Application of woven waste tires gabion wall as slope reinforcement for preventing landslide in laboratory

Arwan Apriyono^{1,*}, Sumiyanto¹, Yanto¹, and Bogie Arif Hidayat¹

¹Civil Engineering Department, Jenderal Soedirman University, Purwokerto, Indonesia

Abstract. This study presents the application of woven waste tires as slope reinforcement for preventing slope failure, reducing construction costs and minimizing environmental hazards associated with the increasingly large amount of waste tires in Indonesia. To this end, we performed laboratory experiments using five stripe distance variations of woven tires – i.e. 3, 4, 5, 6, and 7 cm as ribs of a gabion wall. Five gabion wall samples sized 50 cm x 50 cm x 25 cm each were made. Each sample was fastened using one of these woven tires. A loading test was conducted on each gabion wall sample and the strength was determined from the maximum capacity before failure. The correlation between the gabion wall strength and strip distance – boulder diameter ratio was used to infer the most effective model. The result suggests that the strip distance – boulder diameter ratio of 0.4 is optimum with a corresponding strength value of 1718 kg.

1 Introduction

Landslides are one of the most dangerous disasters in Indonesia with respect the scope of damage and lives lost in the last decade. According to National Disaster Management Coordinating Board data, more than 500 landslides have occurred in Indonesia [1] spread along hundreds of areas as shown in Fig. 1 [2]. Hundreds of people are killed and thousands displaced by landslides during the rainy season every year [3]. To reduce the number of victims, effective mitigation measures are important.

* Corresponding author: arwan.unsoed@gmail.com

Fig. 1. Spatial distribution of landslide in Indonesia.

Many landslide prone areas are not equipped with landslide mitigation infrastructure due to limited financial resources available from the government [4]. On the other hand, common mitigation measures currently applied in Indonesia such as retaining walls made from arranged rock or concrete, gabion walls and sand bags are very expensive to build and unaffordable by local people. Hence, low-cost materials for landslide mitigation measures are helpful in reducing the impact of landslides on people.

In this study we propose woven waste tires as part of a gabion wall as an alternative material for landslide mitigation measures. This material will substitute more common material such as galvalume wire as well. As the amount of waste tire is abundant, its availability is high and its cost is cheap, and woven waste tire will be able to be independently built by local people in landslide-prone areas. Here, we present an experiment with a woven waste tire design with various stripe distances to determine the optimal stripe distance. Moreover, laboratory testing on its strength is also presented.

2 Retaining structures

Retaining structures such as retaining walls, gabion walls and sand bags are common constructions widely used in landslide mitigation. These structures are built in order to stop the landslide movement so damage can be minimized [5]. Here are some examples of construction often used retaining structures: impoundments, roads, and railways. [6]. As the geotechnical industry has evolved in the last decade, many new techniques of retaining structures have been developed. For instance, a combination between retaining structures and geosynthetics was applied in bridge abutments well known as Geosynthetic Reinforced Soil Integrated Bridge Systems [7].

The most simple and effective retaining structure widely used in both rivers and hilly areas is the gabion wall [8]. A gabion wall is commonly made from galvalume wire mesh filled with stone as demonstrated in Fig. 2 [9]. They are stacked one above the other and securely tied together to form a massive structure. The stability is achieved by the self-weight, hence high-density rocks are used as the most common filling material.

Fig. 2. Example of a Gabion Wall.

3 Waste tires application in civil engineering

Rapid growth of the automotive industry increasingly produces waste tires. Unfortunately, poor management of these wastes will cause environmental problems. Waste tires are uneasily biodegradable even after a long period of landfill treatment [10]. Application of waste tires in civil construction can reduce the environmental problem, and several advantages of these materials can be determined.

In the last decade, waste tires have been used for civil engineering purpose, e.g. concrete mixing, pavement structure and soil improvement [10]. In concrete engineering, waste tires can also be used to replace the aggregate. Mixing concrete with waste tires improves both mechanical properties and durability [11]. Waste tires are also used in rigid pavement to increase flexural strength [12] and the toughness of the structure [13].

Especially in the geotechnical field, waste tires are widely used for soil improvement. Considering the advantages of these materials including durability, tensile strength and overwhelming availability, waste tires have a great potential for alternative soil reinforcement. To do this, much research has been conducted to exploit waste tires as soil improvement, such as for soft soil stabilization [14], back fill reinforcement [15], and scouring prevention [16]. Those studies prove that waste tires have high potential as an alternative material in soil improvement.

4 Methodology

Woven waste tires consist of tire stripes by which different stripe distances yield different strengths. In this study, the optimum stipe distance is sought. To do this, laboratory scale model testing was conducted. The laboratory experiments required for this purpose are described below.

4.1 Preliminary testing

Two main materials are required for a gabion wall: a gabion box and stones as filler. In this study, the gabion box was formed by woven waste tires to replace galvalume. Stone boulders with approximately 10 cm in diameter was used as filler material. A tensile strength test of the waste tires was performed in the laboratory to determine the quality of this material. These tests used a universal testing machine in the Civil Engineering Laboratory of Jenderal Soedirman University. Documentation of the waste tire tensile strength test is shown in Fig. 3.

Fig. 3. Waste tire tensile strength test.

4.2 Loading test

The performance of the wasted tires gabion wall was measured through a loading test conducted in the laboratory. Five variations of woven waste tires stripe distance were applied to the model: 3, 4, 5, 6, and 7 cm as shown in Fig. 4.

Fig. 4. Stripe distance variation.

These woven waste tires were used to create the gabion boxes, and together with the stone as filler, form gabion wall structures. Accordingly, five gabion wall samples sized 50 cm x 50 cm x 25 cm each was made. A loading test was conducted on each gabion wall sample and the strength was determined by the maximum capacity before failure. The correlation between the gabion wall strength and strip distance was used to infer the optimum woven tires strip distance, indicated by the largest strength value. One of the gabion walls loading test samples are shown in Fig. 5

Fig. 5. Loading test.

5 Result and discussion

Based on the test, the tensile strength of waste tires is approximately 27.28 MPa. Considering the tensile strength of galvalume wire (± 400 MPa), a higher area of woven waste tires was applied to reach the same tensile force. The result of the tensile strength test is shown in Table 1.

Table 1. Waste tires tensile strength test result.

No	Width (cm)	Thin (cm)	Length (cm)	Max Load (kN)	Tensile Strength (MPa)
1	3.0	0.2	9.0	1.50	25.00
2	3.0	0.2	9.0	1.85	30.83
3	3.0	0.2	9.0	1.65	27.50
Average					27.78

Correlation between displacement and load resulted from the loading test used to determine the strength of the gabion wall. From that loading test, the strength for every stripe distance variation was obtained and shown in Fig. 6.

Fig. 6. Loading test result for each stripe distance variation.

Fig. 6 shows that every variation of stripe distance has the same pattern of displacement-load correlation. Strength hardening behaviour for all of the samples can be identified from these patterns. When load was applied on the sample, the gabion wall almost reached failure, though the box endured it until the real failure. This proves that the strength of the gabion wall is determined by the strength of the box.

Fig. 6 is used to analyse the strength of the gabion wall. Considering the gabion wall application in the field, effective variation will be determined by analysing the correlation between the ratio of stripe distance and boulder diameter (J/D) and maximum load. The result is presented in Fig. 7.

Fig. 7. Correlation between J/D and Maximum load.

Fig. 7 shows that the maximum load is about 1750 kg when J/D is 0.3 and the minimum load is about 1450 kg when J/D is 0.7. The pattern of the graph shows that increasing J/D will decrease the gabion wall strength. The strength slightly declines when the J/D increases from 0.3 to 0.4 cm (1 %). On the other hand, the strength decreases steeply when the J/D increases more than 0.4 ($\pm 5\%$).

6 Conclusion

Based on the laboratory model test, woven waste tires are worthwhile as an alternative material for gabion wall boxes with respect to both tensile strength and environmental effect. The correlation between displacement and load from the loading test shows that the gabion wall has strength hardening models of failure. In the field application, the most recommended J/D is less than 0.4.

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