The Study of Compressive Strength of Wall Panels with a Mixture of Used Tire Rubber Waste and GRC

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Abstract. The utilization of used tire rubber waste, particularly in the construction industry, becomes a critical issue in Indonesia due to its abundant presence and the challenges related to waste disposal. One solution to repurpose used tire rubber waste into a valuable resource, especially in the construction sector, is the substitution of one of the composition elements in wall panels. The panel composition which is researched consists of water, cement, fine aggregates, with the used tire rubber waste constituting 40% of the fine aggregates.
The purpose of this research is to assess the vertical compressive strength with the addition of GRC (Glass Reinforced Concrete) layer to wall panels. Test specimens are 150 mm x 150 mm cubes and wall panels with dimensions of 50 mm in thickness, 400 mm in width, and 800 mm in length for vertical compressive strength testing. The result of this study is a compressive strength of 82.18 Kg/cm^2 for the cube specimens, while the vertical compressive strength of wall panels with a mixture of used tire rubber fiber mortar is 5.02 MPa. Furthermore, the addition of GRC significantly increases the vertical compressive strength of wall panels to 6.46 MPa.

Keywords: Used Tire Rubber Waste, Wall Panels, GRC

1 Introduction

The growth in the number of four-wheeled vehicles indicates the strengthening of the automotive industry's performance and the purchasing power of the public. This growth also has an impact on the increased demand for tire production in Indonesia. Conversely, the extensive use of tires domestically results in a significant number of used tires produced by these vehicles. The accumulation of used tires is causing them to be underutilized and become difficult-to-manage waste.O ne of the largest contributors to industrial waste is waste from used vehicle tires [4].

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Rubber tires are a type of synthetic polystyrene polymer. Polystyrene is not easily recyclable, so polystyrene waste should be properly managed to prevent environmental damage. The utilization of used rubber tires in Indonesia is still limited compared to the volume of rubber tire waste. Therefore, there is a need for recycling rubber tire waste in civil engineering, as it is considered an ecological and economical solution due to the benefits it offers. One of the uses of recycled used rubber tires in civil engineering is their incorporation into panel wall mixtures.

Wall Panels are one of the non-structural components of a construction building. It is made of mortar material, which consists of cement and sand mixed with additives to make it lighter. The additive used is recycled crushed rubber tire fibers to make it easier to incorporate into it. Research on these panels can reduce solid waste as an aggregate in panel materials and also provides an environmentally friendly solution as it involves recycling used tires and replacing some natural aggregates, thus preserving natural resources.

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1.1 Wall Panel Mixture

1.1.1 Wall Panel

Wall panels are one of the non-structural components of a construction building. These panels are made from mortar material, consisting of cement and sand, mixed with additives to make them lighter. Typically, wall panels in the market weigh about 1/5 of normal concrete and have a homogenous structure (without vertical and horizontal cavities). Wall panels can also reduce the risk of earthquakes [3].

1.1.2 Types of Material for Wall Panel

a. Cement

Cement is an important binding material widely used in physical construction in the civil construction sector. When mixed with water, cement will become cement paste [6].

b. Fine Aggregate

Fine aggregate is aggregate with small grains measuring less than 5 mm. The selection of fine aggregate must meet the specified requirements, as it significantly influences the workability, strength, and durability of the resulting concrete. Sand, as a component of mortar along with cement and water, plays a role in binding the coarse aggregate into a strong and dense unit [6].

c. Water

Water is the most important and cost-effective basic component of concrete. It serves as a binding material (for hydrating the cement) and as a lubricant between aggregate

particles to facilitate the mixing of aggregate and cement, making the concrete easier to pour (workability). Excessive water usage can lead to a reduction in concrete strength. Besides being a component of the concrete mixture, water is also used to cure concrete by wetting it after pouring [6].

d. Rubber

Rubber is an essential material in the field of engineering. All tire industries require rubber, and other modes of transportation that use tires also rely on rubber. Used tire rubber is used in the form of shreds and powder, and it is mixed into mortar or concrete as a substitute for sand. Adding used tire rubber shreds to mortar mixtures results in a reduction in mortar strength, but it increases ductility and the ability to dampen vibration energy (damping) [2].

1.1.3 Glass Reinforced Concrete (GRC)

GRC is a combination of two materials with different characteristics. It has high compressive strength, but it is weak in terms of flexural strength, which is a characteristic of the hardened cement-sand mixture. On the other hand, glass fibers have good flexural strength. The combination of these two materials creates a composite material that combines the properties of both cement-sand or concrete and glass fibers, whether it's strength in compression, flexure, or shear [1].

2. Methodology

2.1 Study of Literature

The literature review is a critical first step in research as it provides a solid foundation of knowledge and ensure that the research has a robust base. It also helps researches avoid duplicating previous studies and contributes to the advancement of knowledge.

2.2 Preparation of Equipment and Materials

In the research, material and equipment were prepared for all testing and research activities. The materials and equipment that had been readied were expected to yield optimal result in this study.

2.3 Setting and Materials

The research carried out an examination of the material for the mixture on the panel. As for materials that were examined include rubber tire powder, cement, fine aggregate and water (See Table 1).

Table 1. Spesific Gravity of Material

No	Materials	Specific Gravity
1	Rubber tire powder	1.12
2	Cement	3.15
3	Fine Aggregate	2.51
4	Water	1

2.4 Manufacture of Test Specimen

The wall panel test objects with a thickness of 5 cm, a width of 40 cm, and a length of 80 cm were used for testing vertical compressive strength [5], and there were 6 pieces in total. In this research, the compressive strength of the mortar was also tested, and three cubes were used for this purpose.

2.5 Compressive Strength Test

The compressive strength of mortar involved the creation of test specimen in the form of cubes or cylinders from the mixed mortar that had been blended and bonded in a specific manner. Thes test specimens were then subjected to increasing pressure until they reached the point of cracking or breaking. The measurement result were expressed in pressure units, such as megapascals (MPa).
The compressive strength of a material can be calculated using the following formula:

$$fc = \frac{P}{A} \tag{1}$$

In this formula:

- fc = Compressive Strength (MPa)
- P = Maximum Load (Newtons)
- A = Surface Area (mm^2)

Compressive strength testing is typically conducted in a laboratory or material testing environment using appropriate equipment. The results of these measurements are essential for evaluating a material's ability to withstand vertical pressure in various construction applications.

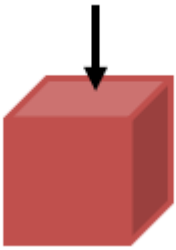

Figure 1. Cube Compressive Strength Testing

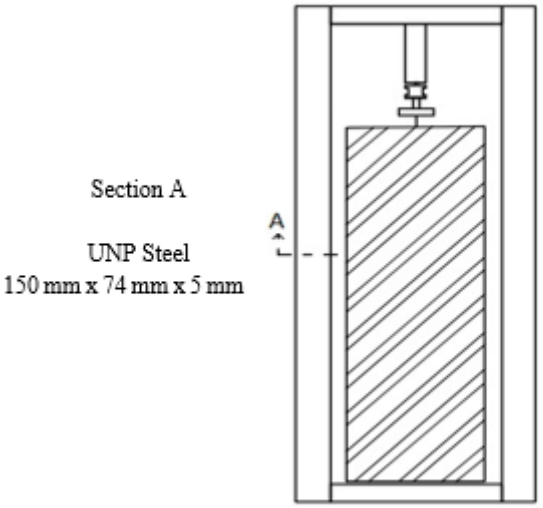

Figure 2. Wall Panel Vertical Strength Testing

3. Result and Discussion

3.1 Wall Panel Compression Testing Machine

The compression strength testing machine was an instrument used to measure the resistance of a material to compressive forces. This machine was equipped with load cell as a pressure measurement sensor applied the concrete being tested.
The frame used for the testing was made of UNP 150mm x 74mm x 5mm material . UNP represents the shape of the steel (Fig 3). The frame was a component that played a significant role in the compression strength testing as it functioned as the structure that supported the loas applied by the test specimen. The analysis of the frame with load cell indicated a deflection of 0.714 mm. However during the compression strength test, the result showed that frame did not undergo any deformation. This indicated that the UNP 150mm x 74mm x 5mm . Frame was capable of withstanding the pressure effectively.

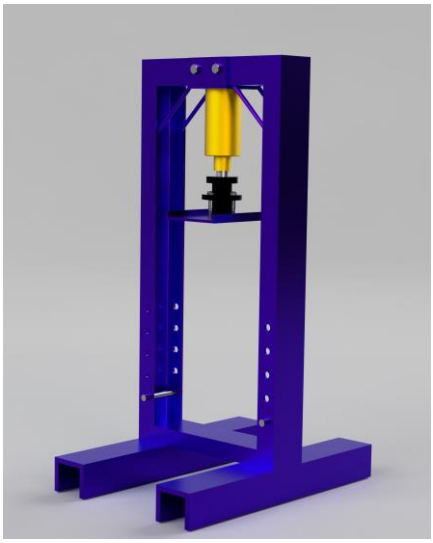

Figure 3. Vertical Load-Bearing Frame

3.2 Cube Compressive Strength Testing

Cube compressive strength testing was carried out to determine the strength parameters of a rubber mixture mortar with a content of 40% (Fig 4). This test can provide information on how strong the mortar is to the load that is applied safely. This cube compressive strength can be used as a reference in planning and calculating wall components. The test results showed an average compressive strength of the cube of 82.18 Kg/cm^2 (See Table 2).

Figure 4. Cube Compressive Strength Testing

Table 2. Results of The Compressive Strength Test on Cubes

No	Test Specimen Code	Maximum Load (kN)	Compres-sive Strength (Kg/cm^2)
1	PK1-KB	179	81.12
2	PK2-KB	176	79.76
3	PK3-KB	189	85.65
Average			**82.18**

3.3 Wall Panel Vertical Strength Testing

Testing the compressive strength of wall panels is an important procedure to ensure that the panels can withstand vertical loads (Fig 6), whether it be the weight of the panel itself or additional vertical loads experienced in construction . This testing is conducted to assess the safety of wall panels in various applications, including as walls, partitions, or facades. In this testing, there are two variations: wall panels made from recycled rubber tires and wall panels made from recycled rubber tires with the addition of GRC (Glass Reinforced Concrete). The results of the testing for wall panels made from re-cycled rubber tires showed an average compressive strength of 5.02 MPa. Meanwhile, the wall panels made from recycled rubber tires with the addition of GRC had an aver-age compressive strength of 6.46 MPa (See Table 3). Six panels were tested, and they were able to withstand a load of 130 kN, which occurred in the PKGT1 test specimen. Therefore, the compressive strength result for the PKGT1 test specimen was 6.52 MPa (Fig 5). The comparison between the wall panel variations shows that the addition of GRC significantly increases the compressive strength compared to panels without GRC. The addition of GRC enhances the ability of wall panels to withstand vertical loads.

Table 3. Results of Vertical Compressive Strength Testing on Panel Walls

No	Test specimen code	Wall Panel Variations (mm)	Maximum Load(kN)	Compressive Strength (MPa)	Average Compres-sive Strength (MPa)
1	PKT1	Rubber tire powder	95.70	4.79	5.02
2	PKT2		103.50	5.18	
3	PKT3		102.00	5.10	
4	PKGT1	Rubber tire powder + GRC	130.30	6.52	6.46
5	PKGT2		129.60	6.48	
6	PKGT3		127.60	6.38	

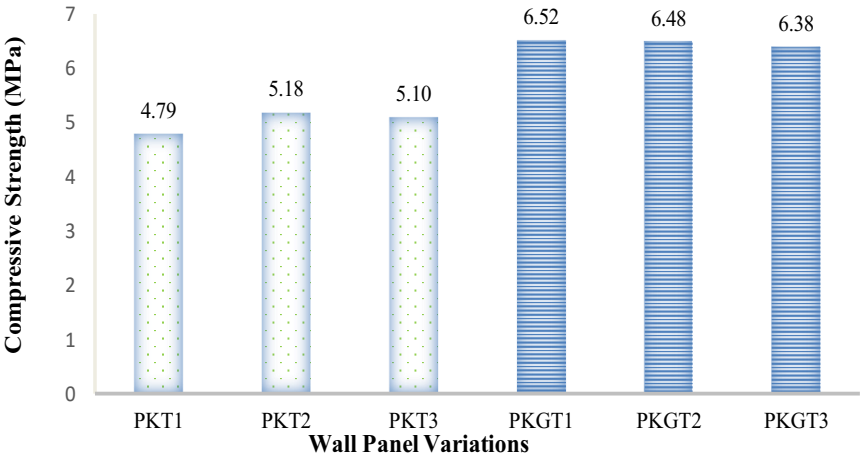

Figure 5. Vertical Compressive Strength of Wall Panels

The damage pattern observed in the wall panel without GRC (Fig 7) is quite similar to the damage pattern in the wall panel with GRC (Fig 8). In both cases, cracks occur at the top when subjected to pressure or load.

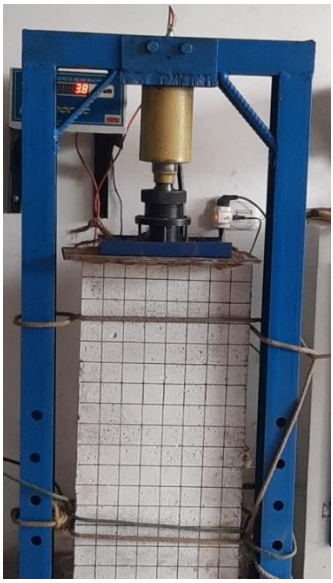

Figure 6. Wall Panel Vertical Strength Testing

3.4 Test Specimen Damage Pattern

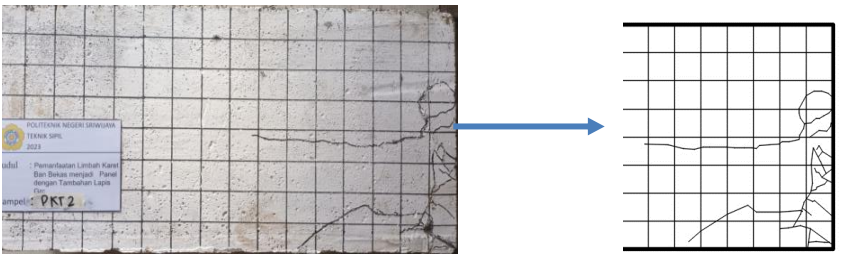

Figure 7. PKT2 Test Object Damage Pattern

Figure 8. PKGT1 Test Object Damage Pattern

4. Conclusion

The vertical compressive strength obtained between wall panels without GRC and wall panels using GRC shows that the addition of GRC provides an increase in the vertical compressive strength of the wall panels. Therefore the addition of GRC mixed with used tire rubber can be used for progress in the field of sustainable construction.

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