infrastructures

Review

Ballast Contamination Mechanisms: A Criterial Review of Characterisation and Performance Indicators

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Abstract: Across the world, ballasted railway tracks are utilised extensively due to their cost efficiency, ease of drainage, and capacity to withstand cyclic imposed loadings from heavy trains. In spite of these benefits, the ballast is often considered as a flexible medium; as such, its continuous deterioration is largely disregarded. Geotechnical challenges such as ballast contamination in the form of particle fragmentation, deposition of weathered materials, upward pumping of clay and fines from underlayers, and coal intrusion have led to differential settlements and reduced drainability of tracks, thereby exacerbating track maintenance costs. This study reviews existing works of literature to expound on the mechanisms for ballast contamination and to highlight the fundamental parameters that guide the characterisation and performance evaluation of railway ballasts. The study shows that ballast fragmentation accounts for about 76% of commonly recorded contaminations, while it is also observed as the most critical to track stability. As such, a variety of indices and specifications for ballast gradation have been established worldwide to guide practice in ballast characterisation and performance evaluation. However, the mechanisms of ballast fragmentation and deterioration require further research to guide the improvement of contemporary guidelines, and mitigate the risk of abrupt track failures, especially in developing countries.

Keywords: railway; ballast; fouling; degradation; ballast breakage; track drainage

1. Introduction

Ballasted railway tracks constitute the major transportation grids in many countries across the globe; they convey commuters, as well as freight and bulk cargoes, between cities, mines, farmlands, and ports [1]. The railtrack structure can be categorised into two groups: the substructure and the superstructure. The substructure comprises the subgrade, the sub-ballast, and the ballast, while the superstructure encompasses the sleepers (timber or concrete), the fastening mechanism, and the steel rails [2]. However, the ballast may be regarded as a superstructure component in certain regions of Europe [3]. The safety and efficiency of ballasted track railways rely entirely on the complex and integrated collaboration of all track components in response to the recurrent loads imposed by high-speed locomotives. While components of the superstructure are mostly elastic in nature and generally endure minimal deformations, granular-layered substructures such as the sub-ballast and the ballast frequently undergo deformations of high significance subject to the massive recurring stresses induced by the combined effects of aggravatingly heavier and speedier locomotives and the dynamic loading initiated by rail or wheel irregularities [4]. As such, the reactions of the substructure often