

Bentonite Manufacturing & Supply Limited

INFILLING TUNNELS

The performance trade off when using a Bentonite/Portland Cement/GGBFS highly fluid slurry versus a traditional Portland Cement slurry .

One of the major concerns with infilling long underground tunnels that require large volumes of a highly fluid grout, is the setting time of the material used. To get the grout pumped and placed prior to setting is a major challenge. Should the grout start hardening before the completion of the pour then this will cause a blockage which may result in only partially in filling of the tunnel.

To overcome this challenge, some tunnel filling projects do allow multiple access so pipework can be attached to the side walls and to the soffit. By doing this, the material can be pumped in at different locations (through the whole length of the tunnel) and the pumping can be conducted over a period of time ensuring a complete fill.

However, if there is no access allowed in the tunnel due to safety concerns, then the only way forward is to pump material from *one* or *both sides* in order to place the liquid grout/slurry in-situ. This is achieved by firstly inserting an injection pipeline a few metres in the entrance of the tunnel so the grout feed pipes, carrying the material from the batching plant, can connect on to. The grouting material to be used then must be highly flowable and have the ability to be pumped and placed over long distances without setting too fast.

At Bentonite Manufacturing and Supply Limited (BMSL) we are able to produce and pump a grout, in slurry form, that can maintain a highly flowable consistency for up to 72 hours before it starts setting and hardening. This ensures that the material is fluid enough to be pumped long distances within the tunnel and fill it before the material starts to set, thereby causing a blockage. This unique ability of our grout guarantees complete infilling of the tunnel.

Normal grout mixes exhibit a typical fresh wet density of 1800 kg/m³ comprising 1200 kg/m³ of cementitious powder and 600 litres of water. From a, 30-ton bulk tanker load will therefore enable around 25 m³ of liquid slurry to be produced on site. High cement powder mixes also take longer to manufacture.

In contrast, BMSL grout densities range from 1175 kgs – 1250 kgs/m³ depending upon the strength requirement of the material. Using the same 30-ton bulk tanker load example, our BMSL design mix, can produce around 100 m³ of the final grouting product. This is four times more mixed volume from a 30-ton load than the higher density cementitious grouts. Not only are we able to produce much higher volumes per powder content but the resultant grout/slurry is significantly easier to pump and place than grouts with a density of 1800 kgs/m³ material.

With our specially engineered bentonite/cement/ggbfs grout mix designs and large batching plants BMSL can supply exceptional volumes on a daily basis (300-500 m³/day from only 1 batching plant; this can be doubled if we have 2 plants on site).

Another key consideration is a significant reduction on bulk tanker movements to and from the site. Fewer deliveries to site bring benefits of safety and the positive environmental impact of less movements together with lower diesel usage.

However, there is a performance and application **TRADE OFF** when considering the use of Bentonite/ Portland cement/GGBFS mixes versus more traditional Portland cement rich slurries. This is down to the different features and benefits of the two grouting 'systems' some of which are summarised below. These properties need to be taken in to account when choosing a 'fit for purpose' grout/slurry for your project.

The use of Portland cement slurry/grout

- 1) high strength potential of 40+ N/mm² @ 28 days
- 2) high fresh wet densities of 1800 kgs/m³
- 3) mixes exhibit high bleed.
- 4) low production rates per cement powder tanker load 25-30m³/hour
- 5) high initial 'heat of hydration' (HoH) i.e. 95 °C at 21 hours
- 6) possible thermal cracking of the grout due to high temperatures in the tunnel
- 7) higher pumping pressure over long distances
- 8) the additional bulk tanker deliveries required to complete the pour over the duration of the project.
- 9) longer project time on site to complete a pour.

The use of bentonite/Portland cement/ggbfs slurry/grout

- 1) lower strength, from 300 Kpa - 1.5 N/mm² @ 28 days
- 2) low powder requirement of 200-350 kg/m³
- 3) grout mixes exhibit very low bleed of typically 1%-2%
- 4) marsh funnel test 36-38 seconds
- 5) low 'heat of hydration' (HoH) i.e. 15 °C @ 24 hours
- 6) greatly reduced risk of thermal cracking
- 7) excellent permeability (minimum 1 x 10⁻⁹ m/s)
- 8) grout exhibits an extended set time of up to 72 hours.
- 9) fewer number of bulk tanker deliveries to site
- 10) high production rates of 100+ m³ from 1 x 30-ton bulk tanker load
- 11) higher water content around 900 litres/m³ (against 600 litres/m³ for cement grouts)
- 12) pump longer distances (500+ linear metres) with less pressure.
- 13) high production volumes in the range of 15-60 m³/hour depending upon type of batching and placing equipment employed by BMSL on site.
- 14) lower material costs.
- 15) shorter project duration time.

To sum up the possible key material performance trade-offs to be considered when making the best grout/slurry choice for your project you have.

- Traditional Portland cement grouts/slurries (with or without the addition of ggbfs) which will exhibit high STRENGTHS but with corresponding higher HEAT OF HYDRATION (HoH) and also FASTER SETTING TIMES. There is also the risk of THERMAL CRACKING in the material.
- 'New generation' BMSL bentonite/Portland cement/ggbfs mixes which offer LOWER STRENGTHS, LOW HEAT OF HYDRATION, LONGER SETTING TIMES and NO THERMAL CRACKING.

The other trade-offs and things to consider, thereby ensuring a successful project are.

- As BMSL, having large batching plants available that can manufacture and pump high volumes of bentonite/Portland cement/ggbfs grout/slurry each day, project pours will be completed over a shorter time period. Coupled to this we can offer 2 machines/batching plants to manufacture the slurry and pump from either end of a tunnel at the same time.
- Due to the composition of the material, there is no loss of grout volume from the material 'breaking down' i.e. losing density when being pumped long distances.
- With 28-day strengths of 300 KPa to 1.5 MPa, the heat of hydration (HoH) is very gradual and low. This enables the mixing and pumping of high volumes of highly fluid and flowable grout into the tunnel in one pour.
- Also, since our grout exhibits excellent permeability (1×10^{-9} m/s) it can stop the seeping of water into the tunnel once infilling is complete. This feature alongside reduced bleed of around 1%-2%, no excess water is present in the pour.

Below is a picture of the liquid grout taken from inside a tunnel. This shows how free flowing the material is.



At BMSL we can offer batching plants to suit different site footprints and conditions.

Our small mixer, with material supplied by bulk tankers in to our on-site silo, can manufacture up to 16 m^3 of grout/slurry per hour. This machine weighs both water and powder fully automatically. We use material which is pre-blended off site to our specific mix design for each project.



4 m³ batching plant with 20-ton vertical silo holding pre blended material fully computerized for quality control there is a computer printout of each batch manufactured throughout the day (16 m³ /hour)

Our larger batching plants are also fully computerised and are designed with the capacity to supply much greater volumes per day. They range from 30-60+ m³/hour with pumping distances of around 500 linear metres measured from the rear of the units.



Picture shows our recently built 2 m³ continuous fully computerized mixing unit which can be fed by 3 x 30-ton vertical silos holding 3 separate powders or 1 x 45-ton horizontal silo holding pre-blended material (40 m³/hour of cement grout or 60+ m³/hour of liquid B/C/GGBFS grout) having 2 x duplex 100 peristaltic pumps to discharge the material. Material is recorded on a print out for each batch throughout the day.



Above picture shows our batching unit set up which can manufacture 16 m³ in one batch it is computerized with print off of material batched throughout the day with 1 x 38-ton vertical silo (30+ m³/hour) with 2 large grout pumps each discharging 4000 litres of grout a minute, can easily pump 500 linear meters from rear of unit.



A fully computerized batching plant that can manufacture grout and light weight foam concrete with print out of tonnage used/day, 2 x 30-ton vertical silos (60+ m³/hour foam concrete, 20+ ton/hour grout) with 2 x SP 65 peristaltic pumps for discharging the material.

Our larger batching plant and machinery units are designed to have large silos attached due to their capacity of being able to produce up to 150 tons of material per day. The larger units can pump material to two different locations at the same time. Since they have large discharge pumps these can be hooked up to the injection pipelines leading into the tunnel and the slurry can be pumped into different areas thereby significantly increasing productivity and infilling the tunnel at different locations.