Waste-based fiber concrete properties using supplementary material of bead wire scrap

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Abstract. Fiber concrete has gained its popularity for the past few years to improve the tensile capacity of concrete by the presence of natural or synthetic fiber as the supplementary. The contrary, synthetic fiber mostly derives from the high energy consumption process so that fiber concrete is still considered not eco-friendly material. Thus, the alternative material for fiber is still widely opened such as utilizing wire-based waste like bead wire scrap from the used tires. The exposure of this paper is examining the fiber concrete properties of waste-based fiber concrete using up to 2% of bead wire scrap supplementary to the weight of cement. The physical and mechanical characteristics of bead wire scrap are eligible for the fiber in concrete which tensile strength reaching 615 MPa. Split tensile test of the fiber concrete resulted is best at 0.5% of bead wire scrap supplementary with the split tensile capacity of 2.57 MPa. Though, the capacity of the fiber concrete is investigated to have fluctuation on its supplementary variation percentage which could be concluded due to the non-uniformity of the fiber distribution in the concrete during mixing and moulding.

1. Introduction
Prominently, non-biodegradable waste cause major threat to the environment which needs extra energy to decompose. One of them is scrap tire which dominantly consist of rubber and wire. The usual option of decaying the tires is burning them that definitely cause harmful effects, therefore the efficient way to dispose them are seriously needed [1]. Hence, the usage of scrap tires from cars and trucks has been developed nowadays for construction.

Tires are made of plies of reinforcing cords extending transversely from bead to bead, on top of which is a belt located below the thread [2]. Tires from trucks and cars are quite different but both have steel beads attached to the rubber which steel fibers but the distribution is mostly uniform for truck tires [3]. Noting from the scrap tires composition, wider application from them has been investigated due to the utilization of the rubber and the steel bead wire for aggregate in construction material. As we notice that steel has good contribution for tensile, the possibility of using steel bead wire scrap could be eligible as reinforcement in concrete.

Previous studies shown the utilization of bead wire scrap from tire to be formed as reinforcement in concrete shown that there is no significant increment in mechanical behavior of concrete such as compressive strength, flexural strength and tensile strength [4,5]. However, it could save the construction cost rather than using new steel fibers due to long life mechanical properties of the steel [4]. Scrap steel still have high price but not higher than new steel fiber.
This paper investigate bead wire scrap as the supplementary material for fiber concrete will be explained from the split tensile test result. On the other hand, the crack pattern resulted after the test is interesting to be discussed in order to observe the distribution of the bead wire scrap in the concrete mixture.

2. Material and methods

2.1. Bead wire scrap
A tire is a composite complex elastomer formulations, fibers and steel fiber cord [2]. The cord of steel fibers from trucks has the diameter of 0.15 – 0.32 mm, otherwise from cars are random and simple [3]. The difficulty faced for separating the fine crumb rubber and steel particles has proven limited attention of using this type of waste for further applications [6]. In this experiment, the bead wire scrap got from passenger cars and the diameter was 1.2 mm. Tensile test was conducted to the bead wire scrap resulting 615 MPa and the maximum elongation about 5.68 mm before it was broken. From the result, we could make sure that the quality of the bead wire scrap is still as good as the waste of steel fiber and PVA fiber about 1250 MPa [7].

In the preparation stage, the bead wire scrap was cut for the length of 50 mm. Requirement of fiber in the fiber concrete are limited to the length and diameter, which length ranges from 10 to 600 mm with equivalent diameters between 0.5 to 1.2 mm [8]. The aspect ratio of the fiber was not calculated, but the length size distribution was generally equal. Bead wire scrap supplementary could be considered as a relative material to steel fiber reinforced concrete, however main difference existed as the dimension and properties of the steel fiber used compare to the large variations in shape, length, diameter and mechanical properties of the bead wire scrap [9].

2.2. Methodology
The research conducted through laboratory experiment including preliminary experiment and destructive experiment in observing the mechanical behaviour of the concrete specimens. Preliminary experiment for the matrices of the concrete was conducted to predict the quality of the targeted concrete as shown in table 1. It is shown that both fine and coarse aggregates are not qualified for concrete mix design. Noting that water absorption is more than 4%, the possibility of reaching the target strength could be troublesome.

| Table 1. Properties of aggregates. |
|---|---|---|
| Property | Fine aggregate | Coarse aggregate |
| Specific gravity | | |
| - Apparent | 2.42 gr/cm³ | 2.60 gr/cm³ |
| - Dry | 2.13 gr/cm³ | 2.33 gr/cm³ |
| - SSD | 2.25 gr/cm³ | 2.43 gr/cm³ |
| Water absorption | 5.56% | 4.45% |
| Mud content | 2.92% | NT |
| Water content | NT | 3.82% |
| Organic content | Standard colour No.2 | NT |
| Fineness modulus | 3.6 | 7.54 |

Note: NT = Not Tested

The fiber concrete mix design followed [10] for normal concrete with the target compressive strength of 30 MPa. Besides, the target slump was 25 – 75 mm for the water cement ratio of 0.46. Supplementary of bead wire scrap was 0%, 0.5%, 1%, 1.5% and 2% from the weight of cement which was not reaching the aspect ratio of 50. Mixing process was started with the dry matrices from fine and coarse aggregate about 1 minute, continued with bead wire scrap and cement for about 2 minutes, the last poured the
water regularly in small amount until finished. After mixing, the distribution of the bead wire scrap could not be convinced uniform, moreover in the moulding process.

3. Results and discussion

Three main results to be discussed in this section are slump, concrete dry density, and split tensile strength. However, the compressive strength value is discussed as the control for the target compressive strength. The average compression performance value is 23.68 MPa below the target of 30 MPa. As stated before, the quality of concrete matrices was below standard, it is not surprising that the target strength can not be reached.

Observing figure 1 for the detail result of slump, density and split-tensile strength of concrete. First, slump value indicates that all the samples reach the target and surely gaining lower slump as the fiber was added. It should be noted that the “workability” of concrete is underestimated by slump test, so the smaller the value the condition of the fresh concrete is hard and loamy [8]. Augmentation of fiber only up to 2% from the weight of the cement has significantly decrease the flowability of fresh concrete. Further, bead wire scrap creates improper compaction of the concrete in fresh state, hence porosity of concrete climbs over. It is proven that the addition of recycled steel fiber by 2% will increase the porosity around 3-7% [11].

The trendline of density is quite different with the slump value where the addition of the fiber does not confidently increase the density of dry concrete. Logically, the more fiber adds, the more weight gains. The maximum density obtains by adding 0.5% of bead wire scrap. However, the possibility of unequal mixture of the concrete may lead to this situation where the porosity increased. It is interesting to capture the result of split-tensile strength and density, as the increased weight of fiber then the tensile-split strength is getting smaller. Noticing the 2% addition of fiber is ascending, it strengthens that the difficulty of compaction process for fiber concrete that lead to strength fatalities.

![Figure 1. Slump, density and split-tensile strength values.](image-url)
In a big frame, the fiber concrete by using bead wire scrap is promoting unsatisfactorily result. The diameter of the bead wire of 1.2 mm and the addition of percentage in the concrete could pass the aspect ratio of the concrete so that the quality of fresh concrete is very tough for compaction. Thus, the porosity of concrete might be high that inhibits the split-tensile strength to reach its maximum capacity. The procedure during mixing and compacting may contribute to the given result. Investigating the pattern of crack as seen from figure 2, the contribution of the bead wire scrap was quite distinct. Once we compare the crack of normal concrete (0%) and fiber concrete, the path of crack of normal concrete was like a straight line, hence the fiber concrete was not. The addition of 0.5% of concrete produces crack path like 0% but the distribution of the fiber is equal to the ratio of concrete volume so that the bonding between the cement, fiber, and matrices were still good.

![Figure 2. Crack pattern after split-tensile test.](image)

Arbitrary path of crack for higher percentage of bead wire scrap informed that the fiber held the tensile force good. However, the bonding of matrices inside was too weak so that the composite concrete did not work well in handling tensile force.

4. Conclusion

After examining the experiment results, we may conclude as follow:

- Maximum addition of bead wire scrap is only 0.5% for the diameter of fiber 1.2 mm and the length of 50 mm.
- The fiber aspect ratio should be seriously considered to derive targeted strength of fiber concrete as the bead wire scrap used in this experiment was quite big and the length was quite long.
- Distribution of the fiber inside the concrete mixture must be equal as well as the compaction process so that the porosity will not climb high.

References

[1] Gul S and Naseer S 2019 Concrete Containing Recycled Rubber Steel Fiber Procedia Struct. Integr. 18 101–7
[2] Siddique R and Naik T R 2004 Properties of concrete containing scrap-tire rubber – an overview Waste Manag. 24 563–9
[3] Flores N, Flores D, Hernández-olivares F and Navacerrada M A 2017 Mechanical and thermal properties of concrete incorporating rubber and fibres from tyre recycling Constr. Build. Mater. 144 563–73
[4] Samarakoorn S M S M K, Ruben P, Wie J and Evangelista L 2019 Mechanical performance of concrete made of steel fibers from tire waste Case Stud. Constr. Mater. 11 e00259
[5] Sengul O 2016 Mechanical behavior of concretes containing waste steel fibers recovered from scrap tires *Constr. Build. Mater.* **122** 649–58

[6] Onuaguluchi O and Banthia N 2019 Value-added reuse of scrap tire polymeric fibers in cement-based structural applications *J. Clean. Prod.* **231** 543–55

[7] Ganjian E, Jalull G and Sadeghi-pouya H 2015 Using waste materials and by-products to produce concrete paving blocks *Constr. Build. Mater.* **77** 270–5

[8] Newman J and Choo B S 2003 Advanced Concrete Technology - Processes (Burlington: Elsevier Ltd)

[9] Papakonstantinou C G and Tobolski M J 2006 Use of waste tire steel beads in Portland cement concrete *Cem. Concr. Res.* **36** 1686–91

[10] Nasional B S 2000 *SNI 03-2834-2000 tentang Tata cara pembuatan rencana campuran beton normal*

[11] Liew K M and Akbar A 2020 The recent progress of recycled steel fiber reinforced concrete *Constr. Build. Mater.* **232** 117232