ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization Volume 3, Special Issue 5, July 2014

International Conference On Innovations & Advances In Science, Engineering And Technology [IC - IASET 2014]

Organized by

Toc H Institute of Science & Technology, Arakunnam, Kerala, India during 16th - 18th July -2014

Properties and Application of EPS beads as a Lightweight Fill Material for Embankment Construction

Sree Rekha S[1], Dr. P Rajeev Kumar[2]

Student, Dept of Civil Engineering, Toc H Institute of Science and Technology, Arakunnam, Kerala, India[1]

Professor, Dept of Civil Engineering, Toc H Institute of Science and Technology, Arakunnam, Kerala, India[2]

ABSTRACT: Construction industry has a promising future and this situation demands suitable ground condition for foundations. High rise buildings require safe foundations, and it is a design challenge for structural and geotechnical engineers, particularly if situated in a seismically active region, or if underlying soils have geotechnical risk factors such as high compressibility of soil. Some of the major problems are total and differential settlement of foundation, which leads to failure of the structure. Similar problems are also found to be associated with bridges and embankments. The design challenges in construction in soft soil include extensive thickness of compressible sediments, low permeability, scarcity of natural drainage, encountering organic material near the surface, which further increase the chances of settlement. Dealing with total and differential settlements of bridge approach embankments and other structural foundations has become most challenging tasks in the civil engineering projects, especially in soft soil areas. The other challenges in construction industry are bearing failure, slope instability etc, which occur due to the weight of embankment or a weak foundation. In this seminar report, an attempt has been made to highlight the properties of a novel lightweight fill material, viz-a-viz, cement-treated-sand and EPS. Properties of the material were evaluated in laboratory by a series of tests like Standard Proctor Test, Unconfined Compression Test, CBR Test, Unconsolidated Undrained Test and Consolidated Undrained Test. Actual embankment was constructed with this fill and Sand Cone Test and CBR Test were done in field to verify density and strength of the light weight fill. The total weight of embankment was reduced to 30 to 50%. Considering the cost and capacity of reducing the weight of fill material, the use of EPS beads with soil and binder was found to be an effective solution for construction of embankment.

KEYWORDS: Construction, Embankment, EPS Beads, Light Weight Material.

I. INTRODUCTION

An embankment refers to an artificial bank, raised above the surrounding ground, to carry roadway, railway or canal, across a low lying or wet area. They are often constructed using material obtained from a cutting. Embankment failures do not necessarily occur immediately after load placement, but can take several hours or even days due to a phenomenon known as “progressive failure”. The settlement maybe due to excess weight of soil, weak bearing soils, high compressibility of soil etc. A number of ground improvement techniques have been proposed to mitigate these problems. One of the techniques is to reduce the weight of embankment.

The settlement and consequently the unpredictable ground movement may cause heavy damage to the structure. The high cost that may have to be spent for the repair works has made it necessary to develop a solution to this problem. Conventional mechanical treatments are pre-wetting, soil replacement, moisture control etc. These methods have certain limitations, with regard to cost and effectiveness. Considering these limitations, alternate materials are used for soil

ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization   Volume 3, Special Issue 5, July 2014

International Conference On Innovations & Advances In Science, Engineering And Technology [IC - IASET 2014]

Organized by

Toc H Institute of Science & Technology, Arakunnam, Kerala, India during 16th - 18th July -2014

modification. Emphasizing on engineering for sustainable development, recycled materials are used for this cause. An innovative material that could be used as a soil modifier is Expanded Polystyrene (EPS) in the form of beads. In this report an attempt has been made to use EPS beads along with cement treated sand as fill material inorder to reduce the settlement by reducing weight the of the embankment. Also, a case study of using the fill material is highlighted.

II. ABOUT EPS

EPS is generally used as packaging material for sensitive appliances and electronic items during transportation. EPS is a polymeric form of its monomer, Styrene. It is white in colour, and is manufactured from a mixture of 5-10% gaseous blowing agent, most commonly pentane or carbon dioxide and 90-95% polystyrene by weight. The solid plastic is expanded into foam by the use of heat; usually steam. EPS can be used in the form of blocks (also called EPS geo-foam) and beads. It is widely used because of its favourable characteristics, such as very low density, good insulation properties, good chemical and water stability, reasonable mechanical properties, low cost and convenience in construction. It is resistant to biological attacks as well as to attacks by common inorganic acids and alkalis. Being a thermoplastic, EPS do not exhibit a true melting point. It begins to soften at 93^0C. The EPS beads are white, rounded particles with diameters varying from 2 to 3 mm depending on the manufacturing procedure. Typically, EPS beads are manufactured through an expansion process, similar to the method of making popcorn. The first of the two major steps in making EPS blocks is called pre-expansion. The beads are fed into a device called an expander. The beads placed within the expander are injected with steam which simultaneously softens the polystyrene and causes the blowing agent within the beads to vaporize. As the blowing agent within each bead expands as a result of its phase change (vaporization) it causes the softened polystyrene bead to expand to about 50 times their initial volumes. The presence of gas in EPS beads reduces the bulk density of EPS beads to only 0.0127 g/cm^3. EPS beads can be produced either in a factory or at a construction site. The use of the readily available river sand can significantly reduce the cost of embankment construction. Portland cement was selected in this study to bond EPS beads and hydraulic sand together as a mixture, which has strength and stiffness needed for carrying loads and reducing compressibility.

III. ADVANTAGES OF USING EPS BEADS IN EMBANKMENT

Granular materials are preferred as backfill because they exhibit better drainage and settlement characteristics, and the stress characteristics do not change with time. In recent times, the use of alternate materials that are recycled, for construction or for geotechnical application is gaining importance around the world. Use of EPS beads along with cement treated sand in backfill is an innovative attempt to recycle the dumped EPS waste in an effective way. The unit weight of soil using EPS bead reduces to about 6 to 15 kN/m^3.The use of a lightweight fill can reduce the total weight of an embankment by 30% to 50%. Such amount of weight reduction is beneficial for the control of settlement, especially at the connection between bridge and embankment. In addition, the reduced weight of the embankment can avoid possible bearing failure. Some of the drawbacks of EPS blocks are :

1. They have to be prepared off site and hence require transportation cost. Whereas the lightweight fill with EPS beads can be prepared in the site in the form of a slurry and poured before it hardens.
2. EPS blocks have to be cut into regular shapes and so cannot fill irregular volumes.
3. Strength and stiffness cannot be changed to suit the properties of the soil.
   Hence EPS in the form of beads are more preferable.

ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization   Volume 3, Special Issue 5, July 2014

International Conference On Innovations & Advances In Science, Engineering And Technology [IC - IASET 2014]

Organized by

Toc H Institute of Science & Technology, Arakunnam, Kerala, India during 16th - 18th July -2014

IV. COMPOSITION OF THE LIGHTWEIGHT FILL

The lightweight material that has been proposed in this study consists of EPS beads, and cement treated sand.

Fig 1: Lightweight fill with EPS beads
(Source: http://www.Theconstructor.org/geotechnical/EPS)

V. LABORATORY STUDY

Air dried sand was used in the laboratory for study. Particles larger than 2 mm were removed by sieving. The sand passing through 2-mm sieve was used.The EPS beads used in the laboratory tests had a diameter of approximately 2 mm. Cement was used with water as a binder to bond the cohesion less sand and EPS beads together for strength and stiffness after an appropriate curing time.

Standard Proctor Test

Standard Proctor Test is done to assess the amount of compaction and water content required

The dry density initially increases with an increase in water content, till the maximum dry density is obtained. Upon further increase of water content, dry density decreases. The water content corresponding to maximum dry density, optimum water content(O.W.C) ranged from 16% to 17% and the water content increased with an increase in sand to EPS bead volume ratio. Increase of sand volume made the fill less sensitive to water. The observations also indicate that increase of volume of EPS beads reduced the maximum dry density of the fill. But increase of volume of EPS beads increased the cost of the fill, as EPS beads are more expensive than soil. Cost of fill is thus one of the important factors to be considered in determining the volume ratio of sand to EPS beads in addition to density and mechanical properties like strength and compressibility.

The effect of cement content on optimum water content and maximum dry density of the light weight fill was then investigated with five lightweight fills at cement contents of 6%, 7%, 8%, 9% and 10% were tested using the Standard Proctor Test. Sand to EPS beads ratio of 5:5 was adopted in these fills. The compaction curves were obtained as shown in Figure 2.

ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization *Volume 3, Special Issue 5, July 2014*

International Conference On Innovations & Advances In Science, Engineering And Technology [IC - IASET 2014]

Organized by

Toc H Institute of Science & Technology, Arakunnam, Kerala, India during 16th - 18th July -2014

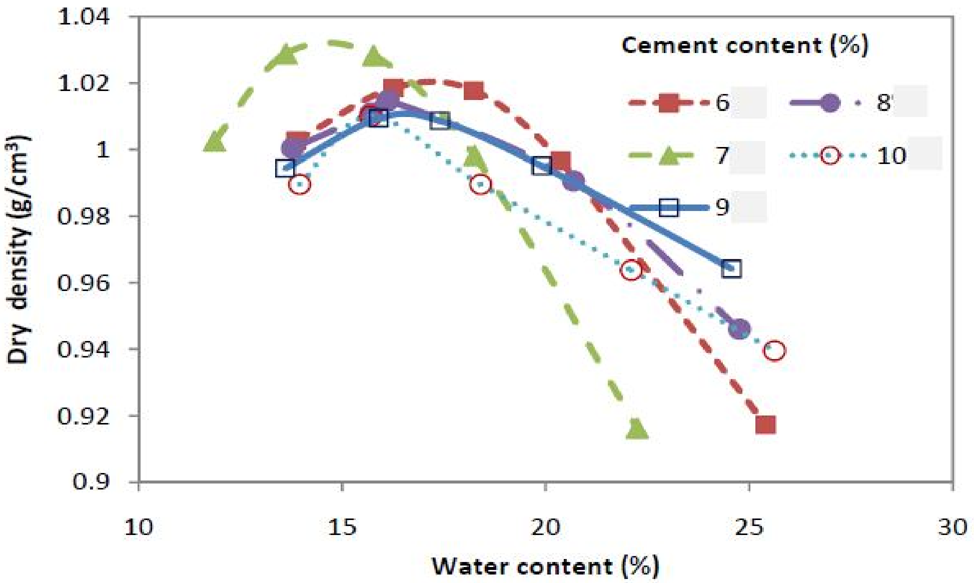
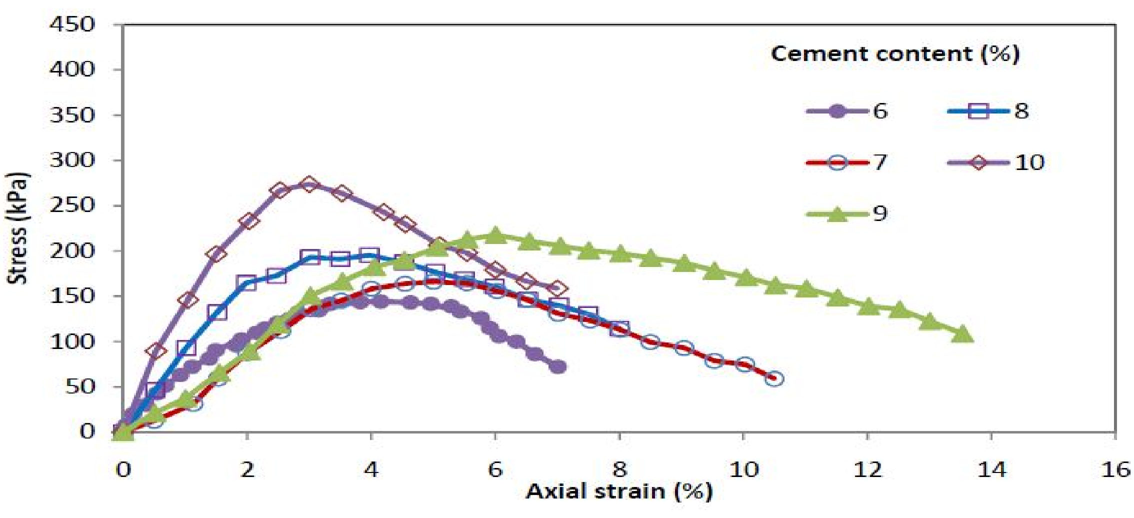


Fig 2: Compaction Curves of Lightweight fills at Different Cement Contents
(Source: http//:www.asce.org/materials in civil engineering)

Unconfined Compression Test

Cube specimens of 70.7 mm X 70.7 mm X 70.7mm were prepared at optimum water content and maximum dry density. The ratio of volume of sand to EPS beads was taken as 5: 5, and cement contents at 6, 7, 8 and 10 %. Specimens were cured for 7 to 14 days at an average temperature of 20^0 C. The stress-strain curves of the specimens at different cement contents and curing times are shown in Figure 3.



ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

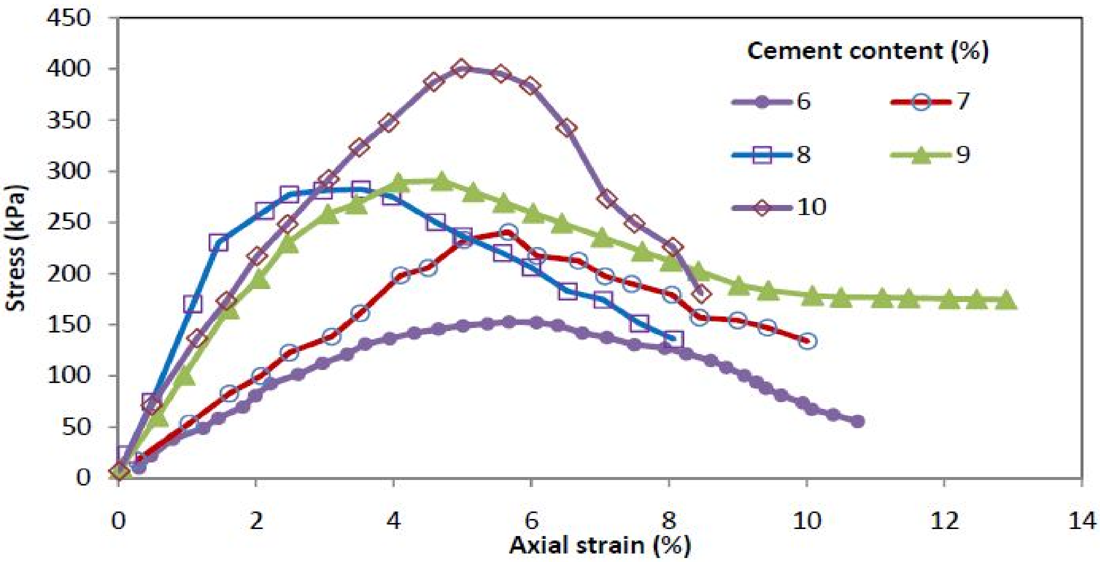
International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization Volume 3, Special Issue 5, July 2014

International Conference On Innovations & Advances In Science, Engineering And Technology [IC - IASET 2014]

Organized by

Toc H Institute of Science & Technology, Arakunnam, Kerala, India during 16th - 18th July -2014



(a)

(b)

Fig 3: Stress-strain Curves of the Lightweight Fills from Unconfined Compression Tests at (a) 7 days (b) 14 days of curing.
(Source: http://www.asce.org/materials in civil engineering)

From the plot, it can be seen that the peak strength of specimen increased with an increase in of cement content and curing time. The axial strain corresponding to the peak strength ranged from approximately 3% to 6%. No sudden failure was observed, but the stress decreased with an increase of the axial strain after the peak value. This result indicate that the cement-treated sand-EPS bead lightweight fill was ductile. The mean elastic modulus of the specimen is calculated based on the stress at 50% peak strength and its corresponding strain, (E50). The cement-treated sand-EPS bead lightweight fill had a relatively high elastic modulus or stiffness so that the compression of this lightweight fill is expected to be small for embankment applications. The lightweight fill had a higher E50 values than lime-stabilized soils, which is approximately 8MPa.

California Bearing Ratio (CBR) Tests

CBR Tests are used for evaluating the suitability of subgrade and materials used in sub base. The specimens were prepared at cement contents of 6%, 7%, 8%, 9%, and 10% and the ratio of volume of sand to EPS beads were taken as 5: 5. The pressure required for the piston to penetrate the specimen to a depth of 2.5 to 5 mm was measured. The results of the test indicate that the value of CBR value of lightweight fill increased with increase of cement content.

Consolidated Undrained (CU) Test

Triaxial test is used to determine shear characteristics of soil under different drainage conditions. The ratio of volume of sand to EPS beads were 5:5 and cement content of 7%. A series of CU test were conducted at different confining pressures (30, 50, 80, 120, 150, 200, 250, 300, and 400 kPa)

Figure 4 shows the stress-strain curves of lightweight fills obtained from CU test at different confining pressures.

ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization *Volume 3, Special Issue 5, July 2014*

International Conference On Innovations & Advances In Science, Engineering And Technology [IC - IASET 2014]

Organized by

Toc H Institute of Science & Technology, Arakunnam, Kerala, India during 16th - 18th July -2014

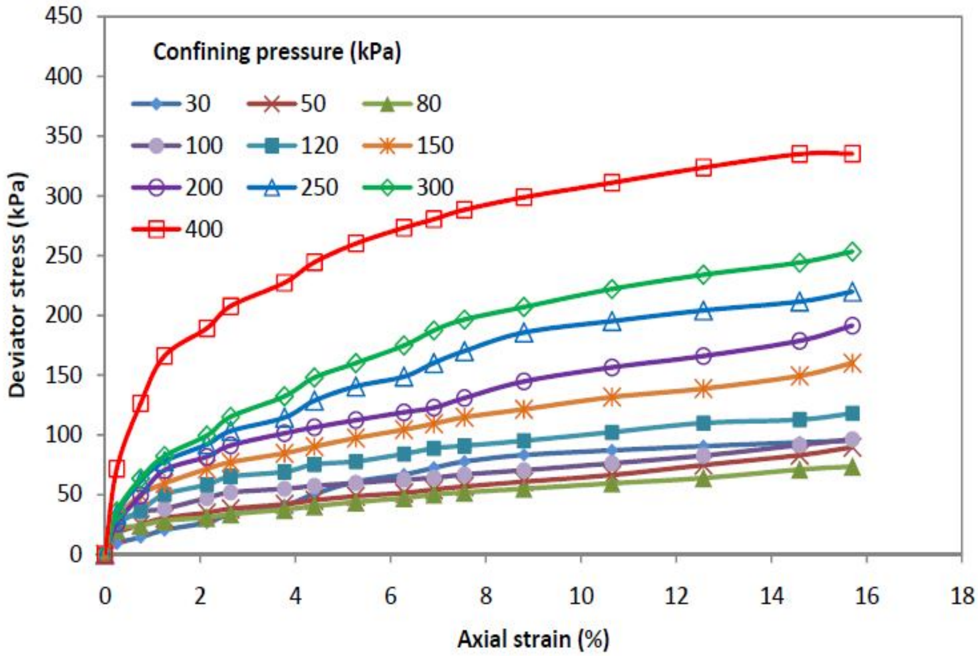


Fig 4: Stress-strain curves of lightweight fills obtained from CU test at different confining pressures (Source: http://www.acse.org/materials in civil engineering)

The test result from Figure 4 shows that when the confining pressure was lower than 80 kPa, it had very less effect on the maximum deviator stress. However, the maximum deviator stress increased with the confining pressure increase when confining pressure was higher than 80 kPa.

ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization Volume 3, Special Issue 5, July 2014

International Conference On Innovations & Advances In Science, Engineering And Technology [IC - IASET 2014]

Organized by

Toc H Institute of Science & Technology, Arakunnam, Kerala, India during 16th - 18th July -2014

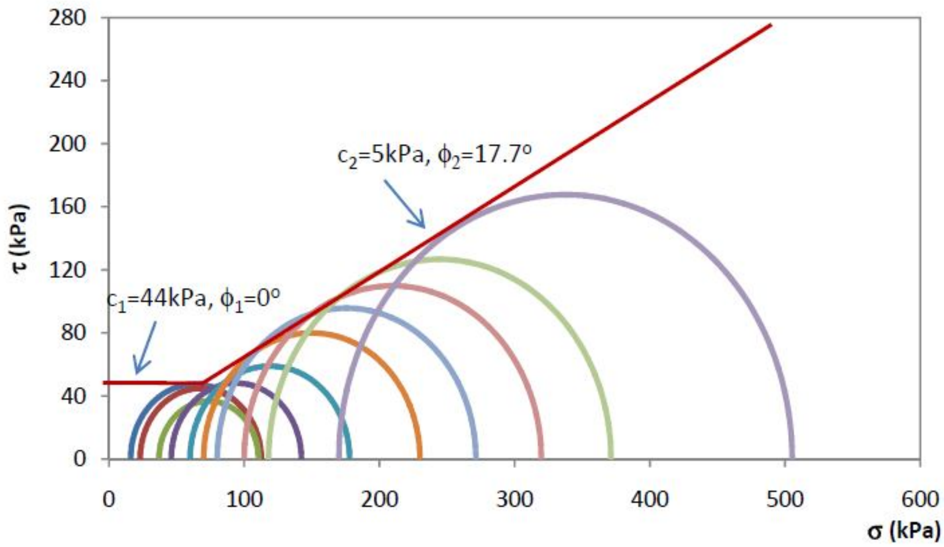


Fig 5: Effective stress failure envelope of light weight fills from CU test
(Source: http://www.asce.org/materials in civil engineering)

The effective stress failure envelope in figure 5 has two straight lines, which are referred as line 1 and line 2 here. Line 1 is horizontal, which means $\phi = 0$ when the total confining pressure is lower than 80 kPa. This result is consistent with the finding from the stress-strain curves.

Unconsolidated Undrained (UU) Test

The tests were carried out at confining pressures of 100, 200 and 300 kPa. At each confining pressure, two specimens were tested in two different curing times. Each specimen was saturated using back pressure method before UU test. Figure 6 and 7 shows the stress strain curves and total stress failure envelopes of lightweight fill obtained from UU test at 7 and 14 days of curing.

ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

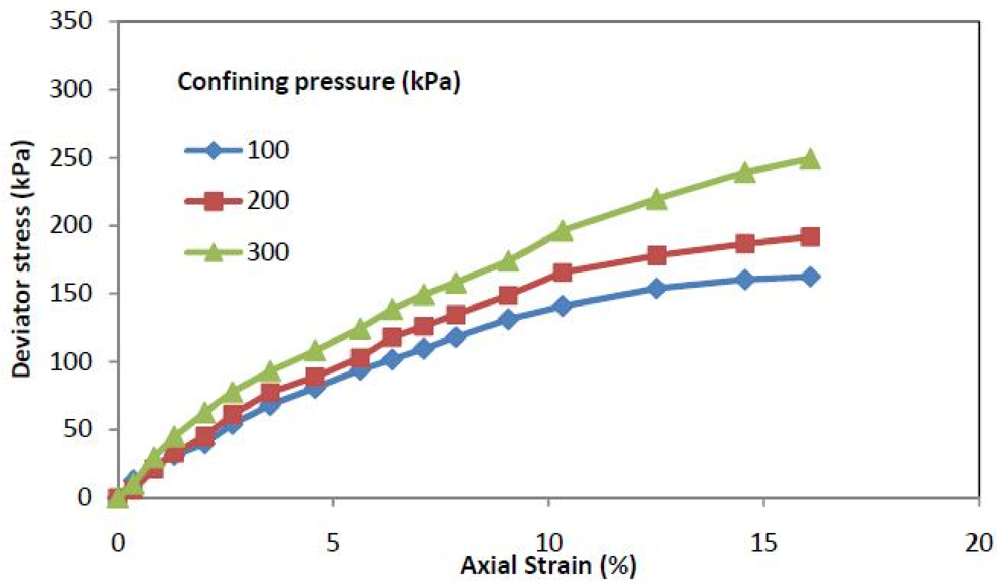
International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization *Volume 3, Special Issue 5, July 2014*

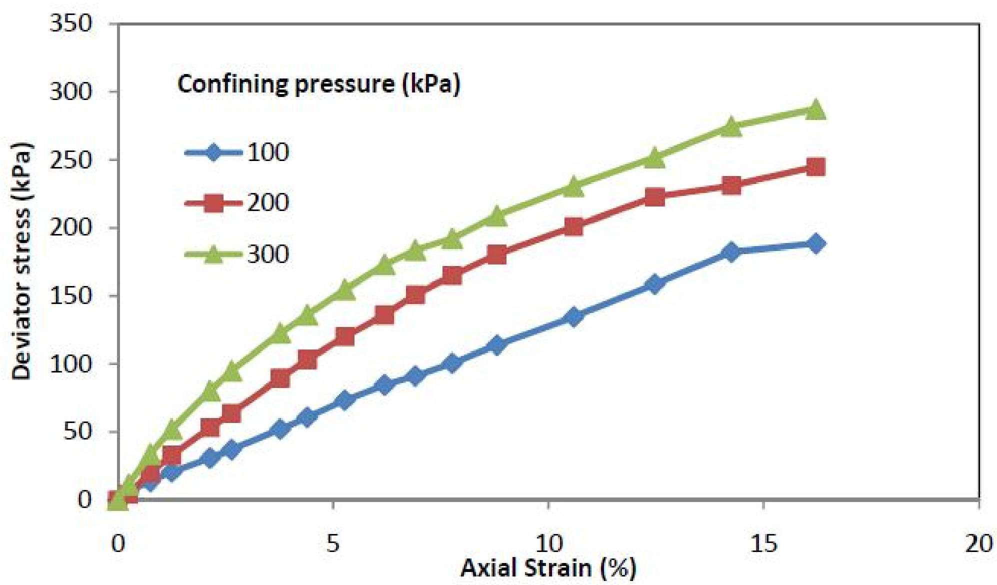
International Conference On Innovations & Advances In Science, Engineering And Technology [IC - IASET 2014]

Organized by

Toc H Institute of Science & Technology, Arakunnam, Kerala, India during 16th - 18th July -2014



(a)



(b)

Fig 6: Stress strain curves of light weight fill from UU test at (a) 7 days (b) 14 days of curing
(Source: http://www.asce.org/materials in civil engineering)

ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

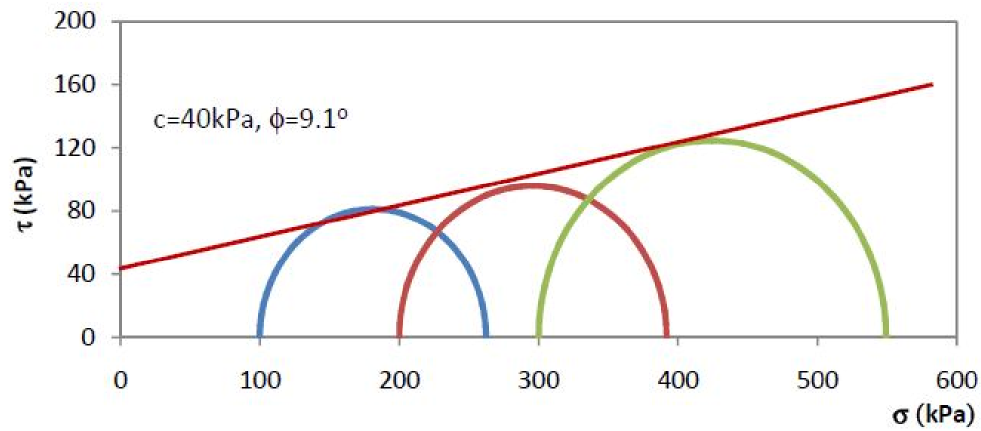
An ISO 3297: 2007 Certified Organization *Volume 3, Special Issue 5, July 2014*

International Conference On Innovations & Advances In Science, Engineering And Technology [IC - IASET 2014]

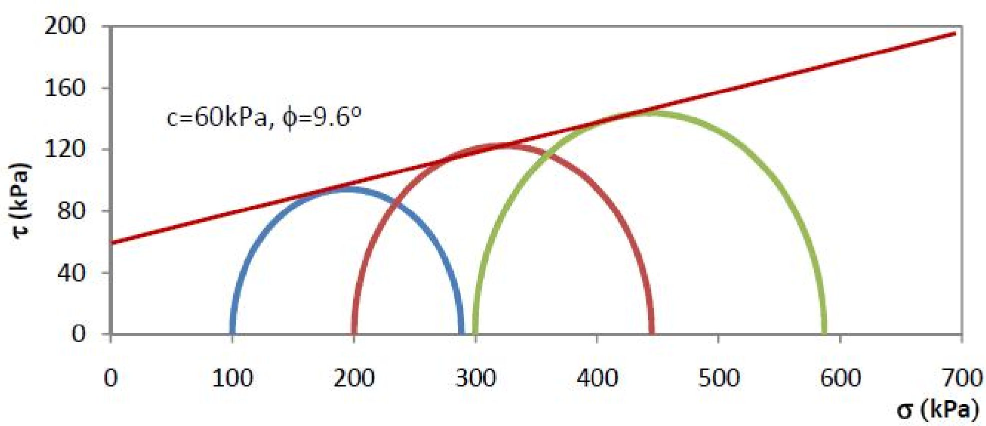
Organized by

Toc H Institute of Science & Technology, Arakunnam, Kerala, India during 16th - 18th July -2014

From Figure 6 it can be observed that the deviator stress increased with confining pressure and curing time. Figure 7 shows the total stress failure envelope of light weight fill from UU test.



(a)



(b)

Fig 7: Total stress failure envelopes of lightweight fills obtained from UU test at (a)7 days (b)14 days of curing (Source: http://www.asce.org/ materials in civil engineering)

Figure 7 shows that the lightweight fill has an undrained cohesion of 40 to 60 kPa and a total friction angle of 9.1 to 9.6^0 , which would have resulted from the presence of EPS beads.

ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization Volume 3, Special Issue 5, July 2014

International Conference On Innovations & Advances In Science, Engineering And Technology [IC - IASET 2014]

Organized by

Toc H Institute of Science & Technology, Arakunnam, Kerala, India during 16th - 18th July -2014

In Figure 5, the intercept of line 1 is 44 kPa, which is almost equal to the undrained cohesion of lightweight fill obtained from the UU test. The undrained cohesion is controlled by the bonding strength of cement; therefore it is independent of the confining pressure. After overcoming the bonding strength of cement (i.e. the confining pressure higher than 80 kPa, the lightweight fill exhibited an increasing shear strength with the confining pressure (Line 2) at an effective friction angle of 17.7 ^{0}. The increase of shear strength with confining pressure was controlled by the shearing between sand or EPS particle.

VI. CASE STUDY

A case study was reported by Miao and Wang (2013). In order to evaluate the performance of the lightweight fill proposed in this study in field, this fill was used in construction of a highway embankment project, which connects the Taizhou Yangtze River Bridge and the Hu-Ning (from Shanghai to Nanjing) highway in China. This highway embankment is located on a back swamp of the Yangtze River, where soft soils exist in a wide area. To construct the embankment, the fill was placed in the lift thickness of 25cm and was compacted for two passes using a 10 ton smooth wheel roller, then for three passes using a 20 ton smooth wheel roller. The fill was smoothened using two passes of a 10 ton smooth wheel roller. The fill was covered with a layer of geotextile. Water was sprayed onto the fill twice a day, depending upon the air temperature and humidity and cure each lift typically for 5 to 7 days.CBR test and sand cone tests were conducted to evaluate the performance of the lightweight backfilled embankment. CBR values were found to be higher than 4%, which is higher than the required value in Chinese specification. The sand cone test results indicate that the degree of compaction required is met by the lightweight fill, which means that the compaction procedure used in the field was effective to control the density of the lightweight fill.

VII. CONCLUSION

The embankment settlement is mainly induced by the weight of the embankment fill. In this report, a new embankment fill was proposed, which consists of cement-treated-sand-EPS beads, to mitigate the settlement problem. Both laboratory tests and the field study of the actual embankment were conducted to determine the properties of this fill and evaluate the performance of the embankment constructed with this fill. From this study, the following conclusions can be drawn:

1. The density of the lightweight fill depended on the amount of EPS beads in the mix.
2. The maximum dry density of the cement- treated sand- EPS bead lightweight fill was much lower than the lime-stabilized soil embankment fill.
3. The lightweight fill had ductile behavior without sudden failure in the unconfined compression tests.
4. The lightweight fill had a suitable CBR value (higher than 4%), which can be used as an embankment fill based on the specifications.
5. The results of sand cone tests and CBR tests in the field verified the suitability of the lightweight fill used for highway embankment construction. The settlement observations of three comparable embankments showed that the embankment backfilled with the cement-treated sand-EPS lightweight fill had less than half of the settlement of the lime-stabilized soil embankment on the untreated ground and 20% less than the settlement of the lime-stabilized embankment on the treated ground by deep mixing.

REFERENCE

[1]Arora.K.R, (2008). *Soil Mechanics and Foundation Engineering*, Standard Publishers, Delhi,306--356.
[2]Deng, A., and Xiao, Y. (2008). Shear behavior of sand-expanded polystyrene beads lightweight fills, *J.Cent.South.Univ.Technol*, 15(2), 174--179.
[3]Deng, A., and Xiao, Y. (2010). Measuring and model proportion-dependent stress-strain behavior of EPS-sand mixture, *ASCE Journal of Geomechanics*, 10, 214--222.

ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization *Volume 3, Special Issue 5, July 2014*

International Conference On Innovations & Advances In Science, Engineering And Technology [IC - IASET 2014]

Organized by

Toc H Institute of Science & Technology, Arakunnam, Kerala, India during 16th - 18th July -2014

[4]Hatami, K. and Witthoeft A.F., (2007). Reduction of backfill earth pressure in reinforced soil wall using geofoam, *Proc., 86th TRB Annual Meeting*, January, 21--25, 2007, Washington, DC, USA.
[5]Ikizler, S.B., Aytekin, M., and Nas, M. (2007). Laboratory study of expanded polystyrene(EPS) geofoam used with expansive soils, *Geotextiles and Geomembranes* , 26(2), 189--195.
[6]Liu, H., Deng, A., and Chu, J. (2006). Effect of different mixing ratios of polystyrene pre-puff beads and cement on mechanical behavior of lightweight fill, *Geotextiles and Geomembranes*, 24, 331--338.
[7]Miao, L.C., and Wang, F. (2013). Properties and applications of cement-treated-sand-expanded polystyrene bead lightweight fill, *ASCE Journal of Materials in Civil Engineering*, 25, 86--93.
[8]Miki, H.(1996). An overview of lightweight banking technology in Japan, *Proc., of the international Symposium on EPS Construction Method* (EPS-Tokyo'96), 9--30.
[9]Tsuchida, T., Kang, M.S.(2002). Use of lightweight treated soil method in seaport and airport construction projects, *Proc., Nakase Memorial Symposium, Soft Ground Engineering in Coastal Areas.* A.A. Balkema Publisher, London, 353--365.
[10]Wang, F., and Miao, L.C.(2009). A proposed lightweight fill for embankments using cement treated Yangtze River sand and expanded polystyrene (EPS) beads, *Bull.Eng.Geol.Environ.*,68(4), 517--524.