

PAPER

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# Mechanical performance of carbon fiber reinforced polymer as repair material for damage wall structure

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**Abstract.** The quality of fired clay brick from different factory varies due to the different method of a manufacturing process. This research was design into three stages which are i) characteristic material study, where the material sources was from 3 states in Malaysia (Sidam Kiri Kedah, Serendah Selangor and Beruas Perak), ii) wall performance before retrofit and iii) damage wall performance after retrofitting process using CFRP. Based on the result obtained, the engineering properties of fired clay brick from Serendah Selangor shows the highest value of compressive strength as compared to brick from the other states. It has the higher flexural strength, low value of IRA, low value of water absorption, and low value of porosity. For the wall performance, the result show that the CFRP horizontal pattern for brickwall made from Serendah Selangor was better than oher types Beruas Perak and Sidam Kiri Kedah with percentage of increment 76%, 22% and 1.9% respectively, after being repair with CFRP. As for conclusion, the strength of brick wall can be improved significantly with the application of using CFRP strip in the research.

## 1.0 Introduction

Damage building can happen due to several reasons. They can be affected by vertical or horizontal loading. Example of loading from vertical is like the installation of a new air ventilation compressor, heavy machinery, and so forth. For horizontal loading, the most common type of loading is wind load and earthquake load. A masonry wall is easily damaged due to this effect. In practice, observation on the wall will show some crack on the wall surface. The use of fiber reinforced polymer (FRP) to improve strength and modify the existing reinforced concrete, or masonry building becomes popular nowadays [1]. According to [2], the confinement of structure component with FRP composite can enhance the strength and its' ductility. Besides, the utilisation of FRP also can be considered as an alternative to prevailing corrosion related problems as the corrosion of steel reinforcement especially in the aggressive environment can cause damage to the reinforced structure [3].

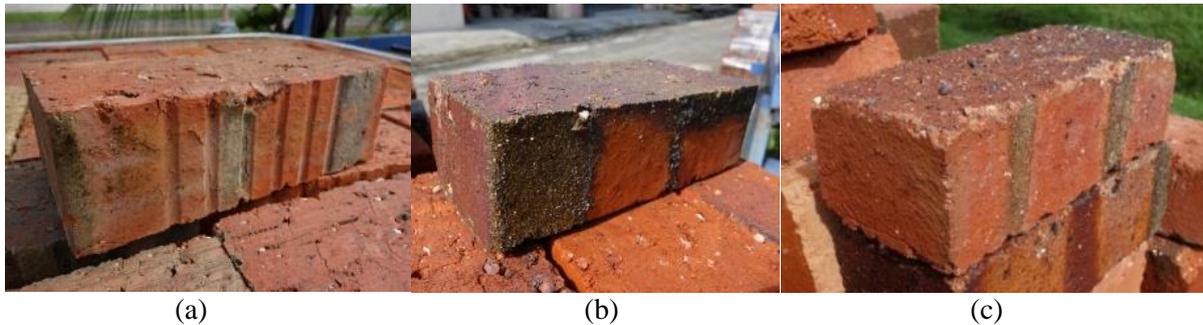


As refer to [4], masonry is the oldest building material used in the construction. In a nutshell, masonry is the assemblage of the brick, block, stone, etc. to resist vertical compression loading and provide resistance against in plane and out of plane lateral loading. However, the different in masonry units such as differences in materials, sizes, and fabrication process may influence regarding compressive strength [5]. According to [4], the most common application of concrete masonry is walls for building, and the benefit of using block masonry is the minimisation in construction time, less formwork usage, and can be repaired using available repair material such as fiber reinforced polymer (FRP). This research aim is to study the usage of FRP in improving three (3) types of wall structure using a masonry unit from three (3) different states in Malaysia.

## 2.0 Materials

### 2.1 Fired Clay Brick

There are three samples of fired clay brick from three different states. They are prepared accordingly to BS3921 for this research. Figure 1 (a), (b) and (c) is an examples of brick unit collected from different state in Malaysia



**Figure 1.** a) Brick from Beruas Perak, b) Serendah Selangor, c) Sidam Kiri Kedah

### 2.2 Mortar

In this study, the mortar use is M6 and it is an accordance to [6]. The mix ratio used is 1:4:1.5 where cement to fine aggregate to water.

### 2.3 Carbon Fiber Reinforce Polymer (CFRP)

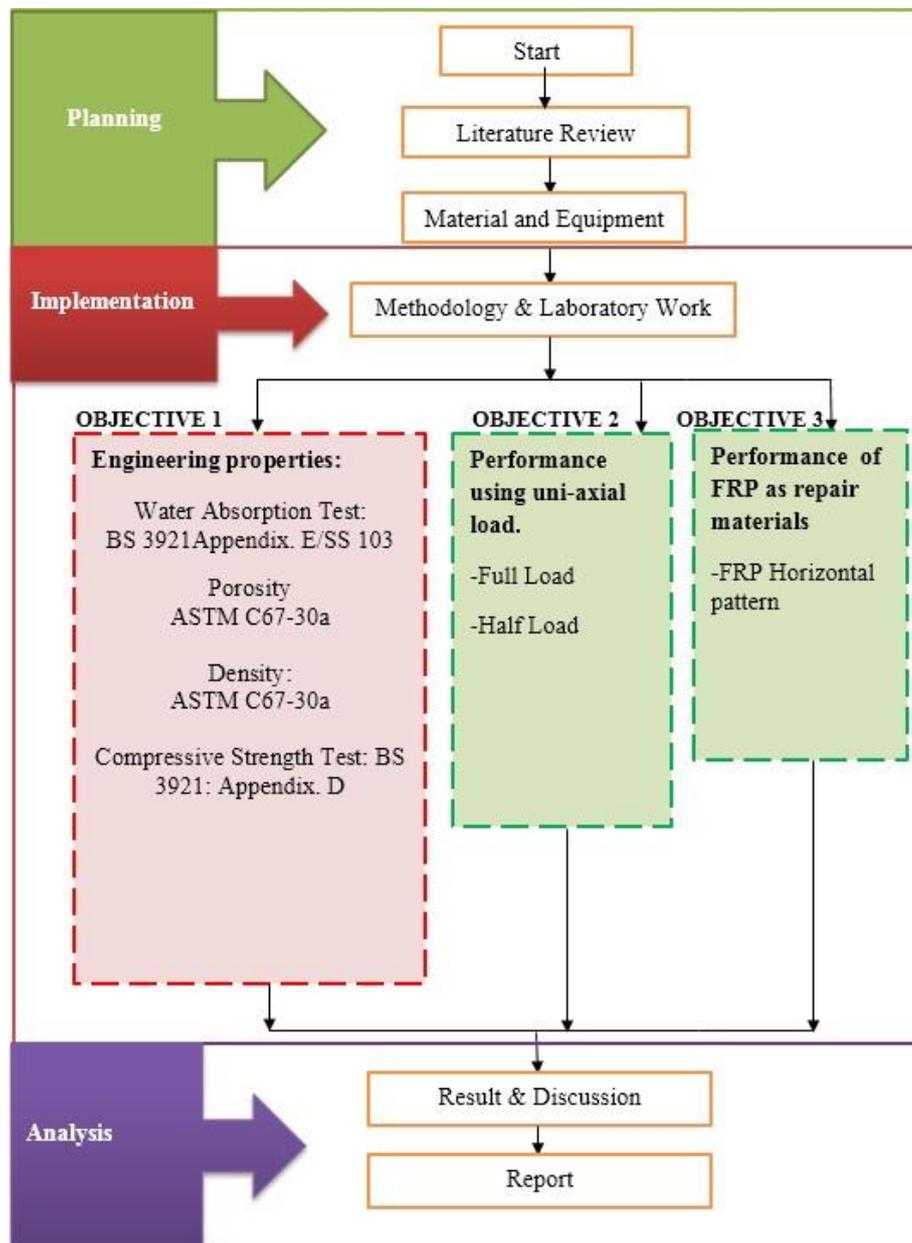
In this research, the type of CFRP used was supplied by Build Seal ® CFFS 300 with tensile modulus of 3850MPa.

### 2.4 Epoxy Resin

There are two components of epoxy resin. The first one is MBrace Primer (A) and the second one is MBrace Saturant (B). The ratio of this adhesive is 1 (A) : 3 (B). These epoxy resin has a tensile strength of 2400Mpa when hardened.

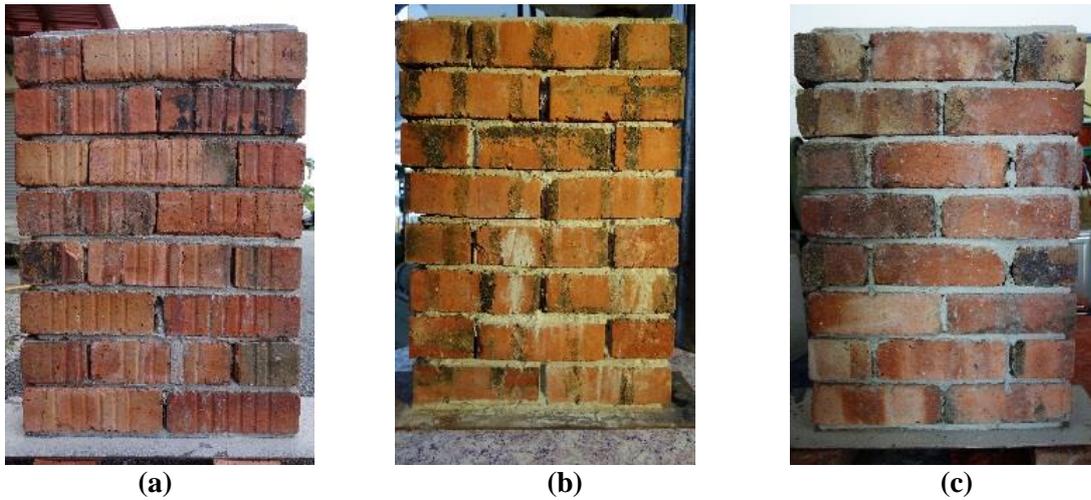
## 3.0 Methodology

Figure 2 shows the research flowchart to investigate the performance of CFRP as repair material for wall structure.



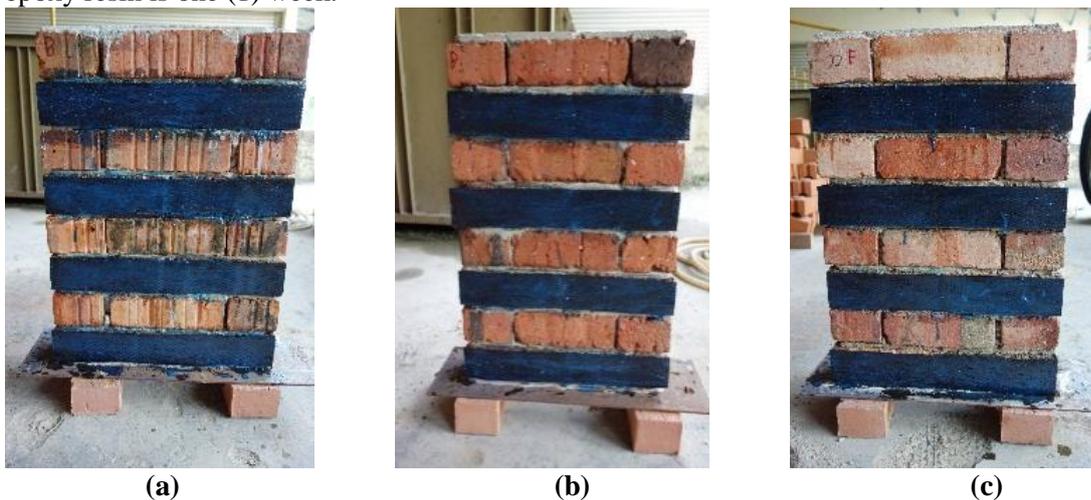
**Figure 2.** Flowchart of research work

Figure 3 shows the brickwall before loading and repair process. The size of this wall is 430mm (L) X 110mm (W) X 650mm (H). The test for compressive strength and water absorption is accordance to [7] and porosity and density is accordance to [8].



**Figure 3.** a) Brickwall Beruas Perak, b) Brickwall Serendah Selangor, c) Brickwall Sidam Kiri Kedah

Figure 4 shows the brickwall after being load and repair process. At this stage, the curing time for epoxy resin is one (1) week.



**Figure 4.** a) Brickwall Beruas Perak, b) Brickwall Serendah Selangor, c) Brickwall Sidam Kiri Kedah

#### 4.0 Results and Discussions

The water absorption was the amount of water which taken up from the mortar to fill pores in the clay brick and it an important factor for the durability of fired clay brick. Table 1 presented the water absorption of the fired clay brick from Selangor, Kedah, and Perak. The highest water absorption was from Sidam Kiri, Kedah which was 21.18%. The lowest water absorption was from Serendah Selangor which was 16.11%. When water absorbs more amount of water, it can decrease the durability of brick. The absorption plays important roles because it also desired a suitable amount of water if it too little brick would tend to run off very quickly towards the joints and may find its way into the building as well as reduce the durability of the mortar joints. Besides, a high absorption results in vulnerability to volume changes that would result in cracking of the bricks and structural wall damage on buildings. The wall properties are highly influenced by its density. A denser brick generally provides higher strength and fewer amounts of voids and porosity. Smaller the voids in brick, it becomes less permeable to water and soluble elements. Table 1 presented the density of the fired clay brick from Selangor, Kedah, and Perak. The highest value of density was brick from Serendah Selangor which achieved 2179.10 kg/m<sup>3</sup> than other states. The lowest value of density was brick from Sidam Kiri, Kedah which is 2017.91 kg/m<sup>3</sup>. This was due to the difference manufacturing process for each state.

Porosity is an important characteristic of brick which the porosity of brick was being caused by to its fine capillaries. The capillary effect, the rate of moisture transport in the brick was faster than in other building materials. During the day-time the moisture was released, while during the night-time the moisture was re-absorbed. The ability to release and re-absorb moisture by capillary effect is one of the most useful properties of brick that helps to regulate the temperature and humidity of atmosphere in a house. Table 1 shows the porosity of fired clay brick from three (3) different states. The higher value of porosity has the highest water absorption which bricks from Sidam Kiri, Kedah was 36.02%. The lowest porosity has the lowest water absorption value which was brick from Serendah, Selangor with 30.23%. The characteristic strength considers the inherent variations in the material strength due to its quality, manufacturing and the size of samples. Table 1 shows the compressive strength value of fired clay brick from three different states. The compressive strength of fired clay brick from Serendah, Selangor has the highest value which was 14.05 N/mm<sup>2</sup>. The highest value of compressive strength was due to the reduction of porosity and water absorption of brick. The compressive strength value obtained from the test was the actual strength of the brick sample which will be used for the construction of building. Therefore, the compressive strength test must be carried out carefully to determine the quality of buildings material.

**Table 1.** Engineering properties of brick unit from three (3) different states

Bricks	Water absorption (%)	Density (Kg/m <sup>3</sup> )	Porosity (%)	Compressive Strength (N/mm <sup>2</sup> )
Serendah Selangor	16.11	2179.10	30.23	14.05
Beruas Perak	20.12	2116.99	35.45	10.66
Sidam Kiri Kedah	21.18	2017.91	36.02	7.50

From Table 2, the maximum load for control wall is shown and will be use as guidance to get half load results. After the wall being load with a half load, CFRP will be use with horizontal pattern to repair the damage wall and the results shows an increase in value of maximum load. For the wall performance, the result show that the CFRP horizontal pattern for brickwall made from Serendah Selangor was better than other types, Beruas Perak and Sidam Kiri Kedah with percentage of increment 76%, 22% and 1.9% respectively, after being repair with CFRP.

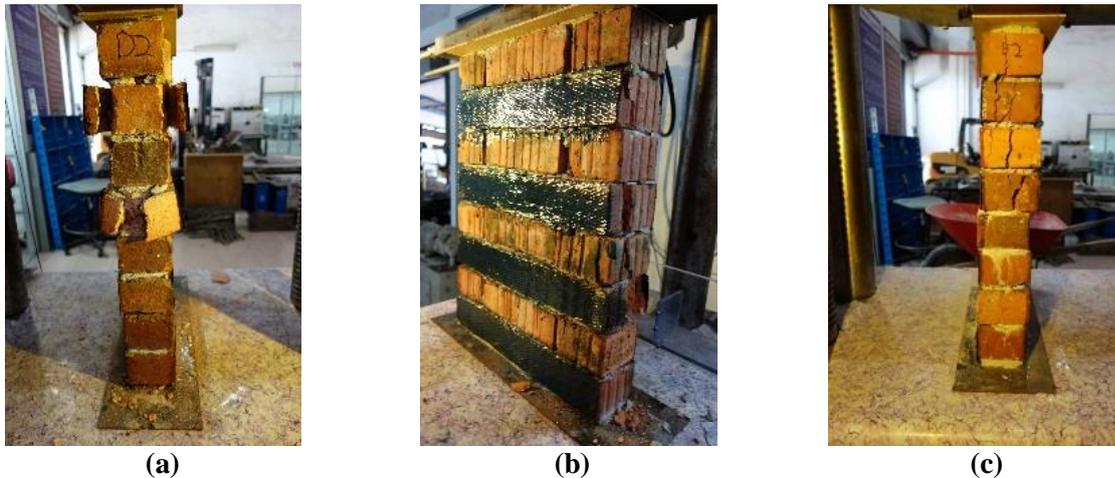
**Table 2:** Brickwall testing results for brick from three (3) different states

Brick Types	Maximum Load (N/mm <sup>2</sup> ) (Control)	Half Load (N/mm <sup>2</sup> ) (Damage)	Maximum Load for Horizontal Pattern (N/mm <sup>2</sup> ) (repaired)
Beruas, Perak	5.65564	3.70566	6.91073
Sidam Kiri, Kedah	3.69483	1.82853	3.76586
Serendah, Selangor	3.28494	1.99125	5.79545

From Table 3, the observation from the tested wall shows the failure was not due to the bonding. It is the brick that failed under compression load. As shown in Figure 5, the CFRP was still stick to the brick even though the wall has failed.

**Table 3.** Brickwall bonding results for brick from three (3) different states

Bricks	Horizontal
Serendah, Selangor	Still attached
Beruas, Perak	Still attached
Sidam Kiri, Kedah	Still attached



**Figure 5.** a) Damage brickwall Beruas Perak, b) Damage brickwall Serendah Selangor, c) Damage brickwall Sidam Kiri Kedah

## 5.0 Conclusion

As a conclusion, the brick from Serendah Selangor give a better wall performance compared to the other two. The quality of brick has an influence on the overall performance of wall. The CFRP helps to increase the capacity of load up to 76% for wall using brick from Serendah Selangor. It shows that CFRP can be used as a repair material and strengthen the damage. The result shows, CFRP horizontal pattern is better than control specimen because it held the original position of the specimen. It is observed that less cracking and crushing on the wall specimen. In other words, the strength of brick wall can be improved significantly with the application of using CFRP strip in the research.

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