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Effects of aluminum fibers additive on the compressive strength of a concrete

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ABSTRACT

Utilizing recycled waste as an additional construction material is an innovation that can reduce the negative environmental impacts caused by waste. One of the wastes that can be utilized in this case is aluminum cans. The use of aluminum fiber in concrete mixtures is appropriate since aluminum is resistant to corrosion or rust. This research aims to determine the effect of adding aluminum fiber on the compressive strength of concrete. The aluminum cans were shaved into fibers with dimensions of 2 x 35 mm. The resulting aluminum fiber is then added into the concrete mixture with a percentage of 0%, 0.05%, 0.075%, 0.1%, and 0.125% of the total volume of the test objects. Tests for compressive strength was then carried out after test specimens were aged for 28 days. The test results showed a peak compressive strength of (20.72 ± 0.35) MPa is observed at the addition of 0.05% aluminum fiber relative to the volume of concrete used for testing. A regression analysis was performed based on the relationship between the amount of aluminum fiber additive and the resulting compressive strength. Based on this analysis, the optimum value for aluminum fiber to be added to the concrete is 0.040% of its volume.

Keywords: concrete; aluminum fiber; mechanical properties; recycling

1 Introduction

The need for infrastructure improvements continues to increase along with the technological developments over time. This increase is also accompanied by a growing demand for high quality construction materials, one of which is concrete. Concrete is a building structure-forming material consisting of cement (portland cement), water, coarse aggregate (gravel), fine aggregate (sand), and additional materials (admixture or additive). The characteristic of concrete is a very strong material, does not rust, is resistant to fire and is known as a material that is able to withstand compressive strength well, can be shaped according to desired needs, is easy to produce both in the factory and directly at the project site, and is easy to maintain. However, concrete also has weaknesses in its use. These weaknesses include the brittle nature of concrete which causes it to be unable to withstand tensile stress, where the tensile strength value of concrete ranges from 8% -15% of the compressive strength of concrete. Therefore, as a substitute for resisting tensile forces, reinforcement is used in the concrete. The reinforcement used is generally in the form of main steel reinforcement and stirrups in certain areas that require it. Efforts to improve the quality of concrete are also carried out by mixing other ingredients in the mixture. One of them is the addition of fiber which is expected to increase the tensile strength and ductility of the concrete material. The use of fiber in the concrete mixture can also minimize the use of reinforcement in the concrete. The fibers mixed can be steel fibers, polymers or natural fibers. The addition of fiber to concrete can make a significant improvement in several properties of concrete, for example increasing ductility, impact resistance, tensile strength and flexibility, resistance to melting, resistance to shrinkage and resistance to peeling [1].

Aluminum is widely used in everyday life such as packaging for instant food or drinks, cooking utensils, components for cars, bicycles, computers, and so on. Currently, food or drink can waste is one of the largest wastes produced by society. One alternative that can be done to reduce the negative impact of this type of waste is to use it optimally, for example as a

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construction material in the form of fiber. Utilizing waste materials can not only overcome the negative impacts of waste, but also produce construction materials that are strong and sustainable. The addition of aluminum fiber to the concrete mixture can increase the compressive strength and reduce the brittle properties of concrete, where the percentage of influence is influenced by the fiber dimension ratio, variations in fiber percentage, and the shape of the fiber itself. The addition of aluminum fiber can also increase the flexural load capacity and crack load of reinforced concrete [2-3]. Using aluminum fiber in concrete also leads to an improvement in the concrete properties, an increase in compressive strength, and a better enhancement in the structural behavior. Previous studies show that aluminum fiber content of 0.2% is able to increase the characteristics of strength, deformation, and energy of a concrete, while excess aluminum fiber reduces the original performance due to agglomeration and other factors [4-9]. Other than aluminum fiber, steel fiber, carbon fiber, and organic fiber are also common to be incorporated to improve the performance of a concrete [10-12].

The bond that occurs between fiber and cement will help the concrete to resist tension and cracks that arise, so that the use of waste as a construction material is one innovation and solution to increase the usability of aluminum waste. This research aims to determine the effect of adding aluminum fiber on a concrete and to determine the optimal percentage of aluminum fiber additive in order to have higher increase in compressive strength.

2 Data and Methods

The test specimens used in this research were cylindrical concrete specimens (15 cm in diameter and 30 cm in length) and concrete blocks (15×15×65 cm) mixed with used drink can fiber with variations in fiber percentage of 0%, 0.05%, 0.075%, 0.1%, and 0.125% of the total volume of concrete. The dimensions of the aluminum fiber itself are 2 × 35 mm. These aluminum fiber percentage were chosen in accordance to ACI 544.1R-96 [13] where the optimum compressive strength of a particular aluminum fiber reinforced concrete has a fiber content of less than 1%.

In designing the mix of the concrete, we flowed the national standard (SNI) 03-2834-2000 [14] about the methods of constructing mix design for normal concretes. Our concrete mix design in m³ and the composition for cylindrical and concrete blocks are contained in Tables 1 and 2, respectively.

In order to obtain the compressive strength of the test objects, we performed compressive strength tests. These tests were carried out after the concretes aged for 28 days. Every material that was used in the concrete mixture went through a testing process first. Material testing in this study includes bulk density, specific gravity, sieve analysis, organic content, mud content, water content, wear, initial consistency, and setting time. The concrete compressive strength test was carried out by applying a maximum axial load to the cross-section of the test object until the test object is destroyed. The testing procedures used in this research were adapted to [15] and the formula of Equation 1

$$f_c' = \frac{P}{A} \quad (1)$$

where f_c' is the compressive strength of a concrete, P is the maximum axial load, and A is the area of the test object.

Table 1. Concrete mix design for the test objects

Material/m³ (kg)	Percentage of Aluminum Fiber (%)				
	0.000	**0.050**	**0.075**	**0.100**	**0.125**
Cement	360.28	360.28	360.28	360.28	360.28
Aluminum fiber	0.00	1.19	1.78	2.37	2.96
Fine aggregate	899.36	899.36	899.36	899.36	899.36
Coarse aggregate	955.43	955.43	955.43	955.43	955.43
Water	154.93	154.93	154.93	154.93	154.93

Table 2. Concrete mix design for the test objects

Material/m3 (kg)	Percentage of Aluminum Fiber (%)				
	0.000	**0.050**	**0.075**	**0.100**	**0.125**
Cement	27.80	27.80	27.80	27.80	27.80
Aluminum fiber	0.00	91.44	137.16	182.89	228.61
Fine aggregate	69.40	69.40	69.40	69.40	69.40
Coarse aggregate	73.73	73.73	73.73	73.73	73.73
Water	11.96	11.96	11.96	11.96	11.96

Table 3. Results of compressive strength test

Concrete code	Start date	Test date	Initial compressive strength (MPa)	Concrete mass (kg)	Final compressive strength after 28 days (MPa)	Average final compressive strength (MPa)
NP 0%	16/06/2023	14/07/2023	20	12.92	21.00	
NP 0%	16/06/2023	14/07/2023	20	12.89	18.23	20.08 ± 1.60
NP 0%	16/06/2023	14/07/2023	20	12.89	21.00	
NP 0.050%	05/06/2023	03/07/2023	20	12.92	20.33	
NP 0.050%	05/06/2023	03/07/2023	20	12.91	21.00	20.72 ± 0.35
NP 0.050%	05/06/2023	03/07/2023	20	12.91	20.84	
NP 0.075%	06/06/2023	04/07/2023	20	12.98	20.21	
NP 0.075%	06/06/2023	04/07/2023	20	13.10	19.82	20.19 ± 0.37
NP 0.075%	06/06/2023	04/07/2023	20	13.10	20.55	
NP 0.100%	06/06/2023	04/07/2023	20	12.97	19.19	
NP 0.100%	06/06/2023	04/07/2023	20	12.88	19.65	19.51 ± 0.28
NP 0.100%	06/06/2023	04/07/2023	20	12.88	19.70	
NP 0.125%	07/06/2023	05/07/2023	20	12.73	18.85	18.85 ± 0.00

3 Results and Discussion

The results of compressive tests of all test objects can be found in Table 1. From these, we can see that the final compressive strength of the concretes generally increases at the addition of 0.050-0.075% of aluminum fiber, but otherwise decreases at higher addition of the fiber. The highest final compressive strength is (20.72 ± 0.35) MPa at the addition of 0.050% aluminum fiber relative to its volume from an initial compressive strength of 20MPa. On the other hand, the lowest final compressive strength is 18.85 MPa at the addition of 0.125% of aluminum fiber. In a previous study, peak compressive strength was reached when the fiber composition is of 0.2% [4]. The compressive strength was then keeping on decreasing with the addition of more aluminum fiber, which although does not reflect the exact fiber percentage of our research, the trend is quite similar. When aluminum fiber percentage is increased pass the optimum compressive strength, the fiber content is negatively correlated with compressive strength of the concrete. This was probably caused by the formed agglomeration due to incomplete dispersion of fibers in the concrete matrix.

Figure 1. Crack patterns observed in one of the concretes we used for testing.

The test objects also showed similar cracking patterns, which is parallel to the direction of the load. Hence this cracking can be categorized as a columnar crack pattern [16]. In general, the crack patterns that occur during compressive strength testing tend to have cracks in a vertical direction. The observed cracking pattern can be seen in Figure 1.

In order to determine the optimum percentage of aluminum fiber, we performed a regression test between the added aluminum fiber percentage and the resulting compressive strength of a concrete. The resulting curve is shown in Figure 2, with the value of R^2 coefficient of 0.9632 that indicates high reliability. The figure shows that the optimum percentage of aluminum fiber additive is at 0.040%. The regression test result also shows that increasing the amount of aluminum fiber past this point may result to a decrease of compressive strength.

4 Conclusion

In order to observe the effect of aluminum fiber additive to the compressive strength of a concrete, several tests have been performed to concretes with 0%, 0.05%, 0.075%, 0.1%, and 0.125% aluminum fiber additive relative to their total volume. These tests were carried out after test specimens were aged for 28 days, resulting in a variety of final compressive strength values from the initial of 20 MPa. The test results showed a peak compressive strength of (20.72 ± 0.35) MPa is observed at the addition of 0.05% aluminum fiber relative to the volume of concrete used for testing. Regression analysis based on experimental data shows that the optimum percentage of aluminum fiber additive is at 0.040%. Increasing the amount of aluminum fiber past this point may result to a decrease of compressive strength.

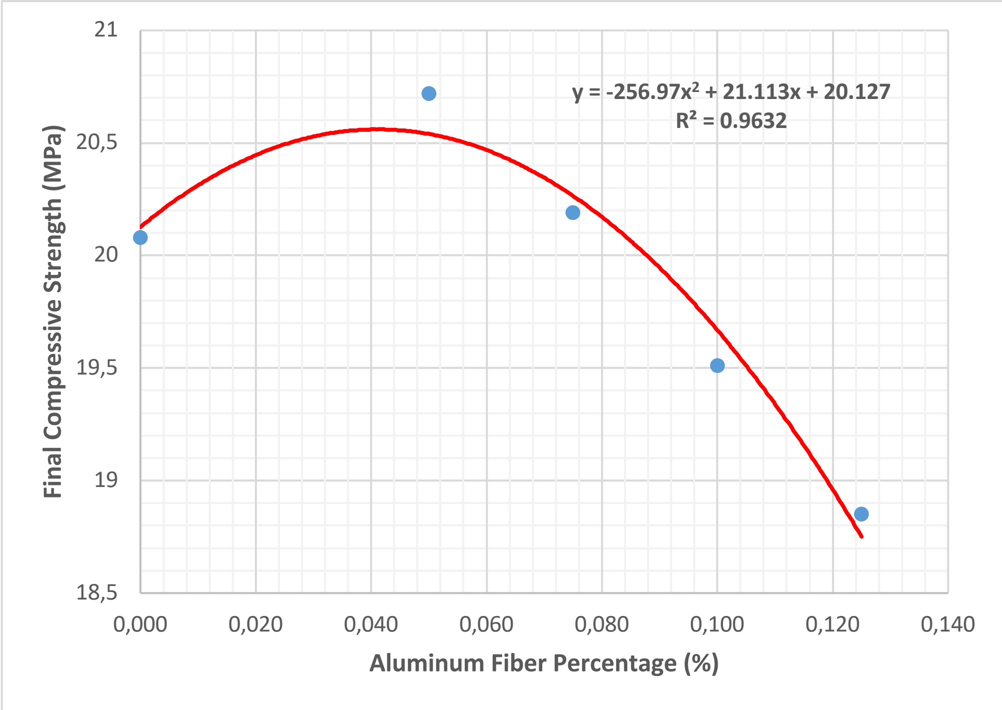

Figure 2. Quadratic relationship between the added aluminum fiber percentage and the resulting compressive strength of a concrete. Blue dots are the final average compressive strength and the red solid lines indicates the trend line from the regression analysis.

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