Paste backfill mix

Corina-Maria Aldea and Bruce Cornelius discuss why the mix design matters and how to find the optimal solution

The use of paste backfill is particularly prevalent in Canada and the US because of increasingly stringent environmental regulations. Its main benefits are lower operating costs and a reduction of the amount of water sent to the tailings facility for disposal. The decrease of the amount of waste reduces the environmental impact and offers significant environmental and cost benefits for mines.

Paste backfill, or cemented paste backfill, is being increasingly used underground. It is a cementitious composite, like concrete, and therefore there are a lot of similarities in terms of mix designs, rheology, material evaluation and transportation to conventional concrete. The composition is primarily mine tailings mixed with hydraulic binders, which are typically Portland cement and some form of supplementary cementing materials, and water. The role of the binding agents is to develop cohesion and strength within the paste backfill so that the exposed fill faces will be self-supporting and stable when adjacent stopes are extracted. Although not typically used as paste backfill mix ingredients due to perceived high added costs, chemical admixtures have the potential benefit of significantly reducing the amount of water to be pumped out of the mix after placement, thus increasing the effectiveness of the process and reducing overall costs.

Paste backfill is a high density engineered material, typically with more than 70% solids. The goal for the high density paste formulations is to produce a pumpable material that does not segregate when placed, and hence does not have fine materials runoff on beaches or require removal of significant quantities of bleed water. In order to pump material at this density, the fines content (particles <20 to 45 µm) should be a minimum of 15% by weight of the paste. The fines are also required to both maximise the solids content of the paste and to act as a lubricant for pipeline flow. Proper high solids content paste backfill design significantly reduces the need for high transport water volumes, as are typical in some sand fill applications. A portion of the water is consumed during cement hydration, and more retained as interstitial water within the fill mass, thus significantly reducing or eliminating the need for drainage. Due to compaction, the constituent particles of a high density paste backfill do not settle out of suspension at zero flow rates.

Mix designs must be formulated for both placement (rheological properties) and in-situ performance (strength development). They must have good long-term durability to ensure stability in a given mine environment and to meet the limiting strength and the pressures which will be developed in the fill. This can be done by choosing the optimal mixes for each type of tailings, as well as by taking into account the cost of the backfilling operations. Among the material properties which can be designed for are conventional fresh and hardened mix properties, such as slump and unconfined compressive strength (UCS), which are determined for the fill material. Practical experience dictates that the designs and operating controls of backfill placement should be based upon rheological properties. However, accurate rheological properties of paste backfill can be difficult to obtain during production due to their complexity. Therefore, the slump test, which is a standard, relatively simple concrete test can be used as a measure of paste backfill consistency prior to pumping.

Slump measurement of cemented copper tailings paste fill

Paste backfill mix ingredients (tailings, binder and water) greatly affect the performance of the paste fill during its transportation, delivery and strength development.

Tailings represent, typically, between 70 and 85% of the weight of the paste mix. Proper characterisation of potential tailings materials is crucial in order to ensure chemical compatibility with the binder materials for a cemented paste backfill. The properties of the tailings are used to determine an appropriate cementitious binder or combination of binders to achieve the desired strength properties. The following tailings properties affect the
performance of cemented paste backfill:

- **Physical properties**, such as top particle size, particle size distribution, and density, have an effect on compressive strength, cost and water demand of the paste. The proportion of fine particles (<20 µm) in the tailings affects the microstructure of the paste. The paste porosity and pore size distribution are closely related to strength and the ability of the paste to drain water. The fineness of the tailings affects the water demand of the paste mix, e.g. water demand increases with the fineness of the tailings. Tailings density is related to binder consumption in the mix, with higher tailings density being associated with higher binder consumption, and thus higher costs.

- **Chemical properties** need to be assessed to ensure compatibility with the binders used in the paste mix. It is known that higher sulphur content in the tailings is associated with higher tailings density, which results in a higher binder consumption and consequently higher paste strengths. However, higher sulphur content can also lead to strength loss due to sulphate attack, where sulphate is obtained as a result of the oxidation of sulphide minerals under some conditions in the non-cemented tailings. The use of blended cements containing slag, fly ash or other pozzolanic materials, can mitigate this.

- **Mineralogical properties**, such as hardness and angularity of the crushed material, may be issues with wear on mixing and placing equipment. **Binders** are used in paste backfill where structural strength is required and where resistance to liquefaction is necessary. Binder dosage rates to achieve typical strength requirements range between 2% and 6% by weight of the paste mix. Unconfined compressive strength is a function of binder content for a given curing age and curing conditions, as well as other factors, including tailings type and water-to-cementitious materials ratio (w/cm) of the mix. General use Portland cement (ASTM C 150 Type I, or CSA A3001-03 Type GU) is most commonly used for these purposes. Supplementary cementing materials (SCM), such as ground granulated blast furnace slag (slag), fly ash (FA) and natural pozzolans, or waste materials, such as cement kiln dust (CKD), and finely ground industrial and municipal waste glass can be added to the paste as a partial replacement of Portland cement in binary or ternary blends. Economic and environmental/sustainability considerations are a primary driver behind the use of non-Portland cement binders. Although their use can result in a slower strength gain over time, mixes with SCM are known to have good engineering performance as well as reducing costs. In addition to technical performance with a particular mine tailings, the selection and use of a specific alternative binder for paste backfill is primarily governed by sustainable material sources and overall cost effectiveness. The hardening process of the paste is time dependent, with increasing strength reliably and predictably occurring with curing time. **Water** is necessary for cementitious material hydration. The chemical composition of the mixing water from different sources can affect the strength development of a paste mix, and with higher salt contents the setting time can be affected. Therefore, chemical characterisation of the process water is important in order to ensure chemical compatibility with the tailings and binders used for the paste mix for a specific application. The main concerns are the pH of the water and the amount of dissolved salts, particularly chloride and sulphate salts. In particular, acidic water with a pH below 6.5 and sulphate salts can react with the hydration products from the binders and lead to long-term loss of strength and durability of the paste. The w/cm varies depending on target slump and UCS values for a mix. Water demand depends on the fineness of the tailings. Higher amount of mixing water results in higher slump, a more porous mix and lower strengths.

There can be frustration with the use of paste backfill based upon ‘issues’ with real or perceived variability of the product. This frustration is often a result of basing all design and operating criteria for a particular application on a single solids and binder content for the paste, rather than using good mix design practices backed up by comprehensive laboratory development. Such laboratory development should include thorough characterisation of all paste backfill components and evaluations of plastic properties, rheological behaviour and set properties. There is no universal recipe for paste backfill mixture production: each type of tailings, mix water and binder for a paste backfill mix has to be optimised in the laboratory prior to full scale implementation. **IM**