Analysis of concrete mixtures with marble waste material as cement substitution and glass waste as sand substitution on concrete compressive strength

F Zulkarnain¹, J Hadipramana¹ and Krisnianda²
¹Lecturer, Civil Engineering, University of Muhammadiyah Sumatera Utara, Medan, Indonesia.
²Freshgraduate, Civil Engineering, University of Muhammadiyah Sumatera Utara, Medan, Indonesia.

*Email: fahrizalzulkarnain@umsu.ac.id

Abstract. Concrete technology that continues to develop produces high quality concrete which will be a problem of increasing concrete needs. Along with the soaring price of cement as the main ingredient in making concrete, the cost of making concrete is a problem that needs to be sought as a solution for technological development in the field of building construction. Therefore making concrete mixes by suppressing the amount of cement used can be one of the solutions to the problem. The many needs of the Indonesian community for buildings cannot be separated from the increasing demand for building materials. One of them is marble and glass which in the process there is trash or waste from the results of the remains of the pieces or discarded without any prior management. Therefore the need for efforts that can be made to handle the amount of marble or glass waste by utilizing it as a filler in making concrete. This research is to find out the quality of compressive strength of concrete mixed with marble waste. This study used a compressive strength of 20 MPa plan after the study was carried out obtained the average compressive strength of 10% marble concrete waste at 14 days at 22.35 MPa and at 28 days at 23.20 MPa. The average compressive strength value of glass waste concrete 8% at 14 days is 22.64 MPa and at 28 days is 23.48 MPa. Meanwhile, the average compressive strength value of the concrete combination of 10% marble waste + 8% glass waste at 14 days is 22.92 MPa and at 28 days is 23.77 MPa it can be concluded that all concrete variations in marble waste of 10% and glass waste of 8% have increased. This proves that marble and glass waste can be used in certain variations.

1. Introduction
Concrete is a composite material consisting of cement, coarse aggregate and fine aggregate which has a certain ratio and mixed with water as a hardening aid which when stirred with water and without any additives will have a certain solid mass and quality. Concrete is also a mixture of cement, coarse aggregate, fine aggregate, water and with or with additional materials with a certain ratio that will from fresh concrete. The use of concrete is more desirable because it is relatively strong, easily formed, and more economical when compared to construction using steel, wood or using other materials. The development of the construction world in Indonesia at this time is very impacting on the increasing use of concrete as a material in strengthening structures, in addition to that technology in concrete also always experiences more dynamic development. Fine and coarse aggregates are...
referred to as mixed coarse materials which are the main components of concrete [1].

Along with the soaring price of cement as the main material for making concrete, the cost of making concrete is a problem that needs to be solved in order to develop technology in the field of construction, especially in the cost of making a building structure. For the reason, it is necessary to have a substitute for cement in the manufacture of concrete or just a filler to reduce the amount of cement needed in the manufacture of concrete, but it does not reduce the quality of concrete so that it still meets the requirements in construction work. The use of marble waste is based on research [2]. The study was conducted by utilizing marble as a partial cement filler with a composition of 10% of the volume of cement. In general, the most marble content is Calcium Oxide (CaO) and a little Magnesium Oxide (MgO), Aluminium Dioxide (Al₂O₃) and Silicon Dioxide/Silicate (SiO₂) marble chemical content is mostly also found in cement. Whereas for the use of glass waste is based on [3]. The study was conducted utilizing glass waste as partial sand filler with a percentage variation of 8% of the volume of fine aggregate. Chemical content that is in the glass in the form of Silicate (SiO₂), Calcium Oxide (CaO), Magnesium Oxide (MgO), Aluminium Dioxide (Al₂O₃) dan Soda Fluks (Na₂O). For that the authors conducted research using marble waste and glass waste in a concrete mixture, to determine the compressive strength of concrete.

2. Review the library Concrete Understanding

In construction, is a composite building made of a material consisting of a mixture of cement, water, aggregates (coarse and fine) and additives when needed. Normal concrete in concrete which has a weight of 2200-2500 kg/m³ by using natural aggregates which are broken down or without being broken down [4].

Concrete itself is a function of the preparation material consisting of cement or portland cement, coarse aggregate, fine aggregate, water and additives or admixture. Concrete also has several advantages compared to other construction materials, including having a large compressive strength, resistant to fire, easily formed, no special expertise is required in its manufacture, and raw materials are easy to obtain so that concrete contains about 1%-2% air cavity, cement paste (cement and water) around 25%-40%, and aggregate (fine aggregate and coarse aggregate) around 60%-75% [5].

Concrete preparation materials include water, portland cement, coarse aggregates and fine aggregates as well as added materials, where each constituent material has different functions and influences. Important properties, in general, are also good. The factors that influence the compressive strength of concrete consist of the quality of the constituent material, the value of the cement water factor, aggregate gradation, maximum aggregate size, method of working (mixing, transportation, compaction, and maintenance) and the age of concrete [6].

2.1. Marble

Marble or marble is the result of metamorphic rocks or metamorphic rock. The influence of temperature and pressure produced by endogenous forces causes recrystallization of these rocks to form various foliation and non-foliation. Due to the recrystallization of the structure of origin of the rock to form a new texture and grain order.

![Figure 1. Before and after the marble is processed.](image)

Marble waste used in this study is the result of the rest of the pieces of whole marble carried out in building work. The pieces of marble are then pounded to get the ashes, then the ashes are sieved using sieve number 200.
Chemical content in marble fractions containing 55.07% Calcium Oxide (CaO) and other chemical elements [7]. The results of chemical analysis of marble shards can be seen in Table 1.

| No. | Chemical Elements                  | Ingredients (%) |
|-----|------------------------------------|-----------------|
| 1.  | Silica Dioxide (SiO₂)              | 0.13            |
| 2.  | Aluminium Dioxide (AlO₃)           | 0.31            |
| 3.  | Oxide Ferries (FeO₃)               | 0.04            |
| 4.  | Calcium Oxide (CaO)               | 55.07           |
| 5.  | Magnesium Oxide (MgO)              | 0.36            |
| 6.  | Potash (K₂O)                       | 0.01            |
| 7.  | Sulfur Trioxide (SO₃)              | 0.08            |
| 8.  | (LoI)                              | 44              |

Calcium Oxide (CaO) is the biggest chemical element in the marble content, which is 55.07% the same as the basic material for making portland cement, so that marble can serve to increase the binding distribution in the concrete mixture.

2.2. Glass

Glass bottles are products of the chemical industry that are most familiar with our daily lives. In terms of physical glass is a very cold liquid. So called because the structure of the particles are arranged far apart from each other as in liquid but they themselves are solid. This occurs due to the rapid cooling process, so Silica particles do not have time to arrange themselves regularly. In terms of chemistry, glass is a combination of various non-volatile inorganic oxides, which are produced from the decomposition and melting of alkaline and alkaline earth compounds, sand and various other preparations. Typical glass properties are influenced by the unique Silica (SiO₂) and formation process.

Glass is a substance made by cooling down melted materials. Not in the form of crystals but remains in a hollow condition. Waste glass is usually separated based on the color of the glass, in general, the glass is divided into 3 colors:

a. Clear/colorless, usually used as a household appliance.
b. Green, usually used as a beer or wine bottle.
c. Chocolate, usually used as a soft drink bottle.

![Figure 2. Before and after the glass is processed.](image)

Glass waste can be obtained from the remaining pieces of glass in building work such as window glass or others. In this study, the glass used was clear/colorless. The broken glass pieces are then crushed which will later become powder, then sifted using a filter number 30 held in filter number 50.

Chemical content in broken glass contains 73.5% Silica Oxide (SiO₂) and other chemical elements [8]. The results of chemical analysis of broken glass can be seen in Table 2.
Table 2. Chemical content of broken glass (Setiawan, 2006).

| No | Chemical Elements                         | Ingredients (%) | Type of Glass (Clear Glass) |
|----|------------------------------------------|----------------|----------------------------|
| 1  | Silica Dioxide (SiO$_2$)                 | 73,2-73,5      |                            |
| 2  | Aluminium Dioxide (AlO$_3$)              | 1,7-1,9        |                            |
| 3  | Sodium Oxide + Potash (Na$_2$O + K$_2$O) | 13,6-14,1      |                            |
| 4  | Calcium Oxide + Magnesium Oxide (CaO + MgO) | 10,7-10,8   |                            |
| 5  | Sulfur Trioxide (SO$_3$)                 | 0,2-0,24       |                            |
| 6  | Oxide Ferries (Fe$_2$O$_3$)              | 0,04-0,05      |                            |
| 7  | Chromium Oxide (Cr$_2$O$_3$)             |                |                            |

Many potentially beneficial things from using glass as a concrete aggregate, between others:

a) Has a high degree of durability, considering that glass is a material that does not absorb water.

b) Glass has a high resistance to abrasion and this characteristic is a rare characteristic found in other natural aggregates, as for the use of additives for natural aggregates to achieve the same strength.

3. Data Analysis And Discussion

3.1. Concrete Mix Data

In this case, the author will analyze the data that has been obtained during the study in order to obtain the values of the aggregate basic examination results listed in Table 3 below. These data can be used for planning concrete mix (Mix Design) with a compressive strength required of 20 MPa using the method (SNI 03-2834-2000).

Table 3. Aggregate base inspection data.

| No | Basic Inspection Data                  | Values   |
|----|---------------------------------------|----------|
| 1  | Fine aggregate specific gravity       | 2,57 gr/cm$^3$ |
| 2  | Coarse aggregate specific gravity     | 2,70 gr/cm$^3$ |
| 3  | Fine aggregate mud content            | 3 %      |
| 4  | Coarse aggregate mud content          | 0.83 %   |
| 5  | Weight of fine aggregate content      | 1,15 gr/cm$^3$ |
| 6  | Weight of coarse aggregate content    | 1,69 gr/cm$^3$ |
| 7  | Fine aggregate modulus of refinement  | 2,73 %   |
| 8  | Coarse aggregate modulus of refinement| 7,28 %   |
| 9  | Fine aggregate water content          | 2,22 %   |
| 10 | Coarse aggregate water content        | 0,86 %   |
| 11 | Absorption of fine aggregates         | 1,73 %   |
| 12 | Absorption of coarse aggregates       | 0,72 %   |
| 13 | Rough aggregate wear                  | 16,36 %  |
| 14 | The value of the plan slump           | 30-60 mm |
| 15 | Maximum aggregate size                | 40 mm    |

3.2. Concrete Compressive Strength Testing

Concrete compressive strength testing is performed when the concrete is 14 days old, and 28 days old, using a press machine with a capacity of 1500 KN, the test object to be tested is cylindrical with a diameter of 15 cm and a height of 30 cm with a total of 24 specimens, with grouping test specimens according to the variation of the mixture. Concrete compressive strength testing is done to get a picture of the quality of concrete, and also proof of the Mix Design that is made based on the quality of the concrete that has been planned.
Mix ratio for 1 cylinder test specimen,
Cement : Sand : Broken stone : Water
2,09 kg : 3,39 kg : 6,56 kg : 0,88 kg

Based on the comparison above explains the amount of cement weight for 1 cylindrical specimen is 2,09 kg, the weight of marble waste is 10% of the cement weight for 1 cylindrical specimen which is 0,209 kg. Hence, the weight of cement for 1 cylinder test object is 1,881 kg.

Based on the comparison above explains the amount of cement weight for 1 cylindrical specimen 3,39 kg – the weight of sand weight 8% of the sand weight for 1 cylinder test object that is 0,271 kg. Hence, the weight of sand for 1 cylinder test object is 3,12 kg.

3.3. Normal Compressive Strength of Concrete

Table 4. Normal concrete compressive strength test results.

| Concrete age 14 days | Compressive load (P) (kg) | $A = 176.71 \text{ cm}^2$ | Estimated 28 days $f'_c/0.88$ (MPa) |
|----------------------|---------------------------|---------------------------|-------------------------------------|
| Test object          | $f'_c = (P/A)$           |                           |                                     |
| I                    | 43500                     | 24.62                     | 27.97                               |
| II                   | 33000                     | 18.67                     | 21.22                               |
| II                   | 34500                     | 19.52                     | 22.19                               |
| $f'_c$ average       |                           | 20.94                     | 23.79                               |
| Concrete age 28 days | Compressive load (P) (kg) | $A = 176.71 \text{ cm}^2$ | Estimated 28 days $f'_c/1.00$ (MPa) |
| Test object          | $f'_c = (P/A)$           |                           |                                     |
| I                    | 42000                     | 23.77                     | 23.77                               |
| II                   | 45000                     | 25.47                     | 25.47                               |
| II                   | 30000                     | 16.98                     | 16.98                               |
| $f'_c$ average       |                           | 22.07                     | 22.07                               |

Based on the results of normal concrete compressive strength test 14 days and 28 days, the average value of 14 days of normal concrete compressive strength is 20.94 MPa, 28 days is 22.07 MPa.

3.4. Compressive Strength of Concrete Mixture of 10% Marble Waste

Table 5. Concrete compressive strength test results of mixed marble waste 10%.

| Concrete age 14 days | Compressive load (P) (kg) | $A = 176.71 \text{ cm}^2$ | Estimated 28 days $f'_c/0.88$ (MPa) |
|----------------------|---------------------------|---------------------------|-------------------------------------|
| Test object          | $f'_c = (P/A)$           |                           |                                     |
| I                    | 36000                     | 20.37                     | 23.15                               |
| II                   | 40500                     | 22.92                     | 26.04                               |
| II                   | 42000                     | 23.77                     | 27.01                               |
| $f'_c$ average       |                           | 22.35                     | 25.40                               |

Concrete age 28 days
Based on the results of the compressive strength test of concrete with a mixture of marble waste 10% age 14 days and 28 days, the average value of compressive strength of concrete with marble waste 10% age 14 days is 22.35 MPa, age 28 days is 23.20 MPa.

3.5. Compressive Strength of Concrete Mixture of 8% Glass Waste

Table 6. Concrete compressive strength test results of mixed glass waste 8%.

| Concrete age 14 days | Test object | Compressive load (P) (kg) | A = 176.71 cm² | Estimated 28 days $f'_c/0.88$ (MPa) |
|---------------------|-------------|---------------------------|----------------|-----------------------------------|
|                     | I           | 45000                     | 25.47          | 28.94                             |
|                     | II          | 42000                     | 23.77          | 27.01                             |
|                     | II          | 33000                     | 18.67          | 21.22                             |
| $f'_c$ average (MPa)|             |                           | 22.64          | 25.72                             |

| Concrete age 28 days | Test object | Compressive load (P) (kg) | A = 176.71 cm² | Estimated 28 days $f'_c/1.00$ (MPa) |
|---------------------|-------------|---------------------------|----------------|-----------------------------------|
|                     | I           | 49500                     | 28.01          | 28.01                             |
|                     | II          | 39000                     | 22.07          | 22.07                             |
|                     | II          | 36000                     | 20.37          | 20.37                             |
| $f'_c$ average (MPa)|             |                           | 23.48          | 23.48                             |

Based on the results of the compressive strength test of concrete with a mixture of glass waste 8% age 14 days and 28 days, the average value of compressive strength of concrete with glass waste 8% age 14 days is 22.64 MPa, age 28 days is 23.48 MPa.

3.6. Compressive Strength of Concrete Mixture Marble Waste 10% + Glass Waste 8%

Table 7. Compressive strength test results of concrete mixture marble waste 10% + glass waste 8%.

| Concrete age 14 days | Test object | Compressive load (P) (kg) | A = 176.71 cm² | Estimated 28 days $f'_c/0.88$ (MPa) |
|---------------------|-------------|---------------------------|----------------|-----------------------------------|
|                     | I           | 33000                     | 18.67          | 21.22                             |
|                     | II          | 42000                     | 23.77          | 27.01                             |
|                     | II          | 46500                     | 26.31          | 29.90                             |
| $f'_c$ average (MPa)|             |                           | 22.92          | 26.04                             |
Concrete age 28 days

| Test object | Compressive load (P) (kg) | A = 176.71 cm² | Estimated 28 days $f'_c/1,00$ (MPa) |
|-------------|--------------------------|----------------|-----------------------------------|
| I           | 51000                    |                | 28,86                             |
| II          | 39000                    |                | 22,07                             |
| II          | 36000                    |                | 20,37                             |

$f'_c$ average (MPa) 23,77 23,77

Based on the results of the compressive strength test of concrete with a mixture of marble waste 10% + glass waste 8% age 14 days and 28 days, the average value of concrete compressive strength with a mixture of marble waste 10% + glass waste 8% age of 14 days is 22,92 MPa, the age 28 days is 23,77 MPa.

From the compressive strength test results obtained compressive strength value for each variation of mixtures with different concrete ages, as attached in Figure 3, as follows:

![Figure 3. Graph of average compressive strength at 14 days and 28 days.](image)

From the picture above we can see an increase in the compressive strength of concrete from the age of 14 days and 28 days on each variation of concrete mixes, all have a compressive strength value of concrete according to the quality of the concrete plan of 20 MPa.

4. Discussion

When compared between the compressive strength values of normal concrete with concrete that uses a mixture of marble waste 10%, glass waste 8%, and marble waste mixture 10% + glass waste 8% for concrete age 14 days and 28 days, it can be seen an increase or not on the compressive strength value of concrete that uses a mixture of materials in each variation.
From the picture above it can be seen that the percentage of compressive strength of concrete combined with 10% marble waste + 8% glass waste has increased, with a percentage of 9.46% of normal concrete at 14 days concrete age and at 28 days concrete age has increased, with a percentage of 7.70% of normal concrete. The increase in compressive strength of glass waste concrete has increased, with a percentage of 8.12% of normal concrete at 14 days concrete age and at 28 days concrete age has increased, with a percentage of 6.39% of normal concrete. The increase in compressive strength of marble waste concrete has increased, with a percentage of 6.73% of normal concrete at 14 days concrete age and at 28 days concrete age has increased, with a percentage of 5.12% of normal concrete. In this case, it can prove that marble waste as a partial filler of cement and glass waste as a partial filler of sand can increase the compressive strength of a concrete plan.

5. Conclusion
From the results of research and testing of concrete compressive strength age 14 days and 28 days, several conclusions can be drawn including:
1. As for the results of the compressive strength testing of 10% marble waste as a partial filler of cement experienced a percentage increase of 6.73% at 14 days and 5.12% at 28 days of normal concrete. While the glass waste of 8% as a partial filler of sand also increased by 8.12% at the age of 14 days and 6.39% at 28 days of normal concrete.
2. As for the results of the compressive strength test of the combination of marble waste 10% + glass waste 8% as a partial filler of cement and sand experienced the most optimum percentage increase of 9.46% at 14 days and 7.70% at 28 days of concrete normal. Based on the results of research on the influence of the use of marble waste 10% and glass waste 8% as filler material for concrete mix is the reduced amount of cement and sand in the concrete mixture.

Acknowledgements
Thank you to Dr Fahrizal Zulkarnain as a Supervisor I and thank you to Dr Josef Hadiprmana as a Supervisor II who has provided direction and input to this study. Thank you to Munawar Alfansury Siregar, S.T, M.T as the Dean of the Faculty of Engineering, University of Muhammadiyah Sumatera Utara.

References
[1] Mulyono, T. (2004). “Teknologi Beton”. Penerbit: Andi, Yogyakarta.
[2] Istiqomah & Kurnia, S. (2013). “Pengaruh Limbah Marmer Sebagai Bahan Pengisi Pada Beton (179S)”. Jurnal Teknik Sipil Istiqomah & Kurnia, S. Fakultas Pendidikan Teknik Sipil Universitas Pendidikan Indonesia, Bandung, Jawa Barat, 2013.
[3] Suhartini, A., Gunarti, A. S. S. & Hasan, A. (2014). “Pengaruh Penambahan Tumbukan Limbah Botol Kaca Sebagai Bahan Subtitusi Agregat Halus Terhadap Kuat Teken Dan
Kuat Lentur Beton”. *Jurnal Teknik Sipil* Suhartini, dkk. Fakultas Teknik Sipil Universitas Islam 45 Bekasi, Jawa Barat, *Vol. 2 No. 1 Januari 2014.*

[4] Sugiyanto. (2000). “Pengaruh Abu Terbang Sebagai Bahan Pengganti Semen Pada Beton Beragregat Halus Bottom Ash”. *Skripsi* Lincolen, K. Fakultas Teknik Universitas Lampung, Bandar Lampung, 2017.

[5] Mulyono, T. (2005). “Teknologi Beton”. Penerbit: Andi, Yogyakarta.

[6] Tjokrodimuljo, K. (1996). “Teknologi Beton”. Penerbit: Nafiri, Yogyakarta.

[7] Wihardi dkk. (2006). “Penggunaan Limbah Batu Marmer Dari Gunung Batu Naitapan Kabupaten Timor Tengah Selatan Sebagai Alternatif Pengganti Agregat Pada Campuran Beton”. *Jurnal Teknik Sipil* Nauk, S. S. Fakultas Teknik Sipil Universitas Nusa Cendana, Nusa Tenggara Timur, *Vol. 1 No. 4 September 2012.*

[8] Setiawan. (2006). “Analisa Kuat Tekan Beton Dan Penyerapan Air Kombinasi Filler Abu Ampas Tebu Dan Botol Kaca Substitusi Pasir (Studi Penelitian)”. *Skripsi* Harahap, R. S. Fakultas Teknik Sipil Universitas Muhammadiyah Sumatera Utara, Medan, 2018.