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# Compressive strength and water absorption of precast concrete wall panels with different content of plastic waste and silica-rich recycled materials

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## ABSTRACT

This study was conducted to analyse the strength and water absorption of precast concrete wall panels made by adding plastic powder and silica-rich recycled materials as partial replacements for sand and cement. Precast concrete wall panels are made from a mixture of sand to cement ratio of 3:1 and added with sufficient water. Gradually, the sand fraction is replaced with plastic powder, while the cement fraction is replaced partially by rice husk ash and glass powder. The variables studied include the effect of plastic powder, silica-rich recycled materials, and water-to-binders ratio on compressive strength and durability, including water absorption, sulfate and acid attack resistance of precast wall panels. The research revealed that replacing 20% of sand and 10% of cement with plastic powder and silica-rich recycled materials with the water-to-binder weight ratio of 1.6 produces precast concrete wall panels with a water absorption, and compressive strength of 11.14–11.48%, and 4.85–5.06 MPa, respectively. These precast concrete wall panels are acceptable for lightweight concrete wall panel requirements according to ASTM C129-06.

**Keywords:** compressive strength, precast concrete wall panel, plastic powder, silica-rich recycled material.

## INTRODUCTION

The presence of plastic waste in the environment has a negative impact on human and environmental health. In water, plastic becomes toxic to aquatic organisms, while burning plastic causes the release of several toxic gases such as vinyl chloride, dioxins, phthalates, and bisphenols, which disrupt the respiratory and nervous systems [1, 2]. Indonesia's annual national waste generation in 2023 was recorded at 4.01million tons, of which 19.15% was plastic waste. To reduce the amount of plastic waste and at the same time overcome the environmental problems it causes, processing plastic waste into economically valuable and environmentally friendly products is an urgent action that must be taken.

A multitude of studies have been undertaken concerning the conversion of plastic waste into economically valuable products, particularly within the manufacturing sector, including its fabrication of paving blocks [3, 4], asphalt [5], eco-bricks [6], and non-load-bearing wall panels [7]. Wall panels are a significant construction element that have gained popularity for their ability to be affixed to building walls as decorative enhancements, augmenting the aesthetic appeal of the walls. Natural stone for wall cladding has traditionally served as an exterior wall cladding due to its durability, visual allure, and low maintenance needs. However, the excessive exploitation of natural stone for wall covering purposes is not sustainable and causes various environmental problems, such as damage to environmental aesthetics, former excavation holes that can endanger human safety, and these excavation holes are flooded in the rainy season as a breeding ground for various types of mosquitoes that threaten health. To reduce excessive exploitation of natural stone, a study regarding the fabrication of artificial stone for wall cladding, especially precast wall panels using by-product materials, including recycled material as a mixture, is required urgently.

In general, concrete wall panels are produced using cement and sand, and the addition of sufficient water to form a concrete paste that is ready to be molded. The addition of solid materials as fillers without significantly reducing the quality of the concrete. Solid waste materials such as limestone waste combined with polyester resin adhesive [8], iron ore tailings [9], fly ash, waste from granite and marble processing plants [10, 11], coconut shells [12], rice husks, red clay [13], and a composite of sand, limestone, cement, and recycled rubber [14], have been widely studied as mixed materials in the manufacture of precast concrete wall panels. Among the waste materials available, the use of silica containing materials for concrete wall panel mixtures has advantages over other materials because its can act as pozzolans, where when in the form of fine powder added with a little water can show cement properties [15]. Some of the materials and recycled materials that are rich in silica include glass powder [16], volcanic ash [17] and ash from agricultural by products [18]. Due to their high silica content, accessibility, and cost-effectiveness, rice husk ash and glass powder may serve as valuable cementitious additions. As a result, it is very important to use rice husk ash and glass powder as pozzolanic materials in the production of precast non-loading concrete.

This study investigates the characteristics of precast concrete wall panels made from polyethylene terephthalate (PET), a type of plastic waste reinforced with silica-based materials, namely rice husk ash and glass powder, to replace some of the sand and cement. In this study, plastic powder is intended to replace some of the sand, while silica-rich materials are used to reduce cement use. The variables studied include the effect of replacing some of the sand and cement with plastic powder and silica-rich materials, as well as the ratio of cement to water on the compressive strength and durability of artificial concrete panels for wall coverings. The values of water absorption and compressive strength of concrete wall panels were compared with the ASTM C129-06 standard for non-load concrete wall panels [19].

## MATERIALS AND METHODS

### Materials

The materials used for precast concrete wall panel preparation consist of sand, ordinary Portland cement, plastic powder, rice husk ash, glass powder, and water. These materials are determined for specific gravity using the pycnometer method, water absorption, and oxide metal content through X-ray fluorescence (XRF). The water absorption and specific gravity of sand, rice husk ash, and glass powder are shown in Table 1, whereas the oxide metal content of cement, sand, rice husk ash, and glass powder are presented in Table 2.

**Table 1**. The water absorption and specific gravity for precast concrete wall panel materials

| Properties | Sand | Plastic powder | Rice husk ash | Glass powder |
|---|---|---|---|---|
| Water absorption, wt.% | 1.17 | 0.86 | 2.67 | 1.09 |
| Specific gravity, kg/m$^3$ | 2.74 | 1.06 | 2.10 | 2.50 |

**Table 2**. The dominant metal oxides of precast concrete wall panel materials

| Materials | Metal oxides content, wt. % | | | |
|---|---|---|---|---|
| | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO |
| Sand | 41.10 | 13.00 | 24.80 | 15.40 |
| Portland cement | 10.20 | 2.10 | 5.07 | 76.01 |
| Rice husk ash | 97.90 | 0.42 | 0.34 | 0.63 |
| Glass powder | 71.90 | 0.51 | 2.71 | 20.80 |

## Methods

### *Preparation of plastic powder*

Plastic powder is prepared by the cutting of plastic into small pieces (diameter of 1–2 cm) using a plastic shredder machine. The shredded plastic is heated using a drum filled with a little oil while stirring until evenly distributed until all the plastic becomes plastic pulp. Then it is cooled and crushed using a crusher machine equipped with a 1 mm sieve.

### *Preparation of silica rich-recycle materials*

The silica-rich recycled materials used in this study were rice husk ash and glass powder. The production of rice husk ash was carried out by burning rice husks in a drum until a blackish-white ash was obtained. Furthermore, the blackish-white ash was reheated at a temperature of 800 °C for 5 hours using a furnace until a white ash was formed. Meanwhile, the production of glass powder was carried out by converting glass into glass powder using a grinding machine. The silica contained in rice husk ash and glass powder was analysed using XRF.

### *Mix. design precast concrete wall panels*

The materials for making precast concrete wall panels consist of 3 parts of sand and 1 part of cement, and with water to cement ratio is 1.2. All materials that pass the 100 mesh sieve are used to make concrete wall panels (Fig. 1).

The use of sand in the mixture is gradually reduced by adding plastic powder, while the amount of cement is partially replaced with rice husk ash or glass powder. The mix. proportion of precast concrete wall panels is listed in Table 3.


**Figure 1.** Materials for precast concrete wall panels preparation

**Table 3.** Mixture composition materials of precast concrete wall panels for one specimen

| Specimen | Sand (g) | Plastic (g) | Cement (g) | Silica-rich recycled material | | W/C (g/g) |
|---|---|---|---|---|---|---|
| | | | | Rice husk ash (g) | Glass powder (g) | |
| 1 | 200 | 0 | 66.70 | 0.00 | 0 | 1.2 |
| 2 | 190 | 10 | 66.70 | 0.00 | 0 | 1.2 |
| 3 | 180 | 20 | 66.70 | 0.00 | 0 | 1.2 |
| 4 | 170 | 30 | 66.70 | 0.00 | 0 | 1.2 |
| 5 | 160 | 40 | 66.70 | 0.00 | 0 | 1.2 |
| 6 | 150 | 50 | 66.70 | 0.00 | 0 | 1.2 |
| 7 | 160 | 40 | 63.40 | 3.30 | 0 | 1.2 |
| 8 | 160 | 40 | 60.00 | 6.70 | 0 | 1.2 |
| 9 | 160 | 40 | 56.67 | 10.00 | 0 | 1.2 |
| 10 | 160 | 40 | 53.34 | 13.33 | 0 | 1.2 |
| 11 | 160 | 40 | 63.40 | 0 | 3.5 | 1.2 |
| 12 | 160.0 | 40.0 | 60.00 | 0 | 6.70 | 1.2 |
| 13 | 160.0 | 40.0 | 56.67 | 0 | 10.00 | 1.2 |
| 14 | 160.0 | 40.0 | 53.34 | 0 | 13.33 | 1.2 |
| 15 | 160.0 | 40.0 | 67.0 | 6.70 | 0 | 1.4 |
| 16 | 160.0 | 40.0 | 67.0 | 6.70 | 0 | 1.6 |
| 17 | 160.0 | 40.0 | 67.0 | 6.70 | 0 | 1.8 |
| 18 | 160.0 | 40.0 | 67.0 | 6.70 | 0 | 2.0 |
| 19 | 160.0 | 40.0 | 67.0 | 6.70 | 0 | 2.2 |
| 20 | 160.0 | 40.0 | 67.0 | 0 | 6.70 | 1.4 |
| 21 | 160.0 | 40.0 | 67.0 | 0 | 6.70 | 1.6 |
| 22 | 160.0 | 40.0 | 67.0 | 0 | 6.70 | 1.8 |
| 23 | 160.0 | 40.0 | 67.0 | 0 | 6.70 | 2.0 |
| 24 | 160.0 | 40.0 | 67.0 | 0 | 6.70 | 2.2 |

For testing purposes, the tested specimens were prepared in cube form (5 × 5 × 5 cm). After 28 days of curing time, the specimens were measured for their compressive strength and water absorption to obtain the optimum mixture composition of precast concrete wall panels. To study the effect of water to cement ratio on compressive strength and water absorption of precast concrete wall panels, the water was gradually added to the material mixtures to form water to cement ratios of 1.4, 1.6, 1.8, 2.0, and 2.2, respectively. Based on the optimum mixture proportion obtained, precast concrete wall panels were then produced in dimensions of 30 × 30 × 2.5 cm using fiberglass molds.

### *Compressive strength test*

The compressive strength of cube-shaped specimens (5 × 5 × 5 cm) after being left for 28 days was determined by following the standard procedure issued by SNI 03-0691-1996 [20]. A compression testing machine used to measure the specimens is shown in Figure 2.

The specimen is placed in the compressive machine and slowly compressed until the test object breaks. The value of compressive strength was determined using equation

$$Compressive\ strength\ (MPa) = \frac{P}{A} \quad (1)$$

where: $P$ is compressive load (N) and $A$ is compressive load area (cm$^2$).


**Figure 2.** ADR touch compressive testing machine

### *Water absorption test*

The water absorption test of specimens was carried out using a procedure issued by SNI 03-0691-1996. Specimens with dimensions of 5 × 5 × 5 cm were immersed in water for 24 hours until a water-saturated sample was obtained. The water bound to the specimen surface was removed using a cloth and weighed ($Ww$). The specimen was dried in an oven at 105 °C for 24 hours. Drying and weighing samples were repeated until a weight difference of no more than 0.2% was achieved and expressed as dried sample ($Wd$). The water absorption of precast concrete wall panel is calculated using the equation:

$$Water\ absorption\ (\%) = \frac{Ww - Wd}{Wd} \times 100\% \quad (2)$$

where: $Ww$ and $We$ are the wet and dry weight of the sample, respectively.

## Sulfate attack resistance analysis

The sulfate attack resistance of the specimen was carried out following the procedure JSTM C 740 [21]. The dry specimens that had cured for 28 days were immersed in a $Na_2SO_4$ solution with a concentration of 6000 mg/L. The dry weight of the sample was measured every 7 days for 28 days, where the sulfate solution was renewed a week. The resistance of specimen to sulfate attack was evaluated in terms of compressive strength and weight change. The weight change ratio of test specimen was calculated using the following equation.

$$Weight\ change\ (\%) = \frac{Wa - Wb}{Wa} \times 100\% \quad (3)$$

where: $W_a$ and $W_b$ are the weight of specimen at after and before immersion in sulfate solution, respectively.

### *Acid attack resistance analysis*

Acid resistance testing on test specimen with dimensions of 50 × 50 × 50 mm which has been left for 28 days. The dry weight of the specimens was immersed in HCl with a pH of 4 for 28 days where the hydrogen chloride solution was renewed a week. An acid solution with a pH of 4 was chosen considering that rainwater in Indonesia is in the pH range of 4–5. The dry weight of the specimens was measured every 7 days for 28 days of immersion in the acid solution. Test specimens that have been treated with acid, their weight loss and compressive strength are evaluated. The loss in weight was calculated with the equation:

$$Loss\ of\ weight\ (\%) = \frac{Wa - Wb}{Wa} \times 100\% \quad (4)$$

where: $W_a$ and $W_b$ are the weight of specimen at after and before immersion in HCl solution, respectively.

## RESULTS AND DISCUSSION

The visual appearance of concrete wall panels is composed of three parts sand, one part ordinary Portland cement, and adequate water. Then gradually 5–25% of the sand is replaced with PET plastic powder, while 5–20% of the cement used is replaced with silica-rich recycled materials. The visual appearance of the test specimen and precast concrete wall panels are presented in Figure 3.

Several factors, such as the influence of plastic powder addition, silica-rich recycled materials, the water-to-binder ratio, and sulfate and acid attack resistance, on the physical properties, including compressive strength and water absorption for concrete wall panels, were investigated.

### *Compressive strength and water absorption with different content of PET plastic*

Six types of specimens were fabricated with a plastic powder proportion of 0%, 5%, 10%, 15%, 20%, and 25% of the weight of the sand used. The strength and water absorption of each specimen are presented in Figure 4 and Figure 5, respectively.

Figure 4 demonstrates a decrease in the compressive strength of precast concrete wall panels with increasing amounts of plastic powder used to replace sand. The strength decreased from 9.68 MPa to 8.36, 7.29, 5.68, 4.65, and 4.13 MPa, respectively, when the plastic powder portions were 5%, 10%, 15%, 20%, and 25%. Despite the observed decline in compressive strength with elevated plastic content in concrete, substituting 20% of sand with plastic powder yields a compressive strength that satisfactorily fulfils the minimum requirements set by ASTM C129-06 for non-loading concrete, specifically 4.14 MPa for the average of three specimens and 3.45 MPa for a single specimen. In SNI 03-3122-1992 concerning lightweight fiber concrete panels, it is also stated that the minimum compressive


**Figure 3.** Physical appearance of concrete containing plastic waste and recycled materials

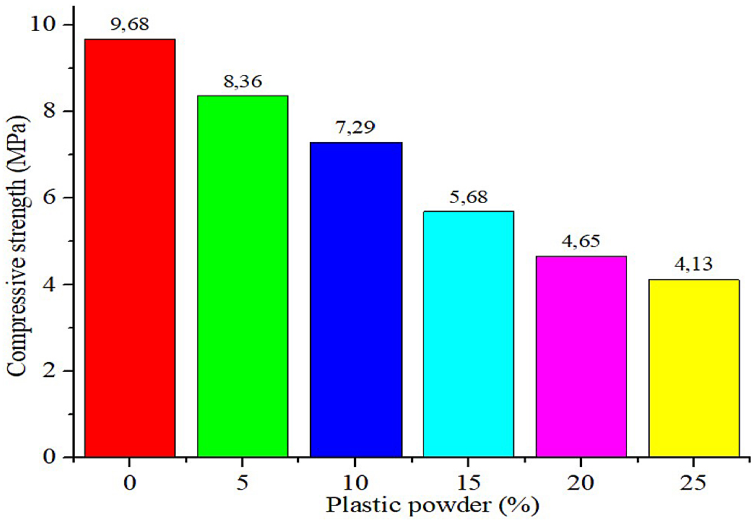


**Figure 4.** Compressive strength of concrete wall panels as a function of partial replacement of sand with plastic powder

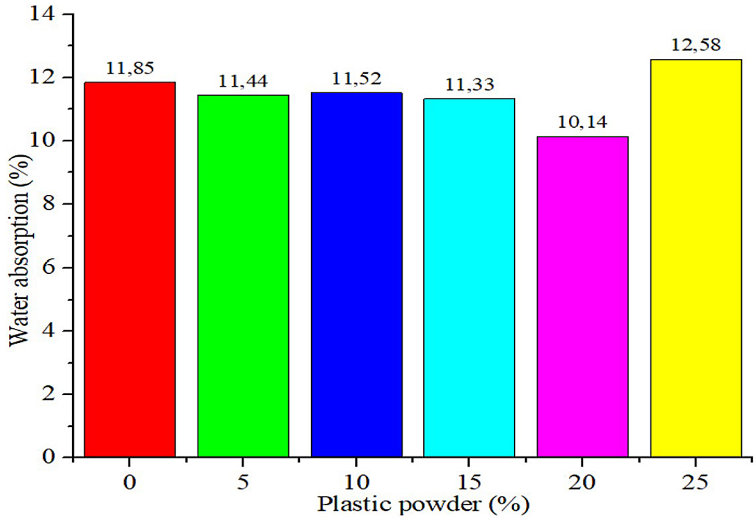


**Figure 5.** Water absorption of concrete wall panels as a function of partial replacement of sand with plastic powder

strength requirements for concrete wall panels for class A and class B are 2.82–3.12 MPa and 2.19–2.51 MPa, respectively [22]. In our previous research, it also obtained a trend of decreasing compressive strength of non-load concrete with increasing amounts of sand substituted by plastic waste [23]. The research was conducted by Tota-Maharaj et al. (2022) found that the decrease in concrete compressive strength is in line with the increasing amount of plastic in concrete [24]. Several other research findings, the compressive strength can be impacted by the addition of plastic trash, with different ideal replacement percentages. The decrease in the compressive strength of concrete wall panels with increasing amounts of plastic added can be attributed to the weak bond nature of plastic particles with other aggregates in concrete [25,26].

Water absorption is a critical metric for evaluating the durability of concrete wall panels. Generally, concrete with lower water absorption has a better quality than higher water absorption. As shown in Figure 5, there is a tendency for the water absorption capacity of concrete wall panels to decrease if the amount of plastic added as a sand substitute is increased from 5% to 20%, but it increases if the amount of plastic added is more than 20%.

Replacing sand with plastic powder portions of 5%, 10%, 15%, 20%, and 25% produced concrete wall panels with water absorption capacities of 11.44%, 11.35%, 10.85%, 10.14%, and 12.5%, respectively. The replacement of 5–20% sand with PET type plastic still meets the maximum water absorption requirements for non-loading concrete according to ASTM C129-06, which is a maximum of 12%. The study regarding the impact of using polyethylene terephthalate (PET) plastic waste as a partial replacement for sand in the manufacturing of non-structural concrete has been conducted by a number of researchers. Comparable results were also generated by several studies. Babatunde et al. (2022) found that there was a decrease in water absorption reaching around 15%, 19%, and 29% compared to the control as the PET plastic aggregate content increased by 10%, 20%, and 30% in the concrete mixture [27]. The research by Al-Hadithi and Al-Ani (2018) also found that high-performance concrete has lower water absorption with more plastic particles used as a substitute for natural sand [28]. Usman and Jabba (2022) reported that the water absorption value of concrete in the range of 1.70–2.04% was obtained when sand was replaced with plastic powder in the range of 10–50%, while without the addition of plastic, the water absorption capacity was found to be 17.7% [29]. Awoyera et al. (2021) reported that paving blocks without plastic fiber addition after curing for 28 days had a water absorption of 16.48%, while paving blocks with the plastic fiber content of 0.5%, 1.0%, 1.5%, and 2.0% showed water absorption of 7.53%, 9.06%, 11.31%, and 11.76%, respectively [30].

### *Compressive strength and water absorption with different content of silica-rich recycled materials*

To evaluate the effect of cement replacement with silica-rich recycled material (rice husk ash and glass powder) on the compressive strength and water absorption of precast concrete wall panels, the test specimens for one unit were made with a composition of sand, plastic powder, and cement of 120, 30, and 50 g, respectively, with a water-to-binder weight ratio of 1.2. Then, the cement was gradually substituted in a range of 5% to 20% with silica-rich recycled materials. The mixture was molded in a cube-shaped mold with dimensions of 50 × 50 × 50 cm, and the results of the compressive strength and water absorption measurements are presented in Figure 6 and Figure 7.

Figure 6 shows the increase in compressive strength of concrete wall panels when the use of rice husk ash and glass powder is increased to 10% as a partial replacement of cement. However, the addition of these recycled materials above 10% causes a decrease in compressive strength. Replacing cement with 5% and 10% rice husk ash resulted in an increase in compressive strength of 7.10% and 10.75%, respectively, compared to concrete wall panels without rice husk ash, while replacing it with glass powder with the same proportion resulted in an increase of 10.11% and 16.13%, respectively. The addition of silica at a replacement level of 10% resulted in an increase in compressive strength of 10–16% after 28 days of drying at room temperature. However, the addition of this silica-rich recycled material above 10% causes the compressive strength to decrease. Similar findings were also obtained by Alishah and Razaei, (2020), who reported that the maximum addition of 8% pozzolanic material

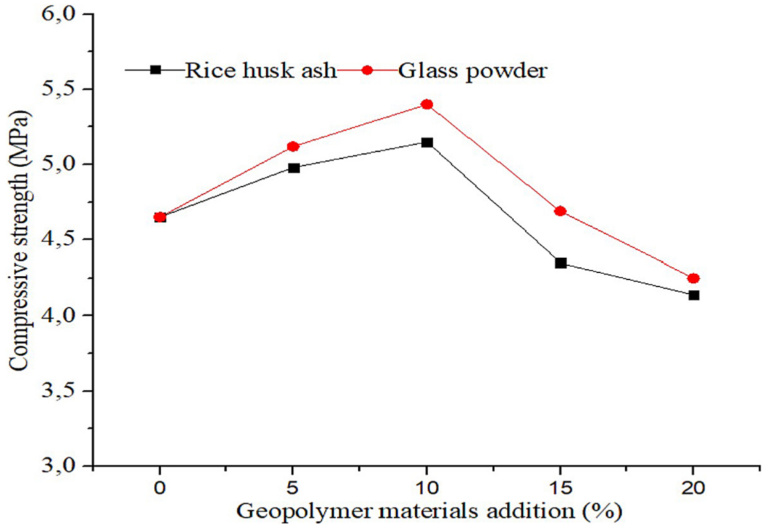


**Figure 6.** Compressive strength of concrete wall panels as a function of partial replacement of cement with silica-rich recycled materials

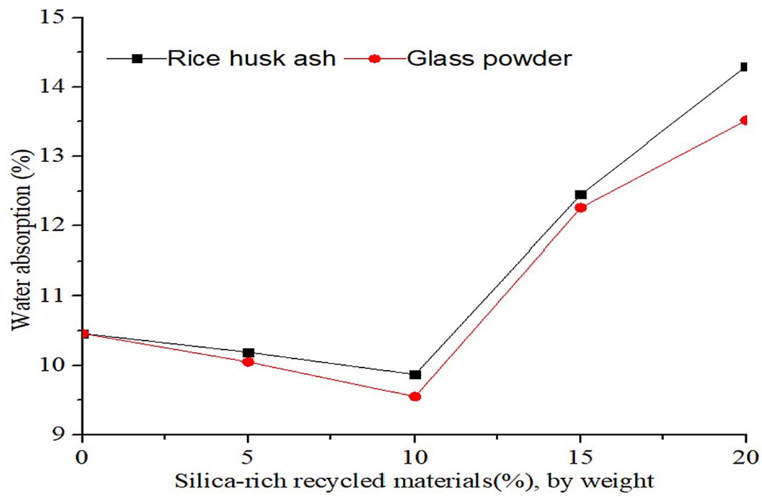


**Figure 7.** Water absorption of concrete wall panels composed with 20% plastic powder and different addition of silica-rich recycled materials

was able to increase the compressive strength of concrete, and there was a decrease in compressive strength with continued addition [31]. In the research of Aakash et al. (2024), it was found that when the addition of silica reached 14% in concrete, the compressive strength of the concrete increased from 8 MPa to 14.22 MPa. However, when the silica was increased to 17%, there was a drastic decrease in compressive strength, reaching a value of 10 MPa [32]. The previous study by Valipour et al. (2013) and Mohseni et al. (2017) reported that the concrete with 10% zeolite showed respectable mechanical performance and durability characteristics [33,34]. The increase in compressive strength with the addition of silica-containing materials is associated with its property as a pozzolan, where silica or a combination of silica and alumina has cementitious properties when made into fine powder and mixed with a little water [35]. The chemical reaction between silica and calcium hydroxide in the presence of a small amount of water resulting Calcium Silicate Hydrate (C-S-H) gel formation [36].

$$Ca(OH)_2 + H_2O \rightarrow Ca^{2+} + 2OH^- \quad (5)$$

$$3Ca^{2+} + 6OH^- + 2SiO_2 \rightarrow 3CaO\cdot 2SiO_2\cdot 3H_2O \quad (6)$$

Water absorption is a critical factor in evaluating the durability of concrete. In general, concrete with low water absorption has better durability compared to concrete with high water absorption. It was clearly seen in Figure 7 that the water absorption of the concrete wall panel test object decreases when silica-rich recycled materials are added up to 10% as a cement substitute, but when the cement replacement is greater than 10% by silica-recycled materials, the water absorption capacity increases.

Precast concrete wall panels without a silica-rich material content absorb 10.46% of water. However, the water absorption becomes 10.19%, 9.87%, 12.45%, and 14.30% when 5%, 10%, 15%, and 20% of rice husk ash are added to the mixture in partial replacement of cement. While the water absorption is 10.05%, 9.55%, 12.25%, and 13.52% when glass powder is used to cement partial replacement. This finding is in accordance with the research results of Amin et al. (2023), which stated that the addition of glass powder as a substitute for cement up to a level of 10% can reduce the water absorption of concrete from 6.53% to 4.95%, but cement replacement of 12.5% and 15.0% increased the water absorption to 5.87% and 6.55% [37]. The reduction in water absorption capacity with the increase in silica-rich material content at certain levels can be ascribed to its characteristics as a pozzolan, which fills the voids between the aggregate and cement paste [38].

*Compressive strength and water absorption with different water-to-binder ratio*

The water-to-binder weight ratio is a crucial factor in the production of concrete due to its influence on the porosity, which in turn determines the strength and durability. In the evaluation of compressive strength and water absorption, it was made using a mixture of 3 parts sand and 1 part cement, where 20% of the sand was replaced by plastic powder while 10% of the cement was replaced by silica-rich material (rice husk ash and glass powder). The composition was formulated with differing weight ratios of water to cement and cast in a cubic mold of 50 × 50 × 50 cm. The compressive strength and water absorption of the test specimens at various ratios of water to cement are presented in Figure 8 and Figure 9.

Figure 8 illustrates how the test specimens' compressive strength decreased as the water-to-cement ratio increased. The compressive strengths at water-to-cement ratios of 1.2, 1.4, 1.4, 1.8, 2.0, and 2.2, in order, were 5.15, 5.05, 4.85, 4.74, 4.15, and 3.83 MPa. The same trend in strength was also found in the study of Dehghan et al. (2019), where concrete made from lime, cement, and fine sand with variations in the water-to-cement ratio of 1.8, 2.0, and 2.15 produced concrete compressive strengths of around 3.1, 2.7, and 2.0 MPa, respectively [39]. The addition of water to the concrete wall panel mixture is intended to facilitate the mixing of aggregate and cement so that the concrete is easier to pour. The mixture may become less workable if the water-to-binder ratio is either low or too high. The reassessment of the test specimen revealed that wall panels with a water-to-binder weight ratio between 1.2 and 2.0 had a compressive strength of 5.15–4.15, continuing to meet ASTM C129-06's minimum requirements of 4.14 MPa for average three-unit testing.

The percentage of water absorption in concrete wall panels is influenced by the water-to-binder weight ratio employed in their manufacture. Figure 9 demonstrates that increasing the water-to-binder ratio during concrete manufacture resulted in an increase in the percentage of water absorption. For the non-structural concrete wall panel specimen, 20% sand was substituted with rice husk ash, and water was added in amounts of

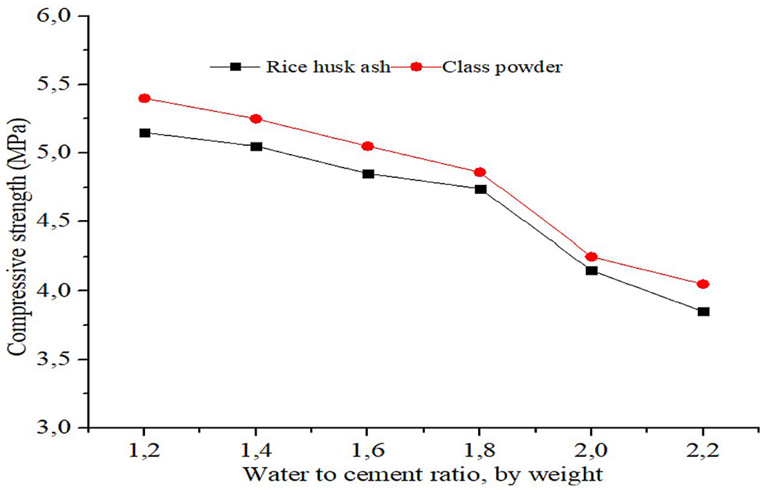


**Figure 8.** Compressive strength of concrete wall panels specimen with different water-to-binder weight ratios

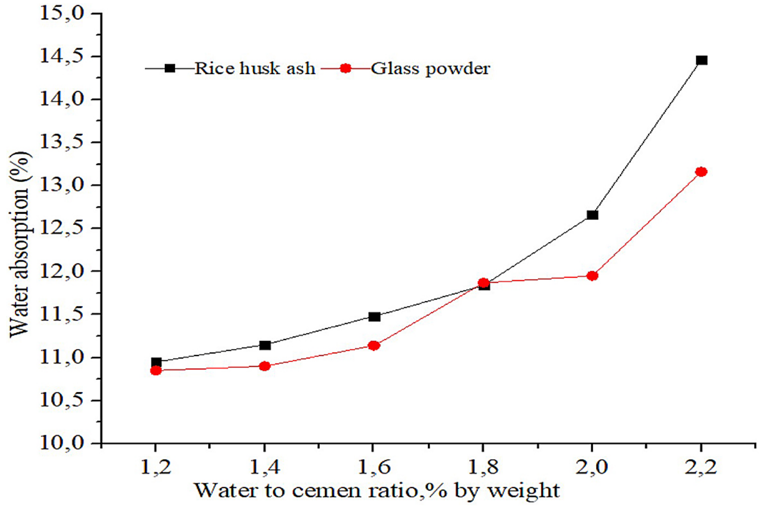


**Figure 9.** Water absorption of concrete wall panel specimens with different water-to-binder weight ratios

1.2, 1.4, 1.6, 1.8, 2.0, and 2.2 to cement weight. After 28 days of curing, the water absorption was 10.95%, 11.15%, 11.48%, 11.86%, 12.69%, and 14.46%. In contrast, water absorption in the same formulation with a partial substitution of cement with glass powder was obtained at 10.85%, 10.90%, 11.14%, 11.7%, 11.95%, and 12.83%, respectively. This result is consistent with the study by Ali et al. (2018), who discovered that after 28 days of curing, the concrete specimen made with water-to-cement ratios of 0.35, 0.40, 0.45, and 0.5 had water absorption in the range of 10.33%, 5.32%, 4.18%, 2.17%, and 1.9% [40].

The increase in water absorption, along with the increase in the water-to-binder weight ratio, can be attributed to the increase in air content in the concrete, which triggers the formation of voids and results in an increase in the water absorption capacity [41].

*Resistance from sulfate attack*

The resistance of precast concrete wall panels to sulfate attack was assessed using weight changes and compressive strength after being given 6000 mg/L sodium sulfate ($Na_2SO_4$) solution for 28 days. Changes in weight and compressive strength of the specimen prepared with material mixtures consisting of 120 g sand, 30 g plastic powder, 45 g cement, and 5 g rice husk ash or glass powder with a water-to-binder ratio of 1.6 exposed to sulfate solution are presented in Figure 10.

Figure 10 illustrates the percentage change in weight of concrete wall panel specimens after being immersed in 6000 mg/L sulfate solution for 7, 14, 21, and 28 days. The percentage changes in weight are 0.05%, 0.15%, 0.19%, and 0.24% for specimens added with rice husk ash, while the percentage weight changes are 0.18%, 0.33%,

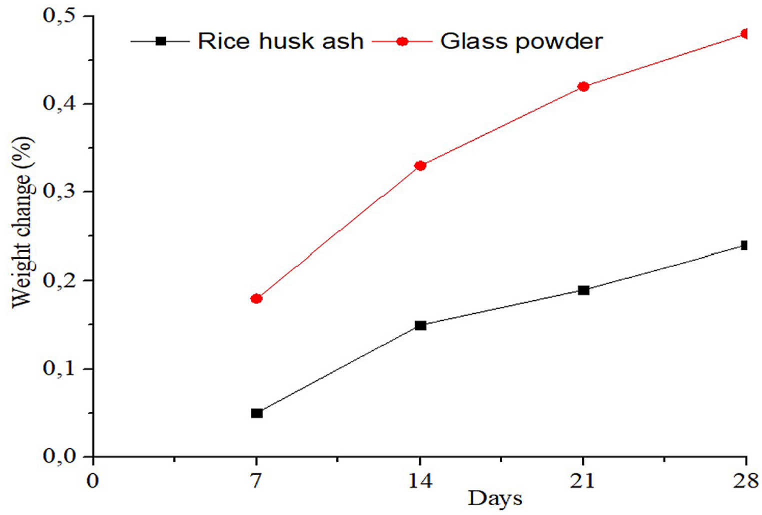


**Figure 10.** Weight change of concrete wall panels specimen during treatment with sulfate

0.42%, and 0.48% for specimens containing 10% glass powder. After being soaked for 28 days in sulfate solution, the specimen with added rice husk ash had a compressive strength of 4.28 MPa, while the specimen containing glass powder had a compressive strength of 5.05 MPa.

Numerous prior investigations indicated that concrete samples affected by sulfate exhibited a reduction in compressive strength following several months of exposure. Han and Li. (2024) reported that the strength of the concrete attacked by sulfate slightly increases at the initial stage and then decreases after extending the contact time in the sulfate solution [42]. In addition, ettringite can be created by adding $Na_2SO_4$, and its inclusion can enhance strength early age strength of concrete [43,44]. Decrease in strength of concrete after longer immersion with sulfate may be due to the reaction of sulfate ions and calcium hydroxide produced during cement hydration results in the formation of gypsum. The reaction of sulfate ions and cement hydrates is as follows [45].

$$Ca(OH)_2 + Na_2SO4 \rightarrow CaSO_4 + NaOH \text{ gypsum} \quad (8)$$

*Resistance from acid attack*

The change in weight and load compression of concrete wall panel test specimens consist of 120 g sand, 30 g plastic powder, 45 g cement, and 5 g rice husk ash or glass powder with a water-to-binder ratio of 1.6 after aged 28 days. The percent change in weight of concrete wall panel specimens after 7, 14, 21, and 28 days of immersion in hydrochloric acid at pH 4 is presented in Figure 11.

Immersion in hydrochloric acid with a concentration of $1.0 \times 10^{-4}$ M for 7, 14, 21, and 28

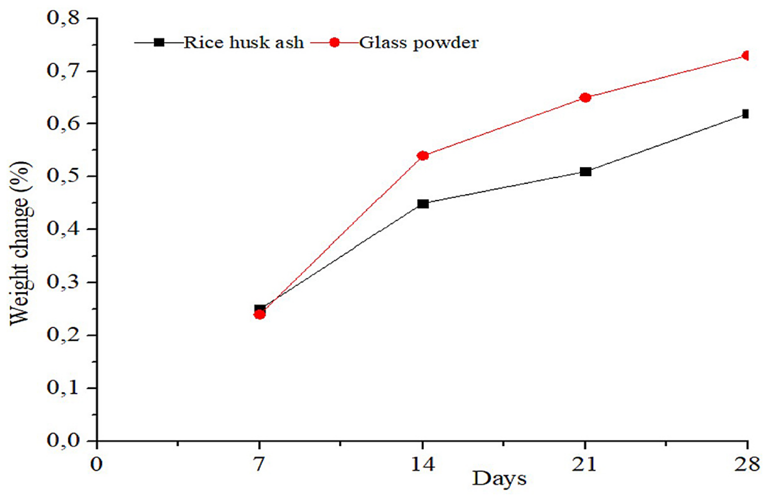


**Figure 11.** Weight change of concrete wall panels specimen during treatment with hydrochloric acid

days for wall panel test specimens containing 10% rice husk ash showed weight percentage changes of 0.25%, 0.45%, 0.51%, and 0.73%, while concrete wall panels containing 10% glass powder showed weight percentage changes of 0.24%, 0.54%, 0.64%, and 0.73%, respectively. In addition, it was observed that there was a decrease in compressive strength from 4.5 MPa to 4.20 MPa for wall panels containing 10% rice husk ash and from 5.05 MPa to 4.35 MPa after being soaked in a $1.0 \times 10^{-4}$ M hydrochloric acid solution. This finding is in line with Hosseini et al. (2023), who reported that there was a decrease in the compressive strength of concrete by 3% when soaked in 2% HCl solution for 28 days [46]. The concrete wall panels damage in acid environment due to the dissolution of the cement paste matrix due to the reaction between the acid and hydrated and unhydrated cement to produce calcium chloride ($CaCl_2$) which is able to stay on exposed surface of hardened cement [47].

## CONCLUSIONS

A study was conducted to evaluate the physical properties of precast lightweight concrete wall panels with the addition of plastic powder and household ash as a partial replacement of sand and cement. The physical properties of precast lightweight concrete wall panels were greatly influenced by the percentage of plastic and household ash addition. The water absorption, and compressive strength of concrete wall panels with 20% plastic and 10% silica-rich recycled materials were 10.14–10.48 %, and 4.85–5.06 MPa, respectively. The precast lightweight concrete wall panels met the requirements of precast concrete wall panels, according to ASTM-C129-06. Utilization of plastic waste and silica-rich recycled materials such as rice husk ash and glass powder for concrete production contributes to waste reduction and resource conservation.

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