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BIOSOLIDS AS A CONSTRUCTION MATERIAL FOR ENGINEERED FILLS

V. Suthagaran\textsuperscript{1}, A. Arulrajah\textsuperscript{2}, M.W. Bo\textsuperscript{3} and J. Wilson\textsuperscript{4}

ABSTRACT. Biosolids are defined as appropriately treated sewage sludge consisting of untreated organic slurry residue derived from wastewater treatment processes. 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 and laboratory test were performed at the Western Treatment Plant in Victoria, Australia to assess the viability of using biosolids as fill material for road embankments. Geotechnical parameters obtained from the field and laboratory tests were compared with the existing local road authority specification for fill material.

INTRODUCTION

With the advent of global industrialization, extensive amounts of waste are generated daily by various industries and human activities. The disposal of solids waste such as biosolids is a major problem throughout the world. The sustainable usage of waste materials in engineering applications is of social and economic benefit to industrialized nations. Due to the shortages of natural mineral resources and increasing waste disposal costs, recycling solids wastes has become significant in recent years.

Biosolids refers to dried sludge having the characteristics of a solid typically containing 50% to 70% by weight of oven dried solids. Sludge refers to solids-water mixture pumped from wastewater treatment lagoons having the characteristics of a liquid or slurry typically containing between 2% to 15% of oven dried solids. The quantity of the municipal biosolids produced annually in the world has increased dramatically over the decades. The engineering characteristics of biosolids is being investigated to assess the suitability of biosolids in

\textsuperscript{1} PhD Candidate, Faculty of Engineering and Industrial Science, Swinburne University of Technology, Melbourne, Australia, e-mail: vsuthagaran@swin.edu.au
\textsuperscript{2} Senior Lecturer, Faculty of Engineering and Industrial Science, Swinburne University of Technology, Melbourne, Australia, e-mail: aarulrajah@swin.edu.au
\textsuperscript{3} Director (Geo-Services), DST Consulting Engineers Inc., Thunder Bay, Ontario, Canada, e-mail: mwinbo@dstgroup.com
\textsuperscript{4} Professor, Faculty of Engineering and Industrial Science, Swinburne University of Technology, Melbourne, Australia, email: jwilson@swin.edu.au
engineering projects such as roads, embankments and other stabilised fill applications. The engineering characteristics of biosolids have been reported previously by O’Kelly (2005, 2006) and Hundal et al. (2005). Reinhart (2003) has also reported on the engineering properties of biosolids and sewage sludge.

The characteristics of the biosolids around the world vary as the properties of the biosolids depend on factors such as the type of waste, type of treatment process and age of the biosolids. The biosolids sampled from a waste water treatment plant in Victoria, Australia was evaluated and investigated as a suitable fill material for embankment construction. 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 tests undertaken included standard penetration tests, field vane shear tests and dynamic cone penetration tests to determine the shear strength with depth of biosolids. Laboratory tests undertaken included compaction and California Bearing Ratio (CBR) tests.

FIELD TESTING OF BIOSOLIDS

Site Descriptions

Field sampling and tests were carried out on a recently constructed Biosolid Stockpile Area located in the Western Treatment Plant in Victoria, Australia. The treatment plant is located approximately 50 km to the west of Melbourne. Following the construction of the 18 ha Biosolid Stockpile Area, approximately 150,000 m$^3$ of biosolids were harvested from sixteen existing Sludge Drying Pans and stockpiled. The Biosolid 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 sampling and field testing works were carried out from the top of the three existing biosolids stockpiles within the Biosolid Stockpile Area.

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. Four undisturbed samples were obtained with 100 mm diameter sample tubes in each of the borehole. A total of 48 undisturbed samples were obtained from the field and transferred to the laboratory. The standard penetration tests carried out in the stockpiles are summarized in Figure 1.

Twenty field vane shear tests were carried out within the boreholes at one meter 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 2. The sensitivity of the biosolids is the ratio of the undisturbed to remoulded shear strength is presented in Figure 3. Twelve dynamic cone penetrometer (DCP) tests were carried out at locations adjacent to each of the borehole and the in-situ California Bearing Ratio (CBR) was determined. Approximately 2500 kg of bulk biosolid samples were also obtained from the biosolids stockpile area for laboratory testing purposes. Bulk samples were collected in large bags which were sealed to maintain the natural moisture content of the biosolids.
Figure 1. Standard penetration test (SPT) results for biosolids

Figure 2. Field vane shear strength of biosolids

Figure 3. Sensitivity of biosolids
Evaluation of Field Testing Results

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 field vane shear tests results indicated that the undrained shear strength of biosolids generally increased with the depth of the stockpile. Consistency of the biosolids based on the field vane shear test can be classified as very stiff to hard and the sensitivity of the biosolids was found to vary between 2.3 to 6.8.

Table 1 shows the average in-situ CBR of each biosolids stockpile with depth. In-situ average CBR values obtained from the DCP test results ranged between 2 to 19 %. The DCP test results obtained from Stockpiles 1 and 2 indicate that the biosolids are firm to very stiff at depths from 0 to 0.5 m whilst below the depth of 0.5 m, the biosolids are found to be stiff to hard. The DCP test results obtained from Stockpile 3 indicate that the biosolids is firm to stiff at depths from 0 to 0.5 m and stiff to very stiff below a depth of 0.5 m. It is noted that the various field testing methods consistently indicate that the biosolids at the stockpiles are firm to hard. The slight variability between the various field testing methods is expected due to various assumptions and empirical equations used in each test methods.

<table>
<thead>
<tr>
<th>Stockpile No.</th>
<th>Depth (m)</th>
<th>Average In-situ CBR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0 – 0.5</td>
<td>2 – 9</td>
</tr>
<tr>
<td></td>
<td>0.5 – 0.9</td>
<td>10 – 16</td>
</tr>
<tr>
<td></td>
<td>0.9 – 1.6</td>
<td>13 – 19</td>
</tr>
<tr>
<td>2</td>
<td>0.0 – 0.5</td>
<td>2 – 9</td>
</tr>
<tr>
<td></td>
<td>0.5 – 0.9</td>
<td>6 – 10</td>
</tr>
<tr>
<td></td>
<td>0.9 – 1.6</td>
<td>9 – 15</td>
</tr>
<tr>
<td>3</td>
<td>0.0 – 0.5</td>
<td>2 – 8</td>
</tr>
<tr>
<td></td>
<td>0.5 – 0.9</td>
<td>4 – 8</td>
</tr>
<tr>
<td></td>
<td>0.9 – 1.6</td>
<td>5 – 13</td>
</tr>
</tbody>
</table>

LABORATORY TESTING OF BIOSOLIDS

Geotechnical laboratory tests including compaction and California Bearing Ratio (CBR) tests were performed on three different samples collected from the stockpiles. The geotechnical laboratory tests were performed in accordance with Australian standard methods of testing soils for engineering purposes. Table 2 presents a summary of CBR test results of untreated biosolids samples. Table 3 presents a summary of CBR test results of biosolids mixed with 5% cement.
Table 2. Laboratory CBR test results for untreated biosolids

<table>
<thead>
<tr>
<th>Test</th>
<th>Stockpile 1</th>
<th>Stockpile 2</th>
<th>Stockpile 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>California Bearing Ratio Test</td>
<td>CBR Value*</td>
<td>% 0.8 - 0.9</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>CBR Swell**</td>
<td>% 0.36 - 0.47</td>
<td>0.43 - 0.56</td>
</tr>
</tbody>
</table>

* - CBR value at 95 % of MDD at OMC
** - CBR swell at end of four days soak period also load applied during end of soak period

Table 3. Laboratory CBR test results for biosolids mixed with 5% cement

<table>
<thead>
<tr>
<th>Test</th>
<th>Stockpile 1</th>
<th>Stockpile 2</th>
<th>Stockpile 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>California Bearing Ratio Test</td>
<td>CBR Value*</td>
<td>% 4.1</td>
<td>4.6</td>
</tr>
<tr>
<td></td>
<td>CBR Swell**</td>
<td>% 0.59</td>
<td>1.29</td>
</tr>
</tbody>
</table>

* - CBR value at 95 % of MDD at OMC
** - CBR swell at end of four days soak period also load applied during end of soak period

Evaluation of Laboratory Testing Results

The CBR value for the untreated biosolids was found to range between 0.8 to 1.1 %. The CBR value for the treated biosolids with 5% cement was found to range from 3.8 to 4.6 %. The CBR tests samples were prepared to 95 % of maximum dry density (MDD), which was obtained from the standard compaction test. The CBR tests were also performed on four day soaked specimens.

CBR swell is defined as a ratio of change in length to original length and expressed as a percentage and was measured for all the samples after soaking.

COMPARISON WITH LOCAL ROADWORK SPECIFICATIONS

VicRoads is the local road governing authority in Victoria, Australia and classifies fill material for earthworks into three types; Type A, B and C. The VicRoads requirement for Type B fill is a California Bearing Ratio (CBR) value of 2 to 5 % (VicRoads, 2006). VicRoads also classifies fill material based on the type, particle size and physical and mechanical properties of the material.

Type B fill material is defined by VicRoads (2006) to be “free of top soil, deleterious and/or perishable matter and after compaction shall have a maximum particle dimension of not more than (i) 150 mm within 400 mm of subgrade level; (ii) 400 mm at depths greater than 400 mm below subgrade”.

In-situ average CBR values obtained from the DCP test results ranged between 2 to 19 %. The laboratory CBR value for treated biosolids with 5 % cement was found to vary between 3.8 to 4.6 %. Both the in-situ and laboratory CBR with 5% cement were found to satisfy the VicRoads specification for Type B fill material without further compaction.
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 CBR values of biosolids samples obtained at a waste-water treatment plant in Victoria, Australia.

The consistency of biosolids in the stockpiles was found to vary from very stiff to hard based on the field vane shear tests, firm to very stiff based on the standard penetration tests and firm to hard based on the dynamic cone penetrometer tests.

In-situ CBR values obtained from the dynamic cone penetrometer test results ranged between 2 to 19 % for the biosolids in the stockpiles. Laboratory CBR values for treated biosolids with 5% cement indicate values of between 3.8 to 4.6 % using the standard CBR test. As such it was found that treated biosolids with 5% cement would meet the requirements of the local roadwork specifications.

The field and laboratory testing results both indicate the potential for reuse of biosolids as a construction material for embankment fill. Further laboratory tests such as triaxial, permeability and oedometer tests will be undertaken in the next phase to confirm these findings.

ACKNOWLEDGEMENT

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REFERENCES