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Laboratory investigation of the effect of rubber coating on stone ballast life

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Abstract

So far, many studies have been conducted to improve the degradation behavior of ballasted tracks by using waste tires mixed with ballast. However, coating stone ballast materials with rubber particles, which has been proposed in recent years, has received less attention in the literature. In this paper, a laboratory investigation on the effect of rubber coating on ballast life was carried out. For this purpose, the optimal coating method with a focus on selecting the appropriate percentage of rubber particles mixed with adhesive was presented in the first stage. Then, by applying the selected coating, its effect on the abrasive behavior of ballast taken from a quarry in Tehran city was investigated through Los Angeles and Micro-Deval tests. In the next step, breakage and settlement of the ballast with and without rubber coating were evaluated by performing ballast box test by applying 100,000 loading cycles with an amplitude of 15 kN and frequency of 3 Hz. The results confirm that the application of rubber coating has led to a reduction in the Los Angeles and Micro-Deval coefficients by 66.15% and 93.18%, respectively, and increasing settlement and decreasing breakage under cyclic loading by 24.17% and 88.32%, respectively. In general, according to the Canadian Pacific Rail Code, the use of this technology can enhance the average ballast life by almost 91%.

Keywords: Stone ballast, rubber particle, rubber coating, ballast life, abrasion, breakage, settlement.

1 Introduction

Despite the extensive advances in the railway industry, the use of ballast in railways has always been welcomed by the world's railways, which is due to the merits of this material such as its low cost of implementation, and high ability to dampen noise and vibration, free drainage, etc. One of the demerits of this important layer is the high rate of deterioration and short maintenance intervals, which leads to high costs in the long run. For this reason, several solutions have been proposed to increase the life of the ballast layer and reduce its degradation rate.

Covering ballast aggregates with crumb rubber is also a new method to increase ballast durability that has been studied in recent years. Based on the study of Fontserè et al., this method reduced the Los Angeles abrasion (LAA), Micro-Deval abrasion (MDA) and increased the resistance to weathering [1]. In accordance with conducted research by Sol-Sánchez et al., Coating aggregates with crumb rubber smaller than 0.5 mm reduced long-term settlement and damping [2]. The study of the shear properties of these materials by Guo et al. has shown that the use of ballast with rubber coating decreased the shear strength and stiffness of the track, but the use of 0-0.025 mm rubber particles caused less reduction in these two parameters [3]

In the literature, the effect of rubber coating on ballast life has not been considered. Therefore, in this study, after selecting the best method for creating rubber coating on ballast aggregates, the effect of using this material on increasing the lifespan of materials was studied by performing Los Angeles and Micro-Daval experiments. Besides, the rate of short-term settlement and breakage of this material with traditional ballast was compared.

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2 Methods

In the present study, ballast taken from the Shahriyar quarry has been examined. The geological origin of the rocks of this quarry is igneous (andesite) and the grading of the ballast aggregates has been selected according to the Australian TFNSW freight rail network and AS2758.7-1996 [4] (see Figure 1).

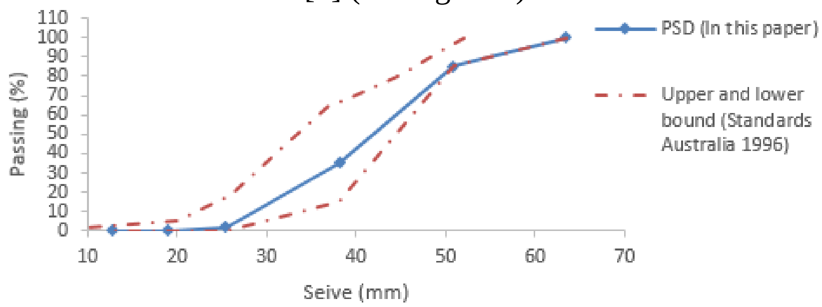

Figure 1. Ballast graduation curve

Based on conducted studies, ballasts covered with smaller rubber particles have higher shear resistance and experienced less settlement [3]. In the literature, the behaviour of ballast covered with rubber particles smaller than 0.5 mm has also been certified [2]. Therefore, a size smaller than 0.5 mm was selected to coat the stone ballast aggregates. The adhesive chosen to cover the ballast aggregates is a single-component adhesive with a polyurethane base made by the Siklame Company.

Sample preparation

To find a low-cost method of coating aggregates, first, the strength and economic efficiency of various adhesives were evaluated. Then, six 10 kg ballast samples were coated with adhesives containing zero, 10, 15, 20, 25, and 30% rubber and placed in a container full of rubber particles. Afterwards, the Los Angeles coefficient of these samples by ASTM C535-03 [5] was calculated. The amount of adhesive utilized to cover the samples was, also, compared. According to the results of the studies, the optimal percentage of rubber mixed with the adhesive has been obtained by Minitab software, which was 15% [6].

Ballast box test

The ballast box apparatus in the superstructure laboratory of the Faculty of Railways of Iran University of Science and Technology has been employed to evaluate the mechanical behaviour of ballast samples with and without rubber coating. The box of this apparatus is in dimensions of 70 × 30 × 45 cm. This ballast box is planned to simulate the passage of half of the train axle wheel over a part of the tie under the rail. In this test, cyclic load with an amplitude of 15 kN and a frequency of 3 Hz was applied to the sample through a piston.

3 Results

Ballast life with and without rubber coating

After coating ballast aggregates, the dry and wet abrasion of the coated sample was investigated and its lifespan was calculated and the obtained values were compared with the traditional ballast introduced by Esmaeili et al.[7]. Results indicate that the LAA of the ballast sample with rubber coating was 0.7 which was 66.15% less than the reference ballast. Moreover, in the ballast sample with rubber coating, the Micro-Deval abrasion was 0.007. It means that the use of ballast with rubber coating led to an almost 93.18% decrease in MDA.

According to research by Klassen et al. for Canadian Pacific Rail, ballast life is calculated using equation 1[8].

$$M_e = \frac{e_x}{0.567} \times 10^a \tag{1}$$

$$a = [(-0.017)(A_n - 60)] + 2.5 \tag{2}$$

In equations 1 and 2 M_e refers to the gradation corrected ballast life and e_x is the void ratio for the gradation which was used. A_n is also the abrasion number of ballast, which is equal to the sum of the Los Angeles coefficient and 5 times the Mill or Micro-Deval abrasion of the sample [9].

$$A_N = LLA + 5MDA \tag{3}$$

The void ratio was considered to be approximately 0.58 and the predicted lifespan for the ballast specimens with and without rubber coating was as shown in Figure 2[10].

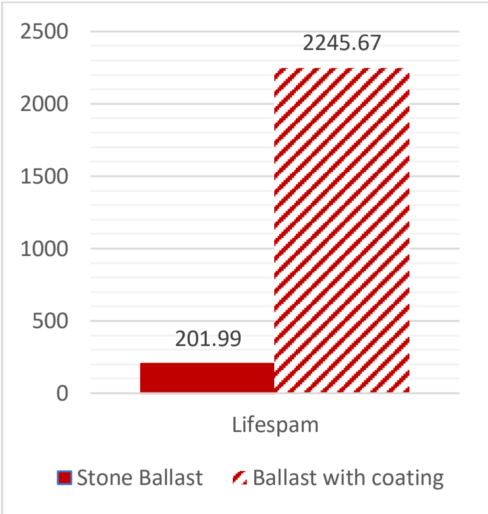

Figure 2: The lifespan of ballast with and without coating.

Following Figure 2, coating ballast aggregates with rubber particles increased the sample life by 91%.

Ballast box test results

The vertical settlement of ballast with rubber coating was 9.1 mm after 100,000 cycles, while it was 6.9 mm for ballast without coating. In other words, the settlement of coated ballast in the short term was 24% more than reference ballast.

In this research, following the gradation of ballast, the Indraratna index has been employed to evaluate breakage. BBI was calculated according to equation 4 [11].

$$BBI = \frac{A}{A+B} \tag{4}$$

A: The area enclosed between the ballast graduation curve before and after the test.
B: The area enclosed between the ballast granulation curve after the test and the desired boundary of the maximum fracture and the smallest sieve size available.

The BBI of stone ballast was around 0.0412 and it was 0.0048 for ballast coated with rubber particles. Therefore, the replacement of traditional ballast with coated ballast brought about a decrease of around 88.32% in BBI.

4 Conclusions and Contributions

The results of the evaluations are as follows:

- The use of glue containing 15% rubber particles was desirable.
- LAA in ballast with coating compared to stone ballast decreased 66.15%.

- Coating ballast aggregates with rubber particles led to a decrease of 93.18% in Micro-Deval abrasion in comparison with stone ballast.
- The lifespan of rubber-covered ballast increased by 91% compared to ballast without coating.
- Settlement of coated ballast was 24% more than reference ballast while BBI of this sample was 88.32% less than traditional ballast.

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