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Editorial: Advances in the Design and Implementation of Cementitious Backfills

Erol Yilmaz[1]*, Shuai Cao[2,3]* and Di Wu[2,3]*

[1]Department of Civil Engineering, Geotechnical Division, Recep Tayyip Erdogan University, Rize, Turkey, [2]State Key Laboratory of High-Efficient Mining and Safety of Metal Mines of Ministry of Education, University of Science and Technology Beijing, Beijing, China, [3]School of Civil and Resource Engineering, University of Science and Technology Beijing, Beijing, China

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Edited and reviewed by:
John L. Provis,
The University of Sheffield,
United Kingdom

***Correspondence:**
Erol Yilmaz
erol.yilmaz@erdogan.edu.tr
Shuai Cao
sandy_cao@ustb.edu.cn
Di Wu
DiWu1218@ustb.edu.cn

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Editorial on the Research Topic

Advances in Design and Implementation of Cementitious Backfills

Backfill plays an essential role in the most modern mining industries worldwide. It is usually applied in the cementitious form to fill underground mined-out openings (stopes and/or voids). Consisting usually of an engineered blend of tailings, binders, and water, cementitious backfills provide numerous benefits ranging from the rapidity of their delivery and mechanical strength to environmental advantages from placing high voluminous processing tailings underground and reducing the size of surface tailing storage facilities like dams. Without hesitation, it expressively improves the safety and productivity of mines and is employed in a more unique role to form advanced mining methods. The design and operation of the backfill are multi-dimensional, covering metallurgical, rheological, hydraulic, mechanical, and geotechnical engineering disciplines. Since any backfill system comprises up to 35% of the mine's operating budget, it is vital for diverse disciplines to work in harmony with each other to create a system that is functional, optimized, and cost-effective for sustainable/green mining. Therefore, there is a need to develop innovative backfill materials and techniques for the negative impact of mining activities on the environment. Recent papers have highlighted improvements in the design and application of cementitious backfills, focusing on their preparation, design, placement, monitoring, performance, and optimization stages. This Research Topic consists of nine research contributions, delivering a broad range of knowledge on mining with a backfill that enhances underground mining efficiency via reduced stope cycle time and the increased recovery of ore. These contributions highlight several examples of cost-effective backfill types and materials, backfill recipe optimization, backfill preparation and delivery to stopes, field placement/curing conditions, stress, and temperature measurements during the pour of cementitious backfills, and monitoring.

The first contribution discusses the strength/quality characteristics of cementitious backfill produced with Pb-Zn mine tailings (Akkaya et al.). Sulfide-rich processing tailings (Pb-Zn ore) were employed to form structural cementitious backfill mixtures. It is estimated that sulfide-rich tailings backfill cured under the influence of air and water cannot resist the chemical reactions that occur, especially in the long term. The mobility of sulfur ions present in Pb-Zn tailings was explored and their effects on backfill strength/durability performance were investigated by some lab experiments (i.e., SEM, XRD, pH, ion chromatography/zeta potential/combustion experiments, and chemical analysis. To eliminate the deleterious effect of sulfurous components, type II and type IV cement (at dosages varying from 3wt% to 7wt%) were used in the backfill. It was suggested that the sort and quantity of the cement experimented on were unsatisfactory owing to the spread-out components and inner sulfate-attack present within these tailings. Cementitious backfills caused the gypsum problem, as revealed clearly by SEM observations. Nevertheless, the study noticeably showed that elemental analysis conducted by the combustion test system could offer fast/consistent outcomes in the examination of sulfur in Pb-Zn tailings. Hence, important information could be gained about the long-term backfill performance.

The second contribution evaluated the mechanical behavior of fly ash-based cementitious backfill considering the filling rate, cement dosage, and solid content (Chang et al.). In this study, to enhance the mechanical strength of underground filling, and to reduce the cement-related costs leading to social/economic benefits, gold mine tailings and fly ash (industrial solid waste) were effectively utilized. The strength of the 28–56-days cured backfill was greatly affected by the dose of fly ash in the mixture. The addition of too much fly ash caused many fine grains in the backfills and delayed the cement hydration, meaning it did not gain strength in a timely manner. The backfill with a solid content of 74%, a cement dosage of 5%, a tailings-waste rock-fly ash fraction of 2-6-3, and a calcium oxide of 3% provided better mechanical strengths than the backfill recipe implemented in the tested mining site. The backfill's strength is closely related to its pore structure, suggesting that there is a proper ratio of backfilling for cement hydration. If fly ash was being activated first and then contained in the backfill, the corresponding backfill's strength becomes higher because of the improved gel structure created by the hydration of cement. Good integration of fly ash and aggregate will lessen the fill's porosity and ensure a high-quality fill material. As a result, the paper highlighted the significance of the use of fly-ash within filling for its further promotion and application in mines.

The third contribution examines the mechanical strength characteristics of cementitious paste backfills containing alkali activated slag (AAS-CPB) via response surface modeling (Dai et al.). In this paper, the effects of factors such as slag powder SP, silicate modulus SM, and activator content AC on the strength acquisition of 3-/28-days cured AAS-CPB samples were explored. ANOVA was used to explore the status of liberated factors and their connections. It was statistically shown that a robust connection between curing age and strength variation properties exists. The major variables were silicate modulus and activator content. Increasing slag fineness and pH surge backfill strength at early curing ages (3 days), but unreacted slag limits its hydration and strength performance at longer cures. The optimum response values for the backfill were respectively, 0.3, 12,630, and 0.5 for SM, SP, and AC. This contribution highlighted that there was a robust connection among AAS-CPB's test variables, which are necessary to achieve a resilient, lucrative, and viable mine fill for most modern mines worldwide.

The fourth contribution discussed the mechanical/microstructural properties of cementitious backfill exposed to seepage conditions (Ke et al.). The backfill materials placed into underground openings unavoidably endure seepage fields, which negatively affect their ultimate strength behavior. An evolution of strength and pore structure behavior of cemented tailings backfills subjected to diverse seepage water pressures was explored in the present study. It was interpreted that the backfill's strength reduces with augmenting seepage water pressures, which leads to the backfill's microstructure being looser and more porous. The strength of the backfill exposed to seepage also drops with increasing porosity. The initiation/propagation of micro-cracks/pores in the backfill is accelerated by seepage. This eventually results in serious damage to the pore structure of the backfill and a deterioration in its strength properties. This paper also provides information on the strength/microstructure characteristics of the backfill when subjected to seepage and a technical reference for durability analysis of the backfill in water-rich underground mines.

The fifth contribution examines the Mohr-Coulomb strength factor of cementitious tailings backfill, considering temperature influence (Hasan and Ting). Field backfill monitoring indicated inconsistent escalations in total stress during curing, which could be clarified by volumetric expansion, led by a temperature rise in the backfill. Temperature, which is one of the most important curing conditions (i.e., stress and time), actually has a very serious effect on the fresh/hardened characteristics and performance of the backfill. This study explores the effect of temperature (25, 50, and 70°C) under five diverse shearing situations and three effective-stress ranks (16-32–48 kPa) on the shear-strength property of internal/interfacial-friction between non-cemented backfill and cemented backfill containing 5% cement. It suggests that the interfacial friction angle increases with rising temperature, based on the sort of product and the shearing state. The fill's cohesion does not alter with temperature variations occurring in the placed mine backfills over curing time. As a result, the paper highlights the connotation of exact plan limits (i.e., cohesion, friction angle, and shear-strength at diverse temperature-settings) for an accurate and secure stress regime in the placed cementitious backfill materials.

The sixth contribution focuses on the direct tensile properties of cemented paste backfill (Guo et al., 2022). Although many studies have been carried out on the compressive strength of cementitious backfill, the number of studies on its tensile strength is limited due to both the absence of a proper experimental technique and the fill's low tensile strength. Therefore, as an alternative to the traditional indirect tensile strength testing technique, there is a need for new alternative experimental test setups that will provide the direct tensile strength of filling. In this study, a specially designed compression-tensile load transducer (CTLT) was developed and a direct tensile test (DTS) using filling samples was prepared in the shape of a dog bone. Using this newly developed experimental setup, both direct tensile and compressive strength tests were carried out on a total of 47 filling samples and the results were evaluated. The experimental results indicated that the DTS value of the backfill rises with increasing cement content (the most sensitive parameter), solid contents, and curing age. From experimental results, it was observed that a strong link between the fill's direct tensile and compressive strengths exists. The principal contribution of this study is to disclose an innovative experimental test setup that determines the tensile strength of backfill samples. The DTS value determined from filling samples manufactured in the shape of a dog bone and placed in the newly developed CTLT device are critical to efficiently mining backfill designs for most modern mines around the world.

The seventh contribution reviews the geomechanical characteristics of fiber-containing cementitious backfills subjected to cyclic loading conditions (McLean and Cui). During their service life, cementitious fills are exposed to impact/blasting/seismic loads. To enhance the strength performance of backfills subjected to these loads, there are diverse techniques such as fiber reinforcement in the mining or construction industries. In this review paper, a new perspective is given for fiber reinforced cementitious composites (FRCC), considering the geomechanical processes of embankments subjected to cyclic tensile-shear-compression loading conditions. In terms of macro-scale strength property, it contains state-of-the-art research on pre-/post-peak response and hysteretic behavior. Besides, the pore-pressure effect on the dynamic behavior of non-matured FRCC is thoroughly discussed. A link between microscale crack propagation and damage accumulation for FRCC is also provided, offering future perspectives on fiber reinforcement. The review provides guidance and reference on the multiscale behavior of FRCC subjected to repeated loads. Additionally, it also provides updated information on innovative techniques such as using fibers within cementitious backfills.

The eighth contribution thoroughly examines the engineering design and quantitative experiments of the wear resistance of pipeline transporting backfill mixtures (Wang et al.). Being considered one of the most vital performance signs of backfilling pipelines, wear resistance is really important to better estimate the pipeline's service life. Since it is very difficult to carry out an experimental study on pipelines in underground conditions, there is a need for laboratory devices that measure the pipeline's wear resistance via pipeline material wear. In this article, a new experimental setup and application technique are offered for depicting the wear resistance of newly-established liner complex, conventional, and normal carbon-structural-steel pipelines. Using experimental tests, it determined that the newly developed composite pipeline is respectively, 12.35 and 7.32 times better than the wear resistance of conventional and ordinary carbon structural steel pipelines that are currently used in the industry. Depending on the nature of the materials used in the manufacture of the composite lining, the wear resistance mechanism of the pipeline transporting cementitious backfills to underground mine voids has been well studied. The main contribution of this paper is that composite pipelines provide a good wear resistance during the transport of fill into underground mined-out stopes. Wear resistance, especially in the elbow part of the pipeline, has been an important parameter to evaluate the best way to apply the cementitious backfill.

The last contribution to this Research Topic focuses on the wetting/drying sequence of concrete containing metal tailings (Wu et al.). The tailings can be successfully used together with slag in the production of concrete to utilize large amounts of tailings and to address the shortage of the mineral admixtures used in concrete. In this paper, concrete containing diverse contents of tailings was prepared and subjected to a wetting/drying series experiment for investigating concrete's corrosion resistance. Moreover, the degradation mechanism of the tailings-added concrete material abraded with sulfate is explained by SEM, XRD, and NMR experiments. It has been determined from experimental studies that sulfate corrosion resistance will increase if the tailings are added to the C50 concrete in appropriate amounts. If the tailings/slag ratio used in concrete is 3:7 and 5:5, the resistance to sulfate corrosion could achieve KS180. It has also been determined that a strong link between ultrasonic velocities and the mechanic strengths of concrete samples containing tailings exists. The failure of concrete that has tailings is usually due to the formation of corrosion materials (i.e., ettringite, gypsum). In conclusion, the principal contribution of this study could be considered the addition of tailings powder into conventional concrete, which can significantly reduce its alkalinity, thereby significantly changing its pore structure, and increasing the sulfate corrosion resistance of concrete.

This Research Topic selects and collects eight original research papers and one review paper that have undertaken studies on cementitious materials, undertaken in the lab and via field performance tests. It introduces recent developments in these areas. This Research Topic sheds new light on critical aspects of the backfilling process, with important implications for the mining industry, providing important scientific information that will benefit future research.

AUTHOR CONTRIBUTIONS

This Editorial was cooperatively prepared by EY, SC, and DW. The authors approved the final submitted version.

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