Future Tails: an industry–university collaboration to provide training for professionals working in the field of tailings management

By Professor Andy Fourie, The University of Western Australia, Australia

FUTURE TAILS

THE UNIVERSITY OF WESTERN AUSTRALIA · BHP · RioTinto

Graduate Certificate in Tailings Management offered by The University of Western Australia

Addressing the worldwide shortage of tailings professionals

Although there have been a number of high-profile failures of tailings storage facilities (TSFs) in recent years, including one in Australia in 2018, the failure of the Feijão (sometimes referred to as Brumadinho) TSF in Brazil in January 2019 has changed the industry irreversibly. Video footage of the failure provided graphic imagery of the sudden nature of the failure, and the devastating flow of liquefied tailings that ensued. More than 260 fatalities occurred due to the flow failure and major legal proceedings are underway, with costs estimated to be many billions of dollars.

In reaction to the Feijão failure, the Global Industry Standard on Tailings Management (GISTM) was developed, with the standard being launched in August 2020. Among the many requirements detailed in the GISTM was the identified need to have personnel with dedicated and explicit responsibilities related to the management of TSFs. Of relevance to this discussion, particular roles that the GISTM requires are the engineer of record (EoR) and the responsible tailings facility engineer (RTFE). Although some companies have different terms for the latter position, such as responsible tailings facility person, the intended roles and responsibilities are the same, and require someone with engineering qualifications and experience.

The specific roles identified in the GISTM, as well as the associated increase in demand for planning, design and construction supervision engineers in the tailings field has led to a rapid and dramatic increase in the demand for people with expertise in this field. Unfortunately, tailings engineering is not taught as a dedicated unit (e.g. a semester-long course) at any universities internationally (to my knowledge). University curricula are already crammed with traditional technical courses and increasingly with predominantly non-technical courses. Training in the specialised field of tailings engineering has thus become the responsibility primarily of industry, with many industry–university partnerships having been developed in the past two or three years to tackle this shortage of suitably qualified engineers. Future Tails is one of these partnerships.

Future Tails is a project, funded by BHP and Rio Tinto, based at The University of Western Australia (UWA) in Perth, Australia. The primary focus is to prevent future catastrophic failures of TSFs. To this end, Future Tails has three components: targeted research, preparation of a guidance e-book dealing with tailings engineering, and provision of relevant training. This article deals with only the third of these components, i.e. provision of relevant training.

There are four levels of training under Future Tails, these being for senior executives (e.g. board members), senior engineers – the target being EoR level engineers, junior to mid-level tailings engineers plus those with overlapping tailings related responsibilities who may be more senior but lack a tailings background, and finally, site operational personnel. Given space constraints, this article discusses only the third of these training programs, which is offered through a graduate certificate at UWA.

The Graduate Certificate in Tailings Management is a completely online program that has been developed to provide training for graduate and mid-level engineers working in tailings-related fields, as well as senior engineers who may be transitioning from other, related fields of engineering. It is also relevant to senior personnel who have no training in tailings engineering but whose responsibilities include aspects of tailings engineering that potentially influence the performance of TSFs. An example is those responsible for planning activities, where inclusion of sufficient land for tailings deposition throughout the life of asset is critically important, but not always recognised.

The graduate certificate is a formal UWA qualification that will be awarded to those candidates who satisfy all the requirements of the 12 micro-credentials. The concept of micro-credentials is relatively new to many universities. The intention is often to provide relatively short modules that students can take while working – the intention being to stack these modules (micros) towards an eventual university-accredited qualification. The tailings graduate certificate at UWA comprises of 12 micro-credentials, each counting for two credit points. The micros are offered online, with bespoke training material having been prepared for each of the 12 micros, as discussed in more detail later in this article. Students can work through the learning material at their own pace, with practice-worked examples provided, where relevant to the material being covered. There are no time-specific online lectures, as the intention is to enable students from across the globe to participate. However, each micro does have two one-hour online discussion sessions where students are able to pose questions regarding the material covered. These discussion sessions are recorded and made available through the UWA learning management system. As the graduate certificate is a formal university award, assessments are necessary. These are usually an online test (or tests) and a written assignment (or assignments). Four tranches of micros run throughout the year, as outlined below.

Each micro runs for eight weeks, with up to three micros running concurrently. In accordance with UWA's expectations of the work required for two credit points (i.e. one micro-credential), the expected time commitment, for an average student, is 50 hours including all time spent on self-study. The 12 micros are batched into four units, where a unit is the UWA equivalent of a semester-long course and thus worth six credit points. There are four units making up the graduate certificate, these being Introduction to Tailings Management, Tailings Operations and Water Management, Tailings Risk Evaluation, and Tailings Governance. As noted above, each of these units is made up of three micro-credentials. Confused? Hopefully the table below helps explain the structure of the graduate certificate.

Table 1. Graduate Certificate Structure

Unit Titles	Introduction to Tailings Management	Tailings Operations and Water Management	Tailings Risk Evaluation	Tailings Governance
Micro-credential* Titles	Preparation, Transport and Deposition of Tailings	Operations	Risk Evaluation	Conformance
	Basics of Tailings Geotechnics	Water Balance	Monitoring	Roles and Responsibilities
	Tailings Testing - an Introduction	Dewatering Technologies	Case Studies of Failures	Tailings Management Plans

*(Each micro-credential is worth two credit points)

The first micro-credential (Preparation, Transport and Deposition of Tailings) was first offered in 2021 and has been offered twice more since. The first students to graduate from this program will likely graduate in mid to late 2023. By the end of 2022, 172 students had participated in the program, with 76% of these students being from either BHP or Rio Tinto.

The online nature of the graduate certificate program has enabled students from across the world to participate. Although most of the students to date have been based in Australia (71%), we have had students from 16 different countries participate, with Chile, the USA and Canada providing a number of students. Pleasingly, we have also had several students from developing countries participate, including from Cote d'Ivoire, Ghana, Madagascar, Panama, Peru and Zambia.

As we receive feedback from students and from our sponsors (BHP and Rio Tinto), the micro-credentials will be reviewed and revised where necessary. With the tailings industry moving and transforming rapidly, it is essential that material be regularly updated, otherwise there is the risk of irrelevance occurring. Monthly meetings with our project sponsors have proved invaluable in helping to work towards constant benchmarking of what material is covered in the graduate certificate. The option will be provided in the future to upgrade the graduate certificate to a Master's of Engineering degree by completing additional technical courses and a thesis.

Finally, it is stressed that the graduate certificate, although funded by BHP and Rio Tinto, is open to anyone with an interest in improving their skills and knowledge related to tailings. Further information, including entry requirements for admission to the graduate certificate, can be found at shorturl.at/ewGM2

AB Fourie
The University of Western Australia, Australia

Commingling tailings and waste rock

By Dr G Ward Wilson, University of Alberta, Canada

Introduction

The practice of co-disposal for mine tailings and waste rock is becoming more and more popular. There are progressive degrees of co-disposal, beginning with i) the deposition of tailings and rock into the same impoundment, ii) the deposition of waste rock into a tailings impoundment, iii) the case where tailings are added to the waste rock pile, and iv) the case where coarse and fine tailings are pumped to an impoundment together for co-disposal, otherwise known as pumped co-disposal (Wickland 2006). All of these methods, while shown to be feasible and relatively easy to implement, produce deposits where the fine tailings and coarse waste are segregated upon deposition. Segregation often produces problematic deposits that lead to both chemical and physical instability.

The problems associated with segregation for the co-disposal of tailings and waste rock can be resolved with a new practice best referred to as commingling. The *Merriam-Webster dictionary* defines commingle as 'to blend thoroughly into a harmonious whole.' The word commingle is a verb and is an antonym of the word segregate. Over the last 20 years, research has shown that commingling tailings and waste rock offers significant benefits. This article briefly highlights some of the basic theory and design principles for commingling tailings and waste rock, along with laboratory testing and field trials.

Basic theory and design principles

The Porgera Gold Mine, in Papua New Guinea, investigated the co-disposal of fine autoclaved gold tailings within its waste rock dumps (Wilson 2001). It was found that mixing the tailings, after dewatering and thickening, with the waste rock would produce a new material with highly desirable characteristics. Figure 1 shows an example of this new blended material that is referred to as commingled tailings and waste rock in this article. A variety of names have been used in the past, such as co-mix and paste rock, to describe this new material; however, commingled tailings and waste rock is considered to be the most descriptive term.

The new commingled material in Figure 1 combines the physical attributes of both the waste rock and the tailings. It can be seen that the waste rock particles have clast-to-clast contact. Hence, the compressibility and shear strength of this material remain similar to the waste rock. At the same time, the hydraulic properties of the tailings, including the saturated hydraulic conductivity (Ksat) and air entry value, are controlled by the tailings that fill the voids in the waste rock. Figure 2 presents a computed tomography scan showing the voids (in red in left image) within a shale waste rock (shown in the right image). In short, these are the voids in the waste rock that are filled with tailings to produce the new commingled mixture. The volume and pore size distribution of these voids control the blending ratio and physical behaviour of the commingled material.

Wickland (2006) provides a comprehensive and theoretical framework for describing the phase relationships, volume change and permeability of mixtures of tailings and waste

Figure 1. Example of commingled tailings and waste rock.

rock. Wickland (2006) specifies design criteria to determine the blend ratio of tailings and waste rock such that the voids within the waste rock are completely filled with tailings while maintaining clast-to-clast contact within the matrix of the waste rock. This blend ratio is referred to as the just filled blend. The primary properties of the tailings and the waste rock, which control the blend ratio and behaviour of the mixture, are i) grain-size distributions of the tailings and waste rock, ii) porosity and water content of the waste rock, iii) solids content of the tailings, iv) specific gravity of each material, and v) in situ stress and final density of the mixture.

Laboratory testing and field trials

The field trial conducted at the Porgera Gold Mine led to the development of a major research program under a Strategic Partnership Grant funded by the Natural Sciences and Engineering Research Council of Canada and supported by Placer Dome Inc., INCO, Klohn Crippen Berger and Golder Associates Ltd. Wickland (2006) describes a meso scale experiment with four 6 m high columns constructed to measure the performance of the mixtures for tailings and waste rock. In addition, five large field lysimeter trials were installed at Copper Cliff Mine, Ontario (Figure 3). Commingled mixtures of tailings, waste rock and slag to produce barrier cover systems to limit infiltration and to control acid rock drainage were placed in these lysimeters. The results of the field study showed that the annual amount of infiltration of snowmelt and rainfall for the uncovered beach tailings decreased from about 500 mm/year to approximately 100 mm/year for a 1 m thick non-compacted commingled cover and to values approaching 10 mm/year for a 300 mm thick compacted commingled barrier cover. Furthermore, the pH was seen to increase from approximately 3.5 to values approaching 6 for all commingled covers profiles. Wilson et al. (2008) summarise the research programs completed at both the Porgera Gold Mine and the Copper Cliff Mine.

Most recently Ralph Burden (2021) completed a PhD thesis directed at achieving stable dry-stacked tailings using blended tailings and waste rock. Burden et al. (2019) showed how the properties of filtered tailings can be improved for dry stacking by commingling the filter tailings with waste rock. Figure 4 shows the slurry (or dynamic) consolidometer at The University of Queensland, in Australia, made available by David Williams who served as co-supervisor for Burden's PhD research program. The dynamic consolidometer is 400 mm high and allows vertical stress and loading rates to be applied to a tailings profile at a constant rate with direct measurements of deformation and porewater

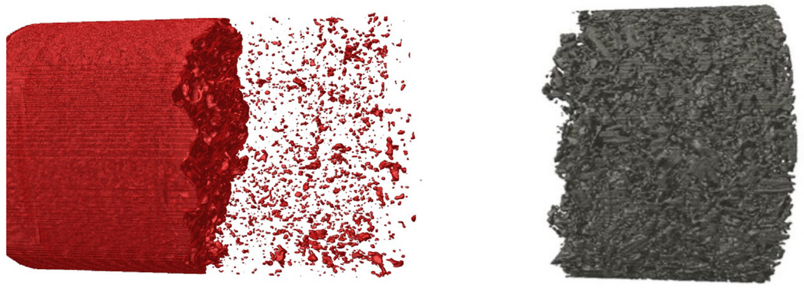

Figure 2. Computed tomography scan showing voids (in red in left image) in a shale waste rock (shown in right image).

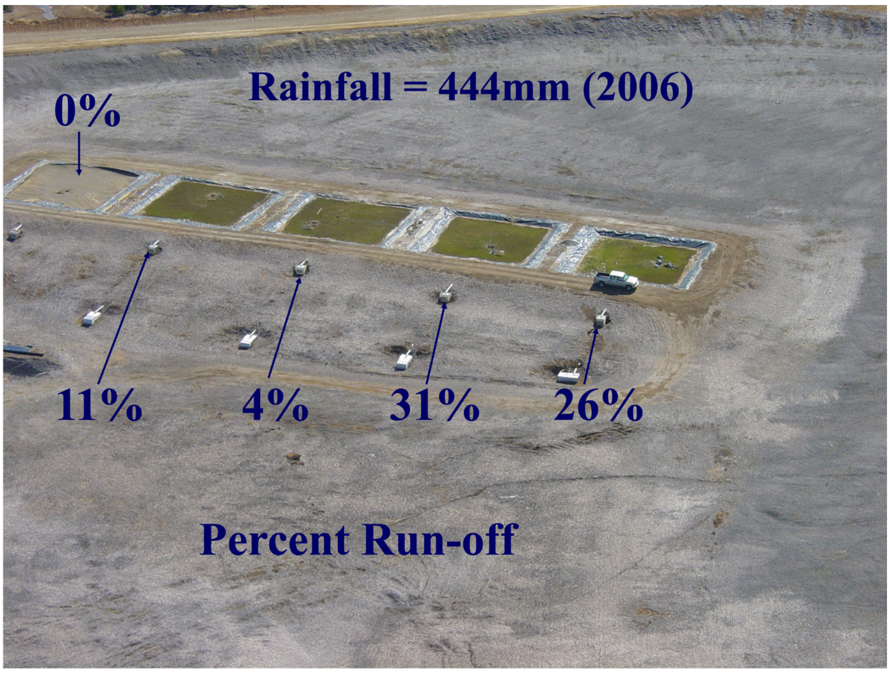

Figure 3. Field lysimeter trial at Copper Cliff Mine, Ontario.

Figure 4. Dynamic consolidometer with filtered tailings (Burden 2021).

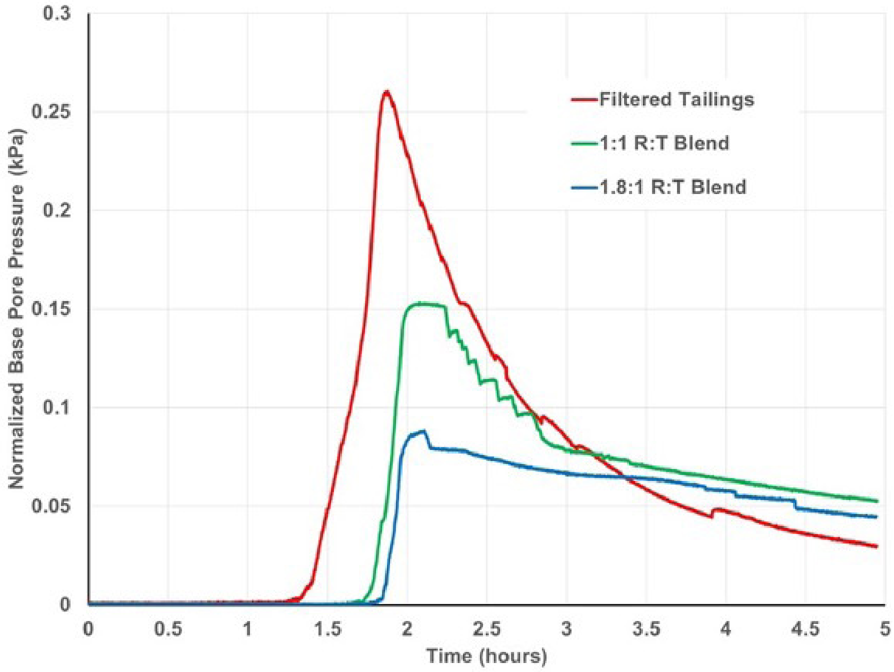

Figure 5. Pore pressure during loading for filtered tailings and filtered tailings blended with waste rock (Burden 2021).

pressure development in the column of tailings. In the case of unsaturated filtered tailings for dry stacking, the development of positive porewater pressures will reduce stability.

Figure 5 shows porewater pressure at the base of the profile during loading for filtered tailings and commingled filtered tailings, blended with waste rock at ratios of 1:1 rock to tailings and 1.8:1 rock to tailings (based on dry mass). Figure 5 shows that significant porewater pressure can develop within the unsaturated profile of filtered tailings during loading that can lead to significant reductions in shear strength with the potential for liquefaction to develop. The figure also shows that commingling waste rock with filtered tailings dramatically reduces the development of porewater pressures and thus indicates the stability of dry-stacked tailings systems can be enhanced by commingling with waste rock.

The examples described here for commingled tailings and waste rock are based on thickened/paste and filtered tailings. However, commingling tailings and waste rock can be carried out with a wide variety of tailings. Figure 6 shows a dry stack of commingled sand and dredged waste rock near Dawson City, Yukon. In this case, the fine washed sand that typically flows off the deck of the dredge was collected and deposited on top of the conveyor transporting the coarse cobble sized rock at the rear of the dredge. It is important to note that the sand and rock was well mixed for deposition with a relatively short conveyor of about 30 m, indicating that blending and commingling can be easily achieved with conveyor systems.

Summary

Interest in the mining industry to improve tailings and mine waste facilities is developing rapidly. There is a need to form mine waste facilities that are both geochemically and physically stable. Commingling of tailings and waste rock is a relatively new method that potentially offers significant benefits. The commingling concept combines tailings and waste rock to a specified mix design ratio for deposition in a single repository. These two materials are blended to produce an engineered material with superior physical and hydraulic properties for the construction of post-mining landforms

Figure 6. Example of commingled dredged rock and sand near Dawson City, Yukon.

compared to the waste rock or tailings themselves. The commingled material has high strength, high density and low compressibility characteristics, similar to that of well-placed engineered waste rock piles. Furthermore, this new commingled material also has a hydraulic conductivity similar to tailings, with excellent water retention characteristics without loss in geotechnical strength. These properties of the commingled material restrict both oxygen entry and water seepage for the minimisation oxidation and metal leaching. Furthermore, the commingled material has a higher density than either conventional tailings or waste rock deposits, thus reducing the total footprint required for the storage when compared to conventional storage facilities for the management of tailings and waste rock.

References

Burden, R 2021, *Using Co-disposal Techniques to Achieve Stable "Dry-Stacked" Tailings: Geotechnical Properties of Blended Waste Rock and Tailings in Oil Sands and Metal Mining*, PhD thesis, Department of Civil & Environmental Engineering, University of Alberta, Edmonton.

Burden, R, Williams, DJ, Wilson, GW & Jacobs, M 2019, 'The geotechnical properties of filtered tailings and waste rock blends', *Proceedings of The 6th International Seminar on Tailings Management*, Gecamin, Santiago.

Wickland, B 2006, *Volume Change and Permeability of Mixtures of Waste Rock and Fine Tailings*, PhD thesis, Department of Civil Engineering, The University of British Columbia, Vancouver.

Wilson, GW 2001, 'Co-disposal of tailings and waste rock', *Geotechnical News*, vol. 19, no. 2, pp. 44–49.

Wilson, GW, Wickland, B & Miskolczi, J 2008, 'Design and performance of paste rock systems for mine waste management', *Proceedings of Rock Dumps 2008*, Australian Centre for Geomechanics, Perth, pp. 107–116.

G Ward Wilson
University of Alberta