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Technical note

# Durability and strength of fiber-reinforced compacted gold tailings-cement blends

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ABSTRACT

In order to investigate techniques to support mine tailings use as earthwork material, the improvement of mechanical properties of gold tailings through compaction, insertion of fibers and cement is studied. Present investigation intends to assess the impact of Portland cement content and dry density, as well as fiber insertion in the enhancement of durability and strength of compacted gold tailings-cement mixes. This manuscript advances in understanding the parameters that control durability and strength of fiber-reinforced compacted gold tailings-cement blends. Its main significant addition to knowledge is quantifying the accumulated loss of mass (ALM) of fiber-reinforced compacted gold tailings-cement blends after wet/dry cycles and unconfined compressive strength ($q_u$) as a function of the porosity/cement index. In addition, the existence of exclusive relations connecting accumulated loss of mass divided by the number of wetting/drying cycles and porosity/cement index is empirically revealed for the studied materials. This broadens the applicability of such index by demonstrating it controls not only mechanical but also endurance performance of fiber-reinforced compacted gold tailings-Portland cement mixes.


## 1. Introduction

Mine tailings have been of particular interest in the last years due to potential environmental damages and the possibility of using as geomaterial in earthworks. Such materials are defined (Wijewickreme et al., 2005) as a compound of crushed rock waste particles derived from ore processing.

Particularly, cemented tailings backfill (CTB), which consists of disposal tailings materials hardened by cement paste and transported to the underground mine (Fall et al., 2008) has been broadly studied. This technique has been widely used in Australian/Canadian underground mines and in other parts of the world and it provides several economic benefits in relation to conventional mine backfill methods (Lerche and Renetzeder, 1984; Hassani and Archibald, 1998; Fall and Benzaazoua, 2003). Such technology not only provides stability of mine openings during the safe recovery of ore, but also represents a significant environmental advantage (Huynh et al., 2006). Fall et al. (2008) carried out extensive research to predict the technical (unconfined compressive strength, slump, solid concentration) and economical (binder cost) performance properties of CTB's. Tailings grain size and density, water-cement ratio and type of binder were found to be the main factors controlling CTB properties. Doherty et al. (2015) found out that the factor that has larger influence in barricade pressures in underground stopes is the rest periods between tailings filling. Walske et al. (2016) studied the effect of curing cemented paste backfill under combined effective stress and temperature conditions on the development of small-strain stiffness. These authors found that curing with both elevated temperature and effective stress significantly increase the mechanical properties of cemented paste backfill compared with curing at elevated effective stress or ambient temperatures alone. Consoli et al. (2017) have found linear relationships between stiffness ($G_{max}$) and loss of mass (LM) of cement treated gold tailings. Suazo et al. (2016) used a constant-volume direct simple shear apparatus to characterize the liquefaction resistance of cemented paste backfill prepared with fine-grained tailings.

Besides the addition of cementitious materials for improving tailings properties, the addition of synthetic fibers has also been examined. Festugato et al. (2013) investigated the monotonic and cyclic shear response of cemented gold mine tailings reinforced with polypropylene fibers. Monotonic shear tests showed that fiber inclusions create a hardening behavior of the samples. Regarding

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0266-1144/

**Table 1**
Physical properties of the gold tailings sample.

| Plasticity index | Non-plastic |
|---|---|
| Specific gravity | 2.86 |
| Fine sand (0.075 mm < diameter < 0.425 mm) (%) | 28 |
| Silt (0.002 mm < diameter < 0.075 mm) (%) | 71 |
| Clay (diameter < 0.002 mm) (%) | 1 |
| Mean particle diameter, $D_{50}$ (mm) | 0.06 |
| Maximum dry unit weight for standard Proctor compaction effort ($kN/m^3$) | 17.0 |
| Optimum moisture content for standard Proctor compaction effort (%) | 17 |
| USCS class | ML (silt with sand) |

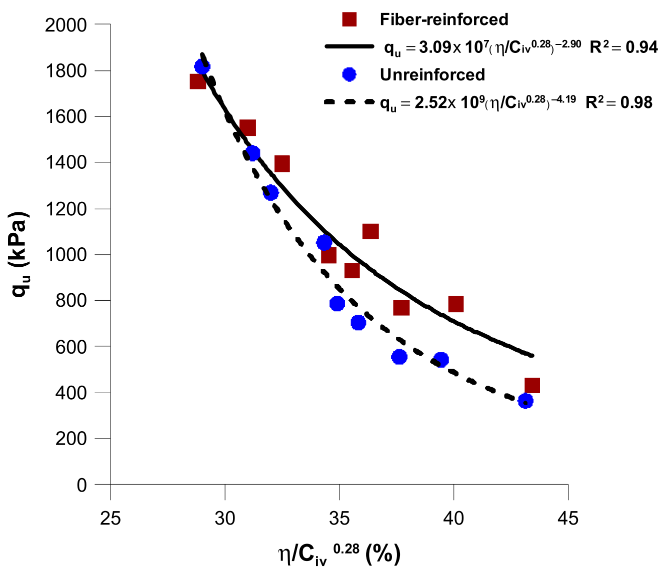


**Fig. 1.** Variation of unconfined compressive strength ($q_u$) of unreinforced and fiber-reinforced specimens with adjusted porosity/cement index for gold tailings-Portland cement blends.

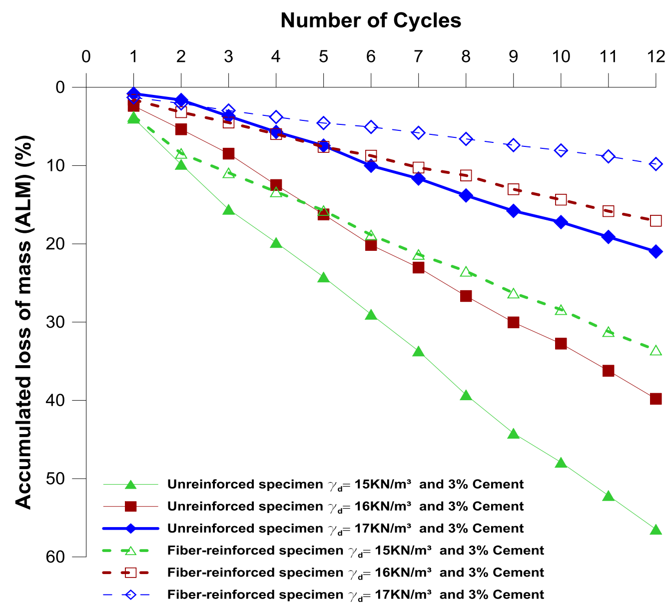


**Fig. 2.** Accumulated loss of mass versus number of wet/dry cycles for gold tailings-Portland cement blends considering distinct dry unit weight (15, 16 and 17 $kN/m^3$) specimens considering unreinforced and fiber-reinforced specimens.

the cyclic tests, it was observed that the addition of fibers increased the shear stress values of the cemented samples after successive load cycles. The strength envelopes of both monotonic and cyclic specimens showed good agreement, which allows the use of the same strength parameters under different loading conditions. Furthermore, Festugato et al. (2015) also carried out shear tests in fiber-reinforced gold mine tailings. It was found that fibers improve the material shear response and increase its stiffness. The agreement of the strength envelopes of both monotonic and cyclic stress paths was again reported for such material. Moreover, Yi et al. (2015) performed unconfined compression tests on fiber-reinforced cemented paste backfill (CPB), using sandy silt tailings from a nickel mine. A significant reduction on the post-peak strength loss was observed, showing a more ductile behavior of such material in respect to the unreinforced specimens. X-ray computed tomography demonstrated that the fibers contributed to preventing the crack growth by mobilizing tensile strength.

From all the aforementioned tests carried out in tailings, strength tests are the mostly reported in previous studies with other materials. Strength tests are usually employed as a way to examine the influence of diverse variables on fiber-reinforced soil-cement behavior. It seems reasonable, though, that such tests are performed in fibre-reinforced cemented tailings. A logical dosage procedure for fiber-reinforced soil-Portland cement was created by Consoli et al. (2010) taking into consideration the porosity/cement index, defined as the porosity of the compacted mixture divided by the volumetric Portland cement content. The suitability of the porosity/cement index to predict the strength of fiber-reinforced cement treated soils has been demonstrated by Consoli et al. (2010, 2013). These authors have revealed that rates of change of strength with porosity ($\eta$) and the inverse of the volumetric cement content ($1/C_{iv}$) (where $C_{iv}$ is the volume of cement divided by the total specimen volume) are usually substantially different. A way to make the variation rates of $\eta$ and $1/C_{iv}$ compatible is through the application of a power (generally 0.28 for materials containing fines – Consoli et al., 2007, 2010, 2013) to $C_{iv}$. This index has been shown to be appropriate to evaluate the unconfined compressive strength ($q_u$) for fiber-reinforced Portland cement treated soils, but no attempt has been made to relate this index to fiber-reinforced tailings treated with cement. Yet, no research has been done for checking the effectiveness of the porosity/cement index ($\eta/C_{iv}$) in assessing fiber-reinforced compacted tailings-cement mixes in terms of loss of mass after wetting/drying cycles. This work targets to determine direct relations between accumulated loss of mass after dry/wet cycles (durability) and $q_u$ with $\eta/C_{iv}$ for fiber-reinforced compacted gold tailings-cement blends.

## 2. Experimental program

The materials and methods used in present research are discussed below.

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