Performance quality of waste-based paving block using rebar tie wire supplementary

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Abstract. The construction industry undeniably contributes to the CO₂ emission to the earth due to the time-consuming process and high energy needed. Steel, concrete, iron, glass and plastic material are commonly used in the construction site so as the waste can be seen around. Construction waste treatment is potentially reused for another construction product due to its good material properties. Rebar tie wire is one of the beneficial construction wastes besides steel due to its remarkable tensile properties about 173 MPa. Utilization of rebar tie wire addition for enhancing the mechanical properties of a paving block will be the focus of this paper. The percentage of the rebar tie wire addition was limited until 3.5% to the weight of cement. The water-cement ratio of the paving block mixture was locked to 0.3, other than that the proportion of cement to sand was 1 to 2.5. The target of A type of paving block based on SNI 03-0691-1996 was reached by the addition of rebar tie wire between 2% and 3.5% which best compressive strength of 46.67 MPa resulted from 3% of addition. Moreover, the abrasion and absorption test showed the same good result as the quality of compressive strength.

1. Introduction
Waste production in a lifetime of construction project is quite massive and mostly needs further treatment of disposal. Organic waste such as soil, water and wood are easy to degrade, however some big parts of the waste are non-degradable like steel, plastic, concrete, chemical material, and so forth. Current regulation has forced the utilization of previously discarded construction and demolition waste as recycled materials [1]. Recycled utilization is an idealism method to deal with construction and demolition waste in economic and environmentally friendly characteristics [2].

Concrete waste is mostly used for soil improvement before compaction. Along with concrete, steel wastes are also recyclable to be used as new composite materials. Utilization of steel wastes such as rebar tie wire (RTW) waste from construction site for composite material are widely opened for development. In this paper, RTW is evolved in the concrete paving block in order to increase the mechanical behavior.

Initial research of concrete paving block for blockmaking plants using 75% recycled aggregate were successful. Sufficient proportion of fine recycled aggregate ensured that the clogging of the plant did not happen so that coarser recycled aggregate used was profitable for this application [3]. The development of using RTW in concrete paving block might be essential for efficient construction waste disposal to be used for commercial construction material.
Definition of paving block according to [4] is a material composed by Portland cement, water, aggregate with or without admixture which do not decrease the strength of the paving block. Common application of paving block is pavement, other than that the quality of the paving block will notify the load capacity that can be resisted.

2. Material and method

2.1. Rebar Tie Wire (RTW)
The availability of RTW in construction site is mounted and usually in one size diameter use, however the length size was varied in length. The diameter and length of RTW used in this research were 0.8 mm and 30 cm respectively. Preliminary experiment regarding the RTW conducted was tensile test (see figure 1) which resulted tensile strength = 173.73 MPa and maximum elongation = 63.92 mm.

![Figure 1. Rebar tie wire tensile test.](image)

Mechanical properties of RTW is not as good as steel wire so that chemical substances will probably much different than steel wire. Utilization of RTW as the supplementary material of concrete paving block will require 0%, 2%, 2.5%, 3% and 3.5% from the weight of cement. Previous work from [5] shown that the addition of steel fiber until 1.5% did not the required spilt tensile strength of 3.6 MPa. Preliminary examination to the fine aggregates is served in table 1. We can infer that the quality of fine aggregate is good for the concrete paving block design.

| Properties         | Fine aggregate |
|--------------------|----------------|
| Specific gravity   |                |
| - Apparent         | 2.78 gr/cm³    |
| - Dry              | 2.55 gr/cm³    |
| - SSD              | 2.63 gr/cm³    |
| Mud content        | 3.37 %         |
| Organic content    | Standard color No.2 |
| Water content      | 3.67 %         |
| Fineness modulus   | 3.74           |
| Absorption         | 3.14 %         |

2.2. Methodology
The concrete paving block mix design utilizing RTW as supplementary material was following the design standard SNI 03-0691-1996. The composition of cement and fine aggregate was 1 to 2.5 and water-cement ratio applied was 0.3. Based on that restrictions, the target quality of concrete paving block was expected to reach class A which can hold the compressive strength up to minimum 35 MPa. After all the required materials were ready, the mixer concrete was operated. At the very first, the RTW fiber was dry mixed with cement by hands in order to make sure the uniformity of the final concrete
block mixture. The concrete block is rectangular cube with detail size of $(210 \times 105 \times 80)$ mm. Curing session by soaking into the water for paving block specimen was 28 days before conducting compression, abrasion and absorption test. Particularly for abrasion test, the specimen was cut into a dimension of $(50 \times 50 \times 20)$ mm. The standard procedure of absorption based on SNI 03-0691-1996 must be soaked in the water for 24 hours and dried using the oven in the temperature of $105^\circ C$ [6].

3. Result and discussion
Absorption of the concrete paving block as served in figure 2 detriment as the number RTW supplementary added to the concrete. Water absorption of concrete is naturally related to the nature of the pore system which is affected by the properties of cement used. For the same water-cement ratio, coarse cement tends to a hardened cement paste with higher porosity than finer cement [7]. Augment of RTW contributes to negative porosity of the concrete paving block so that the compressive strength of concrete rises too. However, the 3.5% of RTW supplementary has shown unsatisfactorily result of larger absorption value. The condition of greater amount of RTW fiber has developed more voids in the specimen which probably due to uneven distribution of the RTW fiber. From the result of compressive strength, we could convert into tensile strength using the approach proposed by ACI about 5.8 MPa [8].

![Figure 2](image_url)

**Figure 2.** Compressive strength, abrasion, and absorption values

The purpose of performing absorption was to determine the moisture absorption capacity in the specimen. From previous work of concrete paving block employing recycled plastic waste indicated that
the specimen was gauged to be hydrophobic [9]. Thus, supplementary material of fiber-like may result lower absorption in certain proportion.

Abrasive forces applied between the forces and moving objects was the procedure of knowing the abrasion of some construction materials applied in pavements, floors, highways and so on [7]. Indeed, the abrasion will inversely correlate the compression behavior of the material. From figure 2, the lower the abrasion, the higher the compressive strength. The percentage of RTW by 2.5% until 3% is the most sufficient proportion for getting the best quality of class A concrete paving block.

Noting RTW fiber characteristic is not water absorber, the reaction of cement and water does not affect the cohesion of the concrete paving block mixture at all. Different with the utilization water-absorber fiber type which may contribute the loss of cohesion between concrete mixture [10]. The compression behavior by adding non-water absorber will develop higher compression strength and better abrasion. However, the amount of supplementary fiber must be considerable.

4. Conclusion

Construction waste is better solved by recycling into another new construction material so that the zero waste of the construction project could be viable. Implementation of RWT in concrete paving block has proven to meet good requirement of new by-product concrete paving block. However, further research and development regarding RTW could be helpful for the following suggestions:

- The aspect ratio of the RTW fiber should be calculated first so the percentage of addition in concrete block mixture can be precise as the target strength.
- In order to conclude integral performance of RTW concrete paving block, the remaining test of acid resistance should be better conducted.
- Distribution of the RTW fiber must be attempted so that the voids will not present for the hardened concrete block.

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