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# Development of Mortar for Repair of Cracked Concrete with Injection Method

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**Abstract.** This study aimed to develop a mortar with the addition of glass fiber as a mortar reinforcement with variations in the addition of glass fiber (0 gram; 5.99 grams; 17.97 grams) which was homogenized with variations in the addition of aggregate (5.32 kg; 2.66 kg; 0 kg) and cement variations (1.56 kg; 3.41 kg; 5.25 kg). Mortar is used as a material for repairing cracked concrete by using the injection method. The mortar tests carried out were mortar flow testing, flexural strength testing, compressive strength testing, adhesive strength testing, and OM observations. The results of the mortar flow test with a mixture of cement without aggregate and the addition of 5.99 grams of glass fiber showed that the mortar could flow in gaps of 1 mm, 3 mm, and 5 mm. The optimum flexural strength test results with the addition of glass fiber are that the cement mixture is more than the aggregate with glass fiber 17.97 gram, the flexural strength value of the mortar is 0.74 MPa. While the optimum compressive strength with the addition of glass fiber is a mixture of more cement than aggregate with glass fiber 17,97 gram, the compressive strength value of mortar is 16.6 MPa. The results of the optimum mortar adhesive strength test value flowing in a gap are the addition of 5.99 grams of glass fiber; the mortar adhesive strength value is 3.31 MPa. Based on the results of observations using OM, the glass fiber that binds or can blend with the mortar is a mixture of cement without the addition of aggregates.

**Keyword:** Glass Fiber, Compressive Strength, Mortar Injection

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## 1 Introduction

Cracks are cracks in concrete, in the form of long narrow lines. These cracks usually occur due to hot and windy weather. This type of damage is superficial and interconnected [1]. Cracks in concrete can be divided into structural and non-structural cracks. Structural cracks occur due to errors in planning or loads that exceed capacity, while non-structural cracks mostly occur due to physical chemical processes in concrete in the early stages of concrete age. In general, non-structural cracks do not directly cause the weakening of the building structure [2].

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Concrete hardens in winter, shrinkage, settlement and formwork [3]. Cracks in the concrete structure are the separation of the concrete surface due to a gap in the concrete surface. Concrete surface cracks can be identified by several parameters, namely crack width, crack length, crack depth and crack pattern. The width of the micro crack is difficult to measure because the irregular shape is difficult to detect because it is too small [4].

Cracks in concrete should not be ignored as they are one of the main causes of failure. Therefore, investigation of the concrete structure is needed. Crack inspection in terms of crack width is not sufficient to evaluate the damage to concrete structures. But it is also necessary to measure the depth of concrete cracks [5]. Efforts to repair concrete cracks so far can be done with epoxy injection. Epoxy is a component that has a very high adhesion between normal concrete and repair materials and has low permeability. The disadvantage of this material is that it is relatively more expensive than cement grout and polyurethane [6]. Commercially available and obtained using mechanical and thermal treatments can work very well as reinforcement in concrete, ultimately preventing cracking. Fiber type additives are widely used in various types of composites not only concrete (for example polymer), currently more than 95% of glass fiber reinforced composite products because of their low cost. The most important parameter that determines successful production is the fiber size. Size is indispensable in the fiber production process [7].

## 2 Methods

Preparation of all materials in the form of aggregate, cement, glass fiber, water, and besmittel. In the first mortar mixture, 5.32 kg of aggregate was weighed using a digital balance, 1.56 kg of cement, 0.69 kg of water as a diluent and 7.8 grams of besmittel, for the second mortar mixture, 3.41 kg of cement was weighed, aggregate 2 .66 kg, water as a diluent 1.50 kg and 17.5 grams of besmittel then for the third mortar mixture, 5.32 kg of cement was weighed, without the addition of aggregate, 2.31 kg of water as a diluent and 26.25 grams of besmittel after that cement and the aggregate was stirred, and added water that had been mixed with besmittel for 2 minutes. Then added glass fiber with variations of 0 grams, 1800 grams, 5400 grams into each mortar mixture and homogenized for 3 minutes then poured into a mold measuring 4x4x16 cm, then the mortar was disassembled and stored in water for 7, 14, 28 days. Then the compressive strength, flexural strength, adhesive strength and OM observations can be carried out. Making a new mortar paste with three different types of mortar mixture then tested the mortar flow using acrylic glass with a gap of 1 mm, 3 mm, 5 mm and slump test.

## 3 Result and Discussion

### 3.1 Mortar Flow Testing

The mortar flow test was carried out using acrylic glass. The first thing to do is to make variations of the acrylic glass gap, namely 1 mm, 3 mm, and 5 mm gaps. After that make a

mortar mix to do the slump test. This mortar is also used for flow testing on acrylic glass. To find out how far the mortar flows on the acrylic glass, it is done by measuring the length of the acrylic that the mortar has passed.

**Table 1.** Mortar Flow Test Results

| Sample Code | Slump | | Width (cm) | Acrylic Slit (cm) | | |
|---|---|---|---|---|---|---|
| | Initial High (cm) | Final High (cm) | | 1 mm | 3 mm | 5 mm |
| AC1 | 16 | 12 | 18 | 0 | 0 | 0 |
| BC1 | 13 | 9 | 23 | 0 | 35 | 76 |
| CC1 | 12 | 3 | 54 | 34 | 75 | 99 |
| AC2 | 20 | 13 | 36 | 0 | 0 | 0 |
| BC2 | 13 | 5 | 40 | 0 | 16 | 72 |
| CC2 | 12 | 3.5 | 53 | 30 | 66 | 75 |
| AC3 | 18 | 12 | 16 | 0 | 0 | 0 |
| BC3 | 14 | 6 | 20 | 0 | 0 | 0 |
| CC3 | 13 | 3 | 51 | 0 | 0 | 0 |

### 3.4 Mortar Flexural Strength Test

#### 3.2.1 The Relationship of Addition of Glass Fiber to the Flexural Strength of Mortar

The addition of variations in the amount of cement aggregate and glass fiber in the mortar mixture was carried out to determine the flexural strength test value of the mortar on the age of the mortar.

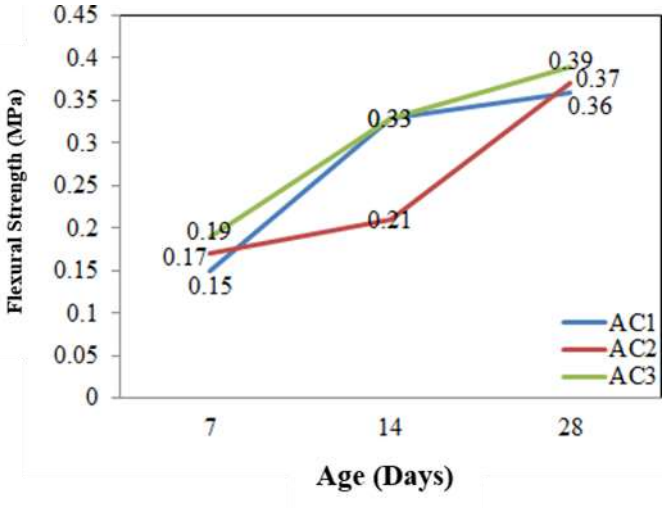


**Figure 1.** Graph of flexural strength of mortar (more aggregate than cement)

Figure 1 shows that the three mortar mixtures have increased flexural strength values. The higher flexural strength of the mortar was with the addition of 17.97 grams of glass fiber where at the age of 7 days the flexural strength of the mortar was 0.19 MPa and increased up to the age of 28 days to 0.39 MPa. The addition of fiber has a higher flexural strength compared to normal concrete [8].

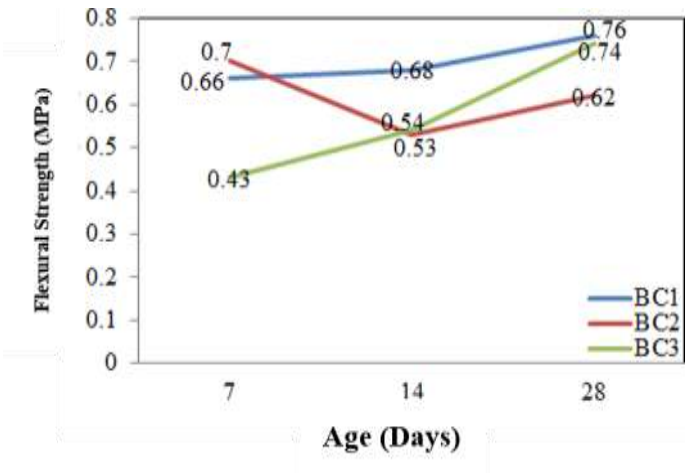


**Figure 2.** Graph of flexural strength of mortar (more cement than aggregate)

Figure 2 shows that the mortar without the addition of glass fiber has an increased flexural strength until the age of 28 days. At the addition of 5.99 grams of glass fiber, at the age of 14 days the flexural strength of the mortar decreased. Meanwhile, with the addition of 17.97 grams of glass fiber, the flexural strength of the mortar increased until the age of 28 days. The highest flexural strength value was obtained for samples containing 5.99 grams of glass fiber of 10.4 MPa [9].

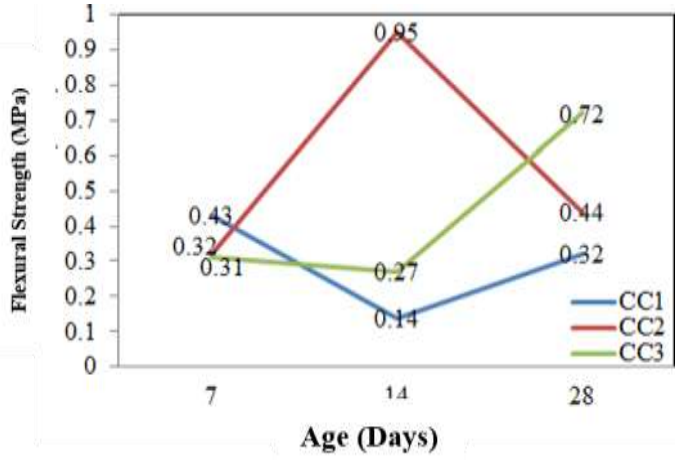


**Figure 3.** Graph of flexural strength of mortar (cement without aggregate)

Figure 3 shows that the mixture without aggregate with 17.97 grams of glass fiber has a better flexural strength value. Because at the age of 28 days the flexural strength of mortar was higher than other mortar mixtures. While the addition of glass fiber 5.99 grams of mortar flexural strength decreased at the age of 28 days. Fiberless mortar has a lower flexural strength value. The use of additional materials such as fiber in mortar has a higher mortar strength than ordinary mortar [10].

### 3.2.2 The Relationship of Addition of Glass Fiber to the Compressive Strength of Mortar

The addition of variations in the amount of aggregate, cement and glass fiber in the mortar mixture is carried out to determine the compressive strength test value of the mortar on the age of the mortar.

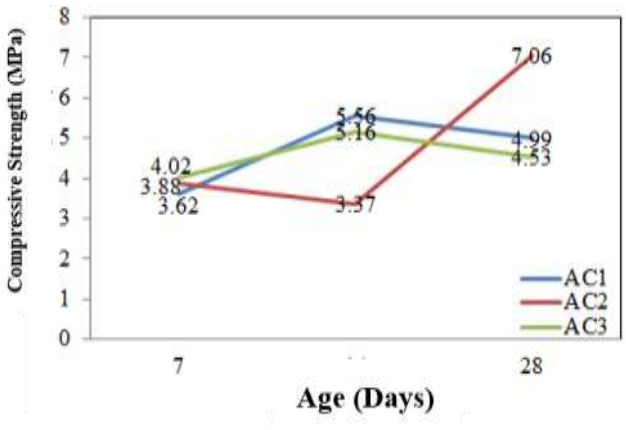


**Figure 4.** Graph of compressive strength of mortar (more aggregate than cement)

Figure 4 shows that the mortar with the addition of 5.99 grams of glass fiber, the compressive strength value at 28 days was higher than other mortar mixtures, but at 14 days the compressive strength of the mortar decreased. Mortar without glass fiber at the age of 28 days its compressive strength value decreased. Meanwhile, the mortar with glass fiber was 17.97 grams, at the age of 28 days the mortar strength value also decreased.

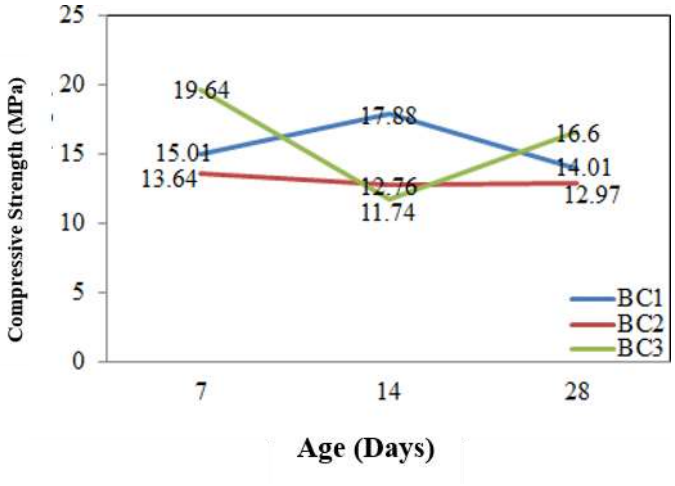


**Figure 5.** Graph of the compressive strength of mortar (more cement than aggregate)

Figure 5 shows that the addition of glass fiber 0 grams, 5.99 grams and 17.97 grams of the three mortar mixtures has a high compressive strength value at the age of 7 days while at the age of 28 days the compressive strength value of the mortar is lower. The higher strength of the concrete at an early age is due to an increase in the internal curing temperature of the concrete mixture due to the higher heat of hydration and the shorter distance between the hydrated particles due to the low water-cement ratio [8].

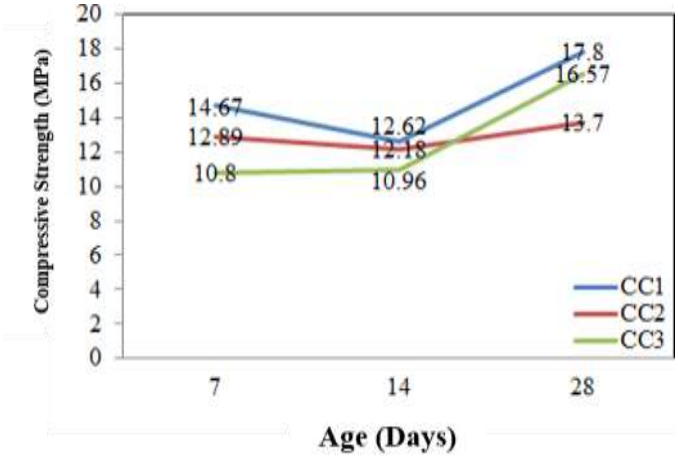


**Figure 6.** Graph of compressive strength of mortar (cement without aggregate)

Figure 6 shows that the mixture of mortar without glass fiber and mortar with 5.99 grams of glass fiber both has a decreased compressive strength value of mortar at the age of 14 days. While the addition of 17.97 grams of glass fiber, the compressive strength value increased.

### 3.4 Mortar Adhesive Strength Test

In testing the adhesive strength of the mortar, the first thing to do is to make a mortar paste then glue the blocks of concrete to one another, the concrete is dried for 7 days and then the adhesive strength test is carried out.

**Table 2.** Test of Mortar Adhesive Strength at 7 Days Age

| Sample Name | Maximum Load(kg) | Pressure (MPa) |
|---|---|---|
| AC1 | 255.9 | 1.62 |
| BC1 | 674.6 | 4.41 |
| CC1 | 0 | 0 |
| AC2 | 0 | 0 |
| BC2 | 428.5 | 2.69 |
| CC2 | 512.2 | 3.31 |
| AC3 | 0 | 0 |
| BC3 | 656.3 | 4.23 |
| CC3 | 0 | 0 |

Based on table 2 shows that the adhesive strength test on mortar with a mixture of cement is more than aggregate and without the addition of glass fiber has a higher compressive strength intention of 4.41 MPa, but for the compressive strength test and the flexural strength test the mortar strength value is low. While the mortar with a mixture of cement is more than the aggregate with the addition of glass fiber of 17.97 grams has an adhesive strength value of 4.23 MPa and the results of the flexural strength test and the compressive strength test of the mortar also have a high strength value.

### 3.4 Optical Microscopy (OM) Characterization

OM observations were carried out to determine the position/presence of glass fibers in a mortar. The magnification in this test is carried out to the extent that the sample can be enlarged. The following are the results of the surface morphology test with a magnification of 1000x.

**Figure 7.** Morphological results of variation of mortar (a) more aggregate than cement (b) more cement than aggregate (c) cement without aggregate

Figure 7 shows that the presence of glass fibers in the mortar does not bind / stick together in the mortar. The results obtained by electron microscopy (SEM) showed that in the mortar there was no adhesion between the fiber and cement (there was a vacuum). Friction between the fibers and the mortar on the one hand and between the long fibers on the other (there is a vacuum) in the mortar [10].

## 4 Conclusion

The addition of excessive aggregate and glass fiber to the mortar mixture will inhibit the flow of mortar in the gap. In this study, the optimum mortar flowing in the gap was a mixture of cement without aggregate with 5.99 grams of glass fiber, while the mortar with the addition of a little aggregate, the mortar could not flow in the gap of 1 mm. The suitable mortar mixture in the mortar injection method is cement without aggregate with 5.99 grams of glass fiber, the mortar can flow at a gap of 1 mm and the mortar flow is 30 cm far. The highest value of the flexural strength of the mortar was the addition of more cement than the aggregate with 17.97 grams of glass fiber. The highest compressive strength value of mortar is the addition of more cement than aggregate with glass fiber 17.97 grams.

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