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Experimental Study on the Properties of Artificial Lightweight Aggregate Concrete Reinforced with Carpet Waste Fiber

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Abstract. Lightweight concrete is a low-density concrete that can be made by replacing coarse aggregate with artificial lightweight aggregate such as bloated clay, crushed bricks, or coarse fly ash. This paper presents a study of the influence of carpet waste fiber on the properties of artificial lightweight aggregate concrete. Tests are performed on 30 concrete cylinders of 150 mm in diameter and 300 mm in height with various additions of carpet waste fiber, namely 0%, 0.25%, 0.50%, 0.75%, and 1.00%. Superplasticizer is added at 2% of cement weight for convenience of casting. We find that using artificial lightweight aggregate can reduce concrete density to a maximum of 1.94 t/m³. The compressive strength of artificial lightweight aggregate concrete increases by 17.22% with addition of 0.44% carpet waste fiber, while the split tensile strength of artificial lightweight aggregate concrete increase by 75.18% with addition of 0.85% carpet fiber.

1. Introduction

Concrete is an old and extensively used building material, because it has several advantages over other materials, including its ability to support high compressive stress, its relatively low price, and its ability to incorporate materials found in the surrounding environment. In addition, concrete has good resistance against weather, corrosion, and fire. However, drawbacks to concrete include its low tensile strength and its brittleness. Concrete also has a relatively high density, 2.4 t/m³ [1], influencing the amount of load that can be supported by a building structure. Improvements in concrete to overcome weaknesses include making lightweight concrete and addition of fiber into concrete mixtures [2, 3]. This study complements previous studies by characterizing artificial lightweight aggregate concrete reinforced with carpet waste fiber.

Fibers in concrete may bridge cracks in the concrete matrix, providing resistance against propagating and widening before cracks collapse. According to Wang [4, 5, 6], properties of fiber reinforced concrete generally depend on the strength, type, and fiber properties used. There are many types of fibers available in the concrete industry and each type of fiber has advantages and limitations. Fiber selection is primarily based on concrete application. Some types of fiber which may be used in concrete are, steel fiber, glass fiber, natural fiber, synthetic fiber (carbon and polypropylene), and recycled fiber (carpet fiber, fiber from soda cans, and steel fiber from waste tires). Most waste fiber consists of natural materials and synthetic polymer material such as cotton, wool, silk, polyester, nylon, and polypropylene. Waste fiber is consumed and disposed of in large amounts. The carpet industry produces a large amount of waste materials mostly composed of fiber with 50%-70% nylon and 15%-25% polypropylene [7, 8, 9]. Typical carpet fiber is shown in Figure 1.



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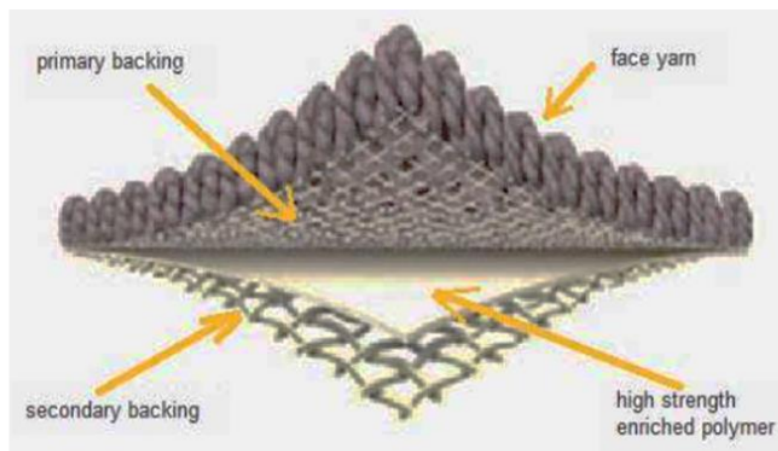


Figure 1. Typical carpet fiber [10].

The artificial lightweight aggregate used in this study is manufactured by *Loka Perintisan Bahan Bangunan Lokal Cilacap*. Use of aggregate is intended to reduce dependency on gravel as concrete construction material. Continuous utilization of gravel as a concrete material may affect natural environments, because gravel is a non-renewable resource. Puskim [11] states that shale has abundant potential as an artificial lightweight aggregate material in Indonesia. Haryanto [12] reports the impact resistance of lightweight aluminum fiber concrete with artificial lightweight aggregate, with the most significant increase in impact resistance and absorption energy obtained by adding aluminum fiber 0.75%, resulting in 10 strokes (46.60 J) or an increase of 250% for the first crack, and 15 strokes (69.90 J) or an increase of 300% for total collapse. Addition of 1.00% aluminum fiber decreases the workability level making concrete mixture solidification difficultly resulting in porous concrete with decreased impact resistance and absorption energy.

Kristiyanto [13] tested specific gravity, pore volume, and compressive strength of no-fine lightweight concrete with artificial lightweight aggregate of 15-20 mm, with a water to cement ratio of 0.45, and a planned mixture variation comparing volume of cement:aggregate, including 1:2, 1:4, 1:6, 1:8, and 1:10. The test specimen was a 15 x 15 x 15 cm cube submerged under water and tested on days 7, 14, and 28. The test specimen was found to be lightweight concrete with a maximum specific gravity and pores volume of 1.96 ton/m³ and 34.94%, respectively. The concrete compressive strength was 37.66 MPa on day 28, with a cement content of 571 kg/m³. The concrete compressive strength increased in line with increasing specific gravity and decreasing pore volume.

2. Experimental work

The materials used for concrete mixtures include multi-purpose cement, fine aggregate as sand from the Serayu river, Purbalingga, and coarse aggregate as artificial lightweight aggregate (Figure 2) made in Cilacap. The fine aggregate has specific gravity of 2.50 with a fine modulus of 3.55. The artificial lightweight aggregate has a specific gravity of 1.43 with a fine modulus of 6.48. The carpet waste fiber (Figure 3) has a specific gravity of 1.19, is 50 mm x 3 mm x 2 mm, and is added at 0.00%, 0.25%, 0.50%, 0.75%, and 1.00% of the concrete volume. Superplasticizer at 2% of the cement weight is added for convenience of casting. Concrete mixture compositions are calculated as shown in Table 1.



Figure 2. Carpet waste fiber used [3, 14].



Figure 3. Carpet waste fiber used [14].

Table 1. Concrete mixture compositions.

Fractional Volume (%)	Carpet Fiber (g)	Cement (kg)	Sand (kg)	Artificial Lightweight Aggregate (kg)	Water (kg)
0.00	0.00	375	750	525	81
0.25	2997.50	375	750	525	81
0.50	5995.00	375	750	525	81
0.75	8992.50	375	750	525	81
1.00	11990.00	375	750	525	81

To verify the concrete mixture workability, a slump test was conducted according to SNI 1972: 2008 [15]. A compressive strength test (Figure 4) and a split cylinder strength test (Figure 5) are conducted on day 28 on 30 cylindrical test specimens with a height of 300 mm and a diameter of 150 mm, in accordance with SNI 1974: 2011 and SNI 03-191-2002 [16, 17]. The concrete compressive strength was determined using equation (1), while split tensile strength was determined using equation (2).

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

$$f_{ct} = \frac{2P}{\pi Ld} \quad (2)$$

in which:

f_c' = Compressive strength (MPa)

P = Maximum load (N)

A = Area of specimen (mm²)

f_{ct} = Split tensile strength (MPa)

L = Length of specimen (mm)

D = Diameter of specimen (mm)



Figure 4. Compressive strength test [3, 18].



Figure 5. Split tensile strength test [3, 18].

3. Results and discussion

3.1. Workability

The slump value decreases with addition of carpet waste fiber. Use of fiber in concrete mixture increase the surface area covered by water, decreasing the free water, which decreases concrete workability due to difficulty mixing [19]. The slump value of concrete without carpet waste fiber is 4.5 cm and increased to 19 cm by adding superplasticizer (Figure 6).

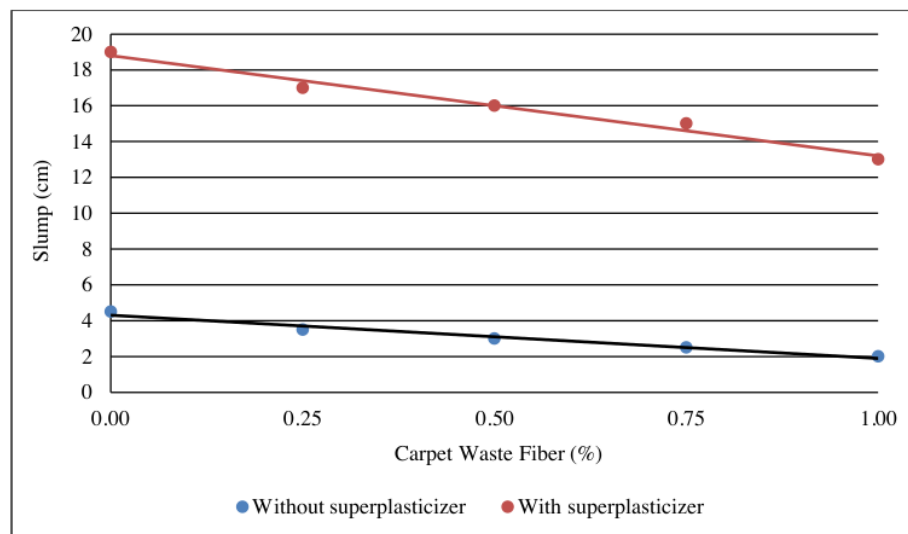


Figure 6. Effect of carpet waste fiber on slump value.

3.2. Density

The use of artificial lightweight aggregate results in a maximum concrete density of 1.94 t/m^3 , classifying it as a lightweight concrete (specific gravity less than 2 t/m^3), which can be used for medium structures [20]. Addition of carpet waste fiber increases concrete density to the optimal content of 0.67%. Afterwards, concrete density reduces due to increased pore density. The test results on concrete density are presented in Table 2, while the effect of carpet waste fiber on concrete density is shown in Figure 7.

Table 2. Concrete density.

Fiber Content (%)	Density (t/m^3)						Avg. (t/m^3)
	1	2	3	4	5	6	
0.00	1.85	2.00	1.91	1.92	1.92	1.91	1.92
0.25	1.91	1.96	1.94	1.92	1.92	1.91	1.93
0.50	1.98	1.89	1.94	1.92	1.92	1.92	1.93
0.75	1.92	1.94	1.94	1.94	1.96	1.92	1.94
1.00	1.96	1.92	1.91	1.94	1.92	1.92	1.93

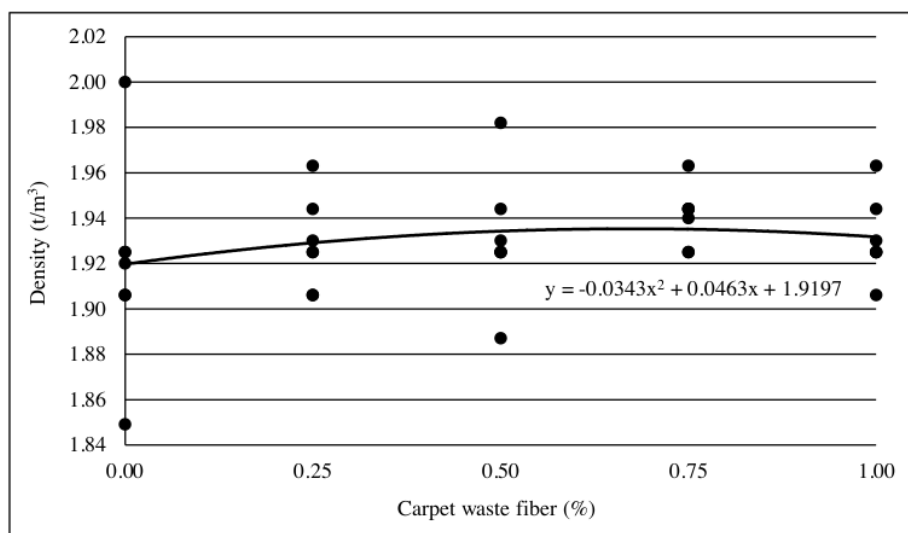


Figure 7. Effect of carpet waste fiber on concrete density.

3.3. Compressive strength

Carpet waste fiber increase the compressive strength of artificial lightweight aggregate concrete up to certain content, followed by a decrease. Fiber makes concrete more resistant to cracking and impact. However, difficulty in mixing may result in inhomogeneous concrete mixtures and difficulty in solidifying may result in porous concrete due to trapped air, decreasing compressive strength [1]. The effect of carpet waste fiber on compressive strength (Figure 8) indicates that the compressive strength of artificial lightweight aggregate concrete can increase up to 17.22% by adding 0.44% carpet waste fiber.

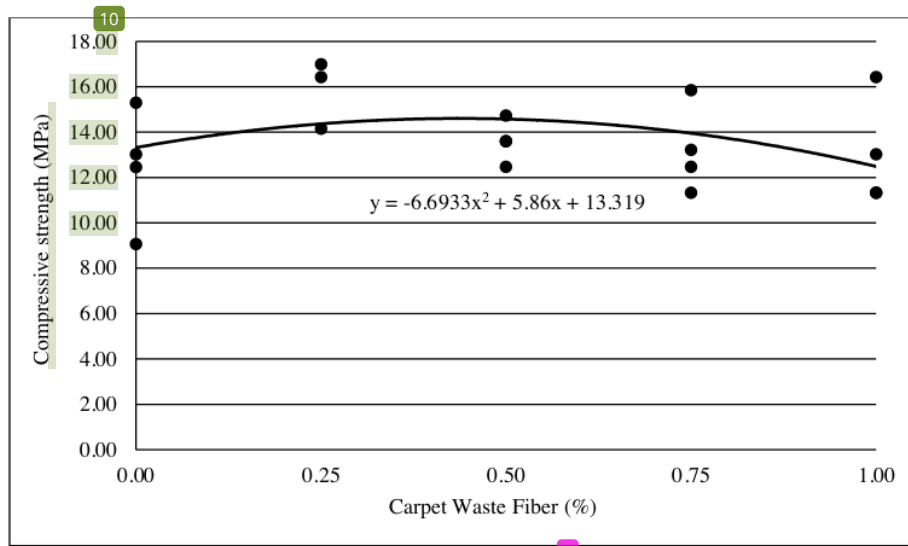


Figure 8. Effect of carpet waste fiber on compressive strength.

3.4. Split tensile strength

The split tensile strength of artificial lightweight aggregate concrete increases by up to 75.18% with addition of 0.85% carpet waste fiber (Figure 9). Artificial lightweight aggregate concrete without carpet fiber is brittle, with the test specimen split in two along the diameter. Meanwhile, artificial lightweight aggregate concrete with addition of carpet waste fiber is ductile with preliminary small cracks. This is in accordance with the fiber bridging and resisting distribution of cracking, allowing concrete paste to support a load even if it has cracked [12].

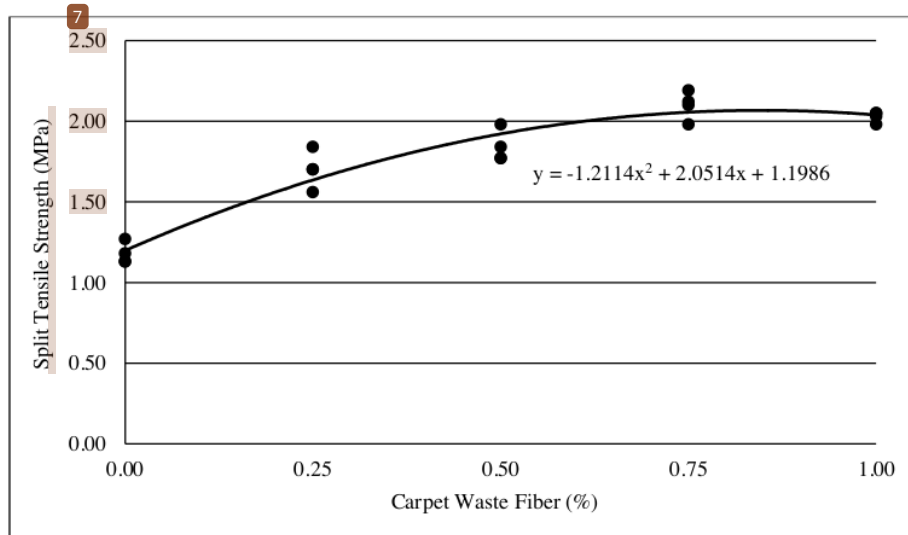


Figure 9. Effect of carpet waste fiber on split tensile strength.

4. Conclusions

Addition of superplasticizer can increase concrete workability up to a slump value of 19 cm. Concretes formed from artificial lightweight aggregate with addition of carpet waste fiber are classified as lightweight concrete with a maximum specific gravity value of 1.94 t/m³. The compressive strength of artificial lightweight aggregate concrete increases by 17.22% with addition of 0.44% carpet waste fiber, while the split tensile strength of artificial lightweight aggregate increases by 75.18% with addition of 0.85% carpet waste fiber.

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