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Improving the swell: Consolidation characteristics of expansive soil using fibre-reinforced

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Abstract
Expansive soil is found almost everywhere throughout the world. In semi-arid country like Bangladesh, this type of soil is found almost everywhere. Expansive clays are considered as a problematic due to high shrinkage and swelling potential. Expansive clays swell considerably when water is added to them and then shrink with the loss of water. For everyday construction activities, various precautions have to be considered in order to minimize the risk of construction on such a soil. Geotechnical experts have proposed several measures in order to improve the properties of expansive soil. This experimental study investigates the effect of the inclusion of Polypropylene into expansive soil on its swell-consolidation characteristics. This fiber chooses due to locally available and economical in Bangladesh. This fiber also uses as a recycling purpose. It also presents the comparison the swell-consolidation and unconfined compression characteristics of two different types of remoulded expansive clays.
The use of such waste materials to improve the swell-consolidation characteristics would be significant. To determine the effect of the inclusion of Polypropylene into expansive soil, one dimensional swell-consolidation tests were conducted in the laboratory. In this paper, two types of soil samples been considered and soil has been collected from two different locations of Bangladesh. One is Ghodagari in Rajshahi that is the north part of Bangladesh and another is Gazipur in Dhaka that is the east part of Bangladesh. The main objectives of this paper is to evaluate the swelling- consolidation and unconfined compression characteristic of fiber-reinforced of two different remolded expansive soils. Various proportion of Polypropylene by weight of soil (0.5%, 1%, and 2%) were mixed with the expansive soil and the samples were subjected to one dimensional swell-consolidation tests. The test results show that the inclusion of Polypropylene has significant effect on the swell-consolidation characteristics of expansive soil.

Keywords: expansive soil, swell potential, vertical swelling pressures, polypropylene

Introduction
Expansive soil has such property that they easily absorb water and swell, when the water evaporates from them, they shrink (Chan, 1988; Nelson and miller, 1992). Due to this, expansive soil is one of the problematic soil like as collapsible soil, quick clays etc. in the field of geotechnical engineering and it causes severe distraction in foundation. Though the amount of destruction is not known in Bangladesh, the annual cost of damage is estimated as £150 million in UK, $1000 million in USA and $300 million in Saudi Arabia during the period of 1977-1987 and also many billions of pound worldwide (Gouley *et al.*, 1993; Al-Muhaidib, 2003) [1]. So geotechnical engineers used many innovative techniques to counteract the problem caused by expansive soil. Swelling indices such as swelling pressure, swelling potential and swelling index which are typically determined in all geotechnical laboratories are required for safe and economic design of foundations.
To find the proper measures to reduce distractive effect, researchers have been adopting the techinique of treatment of expansive soil by adding additives so that the shear strength of expansive soil increases in saturated condition and consequently soil heaving and swelling pressure reduces. Physical alternation (Phanikumar, 2012), belled piers (Chan, 1988) and granular pile-anchors (Phanikumar, 1997; Phanikumar *et al.*, 2004) are some of effective technique of foundation in expansive soil. The expansive soil can be stabilized chemically using lime of fly ash which can efficiently control the volumetric change of expansive soils (Chan, 1988; Coka, 2001; Phanikumar and Sharma, 2004). A new technique, fly ash column (Phanikumar *et al.*, 2009) is also prove to be effective in this type of problem.
Besides this technique, treatment of expansive soil by adding geosynthetics fiber as a technique of random reinforcement have also found satisfactory in controlling swell and shrinkage (Vessel and Wu, 2002; Viswanadham *et al.*, 2009a; 2009b).
Polypropylene can be used as reinforcing fiber for compacted expansive soil which can reduce the tension creaking and control the volumetric change (Al-Wahab and El-Kedrah, 1995). It is found that the fiber inclusions increased the tensile strength (Ziegler *et al.*, 1998; Babu *et al.*, 2008) [11]. The combined effect of polypropylene fibers and fly ash have also been studied to reduce the swelling and shrinkage characteristics (Puppala and Musenda, 2000; Punthutaecha *et al.*, 2006; Tang *et al.*, 2007). In fiber reinforced soil, consolidation settlement and swelling decreased, when the hydraulic conductivity and shrinkage limit increased slightly at the increase in fiber content and fiber length (Abdi *et al.*, 2008).
Al-Akhras *et al.* (2008) mixed nylon and palmyra fiber of diferent aspect ratios (l/d) with three types of expansive soil that had different physical properties. In their study they used four aspect ratio (l/d=25, 50, 75, 100) and five different fiber contents (fc =1%, 2%,3%,4%&5%) and vertical swelling pressure and swell potential were evaluated. From their study, it is obtained that with the increase in percentage of both types of fiber reduced the vertical swelling pressure and swell potential of clay soil significantly. Phanikumar and Singla (2016) also used nylon fiber ranged from 0% to 0.3%

with a (l/d) ratio of 15 to20 with the expansive soil. They found that heave, swell potential and vertical swelling pressure decreases with an increase in fiber content for a given fiber length (l).
This Literature investigate the swell consolidation characteristics of two types of remolded expansive clay specimen reinforced randomly with Polypropylene fiber. The effect in coefficient of compressibility and secondary compression index also studied. It should be mentioned that the work is quite different from Al-Akhras *et al.*, (2005) and Phanikumar and Singla (2016). Instant of of using nulon and palmyra fiber we used Polypropylene and the fiber content was (0%, 0.5%,1%,2%) without considering aspect ratio(l/d).

Swelling potential and swelling pressure

The term swelling potential is generally used to indicate the amount of vertical swell (expressed as percentage of initial sample thickness) obtained under a particular surcharge (usually 1psi).

$$S_p = \frac{\delta h}{h} * 100\%$$

Where, S_p = swelling potential in percentage
δh = amount of vertical swell
h = initial height

The swelling pressure is defined as the vertical pressure required to prevent volume change of laterally confined sample when it is allowed to take in water. Percent expansion decreases with increase in confining pressure for a given initial moisture content and density.

Free swell of soil

This test tries to give a fair approximation of the degree of expansiveness of a given soil sample. In this test, 10cc of dry sample was passed NO-40 sieve into 100cc of distilled warer. Then waited 24 hours until all the sample completely settles on the bottle of the cylinder. After that final volume of the sample was recorded.

$$\text{Free swell} = \frac{Final\ volume - Initial\ volume}{Initial\ volume} * 100$$

Free swell method (Consolidation method)

In this test, an undisturbed soil sample is placed in a consolidometer and applied a normal load equal to 1psi. Then the sample is inundated and allowed it to swell. After the swelling is complete, load the sample in increments until the soil returns to its original volume. The pressure that corresponds to the original volume is the swelling pressure.

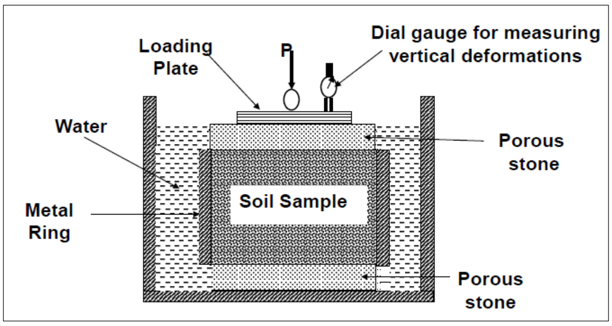


Fig 1: consolidation

Test Materials

Two different types of expansive soil of different physical property were used and garment waste was added as a reinforcing element. Expansive soil samples were collected at a depth of 0.5 meter from the ground level of Godagary, Rajshahi and Gazipur, Dhaka of Bangladesh.

Table 1: Index properties of expansive soils.

Godagary Soil			Gazipur Soil	
Specfic gravity of the soil solids,Gs	2.77		Specfic gravity of the soil solids,Gs	2.66
Water content(%)	18.65		Water content(%)	22.67
Liquid limit(%)	45.28		Liquid limit(%)	35.53
Plastic limit(%)	20.58		Plastic limit(%)	21.79
Shrinkage limit(%)	14.87		Shrinkage limit(%)	15.55
Plasticity index(%)	24.7(High)		Plasticity index(%)	13.74(Medium)
Free swell index(%)	108.33(High)		Free swell index(%)	80(Moderate)
USCS classification	CL		USCS classification	CL

Based on liquid limit and plasticity index the soil was classified as CL. Table-1 represent the index property of the soil. Garment waste which was used to reinforce the soil specimen was randomly oriented as reinforcement.

Test Procedure

The consolidation ring dimension was 52mm in diameter and 20mm in height. The botht unreinforced and reinforced sample were filled and uniformly compacted. The weight of fiber related to the chosen fiber content (fc) was thoroughly mixed with the expansive soil and uniformly compacted. Two porous stone was placed on the top and bottom of the soil sample. After that the sample was allowed to swell freely for 24 hours. After the equilibrium heave had been reached, the samples were subjected to compression by increasing the compressive loads on the specimen. The samples were then allowed to undergo consolidation under each load increment for 24 h. From the result e-log σvs curve is plotted and swelling pressure corresponding to the initial void ratio was determined.

Test Variable

Dry unit weight (γd) of the expansive soils were 19.57 kN/m3 (Godagary) and 19.45 Kn/m3 (Gazipur). The fiber content (fc) used in this study was 0%, 0.5%, 1%, 2% by the dry weight of soil.

Results

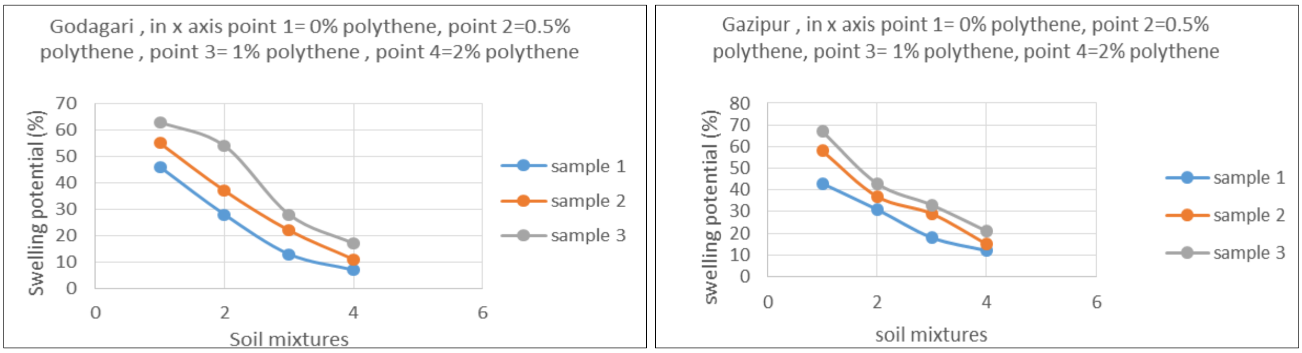


Fig 2: Swelling potential of godagari and gazipur soil sample.

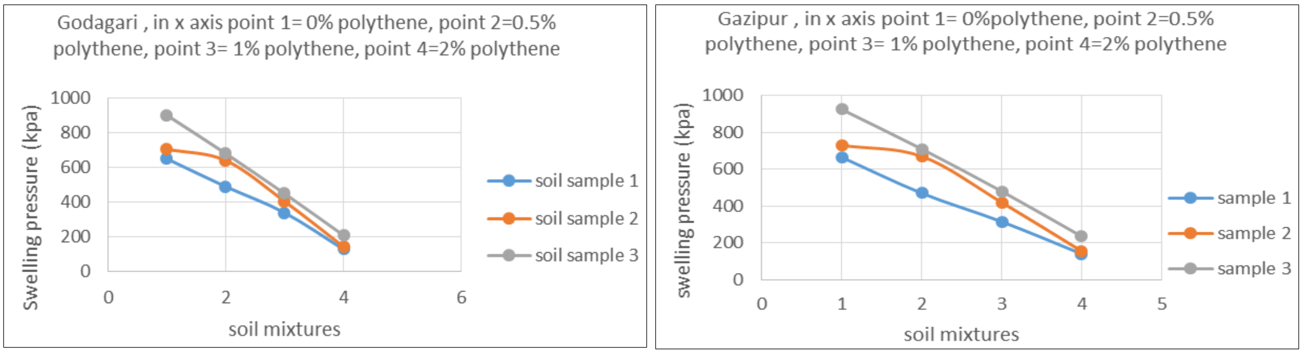
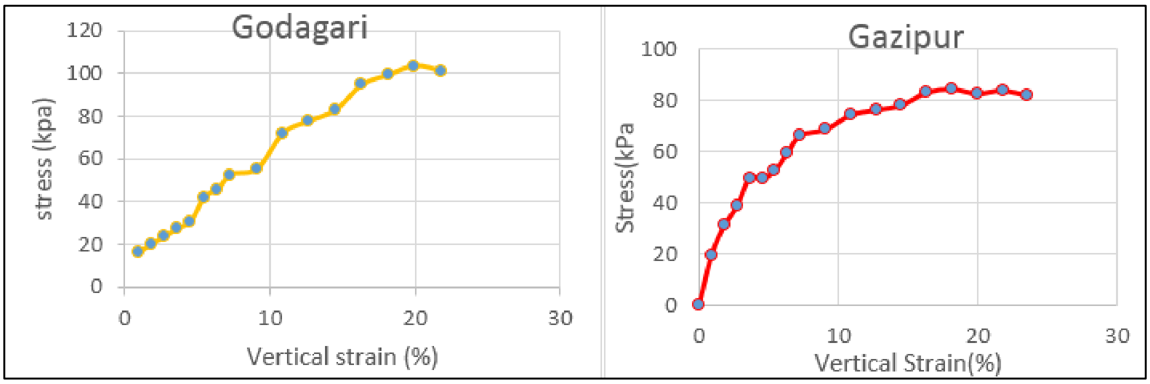
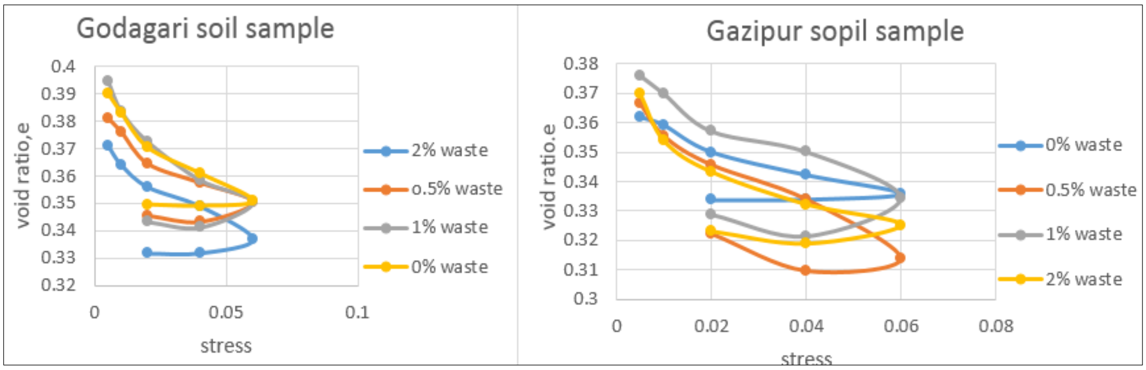


Fig 3: Swelling pressure of godagari and gazipur soil sample.



(a) (b)

Fig 4: relation between stress and strain (a) godagari sample (b) gazipur sample.



(a) (b)

Fig 4: Relation between void ration and effective stress of (a) Godagari and (b) gazipur soil sample

Conclusion

An experimental study is conducted in order to investigate the improvement in swelling characteristics of expansive soil due to using Polypropylene. From this experimental work, it is easily conclude that by using garment waste we can treat the expansive soil and also can use for construction.

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