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STRENGTH CHARACTERISTICS OF WASTED SOFT DRINKS CAN AS FIBER REINFORCEMENT IN LIGHTWEIGHT CONCRETE

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ABSTRACT: Nowadays the problems of lightweight concrete flexural strength have been approached by adding fiber to the mixture. Meanwhile, waste materials are continuously produced as a result of the modern industry. This paper aims to increase the strength characteristic of both compressive and flexural lightweight concrete by introducing wasted soft-drink cans as fiber reinforced. A comprehensive study has been conducted to investigate the optimal amount of fiber fractions and the effect of fiber shape to the concrete mechanical strength. This study cleared the effect of various fractions (10%, 15% and 20% by volume of concrete), followed by two types of fiber shape (hooked and clipped) to the lightweight concrete compressive and split tensile strength. The experimental results of cylindrical lightweight concrete were compared to the normal lightweight concrete. The result showed that the introduction of 10% of fiber performed in higher tensile strength with an increase of 23%, while the hooked shape of fiber increased the compressive strength by more than 40%. It can be concluded that the introduction of waste recycle tin increased the mechanical properties of normal lightweight concrete, however further study can be performed to effectively increase the strength characteristics.

Keywords: Lightweight concrete, Fiber reinforcement, Waste materials, Compressive strength, Tensile strength

1. INTRODUCTION

Performance and durability become the main purposes in upgrading construction method and material. One of the methods is by reducing the weight of the dead load by applying lightweight concrete materials. However, the common problem related to lightweight concrete is low mechanical properties. Meanwhile fiber reinforced concrete (FRC) is a composite material, which aims to increase mechanical properties (i.e. compressive and tensile strength), increase the toughness and improve the energy absorption of concrete [1]. Various type of fiber has been researched, such as glass, steel, synthetic and un-synthetic fiber [2]. Adding fibers into concrete create mixtures that are more cohesive and less prone against segregation, thus the interlock and entanglement around aggregate particle tended to reduce the workability. The inclusion of short fibers in a small fraction improves the mechanical performance of FRC by reducing the size and amount of defect in concrete. One of the benefits of FRC is providing resistance against crack propagation, which may lead to pulled out and rupture. FRC has been known could reduce the bleeding of water that leads to plastic and drying shrinkage cracking. However, each type of FRC has different properties, advantages, and limitations.

Steel fibers have been commonly applied material due to its significant improvement. However, producing steel fibers cost more than their benefit. Therefore, an alternative material based on recycling or wasted is needed.

It has been known that 3R's program (Reduce, Reuse and Recycle) helps to preserve and conserve the environment for sustainability purposes. However, one of the environmental issues is the difficulty in recycling and bio-grade of steel waste material. On the other hand, steel waste material may provide higher tensile characteristic increase the compressive and tensile strength in the concrete, especially lightweight concrete[3][4][5].

Therefore, some study on the use of recycling or waste material has been conducted to understand the behavior of concrete strength. G.C. Behera concluded that the use of soft drink bottle caps as a fiber with a fraction of 0.25%. 0.5% and 1.0% of the total weight increased the compressive strength, split tensile and flexural strength especially in the case of 1.0% with 10-15% increment [6][7]. G. Murali et al studied that introducing crumpled steel fiber concrete with a portion of 0.8% volume of concrete resulting in higher compressive strength, split tensile and flexural strength compare to normal concrete [8]. The used of polyethylene terephthalate (PET) bottles fiber was investigated as reinforcement of specimens [9][10]. The result showed a significant increase to indicate the adherence between PET and concrete for structural reinforcement [11].

This research study on the optimum fraction of wasted soft drink can as fiber to improve compressive and tensile strength, also to study the effectiveness of interlocking in the wasted soft drink can reinforce the lightweight concrete. Further, two types of interlocking are introduced to get a clearer understanding of the mechanical properties of fiber reinforced concrete.

2. MATERIALS

Thirty-sixth cylindrical specimens were cast in order to have a deep understanding of the use of soft drink can as fiber reinforce in lightweight concrete. The component materials are described below.

2.1 Cement

All specimens used locally manufactured Pozzoland Portland Cement (PPC) type 1, which is correspondent with ASTM type 1.

2.2 Aggregates

Fine aggregates were obtained from the river around Lumajang residency, coarse aggregates were obtained from Pasuruan city. Both places are known as the fine production of aggregates materials in East Java provinces (Indonesia). In order to produce lightweight concrete, pumice aggregates were ordered from Bali (Indonesia). Some of the parts were required to be washed to improve the quality, while the rest were in a good quality. A group of grain pumice aggregates 8-16 mm were dipping into a polymer liquid in order to prevent excessive water absorption, which would disturb the water-cement ratio [12]. The coated pumice then dried 24 hours at the room with a temperature of 25 ± 2°C. The properties of aggregates can be seen in Table 1.

Table 1 Properties of Aggregates

Aggregates	Specific gravity	Bulk density (kg/m^3) ASTM		Water absorption 24hr (%)
	Oven-dry	Shoveled Ovendry	Rodded Ovendry	
Coarse Aggregates				
GA	2.67	2696	2589	3.20
PA	1.85	-	-	14
CPA	1.79	-	-	10
Fine Aggregates				
River sand	2.60	2530	2693	3.22

Note: GA (Gravel Aggregates), PA (Pumice Aggregates), CPA (Coated Pumice Aggregates)

As seen in Table 1, coated pumice has a lower specific gravity and water absorption ability compares to uncoated ones.

2.3 Fiber

Fibers were constructed from the metallic waste of soft drink can as shown in Fig.1. After removing the top and bottom of the can, the rectangular shapes of the body were washed thoroughly and dried. The body of the can then was cut into several sizes depending on the interlocking length and the type of interlocking (i.e. type A and type B) as can be seen in Fig. 2.

Fig. 1 Wasted soft drink can as fiber reinforcement

Fig. 2 Sample of fiber with a width of 2mm and length 40mm without interlocking shape.

2.3 Fiber

Local tap water of the city of Malang, Indonesia were used and measured for water-cement ratio and also being used for the curing process of the lightweight concrete.

3. METHODOLOGY

In this research, the concrete mix design was aimed for 17MPa at 28 days. Referring to the Indonesia code (SNI 03-2834-2000), the concrete mix proportion can be seen in Table 2 with the ratio of water-cement was 0.5.

In this research 36 cylindrical specimens were cast with the height of 300mm and the diameter of 150mm. For the purposes of investigating the optimum fraction of fiber, 24 cylindrical specimens were cast with four different fractions of fiber's i.e. 0%, 10%, 15% and 20% of volume, with 6 casted specimens for each scenario.

Table 2 Mix Design proportion

Materials	Bulk density (kg/m^3)	Unit weight (kg)	Volume (m^3)	Ratio
Cement	1350	363	0.268	1
Fine Aggregates	1400	743	0.530	2
Coarse Aggregate	1300	1069	0.822	3
Water	1000	225	0.225	1

The fiber was made from an aluminum soft drink can with the dimension of 40mm length and 2mm width without any particular interlocking shape. Coding of specimens and the attribute data are described in Table 3.

Table 3 Lightweight specimens properties

Specimens code	Amount (specimens)	Fiber's fraction (% vol)	Interlocking type
Norm	6	0	No
Fr1	6	10	No
Fr2	6	15	No
Fr3	6	20	No
Il1	6	10	A
Il2	6	10	B

Further, in order to investigate the effectiveness of interlocking, this study introduced two types of interlocking as can be seen in Fig. 3(a) and Fig. 3(b).

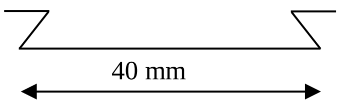

Fig. 3(a) Fiber interlocking type A.

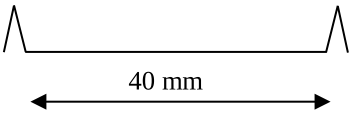

Fig. 3(b) Fiber interlocking type B.

All types of specimens were subjected to compressive tests (3 specimens) and a tensile test (3 specimens). Therefore, in total there were 18 specimens under the compressive tests and another 18 specimens under the tensile tests. An extensometer and stress-strain gauges were used during the compressive tests to measure the stress-strain abilities and elastic modulus.

4. RESULT AND DISCUSSIONS

All specimens were subjected to the compressive and tensile test at the day of 28, with the result that can be described in term of the density and workability, compressive strength and tensile strength.

4.1 Density and Workability

The purpose of coated pumice was to prevent water absorption, which has been indicated from the reduction of fiber pumice reinforce concrete density compared to normal ones.

Table 4 Density and slump of specimens

Specimens code	Density (kg/cm^3)	Slump (cm)
Norm	2250.45	14.5
Fr1	2226.42	14.5
Fr2	2183.33	12
Fr3	2215.30	8
Il1	2213.84	9
Il2	2232.71	14.5

Fig. 4 Identified porous on the concrete surfaces.

Workability of a mixture can be associated with the slump measurement. Table 4 shows the density and slump of specimens, which indicated that the inclusion of fiber has a lower slump value. It has been confirmed by many scholars and in ACI 213R-

87 that the coated pumice and fiber inclusion produced lower slump value due to the low weight as a consequence of water absorption reduction. In order to avert the segregation and to maintain the cohesive, a higher slump value is demanded with the additional effort to preserve the ideal surface of specimens. In this study, the slump value has been kept between 7.5-15cm. However, the addition of waste soft drink can as fiber caused a reduction of slump value and resulting in minor porous on the surfaces as can be seen in Fig. 4.

4.2 Compressive Strength

Compressive strength tests were performed on three cylindrical specimens for each fraction and interlocking type. The dots on Fig. 5 shows the compressive strength on various fractions (0%, 10%, 15%, and 20% respectively), while the continuous line is used to connect the average value of each type. Further, Fig. 5 indicated that though the substitution of strong gravel aggregate by relatively weak pumice aggregates might reduce the compressive strength. However, the inclusion of wasted soft drink can as fiber tended to increase the compressive strength compared to normal ones.

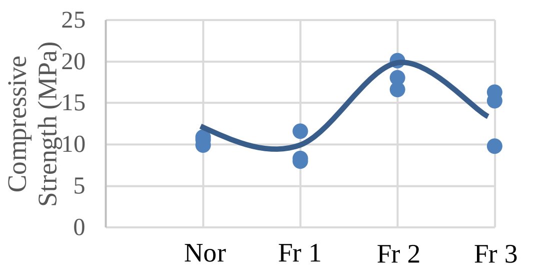

Fig. 5 Compressive strength of FRC with various fiber fractions.

The coated pumice commonly reduce the compressive strength due to the lack of clinker (C_3S), which may be resulting in slow hydration and decrease heat development. However, the inclusion of thin aluminum can help to distribute the heat quicker and the ongoing pozzolanic reactions lead to the continuous hydration phase. Though the FRC tended to have a higher compressive strength, the optimum value can be taken from adding a 15% volume of fiber. An excessive fiber higher than 15% of volume leads to the lack of workability and resulting in porous and multiple fragmented parts.

Figure 6 shows the comparison of compressive strength and deflection between normal concrete and concrete with 15% of fiber inclusions, which can also indicate the stiffness of specimens. The addition of fiber not only increase the compressive strength, but it tended to increase the stiffness as well. The stiffness of specimens with 15% fiber's volume was increased 14% compared to the normal ones.

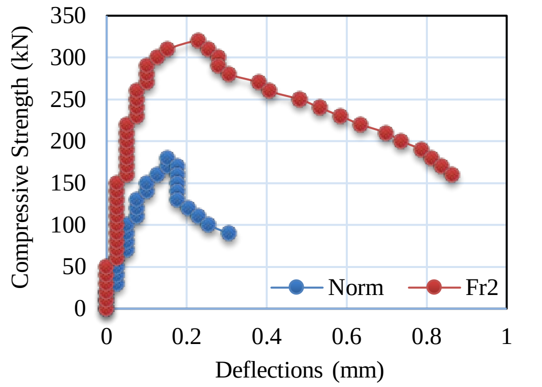

Fig. 6 Compressive strength vs deflection of normal and 15% volume of fiber fractions.

The compressive strength of all various interlocking system generated much stronger compressive ability compare to the normal ones, which can be seen in Fig. 7. Although the average of interlocking type B was the highest, interlocking type A most likely produce higher compressive strength for each specimen.

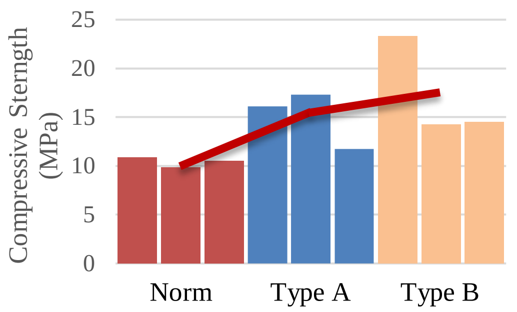

Fig. 7 The compressive strength of FRC with various fiber interlocking.

4.3 Tensile Strength

Fig. 8 Tensile strength of FRC with various fiber interlocking

Tensile tests were conducted on three specimens for each type at the age of 28 days, as can be seen in Fig.8.

Figure 9 shows the tensile strength of various fiber fraction. As can be seen, the inclusion of waste soft drink can increase tensile strength compared to normal ones. Further, the optimum result obtained from the fiber with a 10% volume fraction. However, the smooth and slippery surface of the soft drink can fail the homogenous mix between concrete and fiber, therefore the increase of tensile strength was considered mild (23% from the normal ones).

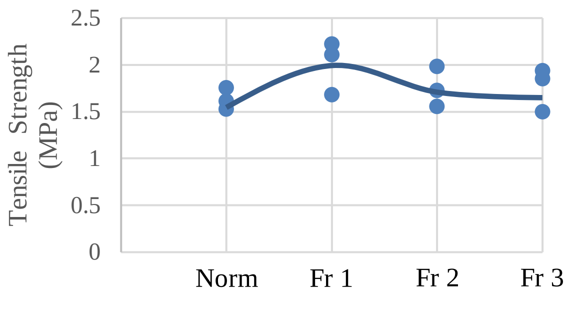

Fig. 9 Tensile strength of FRC with various fiber fractions.

The effectiveness of fiber on increasing tensile strength can be observed visually on the failure mechanism. In the case of normal concrete, the failure mechanism occurred all of sudden followed by strong sound indicate the failure phase achieved. Meanwhile, the FRC based on the waste soft drink can begin the failure mechanism with several cracks on the concrete surface, especially at the section where the load applied. The failure of the specimen occurred without strong sound when the crack elongate from the upper section into the bottom ones as can be seen in Fig. 8. At the same time, the load dial stopped and started showing the reverse number.

Fig. 10 Fiber sticking out of concrete surfaces.

Figure 10 shows the sticking out of fiber at the concrete surfaces in full-length size. This evidence indicated the slip mechanism during tensile strength due to the smooth and slippery surface of fiber can.

Figure 11 shows the tensile strength result in various interlocking. Despite the smooth and slippery surface of the fiber, the result indicates that interlocking increase tensile strength. Interlocking created stronger bound between fibers, which were effective against tensile and strain effect.

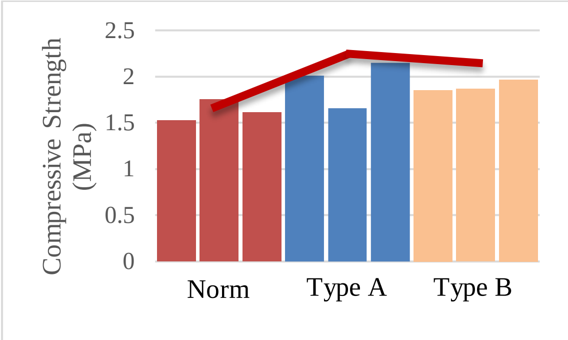

Fig. 11 The tensile strength of FRC with various fiber interlocking

The tensile strength of fiber with interlocking tended to increase as shown in Fig. 11. The interlocking type A has higher tensile due to the shape of interlocking effectively bond each other during the load. However, the distribution of fiber also gives significant impact as shown by specimen with type A interlocking code Il1.2 that had lower tensile strength due to uneven distribution of fiber. The crack was generated at the location without fiber, as it becomes the weakest part against the tensile stress.

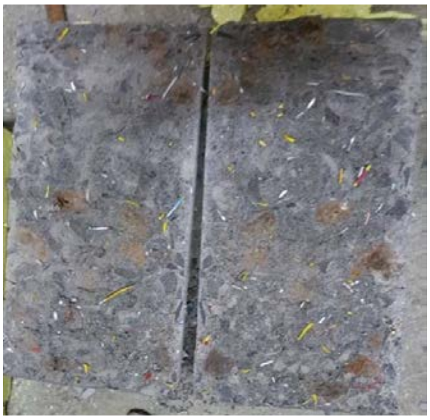

Fig. 12 Pumice distributions on the concrete with high fiber inclusions.

This research also gives significant founding to the issue related to the fiber reinforce concrete by pumice. It has been known that the low density of pumice keeps it difficult to distribute equally during the casting due to floating pumice. However, the inclusion of fiber with interlocking effectively keep pumice from floating and as a result pumice can be distributed equally all around the specimen. Figure 12 shows the equal distribution of pumice due to the existence of fiber.

5. CONCLUSION

Thirty-sixth lightweight fiber reinforced concrete was investigated to have a clear understanding of the effect of the wasted soft drink can as fiber and its interlocking to the concrete mechanical properties. Several outcomes can be observed as follows:

1. The wasted soft drink can increase the compressive strength of lightweight concrete with the optimum volume fraction of fiber is 15%. Further, the interlocking type generates higher compressive strength, which is shown by interlocking type B. The inclusion of fiber also increases the stiffness of specimens as well as its deflection under the axial load.
2. The addition of waste soft drink can give an advantage to the tensile abilities of concrete specimens, as it increases 5-23% from the normal ones. The introduction of two types of interlocking fiber slightly increase the tensile strength with the highest increase was in the interlocking type A.
3. The inclusion of fiber, especially with interlocking, give additional advantages as it helps keeps pumice from floating to the surfaces and hold pumice at the evenly distributed places.

6. ACKNOWLEDGMENTS

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