Feasibility of Coal Mine Overburden as Backfill Material for Mechanically Stabilised Earth (MSE) Wall Supporting High Speed Train

by:
Harshal Verma (2021QIZ8246)

under the supervision of:

Prof. B. Manna, Prof. D. Williams and Prof. P Mishra

Abstract

Rapid urbanization and industrial development have led to an increasing demand for energy and minerals, necessitating the expansion of mining activities worldwide. This large-scale extraction of natural resources generates substantial quantities of waste materials, including tailings and waste rock, which pose significant environmental and geotechnical challenges. Inadequate disposal and management of mine waste can result in land degradation, groundwater contamination, and catastrophic failures. Simultaneously, economic development has driven the expansion of highway and railway networks, necessitating the construction of efficient and reliable transportation infrastructure. Mechanically Stabilized Earth (MSE) walls have become integral to such projects due to their cost-effectiveness, ease of construction, and ability to sustain heavy loads in complex geotechnical conditions. However, the increasing emphasis on sustainable infrastructure and the depletion of naturally available suitable fill material have prompted interest in alternative, environmentally friendly backfill materials for MSE walls. In this context, coal mine overburden presents a viable alternative as a sustainable backfill material for MSE walls. Overburden materials, consisting of soil, rock, and fragmented strata removed during coal mining operations, are typically discarded as waste, contributing to environmental degradation. Repurposing coal mine overburden as backfill can mitigate waste accumulation, lower construction costs, and reduce the environmental impact of mining activities.

This study investigates the feasibility and behaviour of coal mine overburden as backfill material for MSE walls through a series of material and model tests. Comprehensive geotechnical characterization was performed, including direct shear, triaxial, and resonant column tests to assess the mechanical strength of the material. Additionally, a kinetic leaching column test was conducted over twelve weeks to evaluate the geochemical properties of leachate and assess potential environmental impacts. The feasibility of employing electromagnetic wave based method to estimate the basic geochemistry of leachate was also explored. The interaction between coal mine overburden and two different types of geogrids was evaluated through large-scale box geogrid pullout tests, with locally available sand used

as a reference material. The results indicated superior pullout resistance of coal mine overburden compared to local sand. Furthermore, 3D discrete element simulations of geogrid pullout tests were conducted using the open-source software YADE to analyse the influence of various geogrid parameters on pullout resistance.

A reduced-scale physical model of an MSE wall was constructed within a mild steel tank with varying geogrid spacing. Surface vibrations generated by high-speed train operations were considered the primary destabilizing force. Five different loading conditions were applied to represent varying axle loads and train speeds, with dynamic loading simulated using a computer-controlled hydraulic actuator. The results demonstrated that for reduced geogrid spacing, the applied loads were more uniformly distributed, and cumulative wall deflection did not exceed 1.5 mm, affirming the suitability of coal mine overburden as a backfill material.

Lastly, a parametric study was conducted using the 3D finite element software PLAXIS 3D. The numerical models were validated against physical model test results by comparing static stress, dynamic stress, and wall deformation. The study considered six parameters: geogrid length, spacing, wall height, facing thickness, axle load, and train velocity. Performance was assessed based on geogrid displacement, facing deformation, horizontal facing stress, track settlement, and overall factor of safety (FoS). Geogrid spacing and wall height emerged as the most critical factors influencing wall stability, whereas axle load and train speed had minimal impact. Additionally, geogrid length beyond a critical value was found to have negligible benefits. By analysing the behaviour of coal mine overburden as a sustainable backfill material and identifying key factors influencing MSE wall stability, this study provides valuable insights for the design and maintenance of coal mine overburden backfilled geogrid-reinforced MSE walls in transportation infrastructure.