The Behaviour of Palm Oil Fibre Block Masonry Prism under Eccentric Compressive Loading

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Abstract. Dry-stacked masonry offers great benefits in constructing masonry buildings. Several examples from previous research show that dry masonry is a reasonable alternative to the traditional building system. By addition of fibre, the ductility and the propagation of cracking will be improved. This study investigates the dry stack oil palm fibre block prisms which were subjected to eccentricity compression loads. These concrete blocks were cast using a single mould with suitable fibre-cement composition namely 1:4 (cement: sand) and 0.40 water to the cement ratio based on cement weight. Prisms test using 400 (length) x 150 (width) x 510 (height) mm specimen was carried under eccentric load. There were forty eight (48) prisms built with different configurations based on their volume of fibre. In this study, one types of grout were used namely the fine grout of mix 1:3:2 (cement: sand: aggregate (5mm maximum). Based on the test performed, the failure mechanism and influencing parameters were discussed. From compressive strength test result, it shows that the strength of concrete block decreased with the increase of fibre used. Although the control sample has the higher strength compared to concrete with EFB, it can be seen from mode failure of masonry prism that fibre could extend the cracking time. These results show that the oil palm fibre blocks can improve the failure behaviour and suitable to be used as load bearing wall construction in Malaysia.

1. Introduction
Dry stacked masonry actually is the oldest type of masonry. Dry stacked masonry refers to a method of building masonry walls in which most of the masonry units are laid without mortar in the joints [1]. In recent years, there has been a renewed interest in the dry stack form of masonry construction for small buildings mainly homes.

Interlocking mortarless or “dry-stack” masonry construction refers to a method of building masonry walls, in which most of the masonry units are laid without mortar. The structural use of dry-stack masonry relies on interlocking between the masonry or blocks. Murray [2] had conducted a research on dry stacked surface bonded masonry and introduce the ENDURA block system. The author claim that the dry-stack method forms construction significantly easier and reduces the need for skilled labor.

Portland cement concrete is the most generally used manufactured material [3], plain concrete, mortars, and cement pastes are brittle, possess low tensile strength, and exhibit low tensile strains prior to failure. These limitations have been traditionally overcome by implanting within cement-based material some other material with greater tensile strength.
Yalley and Kwan [5] stated that the use of conventional steel bar reinforcement and also inclusion of certain fibre can overcome the weakness in tension for concrete that made with cement. Concrete made with portland cement has certain characteristics: it is strong in compression but weak in tension and tends to be brittle. The use of fibres will alters the behaviour of the fibre-matrix merged after it has cracked, thereby improving its toughness.

Rai and Joshi [6] in their paper, provide information on the properties and applications of the more commonly available fibers and their uses to produce concrete with certain characteristics. They stated that fibers have many benefits. One of the advantage of fiber is that it can improve the structural strength to reduce in the heavy steel reinforcement requirement. When the structure is burdened, the micro cracks will exposed and spread. With the present of fibre, it will dispersed and scattered randomly in the concrete and thus improve concrete properties in all directions.

Natural fibres reinforced cement-based materials have gain increasing application in residential housing components. One of the natural fibres considered is oil palm empty fruit bunches (EFB) fibres which offer advantages such as availability, renewability, low cost and the established technology to extract the fibres. EFB reinforced block concrete is a block made by mixture of cement, fine aggregate, water and EFB fibre. Atkinson et al. [4] state that the prediction of compressive strength and deformation characteristics of full scale masonry based on compressive tests of stack-bond masonry prism and the interpretation of the results of prism tests have a significant influence on the allowable stress and stiffness used in masonry design.

The present study is focuses on the efficiency of using oil palm empty fruit bunches (EFB) fibre which aimed at observing the variation of compression strength by varying volume fraction of EFB in concrete block and form of crack in masonry prism that will be occur during testing.

2. Materials and Method

2.1 Materials

2.1.1 Cement and fine aggregates
Ordinary Portland cement (OPC) was used throughout this research. The aggregate that used in the research is fine aggregate. According to MS 29:1995, fine aggregate should be pass 5.0 mm BS 410 sieve analysis and not contain any particles bigger than that size. Material which is laying between 0.002 mm and 0.06 mm is been classified as clay and silt. According to MS 27: 1971, the aggregate shall be clean and free from deleterious matter. [10]

2.1.2 Water
In concrete mixture, water plays a very important role to determine the strength of concrete block. The volume of water which will be used is according to the design of concrete block density. The strength of block concrete will decrease if the volume water is high while workability is decrease if volume of water is low.

2.1.3 Oil palm empty fruit bunches (EFB) fibres
The natural fibres must be free from pesticides. It must conform to the MS 1408:1997 (P) Specification for EFB. The specimen were prepared with manually cutting about 5mm to 15mm [11]

2.2 Mixture design and sample preparation
Mixture proportions and block concrete are use ratio 1:4. The total quantities of sample that were made as shown in Table 1. For most general purpose concrete masonry construction a 1:4 (cement: sand) are suitable. In this study, one types of grout were used namely the fine grout of mix 1:3:2 (cement: sand: aggregate (5mm maximum)). The grout that use in this studies is classified in Type fine grout according to ASTM C476 [12].
Table 1. Quantities of sample according to unit compression test and prism compression test.

| Mixture | Unit Compression Test | Masonry prism compression test under eccentric loading |
|---------|-----------------------|------------------------------------------------------|
|         | t/0       | t/6 | t/3 | 5t/12 |
| M       | 3         | 9   | 9   | 9     |
| M1      | 3         | 9   | 9   | 9     |
| M2      | 3         | 9   | 9   | 9     |
| M3      | 3         | 9   | 9   | 9     |
|         | 12        | 36  | 36  | 36    |
| Total   |           | 156 |      |       |

2.3 Test for concrete block and grout

2.3.1 Sieve analysis
According to MS 29:1995, fine aggregate were selected with passing 5.0 mm BS 410 sieve analysis and not contain any particles bigger than that size. Aggregate also clean and free from deleterious to avoid the impurity that may effects the workability of block.

2.3.2 Dimension and density
For the checking of dimension and density of block concrete, 3 whole blocks were randomly pick from the sample. Procedure of checking is according to MS27:1971.

2.3.3 Compression strength
The dimension of this blocks (150mm x 150mm x 450mm) after 28th days, were tested for compression strength.

2.3.4 Masonry prism compression strength
For the masonry prism compression test, 3 hollow blocks were bind together using the grout. These masonry prism of age 28 days were tested using Universal Testing Machine. A stress (N/mm²) versus strain (mm/mm) will be plotting to determine the value of modulus elasticity.

3. Result and discussion
During this study, total of sixteen prisms with different configurations based on their volume of fibre were test on different eccentricity of compression loads. The results obtained from lab work i.e. sieve analysis, compressive strength test for unit concrete block and masonry prism were analysed and discussed. The strength of fibre reinforced concrete block was compared with control block in order to determine the behaviours of strengthened fibre reinforced concrete block in terms of compressive strength. In addition, the mode of failure for all the masonry was discussed in this study.

3.1 Compressive strength
The average value of unit compressive strength for concrete block with variable volume of EFB was shown in Figure 1 and for masonry prism in Table 2.
Based on the result, it shows that compressive strength of the block was decreased by addition of EFB. This results was in agreement with the research by Ismail [7], the researcher founds that Palm Oil Fibre that used in the study improved the strength at 7, 28 and 90 days respectively compared with the control mix, however, the strength was not increase linearly with an increase of fibre content. These situation was not shock since the fibres themselves cannot resist axial compressive load that will lead to not contribute to the compressive strength of blocks. Furthermore, it is challenging to compact higher EFB fibre content mix resulting in the increase of voids in the blocks.

Table 2. Compressive strength for masonry prism with variable volume of EFB

| Sample   | Maximum force(kN) | Compressive strength (N/mm²) |
|----------|-------------------|------------------------------|
|          | t/0               | t/6                          |
| Control  | 185.24            | 205.313                      |
| Fibre 5% | 173.63            | 175.344                      |
| Fibre 10%| 149.12            | 85.594                       |
| Fibre 15%| 134.69            | 70.750                       |

Table 2 shows the results of compressive strength of palm oil fibre block masonry prism under eccentric loading. Three levels of eccentricities (\(e = t/0, t/3\) and \(5t/6\) where \(t\) is 75mm thickness of the block) have been considered for this test. From the results, the compressive strength were decreased with the increase of eccentricity. The similar trend was recorded by Dhanasekar et al. [8] where they study the behavior of dry stack concrete masonry blocks under eccentric compression. These showed that prism strength could be a good representative of the actual strength of blocks for walling system.
3.2 Stress strain relationship
There were several observations on the stress-strain curves, as refer to Figure 2, it can be see that the trend of stress for control block and 5% fibre block are almost similar, however 5% fibre block has high strain compared to control block. 10 % fibre block had the highest strain compared to others. This situation explained that the fibre presence in the concrete contributed greatly in offering restrain to early twist or strain in the concrete.

![Stress versus Strain for t/0](image)

**Figure 2.** Graph stress versus strain when compressive load at t/0

![Failure mode of masonry prisms](image)

**Figure 3.** Failure mode of masonry prisms

3.3 Mode failure of masonry prism
All the masonry prism was being tested until total failure occurred. Total failure is defined as the failure where there is a significance crushing or simple tensile crack that prevent the block from sustain higher load. All the fracture and crack at the structure of the masonry prism has been sketches to make a comparison of mode failure between the block control and fibre reinforced concrete block. Picture of actual cracking was taken (Figure3).

| Sample | Force (kN) at the initial crack when load are applied at (mm) |
|--------|------------------------------------------------------------|
|        | t/0 | t/6 | t/3 | 5t/12 |
| Control | BO1 | 87  | 88  | 53  | 23   |
|         | BO2 | 76  | 80  | 50  | 41   |
|         | BO3 | 93  | 69  | 47  | 35   |
|         | Average | 85.33 | 79  | 50  | 33   |
| Fibre 5% | B51 | 107 | 106 | 97  | 79   |
|         | B52 | 132 | 103 | 83  | 84   |
|         | B53 | 117 | 96  | 94  | 66   |
|         | Average | 118.67 | 101.67 | 91.33 | 76.33 |
| Fibre 10% | B101 | 123 | 80  | 69  | 50   |
|          | B102 | 118 | 81  | 70  | 51   |
|          | B103 | 135 | 63  | 63  | 42   |
|          | Average | 125.33 | 74.67 | 67.33 | 47.67 |
| Fibre 15% | B151 | 132 | 67  | 68  | 48   |
|          | B152 | 130 | 70  | 63  | 47   |
|          | B153 | 132 | 68  | 65  | 41   |
|          | Average | 131.33 | 68.33 | 65.33 | 45.33 |

**Table 3.** Observation on the cracking when the force applied
The observation for the first crack was done. Table 3 shows the observation on initial crack was occurring. From the table, we can see that the initial cracking for the control block are occur at the lowest force compared to others concrete block. These showed that the implementation of EFB in concrete mixture had the effects on initial cracking. As stated by Pelisser et al. [9] in their research on drying characteristics of concrete reinforced with oil palm, the addition of fibres was efficient as it could restrain crack formation due to plastic shrinkage.

4. Conclusion
From the results of this research, the following conclusion can be drawn:

1. The addition of EFB in cement blocks resulted in the reduction of strength.
2. Eccentricity in compression had affected the strength for all level of eccentric.
3. Fibre presence in the concrete will help to restrain the twist or strain in the concrete.
4. Cracking with EFB block was delayed to later ages with the presence of fibre and prevent cracks become worse.

Acknowledgements
The author would like to thank the Office of Research, Innovation, Commercialization and Consultancy (ORICC), UTHM, for supporting this research.

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