SUSTAINABLE INFRASTRUCTURE DEVELOPMENT INCLUDING LIMITED LIFE GEOSYNTHETICS

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ABSTRACT

This theme paper presents a summary of the papers that are presented under the topic of sustainable infrastructure development using geosynthetics. The geosynthetic materials can be categorized into natural and polymeric. Both these materials have their own advantages and disadvantages. The natural products have limited life and their engineering properties are rather limited as compared to their polymeric counterparts. However, the natural materials have been applied successfully in several projects in innovative ways. The use of geosynthetics leads to consumption of lesser natural materials like aggregates in roads, lesser quantities of soils in steep embankments, possibility to use local materials in conjunction with geosynthetics, etc. The geosynthetics made of natural materials could be applied in less critical projects like rural roads, erosion control, etc. The processing of natural materials to produce geosynthetics is quite labour intensive which gives employment to many artisans in rural areas.

Keywords: Geosynthetics, natural geosynthetics, coir, jute, kenaf, bamboo,

INTRODUCTION

The themes of the conference and this session converge to the topic of sustainability. The Sustainable infrastructure development is of key importance at this age when the natural resources are dwindling at an alarming rate while the demand for them is ever increasing. The sustainability may also indirectly include the aspects related to the economic development of rural or low skilled artisans by way of employment opportunities.

The geosynthetics help in the sustainability in several ways by cutting down the requirement of natural materials like aggregate and imported soil thus reducing the carbon foot print in infrastructure projects. The use of geosynthetics leads to reduction in thickness of layers, construction time and provides smooth finish to the highways, Rajagopal et al, (2011). This in turn helps in reducing the carbon footprint by way of reducing the fuel usage, lower maintenance requirements of both vehicles and pavements, etc.

The natural geosynthetics are even more environmentally sustainable compared to synthetic materials as their manufacture does not entail much energy. The natural geosynthetics are derived from plants which help in generating oxygen while absorbing the carbon gases. For example, during the 100 days of jute growing period, 1 Hectare of jute plants can absorb about 15 metric tons of CO_2 from atmosphere and release 11 metric tons of O_2 into the atmosphere, Sanyal and Khastagar (2012). On the other hand, the synthetic geosynthetics and byproduct of petroleum industry which leads to depletion of the natural resources and generation of CO_2 and CO gases.

The natural geosynthetics have a much shorter life span compared to their synthetic counterparts. Their life span depends very much on the lignin content and their adaptability is related to the cellulose content, Sanyal and Khastagar (2012), Rao et al. (2012). Some of the applications that were proposed by several investigators (Rao and Balan 2000, Sanyal 2011, Sarsby 2005) are as follows:

- Basal reinforcement in low-height embankments
- Separator or reinforcement layer in low volume roads
- Erosion control applications
- Drainage applications
- Pre-consolidation of soft clay soils

The natural geosynthetics can be used in all situations where the foundation soil gains sufficient strength before the geosynthetic degrades, Sarsby (2005). The natural geosynthetics like coir and jute are excellent choice for erosion control applications as they help in retaining moisture for the growth of vegetation on slopes. They also provide the nutrients to the plants as they degrade.

DETAILS OF THE PAPERS IN THIS SESSION

There are totally 8 papers under this theme apart from the key note and the theme paper. These papers covered various aspects of natural fibres and other innovative products like light weight fills (EPS). The applications considered include the construction of steep slopes, roads and pavements. The different innovative materials considered by different papers are as follows:

Natural fibres
- Bamboo
- Coir
- Jute
- Hemp
- Kenaf fibres

Polymeric materials
- EPS

The following are the different applications of natural and polymeric materials studied in the papers:
- Stabilisation of expansive soils
- Use of reinforced flyash in pavement construction
- Impact absorption
- Subgrade reinforcement
- Granular columns for soft clay reinforcement.

The number of papers received from different countries is shown in alphabetic order below.

China (1)
India (3)
Japan (2)
Korea (1)
Taiwan (1)

NATURAL MATERIALS

The papers in this session have studied the engineering application of different natural materials like bamboo, coir, jute, hemp and Kenaf fibres.

Artidteang et al. (2012) have investigated the interaction between Kenaf natural geotextiles and soils. The geotextiles were made of kenaf or roselle (Hibiscus sabdariffa var altissima) natural fibers to dimensions of 300 mm × 300 mm with 3 mm aperture openings. The manufactured geotextile has a mass per unit area of nearly 1160 g/m^2, thickness of 5.27 mm and index tensile strength of 20 kN/m at a strain of 15%. Large-scale direct shear and pullout tests were performed with a local silty sand as the backfill soil. The tests were performed at both low and high confining pressures. The interaction parameter under direct shear loading was found to be 0.81 constant at all normal pressures. However, the behaviour under pullout loads was different at low and higher normal pressures. At low normal pressures, the failure was by pullout and the failure was by rupture at higher normal pressures. The pullout interaction factor varied from 1.11 to 0.88 as the normal pressures were increased from 20 kPa to 60 kPa.

Balan (2012) has presented several case studies of the successful application of coir geotextiles for a variety of applications. He has presented a brief overview of the application of natural materials for construction purposes in the historical past. He has then presented some case studies of the application of coir geotextiles for erosion control and retaining wall applications. Some laboratory model studies on the use of coir geotextile tubes for shoreline stabilization have been described.

Dutta et al. (2012) have studied the performance of bamboo grid encased stone columns through small-scale model laboratory tests. They have compared the short term performance of the bamboo grid with that of a polymeric geogrid. The index tensile strength and ultimate stiffness of the bamboo grid are 110 kN/m and 2200 kN/m respectively and that of the polymeric geogrid are 32 kN/m and 160 kN/m respectively. The aperture opening sizes for both are 5 mm × 5 mm. The diameter of the stone column was 100 mm and the loading plate had a diameter of 200 mm. The height of the soft clay soil was 500 mm. The in situ vane shear strength of the clay soil was 10 kPa. The observed performance in the laboratory model tests was replicated through axisymmetric finite element modeling. Their conclusion is that the bamboo encasement increased the strength and stiffness of the stone column because of its higher strength and stiffness.

Maity et al. (2012) have studied the use of Sabai grass fibres in granular sub base layers of the pavements. They have tested the efficiency of including these grass fibres in three types of fine granular soils. The fibres were cut to 5 mm, 10 mm and 20 mm lengths. The cut fibres were added to soils randomly in weight percents of 0.5%, 1%, 1.5% and 2%. They found that the addition of the fibres increased the Optimum Moisture contents in the Proctor compaction tests. However, the maximum dry density was found to decrease with increase in percentage of fibres. The California Bearing Ratio (CBR) values were found to increase with the addition of fibres. The optimum fibre content was found to be 1% by weight of soil. In general, the maximum increase in CBR value was about 30% to 35%. Through regression analysis of the test data, equations are proposed to estimate the CBR values with different percentages and lengths of the fibres.

Rao and Sreedhar (2012) have studied the strength and stiffness of pond ash reinforced with coir geotextiles. They have studied the comparative performance of two types of reinforcements woven polymeric geotextile (T_{ult}=52 kN/m and interface friction coefficient of 0.94) and a coir geotextile (T_{ult} = 16 kN/m and interface friction coefficient of 1.07) for improving the performance of a 50 mm square footing. All the tests were performed on a carefully prepared test bed reinforced with the above types of reinforcement products placed at different depths below the footing. The performance under both monotonic and cyclic loads (1 Hz frequency) was compared.

The performance of both ultimate behavior and performance at a settlement equal to 5% of the footing width are compared. The ultimate bearing pressures have developed at lesser settlements for the polymeric geotextiles because of their higher modulus. The apparent resilient modulus at the end of 1000 cycles of loading was also found to be higher for polymeric geotextiles than the coir geotextiles. The authors have concluded that both the interface friction factor and the modulus of the reinforcements play an important role in improving the performance of foundations.

Rao et al. (2012) have discussed the fundamental properties of jute fibres and the potential of jute fibres in geotextiles. They discussed the strategies for the growth of jute based geotextiles. Traditionally, jute has been used mostly for packaging purposes and for manufacturing interior decorative items in India and other countries. The other engineering applications have largely been ignored. The authors discussed the potential of using jute as asphalt overlay fabrics, as pre-fabricated vertical drains, erosion control blankets, etc. The authors have discussed the development of a Brecodrain using a combination of jute and coir and its superior performance as compared to other commercially available vertical drains. The authors discuss a new approach to spur the growth of the demand for the jute products by way of new approaches.

Sanyal and Khastagir (2012) have discussed the utility of jute geotextiles for different engineering applications. They reported that jute fibres can be easily spun into textiles. These jute textiles have high initial tensile strength at low strain levels, high surface roughness coefficient and good drapability properties for their applications. The only disadvantage is their low life span which makes them suitable only for some non-critical applications.

EPS MATERIALS

The EPS material was found to possess several beneficial properties such as light weight, high stiffness, water resistance, low thermal conductivity, good durability. The four papers on this topic in this theme have examined the application of EPS material for different geotechnical works. All the papers mainly dealt with the properties of light weight materials mixed with EPS beads. These papers have discussed the thermal properties, strength and stiffness properties.

Kimata and Sakaguchi (2012) have studied the use of recycled EPS waste material crushed to pieces and mixed with soil. They have studied the impact absorption behavior of soil mixed with EPS beads. As such, the stiffness of soil is very low compared to that of other construction materials such as steel and concrete. The cushioning effect of soil can be further enhanced by addition of EPS beads which reduces the stiffness of soil. The strength of soil was observed to be intact even after the addition of EPS beads. The soil mixed with EPS beads was found to undergo larger deformations under impact loads thereby reducing the impact acceleration. The impact absorption was found to be linearly related to the magnitude of the deformations.

Liu and Zhang (2012) have discussed an innovative method to utilize the low heat conductivity of light weight soils mixed with EPS beads to protect hydraulic structures (pipe lines, etc.) from damage induced by frost action. This new material is to replace the use of more expensive EPS or XPS boards as heat insulator. The materials in the tests include 42.5 grade ordinary Portland cement, EPS foaming particles, high range water reducing agent, air inducing agent, interface agent for particles and water. The soil sample was collected from Wanjia town of Harbin and mixed with EPS foam particles. The diameter of the particles was between 3 and 5 mm and the bulk density was 0.026 g/cm^3. The thermal conductivity was analysed using ISOMET heat character analyzer.

This paper presented the experiment and study on the thermal conductivity of light composite soil mixed with EPS particles (LCSEP) through the application of ISOMET heat character analyzer. The influence of the factors including density, water content and EPS particles dosage on the thermal conductivity of light composite soil mixed with EPS particles under frozen and unfrozen conditions were discussed. The experimental results indicated that the increase of the contents of EPS particles, cement and mineral admixtures resulted in the decrease of thermal conductivity. The mentioned results contributed to heat insulation and preservation, which could lead to the reduction of depth of frost penetration. The decrease of density and water content could resulted in the decline of thermal conductivity. Under frozen condition, thermal conductivity was found to decrease.

Xia et al. (2012) have studied the compression and creep behavior of expanded Polystyrene for the application of stabilization of expansive clays in canal banks. They have studied an innovative application of the EPS layer to reduce the pressures on underwater concrete slabs due to swelling and shrinking of plastic clays. Laboratory tests were performed on three types of EPS with three different densities. They have found that the EPS with higher density have larger stiffness. They found that the EPS materials undergo significant creep strains under constant pressures. The magnitude of creep strains were found to decrease with increase in density of the material. The time required to reach steady state strains under sustained loads is longer for higher density materials.

Yamanaka et al. (2012) have reported the use of EPS mixed soil for subgrade applications in pavements. They have investigated the strength and deformation characteristics of lightweight geomaterials mixed with EPS beads. The authors report that the soil mixed with EPS beads is very different from other geomaterials which requires separate attention before it is put to geotechnical applications. The resilient modulus was found to remain constant even after the addition of EPS beads to the soil.

SUMMARY AND CONCLUSIONS

A brief summary of the different papers related to sustainability is provided in this paper. It is seen that both natural and polymeric geosynthetics could be put to a variety of applications in innovative geotechnical uses.

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