Geotechnical Testing to Determine the Suitability of Biosolids for Embankment Fill

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ABSTRACT. Biosolids are an end product of municipal wastewater treatment and contain many of the constituents removed from the influent wastewater. The use of biosolids and other waste materials in a sustainable manner is currently being investigated in several countries around the world. A series of field tests were undertaken on biosolids stockpiles at Western Treatment Plant in Victoria. Following the field tests and sampling geotechnical laboratory tests were undertaken to assess the viability of using biosolids as fill material for embankment fills. Geotechnical properties of untreated biosolids and stabilised biosolids with 1%, 3% and 5% of cement were obtained from the laboratory tests. The field and laboratory test results were compared with the existing local road authority specification for fill material.

INTRODUCTION

The quantity of the municipal biosolids produced annually in the world has increased dramatically over the decades. Annually 66,700 dry tonnes of biosolids are produced from the 175 wastewater treatment plants in Victoria including 39,700 dry tonnes per annum biosolids from the Eastern and Western treatment plants in Melbourne which are managed by Melbourne Water Corporation (NRE, 2002).

The Western Treatment Plant treats about 52% of Melbourne's sewage where the sewage is mostly treated in vast lagoon systems. Sludge, which settles to the bottom of the lagoons, is pumped into a contained area where it dries to create biosolids. Biosolids by definition are treated sewage solids suitable for beneficial use in accordance with the relevant regulations whilst sludge is untreated sewage solids not suitable for use without further treatment

In this project the engineering characteristics of biosolids at Western Treatment Plant (WTP) in Victoria, were investigated to assess the viability of using biosolids as fill material for embankment fill material. The engineering characteristics of biosolids have been reported previously by Hundal et al. (2005), Reinhart (2003) and O'Kelly (2005, 2006).

The characteristics of the biosolids depend on various factors such as the type of waste, type of treatment process and age of the biosolids. In-situ geotechnical design parameters were obtained from the field tests. Geotechnical engineering properties of the untreated biosolids and cement stabilised biosolids with 1%, 3% and 5% cement were determined from laboratory tests. Field tests undertaken included Standard Penetration Tests (SPT) and field vane shear tests to determine the shear strength of biosolids. Laboratory tests were undertaken included compaction and California Bearing Ratio (CBR) tests. Geotechnical parameters for the biosolids were obtained from the field and laboratory tests and compared with the existing local road authority specification for fill material.

FIELD TESTING OF BIOSOLIDS

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Site Description

Geotechnical sampling and field testing works were carried out from the top of three existing biosolids stockpiles in the Biosolids Stockpile Area, Western Treatment Plant, located approximately 50 km to the west of Melbourne. Following the construction of the 18 ha Biosolids Stockpile Area, approximately 150,000 m^3 of biosolids were harvested from sixteen existing Sludge Drying Pans and stockpiled. The Biosolids Stockpile Area was constructed with a provision for the stockpiling of seven rows of biosolids stockpiles each up to 5 meters high and separated by access roads.

Geotechnical Testing

Geotechnical field tests carried out in this project included field vane shear tests and standard penetration tests, with the assistance of a geotechnical drilling rig. The field vane shear test was used to determine the undrained shear strength of the biosolids whilst the standard penetration test was used to determine the bearing capacity and the strength consistency of the biosolids.

Geotechnical laboratory tests carried out include compaction and California Bearing Ratio tests. Compaction tests enable the maximum dry density and optimum moisture content of the samples to be obtained. The optimum moisture content refers to the amount of water which is added to achieve the maximum dry density of the biosolids. Generally, it is possible to achieve 95% to 98% of laboratory maximum dry density values in the field. Standard compaction test were undertaken according to Australian standard methods of testing soils for engineering purposes (AS 1289, 2003).

California Bearing Ratio is a strength measurement test commonly used in the design of embankments and pavements. The CBR tests were performed on four day soaked specimens in accordance with Australian standard methods of testing soils for engineering purposes (AS 1289, 1998). The CBR values are useful to evaluate the suitability of biosolids as engineered fill material.

Sampling and Testing

Twelve boreholes were drilled from the top of the biosolids stockpiles for the full 4-5 m depth of the biosolids with a geotechnical drilling rig. A total of 48 undisturbed, 100 mm diameter sample tubes were obtained from the field and transferred to the laboratory. Four standard penetration tests were carried out in selected boreholes as shown in Figure 1 with the test results displayed in Figure 2.

Twenty field vane shear tests were carried out within the boreholes at one metre depth intervals to determine the in-situ vane shear strength of the biosolids. The field vane shear strength of biosolids in the stockpiles is presented in Figure 3. Approximately 2500 kg of bulk biosolids samples were also obtained for laboratory testing purposes which were collected in large bags which and sealed to maintain the natural moisture content.

Figure 1 : Standard Penetration Tests (SPT) carried out on site

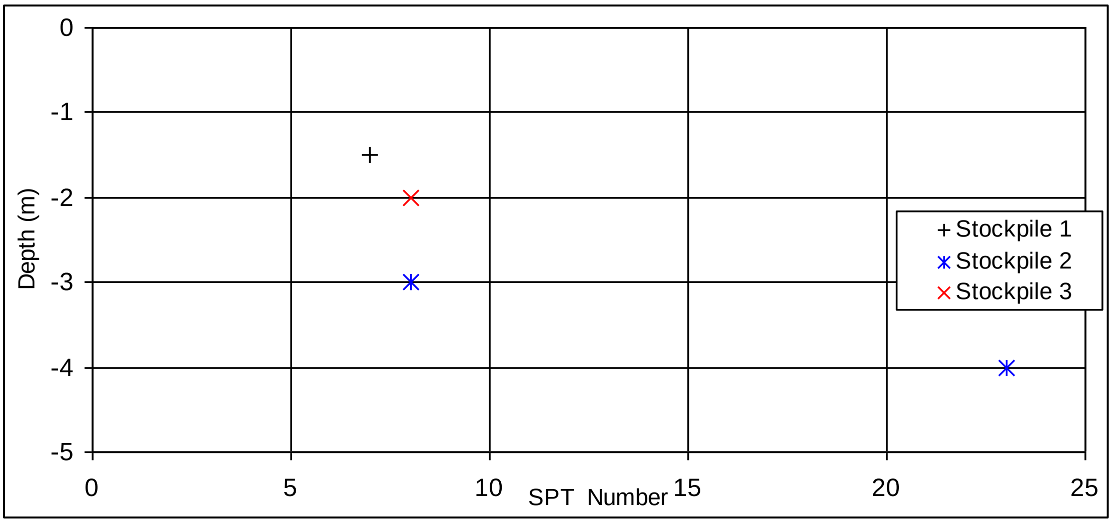

Figure 2 : Standard penetration test (SPT) results

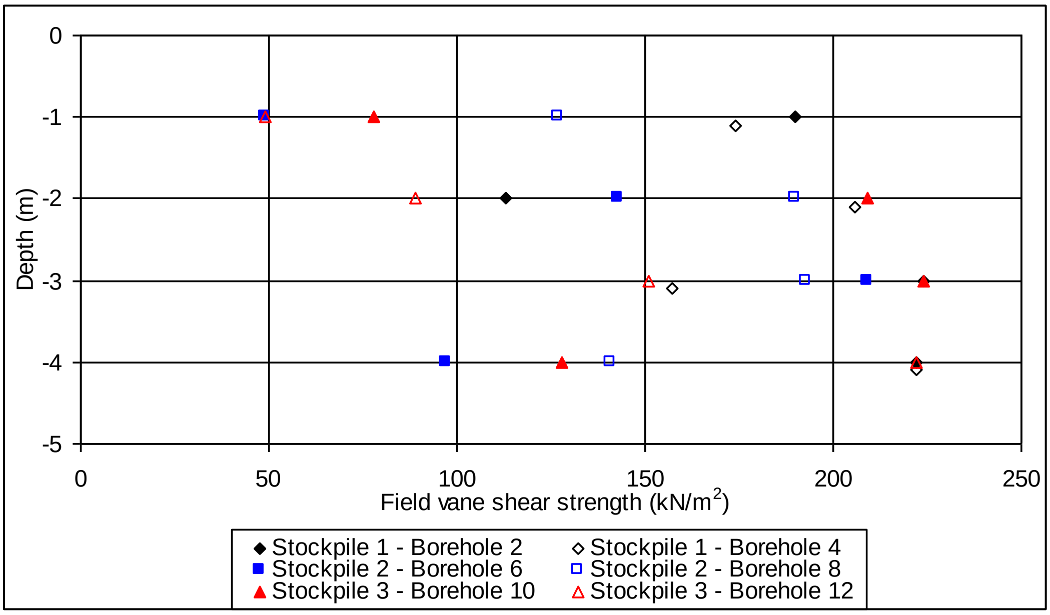

Figure 3 : Field vane shear test results of biosolids

Evaluation of Field Testing Results

In general consistency of biosolids in the stockpile increases with depth. A firm layer of biosolids (4<SPT<8) was encountered in the three stockpiles at depths ranging from 1.5 m to 3.0 m whilst a very stiff layer of biosolids (16<SPT<30) was encountered in Stockpile 2 at a depth of 4.0 m. The slight variability between the various field testing methods is expected due to various assumptions and empirical equations used in each test methods.

LABORATORY TESTING OF BIOSOLIDS

Geotechnical laboratory tests including compaction and California Bearing Ratio (CBR) tests were undertaken on six untreated biosolids samples from three stockpiles. Four biosolids samples stabilised with 1%, 3% and 5% cement were also tested. The compaction and CBR tests were performed in accordance with Australian standard methods of testing soils for engineering purposes. The CBR test samples were prepared at the optimum moisture content which was obtained from the standard compaction test.

Evaluation of Laboratory Testing Results

Figure 4 presents the maximum dry density of stabilised biosolids with various percentages of cement as compared to untreated biosolids. The maximum dry density of cement stabilised biosolids was 0.84t/m^3 to 0.85t/m^3 with 1% of cement; 0.86t/m^3 to 0.88t/m^3 with 3% of cement and 0.87t/m^3 to 0.88t/m^3 with 5% of cement. Increasing the proportion of cement had little effect on the maximum dry density of the biosolids.

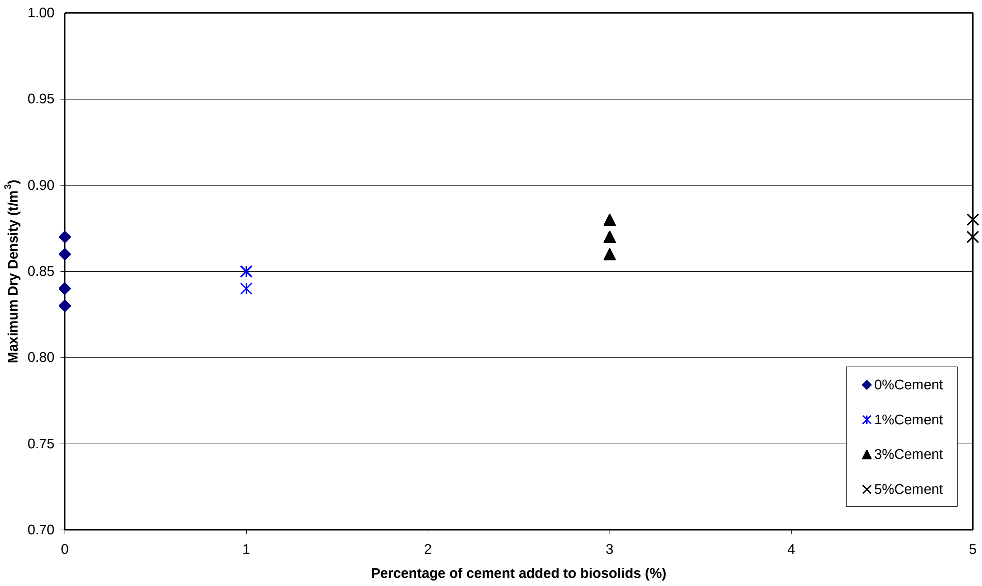

Figure 4 : Maximum dry density of biosolids

Figure 5 presents the optimum moisture content of biosolids stabilised with various percentages of cement as compared to untreated biosolids. The optimum moisture content of cement stabilised biosolids was 38% to 40% with 1 % of cement; 38% to 40% with 3 % of cement and 37% to 40% with 5% of cement. The addition of cement had little effect on the optimum moisture content of the biosolids as compared with the untreated biosolids.

The CBR value for the untreated biosolids was found to range between 0.8 to 1.1 %. The CBR value of stabilised biosolids varied from 1.7% to 2.0% with the addition of 1% of cement; 2.0% to 2.4% with the addition of 3% of cement and 3.8% and 4.6% with the addition of 5% of cement. The stabilisation of biosolids with cement increases the CBR value of biosolids with the percentage added to the mix.

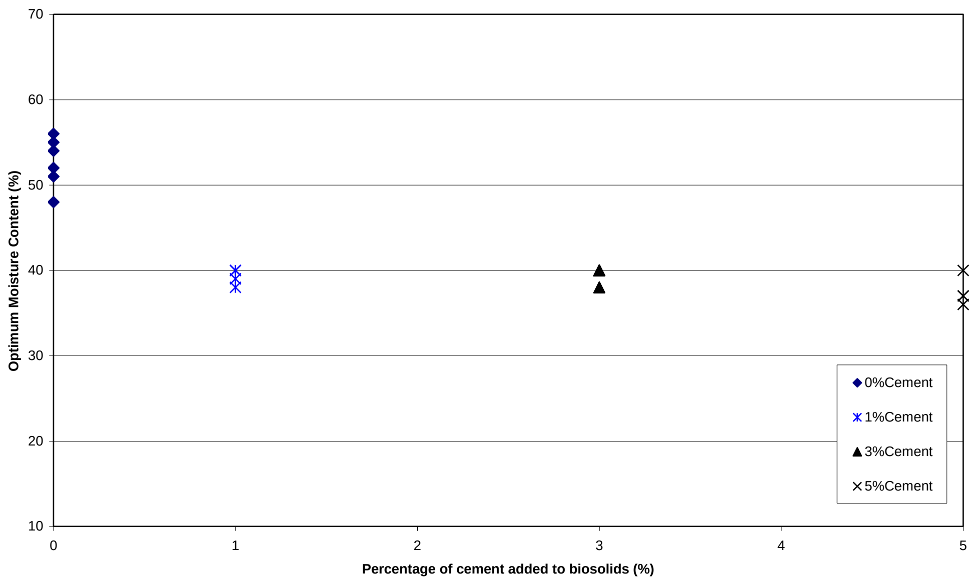

Figure 5 : Optimum moisture content of biosolids

COMPARISON WITH LOCAL ROADWORK SPECIFICATIONS

VicRoads is the local road governing authority in Victoria and classifies fill material for earthworks into three types; Type A, B and C. Type B fill material is defined by VicRoads (2006) to be "*free of topsoil, deleterious and/or perishable matter and after compaction shall have a maximum particle dimension of not more than:*

- 150 mm within 400 mm of subgrade level;
- 400 mm at depth greater than 400 mm below subgrade".

VicRoads requirement for Type B fill is a CBR value of 2% to 5%. Figure 6 presents the CBR results for biosolids stabilised with 1%, 3% and 5% of cement as compared to untreated biosolids and also VicRoads requirement for Type B fill materials. The result in Figure indicates that stabilised biosolids with 3% and 5% cement satisfy the VicRoads requirement for Type B fill material.

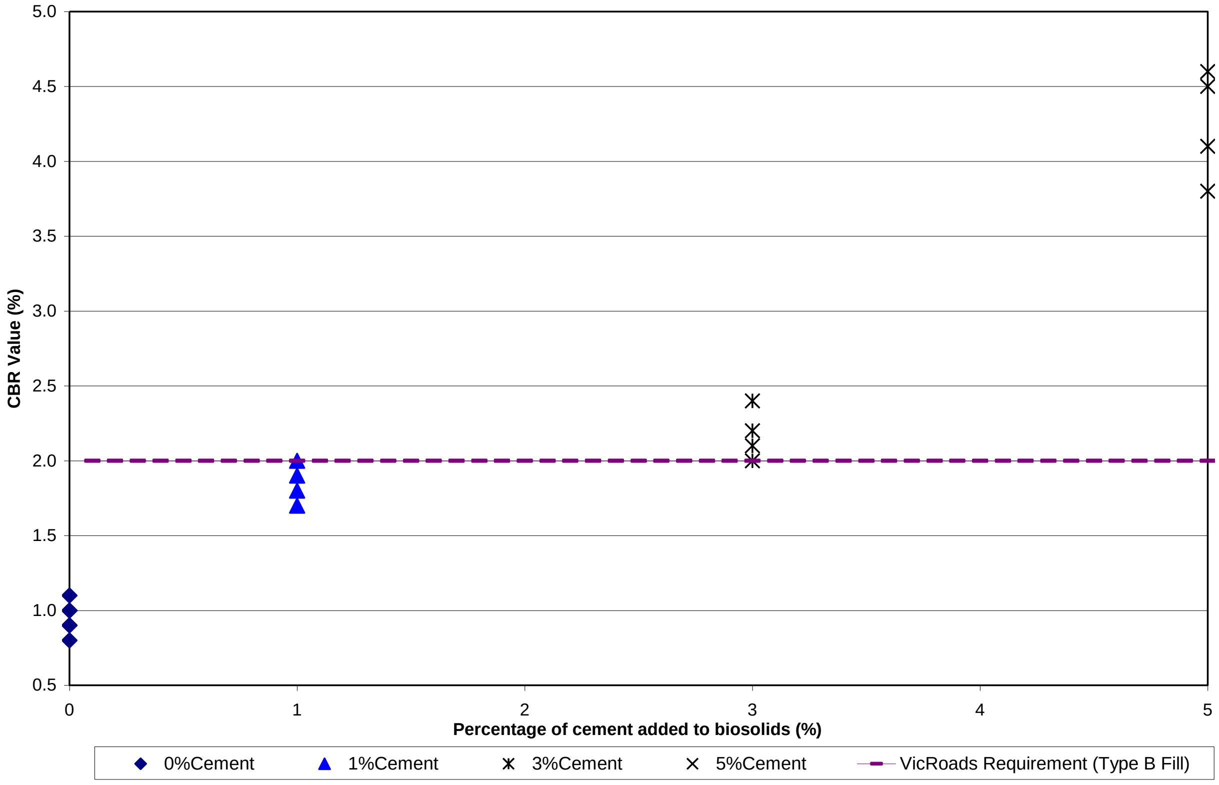

Figure 6 : CBR results of biosolids and Type B fill material

CONCLUSIONS

This study was conducted in order to evaluate the potential use of biosolids as fill material in road embankments. Field and laboratory tests were undertaken in this study to evaluate the geotechnical engineering properties of biosolids samples obtained from a waste-water treatment plant in Victoria. The consistency of biosolids in the stockpiles was found to vary from firm to very stiff based on the field tests and considered a fairly consistent material in geotechnical terms.

The CBR values obtained from standard laboratory CBR test for untreated biosolids ranged between 0.8 to 1.1 %. The CBR value of stabilised biosolids increased with increasing amounts of cement. The biosolids stabilised with a minimum of 3% cement satisfies the VicRoads specification for Type B fill material. The field and laboratory testing results both indicate the potential for reuse of biosolids as a construction material for embankment fill.

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REFERENCES

Department of Natural Resources and Environment (NRE) (2002). "Moving Towards Sustainable Biosolids Management", Victoria, Australia.

Hundal, L. Cox, A. and Granto, T. (2005). "Promoting beneficial use of biosolids in Chicago: User needs and concerns", *Report No. 03-8*, Metropolitan Water Reclamation District of Greater Chicago, USA.

O'Kelly, B.C. (2005). "Consolidation Properties of a Dewatered Municipal Sewage Sludge", *Canadian Geotechnical Journal*, Vol. 42, 1350-1358.

O'Kelly, B.C. (2006). "Geotechnical Properties of Municipal Sewage Sludge", *Geotechnical and Geological Engineering*, Vol. 24, 833-850.

Reinhart, D. Chopra, M. Sreedharan, A. Koodthathinkal, B. and Townsend, T. (2003). "Design and operational issues related to the co-disposal of sludge and biosolids in Class I landfills", Florida Centre for Solid and Hazardous Waste Management.

Standards Australia (2003). Methods of testings soil for engineering purposes: Method 5.1.1: Soil compaction and density tests-Determination of the dry density/moisture content relation of a soil using standard compactive effort, AS 1289.5.1.1–2003.

Standards Australia (1998). Methods of testings soil for engineering purposes: Method 6.6.1: Soil strength and consolidation tests - Determination of the one-dimensional consolidation properties of a soil - Standard method, AS 1289.6.6.1–1998.

VicRoads (2006). "Specification for Roadworks and Bridgeworks", *Section 204 Earthworks,* Australia.