Experimental studies on the mechanical behavior of fouled ballast using large-scale testing

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Introduction

Rail transportation is a resource-efficient mode of transportation that provides economic benefits, higher safety, and lessens travel time. Ballasted rail tracks are the conventional and popular rail tracks all around the world. The ballast layer, which consists of highly angular granular particles with sizes ranging from 15 to 65 mm, is designated as the principal load-bearing structure in a ballasted track foundation. The void ratio of the ballast layer is high as it consists of various sizes of angular particles, facilitating water to drain out efficiently from the track. Nevertheless, ballast is fouled and degraded with time due to particle breakage and foreign material intrusion. This deterioration of the ballast layer significantly affects the performance and longevity of the rail track while impeding track drainage.

The shear strength of the ballast plays a vital role in the provision of lateral stability to the rail track and in maintaining the track geometry. The conventional direct shear apparatus does not have the potential to conduct direct shear tests on large-size granular materials due to its size constraints. In addition, only limited studies have been performed to understand the effect of fouling on the permeability behavior of railway ballast. Consequently, this study explores the shear, dilation, and permeability behavior of fouled ballast using the large-scale testing facilities available at the Department of Civil Engineering, University of Peradeniya, Sri Lanka (Fig. 1).

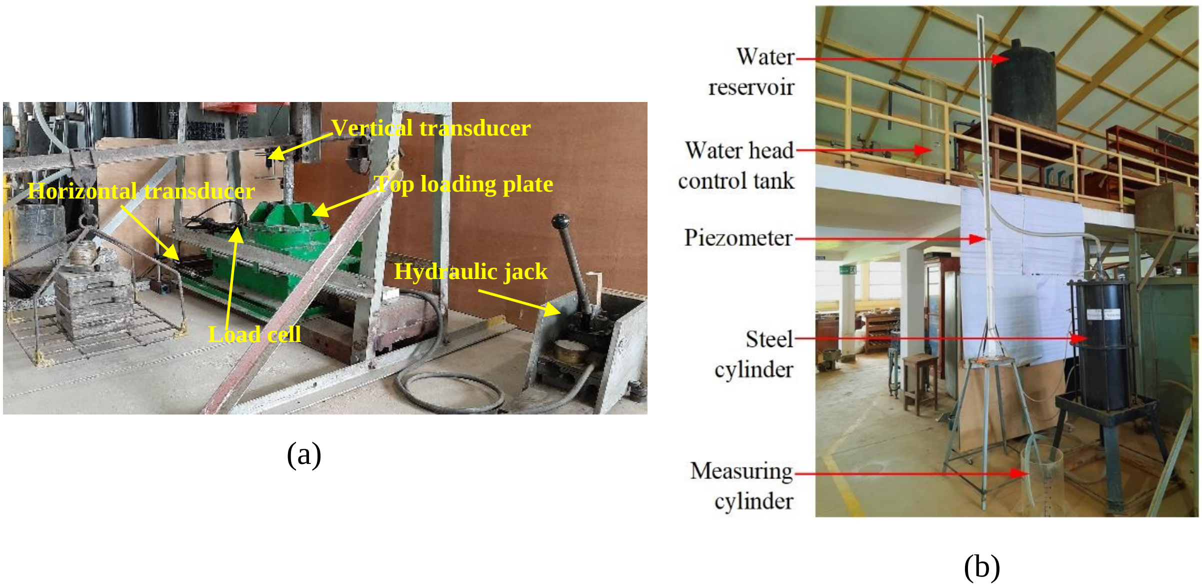
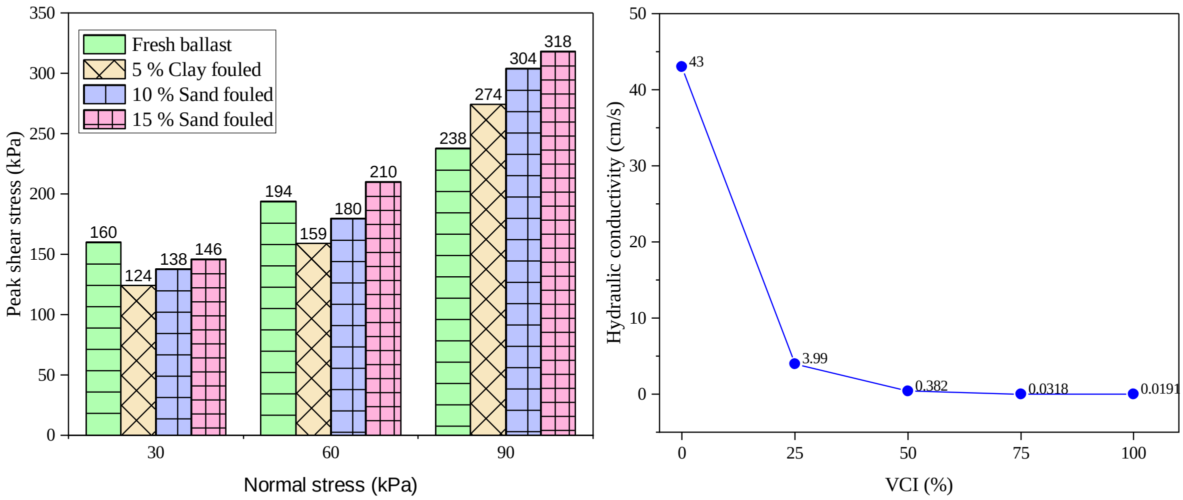


Fig. 1: (a) Large-scale direct shear apparatus; (b) Large-scale constant head permeability apparatus

Methodology and Results

A series of direct shear tests were conducted on fresh and fouled ballast (5 % clay fouled, 10 and 15 % sand fouled) to study the effect of fouling on the shear behavior of ballast using large-scale direct shear apparatus. The fouling percentage was chosen as the mass percentage of fresh ballast. Tests were conducted under three different normal stresses with a constant shearing rate of 4 mm/min. As expected, higher shear stress was observed with larger normal stress irrespective of the type of test specimen due to the induced particle interlocking. Peak shear stress variation of all specimens (Fig. 2(a)) showed that the fouling reduces the shear stress of ballast under 30 and 60 kPa normal stresses as fouling materials reduce the contact between adjacent ballast particles thus reducing the friction. Under the higher normal stress (i.e. 90 kPa), the effect of densification of the specimen with the fouling material intrusion was more significant as fouled ballasts showed higher peak stresses than that of fresh ballast.

The large-scale permeability test was carried out at the laboratory to attain the hydraulic conductivity of fresh ballast used in ballasted tracks in Sri Lanka and to examine the effect of fouling (i.e. used sandy clay as fouling material) on the permeability behavior of ballast. The void ratio and the hydraulic conductivity of fresh ballast were 0.74 and 43 cm/s, respectively. Further, tests were conducted on fouled ballast with different fouling levels using an index called Void Contamination Index (VCI) of 25, 50, 75, and 100 %. It is found that the hydraulic conductivity of fouled ballast was less than that of fresh ballast and it reduced with the increase in VCI (Fig. 2(b)).



(a) (b)

Fig. 2: (a) Peak shear stress vs Normal stress; (b) Hydraulic conductivity of fresh and fouled ballast

Conclusions

The scope of this paper was limited to the laboratory tests conducted on fresh and fouled ballast using large-scale testing facilities. Based on the direct shear test results, the shear stress increased with the normal stress increment and reduced with fouling at lower normal stresses. Even though the shear strength of fouled ballast is higher than the fresh ballast at the higher normal stresses, the permeability test results show that hydraulic conductivity is dramatically reduced by the fouled ballast.

Acknowledgment: *Accelerating Higher Education Expansion and Development (AHEAD) Operation of the Ministry of Higher Education funded by the World Bank (Grant No: AHEAD/RA3/DOR/STEM/No.63) is appreciated for the support.*

Keywords: Large-scale testing, fouled ballast, shear, permeability