Interlocking concrete block is a new concrete masonry unit that is used in the construction industry. This masonry unit can improve the quality of the construction process; reduce the cost of labor, no need high skill workmanship and speeding the construction time. Normally, the interlocking concrete block masonry unit in the market place was designed in one way interlocking concept only either x or y-axis, shorter in length and low compressive strength value. However, the biaxial interlocking concrete block is a new concept being introduced in this research. Biaxial interlocking concrete block is a block with the interlocking system at both directions. Besides that, this masonry unit is offered the specialty compared to the normal interlocking concrete available in the market place due to its length and the geometry of the groove and tongue. This concrete masonry unit can be used as a non-load bearing wall or load-bearing wall depends on the application of the masonry. But, there is a lack of technical data was produced before. This paper presents a new finding on the compressive strength of biaxial interlocking concrete block masonry unit. Two series of biaxial interlocking concrete block unit namely BICB1 and BICB2 have tested the compressive strength. BICB1 is the masonry unit of a hollow biaxial interlocking concrete block meanwhile; BICB2 is the masonry unit of groove infill interlocking concrete block. The masonry unit sample tested under static compressive load. The results examine that BICB2 is higher in compressive strength compared to the BICB1. This result shows that BICB2 is better than BICB1, especially in load-bearing wall application.

1. Introduction

Nowadays, masonry structures are widely used in most building construction. It is a common component with low maintenance and good durability aspect. Normally, masonry structures can react as a load-bearing or non-load bearing structures. Basically, in masonry structures, it can be divided into beam structures, column structures or wall structures. The traditional masonry unit that has been used in the masonry construction are clay @ earth brick, cement sand brick, and concrete block. Typically this masonry unit has the weakness in their application such as environmental issues for clay
brick[1], quality control during construction for cement sand brick and the self-weight load for concrete block. In view of this weakness, several new masonry units and modern building masonry technologies are now available in the building marketplace to speed up the masonry construction project.

Biaxial interlocking concrete block (BICB) unit is one of the new concrete masonry units that is used in masonry construction especially in a building project. This material was developed with the interlocking system in both direction, x and y-axis and purposely used as a walling system. The interlocking was reacted through the groove and tongue element of the interlocking concrete block unit. Furthermore, this element is good to resist the loading acting on the structure from both sides and reduce the buckling and shear effect of the structure from the compressive load and lateral load. Besides that, this new material also giving the industries benefit from its geometry. The larger of their length reduces the number of material used in masonry wall construction. BICB can improve the process of masonry construction by speed up the construction time, reduce the number of skilled workers and its good in mechanical properties such as high compressive strength. Regarding [2], hollow element in concrete block offers many benefits such as ventilation aspects, reduce the dead load compared to the solid concrete block and its require less amount of mortar. However, since this is a new product, there is a lack of technical data has been produced before.

On the other than, this material comes out with the new technique in masonry construction called mortarless or dry stacked system. Dry-stack system or mortarless is a new technique of masonry wall construction without traditional mortar application in bed and heads joint [3][4][5]. This system reacts through interlock part by groove and tongue to led the masonry unit connected tightly to be an entire system [6]. The material being used in walling system by stacked directly on top of each other likes a lego concept and used 2mm cement glue as a binder to increase the capacity of the masonry wall [4].

As a new material, there is a need to identify its capability to be used as a masonry unit to replace the traditional one. Biaxial interlocking concrete block (BICB) is a hollow interlocking concrete block that can be used as a non-load bearing masonry wall. However, the application of this material can be extended to the load-bearing masonry wall by putting groove infill in the multiple groove area. This method called as grouting procedures. Regarding [7] in their research found out that the insertion of grouting material in the hollow concrete walls increased about 80% of their resistance capacity. The most important mechanical properties of the concrete masonry unit are their compressive strength. It is because the capacity of the masonry wall highly depends on the masonry unit performance. By that’s, the compressive strength of the interlocking concrete block plays a significant role to enhance the capacity of the masonry wall. It is supported by [8] that the capacity of masonry wall under axial compression is influenced by different parameters such as the compressive strengths of masonry units and mortar, the thickness of mortar binder, shape of the units, mortar bedding or binder methods (full or face shell), type of testing (prism or wallette) and masonry specimen aspect ratio.

This study aims to investigate the capacity of biaxial interlocking concrete block units under compression load due to its hollowness and groove infill material effect.

2. Methodology

2.1 Material Properties

Materials used in this study are a biaxial interlocking concrete block (BICB), sand, cement, and water. The details of the material used are per discussed as follow.

2.2 Biaxial Interlocking concrete block (BICB)

Interlocking concrete block namely Biaxial interlocking concrete block (BIPB) is a block produced and supply by Innovative Precast Builder Sdn.Bhd. The dimension of the IPB unit is shown in Figure 1.
Figure. 1 (a) and (b) Dimension of the biaxial interlocking concrete block unit

This BICB unit is 700 mm x 100 mm x 150mm in size consist of seven (7) numbers of grooves and 2 sides of the tongue. For this research, 40 unit of IPB was involved in its physical and mechanical properties. The numbers of block required for the testing as follows in Table 1. Out of 40 units, 20 units group as a hollow unit and 20 units as a grouted.

| BICB sample        | No of sample | Type of testing                      |
|--------------------|--------------|--------------------------------------|
| Hollow unit        | 10           | Compressive strength test/modulus of elasticity |
|                    | 10           | Density test/Dimension check          |
| Groove infill unit | 10           | Compressive strength test/modulus of elasticity |
|                    | 10           | Density test/Dimension check          |

2.3 Groove infill material

In this study, the groove infill material used as a reinforced method to enhance the capability of the block. Besides that, to compliance the requirement by Malaysian Standard as a number of percentages the void area is less than 35%, the grooves should be infill to become a solid. For the grouting process, it is involved the mixture between ordinary Portland cement, sand and water. The mix proportion of this material shows in Table 2.

| Design mix         | Cement               | Aggregates      | Water/cement ratio (w/c) |
|--------------------|----------------------|-----------------|--------------------------|
| 1:3 (grouting material) | Ordinary Portland Cement | Fine sand | 0.5                      |

Grouting material design mix was as shown above. Based on [9], the design mix 1:3 with 0.5 water-cement ratios produced enough compressive strength to fill in the grooves. Meanwhile, the chemical compositions of OPC Type 1 as shown below in Table 3.
### Table 3. Chemical Compositions for ordinary Portland cement [10]

| Chemical Compositions | %   |
|-----------------------|-----|
| CaO                   | 63.00|
| SiO₂                  | 20.00|
| Al₂O₃                 | 5.70 |
| MgO                   | 0.99 |
| Fe₂O₃                 | 2.90 |
| SO₃                   | 3.50 |
| K₂O                   | 3.55 |
| LOI                   | 2.8  |

### 2.4 Sample preparation

The experimental program involved the preparation of BICB unit sample for determination of its mechanical properties and the preparation of cube sample for groove infill material. The samples divided into two groups as a hollow and grouted as shown in Table 4. The experimental program involved the preparation of cube sample for determination of the mechanical properties of the groove infill material. Twelve (12) numbers of a cube sample size of 150mmx150mmx150mm and 50mmx50mmx50mm prepared in the concrete laboratory. The sample cured by immersed in the water for 7 and 28 days of age. Meanwhile, twelve (12) numbers of the hollow and groove infill biaxial interlocking concrete block tested to certify the Malaysian Standard MS 1933-1-2017, Compressive strength of the unit. Blocks were cut and grind for surface preparation and capped on top and bottom to reproduce the same contact area to simulate the actual compression state of the block in the masonry.

### Table 4. Numbers of BICB unit for testing

| BiPB sample       | No of sample | Type of testing                  | Standard compliance                                                                 |
|-------------------|--------------|----------------------------------|--------------------------------------------------------------------------------------|
| Hollow and Groove | 20           | Compressive strength test/ modulus of elasticity | MS 1933-1-2017: Methods of test for masonry units – Part 1: Determination of compressive strength |
| infill unit       | 20           | Density test                     | MS 1933-13-2007: Methods of test for masonry units – Part 13: Determination of net and gross dry density of masonry units (except for natural stone) |

![Figure 2](image-url) (a) hollow BICB unit, (b) groove infill BICB unit
2.5 Testing procedures

The testing procedures involved grouting material and BICB unit compliance with Malaysian Standard.

2.5.1 Compressive strength and density of grouting material

The compressive strength of mortar is determined by using 50mm cubes as per ASTM C109 / C109M – Standard Test Method for Compressive Strength of Hydraulic Cement Mortars. The test was conducted for six (6) cubes and report the average value as the test result for both 7-day and 28-day compressive strength.

2.5.2 Density test of IPB unit

All the sample will follow the MS 1933-13-2007: Methods of test for masonry units – Part 13: Determination of net and gross dry density of masonry units (except for natural stone). Total 20 unit of IPB as a hollow or grouted used to determine the net and gross density of masonry units. For whole unit specimens, dry the specimens to constant mass, in a ventilated oven at a temperature of 70°C ± 5°C. Constant mass is reached, if during the drying process in two subsequent weighing with a 24h interval, the loss in mass between the two determination is not more than 0.2% of the total mass.

2.5.3 Compressive strength test of IPB unit

All the sample will follow MS 1934-1:2007(confirmed 2014) Method of test for masonry-part 1: Determination of compressive strength. A minimum number of sample required is six (6) per 1000 consignment. Firstly, immerse the specimens in the water at a temperature of 20°C ± 5°C for a minimum period of 15 h and subsequently allow them to drain for 15 min to 20 min. According to clause 7.4.2 where the net loaded area of masonry units with a frog which is intended to be filled with mortar in practice (see also 7.2.3) is not less than 35 % of the gross area then the compressive strength shall be calculated on the basis of the net loaded surface of the frogged bed face. Where the net loaded area of masonry units with a frog is less than 35 % of the gross area then the compressive strength shall be calculated on the basis of the gross area of the masonry unit.

3 Result and Discussion

3.1 Density value of the sample

Density is a physical property of the concrete block that plays a significant role in masonry construction. Based on the density values, the material can be classified as a normal concrete block or lightweight concrete block. The denser of the material, it will reduce the dead load of the structures. The density of the sample will be influenced by the load resistance capacity of the structures.
Figure 3. Comparison of the density value for BICB blocks

3.2 Compressive strength of the biaxial interlocking concrete block unit.

Figure 4, presents the compressive strength of hollow BICB and groove infill BICB. From the figure, it is shown that the compressive strength of hollow BICB is 19.8 N/mm$^2$ meanwhile grouted BICB is 23.7 N/mm$^2$. It is found that the compressive strength of grouted BICB is higher than hollow BICB unit. The compressive strength of the grouted IPB is higher than the hollow unit might be due to the effect of groove infill material compressive strength when reacting with the hollow block. A study conducted by [14] mentioned that the voids number of block unit significantly affect the compressive strength value. Regarding [15], their study showed that the grout bond strength is improved with the decrease of the water/cement ratio.
3.3 Correlation of compressive strength with the density.

![Figure 5. Relationship of compressive strength and the density of the blocks](image)

Figure 5, presents the relationships of compressive strength of BICB 1 and BICB 2 with their respective density. From the figure, it is shown that the linear relationships between these two types of sample. The higher the density value leads to the higher in compressive strength and vice versa. It is found that the higher compressive strength with higher density leads to an increase in a dead load of the BICB unit. By that, these results show that to develop a new lightweight concrete block it must take into account the reliable density but produced the good compressive strength. The raw material that been used must lighten but have a good capacity.

4. Conclusion

This paper presented a comprehensive experimental program with the objective of assessing the compressive strength of the biaxial interlocking concrete blocks. Nominal resistance of blocks was 23.7 N/mm² with the groove infill material produced with shrinkage-compensating admixture. The main conclusions of the research presented here are:

- a) The density of the sample depends on the weight of the sample
- b) All the BICB 2 units showed a higher value in compressive strength compared to the BICB 1 unit;
- c) There is a linear relationship between the density and the compressive strength of the sample
- d) Experimental results show the significant result of compressive strength of BICB units due to the effect of the groove infill material.

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