Put more tails in less s

Explosive compaction may be a boon

by Tonia Jurbin, P. Eng.

There's a proven technology that will be a boon for the mines dealing with large volumes of tailings.

Explosive compaction (EC) is a densification technology that is predominantly used by the geotechnical community to pack loose, saturated, medium to coarse materials. It has been used as a soil densification technique since the 1930s in both Russia and the United States. The U.S. Army used EC in the early 1930s for dam foundation densification, but the method was not used extensively until the late 1960s, partly because of the lack of familiarity with design procedures. The Russians and eastern Europeans continued to use EC, though much of the research was not disseminated because of Cold War tensions. Though still not widely used in North America, it is slowly starting to gain in popularity as the number of success stories increases.

Mines typically increase the storage space for tailings by increasing the height of the tailings dam or the size of the reservoir. Often, to spread the cost of constructing these dams over time, they are constructed in stages and raised as needed. A Vancouver-based group, **Explosive Compaction Inc.** (ECI), has been pioneering and refining explosive compaction technology for increasing tailings storage, and it is currently the most experienced group carrying out this type of work in North America.

ECI thinks it might be onto something big. It has been exploring an unusual application of the technique: on a large mining project, the company believes it can provide a competitive alternative to raising tailings dams by increasing the capacity of a reservoir using explosive compaction to induce settlement, therefore decreasing the volume of the tailings.

The ECI team consists of Dr. Blair Gohl, P.Eng., of **Pacific Geodynamics** based in Delta, B.C., who has a strong geotechnical background, particularly in the area of soil densification, along with **Foundex Explorations Ltd.**, a geotechnical drilling contractor out of Surrey, B.C., and Ron Elliott, vice-president of the blasting division of **Pacific Blasting & Demolition Ltd.** of Burnaby, B.C. They had all been experimenting independently with this technology since the late 1980s, but the project that drew them together as a group was the Molikpaq blast densification job in 1998.

The Molikpaq is a semi-submersible offshore oil rig, which was sunk about 7 km off a coastal island in eastern Russia in water up to 30 m deep. Essentially, Molikpaq is an enormous caisson 75 m in diameter with hollow walls that act as large ballast tanks. The walls are empty when the structure is being towed to into position, then flooded to sink it. The caisson is placed on a prepared mattress of sand and gravel, and the core is subsequently filled with dredged sand.

On this particular job the sand core had to be compacted, or densified, because it was believed that earthquake vibrations or wave loading could liquefy the loose saturated sand and destabilize the rig. The challenge was to densify the sand and the foundation pad beneath the rig for a total height of about 36.5 m. Conventional densification methods were considered impractical because of the limited headroom and a tight timeline. Using EC the density of the sand core was increased by about 25%. Firing multiple delayed decks of explosives kept the vibrations and strains in the hull of the structure within acceptable limits.

Explosive compaction requires installing plastic casings ranging in size from 8 cm to 13 cm in diameter to any depth. ECI has experience in densifying up to 40 m. The holes are charged with multiple, prepackaged explosive cartridges separated by gravel stemming. Sounds simple? What ECI brings to the table is experience in selecting the charge weight, explosive products, and the sequence of detonation (designing the blast pattern) that will result in the maximum densification without inducing excessive vibrations, or in other words getting the biggest bang for the explosive buck.

ECI started looking at tailings ponds when they were retained in conjunction with **Geopac Tech Inc.** of Montreal, Que., to do a densification study on the foundation of the Guindon tailings dam for **Inco Ltd.** in Sudbury, Ont. This work was carried out adjacent to the existing dam. Ron Elliott picks up the story: "In carrying out the test work we realized that we were getting a significant decrease in the volume of the material. This led [my partner] Blair to believe that we could do this [EC] to densify the loose saturated tailings. The challenge to using explosive compaction in a water-based application was to find a cost-effective way to work on the water."

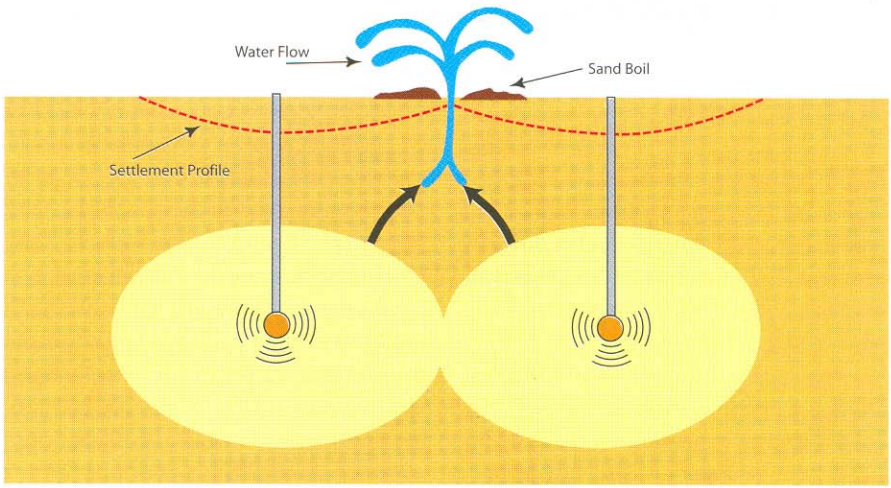
Blair Gohl elaborates: "Mobility on the water is a key issue for using this method. We need to be very mobile to make this economic. The barge-based technology

space and save money

has its limitations in that you need at least two feet [0.6 m] of water and it is difficult to move quickly and efficiently. Swamp buggies also have their limitations with the size of drilling equipment that can be supported and with water depths." Without giving too much away, using a combination of barges, swamp buggies and dewatering cells within the pond, ECI is confident that it can effectively place and charge blastholes in a wet environment.

Gohl estimates that for land-based project densification, it costs about $3/m^3$ to use dynamic compaction, about $5 to $6/m^3$ for vibro-flotation, and vibro-replacement comes in at about $10 to $15/m^3$. Costs typically are lower on the larger projects. Explosive compaction costs $3.50/m^3$ or less depending on the size of the job and the difficulties that may be encountered during the drilling. For the tailings pond process, ECI estimates the costs of densification to be about $1.50 to $2 per dry tonne of increased tailings storage capacity.

For land-based work, clients need assurances that a densification target will be met, leaving the contractor to choose the method based on its experience and equipment. Confirmation testing is carried out because on land-based projects the owner is intending to build something on the site. However, on tailings ponds confirmation testing is not generally required as the client is only interested in decreasing the volume of tailings so that more can be impounded. Densification can be easily demonstrated by measuring surface settlement and settlement at different depths. In large-scale testing for Inco, ECI was consistently getting about 10% volume reduction. An additional benefit is that by densifying the soil mass, the void ratio is decreased, decreasing the permeability, which in turn reduces environmental impact. Once the soil mass is densified, it can be used for reclamation projects.



Charge detonations cause shock front propagation, shearing of the soil mass, development of elevated water pressures, and settlement of the soil mass as water pressures dissipate.

For obvious reasons this method is not well-suited for tailings ponds with a manufactured or designed liner; nor is it well-suited to clay or silt with a high plasticity as the blast-induced settlement is delayed by the low permeability of the material.

In a tailings application, an extensive testing phase will determine the vibrations and the pore water pressures within the dam through the slime medium. The testing will start at the furthest from the dam or otherwise least-sensitive part of the tailings. The vibrations and pore water pressures induced by the blasting are carefully monitored by the geotechnical designers who will define the tolerances. Controlling the vibrations of the dam is achieved by limiting the charge weight/delay, using electrical sequential blasting methods, electronic detonators, and controlled blasting techniques that evolve from blast vibration analysis. ECI has had much success using custom-designed and prepackaged explosives with high strength microspheres.

Explosives must be selected that prevent sympathetic detonation, or the premature explosion of the upper decks from overpressure.

These specialty explosives add about one-third more to the materials cost and come in at around $10/kg including detonators, delays, explosives and lead-in line. Gohl explains that for the tailings pond application, ECI is using less-expensive bulk explosives with high-strength microspheres, rather than the prepackaged variety.

The ECI team is pioneering and refining its technology for this novel tailings application. Although still in the research stage, the developers feel that they are finally ready to give the dam-heightening option a run for its money. Not only that, they are sure that with a few projects under their belt their technique will be in great demand. All they need right now is a couple of big slimy wet ponds to improve. **CMJ**

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