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Behaviour of sand bentonite mixture by application of fiber and Geo-synthetic clay liner (GCL)

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ABSTRACT

Permeability is one of the most important properties of sand-bentonite mixture which is used as a liner material at the waste disposal site, and needs to be understood for settlement analysis. When bentonite comes in contact with water, its swells and exhibits a lower value of hydrolic conductivity. However due to desiccation of bentonite, it shrinks and the hydraulic conductivity increases significantly.This is the general problem of compacted clay.Now a days a geo-synthetic clay liner (GCL) with equivalent performance may be used in place of a compacted clay liner. Furthermore, synthetic fiber generally used to reduce the shrinkage of clays. However, no studies have been carried out on fiber reinforced sand-bentonite mixture with geo-synthetic clay liner (GCL) inclusion. In order to check the influence of GCL and glass fiber on these parameters, such as swelling potential, swelling pressure, compression index, hydraulic conductivity,co-efficient of consolidation and unconfined compressive strength of the mixture. Bentonite-sand mixtures, mixed in the proportion of 60% sand-40% bentonite (SB40), were mixed with 0.5% and 1% of glass fiber of 10mm length with addition of one layer geo-synthetic clay liner. Test result shows that hydraulic conductivity is reduced significantly with interaction of GCL then slightly increased with addition of glass fiber. It has also observed that compression index and swelling pressure reduced with addition of glass fiber. Swelling pressure was more for GCL inclusion. Compression index (c_c) is found to be increased for GCL inclusion. Co-efficient of consolidation (c_v) is found to be increased with the increased in consolidating pressure, indicating the mixtures gets consolidated at a higher rate under a higher overburden pressure. Unconfined compression strength decreased with addition of GCL due to effect of structural integrity of continuous soil column or predetermined failure plain has to be created automatically by inclusion of GCL. This behavior is confirmed that all the failure observed where GCL placed. Furthermore, UCS enhanced with inclusion of glass fiber. Therefore, SB40+GCL+ 1% fiber composite is optimum combination which have to be used for landfill liners.

Keywords: Geo-synthetic clay liner, Glass fiber, Sand-clay mix

1. INTRODUCTION

Volume change phenomena of expansive soil are influenced by variation of moisture content. Generally, expansive soil comes in contact water, its swells and exhibits a lower value of conductivity. However, hydraulic conductivity of expansive soil increased significantly due to shrinkage crack (Abdi et al., 2008). Generally, mixture of locally available river sand with bentonite is used as a liner material of waste disposal site. Chalermyanont (2005) observed that hydraulic conductivity of mixture decreases about four orders of magnitude when mixed with 5% bentonite or more. Mishra et al. (2010) performed experimental study of fifteen different soil- bentonite mixtures to understand their physical, chemical and mineralogical composition and found that bentonite's physical and mineralogical properties influence the hydraulic and consolidation properties of sand-bentonite mixtures considerably. Bello (2011) conducted the compaction and unconfined compression test on radish brown tropic soils to study the range of water content and dry unit weight at which compacted test specimens would have adequate shear strength and observed that unconfined compressive strength values should be ≤ 200 kN/m^2 which is the minimum acceptable for materials to be used as hydraulic barriers in containment structures. Sand-bentonite mixture with geo-synthetic clay liner (GCL) interaction has very less hydraulic conductivity (Estornell et al., 1992 and Petrov et al., 1997). Over decades, GCL have replaced compacted clay liner (CCL) for the use as a landfills liners material. GCL has made from some geotextile and consists of a thin layer of sodium bentonite, which placed in between two layers of geo-synthetic (commonly geotextile). Since shear strength of hydrated geo-synthetic clay liner (HGCL) is very less, it is one of the key factor to design the cover soil thickness before installation of hydrated geo-synthetic clay liner (HGCL) (Koerner, 1995 and Fox et al.,1996).However, no studies have been carried out on fiber reinforced sand-bentonite mixture with geo-synthetic clay liner (GCL) interaction. Hence, the main purpose of this study is to examine the effect of GCL and fiber on consolidation, hydraulic, swelling and strength criteria of fiber reinforced sand-bentonite mixtures.

2. MATERIALS AND METHODS

Bentonite used in this study is a commercially available. The particle-size distributions based on the hydrometer analyses indicate that bentonite are comprised primarily of clay-size particles and classify as high plasticity clay (CH) according to unified soil classification system (USCS). The basic properties of the soil are presented in the Table 1. Brahmaputra river sand was used in the experiment and its basic properties have been shown in the Table 2.

Table 1 Properties of bentonite clay and sand

Properties of Bentonite clay	Values	Properties of Sand	Values
Liquid Limit (%)	217%	Specific Garvity	2.68
Plastic Limit (%)	43%	D_{60}	0.5mm
Plasticity Index	174%	D_{30}	0.29mm
Specific gravity	2.59	D_{10}	0.17mm
Specific surface area	503 m^2/gm	Coefficient of Uniformity (C_u)	2.94<6
Clay content	64%	Coefficient of curvature(C_c)	0.98<1 or 3
Silt Content	36%	Classification of Sand(USCS)	SP
USCS Classification	High plasticity Clay (CH)		

Geo-synthetic clay liner (GCL) used in this study is the commercially available. It was collected from local market. Properties of the GCL have been given below. Glass fiber used in this study was collected from the local market and its properties are shown in the Table 2.

Table 2 Properties of GCL and Glass Fiber

Properties of GCL	Values	Properties of Glass Fiber	Values
Thickness (mm)	5	Diameter (mm)	0.16
Mass per unit Area (gm/cm^2)	5.65	Tensile Strength (GN/m^2)	2
		Specific Gravity	2.55
		Modulus of elasticity(GN/m^2)	151.9

Compaction test was performed to determine the maximum dry density (MDD) and optimum moisture content (OMC) for the different types of sand-bentonite mixtures. Consolidation test was carried out in five sand–bentonite mixtures, and reinforced with glass fiber as well as one layer GCL in order to access the hydraulic conductivity and compressibility of the mixtures. Consolidation test was conducted in accordance with ASTM D 2435 on samples of 15mm thick and 60 mm in diameter. GCL was placed in the consolidation ring of 2/3rd of sample height from the top. The length and amount of fiber used for preparation of a sample was fixed at 10 mm with 0.5% and 1% which was kept constant throughout the investigation. Unconfined compressive strength test was carried out as per guidelines provided in ASTM D 2166, under a constant strain rate of 1.25 mm/min on the samples of 38mm in diameter and 76 mm height.

3. DISCUSSION OF TEST RESULT

3.1. Effect of GCL and Fiber on Swelling Behavior of sand-bentonite mixture

The swelling potential and swelling pressure of different mixtures compacted at OMC and MDD and inundated with de-ionized (DI) water are shown in Figure-1(a) which shows that the mixture with a layer of GCL swelled more in comparison to the mixture without GCL. The swelling potential of SB40 mixture was increased from 10.64 % to 12.32 % due to addition of a layer of GCL. Due to fact that a layer of GCL the swelling pressure of SB40 mixture was increased from 180 to 260 kPa. The bentonite present inside the GCL provides additional swelling to the mixtures resulting in a higher value of swelling potential and swelling pressure. However, Figure-1(a) and Table-3 shows swelling potential as well as swelling pressure was to be decreased by addition of the glass fiber in the mixture. During swelling, repulsive force generates between the individual bentonite particles and this repulsive force is normalized by tensile force which is offered by the fiber resulting in a decrease in the swelling potential and swelling pressure (Abdi et al., 2008; Mhaidib, 2010; Akhras et al., 2008). The reason for the reduction of swell pressure could also be due to the presence of fibers which created path for the dissipation of pore pressures of a loaded soil sample (Puppala and Musenda, 2000).

Table 3 Swelling pressure and compression index of composite mixture

Material	Swelling Pressure (kPa)	Compression Index (c_c)
SB40+GCL	260	0.33
SB40	180	0.31
SB40+GCL+0.5% Fiber	155	0.28
SB40+GCL+1% Fiber	135	0.27

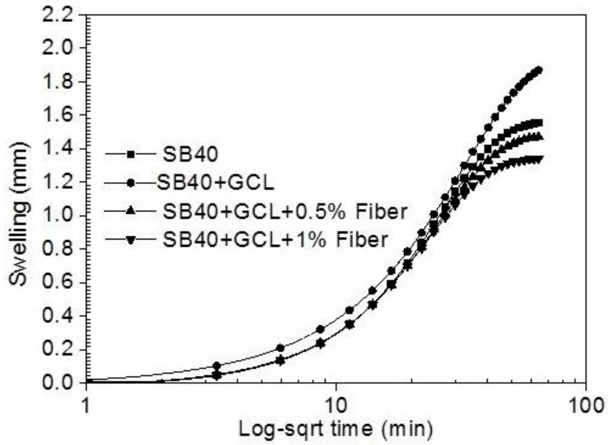


Figure 1 (a) Time swelling plot for mixtures

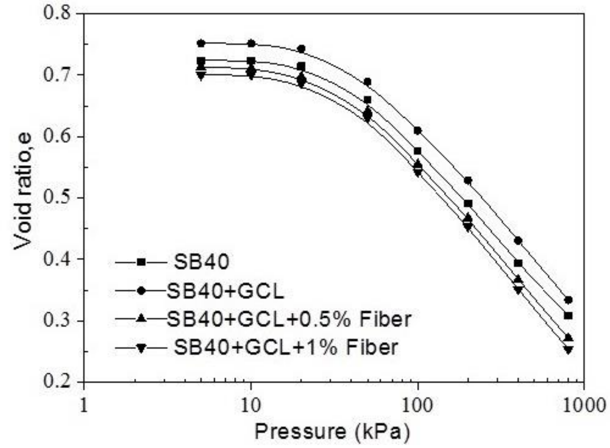


Figure 1 (b) Void ratio pressure plot for mixtures

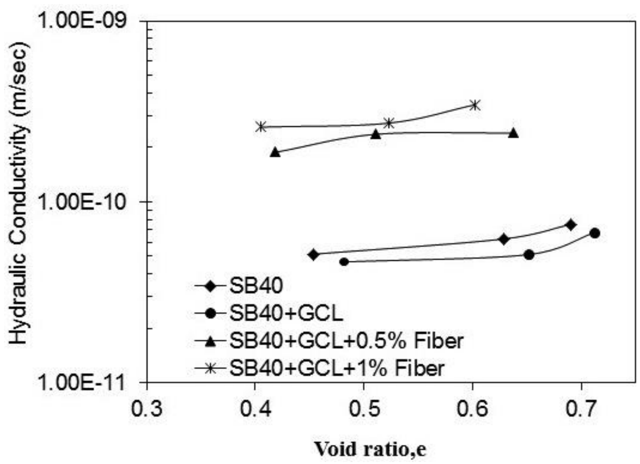


Figure 2 (a) Void ratio vs.Hydraulic conductivity

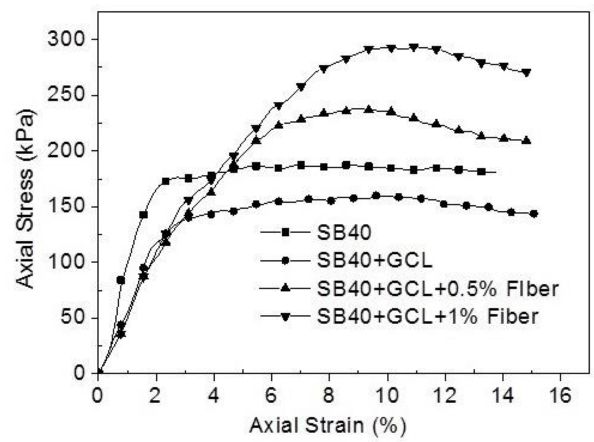


Figure 2 (b) Axial stress vs.Axial strain

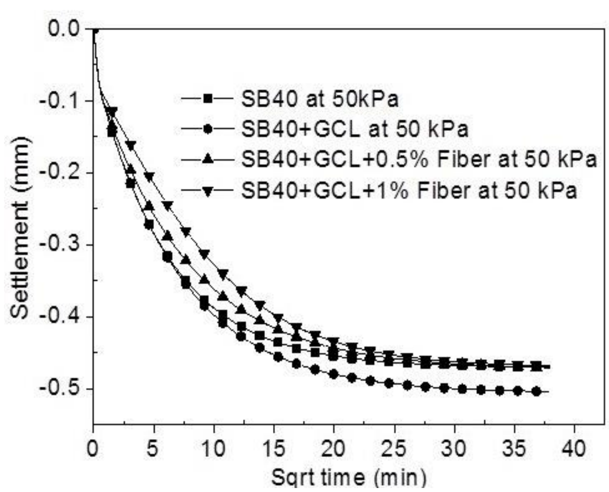


Figure 3 (a) Settlement vs. Time at 50kPa

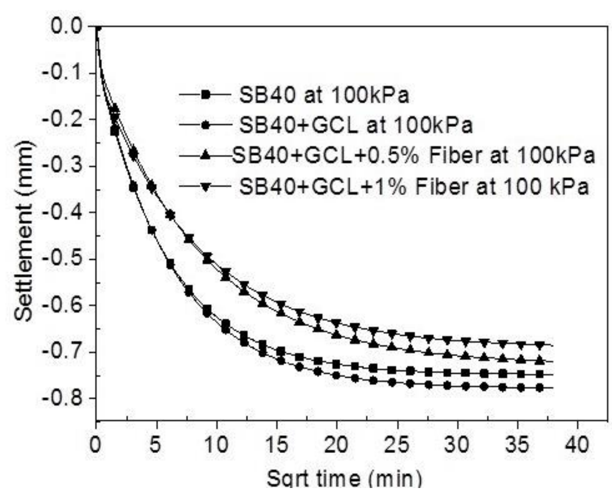


Figure 3 (b) Settlement vs. Time at 100kPa

3.2. Effect of Fiber and GCL on hydraulic conductivity of sand-bentonite mixture mixed in various proportions

Hydraulic conductivity is one of the most important criteria for soil to be used as liner material at waste disposal. The minimum value of hydraulic conductivity of 10^{-7} cm/sec compacted at MDD-OMC. Figure 2 (a) shows the relationship between void ratio (*e*) and hydraulic conductivity (*k*) for four different materials. Result shows that the hydraulic conductivity varies almost linearly with void ratio. Hydraulic conductivity was to be decreased with decrease in the void ratio. With the addition of the GCL in the mixture, the hydraulic conductivity found to be reduced significantly. When water was absorbed by encapsulated dry bentonite which starts to develop the diffuse double as well as the piratical becomes more dispersed and the flow path becomes more tortuous which result in a lower value of hydraulic conductivity. The hydraulic conductivity of the mixture was increased by addition of glass fiber in the mixture. Basically, drainage had been developed due to application of fiber, as well as water can flow through this path and increase the hydraulic conductivity (Abdi et al., 2008).

3.3 Effect on void ratio-pressure, time-settlement, m_v, C_v plot of sand-bentonite mixture mixed in various proportions

Figure 1(b) showed the relation between the pressure and void ratio for four different materials. The result shows that with increase in over burden pressure the void ratio of four different material decreases. The mixture with higher bentonite content showed the higher value of initial void ratio. As the over burden pressure starts to apply on swollen specimen which compressed and resulted in a decrease in the void ratio. The reduction in the void ratio is mainly due to compression of the swollen bentonite. Mixture with higher bentonite content undergoes a higher value of compression. From the Figure -1(a) and Figure 3(a and b), showed that SB mix reinforced with glass fiber shows less swelling and less settlement compare with unreinforced soil. Glass fiber is reinforced material with high tensile strength and also it generated a strong bond between soils particles. Therefore, it is less compressible under the higher load.From the experiment, it has been examined that SB mix with GCL swelled as well as compressed more. From Table-3, compression index value was more for SB mix with GCL and it was decreased with fiber inclusion. This trend has been observed throughout the investigation. Figure-4(a) showed that co-efficient of volume change (M_v) decreased with consolidating pressure. Furthermore, coefficient of volume change (m_v) of soil decrease with inclusion of glass fibres in mixture (Laskar and pal 2013).From the Figure-4(b) explained that "t_{90}" increased with increasing consolidating pressure. In addition to that "t_{90}" decreased with inclusion of glass fiber. Figure-5(a) addressed that c_v increased with the increase in the consolidating pressure, indicating the mixture gets consolidated at a higher rate under a higher overburden pressure. This is fact that increase in the c_v with the increase in the pressure also indicates that the compressibility of the mixture is controlled by the mechanical effect at higher over burden pressure (Mishra et.al, 2010). It has been observed from the experiment Figure 3(a & b), reinforcement material has a tendency to create thin bind along the soil particles. As a result fiber –soil –GCL composite more confined and reduced the settlement.

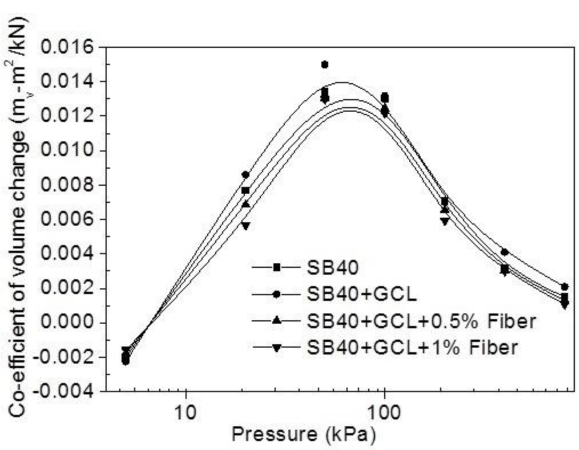


Figure 4 (a) Settlement vs. Time at 50kPa

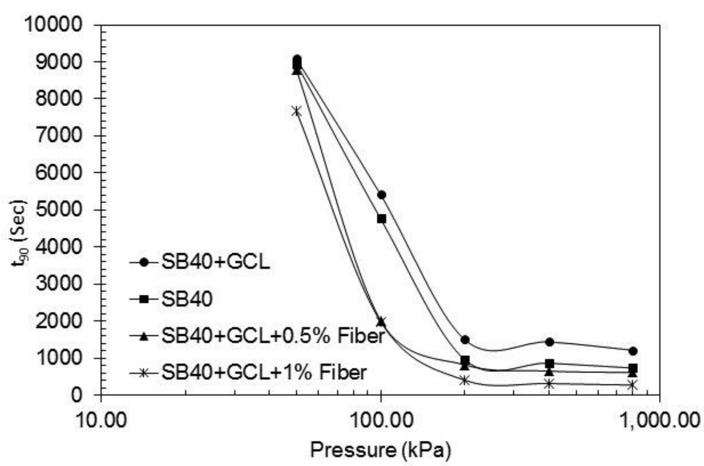
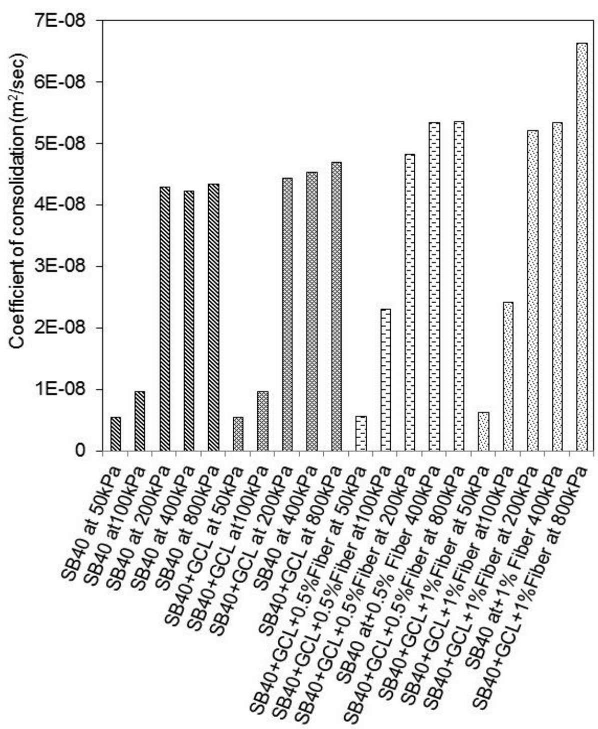


Figure 4 (b) Settlement vs. Time at 50kPa

3.4. Effect of Fiber and GCL on the unconfined compression Test

The stress-strain plot for the various sand-bentonite compacted at their respective OMC and MDD mixtures are shown in Figure 2 (b). Stress-strain plot takes the average of three trials or two similar responses as well as this result were used to obtain the UCS (q_u) of the soil samples .These results were also further used to obtain the undrained cohesion value of the sample. Figure 2(b) shows that the unconfined compression strength of the mixtures found to be decreased with the addition of GCL. When concentrated vertical load was applied to soil sample, thickness of GCL changed continuously as a result, bentonite moved laterally (Koerner and Narejo, 1995; Fox et al., 1996 and Stark, 1998) resulting in a decrease in the unconfined compressive strength. For SB40 mixture, the unconfined compressive strength decreased from 168.0kPa to 141.7kPa due to the inclusion GCL in the mixture. However, the unconfined compressive strength of the mixtures found to be increased when the mixture was reinforced with glass fiber. From the Figure 2(b) and Figure 5(b), unconfined compressive strength increased significantly from 141.7kPa to 199.46 and 256.45 kPa due to the inclusion of 0.5% and 1% fiber in the mixture respectively. Fiber inter-locked soil grains in the soil matrix resulting in an increase in the bond strength of the composite (Maher and Ho, 1994). Therefore, fiber cannot slide and can carry the tensile stress in the soil matrix. However, stretching resistance of reinforce soil matrix is high as well as composite restricts displacement under the vertical load. As a result unconfined compressive strength increased with addition of fiber (Tang et al., 2007**,** Prato & Kalantari, 2012). However, it was also observed that strain was increased with inclusion of different fiber content. Therefore, more strain was required to mobilize the shear.



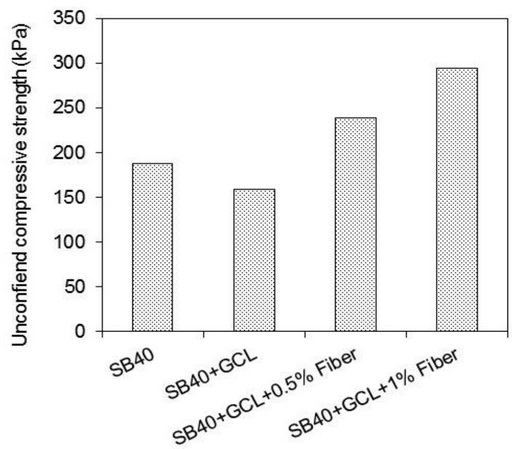


Figure 5 (b) UCS vs. Different mixtures

Figure 5 (a) Coefficient of consolidation with diferent mixture

4. CONCLUSION

Tests were carried out to study the effect of polypropylene glass fiber on the geotechnical behaviour of various sand-bentonite mixtures amended with a layer of GCL. Fibers of 10 mm length in the proportion of 0.5% and 1% were added to the samples. The data shows that the swelling pressure and the swelling potential of the mixtures increased due to the addition of a layer of GCL to the mixtures. However, with the inclusion of the fiber the swelling pressure and swelling potential decreased significantly. The results of the hydraulic conductivity test showed that with the inclusion of the GCL, the hydraulic conductivity of the mixtures decreased significantly. However when the mixture with layer of GCL was reinforced with fiber, the hydraulic conductivity increased. The hydraulic conductivity value was increased with an increase in the fiber content in the mixture and its effect was more pronounced for the mixture with a higher amount of bentonite content. The compression index of the mixtures with GCL was decreased marginally due to the inclusion of fiber. Coefficient of volume change (m_v) of soil decreased with inclusion of glass fibres in mixture. Settlement was restricted by inclusion of fiber. t_{90} decreased with application of fiber. c_v increased with the increase in the consolidating pressure. However, there was significant increase in the unconfined compressive strength of the mixture due the addition of fiber.

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