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2013 B1-18 STOPE COMPLEX BACKFILL PROJECT - LESSONS LEARNED

Dear Mr. Thompson,

This letter represents a collection of the key technical and logistical "lessons learned" compiled by Golder during our involvement in the paste backfilling of the B1-18 stope complex that was completed between the beginning of October and is ongoing to date. The intent of this document is to provide PWGSC, and potentially any future stakeholders, with a reference to the challenges and unexpected events that were encountered during these activities to bear in mind when developing the procurement approach for similar future work. The document only identifies the lessons learned and does not provide any root cause analyses. If further explanation or clarity is required, enquiries should be directed to the Golder.

LESSONS LEARNED

1) Main questions answered:

- Remotely placed barricades can be constructed using high cement content paste delivered placed via accurately drilled boreholes.
- High slump lightly cemented paste delivered via widely spaced boreholes can be used to fill voids with a relatively flat backfill profile.
- Relatively lightly cemented paste (e.g. 2% cement by weight) made with Giant mine tailings gains strength quickly and the UCS normally exceeds 100 kPa within 1 day with 2% cement by weight.
- Paste can be made and placed in boreholes in cold temperatures.

2) Design and planning details can't be tightly constrained ahead of time as the problem changes during project implementation (actual backfilling) and it is problematic to approximate quantities and schedule accurately ahead of time.

- More up-front planning/investigation time would have eliminated some (but not all) of the changes to the work plan that were required due to uncertainty regarding the geometry of the voids to be filled at the B1-18 stope complex.
- Many areas are/will critical to the backfilling process may be inaccessible for workers to install barricades and cameras or to inspect the underground to assess backfill progress.
- The potential for "paste leakage" in all stope complexes is present and impossible to quantify fully.
- For example, at approximately 80% complete for mitigating the risk at stope complex B1-18 the confidence in design was only at approximately ±20% for the remainder of the work required.
- The data used for planning is/will be variable in its reliability.
  - The paste placement sequence changed on an almost daily basis for the B1-18 stope complex depending on the conditions encountered during the previous day.
  - The conceptual mitigation plan for stope complex B1-18 changed significantly from inception to completion. The majority of changes came in the form of additional boreholes, additional barricades, and camera placements.
  - Some exit voids were sealed much sooner than expected and others that were anticipated to seal quickly have yet to do so at the B1-18 stope complex.

3) Working in cold/winter conditions poses production risks.

- Tailings temperature could be a limiting factor – and the fluctuations can be extreme (observed -11 to +8).
- After the initial onset of cold weather, non-frozen tailings could be sourced by first removing the top frozen crust but this was limited as colder temperatures set in.
- Water temperature could play a large role in production due to the variation in tailings temperatures.
- Borehole cameras and computers were very useful but in cold weather conditions: expect extra time for set-up; availability and performance to decrease with decreasing temperatures.
- Frozen tailings and ice lenses in the tailings can affect the paste production volumes and frozen lumps of various sizes may need to be screened.
- Temperature monitors need to be able / suited to operate in -40C conditions.
- Additional equipment could require shelters and heaters to operate. Expect that these would be required if carrying out work in the cold/winter conditions.
- Multiple ways of adding heat to the tailings during mixing of paste could be beneficial. Planning and options would be beneficial when pouring in cold/winter conditions.

- Freezing of equipment (truck beds, loader buckets etc.) is likely when working in cold/winter conditions.
- The storage of tailings in the available facilities should be timed appropriately when/if working during cold months: e.g., tailings storage facilities required keep tailings from freezing need to be constructed prior to the onset of cold.

4) Tailings material could be variable depending on seasonality and heavy machinery traffic.

- Early investigations revealed that the tailings could support heavy traffic as the saturated material was encountered between 2 and 4 m below the tailings surface.
- Heavy equipment traffic on the tailings ponds appears to draw water closer to the tailings surface, possibly due to a wicking action.
- Apparent wicking action appears to reduce the bearing capacity of the tailings surface – equipment will begin to sink in to the tailings with repeated traffic.
- Pushing of tailings with a dozer helps to break the material up, but also appears to cause this wicking action, reducing the depth that the dozer can excavate without sinking into the tailings.
- Excavation of tailings with an excavator causes fewer disturbances to the tailings and allows large debris to be selectively removed and the tailings to be separated by material characteristics, if required.

5) The grain size and consistency of tailings was more variable than the initial field tests (test pitting observations) indicated for the area excavated for the supply of tailings for the B1-18 work.

- The early investigation to assess source material for the B1-18 stope work was the south and central tailings ponds – widely spaced test pit were dug and limited grain-size analysis laboratory testing was carried out due to schedule constraints.
- The tailings are more variable than information from the early investigation programs indicated. The grain size, moisture content and relative density of the tailings changes both laterally and vertically over short distances.
- Little information has been collected in previous investigation programs on the relative density or consistency of the tailings. This information would be useful to assess the likelihood of the tailings to break apart when excavated.
- With additional moisture content encountered in the fall (relative to the initial investigations in summer) the fine grained lenses encountered in the tailings tended to clump up during excavation and handling and without additional mechanical breakage these clumps are problematic.
- Good source material was “scavenged” and other material was discarded or not excavated as the volume required for 2013 was limited and in future much more of the material will be required.

6) Inconsistency in tailings material led to challenges with processing the tailings and mixing the paste.

- When using Reimer trucks to produce paste the tailings have to be relatively "free flowing" and cannot contain chunks of material that do not easily break apart when handled – unless the tailings are mechanically processed to break up any chunks.
- A significant portion of the tailings will likely require mechanical processing before it can be directly used in Reimer type trucks in order to improve efficiency and maximise production – the clumps that will block the built in grizzlies on the trucks need to be broken up.
- Tailings with similar grain size have different suitability for direct use in Reimer trucks depending on their relative density and moisture content.
- Depending on the amount of mixing and processing of the tailings is planned prior to paste production, visual assessment of the tailings during excavation will help to determine what amount of mixing or processing is required.

7) Inconsistency in paste material led to challenges with management of backfilling underground.

- Subtle changes in the character of the tailings feed material and inconstancy of material flow during paste mixing (constant metered addition of water and cement with a potentially inconsistent rate of addition of tailings by the excavator operator) caused variability in the behaviour of the material underground leading to challenges with managing the backfill sequencing.

8) Handling and working with the tailings can be a limiting factor for paste production and depending on the task may pose a health and safety hazard.

- Unknown debris is buried within the tailings; this can include metal, wood, plastics and other items.
- There is the potential for small metal debris of the size to potentially damage mixing and pumping equipment, if not screened out.
- Mechanical screening/processing of the tailings is effective at screening out debris down to a few inches in size.
- Screening of tailings to break up lumps is only partially effective, as wetter and finer grained tailings are expected to plug the screens or be rejected when other methods could allow these tailings to be used for paste production.
- Screening of frozen tailings is only partially effective at screening out frozen lumps – some frozen lumps will pass through the smallest screen.
- The tailings contain crystalline silica and metals (including arsenic).
- The clays found in the tailings if unblended cannot be used in the mixer trucks.
- There is sufficient dust generated due to tailings excavation and paste production activities that worker exposure control programs are recommended for workers working in close proximity to these areas. The details of the programs will depend on the types of activities and the duration and proximity of workers to the activities.
- Laboratory testing of the tailings components and samples air monitoring data collected on workers working near the excavation and paste production activities is available.

9) Physical site, material movement and equipment logistics all contributed to lower than estimated paste production for the B1-18 stope complex.

- Space constraints limited the set-up orientations (mixer trucks/excavator). Buildings, fences, utility locates, natural barriers, environmental buffers, and general site infrastructure made site planning and layout challenging and limited available equipment that could be used for production.
- Surge hopper was not particularly effective in feeding the mixer truck once a second truck was eliminated from the production equipment roster.
- Managing multiple processes/activities is common and should be expected. This requires an organized site and proper management.
- “Just in time” delivery of tailings to the mixing trucks was not effective and was a limiting factor of production for B1-18 paste delivery.
- Tailings material was lost at each stage of the process and this lost amount needs to be accounted for when producing the paste.
- Flushing procedures were a challenge at the start with lack of resources (welding flanges etc.) and not understanding the intent behind doing air flushes and not water.

10) Underground monitoring using fixed cameras and borehole cameras can have significant impact (positive or negative) on paste production and ability to understand if success criteria have been met.

- Underground and borehole cameras were critical to the management of the backfill process, particularly in areas where fill volumes were not constrained and “exit voids” that could not be fully characterised existed.
- Scales in the camera purview identifying a height of back will assist in evaluating whether success criteria has been met.
- The infrared functionality of fixed cameras is a very useful tool, but signal quality suffered due to the long lengths of transmission cable necessary to get out to the UBC portal. A coax based system will likely not be practical for future, deeper areas.
- Fixed underground cameras were reliable and more useful than borehole cameras and observation holes for the B1-18 stope complex.
- The borehole cameras used at B1-18 required significant light to provide useful images. Getting good light down holes will likely be a challenge. Disposable lighting options such as high intensity glow sticks would improve the use of borehole cameras.
- A reliable Underground-to-Surface communication system is a must as work progresses to deeper areas of the mine.
- A wireless monitoring system (i.e., wireless camera feed) that could be distributed over the internet would be an efficient and cost effective way of monitoring paste backfill.
- Sequencing of monitoring devices on a day-to-day basis, and anticipating where other monitoring should be will reduce downtime when pouring.
- Multiple and spare borehole cameras that are easily used and moved will reduce downtime when pouring.

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11) Drilling is a high schedule risk activity due to the tight specification requirements, the proximity to arsenic stopes, and the production limitations that could be realised by having to drill new holes.

- Paste production was constrained at B1-18 stope due to delays in drilling production boreholes.
- Expect last minute design changes to borehole locations and the addition of borehole during backfilling due to unexpected behaviour. Communication with the driller on this at the beginning is crucial.
- Having a proven and actionable methodology to ensure drilling will satisfy the specifications will limit the amount of redrilling.
- Having the appropriate drill for the type of hole will limit the amount of deviation and potential for hole abandonment and redrilling.

12) Various other factors need to be considered to have a successful paste campaign.

- Limitation on water usage (current water license) will likely be a constraint going forward.
- Paste strength and completion criteria assessment would improve if the lab program included different curing conditions to mimic site and underground.
- Paste strength and completion criteria assessment would improve if the lab program included in-situ coring of deposits to test against lab results.
- Develop material standards to be followed and communicate to all parties involved.
- The use of expanding foam underground for construction of barricades (through boreholes or not) should be further investigated.

Yours very truly,

GOLDER ASSOCIATES LTD.

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