EXPERIMENTAL TEST OF COMPRESSIVE STRENGTH OF CONCRETE WITH SUBSTITUTION OF WASTE TYRE RUBBER POWDER 0%, 30%, 60% AS A SUBSTITUTE FOR FINE AGGREGATE

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Abstract
The disposal of rubber tires is one of the impacts resulting from the development of activities in the transportation sector. The accumulation of tire waste occurs along with the increase in the number of vehicle owners in society. This study aims to test the compressive strength of concrete with a mixture of rubber powder waste to reduce environmental pollution. The method used is the experimental method in the laboratory with concrete cylinder test specimens measuring 150 mm in diameter and 300 mm in height. The proportion of the rubber powder waste mixture to the fine aggregate was 0%, 30%, and 60%, consisting of three cylindrical test specimens for each variation. The test results show compressive strength values of 26.8 MPa, 19.6 MPa, and 13.1 MPa at rubber powder mixture percentages of 0%, 30%, and 60%. From the data, it can be concluded that rubber powder can be used as a partial substitute for sand in concrete material. The use of rubber powder in concrete reduces the compressive strength of the concrete.

Keywords: *rubber crumb concrete, compressive concrete*

Introduction

The development of infrastructure facilities in Indonesia today has grown very rapidly. Infrastructure development that occurs is marked by infrastructure development in various fields, one of which is the development of transportation infrastructure (Husen and Baran yanan, 2021). Transportation has become a fundamental need that is currently inseparable in community life. The lifestyle of modern society has led to an increase in the number of vehicles. Ownership of a vehicle in one family is one of the things that is mandatory to meet various kinds of mobility needs, especially in order to meet economic needs. The increasing economic growth of the community is in line with the increase in the number of vehicles in Indonesia (Kaban and Kusumastuti, 2019). Every vehicle that operates must be replaced by tire rubber between two to three years as a safety factor in driving (Faizah et al., 2020). Tire changes in motor vehicles cause a buildup of waste tires.

In developing countries like Indonesia, waste tire rubber is a problem that is often encountered. Waste tire rubber contains material that is harmful to the environment because it is difficult to decompose (Susanti, 2013). Disposal of waste tire rubber in landfills will be a serious problem because the size of tire rubber that is large enough can fill the space of the disposal site. Waste tire rubber treatment must be pursued in order to reduce the amount of waste waste in Indonesia.

Waste tires can be recycled into materials that have high selling value, such as recycling waste into various kinds of crafts, for example shoes, bags, sandals, and so on. Besides being able to be used as processed crafts, waste tires can be processed as a mixture of materials in the construction sector (Kusumastuti et al, 2020). In the world of construction, waste tires can be used as an alternative to building materials. One of the efforts to utilize waste tires is as a substitute for coarse aggregate and fine aggregate in concrete (Saputri, 2019). Waste tires need to be processed into rubber powder first before being used as an added material to replace fine aggregate in concrete. Experimental research on making concrete using rubber powder as a partial substitute for fine aggregate needs to be carried out to determine the effect on compressive strength. This research is expected to be a solution for the utilization of rubber powder waste in the construction sector, especially as a partial replacement material for fine aggregate that can be developed for normal concrete manufacturing. Normal concrete is a type of concrete with a unit weight of 2,200-2500 kg/m3 (SNI 03-2847-2020). Structural concrete is a type of concrete that is able to bear the load of a structure, and also usually in the casting process accompanied by repeating. The function of this structural concrete is for foundation casting, ring beams, columns, and so on. Low quality concrete is concrete that has compressive strength between 10-20 MPa (General Specifications of Highways Division 7 Year 2018).

Several studies have been conducted to utilize waste tires as a concrete mix material. Research on the substitution of fine aggregates in concrete materials has been conducted with several variations, such as rubber crumb paving block (Soebandono, 2024), rubber crumb concrete with the substitution of natural zeolite in coarse aggregates at 5%, 10%, and 15% (Jokar et al., 2019), the use of rubber powder waste in geopolymer concrete (Aly et al., 2019) , the addition of silica fume in concrete with rubber waste (Xue & Shinozuka, 2013), rubber crumb concrete using Self-Compacting Concrete and Polypropylene fibers (Yang et al., 2019), rubber crumb concrete using Polypropylene fibers (Alizadeh et al., 2024) and the flexural strength of concrete with rubber powder waste (Ismail & Hassan, 2017; Jokar et al., 2019; Mahendra et al., 2024). Substitution of fine aggregate by 0.5%, 0.75%, and 1% (Kurnia et al. 2019), substitution of fine aggregate by 2.5%, 5%, and 75% (binti Salehuddin et al., 2015), substitution of fine and coarse aggregate by 10%, 20%, 30%, and 40% (Aslani & Khan, 2019). The use of waste tire rubber powder with a substitution percentage of rubber powder in fine aggregate of 0%, 5%, 10%, and 15% (Nugroho et al, 2022). Research utilizing rubber powder at 0%, 30%, and 60% in concrete has not yet been conducted. The aim of this research is to enhance the use of waste tire rubber powder as a substitute for fine aggregate at 0%, 30%, and 60%.

Method

The research methodology used in this study is experimental testing in the laboratory. The manufacture of concrete test specimens starts from the material inspection of fine aggregate, coarse aggregate and waste tire powder. After the material data is obtained, it is continued with concrete mix design, fresh concrete slump testing, test specimen manufacturing, maintenance and concrete compressive testing.

1. Research location.

The location of the research was carried out in the structural laboratory of the University of Muhammadiyah Yogyakarta.

2. Research Stages

a. Material testing

The materials used are cement, sand, gravel and waste tire rubber powder. Material testing carried out includes, gradation test of fine aggregate granules, coarse aggregate assessment and specific gravity test of waste tire rubber powder. Details of the materials used in the study can be seen in Figure 1 to Figure 4.

Figure 1 Cement

Figure 2.Fine aggregate

Figure 3. Coarse aggregate

Figure 4. Waste tire rubber powder

b. Mix design of concrete.

Method of determining the mixture of materials in making concrete using SNI 7656: 2012. The results of the design mix are needed to determine the amount of mixture needed in one concrete mortar. The calculation of the design mix uses the proportions of 0%, 30%, and 60% as sand substitutions.

c. Slump Test.

Slump testing is carried out using abrams cones and refers to the standard of SNI 7656: 2012. Slump testing aims to measure the degree of abrasion in the concrete mixture before it is printed on the specimen mold. The test details of fresh concrete slump can be seen in Figure 5.

Figure 5. Concrete slump test

d. Manufacture of test specimens.

Making concrete compressive strength test specimens using cylindrical molds with a size of 15 cm x 30 cm with 3 samples each in each variation of mix design 0%, 30%, and 60% which was shown in Figure 6.

Figure 6. Concrete cylindrical test specimens

e. Test specimen maintenance

Specimen curing is carried out after demolding and soaking in water for 28 days.The concrete cylinder test specimens can be seen in Figure 7.

Figure 7. Concrete cylinder test specimen treatment

f. Compressive strength testing

According to SNI 1974:2011 Compressive strength testing on concrete is carried out at the age of 28 days using a compressive test equipment (*Concrete Compression Tester Machine*. Standard calculation of compressive strength of concrete using SNI 1974: 2011, the formula used can be seen in Equation 1:

Compressive strength of concrete = $\frac{P}{A}$ (1)

Where:

fc' = Compressive strength of concrete expressed in (MPa).

P = Axial compressive force expressed in (N)

A = The cross-sectional area of the test specimen is expressed (mm^2)

Result and Discussion

The test results that have been carried out on material testing and testing of concrete cylinder test specimens are as follows:

1. Fine aggregate testing

a)Sludge content testing.

Testing mud content in sand aims to check the sand is clean or dirty. The average yield of sludge content obtained was 2.67%. The maximum mud content in the allowed sand is 5% (SNI: 04-1989), thus it can be concluded that the type of sand used has met the requirements.

b). The gradation of fine aggregates.

The results of the gradation test of fine aggregate grains used in the study can be seen in Figure 8.

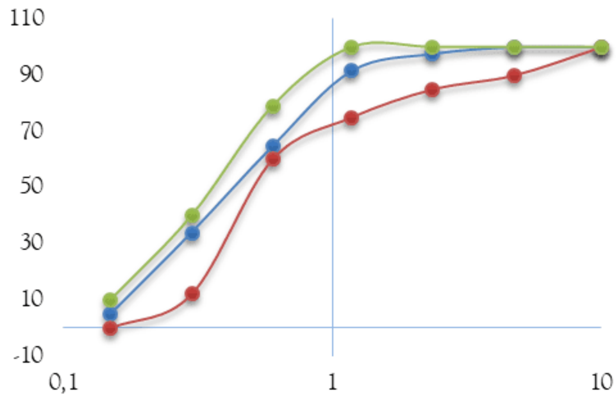

Figure 8. Fine aggregate grain gradation graph

From Figure 8 it can be seen that the MHB obtained is 2.08. The gradation of the sand grains is included in area number 3. MHB grades meet ASTM C136-2014 specifications with a value range of 1.5 to 3.8, thus it can be concluded that the type of sand used meets the requirements of ASTM C136-2014.

2. Coarse aggregate testing

a). Specific gravity and water absorption testing.

The average specific gravity of bulk obtained was 2.58, the average dry specific gravity of the face was 2.65, the average specific gravity of the apparent was 2.63, and the average water absorption was 0.77. Based on SNI 1969: 2008 regulations, the specific gravity of SSD condition gravel that can be used in concrete mixture is in the range of 2.5-2.7, thus the type of coarse aggregate used meets the requirements of SNI 1969: 2008.

b). Wear testing of coarse aggregates.

The average yield of the wear rate obtained is 32%. The wear rate that is considered to meet SNI 2417:2008 specifications is less than 40%, Wear testing aims to determine the level of gravel resistance to destruction. With test results of 32%, it can be concluded that the type of gravel used meets the requirements of SNI: 2417-2008.

3 Mix concrete design

The results of the planning mix design of test specimens per requirement of 1 m^3 was shown in Table 1.

Table 1. mix design of concrete

Rubber Content	Water (kg)	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Rubber powder (kg)
0%	139.8	459.5	760.9	1029.8	0.0
30%	139.8	459.5	722.8	1029.8	14.2
60%	139.8	459.5	646.8	1029.8	42.6

4. Concrete *slump* testing

The test results of fresh concrete *slump* on each test specimen was shown in Table 2.

Table 2. Result of slump test

Rubber Powder	*slump* (cm)
0%	8
30%	8.7
60%	9.2

From Table 2 it can be seen that the *slump* value obtained shows increasing results along with the increasing proportion of rubber in concrete. The increase in slump value is caused because rubber powder has properties that are difficult to absorb water, so that the concrete mixture is increasingly thin and reduces friction between materials which results in an increased *slump* value. According to SNI 7656: 2012, *slump* test results can be used for construction types of beams, columns and reinforced walls of buildings, which are in the range of 25 to 100 mm.

5. Concrete compressive strength testing

The results of the average compressive strength test of concrete cylinder specimens at the age of 28 days are shown in Figure 8.

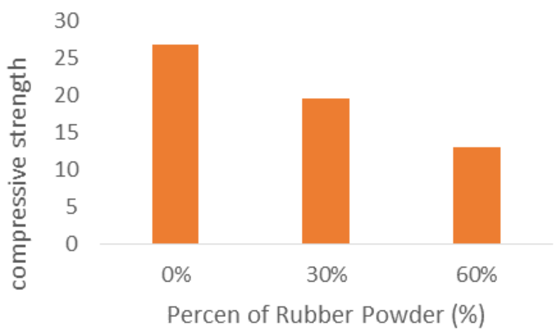

Figure 9. Concrete compressive strength chart

From Figure 9 it can be seen that the compressive strength test results of concrete with a mixture of waste tire rubber powder of 0%, 30% and 60% have values of 26.8MPa, 19.6MPa and 13.1 MPa. The type of damage that occurs in the concrete test object with a 0% rubber powder mix percentage is brittle, characterized by cracks in certain areas with sudden collapse. The addition of tire rubber powder to the concrete mix can reduce the compressive strength (Faizah et al., 2020). The type of concrete damage with a percentage of rubber mixture of 30% and 60% is *ductile* which is characterized by the presence of fine cracks on the entire concrete surface before the collapse of the test object. Concrete with the addition of rubber is able to prevent sudden destruction when concrete is applied pressure.

The value of reducing the compressive strength of concrete that occurs in test specimens with a percentage of rubber powder mixture of 30% and 60% against concrete with a rubber content of 0% is 36.78% and 51.3%. This decrease in compressive strength value occurs due to a decrease in the quality of bonding between concrete components. This is because the powder has the property of tending to be difficult to absorb water so that it reduces the adhesion between concrete materials, so that the compressive strength of concrete decreases along with the addition of the percentage of rubber mixture in concrete. Based on the General Specification of Highways Division 7 of 2018, concrete has criteria, quality and use respectively according to the compressive strength produced, the criteria for the use of concrete can be seen in Table 3.

Table 3. Quality and Use of Concrete

Types of Concrete	fc' (MPa)	Use
High quality	x ≥ 45	Prestressed concrete, prestressed piles, prestressed concrete slabs, and other types of prestressed concrete.
Medium quality	20 ≤ x < 45	Precast concrete kereb, reinforced concrete girder, building under bridge, and other types of reinforced concrete.
Low quality	15 ≤ x < 20	Pavements, cyclope concrete, masonry, and other non-reinforcing concrete structures.
	10 ≤ x < 15	Backfilling and floor work using concrete.

From Table 5. it can be seen that the compressive strength results of concrete with rubber content of 30% and 60% respectively of 19.6MPa and 13.1MPa. These results are in the range of 15-20MPa. It can be concluded that the compressive strength obtained meets the requirements of the General Specification of Highways Division 7 of 2018 as low-quality concrete and functions as a concrete structure without reinforcement and Backfilling and floor work using concrete.

Conclusion

From the results of the research that has been carried out, it can be concluded that

1. The fine aggregate used has met the requirements for the fine modulus of grains with an MHB value of 3.
2. The coarse aggregate material used has met the aggregate wear requirement of 32%.

3. he test results of the slump value of the test specimen show that concrete can be used for the type of construction of beams, columns and reinforced walls of buildings, namely with the slump value in the range of 25 to 100 mm.
4. The addition of waste tire rubber powder as a partial substitute for fine aggregate can reduce the compressive strength value of concrete.

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