Influence of glass fiber on the behaviour of sand-bentonite mixture

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ABSTRACT: Landfills are installed to protect the environment from the leachate generated from the waste and tends to percolate downward to contaminate the ground water. Therefore, an impermeable layer, known as liner, is generally provided between the waste and the ground water table. Generally, mixture of sand-bentonite used as a liner material at the waste disposal site. Due to desiccation of bentonite, it shrinks and the hydraulic conductivity increases and shear strength decreases significantly. Therefore, it is quite essential to reduce the dessication shrinkage of sand-bentonite to achieve a durable landfill liner. High tensile strength glass fibers are added to sand-bentonite mixtures to reduce the desiccation shrinkage. However, due to the addition of the fiber the properties of the sand-bentonite mixture may get affected seriously and may become unsuitable for the use as a liner material. Hence, it is quite essential to investigate the effect of addition of glass fiber on swelling, compressibility and the permeability behaviour of sand-bentonite mixture. In this study oedometer tests were conducted to investigate the hydro-mechanical and compressibility behaviour of sand bentonite (SB) mixture in the presence of glass fiber. Bentonite-sand mixtures, mixed in the proportion of 80% sand-20% bentonite (SB20), were mixed with 1% glass fiber by it's dry weight with three aspect ratio (l/d=40,80,120). The experimental results shows that the hydraulic conductivity of the mixture increased due to inclusion of glass fiber. However, it was observed that the hydraulic conductivity decreased as the aspect ratio increases while concentration of fiber remained constant. Vertical heave (mm) was found to be reduced by different aspect ratio of the glass fiber. Compression index was found to be decreased as aspect ratio increases.

Keywords: Liner, glass fiber and hydraulic conductivty

1 INTRODUCTION:

Generally, most of the solid waste dumped to landfill due its low cost and efficiency. Landfill consists of a liner system at the base and sides of the landfill which prevents migration of leachate or gas to the surrounding soil. Therefore, low permeable soil can be used to construct the engineered land fill. Hydraulic conductivity is one of the most important criteria for soil to be used as liner material at the waste disposal site. Various environmental agencies (USEPA, 1988; Benson and Daniel, 1990) have prescribed a minimum design hydraulic conductivity value for the landfill liner material as 10^{-7} cm/sec. Generally, mixture of sand-bentonite used as a liner material at the waste disposal site. Due to desiccation, bentonite present in sand-bentonite mixture shrinks (Tay et al. 2001**)** resulting in an increase in the hydraulic conductivity (Rayhani et al. 2008). Furthermore, compressibility and consolidation rate increases and soil strength decreases due to formation of cracks (Morris et al.1992). Many researchers considered the use of surface moisture barriers above the soil layer; others have controlled decreasing the crack potential of the soil. Furthermore, a few have focused soil additives to increase the soil strength and resistance to cracking. Omidi et al. (1996) and Leung and Vipulanandan (1995) investigated the effect of soil additives (lime, cement, and sand) on the volumetric shrinkage and hydraulic conductivity of clay soil. It was reported that soil shrinkage was reduced but hydraulic conductivity increased in some cases. Therefore, fibers have arisen to better improve the clay performance as hydraulic barriers without changing the physical properties of the soil. Maher and Ho (1994) performed a series of UCS, splitting-tension, three-point-bending and hydraulic-conductivity to study the mechanical properties of a kaolinite/fiber soil composite. Peak compressive strength, ductility, splitting tensile strength, and flexural toughness significantly increased with inclusion of randomly distributed fibers. Hydraulic conductivity slightly increased with inclusion of fiber. Rodatz and Oltmanns (1997) demonstrated that soil fiber mixed would be used as new liner material. It was reported that fiber mixed with soil up to 1 to 1.5% for plastic fiber and 3% for glass fiber. It was observed that there was no significant change in permeability with inclusion of fiber. Miller and Rifai (2004*)* investigated on the impact of fiber reinforcement on the development of desiccation crack, compaction characteristics, hydraulic conductivity and soil workability in compacted clay samples. It was reported that hydraulic conductivity was increased significantly for fiber content exceeding 1% (Abdi et al.2008).

A review of literature shows that no studies have been carried out on sand-bentonite mixture reinforced with glass fiber. Hence, this paper investigates the effect glass fiber on hydro-mechanical and compressibility characteristics of the sand-bentonite mixtures.

2 Materials and Methods

Bentonite:

Commercially available bentonite used for this study. The physical and chemical properties of bentonite were given below. Clay content of the bentonite was determined by hydrometer test as per as ASTM D422 (2002). Atterberg limits were determined according to ASTM D4318 (2000). The specific surface area (SSA) of the bentonite was determined by the method described by Cerato and Lutenegger (2002).Liquid limit, plastic limit, shrinkage limit, clay content, silt content, fine sand, specific surface area, specific gravity and USCS classification were 286 (%), 44(%), 24(%), 46.66 (%), 22.18(%), 31.16(%), 347(m^2/gm), 2.76 and CH respectively.

Sand:

Air-dried Brahmaputra river sand has been used for this study. Additionally, sand was sieved to remove particles greater than 2 mm (the fraction removed represented less than 0.5% by weight).D_{60},D_{30},D_{10}, coefficient of uniformity(C_u),coefficient of curvature (C_c) and specific gravity were 0.5(mm), 0.29(mm), 0.17(mm), 2.94(<6), 0.98(<1 to 3) and SP respectively. Particle-size distribution of sand was determined as per ASTM, D422-63 (2002).

Glass Fiber:

Commercially available glass fibers used in this study and it was cut into lengths of 6mm, 12mm and18mm. Fixed fiber concentration (f_c=1%) has been used for this investigation. Liquid limit and specific gravity of the mixtures were 42%, 38%, 38%, 2.693, 2.692 and 2.692 respectively. Average diameter of the glass fiber was 0.15mm. Modulus of elasticity of the fiber was determined by applying tangent method as described in ASTM D2256.It was found to be 112.3(GN/m^2). Maximum dry density (MDD) and optimum water content (OMC) were 1.73gm/cc and 15.3% respectively for unreinforced soil. However, maximum dry density (MDD) was almost constant but optimum moisture content (OMC) was found to be decreased by 1% fiber concentration. This is happened due to non-porous fiber was occupied in to the void in to soil – fiber matrix, therefore optimum moisture content (OMC) slightly decreased with fiber concentration.

Oedometer test

Oedometer test was carried out in a standard 60 mm in diameter and 20 mm thickness of ring according to ASTM D2435 (2011) to swelling, hydraulic conductivity and compressibility behaviour of the mixtures. Glass fibers were added to the sand-bentonite mixtures by 1% with different aspect ratio (40, 80 and 120) of the dry weight of the mixtures. Maximum care was taken to separate the strands of glass fiber from each other during the mixing process. The mixtures were then mixed with water to their respective OMC and kept in humidity controlled desiccators for 24 hour to attain the moisture equilibrium. The moisture-equilibrated specimens were then statically compacted in three layers to its MDD in oedometer ring to obtain a sample of diameter of 60 mm and a thickness of 15 mm. Then entire assembly was placed in a consolidation cell and positioned in the loading frame and inundated in DI water under a nominal pressure of 5 kPa and allowed to swell. Once the swelling was completed, thereafter samples were consolidated by increasing the pressure gradually by an increment ratio of 1 (i.e. increased by 5, 10, 20 kPa at each step) to a maximum pressure of 800 kPa. For each pressure increment the change in the thickness of soil sample was measured from the dial gauge readings.

3 Result and Discussion:

Determination of consolidation properties

3.1.1 *Effect of fiber on swelling behaviour*

Figure.1 depicts relationship between swelling and time for the SB20 composite. This is clear from this figure that glass fiber inclusion had a substantial impact on the swelling pressure of mixture. A vertical swelling height of 0.5 mm, 0.36mm, 0.303 mm and 0.29 mm were noticed for the SB20 composite with different aspect ratio of the glass fiber. Hence, it may be concluded that a repulsive force was generated when bentonite reacts with water as a result swelling took place. This swelling phenomenon was fully restricted by tensile strength which comes from glass fiber as a result swelling reduced. Therefore, vertical heave is function of length of the glass fiber which means that vertical heave was reduced as the aspect ratio of the glass fiber increases. This interesting fact was completely understood by Fig.2.However, field emission scanning electron microscope (FESEM) shows that soil particle was interlocked by glass fiber with 2000 times magnifications which has been shown in Fig 4. Similar observation was made by Viswanadham et al. 2008 with expansive soil and coir fiber interaction.

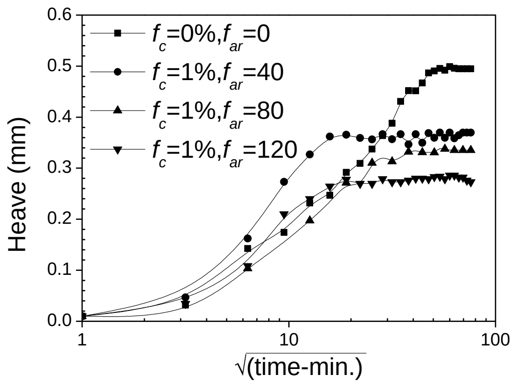

Fig-1 Variation of heave with time

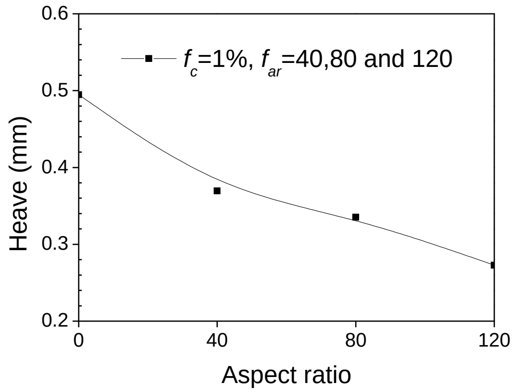

Fig-2 Variation of heave with aspect ratio

3.1.2 *Hydraulic conductivity of the mixture with of glass fiber inclusion*

Hydraulic conductivity is one of the most important criteria for soil to be used as liner material at waste disposal site. Various environmental agencies (USEPA, 1988; Benson and Daniel, 1990) has prescribed a minimum design hydraulic conductivity value for the landfill liner material as 10^{-7} cm/sec. Fig.5 shows the relationship between void ratio (e) and hydraulic conductivity (k) for the SB20 composite. For SB20 composite at 0.5 void ratio, it was found to be noticed that hydraulic conductivity was $5\text{x}10^{-8}$ cm/sec for unreinforced sample but it was increased to$2.8\text{x}10^{-5}$ (560times) and dropped to $0.85\text{x}10^{-5}$ (170times) and $3.9\text{x}10^{-6}$ (78 times) by addition of different aspect ratio (f_{ar}= 0,40,80and120) of the glass fiber. Therefore, hydraulic conductivity was strongly affected by length of the fiber. However, orientation of the fiber is most important factor to control the hydraulic conductivity.it may be happened when water will move along the fiber soil interface. In that case, hydraulic conductivity was increased by inclusion of fiber (Malekzadeh and Bilsel, 2012). On the other way, it may be speculated that water will move across fiber soil interface and water could be prevented by non -porous fiber. In that case, hydraulic conductivity was decreased by longer length of the fiber.

3.1.3 *Effect of glass fiber on compressibility*

Figure.5 shows that with an increase in the consolidation pressures the void ratio of the mixtures decreases. Reduction in void ratio would be happened due to consolidation pressure was higher for the mixture consists with longer length of the glass fiber. This interesting behavior was responsible to reduce the overall compression with increasing the glass fiber length.

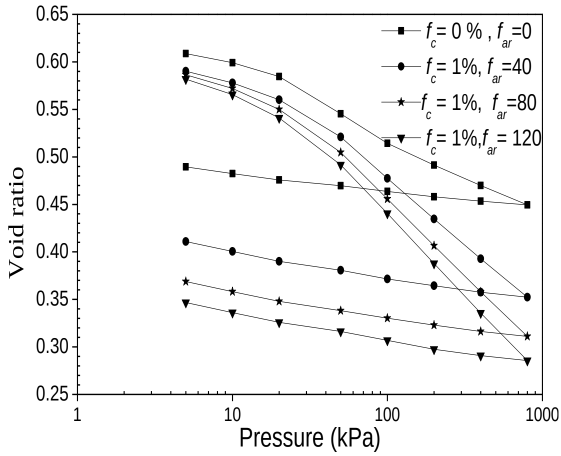

Fig: 3 Void rato vs. Pressure

This mechanism controlled the compressibility of the mixture. This is happed due to longer length of the glass fiber binds the soil particle very tightly thereafter overall composite was becoming more rigid by inclusion of glass fiber as a result compression index decreased. Generally, compression index (Cc) is the slope of the linear portion of the curve of pressure against void ratio on a semi-log plot. From the experiment, it was noted that compression index was found to be decreased from 0.28 to 0.21, 0.23, and 0.26 by different aspect ratio 0, 40, 80 and 120 of the glass fiber .However, compression index was slightly increased by higher aspect ratio of the glass fiber.

Conclusion

Hydraulic conductivity was found to be increased for shorter length of fiber but reverse trend was observed for higher aspect ratio of the fiber. Compressibility decreased for lower aspect ratio of the fiber and slightly increased with its higher aspect ratio. Vertical heave was completely restricted by different length of the glass fiber. Expansion strain was reduced as the aspect ratio of the glass fiber increases.

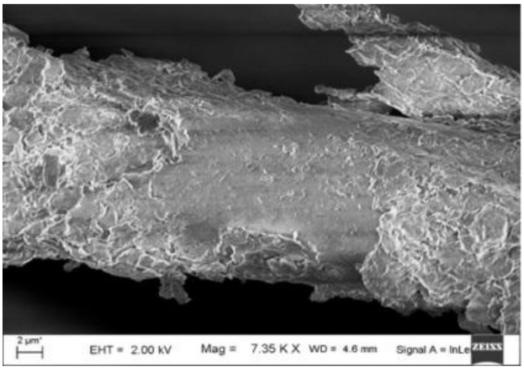

Fig.4 Roughness of glass fiber after test

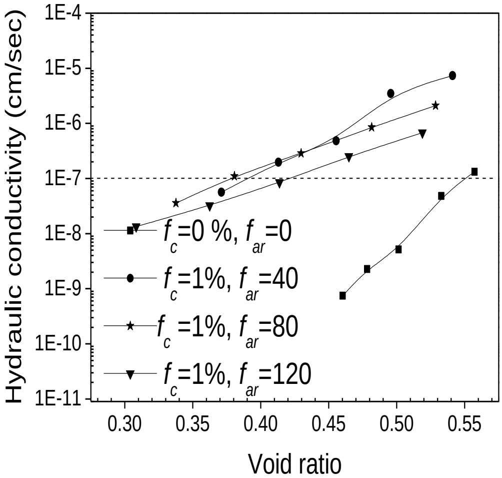

Fig.5 Void ratio- hydraulic conductivity at fixed f_c*=1%*

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