Obtaining block samples from the Philippine Jungle for geotechnical testing and analysis in Australia (International field investigation)

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ABSTRACT: This paper presents the process involved in mobilising personnel from four global regions to the Philippine Jungle to undertake a geotechnical field investigation on an extreme consequence category tailings dam. The site was remote, and all equipment, supplies and materials had to be sourced in country, from locations approximately 14 hours away by vehicle.

The team completed the works under budget, ahead of time with no injury and all 18 samples were shipped back to Australia successfully in good condition. The samples were tested and analysed in Australia for use in an advanced Fast Lagrangian Analysis of Continua (FLAC) model.

This paper presents the purpose of the international field investigation, how the investigation was planned and executed, key logistical and financial considerations, and the methods used to both excavate and protect the undisturbed block samples during local and international transport. This paper presents a real-life case study for engineers and project managers tasked with organising international site investigations in the tailings sector.

Keywords: Geotechnical Investigation, Remote, International Travel, Engineering Management, Study Management

1 INTRODUCTION

Material properties, geometry, loading conditions and the presence of water are four key critical parameters used to evaluate the stability and factor of safety (FoS) of Tailings Storage Facilities (TSFs.) Therefore, changes to the four parameters can fundamentally impact how the TSF may perform and may result in a positive or negative impact on stability and FoS.

The most commonly used methods to determine stability and FoS are the Limit Equilibrium Method (LEM) and the Shear Strength Reduction method. The quality of the input parameters dictates the accuracy and reliability of the result.

Light Detection and Radar (LiDAR) or high precision surveys address knowledge gaps in surface terrain and geometry. Site-specific seismic hazard assessments can be built based on high-resolution survey data to firm up anticipated loading conditions, and the presence of water can generally be measured by a range of methods such as vibrating wire piezometers (VWPs), stand-pipe piezometers or dipped groundwater bores or wells. The material properties of the materials used in the TSFs design are typically estimated until they can be validated by laboratory testing and rigorous site investigation of surface and subsurface conditions.

Site investigation campaigns will generally include drilling and probing, such as Cone Penetration Testing (CPT), Sonic Drilling, HQ drilling to obtain material samples at depth, and bagged or block sampling methods for samples at the surface.

Often, drilling or probing methods lead to disturbed samples or cannot be undertaken due to complexities with the site. Human error can lead to mislabeling of samples, inaccuracy in the coordinates of test locations, inexperience with CPT in the selection of cones, and sample transport can destroy all the efforts put in to collect undisturbed samples. In addition, drilling errors can lead to hydraulic fracturing of the drilled locations, fluidisation of the samples, and probing of the same location resulting in disturbed samples.

In instances where drilling or CPT investigations cannot be undertaken, bagged and block samples can be taken. A block sample is a type of sampling technique that creates the opportunity to collect undisturbed samples; however, the volume of material and effort to obtain samples can be timely, and the transportation can be logistically challenging. In addition, there are usually multiple variables in accessing a mine site and undertaking activities on site, such as weather, storms, landslides, and lacking available tools.

2 DISTURBED VS UNDISTURBED SAMPLES

Soil/tailings samples are collected from site in order to carry out laboratory testing for deriving deriving its physical, mechanical and dynamic properties. The derived geotechnical parameters are subsequently used in finite element analyses (FEA) where a ‘digital twin’ of the TSF is modelled. The more accurate the geotechnical parameters used in these analyses, the more reliable the FEA results are. As such, it is important to collect samples from site that best represent the in-situ conditions.

There are two types of samples that may be collected from site: disturbed and undisturbed samples. The disturbed samples no longer possess key in-situ characteristics such as fabric, void ratio, water content, layering. On the other hand, high-quality undisturbed samples retain most of the in-situ characteristics. Some sampling disturbance is unavoidable during retrieval and trasportation, usually resulting in a slight densification of the soil matrix. Even so, high-quality undisturbed samples provide key insights into the true behavior of the soil/tailings in-situ. Further, by collecting undisturbed samples from locations close to CPT investigations, corrections for densification can be performed following laboratory element testing.

3 SITUATION

The TSF discussed in this paper is an extreme consequence TSF located on the Northern Island of Luzon, in the Philippines, a 12-hour drive north of the capital city, Manila. Therefore, the team was requested to undertake a comprehensive geotechnical investigation of the facility to validate parameters used in stability and deformation analyses.

The TSF is a cross-valley dam with a height of 137 m. The crest of the embankment is 300 m long and comprises an upstream and downstream bench constructed of bulk fill material separated by a clay core and two gravel filters. The embankment retains approximately 90 m of tailings material deposited from dual deposition pipes, 5 km upstream at the head of the valley. The decant pond drains into two vertical concrete inlet structures where the water is treated before being released downstream.

The site, located deep in the Philippine jungle, has access roads that would prove challenging both on and off the mine. In addition, the surrounding topography was subject to natural geohazards, landslides, seismic activity and typhoons. Furthermore, the area was subject to terrorism, rebel forces and political uprising risks.

The team considered deploying CPT and drill rigs via helicopter to gather subsurface information, but due to security and sabotage risks during previous investigations and security issues associated with low-flying aircraft in the region, the team opted for a surface bag and block sampling investigation only.

The team was tasked with collecting 18 block samples (i.e., high-quality undisturbed samples) of material and freighting them back to Australia for geotechnical testing and characterisation.

4 METHODOLOGY

The team mobilised from Australia to the Philippines via Hong Kong, where they purchased all the supplies required for the remote project. (Figure 1) The team executed a procurement plan to ensure sufficient local currency and means of payment were in place.

Figure 1. Supplies included but were not limited to plastic pallets, packaging and wrapping for shipment and transport, blocks of wax, eco expansion foam, excavation tools, tarps, cutting wires, foil and tilt indicators.

Figure 2. Careful excavation of a single test site location.

At the commencement of the project, the team met with 6 local contractors who would support the works. In addition, the site provided a single roller compactor and excavator. The team presented a safety briefing visually via a small whiteboard, as the contractors could not interpret the extensive safety documents due to education and language barriers.

The works commenced, and 12 sampling locations were identified and surveyed. An excavator commenced excavating two trenches to a depth of 2.5m, utilising a benched excavation profile and leaving an undisturbed section in the centre. (Figure 2) The trench was large enough that the soil in the central zone was not disturbed by the operation. The method is described by Clayton et al. (Clayton, 1995) and the ASTM's standard practices for obtaining undisturbed block (cubical and cylindrical) samples of soils. (ASTM, 2010)

Excess soil was gradually and gently removed from the excavated trenches, and the undisturbed central section was then trimmed using hand tools. Three to four block samples were trimmed and ready for transport preparation in as little as 6 hours. (Figure 3)

The Senior Geotechnical Engineer inspected the trimmed block samples, prepared a geotechnical log, captured photographs, and assigned each block with a sample identification card. (Figure 4.) The soils were visually classified, and the in-place condition of the soil, such as the colour, odour, moisture condition, consistency, cementation and structure, was recorded. This process was undertaken in accordance with the standard practice for the description and identification of soils (ASTM, 2015)

Freshly exposed faces of the block sample were layered with cheesecloth, and cool, melted wax was applied. (Figures 5 and 6.) The team took care to avoid applying hot wax to the samples. This process was repeated until the sample was coated with multiple layers, and the top of the sample was marked with the north orientation and a sample ID tag. The process was adopted from the ASTM standard practice for preserving and transporting soil samples. (ASTM, 2018)

Figure 3. Excavation of the block samples through the use of hand tools.

Figure 4. Excavated block samples at one test site location.

Figure 5. A small portable burner stove was used to melt wax blocks for sample preparation.

Figure 6. Photograph of two individual block samples painted with wax.

Figure 7. The wax-sealed blocks were wrapped with plastic wrap.

Figure 8. The wax-sealed and plastic-wrapped blocks were wrapped with aluminium foil and again with an additional layer of plastic wrap.

The waxed layers applied to the block samples help retain moisture content. However, to add an additional layer of protection, the team adopted methods described by Heymann et al. (Heymann et al. 1999) and wrapped the wax-sealed blocks with plastic wrap and aluminium foil. (Figure 7 and Figure 8.)

The prepared block samples were cut at the base with fine piano wire to free them from the underlying foundation (Figure 9) and wrapped in bubble wrap for protection during transport. The samples were then encased in open-ended wooden boxes with rope handles, fabricated on site. (Figure 10.)

The void between the bubble-wrapped block sample and the wooden box was backfilled with eco-expansion foam and left to dry before it was lifted manually to a laydown yard. The remaining void space at the top and bottom of the box was backfilled with foam, and the lid and base of the wooden box were applied. (Figure 11 and Figure 12) The team then marked the wooden boxes with all transport and importation information to manage the risk of missing samples during transit.

All wooden boxes were bubble wrapped and palletised by hand in preparation for international transport. (Figure 13.) Tip'n Tell indicator markers were then applied to all samples and pallets to monitor whether samples had tilted or been dropped during transport. (Figure 14)

Figure 9. Excavated block samples, ready for preparation for transport.

Figure 10. Wooden boxes fabricated by the team on site

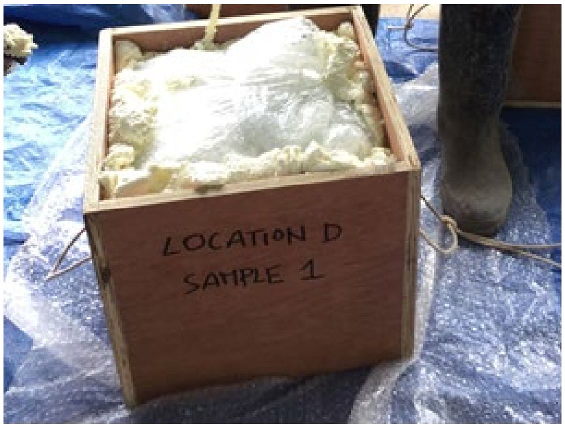

Figure 11. Backfilling of the top and bottom void space

Figure 12. Lids were applied to the top and base of the wooden box when all voids were filled with eco foam.

Figure 13. The bubble wrapped and palletised wooden boxed block samples ready for shipment and transport to Australia.

Figure 14. Tilt'n'tell indicators were affixed to each wooden box and pallet.

Figure 15. The tip'n'tell indicators sighted on arrival confirming the shipment had not tilted or tipped.

Figure 16. Test locations were backfilled and compacted on completion of block sampling activities.

Samples were shipped from the remote site to a port in the Philippines, where they were then transported to an irradiation site in Brisbane before reaching their final destination in Perth, Australia. The team were well prepared with the documentation and processes required to import samples in wooden containers to Australia, and on inspection, the til indicators confirmed the full shipment had arrived without tilt or tip disturbance. (Figure 15.)

The block sampling test locations were backfilled in layers and compacted to ensure the site and location were returned to their original state. (Figure 16.) The Senior Geotechnical Engineer supervised the backfilling operation.

5 DISCUSSION

Detailed planning, a robust understanding of logistical arrangements, an understanding of project-level risks, and an appreciation for project management are key to delivering successful site-based geotechnical field programs. Project Managers and Engineers must consider the practical steps involved, including; how their team members will mobilise to the site, whether flights will align with in-country transport if in-country transport is available and whether security will be required. Project Managers and Engineers should also consider if the team can obtain visas if they have any personal health circumstances, what health and safety measures must be in place and what measures must be in place to support the team if something goes wrong. In the context of this project, Australian Military personnel delivered international travel risk awareness training to the team ahead of mobilisation.

From a technical perspective, Project Managers and Engineers should provide the locations of proposed test areas and proposed methodology in advance, so all stakeholders know what is happening, when and why. This also allows project scopes to be aligned with the objectives of broader stakeholders and the activities and risks to be well understood.

For this project, the team proceeded on the assumption that no equipment or transportation supplies would be available in the remote location and took it upon themselves to arrive with everything in hand. Equipment was sourced to satisfy the requirements of all stages of the investigation life cycle from excavation through the end delivery in Australia. Although it is important that Project Managers and Engineers do not rely on the client or mine site to have all the equipment required readily available, preparation is key to success.

Additionally, Project Managers and Engineers must be prepared with a contingency plan if equipment breaks. In the context of this project, the team ran out of eco-form, and the fan belt on the compactor roller snapped. Fortunately, both items could be procured from small towns 6 hours away. The team also appreciated the ability to pre-order currency well in advance of mobilising.

6 CONCLUDING REMARKS

The field investigation described in this paper was completed within 10 days. During these 10 days, the team successfully collected 18 block samples, prepared and palletised the samples for transport and restored the test site locations to their original state. Obtaining multiple block samples from a single excavation, trimmed with local tools, proved successful for this scope of work and reduced the cost and time involved on site.

The integrity of samples collected during field investigations is critical to ensuring the success of laboratory testing campaigns. Given the importance of accurate geotechnical parameters in the field of stability modelling, Project Managers and Engineers should take care when planning and executing field investigations and consider how the samples will be protected during transport. Tilt'n'Tell indicators were valuable in providing stakeholders with assurance that the samples had been transported safely.

Eco-expansion foam was a useful medium to backfill storage containers to protect block samples during transport. The wooden crate containers were also very simple to construct on site.

Working internationally comes with its own challenges, from communication, language barriers, construction tool selection, and climate, health, safety and security risks. Project Managers and Engineers must understand the practical steps required to undertake proposed activities and shouldn't rely on clients and site operators to have all the equipment they require readily available. International travel risk awareness training and the reminder to organise pre-ordered currency proved valuable in this project.

The transportation and importation of soil and wooden containers varies per country. Therefore, Project Managers and Engineers need to contact government and regulator importation departments well in advance.

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