Influence of Geotextiles on the Engineering Behaviour of Mine Waste

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ABSTRACT: The construction potential of coal tailings is discussed in relation to compaction, permeability and shear strength. Considering both wet and dry tailings, the effect of non-woven geotextiles on the improvement of tailings characteristics is discussed. In particular, the effect of geotextile fabrics on the shear strength and failure modes is investigated. It is shown that the fabric inclusions promote a strain hardening behaviour even at axial strains exceeding 20%. A significant improvement in shear strength is obtained by increasing the number of geotextile layers within a specimen. It is noted that for dry tailings, the increased internal friction is only a function of the reinforcement effect, whereas at very high moisture contents, the non-woven fabrics also contribute as a good drainage medium in the improvement of the effective friction angle.

1. INTRODUCTION

The disposal of rejects from coal processing plants in Wollongong has been a major concern in an environmental point of view. In the Wollongong region, the coarse rejects are readily discarded as embankment materials (including tailings dams), while the fine tailings are pumped in slurry form to sedimentation ponds. Currently, the height of spoil tips and coal wash embankments do not exceed more than about 5 - 6 m. This is because most rejects are not well compacted, hence under soaked (saturated) conditions, such embankments do not possess a sufficient factor of safety against slope failure in the absence of toe protection. The failures of large tips composed of coal tailings and minestone have been reported in several parts of Australia. Erosion of fine particles and crest settlements of such embankments are also of concern (Fell *et al.*, 1992).

The critical height of tailings dams and similar structures can be increased by improving their internal friction and cohesive properties. The cohesion can be improved by chemical stabilisation using low cost pozzolanic materials. However, the improvement of the internal frictional behaviour and shear resistance requires effective compaction, internal drainage and the development of stable interfaces within the mass. In addition to providing reinforcement, the non-woven geotextiles in general are capable of improving internal drainage of wet tailings, such that the excess pore water pressures do not reach critical levels. Furthermore, if geotextiles are placed during the construction of tailings embankments at appropriate spacing, the erosion of fine particles (less than 500 microns) can be minimised by filtration. In the case of blended discards, where fine particles are mixed with coarse fractions (well-graded) in pre-determined proportions, the geotextiles mitigate the downward migration of fine tailings to the base of the embankment during heavy precipitation. Consequently, the development of high porosity layers within the structure can be avoided. Proper spacing of fabrics would reduce the drainage paths, hence enhancing the effective strength by (a) reducing the excess pore water pressures; and (b) increasing the compactability of 'wet' rejects. In this regard, non-woven geotextiles fulfill the functions of reinforcement, filtration, drainage and separation (Hausmann, 1990). In contrast, the relatively stiff woven geomembranes mainly act as internal reinforcements without much contribution to filtration and drainage (Indraratna *et al.*, 1991).

2. TAILINGS CHARACTERISTICS

For the purpose of this study, the tailings samples were obtained from a coal processing plant near Wollongong. The particle size analysis of the tested tailings indicated that this material predominantly consisted of fine sand sized particles (85%) and silt sized particles (10%). Its granular nature can be compared to that of a silty sand. The dark brown to black colour is obviously attributed to the coal residuals remaining in the washery discard after processing. The specific gravity determined for a range of representative specimens varied from 1.98 - 2.04, with an average of 2.02. It is relevant to note that the relatively low specific gravity of tailings is due to the coal particles (specific gravity of 1.65) in comparison with a natural soil of high quartz content. The lower specific gravity of tailings can be considered as an advantage for embankments raised over soft or compressible foundations, where settlement control is essential.

The compactability of tailings was determined using the standard and modified Proctor compaction practices. The modified Proctor compaction is more realistic in the field where coal wastes are utilised in the construction of mine access roads requiring high bearing capacities. It was found that the maximum dry density and the optimum moisture content for standard compaction were 13.7 kN/m^3 and 14%, respectively. The corresponding values for modified Proctor compaction were 15.6 kN/m^3 and 11.9 respectively. The granular nature (cohesionless) and the low specific gravity facilitate handling and compaction using conventional field machinery.

Falling head permeability tests were conducted on compacted specimens. For the standard Proctor compaction, the corresponding permeability co-efficient varied from 4×10^{-7} to 8×10^{-6} cm/s after steady state conditions were attained. For the modified Proctor specimens, the corresponding permeability decreased by a factor of 10 - 20. These permeability co-efficients may appear to be somewhat greater than those of compacted clayey fills. Nevertheless, for tailings dams and road embankments, these values are still acceptable in view of seepage control.

3. EFFECT OF GEOTEXTILES ON TAILINGS STABILITY

A series of triaxial compression tests were conducted on compacted tailings samples (38 mm x 76 mm) with and without non-woven (BIDM-A12) geofabrics. The effect of non-woven fabrics on the strength and failure modes was studied for a range of moulding water contents. Figure 1 illustrates the stress-strain behaviour and failure modes of three unreinforced specimens tested at confining pressures of 20, 50 and 100 kPa. All specimens were prepared at a moisture content of 15%. In general, at moisture contents exceeding the optimum value, the specimens showed a bulging mode of compressive failure, or a distinct shear plane at elevated cell pressures. As expected, the higher confining stresses increased the failure stress and the axial strain at failure. The specimens which developed a shear failure mode were characterised by a strain-softening behaviour, while the 'bulging' specimens indicated a slight strain-hardening response.

The inclusion of non-woven geotextile layers within the test specimens had a significant effect on the strength and failure mechanism of the specimens. The most important effect of geofabrics was the prevention of a shear plane across the specimen. Figure 2 illustrates the stress-strain behaviour of a sample stabilised with two layers of geotextiles at 15% moisture content at compaction. There is no doubt that not only the triaxial strengths of the individual samples are enhanced, but also the risk of shear failure is mitigated. The fabric inclusions promote a strain-hardening behaviour even at axial strains exceeding 20%. The shear strength of the tailings-geotextile interface was determined by direct shear box testing conducted on coal tailings compacted at moisture contents of 14-15%. The resulting strength envelope based on several specimens tested at increasing normal stresses is shown in Figure 3. The linearised Mohr-Coulomb envelope clearly reveals that the interface friction angle (38^o) is significantly greater than that of the internal friction angle of unreinforced specimens (about 32^o), while the affect on the interface cohesion is negligible.

The conclusive role of non-woven geotextiles is illustrated in Figure 4, where the apparent friction angle is plotted against the moisture content at compaction, for varying number of geotextile layers. At the optimum moisture content (close to 14%), the basic internal friction angle (unreinforced) is about 32°. The introduction of a single layer of fabric at the middle of the specimens is capable of increasing the apparent friction angle to 40° or more. Further improvement in shear resistance is obtained at increased number of fabric layers. It may be noted that at moisture levels exceeding the optimum moisture content, the influence of geotextiles is mainly associated through their function as a drainage medium. At low moisture

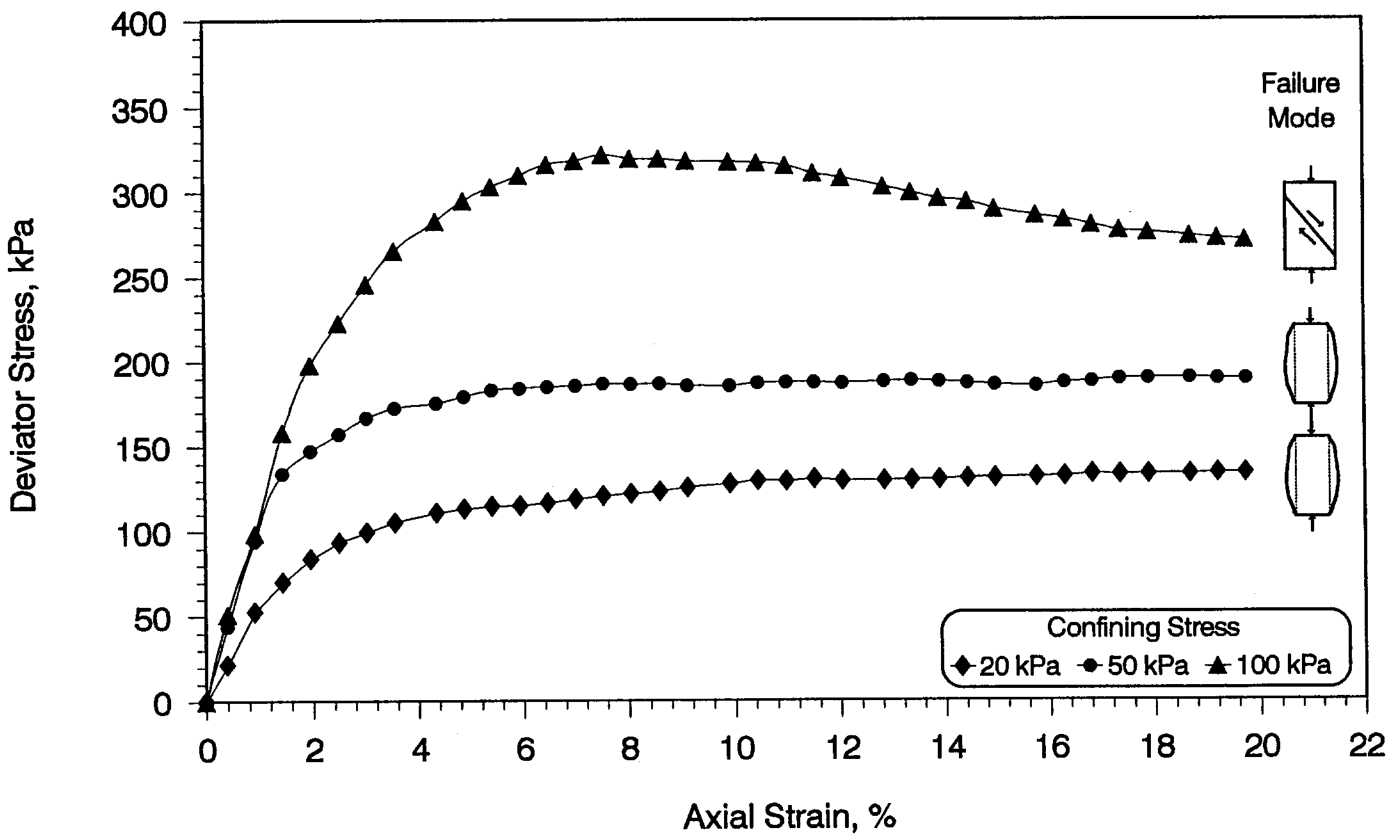

Fig. 1 Stress-strain behaviour of unreinforced tailings at 15% placement moisture content

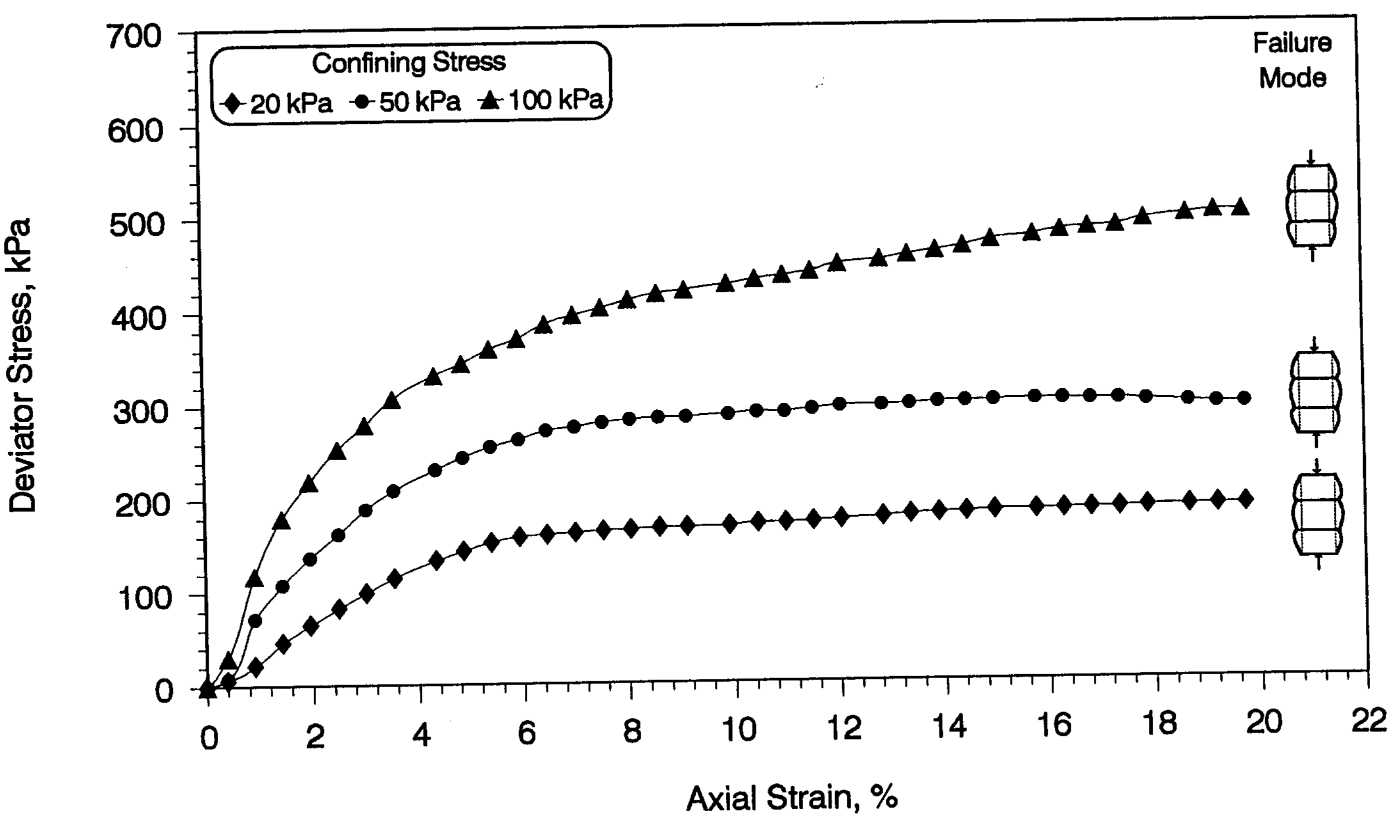

Fig. 2 Stress-strain behaviour of tailings with two layers of fabric inclusions at 15% placement moisture content

contents (dry specimens), the increase in the angle of friction is solely a function of the reinforcement effect (ie. fabric - tailings interface).

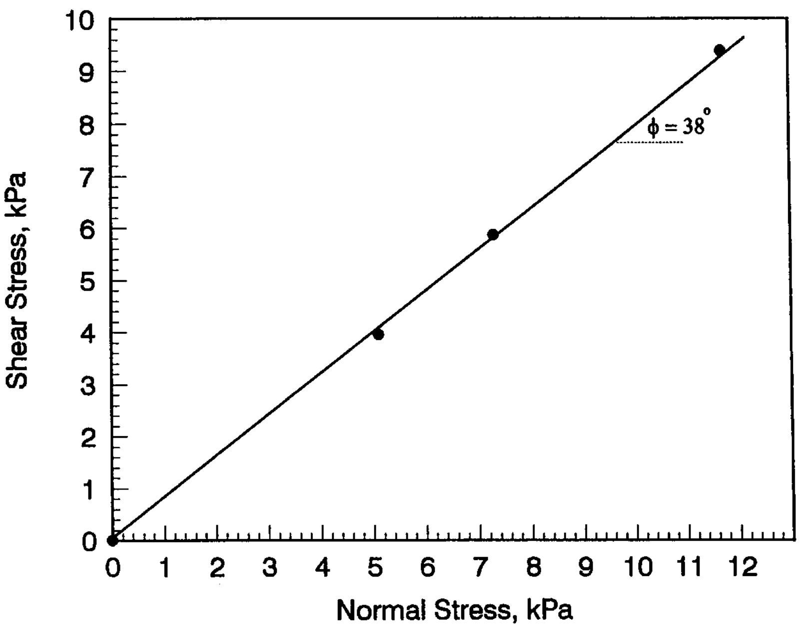

Fig. 3 Shear strength of coal tailings-geotextile interface based on laboratory shear box testing

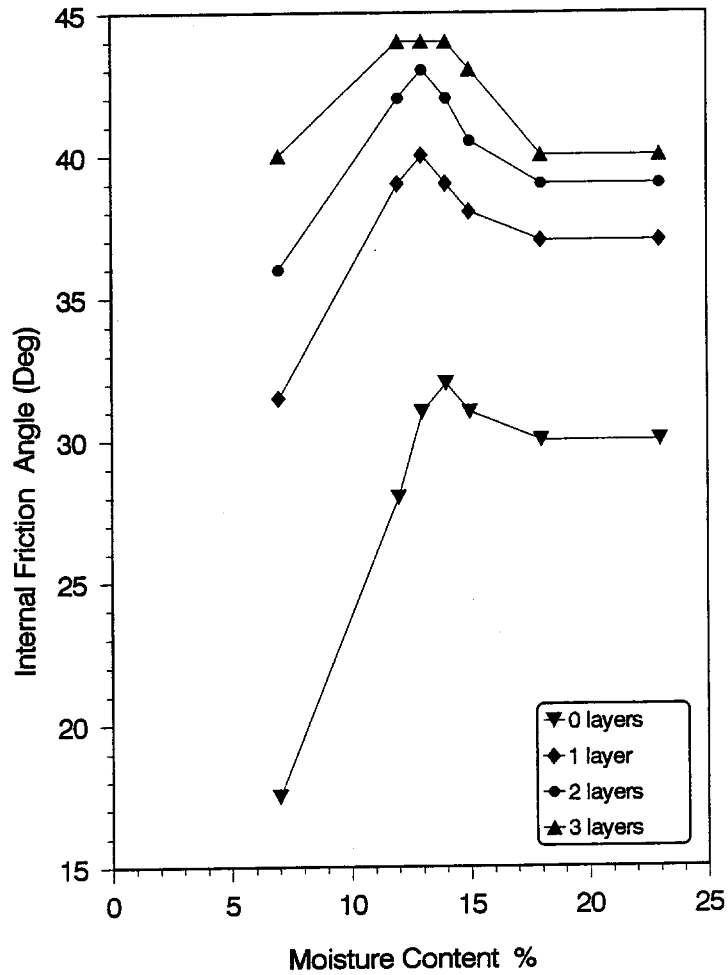

Fig. 4 Variation of internal friction angle with number of fabric layers for tailings compacted at different moisture contents

4. CONCLUSIONS

Non-woven geotextiles are capable of stabilising both 'wet' and 'dry' tailings through their pronounced drainage and reinforcement characteristics. Therefore, the critical height of most tailings embankments can be raised using non-woven geotextiles placed during stage by stage construction. The stress-strain behaviour of reinforced specimens indicated that geotextiles improved the peak stress and the corresponding failure strains significantly, as a function of the number of layers. Non-woven fabrics not only provide an excellent drainage medium, but they also provide a stable interface with enhanced shear resistance and good reinforcement effect.

At the optimum moisture content at compaction, an increase in apparent friction angle from 32° (unreinforced) to at least 42° (multi-layered) reflects an increase in the factor of safety from about 1.08 to 1.44 for a 30° slope, based on an infinite slope analysis. Increasing the number of fabric layers causes a definite change from strain-softening to a strain-hardening behaviour, as well as mitigating the development of a distinct shear plane. It may also be anticipated that at very low moisture contents, the propagation of tensile cracks will also be halted by the presence of geotextile inclusions.

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