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RECYCLE GLASS WASTE AS A REPLACEMENT OF FINE AGGREGATE IN CONCRETE MIX STANDARD COMPARISON

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Abstrak

Daur ulang merupakan salah satu cara yang digunakan untuk meminimalisir jumlah sampah yang ada. Daur ulang juga merupakan proses untuk mengurangi penggunaan bahan baku baru, mengurangi penggunaan energi, mengurangi polusi, degradasi lahan dan emisi gas rumah kaca. Bahan yang dapat didaur ulang terdiri dari limbah kaca, plastik, kertas, logam, tekstil dan barang elektronik. Kaca memiliki karakteristik yang cocok sebagai agregat beton, mengingat kaca merupakan bahan yang tidak menyerap air. Selain itu, kaca memiliki ketahanan abrasi yang tinggi. Kaca juga memiliki flux yang dapat *menurunkan temperatur hingga suhu* di mana *formers* akan *mencair. Stabilisator dalam limbah kaca terbuat dari kalsium karbonat, yang membuatnya menjadi mudah menjadi padat dan tahan air. Limbah kaca ini didaur ulang dengan mencampurkannya ke dalam campuran beton. Metode daur ulang dilakukan dengan cara menumbuk kaca dan memasukkannya ke dalam tahap adukan beton. Tujuan pencampuran limbah kaca diharapkan dapat meningkatkan kuat tekan beton. Penggunaan limbah glass impact sebagai bahan campuran mempengaruhi kuat tekan beton. Beton yang memiliki kuat tekan paling rendah sampai tertinggi adalah beton variasi 4%, beton variasi 2%, dan beton tradisional. Persentase penambahan limbah kaca yang optimal terhadap kuat tekan beton maksimum adalah variasi campuran 2% yang diperoleh 11,88 Mpa & 11,32 Mpa*

Kata kunci*—Limbah Kaca, Beton, Kuat Tekan*

Abstract

Recycling is one way that is used to minimize the amount of waste that exists. Recycling is also a process to reduce the use of new raw materials, reduce energy use, reduce pollution, land degradation and greenhouse gas emissions. Materials that can be recycled consist of waste of glass, plastic, paper, metal, textiles and electronic goods. Glass has characteristics suitable as concrete aggregates, considering that glass is a material that does not absorb water. In addition, glass has high abrasion resistance. Meanwhile, the waste glass flux lowers the temperature to the temperature at which the formers will melt. Stabilizers in glass waste are made of calcium carbonate, which makes the glass waste solid and water-resistant. This glass waste is recycled by mixing it into the concrete mix. The recycling method is done by pounding the glass and putting it into the concrete mix stage. The purpose of mixing the glass waste is expected to increase the compressive strength of concrete. The use of glass waste as a mixed material affects the compressive strength of the concrete. The concrete with the most inferior to highest compressive strength is 4% variation concrete, 2% variation concrete, and traditional concrete. Optimal percentage addition of glass waste impacts on maximum concrete compressive strength is 2% mixture variation which obtained 11,88 Mpa & 11,32 Mpa.

Keywords— *Concrete, Compressive strength, Glass Waste*

I. INTRODUCTION

Waste is a severe problem in developing countries, especially in big cities with a population that exceeds the limit. Waste can be turned into valuable something with help from the right technology. The nature of the waste

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that is a problem as waste, dirty, smells, causes disease and pollutes the environment can be converted into goods that can be used and have high economic value (Nicolaas et al., 2019; Kamajaya, 2021).

Inorganic waste can be used as raw material to develop the recycling industry (recycling). The paper industry can recycle waste paper. Plastic and glass waste can be recycled into industrial raw materials. At the same time, organic waste can develop a compost processing industry into organic fertilizer and be processed into the energy industry/building materials industry (Kamajaya, 2021).

Recycling is one way that is used to minimize the amount of waste that exists. Recycling is also a process to reduce the use of new raw materials, reduce energy use, reduce pollution, land degradation and greenhouse gas emissions. Materials that can be recycled consist of waste glass, plastic, paper, metal, textiles and electronic goods (Windah, 2013). Glass waste is widely used as raw material for handicrafts because it has high aesthetics and marketability.

Concrete is a construction material commonly used for buildings, bridges, roads, and others. Concrete can define as a mixture of aggregates fine and coarse aggregate with cement, which united by water in comparison certain. Due to its unique nature, then requires extensive knowledge including the nature of the basic materials, how to make it, how to evaluate it, and variety of additives. The quality level of concrete or other properties what is to be achieved can be produced with good planning in selection of constituent materials as well as the composition.

The resulting concrete expected to meet the conditions such as traceability and consistency that allows working of concrete with easily without causing segregation or aggregate separation and bleeding, resistance to the special conditions desired, fulfil the power to be achieved, and economical in terms of cost (Olii et al., 2021). This concrete is obtained by mixing fine aggregate (sand), coarse aggregate (gravel), or other types of aggregate and water with Portland cement or hydraulic cement. In addition, concrete mixtures are also often added with chemical or physical additives in specific ratios until they become a homogeneous whole (Suhartini et al., 2014).

Standard quality concrete is concrete containing average aggregate obtained from natural aggregate, which is broken or unbroken so that the density in air is obtained or the mass of concrete is between 2100-2550 kg/m^3 according to ACI. The compressive strength of standard quality concrete is 20 -50 MPa at the age of 28 days. Standard quality concrete is usually used for simple constructions such as housing and buildings that are relatively not too high, where the required compressive strength is not too large. The process of carrying out construction work using standard quality concrete does not require a high level of accuracy and safety. The essential ingredients for which it is formed are easy to obtain and economical. The weakness of standard quality concrete is that it has little strength and limited unique properties. The unique properties in question include water resistance, more resistance against chemical aggression, resistance to environmental influences in which the concrete is used, and others.

According to ACI, high-strength concrete has a compressive strength of more than 42 MPa at the age of 28 days. There are several ways to produce high-strength concrete, including applying pressure high, autoclave, aluminium cement, and addition/substitution. However, the most popular method used lately is the method of addition or substitution. This method due to the ease of implementation, namely, only adding additional materials into the primary materials forming concrete.

The advantage of high-strength concrete, in addition to its high compressive strength, is that there are many aspects and other properties that are not found in normal-strength concrete, such as strength. Other advantages of high-strength concrete are a high start, fresh concrete, more practical, thinner, easier to work with, more resistant to segregation, less bleeding, and more abrasion resistance (Karwur et al., 2013; Marhendi & Yusup, 2017).

Other high strength powers are denser, heat-resistant, resistant to corrosion, higher density, negligible shrinkage and creep, and more durability high and homogeneous. With high-strength concrete, it is possible to optimize the structure, which means the minimization of construction materials, both from the concrete itself and the reinforcing steel used. Applications of high strength concrete, among others, for multi-storey buildings, bridges, tunnels and others (Djawarman et al., 2018). Weaknesses in high-quality concrete include the quality that requires strict supervision (quality control) and the procurement of materials with outstanding "high quality", which are difficult to obtain and relatively expensive. Compared to standard strength concrete, high strength concrete is more easily damaged in areas with seismic activity (earthquakes often occur) because it is very brittle (Djamin & Budianto, 2020).

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Aggregates are natural or artificial mineral grains that function as fillers in concrete mixtures. This aggregate is one of the factors that increase the compressive strength of the concrete mixture. Recycled glass waste can be used as aggregate from concrete mixtures. Glass waste is an amorphous (shapeless) object but is not a solid object. The characteristics of glass waste made of sand (silica), soda (sodium oxide) and lime (calcium oxide) are solid and resistant to environmental conditions. In addition, waste glass contains formers, fluxes, and stabilizers (Tri, 2019; Wijaya, 2015). Formers make up the most significant percentage of the mix. For soda-lime-silica glass waste, the formers are silica in the form of sand.

Glass is a substance made by cooling molten materials and does not form crystals. Glass waste is usually separated by colour and end-use. Glass is divided into three colours:

a. Clear/colourless, usually used as household furniture
b. Green, usually used as a bottle of beer or wine
c. Chocolate, usually used as soft drink bottles.

Glass has characteristics suitable as concrete aggregates because it has a high level of durability, considering that glass is a material that does not absorb water. In addition, glass has high abrasion resistance. This characteristic is rarely found in other natural aggregates. The use of additives for natural aggregates tends to be expensive to achieve the same strength as glass (Windah, 2013).

Meanwhile, the waste glass flux lowers the temperature to the temperature at which the formers will melt. Stabilizers in waste glass are made of calcium carbonate, which makes the waste glass solid and water-resistant. This glass waste is recycled by mixing it into the concrete mix. The recycling method is done by pounding the glass and putting it into the concrete mix stage. The purpose of mixing glass waste is expected to increase the compressive strength of concrete.

Meanwhile, glass also contains several elements that exist in nature, are shown in Table 1 below.

TABLE 1. *Chemical Content of Glass*

No	Element
1	Na^{11}
2	Al^{13}
3	Si^{14}
4	K^{19}
5	Ca^{20}
6	Ti^{22}
7	Fe^{26}
8	Sr^{38}

II. METHOD

This research was conducted at the Laboratory of Structures and Materials, Department of Civil Engineering, State Polytechnic of Ketapang. This type of research is experimental research in the laboratory to test the compressive strength of concrete with glass impact waste as an added material.

A. Preparing material & tools

The research material consists of:

1. Portland Cement
2. Aggregate (fine aggregate and coarse aggregate)
3. Waste Glass shown at Fig. 1.
4. Water

Figure 1. Waste glass

The research tools are:

- Scale
- Sieve
- Picnometer
- Ruler
- Compactor stick
- Compression Tetsing Machine
- Cylinder mould
- Abrams' cone
- Oven

Figure 2. The sieve for aggregate

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Figure 3. The cylinder mould

Figure 4. Abrams' Cone

Figure 5. CTM (Compression Testing Machine)

B. Design of the test specimen
1. Material Weighing
2. Fresh Concrete Mixer

The steps in the mixing process using a mechanical stirrer is as follows:

a. Prepare the aggregates to be stirred.
b. Add fine aggregate and cement first and rotate the mixer machine.
c. Add coarse aggregate and roll again until the mixture is evenly distributed.
d. Add water little by little until 50% of the water will enter.
e. After the mixture does not look dry anymore, add the rest of the following water little by little and stir again until blended until the mixture looks homogeneous.

3. Mixing Concrete with The Addition Of Glass Collisions.

This stirring consists of 2 samples, namely:
• With a composition of 2% glass waste.
• With a composition of 4% glass waste.

a. The first step is to prepare the aggregates and materials for additional glass impact to be stirred.
b. Then enter the fine aggregate and cement first.
c. After that, add the coarse aggregate and the crushed glass has been solved, then stir the composition again.
d. Add water little by little. After the mixture is gone looks dry, put the remaining water back in and stir again until blend until the mixture looks homogeneous

4. Concrete Slump Test with Abrams Cone

a. Provide slump test tools, then pour fresh concrete into the cone mould as much as 1/3 of the height of the cone.
b. Then do a puncture or compaction of the concrete as many as 25 stabs.
c. After the concrete is complete, level the top and lift the cone vertically without any horizontal movement.
d. Then place the conical tube next to the spilled concrete and awl right above it.
e. Measure with a tape measure from the top of the casting to the awl. Results measurement is the slump value of the casting. When the slump value meets the requirements of concrete castings can be used.
f. And do it again on the concrete with the addition of glass impact.

5. Pouring and Compaction of Test Objects

a. Weigh and record the concrete mould.

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b. Enter the fresh concrete mix, enter the concrete mix as much as 3 times, then do the stabbing 25 times evenly.
c. After the layers are pierced, the outside is tapped using a rubber mallet 10 to 15 times slowly to close the hole impact and to allow air bubbles to escape.
d. After the concrete mould is filled, level the surface and clean up.

C. Test Object Treatment Method
1. The cylindrical mould is opened then the concrete is immersed into the tub immersion.
2. The test object is removed from the tub one day before the sample is tested. Also, when tested, the sample is not in a state of wet.
3. The test is carried out when the sample is 7, 14, and 28 days old

III.RESULT AND DISCUSSION

In research on the effect of glass waste as a material added to the compressive strength of concrete carried out at the Civil Engineering Laboratory Ketapang State Polytechnic, it is necessary to have stages in order to obtain optimal results. These stages include preliminary testing, planning mix design, manufacture and maintenance of concrete, compressive strength testing, and analysis of the effect of glass waste on the compressive strength of concrete.

A. Preliminary Testing

In this study, the aggregates used were 1-2 cm of Peacock stone and Pawan sand. Based on the results of tests carried out at the Civil Engineering Laboratory of the Ketapang State Polytechnic. The result of fine aggregate testing shown at Table 2 and Fig.6 below.

TABLE 2. Fine Aggregate Testing

Testing	Result	
	Sample 1	Sample 2
Sludge levels	97,2 %	97,2 %
Water content	46,87%	52,99 %
Absorption	6,38 %	5,93 %

Source: laboratory test results

B. Planning Mix Design
C. Manufacture Concrete
D. Compressive Strength Testing
E. Analysis compressive strength of concrete using glass waste

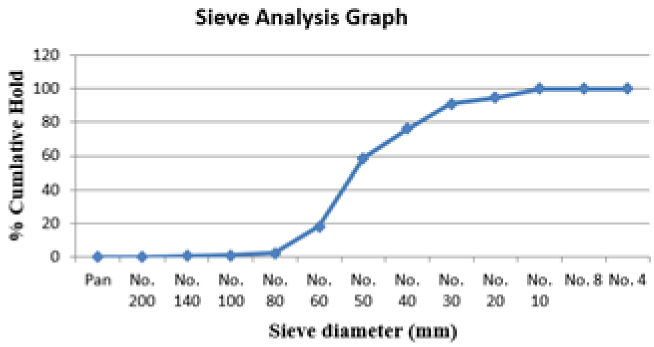

Figure 6. Sieve analysis graph of fine aggregate

The result of coarse aggregate testing shown at Table 3 and Fig.7 below.

TABLE 3. Coarse Aggregate Testing

Testing	Result	
	Sample 1	Sample 2
Wear level	24 %	30 %
Absorption	4,16 %	3,95 %

Source: laboratory test results

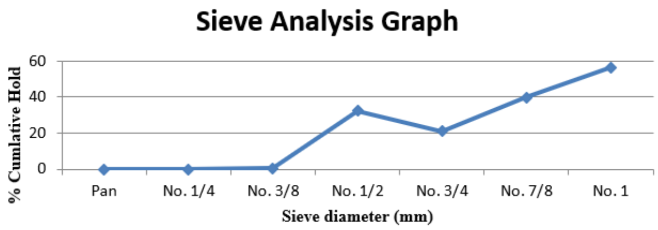

Figure 7. Sieve analysis graph of coarse aggregate

Based on the results of testing in the laboratory on PCC (Portland Composite Cement) type Three Wheel brand cement, the values shown in Table 4 and Fig. 8 below.

TABLE 4. Cement Testing

Time	Time Interval (minute)	Penetration Min
14.00	0	4,5
14.00 - 14.15	15	4,1
14.15 - 14.30	30	4,0
14.30 - 14.45	45	3,9
14.45 – 15.00	60	3,8
15.00 – 15.15	75	3,8
15.15 – 15.30	90	3,8
15.30 – 15.45	105	3,8

Source: laboratory test results

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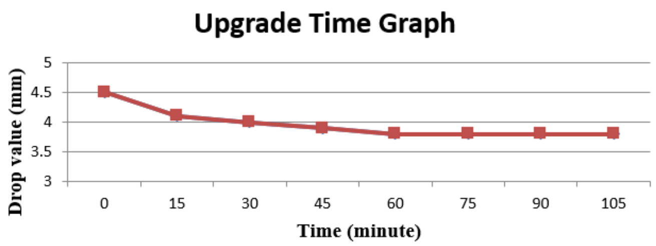

Figure 8. Sieve analysis graph of coarse aggregate

B. Mix Design

The calculation method used in planning the concrete mix is the SNI 03-2834-2000 method (SNI 03-2834-2000).

TABLE 5. Job Mix Design

Testing	Value
The compressive strength required (test object cylinder)	18.67 MPa at 28 days part 5 percent disability, k=1.64
Standard Deviation	7 MPa
Value Added (Margin)	1.64 x 7 = 11.5 Mpa
Average strength targeted	30.17 Mpa
Cement Type	Type 1
Aggregate Type: - Rough - Smooth	 Peacock Stone 1-2 cm Pawan Sand
Water Cement Factor Free	0.50
Water cement factor maximum	0.6
Slump	60 – 180
Aggregate Size Maximum	20 mm
Free moisture content	205 kg/m³
Amount of cement	410 /*cm*³
Amount of cement Minimum	325 kg/m³
Amount of cement maximum	410 kg/m
Amount of cement Customized	0.50
Cement ratio % weight of coarse aggregate and fine aggregate	40% 60%

Testing	Value
Aggregate specific gravity SSD state combined	2.5
Concrete volume weight Fresh	2.275 kg/m³
Combined aggregate weight SSD	1660 /*m*³
Fine aggregate weight	664 /*cm*³
Coarse aggregate weight	996 /*m*³

TABLE 6. Composition of concrete mix variation 0 (normal concrete)

Amount of each material/material	**Cement (kg)**	**Sand (kg)**	**Stone (kg)**	**Water (kg)**
For 1 m³ of concrete	410	664	996	205

Volume of 1 cylinder 150mmx300mm	Cement (kg)	Sand (kg)	Stone (kg)	Water (kg)
0.005303	2.17	3.52	5.28	1.08

Source: laboratory test results

C. Composition of Mixed Concrete with Glass Waste

TABLE 7. The composition of the concrete mixture variation I (Waste Glass 2%)

Amount of each materials	**Cement (kg)**	**Glass waste (kg)**	**Sand (kg)**	**Stone (kg)**	**Water (kg)**
For concrete 1 m³	410	0.070	664	996	205

Volume of 1 cylinder 150mm x 300mm	Cement (kg)	Glass waste (g)	Sand (kg)	Stone (kg)	Water (kg)
0.005303	2.17	70	3.52	5.28	1.08

Source: laboratory test results

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TABLE 8. The composition of the concrete mixture variation II (Waste Glass 4%)

Amount of each materials	Cement (kg)	Glass waste (kg)	Sand (kg)	Stone (kg)	Water (kg)
For concrete 1 m^3	410	0.140	664	996	205

Volume of 1 cylinder 150mm x 300mm	Cement (kg)	Glass waste (g)	Sand (kg)	Stone (kg)	Water (kg)
0.005303	2.17	140	3.52	5.28	1.08

Source: laboratory test results

TABLE 9. Composition of Concrete Mix for Testing

Combination	PCC	Glass waste	Sand	Stone	Water
Normal	2.17	0	3.52	5.28	1.08
2 %	2.17	0.070	3.52	5.28	1.08
4 %	2.17	0.140	3.52	5.28	1.08

Source: laboratory test results

D. Curing The Specimen

After the concrete mix design is complete, it is planned that the concrete is made with the composition, according to each variation. In this study, there are four variations: concrete normal, a variation I (Waste Glass 2 %), variation II (Waste Glass 4%), and each variation of 4 samples.

Concrete treatment is carried out after the concrete is released from the mold ± 24 hours from its manufacture. When removed from the mold, the condition of the concrete is still fragile and easily damaged, so you have to be careful when removing and move it.The curing process can be seen at Fig. 9 below.

Figure 11. The curing concrete process

E. Concrete Compressive Strength Test

The compressive strength test on the test object is carried out at the age of concrete 7, 14, 28 at the Civil Engineering Laboratory of the Ketapang State Polytechnic. Based on the results of the compressive strength test obtained, the calculation is carried out on the data obtained to determine the value of the compressive strength of concrete. Data of compressive strength test shown at Table 10, Table 11, and Table 12.

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Figure 12. Compressive Strength Test

TABLE 10. Concrete Compressive Strength Sample (7 days age)

Sample	Variation	Age (kg)	Weight (kg)	Diameter (mm)	Height (mm)	Max load (N)	Compressive Strength (Mpa)
1	0%	7	11.6	150	300	340000	19.24
2		7	11.6	150	300	330000	18.68
3	2%	7	12.1	150	300	210000	11.88
4		7	12	150	300	200000	11.32
5	4%	7	11.9	150	300	150000	8.49
6		7	11.8	150	300	140000	7.92

Source: laboratory test results

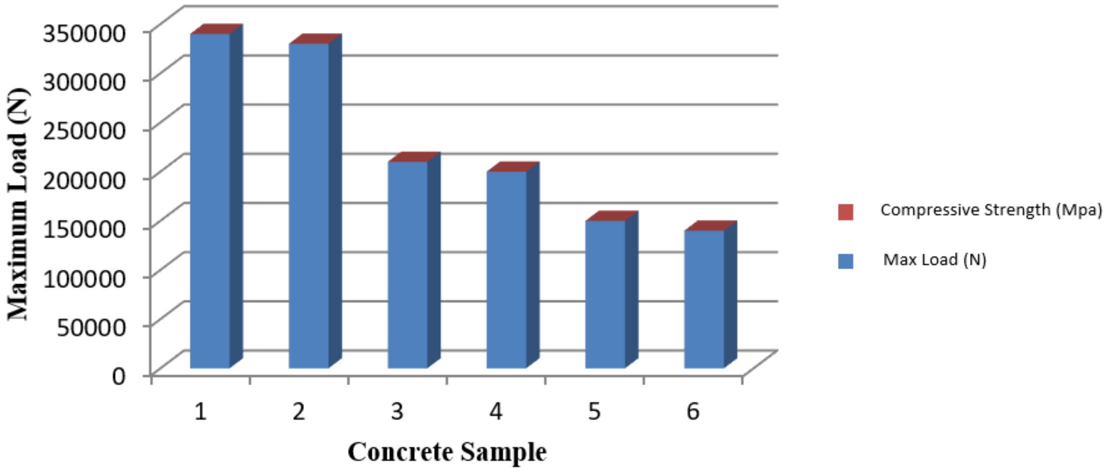

Figure 13. Maximum Load Chart (7 days age)

TABLE 11. Concrete Compressive Strength Sample (14 days age)

Sample	Variation	Age (kg)	Weight (kg)	Diameter (mm)	Height (mm)	Max load (N)	Compressive Strength (Mpa)
1	0%	14	11,6	150	300	350000	19.81
2		14	11,6	150	300	340000	19.24
3	2%	14	11,2	150	300	290000	16.41
4		14	11,1	150	300	280000	15.28
5	4%	14	12,4	150	300	270000	15.85
6		14	12,3	150	300	260000	14.72

Source: laboratory test results

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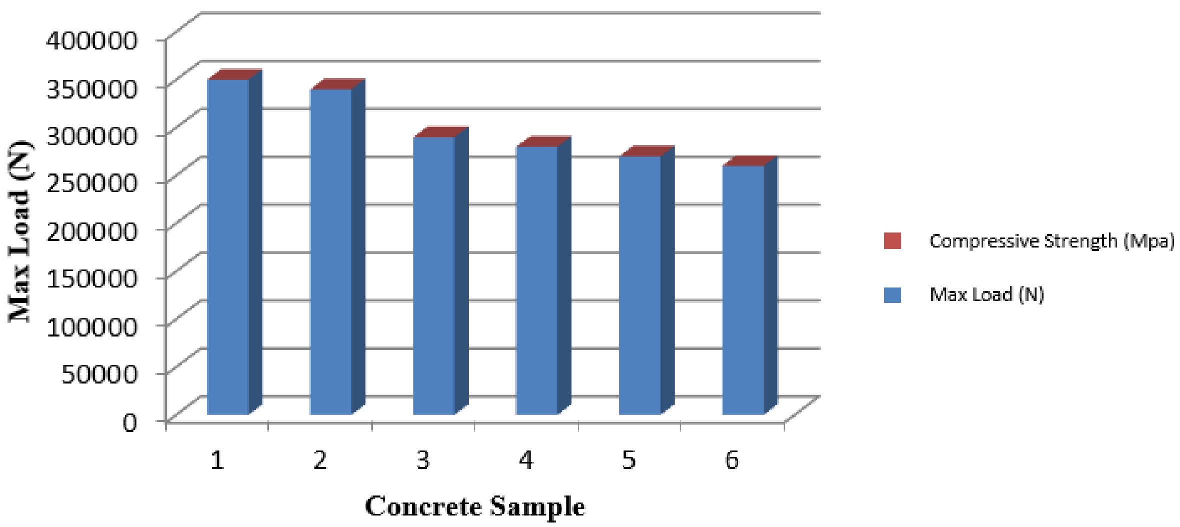

Figure 14. Maximum Load Chart (14 days age)

TABLE 12. Concrete Compressive Strength Sample (28 days age)

Sample	Variation	Age (kg)	Weight (kg)	Diameter (mm)	Height (mm)	Max load (N)	Compressive Strength (Mpa)
1	0%	28	12,2	150	300	360000	19.81
2		28	12,1	150	300	350000	19.24
3	2%	28	12,4	150	300	290000	16.41
4		28	12,3	150	300	280000	15.28
5	4%	28	12	150	300	270000	15.85
6		28	11,9	150	300	260000	14.72

Source: laboratory test results

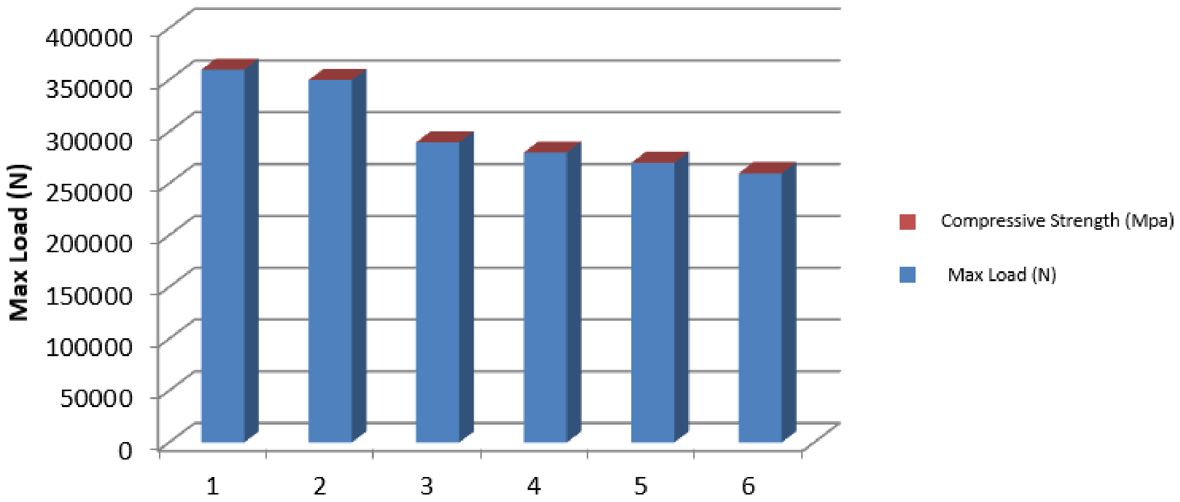

Figure 15. Maximum Load Chart (28 days age)

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Average normal concrete compressive strength test results were shown in Table 13. Compressive strength test results for 2% and 4% variation glass were shown in Table 14 and Table 15. Also, Fig. 16 showed the chart of average normal concrete compressive strength test results.

TABLE 13. Average Normal Concrete Compressive Strength Test

Age	Compressive Strength	Unit
7	18,97	Mpa
14	19,53	Mpa
28	20,10	Mpa

Source: laboratory test results

TABLE 14. Concrete Compressive Strength Test (2% waste glass)

Age	Compressive Strength	Unit
7	11,60	Mpa
14	16,13	Mpa
28	16.3	Mpa

Source: laboratory test results

TABLE 15. Concrete Compressive Strength Test (2% waste glass)

Age	Compressive Strength	Unit
7	11,60	Mpa
14	16,13	Mpa
28	16.3	Mpa

Source: laboratory test results

After making the sample, treating, and testing the compressive strength of the sample, a calculation is carried out on the data obtained to determine the value of the compressive strength of concrete in MPa.

TABLE 16. Compressive Strength Test Results for 7, 14 and 28 Days of Concrete

Sample	Sample Code	Age (day)	Weight (Kg)	Density (Kg/m^3)	Max Load (kN)	Compressive Strength		Age estimate 28 days (MPa)	Average Compressive Strength (MPa)
						MPa	Kg/cm^2		
Normal S.1	7	7	11.6	0.00219	340	19.24	1.924982	29.18	18.97
Normal S.2	7	7	11.6	0.00219	330	18.68	1.868365		
2% S.1	7	7	12.1	0.00228	210	11.8896	1.18896	17.85617072	11.60651097
2% S.2	7	7	12	0.00226	200	11.32343	1.132343		
4% S.1	7	7	11.9	0.00225	150	8.492569	0.849257	12.62997441	8.209483369
4% S.2	7	7	11.8	0.00223	140	7.926398	0.79264		
Normal S.1	14	14	11.6	0.00219	350	19.81599	1.981599	22.19648716	19.5329087
Normal S.2	14	14	11.6	0.00219	340	19.24982	1.924982		
2% S.1	14	14	12	0.00226	290	16.41897	1.641897	18.33622853	16.1358811
2% S.2	*14*	14	12.1	0.00228	280	15.8528	1.58528		
4% S.2	*14*	14	12.4	0.00234	270	15.28662	1.528662	17.04947565	15.00353857
4% S.2	*14*	14	12.3	0.00232	260	14.72045	1.472045		
Normal S.1	*28*	28	12.2	0.00230	360	20.38217	2.038217	20.10	20.10
Normal S.2	*28*	28	12.1	0.00228	350	19.81599	1.981599		
Variasi 2% S.1	*28*	28	12.4	0.00234	290	16.41897	1.641897	16.14	16.1358811
Variasi 2% S.2	28	28	12.3	0.00232	280	15.8528	1.58528		
Variasi 4% S.1	28	28	12	0.00226	270	15.28662	1.528662	15.00	15.00353857
Variasi 4% S.2	28	28	11.9	0.00224	260	14.72045	1.472045		

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Based on table 16, the compressive strength of the mixed concrete is more than lower than the compressive strength of normal concrete. The compressive strength of mixed concrete with a variation of 4% is also lower than the variation of 2%. The concrete with the lowest to the highest compressive strength is the 4% variation of concrete, 2% variation concrete, and normal concrete. The more a mixture of waste glass added to the concrete mix makes strong the compressive strength of the concrete decreases.

This study is also necessary to determine the most optimal variant of concrete, which is close to the value of normal concrete compressive strength. It can also be seen from table 16. The compressive strength of normal concrete, aged seven days, is 18.97 MPa. Variations The closest concrete mix is a variation of 2% with a compressive strength value of 11,61 MPa. While the compressive strength of normal concrete, aged 14 days, is 19.53 MPa. Variation The closest concrete mixture is a variation of 2% with a compressive strength value of 16.14 MPa. The most optimal variant is the variation of the 2% glass waste mix.

IV. CONCLUSION

Based on research on the effect of adding glass waste to the compressive strength of concrete with a mixture ratio of 1:2:3, it is concluded that the use of glass impact waste as a mixed material affects the compressive strength of the concrete. The concrete with the most inferior to highest compressive strength is 4% variation concrete, 2% variation concrete, and traditional concrete. Optimal percentage addition of glass waste impact on strong yield maximum concrete compressive strength is 2% mixture variation.

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