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Geotechnical Challenges for the Use of Sand-sludge Mixtures in Covers for the Rehabilitation of Acid-Generating Mine Sites

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Abstract : The management of mine wastes (waste rocks and tailings) containing sulphide minerals such as pyrite and pyrrhotite represents the main environmental challenge for the mining industry. Indeed, acid mine drainage (AMD) can be generated when these wastes are exposed to water and air. AMD is characterized by low pH and high concentrations of heavy metals, which are toxic to plants, animals, and humans. It affects the quality of the ecosystem through water and soil pollution. Different techniques involving soil materials can be used to control AMD generation, including impermeable covers (compacted clays) and oxygen barriers. The latter group includes covers with capillary barrier effects (CCBE), a multilayered cover that include the moisture retention layer playing the role of an oxygen barrier. Once AMD is produced at a mine site, it must be treated so that the final effluent at the mine site complies with regulations and can be discharged into the environment. Active neutralization with lime is one of the treatment methods used. This treatment produces sludge that is usually stored in sedimentation ponds. Other sludge management alternatives have been examined in recent years, including sludge co-disposal with tailings or waste rocks, disposal in underground mine excavations, and storage in technical landfill sites. Considering the ability of AMD neutralization sludge to maintain an alkaline to neutral pH for decades or even centuries, due to the excess alkalinity induced by residual lime within the sludge, valorization of sludge in specific applications could be an interesting management option. If done efficiently, the reuse of sludge could free up storage ponds and thus reduce the environmental impact. It should be noted that mixtures of sludge and soils could potentially constitute usable materials in CCBE for the rehabilitation of acid-generating mine sites, while sludge alone is not suitable for this purpose. The high sludge water content (up to 300%), even after sedimentation, can, however, constitute a geotechnical challenge. Adding lime to the mixtures can reduce the water content and improve the geotechnical properties. The objective of this paper is to investigate the impact of the sludge content (30, 40 and 50%) in sand-sludge mixtures (SSM) on their hydrogeotechnical properties (compaction, shrinkage behaviour, saturated hydraulic conductivity, and water retention curve). The impact of lime addition (dosages from 2% to 6%) on the moisture content, dry density after compaction and saturated hydraulic conductivity of SSM was also investigated. Results showed that sludge adding to sand significantly improves the saturated hydraulic conductivity and water retention capacity, but the shrinkage increased with sludge content. The dry density after compaction of lime-treated SSM increases with the lime dosage but remains lower than the optimal dry density of the untreated mixtures. The saturated hydraulic conductivity of lime-treated SSM after 24 hours of cure decreases by 3 orders of magnitude. Considering the hydrogeotechnical properties obtained with these mixtures, it would be possible to design CCBE whose moisture retention layer is made of SSM. Physical laboratory models confirmed the performance of such CCBE.

Keywords : mine waste, AMD neutralization sludge, sand-sludge mixture, hydrogeotechnical properties, mine site reclamation, CCBE

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