Utilization of Waste Glass and Fly Ash as a Replacement of Material Concrete

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Abstract. Waste glass creates serious environmental problems, mainly due to the inconsistency of waste glass streams. Increasing environmental pressure to reduce solid waste and to recycle as much as possible. The properties of concretes containing waste glass as fine aggregate were investigated in this study. The purpose of this research was to determine the influence and percentage optimum of glass waste as replacement of fine aggregate and fly ash as replacement of 20% of weight cement in flexural strength and sorptivity of concrete. This study used the experimental method to measure the results of treatment in research samples in the laboratory. The samples used 24 pieces blocks with dimensions of 150 mm x 150 mm with a length of 600 mm as flexural strength specimens and 24 pieces cylinders with a diameter of 100 mm with height of 50 mm as sorptivity specimens. The variation of glass powder starts from normal concrete 0%, 10%, 20%, 30% and 40%, each variation consists of 4 samples. The conclusions of this study are there is significant effect between glass powder variations as a replacement for part of fine aggregate and fly ash as a replacement for 20% of the weight of cement to the flexural strength and sorptivity of concrete. The optimum percentage 18.5% of glass powder with a flexural strength of 2.971 MPa and the percentage of the use of glass waste as a partial replacement for optimal fine aggregate which is in the variation of 20% glass powder with an initial sorptivity minimum value of 0.0076 mm/s\(^{1/2}\) and in the variation of 40% glass powder with a secondary sorptivity minimum value of 0.0034 mm/s\(^{1/2}\).

Keywords: glass waste, fly ash, flexural strength and sorptivity of concrete

1. INTRODUCTION

Indonesia's population growth has increased along with increasing development in the construction sector. In addition to food and clothing, housing is also a basic requirement. The results of the population census conducted in 2016 by the Central Bureau of Statistics Indonesia's total population is 258.8 million people, which is an increase of 1.27% from the previous year. With the increasing demand for such buildings, the need for building materials has also increased. Thus, it must be available in sufficient quantities for building materials. Building materials often used in Indonesia is concrete. The use of concrete as a building material that continues to increase the availability of materials making up the greater concrete that would negatively impact the environment.

Issues of sand mining by the Department of Irrigation, Mining and Natural Disaster Management, changes in natural conditions such as loss of soil fertility due to loss of humus content as a result of the quarrying of sand overload will also impact on the ground will be dry and the area was bare because it was the inability planted tree due to loss of soil fertility. Therefore, continuous sand mining would have a negative effect on the environment. therefore, the natural sand replacement material must be maintained.
Sand replacement material is expected to have the same properties of physical and chemical composition for example, glass powder. Glass is one of the wastes that cannot be described and can be harmful if disposed of carelessly. If the amount of glass waste too much it would damage the environment. According to statistics of the Ministry of Environment in 2013 the percentage of waste glass which is 1.7% of the overall waste 64 million tonnes per year and based on statistical data Secretariat Verse 2015 the amount of trash processed recycled raw materials, namely 0.79% of the total garbage. Processing of waste glass into glass powder which is then used as a substitute of fine aggregate in the concrete is a category of waste treatment that treats recycled raw materials. Glass powder has element content of 97.0080% SiO₂; 0.1273% Al₂O₃; Fe₂O₃ CaO 0.0026% and 0.1804%. (Nursyamsi, Hastuti & Indrawan: 2016).

Addition of broken glass instead of fine aggregate in concrete can increase the concrete flexural strength was evident in research conducted by Abdallah and Fan (2014). In this study, glass material is mixed in the concrete with a mixture of 5%, 15% and 20% as a partial replacement of sand. The results obtained show that the flexural strength of concrete has increased by 5.82%, 18.38% and 8.92% of the concrete without glass powder. In addition to problems with the mining of sand, today it often arises problems in the cement production process, which is about air pollution in the environment around the cement factory for example, conflict between residents and investors of PT Semen Gresik's cement factory in Kendeng Rembang. The factory was set up to provide employment opportunities for the population instead causing serious environmental problems. The emergence of these environmental problems results in the health of the surrounding population. The bad condition of the environment will eventually cause problems for the people around, such as epidemics and ecosystem damage. If the factory stays on track, Rembang farmers are at risk of losing water sources and agricultural land. Based on these problems, we can conclude that it is necessary to replace cement to preserve nature.

According to the Environmental Impact Control Agency fly ash is a hazardous waste category that should not be thrown away carelessly so special handling in order not to pollute the environment. According to Munir Ahmad (Director of Electrical Power Engineering and Environment 2016) 2015 Indonesia's electricity capacity is about 54 GW by consumption of 87.3 million tons of coal. When 35.000MW is completed by 2019, automatic electric capacity increases to 89GW. It requires about 180 million tons of coal per year and 5% of the volume will be fly ash and bottom ash. This means that there will be fly ash and bottom ash as much as 8-9 million tons per year. Seeing the number of coal waste (fly ash) generated by the use of which is still very little, providing development opportunities utilization of coal ash (fly ash), particularly in the fields of construction, namely as a partial replacement of cement. Effect of fly ash contained in very fine particle size to fill the voids in concrete can boost the density and the density of concrete, resulting in a more watertight and resistant to abrasion. (Kocak, Nas: 2014). Besides pozzolan reaction present in fly ash, fly ash reaction occurs between the Ca(OH)₂ will result in a compound Calcium Silicate Hydrate CSH (Saputra, et al: 2015). Calcium Silicate Hydrate CSH compounds will increase the density of concrete thereby increasing the strength of concrete structures (Kumar, et al: 2017). It is necessary to the proper composition of the fly ash to obtain optimal concrete quality. Can boost the density and the density of concrete, resulting in a more watertight and resistant to abrasion. (Kocak, Nas: 2014). Besides pozzolan reaction present in fly ash, fly ash reaction occurs between the Ca(OH)₂ will result in a compound Calcium Silicate Hydrate CSH (Saputra, et al: 2015). Calcium Silicate Hydrate CSH compounds will increase the density of concrete thereby increasing the strength of concrete structures (Kumar, et al: 2017). It is necessary to the proper composition of the fly ash to obtain optimal concrete quality. Can boost the density and the density of concrete, resulting in a more watertight and resistant to abrasion. (Kocak, Nas: 2014). Besides pozzolan reaction present in fly ash, fly ash reaction occurs between the Ca(OH)₂ will result in a compound Calcium Silicate Hydrate CSH (Saputra, et al: 2015). Calcium Silicate Hydrate CSH compounds will increase the density of concrete thereby increasing the strength of concrete structures (Kumar, et al: 2017). It is necessary to the proper composition of the fly ash to obtain optimal concrete quality.

In the study conducted by Solanki and Pitroda (2013), fly ash mixed in the concrete with a mixture of 0%, 10%, 20% and 30% as a partial replacement of cement. The results obtained showed that the concrete
by using a variation of 20% fly ash is an optimal percentage that may increase the flexural strength of concrete equal to 11.08% of normal concrete.

2. LITERATURE VIEW

2.1 Waste-Glass

Glass is one of the wastes that cannot be described and can be harmful if disposed of carelessly. According to statistics of the Ministry of Environment in 2013 the percentage of waste glass is 1.7% of the overall waste of 64 million tons per year. If the amount of glass waste is too much it will damage the environment.

According to GW McLellan, EBShand (1984) book "Glass Engineering Handbook" in the journal Abbas Mohajerani, et al (2017), the chemical content of the glass as are 60-75% SiO₂, 0.7-7% Al₂O₃, 12-16% Na₂O, 0.1-3%, 0.1-3 MgO and 6-12% CaO (Abbas Mohajerani, et al, 2017). Glass powder has element content of 97.0080% SiO₂; 0.1273% Al₂O₃; Fe₂O₃ CaO 0.0026% and 1.804%. Viewed SiO₂ content > 60% can improve the strong urge concrete to improve the quality of building structures (Nursyamsi, Hastuti, & Indrawan : 2016). The content of alkali and silica in a glass causes chemical reactions between the silica in the aggregate result with ion hydration of cement (Mohajerani, A: 2017). Where the results of hydration of cement will result in cracks in the concrete. Therefore, when the result of the hydration of cement reacts with alkali and silica it will increase the density of concrete.

In the study conducted by Abdallah and Fan (2014) The results obtained show that the flexural strength of concrete has increased by 3.54%, 5.03% and 8.92% of the concrete without glass powder in concrete mixtures. And can reduce the absorption of a concrete value obtained in a mixture of 20% instead of sand has decreased 14.68% from the concrete without glass powder. This study uses glass powder with a mixture of 0%, 10%, 20%, 30% and 40% as a partial replacement of sand.

2.2 Fly-Ash

Coal is a producer of energy sources used to generate electricity (power plants). The use of coal as a fuel, produces waste in the form of coal fly ash and bottom ash.

Necessary utilization of coal waste as the waste has increased along with the increasing use of electricity. This would result in severe air pollution. The content of fly ash consists mostly of silicate dioxide (SiO₂), aluminum (Al₂O₃), iron (Fe₂O₃) and calcium (CaO) and magnesium, potassium, sodium, titanium, and sulfur in smaller amounts (Paul Nugraha, 2007). Pozzolan reaction occurs between fly ash with cement hydration results in the form of the Head substance-free or Ca(OH)₂ will produce the compound of CSH (Saputra, et al: 2015). CSH compounds will increase the density of concrete that will produce excellent bonding which will improve the mechanical properties of the concrete. (Kumar, et al: 2017). However, the increasing strength of the concrete occurs only in the concrete after the age of 28 days. That is because the pozzolan reaction is slower than the process of cement hydration reaction (Saputra, et al: 2015).

Fly ash used for this study was obtained from Paiton, Probolinggo. Chemical substances based on PT IPMOMI Paiton power plant have amounts of iron, silica, and aluminum about 85.56%, it's more than 70% therefore fly ash from Paiton for class F.

In the study conducted by Vinod singh Solanki and Pitroda (2013). In this study, fly ash mixed in the concrete mix with a variation of 0%, 10%, 20% and 30% as a partial replacement of cement. Beam test specimen with dimensions of 100 mm x 100 mm and a length of 500 mm. Flexural strength test performed when the concrete age of 28 days. Results obtained maximum flexural strength of concrete has increased 11.08% from concrete without fly ash in concrete with 20% fly ash replacement for cement. Therefore, in this study using the percentage of fly ash as much as 20% of the weight of the cement.
2.3 Flexural Strength

Flexural strength is the ability of concrete blocks placed on two pedestals to withstand forces concentrated on one point in the direction perpendicular to the axis of the specimen was given until the test specimen broke and expressed in Mega Pascal (MPa) force per unit area (SNI 03-4154-1996). Flexural strength testing in this study using the test object beam with a size of 150 mm x 150 mm x 600 mm by SNI 03-4154-1996. The flexural strength testing used one centralized point load directly based on SNI 03-4145-1996.

To find out the flexural strength can be calculated using the following formula (modulus of rupture):

\[
\text{flt} = \frac{3PL}{2bd^2}
\]

Information:
- \(\text{flt}\) = The specimen flexural strength (MPa)
- \(P\) = Maximum load beam collapse test (N)
- \(L\) = Distance (span) between the two blocks of the pedestal (mm)
- \(b\) = Average beam width at the cross-collapse (mm)
- \(d\) = High-beam average miners collapsed (mm)

![Figure 1: Flexural Strength Test](Source: SNI 03-4145-1996)

2.4 Sorptivity Concrete

This test is based on ASTM C1585-04, which is to determine the rate of absorption (sorptivity) water by hydraulic cement concrete when only one surface is exposed to water by measuring the increase in the mass of the specimen resulting from water absorption as a function of time.

The affected water is allowed to take measurements of water absorption during the 8-day measurement period. Changes in the mass of the specimen during the measurement used to determine the initial and secondary levels of absorption in concrete. To find out the sorptivity concrete can be calculated using the following.

\[
I = \frac{Mt}{A \cdot d}
\]

where:
- \(I\) = Absorption (mm)
- \(Mt\) = Changes specimen weight in grams, at time \(t\) (mg)
- \(A\) = Vast areas of exposure in mm\(^2\)
- \(d\) = Density of water in mg / mm\(^3\)

In this test, we will get the initial value of the absorption of concrete (initial sorptivity) and the final value of the absorption of the concrete (secondary sorptivity).

3. RESEARCH METHODOLOGY

This study uses a method experiment to measure the results of treatment in the study sample in the laboratory. The sample used in this study blocks with dimensions of 150 mm x 150 mm with a length of
600 mm by 24 pieces as flexural strength test specimen and a cylinder diameter of 100 mm with a height of 50 mm 24 pieces as sorptivity test specimen. Glass powder begins variation of normal concrete, glass variation of 0%, 10%, 20%, 30%, and 40%. Each variation amounted to 4 fruit samples. Flexural strength testing base on SNI 03-4154-1996 and sorptivity base on ASTM C-158-04.

Stage Research

3.1 First Stage

This stage is for preparation of materials and tools.

The materials needed in this research are as follows:

1. Type I cement with Semen Gresik brand
2. Fine aggregate (sand) from Muntilan area
3. Coarse aggregate (gravel) from Klaten area
4. Water
5. Fly Ash is used waste from Paiton Probolinggo, East Java.
6. Glass powder

    a glass powder used is the result of bottles obtained from garbage collectors. Making glass powder of glass bottle:
    1) Glass obtained from collectors then the glass is washed of dirt or the rest of the contents of the bottle.
    2) Glass is crushed until it becomes granules
    3) Glass that has been crushed then sifted using a 4 mm sieve size. Glass that passes the size of 4 mm is used as a substitute of fine aggregate.

![Figure 2.](image)

(a) Glass from collectors (b) Glass has washed (c) Glass powder sifted (d) Glass powder using as a substitute of fine aggregate

3.2 Second Stage

The second stage in this research is examination and feasibility tests of materials to be used in making concrete samples. Material testing to be carried out includes:

1. Testing the water content base on SK SNI 1971-2011.
2. Testing of organic substance fine aggregate based on SK-SNI03-2816-1992.
3. Testing the levels of sludge in this research based on ISO 4428-1997.
4. Testing of specific gravity aggregate in this study is based on SK-SNI 1970-2008.
5. Testing of fine aggregate gradation based on SK-SNI 03-1968-1990.
6. Testing of coarse aggregate based on SK-SNI 03-1968-1990.
7. Testing of coarse aggregate abrasion test based on SNI 2417-2008
3.3 Third Stage

At this stage to discuss the concrete mix design calculations (mix design) with a compressive strength of 20 MPa with a plan in accordance with the standard mix design SNI 03-2834-2002. Mixture of concrete in the form of adding fly ash which is used by 20% of the weight of cement as a replacement substitute cement and glass powder with variation of 0%, 10%, 20%, 30% and 40% of fine aggregate.

3.4 Fourth Stage

The fourth stage in this research is making test materials in accordance with the composition of the mixture of concrete based on the results of mix design calculation. Making test specimens using blocks with dimensions of 150 mm x 150 mm with a length of 600 mm by 24 pieces as flexural strength test specimen and a cylinder diameter of 100 mm with a height of 50 mm 24 pieces as sorptivity test specimen.

3.5 Fifth Stage

The fifth stage in this research is treatment of specimens. During the maintenance period the humidity must be maintained by immersing it in water until 28 days.

3.6 Sixth Stage

The sixth stage in this research is the testing phase of flexural strength and sorptivity of concrete to get data needed in this research.

The following steps flexural strength testing (SNI 03-4154-1996):

a) Weigh and record the weight of each specimen.
b) Marking of the test object as the bearing pedestal and loading.
c) Installing the tool as a central point flexural loading.
d) Placing the specimens have been marked on the best in the right place with the two-bottom side of the test specimen and the placement mark loading tool is in the middle of the test specimen.
e) Turning concrete compressive testing machine has been prepared, wait approximately 30 seconds.
f) Putting a test object on the pedestal and set the test object so it is ready for testing.
g) Set the loading to avoid a collision
h) Adjusting Samai loading to ± 50% of the maximum expected load, the loading speed may exceed 6kN
i) Reducing the speed of loading at the time of the collapse of the beam specimen
j) Stop loading and record the maximum load that causes breakage of the test specimen.

The following steps sorptivity testing based on ASTM C-158-04):

a) Sorptivity before testing begins the first concrete measure by measuring the dimensions of each specimen concrete.
b) Placing 50-52°C specimens at room temperature for 3 days.
c) After 3 days, place each specimen in a sealed container. use separate containers for each specimen for 15 days.
d) Removing specimens from the storage container and record the weight of the specimen before sealing the surface side
e) Measure the diameter of the specimen at least surface affected by water
f) Closing the side surface of each specimen with a sealing material in this study using a wax/paraffin. Closing the specimen will be exposed to water using a plastic sheet that is attached loosely. The plastic sheet can be protected by using a rubber band.
g) Measuring the mass of the specimen which was closed and recorded as the initial mass for the calculation of water sorptivity.
h) Place a booster specimen at the base tray and fill the tray with tap water so that the water level is 1 to 3 mm above the concrete wedge. Maintaining water levels 1 to 3 mm above concrete during testing.

![Figure 3. Sorptivity Testing](Source: ASTM C1585-04)

i) Start the stopwatch and immediately put the test specimen surface in the support device, record the time and date of the initial contact with the water.

j) Record the weights after the first contact with water. Using the procedure time, as follows:

| Time                   | Tolerance |
|------------------------|-----------|
| 60 seconds             | 2 seconds |
| 5 minutes              | 10 seconds|
| 10 minutes             | 2 minutes |
| 20 minutes             | 2 minutes |
| 30 minutes             | 2 minutes |
| 60 minutes             | 2 minutes |
| Every hour up to 6 hours | 5 minutes |
| Every day up to 3 days | 2 hours   |
| 4 to 7 days to 3 times the measurement | 2 hours |
| Days 7 to 9 | 1 measurements | 2 hours |

(Source: ASTM C1585-04)

k) For each weight determination, the stopwatch is stopped and brooms water from the surface with a cloth/towel. In 15 s removal from the tray, heavy gauge with an accuracy of 0.01 g

l) Repeating these steps for all specimens with variations that exist in this study to complete.

m) Calculating the value of absorption / specimen

n) Incorporating this data and creating graphs by plotting a large absorption (I) with the root of the time to use Microsoft Excel 2013 with the Model Trendline Linear Method. \( \sqrt{t} \)

o) Sorptivity initial value / initial sorptivity obtained from line between (I) with the root of in a time of 1 minute to 6 hours.

p) Values sorptivity secondary / secondary sorptivity obtained from line between (I) with the root of the time 1 day to 7 days.

3.7 Seventh Stage
The seventh stage in this research is the data analysis stage. Data analysis is the process of processing data obtained from the result of testing specimens in a laboratory.

3.8 Eighth Stage
The eighth stage in this research is given conclusions from this research.
4. RESULT AND ANALYSIS

a. The results of the flexural strength testing
   Flexural strength testing results can be seen in the following table:

   **Table 2: Flexural Strength Test Results**

   | Variation | Fly Ash | Glass powder | Samples | Flexural Strength (Mpa) | Mean (Mpa) |
   |-----------|---------|---------------|---------|-------------------------|------------|
   | 0%        | 0%      | A             | 1,962   | 2,060                   |
   |           |         | B             | 2,158   |                         |
   |           |         | C             | 1,766   |                         |
   |           |         | D             | 2,354   |                         |
   | 20%       | 0%      | A             | 2,502   | 2,354                   |
   |           |         | B             | 2,158   |                         |
   |           |         | C             | 2,354   |                         |
   |           |         | D             | 2,403   |                         |
   | 10%       |         | A             | 2,354   | 2,416                   |
   |           |         | B             | 2,158   |                         |
   |           |         | C             | 2,551   |                         |
   |           |         | D             | 2,600   |                         |
   | 20%       |         | A             | 2,845   | 2,943                   |
   |           |         | B             | 3,237   |                         |
   |           |         | C             | 2,747   |                         |
   |           |         | D             | 2,943   |                         |
   | 30%       |         | A             | 2,845   | 2,747                   |
   |           |         | B             | 2,747   |                         |
   |           |         | C             | 3,139   |                         |
   |           |         | D             | 2,747   |                         |
   | 40%       |         | A             | 3,139   | 2,453                   |
   |           |         | B             | 3,041   |                         |
   |           |         | C             | 2,649   |                         |
   |           |         | D             | 2,453   |                         |

b. Testing Results Sorptivity
   Sorptivity testing results can be seen in the following table:

   1. Results of Initial Value Calculation Sorptivity

   **Table 3: Initial Sorptivity Test Results**

   | Variation | Fly Ash | Glass powder | Samples | $S_i$ (mm / $\sqrt{s}$) | Mean (mm / $\sqrt{s}$) |
   |-----------|---------|---------------|---------|--------------------------|------------------------|
   |           | Normal concrete | A             | 0.0184  |                           | 0.01783                |
   |           |           | B             | 0.0177  |                           |                        |
   |           |           | C             | 0.0183  |                           |                        |
   |           |           | D             | 0.0169  |                           |                        |
   | 20%       | 0%       | A             | 0.01887 |                           | 0.0177                 |
   |           |         | B             | 0.01757 |                           |                        |
   |           |         | C             | 0.01679 |                           |                        |
   |           |         | D             | 0.01774 |                           |                        |
### Secondary Value Calculation Results Sorptivity

#### Tabel 4 Seconday Sorptivity Test Results

| Fly Ash          | Samples | Ss (mm / √s) | Mean (mm / √s) |
|------------------|---------|--------------|----------------|
| Normal concrete  |         |              | 0.0060         |
|                  | A       | 0.0074       |                |
|                  | B       | 0.0055       |                |
|                  | C       | 0.0053       |                |
|                  | D       | 0.0057       |                |
| 0%               |         |              | 0.0056         |
|                  | A       | 0.0053       |                |
|                  | B       | 0.0058       |                |
|                  | C       | 0.0063       |                |
|                  | D       | 0.0051       |                |
| 10%              |         |              | 0.0055         |
|                  | A       | 0.0050       |                |
|                  | B       | 0.0057       |                |
|                  | C       | 0.0058       |                |
|                  | D       | 0.0055       |                |
| 20%              |         |              | 0.0043         |
|                  | A       | 0.0041       |                |
|                  | B       | 0.0037       |                |
|                  | C       | 0.0044       |                |
|                  | D       | 0.0047       |                |
| 30%              |         |              | 0.0036         |
|                  | A       | 0.0038       |                |
|                  | B       | 0.0039       |                |
|                  | C       | 0.0031       |                |
|                  | D       | 0.0037       |                |
| 40%              |         |              | 0.0034         |
|                  | A       | 0.0035       |                |
|                  | B       | 0.0037       |                |
|                  | C       | 0.0030       |                |
|                  | D       | 0.0032       |                |

Ss = Secondary Sorptivity

Si = initial Sorptivity
5. DISCUSSION

In this study uses a regression analysis table $F < F_{count} (4.41 < 8.350)$ and a significant value $0.003 < 0.005$ then $H_0$ is accepted. It can be concluded that the use of glass waste as a substitute fine aggregate significant effect on the flexural strength of concrete. A value of $R^2 0.496$, it can be concluded that the major effect of glass powder obtained is 49.6%.

In this study the use of fly ash as a substitute for 20% of the weight of the cement. Normal concrete produces an average flexural strength of 2.060 MPa while concrete using fly ash as a substitute for 20% of the weight of cement produces an average flexural strength of 2.354 MPa. This showed an increase of 14.27% flexural strength. It can be concluded that fly ash also affects or instrumental in improving the flexural strength of concrete. According to Kocak and Nas (2014) very fine particle size, fly ash can be expected to fill the pores in the composition of the concrete, to increase the density of concrete, making it more waterproof, more resistant to abrasion and minimize concrete shrinkage. Other than that, according to Singh and Satyajeet (2017) cement hydration process results in the form of compound free lime Ca(OH)$_2$ will produce spaces or pores which will result in micro cracks, so it will reduce the density and strength of concrete. So with the fly ash in concrete, the crystal Ca(OH)$_2$ reacted with silicate and aluminate elements contained in fly ash forming compounds tobermorite. Tobermorite compound is a compound that serves to fill the pores of the concrete thereby increasing the density and flexural strength of concrete. It is also supported by the results of research from Jayraj and Jayeshkumar (2013), in a study using a variation of fly ash 0%, 10%, 20% and 30% of that in the research of concrete with the percentage of fly ash 20% by weight of cement can increase flexural strength up 11.08% of normal concrete.

This study uses glass powder as a partial replacement of heavy sand obtained from the household waste crushed glass to meet grading standards, namely sand sieve 200. Referring to Figure 4 the results of the flexural strength increased variation in replacement of 10% and 20%. According Mohajerani, A, et al (2017) and the alkali content of silica in the glass causes chemical reactions between the ions of silica in aggregates with cement hydration results. Also, according to Lee, et al (2018) Analyzing the XRD and porosity of resulting concretes, it was confirmed that WGS had a superior micro filler effect and reactivity. It was also concluded that the pozzolanic reaction significantly contributed to improvement of the degree of compaction of concrete and increased the strength, permeability and durability of concrete as well.

The percentage of 30% and 40% decreased in flexural strength. This happens because the percentage of variation of glass powder 30% and 40% experiencing a mortar binding process is less than perfect because of the nature of glass powder that does not absorb water and glass surface slippery. This is in accordance

![Figure 4. Flexural Strength Chart](image)
with the statement by Nasse Almesfer and Jason Igham (Taha and Noum: 2008) The decrease in flexural strength may be due to the decrease in adhesion between the smooth waste glass powder surface and the cement paste, and the organic content from foreign materials with waste glass powder creating voids that weaken the concrete microstructure. Glass powder contains which more will result in the binding that occurs between fine aggregate which was replaced by the glass powder is less than perfect so that it will lower the flexural strength of concrete.

The reason above is reinforced by research conducted by Ismail and Al Hashmi in 2009 by using a variation of glass powder as a substitute for sand 0%, 10%, 20% and 30% by the age of concrete 28 days in a mixture by using a variation of glass powder 20% increase amounting to 10.99% of normal concrete. In addition to the research conducted by Abdallan and Fan in 2014 by using a variation of glass powder as a substitute for sand 0%, 5%, 15% and 20% at 28 days increased the percentage of variation of 20% glass powder at 8.92% of normal concrete. While in this study by using fly ash as a substitute for 20% of the weight of cement increased in variation 20% glass powder 42.8% of normal concrete.

Based on regression analysis obtained equation \[ Y = -0.001X^2 + 0.037X + 2.286 \]. Therefore, the optimal percentage obtained was 18.5% with a yield of 2.9705 MPa flexural strength.

Testing Results sorptivity concrete data obtained as follows:

In this research using descriptive analysis on the graph of Figure 5 and 6 showed that the variation of glass powder 0%, 10%, 20%, 30% and 40% in lieu of fine aggregate there is a change to the value sorptivity concrete, which influenced the value sorptivity concrete, At the initial sorptivity sorptivity obtained initial value to its lowest in the percentage of 20% glass powder of 0.0075 mm / s\(^{1/2}\). But in secondary sorptivity greater the variation, the smaller glass powder sorptivity secondary value.

In this study the use of fly ash as a substitute for 20% of the weight of the cement. Fly ash also affects the value of sorptivity concrete. There can be seen a normal concrete sorptivity secondary value of 0.006
mm/s\textsuperscript{1/2} whereas for concrete using fly ash as a substitute for 20% of the weight of the flexural strength of cement produces an average of 0.0056 mm/s\textsuperscript{1/2}. This shows a decrease in the value of secondary sorptivity 20%. It can be concluded that the fly ash also reduces the value of sorptivity concrete. This is because the particle size of the fine fly ash is expected to fill the pores in the composition of the concrete, so that it will facilitate the process of solidification of concrete and will increase the density of concrete results in more waterproof concrete. As said by Ahmad (2018), a small sorptivity due to pores so small that the capillary forces provided by pores causes fluid to be drawn into the smaller concrete. Besides, the cement hydration process results in the form of compound free lime Ca(OH)\textsubscript{2} will produce spaces or pores which will result in micro cracks, so it will reduce the density and strength of concrete. According to Kumar and Singh (2017) in the presence of silicate and aluminate content of fly ash in concrete, the crystal Ca(OH)\textsubscript{2} reacted with silicate and aluminate elements contained in fly ash forming compounds CSH (tobermorite). Thereby reducing the pore and increasing the density of concrete.

Based on initial results sorptivity Figure 5 decreased significantly on variations of the glass powder 0% had the highest sorptivity initial value of 0.0177 mm/s\textsuperscript{1/2}. Further decrease in the variation of glass powder 10% and 20% of the initial value sorptivity 0.0128 mm/s and 0.0076 mm/s. Furthermore, the increase is not large at 30% and 40% with a sorptivity initial value of 0.0081 mm/s\textsuperscript{1/2} and 0.0094 mm/s\textsuperscript{1/2}. From the results of the initial level sorptivity above can be linked to the results of the flexural strength testing. That the concrete with a variation of 20% glass powder concrete mortar binding perfect experience proved that increasing the flexural strength of concrete, the increased density of concrete means fewer pores present in the concrete so that the rate of initial value sorptivity getting smaller. The lower it can be concluded in sorptivity concrete value, the stronger the concrete or have a maximum strength of the concrete. It is supported by a study by Jalkulski (2015), that the concrete research has had sorptivity highest value of 0.245 cm/√h but has the lowest compressive strength of 14.6 MPa compared with the lowest sorptivity of 0.101 cm/√h reached the highest compressive strengths of 54.8 MPa. As well as on research conducted by Yousef alharbi et al (2018), that the maximum flexural strength resulting from the method Drymix can improve the flexural strength of 28% of wet-mix method, but produces a minimum value which lowers the value sorptivity up to 48% of wet-mix method. Given that the level of sorptivity is influenced by pores or voids that are concrete. The fewer pores or voids in the concrete, the greater the density of the concrete and the concrete is stronger and the rate of water ingress into the lower concrete core.

Based on Figure 6 secondary sorptivity linearly decreased. The highest sorptivity secondary value in normal concrete about 0.006 mm/s\textsuperscript{1/2}. Furthermore, the percentage of variation has decreased glass powder 0%, 10%, 20%, 30% and 40% with secondary sorptivity value about 0.0056 mm/s\textsuperscript{1/2}, 0.0055 mm/s\textsuperscript{1/2}, 0.0043 mm/s\textsuperscript{1/2}, 0.0036 mm/s\textsuperscript{1/2} and 0.0034 mm/s\textsuperscript{1/2}. This is caused because the testing process initial sorptivity (initial testing) the majority of the absorption of water takes place very rapidly during the early minutes until the first 6 hours of testing, so at the beginning of the test secondary sorptivity only lasted absorption slightly only fill the pores in some early hours of testing have not been occupied by water and concrete constituent particles that can absorb water. The results of testing on the secondary sorptivity experience a much lower rate in comparison with the initial sorptivity as in figures 5 and 6. In addition, secondary sorptivity decreases because the more glass powder content in the concrete will reduce the absorption of water due to the glass powder which is unable to absorb water, thereby reducing the field of water absorption.

Based on the above analysis, concrete with a variation of glass powder as a substitute for fine aggregate will look like the sorptivity rate decreased compared to concrete without glass powder as a partial replacement of fine aggregate. This is because the glass powder as a substitute for most fine aggregate has the property to not absorb water, so the rate of water ingress into concrete also will be smaller compared to concrete without glass powder. Besides, the size of the glass powder particles finer concrete to fill the cavity to increase the density of concrete and improve the adhesiveness between the cement paste and aggregate.
Increasing the density would result in reduction of the concrete pores and causes the rate of water ingress into the lower concrete.

In this research, a minimum sorptivity initial value to the percentage of 20% glass powder is 0.0076 mm/s$^{1/2}$ and secondary sorptivity minimal value is 0.0034 mm/s$^{1/2}$ in the variation of glass powder by 40%.

6. CONCLUSION

1. In the condition of this research, the variation in the use of glass waste as a partial replacement of fine aggregate and fly ash (fly ash) instead of 20% of the weight of cement significantly affect the flexural strength and sorptivity of concrete.

2. In this research, using a variation of glass powder 0%, 10%, 20%, 30% and 40% the percentage obtained optimum use of glass waste as a partial replacement of fine aggregate that is equal to 18.5% with a maximum flexural strength value about 2.9705 MPa.

3. In this research, using a variation of glass powder 0%, 10%, 20%, 30% and 40% obtained the minimum sorptivity initial value about 0.0076 mm/s$^{1/2}$ the percentage of variation of 20% glass powder and a minimum value of secondary sorptivity about 0.0034 mm/s$^{1/2}$ in the variation of glass powder by 40%.

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