Optimizing Empty Fruit Bunch (EFB) of palm and glass powder as a partial substitution material of fine aggregate to increase compressive and tensile strength of normal concrete

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Abstract. As a material of construction, concrete have a good compressive strength but low tensile strength. From the previous study, reducing the tensile weakness of the concrete using empty fruit bunch (EFB) of Palm for the concrete mix have a significant result. But in contrary, the use of this fiber decreases the compressive strength of concrete. This research aims to optimize a mixture of glass powders on EFB fiber as a solution to increase the compressive and tensile in strength of concrete as well. The fiber material requires pre condition treatment which is soaked in 10% NaOH for 6-10 hours, then is followed with drying for 24 hours and finally cutting into 4 cm pieces long. Using glass powder as mix design with fiber material which is substitute for fine aggregate in concrete. Variation of 0.25%, 0.5%, 0.75%, 1%, 1.25%, 1.5%, 1.75%, and 2% fiber material mix up with 10% glass powder used for concrete specimens with a diameter of 15 cm and a height of 30 cm at the age of 28 days testing. The results of this study shows an increase in the compressive and tensile strength of concrete compare to normal concrete. The optimum compressive increase 21.02% of normal concrete which is 24.87 MPa. Meanwhile the tensile strength an increase of 31.78% of normal concrete which is 3.11 MPa using 1% fibre and 10% of glass powder. Hence, using glass powder mix in EFB to increase compressive and tensile strength of concrete can be developed optimally in the future.

1. Introduction

Indonesia is one of the largest palm oil producing countries in the world. In 2018, the area of oil palm in Indonesia reached 11.9 million hectares with a total production of 37.8 million tons per year which are 31.4% of the total area of oil palm plantations in Indonesia. Over time, the amount of palm oil production in Indonesia has continued to increase. Every oil palm production produces waste in the form of 23% oil palm empty fruit bunch (EFB), 8% oil palm shells (OPS), 12% fibres and 66% liquid waste [1]. Thus, the EFB production cycle produces waste that continues to increase to reach 1.8 million tons each year [2]. This condition in turn creates environmental problems for the palm oil mill. On the other side, the progress of the construction project sector shows a very rapid development. This can be seen by the increasingly sophisticated of concrete manufacture technology. Research entitled the use of glass powder as a powder in self-compacting concrete showed that the optimal level of partial substitution of glass powder was 10%. The composition resulted in pressure strength and split tensile strength on average 49.08 MPa and 4.08MPa, which represents a + 0.33% and + 4.88% increase in strength. Glass powder levels up to 20% still result in concrete above the plan compressive strength of 40 MPa. At
levels of glass powder up to 30%, structural concrete can still be produced with a compressive strength of 32.23 MPa [3].

Previous study has shown that EFB waste and glass powder can be used as materials for making concrete. Oil palm EFB can be used as fibre [4], while glass powder can be used as a substitute for sand [5-8]. Therefore, in order to reduce the volume of the waste, this study examines the effect of EFB treatment mixed up with glass powder to increase the compressive strength and flexural strength in concrete. As construction material concrete has a weakness with its low flexural strength and brittle nature. Add fibres in the concrete mix will repair the weakness of the concrete properties. This study is using natural fibres, namely oil palm EFB. In preparation stage, first the fibres were rinsed with 10% NaOH for 12 hours, dried out and cut into 4 cm long. From the literature study, research was conducted by combining oil palm EFB as fibres with variations of 0.25%; 0.50%; 0.75%; 1%; 1.25%; 1.5%; 1.75%; 2% respectively mixed up with glass powder. Glass powder used as a substitute for some fine aggregate. In order to obtain a good concrete that has better tensile and compressive strength to support building structures.

2. Methods
The method used for this experiment is studied from some previous research result using EFB and glass powder. The experiments process is conducting at Concrete Laboratory in Civil Engineering Universitas Kristen Indonesia, Jakarta.

The methodology of research flowchart are as follows: (1) Preparing tools and materials, (2) Examining materials for coarse aggregate and fine aggregate include grading, water content, specific gravity, volume weight and absorption, (3) Testing concrete specimens with a diameter of 15 cm and a height of 30 cm at the age of 28 days in normal condition, (4) Mixing up composition of various percentage of EFB with 10% glass powder, (5) Preparing mix design for concrete specimen using EFB and glass powder with a certain percentage include concrete mix, slump test, Mold specimen with a diameter of 15 cm and a height of 30 cm, (6) Curing test, (7) Examining the weight and volume of the specimen, (8) Testing compressive strength for each specimen, (9) Analyzing the result data for compressive strength, (10) Testing tensile strength for each specimen, (11) Analyzing the result data for tensile strength, and final stage (12) concluding all the analyzing data on the experiment results.

Hardening concrete need at least one day in mold with heat release in a number. Hence, the treatment is carried out on the specimen by immersing the specimen in water for the certain time required for testing. Testing of compressive strength and tensile strength of concrete is carried out at the age of 28 days of the specimen. The full-strength 28 days concrete can support the maximum load for testing and also when combining with reinforcement for beam, column, and wall [9]. First of all, use a hammer test to make a best approach of specimen compressive strength value. Then, concrete compression test for specimen carried out by Compression Testing Machine (CTM). Very important to test the compressive strength of the concrete after a hammer test. Result for compressive strength of the specimen can be compared with two different testing method. The compressive strength test using a hammer test is only done in horizontal axis (0°). Meanwhile, tensile strength value of specimen testing also using Compression Testing Machine (CTM) but the specimen pressing in the cylinder position.

3. Results and discussions

3.1. Properties of aggregates
The results of coarse aggregate testing can be seen in Table 1 and Figure 1 as follow:
Table 1. Coarse aggregate testing result.

| Test Result       | ASTM C-33 Standard | Conclusion  |
|-------------------|--------------------|-------------|
| Bulk Specific (SSD) | 2.69 gr/cm³        | 2.5-2.7     |
| Absorption        | 3.68 %             | -           |
| Mud Content        | 1.5 %              | -           |
| Durability         | 9.08%              | -           |

Figure 1. Sieve analysis for coarse aggregate.

The results of fine aggregate testing can be seen in Table 2 and Figure 2 as follow:

Table 2. Fine aggregate testing result.

| Test Result       | ASTM C-33 Standard | Conclusion           |
|-------------------|--------------------|----------------------|
| Bulk Specific (SSD) | 2.65 gr/cm³        | 2.5-2.7              |
| Absorption        | 4.82 %             | 5%                   |
| Mud Content        | 4.6 %              | 5%                   |
| Durability         | 37.7%              | Clear or light yellow|

Figure 2. Sieve analysis for fine aggregate.

Figure 1 and 2 shows This can be seen if the modulus value The greater the aggregate grain refinement (MKB), the greater the percentage of the track the filter is also getting bigger. And vice versa the aggregate the smaller the percentage of passing the coarse aggregate sieve also follows reduce. This happens because of the aggregate grain most likely to withstand heavy impact steel balls less power and
more percentage passes through the filter. There are more pore cavities in the aggregate large size, there is a possibility that the aggregate is more easily crushed

3.2. Slump test

The results of slump testing value on concrete with various types of mixtures of 0%, 25%, 0.50%, 0.75%, 1%, 1.25%, 1.5%, 1.75%, and 2% EFB oil palm can be seen in Figure 5.

![SLUMP TEST](image)

**Figure 3. Slump test.**

In accordance with the concrete mix design plan K-200, mortar specimen will test with a slump test plan of 30-60 mm. Figure 3 shows the results of normal concrete slump test on specimens with a diameter of 15 cm and a height of 30 cm at the age of 28 days. It can be seen that the test results meet the K-200 concrete mix planning criteria.

3.3. Analysis of concrete compressive strength test results

The results analysis of the concrete compressive strength test can be seen in Figure 6.

![CONCRETE COMPRESSIVE STRENGTH TEST RESULT](image)

**Figure 4. Compressive strength test results.**

Figure 4 shows the test results of normal concrete compressive strength with a diameter of 15 cm and a height of 30 cm at the age of 28 days. It can be seen that compressive strength increasing in fibres 0.25%, 0.5%, 0.75% respectively with 2.63 MPa; 1.4 MPa; 0.24 MPa compared to normal concrete. In next process, compressive strength decreasing at 1% fibres of 0.55 MPa compared to Normal concrete. This results shows that glass powder can increase the compressive strength of concrete by 4.32 MPa. Hence, increase a percentage of EFB fibres in some level mixed up with 10% glass powder will decrease compressive strength of concrete because EFB fibres have a flat and slippery texture. Based on SK SNI 03-3449-2000 of a light weight concrete compressive strength system for normal structure, test results were met the standards.

3.4. Analysis of concrete tensile strength test results

The analysis of the concrete compressive strength test result can be seen in Figure 5.
Figure 5. Compressive strength test results.

Figure 5 shows the results of concrete split tensile strength testing on specimens with a diameter of 15 cm and a height of 30 cm at the age of 28 days. The tensile strength of concrete variations of 0%, 0.25%, 0.50%, 0.75%, 1.25%, 1.5%, 1.75% and 2% fibres also increase compared to normal concrete. The result of the split tensile strength test without mixture is 2.36 MPa, lower than tensile strength test result of 10% glass powder and EFB variations of 0%, 0.25%, 0.50%, 0.75%, 1.25%, 1.5%, 1.75% and 2%.

There was 8.89% tensile strength increase in specimen of 10% glass powder mixture, 2.96% with EFB fiber mixture 0.25%, 13.98% with EFB fiber mixture 0.5%, 19.91% with EFB fiber mixture 0.75%, 25.85% with EFB fiber mixture 1%, 29.66% with EFB fiber mixture 1.25%, 31.78% with EFB fiber mixture 1.5%, 22.03% with EFB fiber mixture 1.75%, and 15.68% with EFB fiber mixture 2%. This result confirms that oil palm EFB can increase split tensile in concrete. The maximum value was obtained with EFB fibre mixture 1.5% compared to normal concrete.

3.5. Results

The results of the comparison between the compressive strength and split tensile strength of rigid pavement concrete can be seen in the figure below.

Figure 6. Comparison of compressive strength and split tensile strength.

Figure 6 shows that the percentage ratio of the compressive strength value of concrete and split tensile strength meets the requirements in 10% - 15%.
### Table 3. Ratio of compressive strength and split tensile strength using various EFB fibres.

|                     | Normal Concrete | Glass Powder | EFB Fibres |
|---------------------|-----------------|--------------|------------|
|                     |                 | 10%          | 0.25%      | 0.50%      | 0.75%      | 1.0%       | 1.25%      | 1.50%      | 1.75%      | 2.00%      |
| Compressive Strength (MPa) | 20.55 | 24.87 | 23.18 | 21.95 | 20.97 | 20.05 | 21.01 | 20.22 | 19.98 | 19.67 |
| Split Tensile Strength (MPa) | 2.36 | 2.57 | 2.43 | 2.69 | 2.83 | 2.97 | 3.06 | 3.11 | 2.88 | 2.73 |
| Ratio (%)           | 11.48 | 10.33 | 10.48 | 12.26 | 13.50 | 14.81 | 14.61 | 14.94 | 14.41 | 13.87 |

### 4. Conclusion

The optimum compressive strength of concrete is around of 10% glass powder without EFB fibres with a value of 24.87 MPa and the lowest value is in a mixture of 10% glass powder and 2% EFB fibres with a value of 19.67 MPa. The concrete compressive strength at 28 days with mixture 10% glass powder without EFB fibres increase 21.02% compared to compressive strength of normal concrete while the optimum split tensile strength in 1.5% EFB fibres mixtures is 3.11 MPa or an increase of 31.78% compared to normal concrete split tensile. The mixture of glass powder in EFB fibres affects the compressive strength of concrete. This indicate that 10% glass powder in EFB fibres with various amount of 0.25%, 0.5%, 0.75%, and 1.25% has a significant result to increase the compressive strength of concrete. The compressive strength of concrete is greater than the value of the compressive strength of normal concrete. Instead, the mixture of EFB 1%, 1.5%, 1.75%, and 2% fibres respectively will decrease the compressive strength value of concrete below the normal concrete compressive strength.

Mixture glass powder on EFB fibres can increase the split tensile strength value of the concrete. In this experiment 10% glass powder with the various mixture of EFB 25%, 0.5%, 0.75%, and 1.25% fibres respectively will increase the split tensile strength of the concrete. The results of testing show the split tensile strength increase 8.89%, 9.62%, 13.98%, 19.92%, 25.85%, and 31.78% respectively compared to split tensile strength of normal concrete.

### 5. Suggestion

In further research, it is necessary to make a more varied mixture to strengthen the research results, or using another waste material that can be increased compressive strength of concrete and look for a more effective percentage of increase by using a time variation of 7 days, 14 days, 21 days on the concrete and strength test.

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