Ecompact Concrete as an Alternative to Quality Green Concrete by Utilizing Grashka Waste

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Abstract*— Infrastructure is the driving wheel of a country's economic growth, one of which is Indonesia. Based on the Central Statistics Agency (BPS), infrastructure in the third quarter of 2021 grew by 3.84%. This infrastructure growth increases the use of cement so that it contributes to CO_2 emissions in the world by 5 – 7%. Indonesia is also faced with environmental problems, namely industrial waste that has not been managed optimally, including fly ash waste, glass waste, and granite waste. From these problems came the innovation of eco-friendly concrete that is quality and economical, which is called Ecompact Concrete. This concrete uses Grashka waste (Granite, Fly Ash and Glass) with a proportion of 50% crushed granite as a partial replacement for coarse aggregate, 3% glass powder and 5% fly ash as a partial replacement for cement. The advantage of Ecompact concrete is that it has a higher compressive strength than normal concrete, namely 23.35% at 7 days and 28.71% at 28 days. The price of Ecompact Concrete is 11.72% more economical than ordinary concrete. The application of Ecompact Concrete can also reduce the use of coarse aggregate by 50% and cement by 8%. With Ecompact Concrete, it is hoped that it can reduce the problem of CO_2 gas emissions produced by cement factories, reduce granite, glass and fly ash waste, and develop green infrastructure in realizing sustainable development in Indonesia.

***Keywords*— Green Concrete; Ecompact Concrete; Fly Ash; Granite; Glass**

I. Introduction

Currently, infrastructure development is progressing rapidly in various countries, including Indonesia. According to the Central Statistics Agency (BPS), infrastructure in the third quarter of 2021 grew by 3.84%. The growth in the infrastructure sector is one of the reasons for the increased use of concrete. This leads to higher cement consumption, resulting in increased air emissions, particularly CO_2 emissions, and environmental damage in the material extraction process. The cement industry is estimated to contribute to approximately 5-7% of global CO_2 emissions [1]. Carbon emissions in Indonesia reached 41.4 million tons of CO_2 in 2021, an increase of 2.7% compared to the previous year. This increase in carbon emissions does not align with the Indonesian government's commitment to reducing greenhouse gas emissions by 26% through its own efforts and 41% with international assistance [2]. One of the efforts to fulfill this commitment by the Indonesian government is the need to implement green infrastructure to achieve sustainable development.

Furthermore, Indonesia also faces environmental challenges related to industrial waste, including fly ash, glass waste, and granite waste. According to the SNI 03-6414-2002 standard, fly ash is a waste product from the combustion of coal in steam power plant furnaces. It is fine, round, and possesses pozzolanic properties. Fly ash primarily consists of oxides of silica (SiO_2), aluminum (Al_2O_3), iron (Fe_2O_3), and calcium (CaO), as well as small amounts of potassium, sodium, titanium, and sulfur [3].

According to the Ministry of Environment and Forestry in 2021, glass waste contributed to 6.6% of all types of waste in Indonesia. Glass contains silica (SiO_2), Na_2O, and CaO in concentrations of more than 70% [4]. In addition to glass, there is also granite waste generated from the furniture industry. Granite has a specific gravity of 2.6 – 2.7 kg/m^3 and compressive strength ranging from 1000 kg/cm^2 – 2500 kg/cm^2. Granite pieces have coarse grain characteristics and are denser in nature. The accumulation of granite waste, fly ash, and glass waste, without optimal utilization, can lead to serious problems, one of which is the narrowing of waste disposal areas.

From these issues, an innovative, high-quality, and cost-effective green concrete called "Ecompact Concrete" has emerged. This concrete utilizes fly ash and glass as partial substitutes for cement in concrete, as well as granite as a partial substitute for coarse aggregates. Amiwarti found that the optimal mix composition includes 15% glass powder and 5% fly ash, resulting in an average compressive strength of 26.99 MPa, which represents a 5.55% increase compared to normal concrete strength [5]. Research by Wahyu on waste utilization suggests that the optimal use of granite fragments is 60%, resulting in a compressive strength of 22.7 MPa [6].

Raham conducted research related to High Strength Green (HSG) Concrete with Coal Fly Ash with a variation of fly ash mixtures (0%, 4%, 8%, 12%, 16%, 20%) with a range of HRWR (high range water damper) (0%, 0.4%, 0.7%, 1.0%, 1.3%, 1.6%). Produce The compressive strength of the mixture with fly ash of 4% -12% showed satisfactory results. The peak tensile strength value is 4.9 MPa with 12% fly ash [8].

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Arel et al studied the use of recycled waste granite (WG) as a substitute for various components in concrete or cement materials, such as aggregate and cement. The result is obtained at a substitution rate of 5–7.5%; when recycled WG is used instead of aggregate, the result is obtained at a substitution rate of 15–25%; and when recycled WG is used instead of coarse aggregate, its performance is better than recycled normal concrete aggregate and worse performance than crushed quartzite coarse aggregate. Furthermore, from an economic perspective, it is determined that the use of WG will reduce costs by a minimum of 0.54% and a maximum of 2.1% [9].

Ecompact Concrete is expected to reduce cement consumption, decrease air emissions, and optimize the utilization of local industrial waste in Indonesia. Thus, it can contribute to the development of green infrastructure and the realization of sustainable development goals.

II. RESEARCH METHODS

Ecompact Concrete is an environmentally friendly, high-quality, and cost-effective concrete technology that utilizes waste materials such as granite, fly ash, and glass. The research methodology used in this study is an experimental research method. The research includes literature review, laboratory testing to determine material characteristics, and the production of Ecompact Concrete test specimens with a target strength of 35 MPa, followed by testing.

The research consists of several stages, including the research preparation stage, material testing stage, mix proportion planning stage, test specimen production stage, test specimen maintenance stage, compressive strength testing stage, and data analysis stage.

1. Preparation: This involves preparing the necessary tools, materials, workspace, and technical procedures for the research.
2. Material Testing: The aim here is to understand the properties and characteristics of the materials used in concrete, including cement, fly ash, glass powder, granite, crushed stone, and sand.
3. Determination of Optimal Fly Ash and Glass Powder Content: Testing is conducted on mortar with 16 different variations of fly ash and glass powder percentages to determine the optimal mix. Compressive strength tests are performed on the mortar to establish the best quality.
4. Determination of Optimal Granite Content: This involves a trial-and-error approach with three different granite content percentages: 40%, 50%, and 60%. The concrete mixture includes a 5% substitution of fly ash and 3% glass powder. Compressive strength testing is carried out to determine the highest concrete quality.
5. Concrete Mix Proportion Planning: This step involves calculating the concrete mix proportions using the SNI 03-2834-2000 standard [7].
6. Production of Test Specimens: Test specimens are typically in the form of cylinders with a diameter of 10 cm and a height of 20 cm.
7. Test Specimen Maintenance: Ecompact concrete is typically cured by covering it with wet cloths and burlap sacks for 7 days, along with regular watering.
8. Concrete Compressive Strength Testing: This is done to determine the compressive strength of the concrete. Testing is typically performed at 7 and 28 days of curing, using a Compressive Testing Machine (CTM).
9. Data Analysis: The results from each test are analyzed, and conclusions are drawn based on the data obtained.

III. RESULTS AND DISCUSSION

The compressive strength testing of mortar is aimed at obtaining the optimal percentage of fly ash and glass powder in Ecompact Concrete. There are nine test specimens for mortar compressive strength. These nine specimens have different percentage values to achieve the maximum compressive strength. The variations in the percentages of cement, fly ash, and glass powder can be seen in the following Table 1.

TABLE I. VARIATION IN THE PERCENTAGE OF CEMENT, FLY ASH AND GLASS POWDER

Sample	**Percentage Cement (%)**	**Percentage *Fly Ash (%)***	**Percentage Glass Powder (%)**
S1	92	5	3
S2	87	10	3
S3	82	15	3
S4	89	5	6
S5	84	10	6
S6	79	15	6
S7	85	5	10
S8	80	10	10
S9	75	15	10

The results of mortar compressive strength testing at the age of 3 days with various variations of cement, fly ash, and glass powder can be seen in Fig. 1.

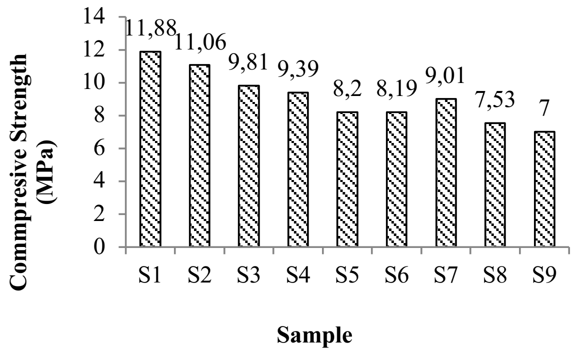

Fig. 1. Compressive strength of mortar

In Figure 1, the mortar with the highest compressive strength is Sample 1. The mixture variation for Sample 1 is 92% cement, 5% fly ash, and 3% glass powder, resulting in a mortar compressive strength of 11.88 MPa.

In addition to conducting compressive strength tests for variations of fly ash and glass powder, compressive strength testing was also carried out for variations in granite substitution. The granite variations performed can be seen in the following Table 2.

TABLE II. VARIATIOND OF GRANITE

Sample	Granite Substitution Variations (%)
G1	0
G2	40
G3	50
G4	60

The compressive strength of granite variations can be seen in Figure 2 below.

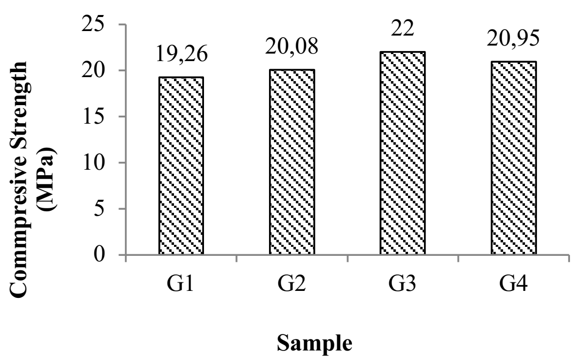

Fig. 2. Concrete compressive strength on granite variations

In the compressive strength experiment, samples G1, G2, G3, and G4 yielded different compressive strengths. The highest compressive strength occurred in sample G3, which produced a value of 22 MPa. The lowest compressive strength was found in sample G1, which measured 19.26 MPa. The highest concrete compressive strength was observed in sample G3 at 22 MPa.

The material requirements for the production of Ecompact Concrete can be seen in the following Table 3.

TABLE III. MATERIAL REQUIREMENTS FOR ECOCOMPACT CONCRETE

No	Description	Value	Unit
1.	Cement	465,68	kg/m^3
2.	Fly Ash	25,31	kg/m^3
3.	Glass Powder	15,19	kg/m^3
4.	Water	177,16	kg/m^3
5.	Superplasticizer	2,02	kg/m^3
6.	Sand	615	kg/m^3
7.	Gravel	546,82	kg/m^3
8.	Granite	546,82	kg/m^3

Before pouring Ecompact Concrete into molds, a slump test is conducted, measured at 3 different points. From this test, an average slump value of 9.23 cm is obtained.

Compressive strength testing is performed when the concrete is 7 and 28 days old using a Compression Testing Machine. Each compressive strength test uses 2 specimens. The results of compressive strength testing for Ecompact Concrete specimens and normal concrete can be seen in Table 4.

TABLE IV. COMPRESSIVE STRENGTH OF ECOMPACT CONCRETE AND NORMAL CONCRETE

Age of Concrete	No. Sample	*Ecompact Concrete*	Normal Concrete
7	1	28,08	21,52
	2	30,30	23,22
	3	29,19	22,37
	Average	29,19	22,37
28	1	46,70	33,29
	2	51,10	36,86
	3	48,90	34,86
	Average	48,90	35,00

Figures 3 and 4 demonstrate an increase in compressive strength in Ecompact Concrete. At 7 days of age, there is a 23.35% increase in compressive strength compared to normal concrete. Meanwhile, at 28 days of age, there is a 28.71% increase compared to normal concrete.

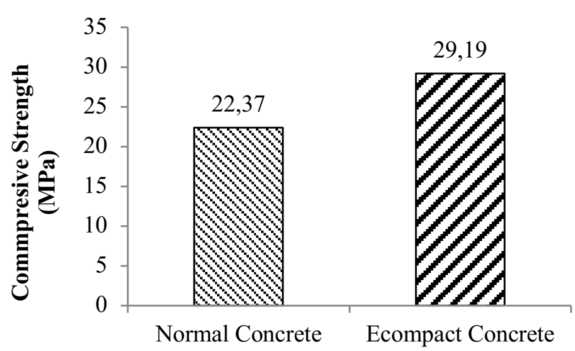

Fig. 3. Comparison of compressive strength of Ecompact Concrete and Normal Concrete at 7 Days of Age

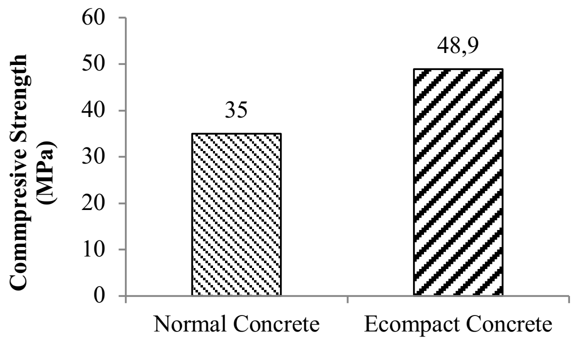

Fig. 4. Comparison of compressive strength of Ecompact Concrete and Normal Concrete at 28 Days of Age

In addition to its strength, cost analysis for the production of Ecompact Concrete is also taken into account. The cost calculation aims to determine the economic value of producing Ecompact Concrete. A cost comparison between normal concrete and Ecompact Concrete can be seen in Figure 5.

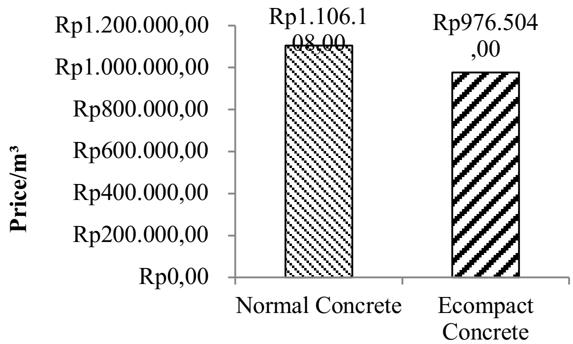

Fig. 5. Comparison of the cost of making normal concrete and ecocompact concrete

The production of Ecompact Concrete incurs lower costs compared to the production of normal concrete. Figure 5 shows a cost difference of Rp 129,604,- in production. The production of Ecompact Concrete is more economical, with a cost savings of 11.72% compared to normal concrete.

The impact analysis of Ecompact Concrete includes the following aspects:

a. **Environmentally Friendly** The cement industry is estimated to contribute about 5-7% of global CO2 emissions, significantly affecting environmental cleanliness, health, and comfort. Carbon emissions contribute to climate change along with greenhouse gas emissions. Therefore, there is a need for innovation to partially or entirely replace the use of cement in concrete production to minimize its use. Reducing the amount of cement in Ecompact Concrete by 8%, replaced with fly ash and glass powder, can reduce cement usage and production. Utilizing granite waste can also reduce waste from the furniture industry and material mining for concrete composition.

b. **High Quality** Ecompact Concrete can be applied in structural construction such as foundations, columns, or beams due to its higher quality, with a 23.35% increase in strength at 7 days and a 28.71% increase at 28 days compared to normal concrete. Therefore, the use of Ecompact Concrete in the field can be more effective than normal concrete.

c. **Economical** Based on the budget cost calculations, Ecompact Concrete is more economical than normal concrete at the same quality (fc' 35 MPa), with a price difference of Rp 129,604,- or 11.72%.

d. **Application to Society** The underutilization of Grashka waste (granite, fly ash, and glass) requires significant land for waste disposal. Furthermore, waste accumulation in certain areas disrupts the comfort of the surrounding community and diminishes the beauty of the environment. The use of fly ash, glass powder, and granite in Ecompact Concrete is expected to have a long service life and equivalent or even superior strength in concrete mixtures.

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