




ENGINEERING
NOVEL-RESULT

The potential use of pumice in mine backfill

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Abstract

The use of natural pozzolans in concrete applications is gaining more attention because of the associated environmental, economic, and technical benefits. In this study, reference cemented mine backfill samples were prepared using Portland cement, and experimental samples were prepared by partially replacing Portland cement with 10 or 20 wt.% fly ash as a byproduct (artificial) pozzolan or pumice as a natural pozzolan. Samples were cured for 7, 14, and 28 days to investigate uniaxial compressive strength development. Backfill samples containing 10 wt.% pumice had almost a similar compressive strength as reference samples. There is strong potential for pumice to be used in cemented backfill to minimize costs, improve backfill properties, and promote the sustainability of the mining industry.

Keywords: Backfill; Cement; Pozzolans; Pumice; Uniaxial compressive strength

1. Objective

The goal of this project is to investigate if partially replacing Portland cement with fly ash or pumice affects the uniaxial compressive strength (UCS) of mine backfill.

2. Introduction

Pozzolans are siliceous or siliceous and aluminous materials that react with the calcium hydroxide (CaOH) released during cement hydration to produce compounds with cementing properties. Pozzolans are widely used in civil and mining applications to reduce costs and improve the mechanical and physical properties of concrete. Cement can account for up to 75% of mine backfill costs; therefore, it is common practice in the mining industry to partially replace relatively expensive cement with relatively inexpensive pozzolans (Edraki et al., 2014). Examples of artificial pozzolans are slag and fly ash, and examples of natural pozzolans are volcanic ash and the pumice formed during lava solidification. Artificial pozzolans are widely used, but natural pozzolans have not been fully exploited, although they are abundant in many countries. For example, Saudi Arabia is fortunate to have a large resource of natural pozzolans, and research is ongoing to investigate their use in the concrete industry (Al-Amoudi et al., 2019; Celik et al., 2014; Kupwade-Patil et al., 2016; Moufti et al., 2000). In this study, pumice was investigated for its potential use in mine backfill compared with fly ash and cement.

3. Methods

Backfill samples were prepared using tailings from a nickel mine in Canada. Figure 1 shows the particle size distribution and Table 1 summarizes the physical properties of the tailings. Control samples were

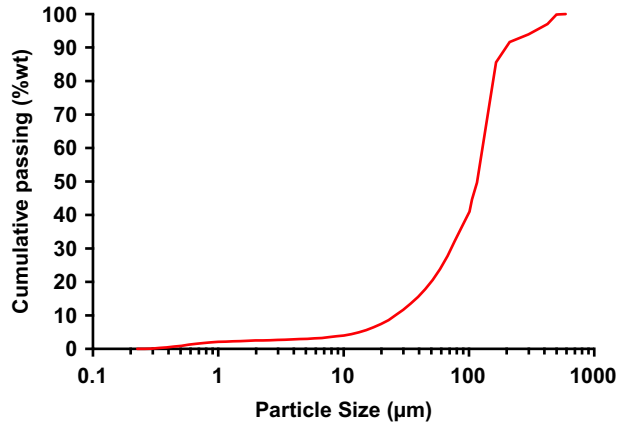


Figure 1. Particle size distribution of tailings from a nickel mine in Canada

Table 1. Physical properties of tailings from a nickel mine in Canada

D10 µm	D30 µm	D50 µm	D60 µm	D90 µm	Coefficient of uniformity	Coefficient of curvature	Specific gravity
4.15	73.62	115.3	127.3	199.6	30.7	10.3	2.7

Table 2. Five backfill treatments tested

Mixture ID	Portland cement (wt.%)	Fly ash (wt.%)	Pumice (wt.%)
PC	100	0	0
FA10	90	10	0
FA20	80	20	0
PUM10	90	0	10
PUM20	80	0	20

prepared with general use Portland cement. Experimental samples were prepared with class F fly ash or pumice, which comprises mainly silicon dioxide (amorphous aluminum silicate), some aluminum oxide, and small amounts of other oxides. The chemical and physical properties of pumice can strongly influence the durability and strength properties of concrete (Çolak, 2003; Lemougna et al., 2018; Pekmezci & Akyüz, 2004).

Five treatments were tested (Table 2): reference samples made with 100% Portland cement; experimental samples made with Portland cement and 10 or 20 wt.% fly ash; and experimental samples made with Portland cement and 10 or 20 wt.% pumice. Binder dosage and pulp density were maintained at 5 and 80 wt.%, respectively.

Backfill samples were cured for 7, 14, or 28 days in a moist cabinet, where temperature and relative humidity were maintained at 25 ± 2 °C and $90 \pm 2\%$, respectively, to simulate underground conditions. At each curing age, two samples from each batch were tested for UCS at a loading rate of 1 mm/min until failure (Figure 2). Duplicate means are reported in the results.

4. Results

The mean UCS of backfill samples increased with curing time (Figure 3a). Samples prepared with 20% pumice had the lowest UCS at all curing times and reference samples had the highest UCS at 14 days



Figure 2. Broken backfill samples after performing uniaxial compressive strength test

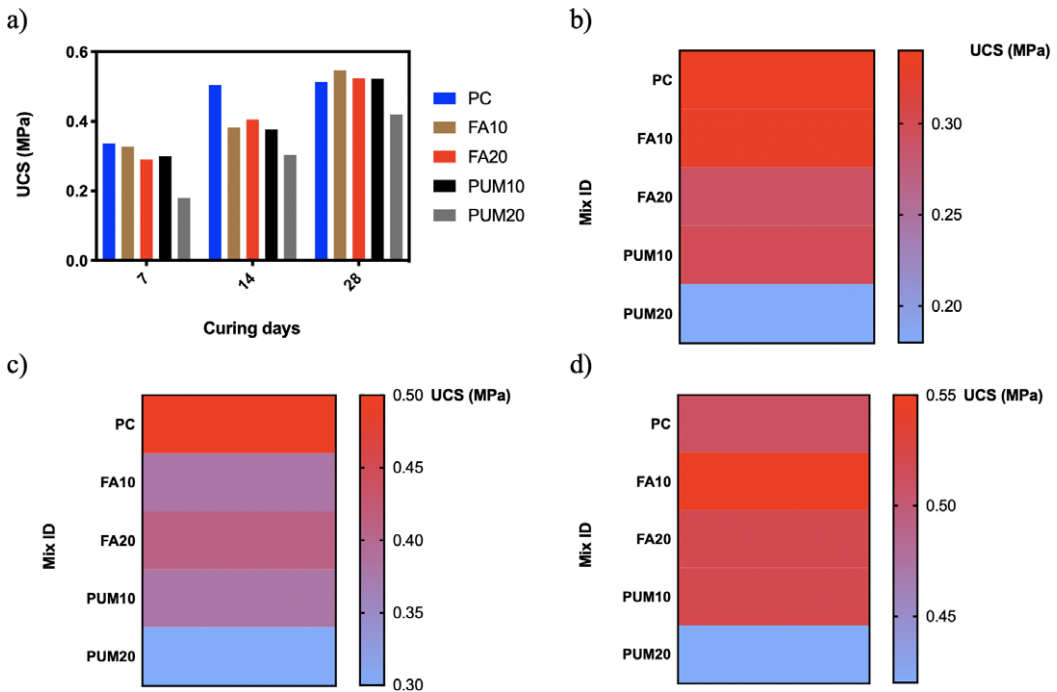


Figure 3. a) Uniaxial compressive strength (UCS) for each cemented mine backfill mixture after 7, 14, and 28 days curing time; heat map for curing times of b) 7 days, c) 14 days, and d) 28 days

curing time (Figure 3a). By 28 days curing time, the reference, fly ash, and 10% pumice samples had almost similar UCS values (0.51–0.55 MPa), whereas backfill prepared with 20% pumice was approximately 19% lower (0.42 MPa).

5. Discussion

The results indicate that after 7 and 14 days of curing, poorer strength was achieved for fly ash and pumice samples than reference samples, which is expected since these pozzolans have a slower hydration rate than Portland cement. However, after 28 days of curing, backfill containing 10 or 20% fly ash or 10% pumice can achieve almost a similar UCS as backfill prepared with Portland cement. Thus, partially replacing cement with 10% pumice appears to be a viable option to achieve a similar UCS at a lower cost. These results agree with those of Zeyad et al. (2019), who studied the use of up to 30% pumice in high-strength concrete and

found that replacement with 10% pumice improved the mechanical properties of the concrete. Although samples with 20% pumice had the lowest UCS values in the present study, Zeyad et al. (2019) found that samples containing 20% pumice have the highest strength development after 180 days of curing. Therefore, future work will investigate UCS development in cemented mine backfill prepared with 20% pumice and cured for at least 180 days.

6. Conclusion

This investigation showed that there is a strong potential for the mining industry to exploit abundant natural pozzolans like pumice in backfilling operations. Cement can be replaced by 10% pumice without compromising UCS and potentially reduce the cost of cement in mine backfilling. Although this study investigated strength development over the short term, the literature suggests that at a higher pumice content, the backfill requires a longer curing time to achieve maximum strength. Future studies will evaluate other types of natural pozzolans cured for 180 days to longer than one year to fully understand the pozzolanic effect on strength development. The use of natural pozzolans to minimize cement consumption in mine backfill will help promote a sustainable and eco-friendly approach to mining.

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Conflicts of interest declaration. The author declares no conflict of interest.

Data availability. The data are presented in the manuscript.

Supplementary Materials. To view supplementary material for this article, please visit <http://dx.doi.org/10.1017/exp.2020.61>.

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Peer Reviews

Reviewing editor: Dr. Daniel Micallef

University of Malta, Environmental Design, Tal-Qroqq, Msida, South, Malta, MSD2080

This article has been accepted because it is deemed to be scientifically sound, has the correct controls, has appropriate methodology and is statistically valid, and has been sent for additional statistical evaluation and met required revisions.

doi:10.1017/exp.2020.61.pr1

Review 1: The Potential Use of Natural Pozzolans in Mine Backfill

Reviewer: Dr. Izhar Mithal Jiskani 

China University of Mining and Technology, School of Mines, Xuzhou, China, 221116

Date of review: 05 November 2020

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Conflict of interest statement. Reviewer declares none.

Comments to the Author: In this article, Pumice has been investigated to know whether it can be used as a mine backfill material. The results show that it can replace cement by 10%. The manuscript can be further improved by revising it based on the following suggestions.

- (1) Include “Pumice” in the title.
- (2) The cited literature in the “Introduction” section is quite old. It is suggested to include some recent and more relevant literature.
- (3) The samples are prepared using tailings from Nickel mine. Please add details to the study area.
- (4) The author claims that the use of Pumice is compared to cement and class F fly ash. However, it is not well elaborated and discussed in the “Results and Discussion” section. Present detailed results and provide a thorough discussion of your findings.
- (5) The first two sentences in the “Conclusion” section should be rewritten to make them completely convincing.
- (6) Figure 2 and Table 2 are not cited in the text.
- (7) Please follow the journal guidelines and recheck the entire manuscript for grammar, spelling, and punctuation errors. Be cautious when writing chemical formulas and equations

Score Card

Presentation



Is the article written in clear and proper English? (30%)

2/5

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3/5

Does the paper cite relevant and related articles appropriately? (30%)

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Context



Does the title suitably represent the article? (25%)

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Does the abstract correctly embody the content of the article? (25%)

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Does the introduction give appropriate context? (25%)

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Is the objective of the experiment clearly defined? (25%)

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Analysis



Does the discussion adequately interpret the results presented? (40%)

2/5

Is the conclusion consistent with the results and discussion? (40%)

3/5

Are the limitations of the experiment as well as the contributions of the experiment clearly outlined? (20%)

4/5

Review 2: The Potential Use of Natural Pozzolans in Mine Backfill

Reviewer: Dr. Hamed Rafezi PhD 

McGill University Faculty of Engineering, Mining and Materials Engineering, 3450 University st., Adams Building, Room 101, Montreal, Canada, H3A 2A7

Date of review: 05 November 2020

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Conflict of interest statement. Reviewer declares none

Comments to the Author: The paper addresses an important topic in the mining industry sustainability. The work is well defined and the “results and discussion” section is scientifically in order with correct control. I would suggest the author consider more elaboration on the environmental and economical benefits of the application of pozzolans to emphasize the significance of the work done; A few sentences could be added to the introduction section accordingly. This experimental research well suits the journal and I would recommend proofreading before the final submission to correct a few typos in the context (e.g. table 3).

Score Card

Presentation



Is the article written in clear and proper English? (30%)

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Context



Does the title suitably represent the article? (25%)

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4/5

Does the introduction give appropriate context? (25%)

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Is the objective of the experiment clearly defined? (25%)

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Analysis



Does the discussion adequately interpret the results presented? (40%)

5/5

Is the conclusion consistent with the results and discussion? (40%)

5/5

Are the limitations of the experiment as well as the contributions of the experiment clearly outlined? (20%)

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