MECHANICALLY AND CHEMICALLY STABILIZED BIO-SOLIDS AS EMBANKMENT FILL MATERIAL

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Abstract

A series of laboratory tests (index properties, particle size distribution tests, compaction tests and CBR tests) were conducted on bio-solids to assess whether it could be compacted to be used in embankment fill material. The dry density requirement was not satisfied although the rest of the geotechnical properties were at acceptable level. Therefore, the second phase of study was aimed in investigating how geotechnical properties of bio-solids could be modified through chemical and mechanical stabilization.

The second phase of study revealed that chemically and mechanically stabilized bio-solids have improved physical properties than untreated bio-solids. The addition of 30% crushed bricks to stabilize bio-solids was found to be sufficient to achieve the desired level of dry density to be applied as an embankment fill material.

To be acceptable for geotechnical reuse, bio-solids must meet the heavy metal contaminant concentration and pathogen limits. It was found that the heavy metal concentration and pathogen limits of biosolids of Biyagama Export Processing zone do not limit the employment of biosolids as geotechnical fill material.

Findings suggest that the stabilized bio-solid admixtures with crushed bricks could be potentially used in place of soil as an effective and low cost compacted embankment fill material.

Keywords: Bio-solids, Chemical stabilization, Embankment fill material, Geotechnical properties, Dry density of bio-solids.

1. Introduction

Large quantities of bio-solids produced from municipal waste water treatments are ever increasing because of the commissioning of new treatment plants and continuous upgrades of the existing facilities. The reason for this could be due to the expansion of urbanization and growth of population. The disposal of sewage sludge is an expensive and environmentally sensitive problem for the community as these contain pathogens, chemical pollutants and heavy metals. It shows that the current management options for bio-solids use / disposal in Sri Lankan waste water treatment plants are not sustainable. Therefore, sustainable and acceptable options for the long-term management of bio-solids which must be environmentally friendly, economically viable and socially acceptable need to be devised. One potential use is as an embankment fill material. The Biyagama Export Processing Zone was chosen as the project location. Earlier they have been using bio-solids as fertilizer in agriculture but it has been found that the high metal content of this plant's bio-solids substantially reduces its potential usability in agriculture, particularly as sources of nutrients or a soil ameliorate. Disposal does not occur and therefore the stockpiles are growing. Thus, this bio-solids should be investigated as a beneficial, sustainable resource rather than as being treated as a waste that requires disposal. The study investigates whether the bio-solids satisfies the environmental standards, has predictable geotechnical characteristics and how dry density of bio-solids could be increased by chemical and mechanical stabilization to satisfy the Road Development Authority (RDA) specifications to be used as an embankment fill material.

2. Material and Methods

Material tested was bio-solids obtained from the Biyagama Free Trade Zone Waste Water Treatment Plant. The samples were collected from 4 different locations from one stock pile. The samples were excavated with a shovel from the depth of 0.4 m, placed in plastic bags and transported to soil laboratory of the Open University of Sri Lanka. A composite sample for testing was made using equal volumes of air dried samples from the four sampling locations and mixing together. This composite sample was used in the study. The physical and chemical properties of bio-solids are determined using standard methods on a laboratory scale.

2.1 R.D.A Specifications

The specifications pertaining to RDA to be used asan embankment fill material are as follows:

Type I Enbankment material – maximum dry density should not be less than 1600 kg/m^3

Type II Enbankment material – maximum dry density should not be less than 1500 kg/m^3

2.2 Methodology

- Check whether the bio-solids conform to the environmental requirements
- Carry out the geotechnical tests for bio-solids
- Testing of crushed bricks as an additive for stabilization of bio-solids to meet the RDA specifications for embankment material

3. Results and Discussion

3.1 Environmental Requirements

To be acceptable for geotechnical reuse, bio-solids must meet the heavy metal contaminant concentration listed in Table 1. Bio-solids that exceed any of the contaminant listed in Table 1 are not permitted for geotechnical reuse in accordance with the Australian Environment Protection Authority (2009) guidelines. The heavy metals were found to be below the acceptable maximum concentration (Table1). Therefore, the heavy metals do not limit the employment of Biyagama Export Processing Zone's (BEPZ) bio-solids as a geotechnical fill material.

Table 1: Comparison of heavy metals in bio-solids

Contaminant	*Australian standard for maximum contaminant heavy metal (EPA 2009)*		*Heavy metal contents in BEPZ CWWTP biosolids (Beling 1996)*		*Heavy metals in BEPZ CWWTP biosolids*
	Concentration (total) mg/kg	*Leachable concentration*	*Total content mg/100g*	*Leachable content*	*Total content mg/kg*
Arsenic	*500*	*0.7*	—	—	—
Cadmium	*100*	*0.2*	*0.23±0.036*	*0.023±0.006*	*0.52±0.12*
Chromium	*500*	*5.0*	*13.99±1.03*	*0.017±0.006*	*175.24±16.90*
Copper	*5000*	*200*	*9.06±2.09*	*0.172±0.052*	*139.31±34.20*
Lead	*1500*	*1.0*	*46.56±7.99*	*0.26±0.073*	*35.33±5.56*
Mercury	*75*	*0.1*	—	—	*1.96±0.05*
Nickel	*3000*	*2.0*	—	—	*16.97±4.36*
Zinc	*35,000*	*300*	*3416±1063*	*181.9±46.34*	*4379.34±909.49*
Cyanide	*2500*	*8.0*	—	—	—

Table 2 shows the pathogen levels of BEPZ biosolids and the Table 3 shows the USEPA allowable pathogen levels. It is revealed that after 40 days of drying period the faecal coliform content decreased to 1.1 X 10^3 MPN/g which is within the limit of USEPA class B bio-solids (2 X 10^6 MPN/g). After 50days of drying period the faecal coliform content decreased to 7 X 10^2 MPN/g which is within the limit value of USEPA class A bio-solids (less than 1000MPN/g). These values ensure that pathogens have been reduced to levels that are unlikely to pose a threat to public health and environment under the specific use conditions. It is also revealed that salmonella was absent in bio-solids analyzed (Perera 2006).

Table 2: Faecal coliform and salmonella content of two bio-solids drying beds from BEPZ CWWTP (Perera 2006)

Parameter	*Biosolid drying bed number with drying time*	
	A1- 40 Days	*B4- 50 Days*
Faecal coliforms MPN/g	*1.1 x 10^3*	*7 x 10^2*
Salmonella / 25 g	*Absent*	*Absent*

Table 3: USEPA allowable level of pathogens in bio-solids for land application (USEPA 1989)

Pathogen reduction	*Organisms to be monitored*	*Allowable level in sludge*
Class A	*Faecal coliform*	*1 x 10^3 MPN/gram total solids (dry weight)*
Class A	*Salmonella bacteria*	*3 MPN per 4 gram total solids (dry weight)*
Class A	*Enteric Viruses*	*Less than one plaque-forming unit per 4*
Class A	*Viable helminth ovum*	*Less than one viable helminth ovum per 4*
Class B	*Faecal coliform*	*Less than 2 x 106MPN per gram of total*

3.2 Geotechnical Requirements

The geotechnical characteristics of the bio-solids are presented in Table 4. The data suggest that the bio-solids studied has properties "similar" to soils and is therefore likely to possess characteristics desirable for embankment filling. It is interesting to note that the bio-solids of this plant are intermediate between a soil and organic material used for agronomic enhancement. The maximum dry density of 960kg/m^3 was not in accordance with the RDA specifications to be used as an embankment material. Therefore the material was stabilized using different proportions of crushed bricks. The variation of maximum dry density with % of crushed bricks is given in Figure 1. Three replicates were used for all testing.

Table 4: Geotechnical properties of virgin bio-solids

Property	*Result*	*Method/ Instrument*
Organic matter content	*25.5%*	*ASTM D 2974-87 Method c / muffle furnace.*
Specific gravity	*1.93*	*ASTM D 854-10 / Pycnometer*
Maximum dry density	*960*	*Proctor compaction test / Bs1377: Part 4: 1990*
Optimum moisture content	*50%*	*Proctor compaction test / Bs1377: Part 4: 1990*
Liquid limit	*79.80%*	*BS1337: Part 2:1990:4.6 /One point Casagrande*
Plastic limit	*NP*	*BS1337: Part2:1990:5.3*
Initial moisture content	*68.79%*	*Oven dry method/BS 1377:Part2: 1990:3.2*

CBR Value at depth 2.5mm	*2.92%*	*ASTM D1883*
CBR Value at depth 5.0mm	*3.14%*	*ASTM D1883*

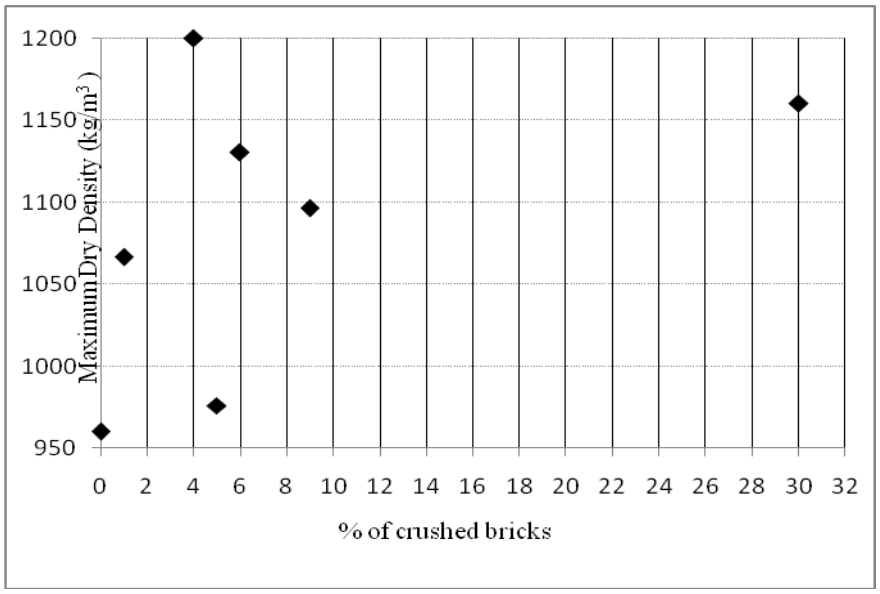

Figure 1: Variation of maximum dry density with % of crushed bricks

Figure 1 indicates that the bricks stabilized with bio-solids did not achieve the RDA specifications. The bio-solids stabilized with 4% crushed bricks gained the highest maximum dry density for standard Proctor compaction test and mechanical stabilization was carried out on 4% crushed bricks stabilized bio-solids and results are shown in Figure 2.

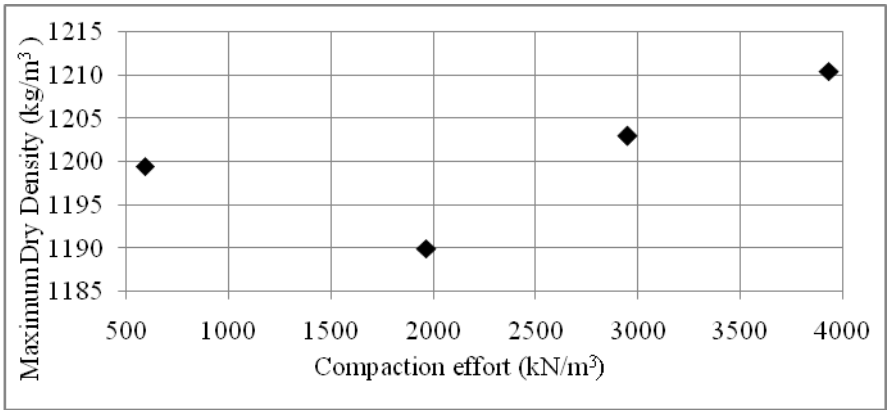

Figure 2: Variation of maximum dry density with compaction effort for bio-solids stabilized by 4% crushed bricks.

The mechanical stabilization was not enough to achive the R.D.A specification for bio-solids stabilized with 4% crushed bricks. Therefore the mechanical stabilization was carried out with 30% crushed bricks stabilized biosolids and the results are represented in Figure 3.

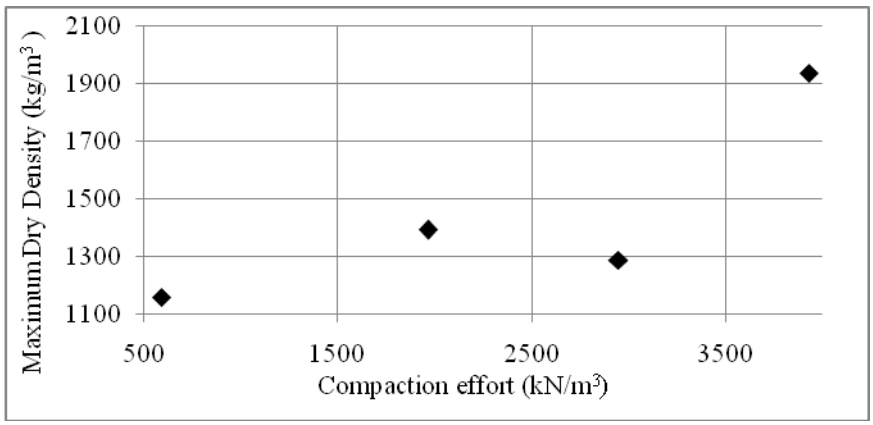

Figure 3: Variation of maximum dry density with compaction effort for bio-solids stabilized with 30% crushed bricks

The bio-solids stabilized with 30% crushed bricks and 100 blows in 5 layers (3929kN/m^3) of 2.5kg rammer achieved a dry density of 1935kg/m^3.

4. Conclusions/Recommendations

- Heavy metal levels of the bio solids in Biyagama Export Processing Zone are lower than the Australian Guidelines for environmental management to be used as a geotechnical fill and therefore it is safe to use as a fill material

- Pathogen levels of the bio-solids in Biyagama Export Processing Zone is lower than that of USEPA standards and therefore it is safe to use as a fill material

- Even though bio-solids satisfy the environmental standards, it is recommended to use adequate clay lining to reduce the heavy metals and pathogens leaching to environment

- The digested sewage sludge did not achieve the standards specified by the RDA and hence to improve the properties, chemical and mechanical stabilization was employed

- Bio-solids stabilized with 30% crushed bricks can be used in Type I and Type II embankment fill material by applying an effort of 3929kN/m^3 according to the Sri Lanka R.D.A. specification indicating the potential for reuse of bio-solids

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