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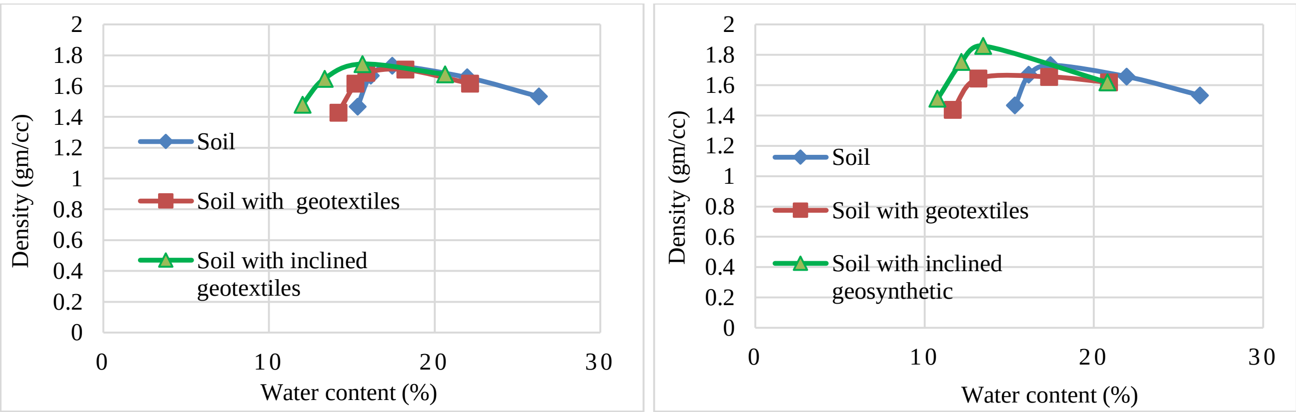
Venue: College of Engineering (Estd. 1854), Pune, India

COMPACTION PARAMETERS OF GEOTEXTILE REINFORCED SOIL

Niraj S. Parihar[1], Rajesh P. Shukla[2], Shivom Dhawan[3], Ashok K. Gupta[4]

ABSTRACT

Composite soils are having a very long history in human history. Geosynthetic materials have a wide range of applications in civil engineering, especially in soil reinforcement. Soil reinforcement is required to strengthen the soil having low bearing capacity. Compaction of soil leads to a change in the volume of the soil mass as it causes the expulsion of air from soil voids. Compaction behaviour of soil changes with the incorporation of reinforcement as reinforcement provides the additional resistance to the compaction and leads to loose packing. In this study an attempt is made to evaluate the compaction parameters of reinforced soil. A series of compaction tests are conducted on c-φ soil reinforced with geotextiles. Woven and non-woven geotextiles are used in study. Geotextiles are used in layers in the sheet form. Tests are conducted for inclined and horizontally placed geotextiles layers. Proctor compaction tests are conducted as per India standard code. A trial and error method is used to determine the initial position and angle of inclination of geotextiles layer in the compaction mould so that after compaction of soil geotextiles layer acquire desirable position and inclination. Effect of woven and nonwoven geotextiles are shown in figure 1 (a) and 1(b) respectively.



(a) (b)

Fig.1 Effect of reinforcement in the compaction parameters; (a) woven geotextiles (b) Non-woven geotextiles

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Use of geotextiles with an inclination to horizontal plane causes the reduction in the optimum moisture content and an increase in maximum dry density of soil. Compaction parameters are more affected by non-woven geotextiles. Horizontal reinforcement, either woven or non-woven causes a reduction in the optimum moisture content and maximum dry density of soil. In case of inclined geotextile, the maximum dry density increases with incorporation of woven and non-woven geotextile. Change in OMC are varied between 15%-25% and 4%-8% for nonwoven and woven geotextile respectively. Change in optimum moisture content is more as compared to dry density of soil. For normal case, effect of reinforcement on dry density can be neglected.

Keywords: compaction, geotextiles, woven, nonwoven, OMC, dry density

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ABSTRACT: Compaction behaviour of soil changes with the incorporation of reinforcement as reinforcement provides the additional resistance to the compaction and leads to loose packing. In this study an attempt is made to evaluate the compaction parameters of reinforced soil. A series of compaction tests are conducted on c-φ soil reinforced with woven and non-woven geotextile layers in the sheet form. Tests are conducted for inclined and horizontally placed geotextiles layers. Use of geotextiles with an inclination to horizontal plane causes the reduction in the optimum moisture content and an increase in maximum dry density of soil. Compaction parameters are more affected by non-woven geotextiles. Horizontal reinforcement, either woven or non-woven causes a reduction in the optimum moisture content and maximum dry density of soil. In case of inclined geotextile, the maximum dry density increases with incorporation of woven and non-woven geotextile. Change in OMC are varied between 15%-25% and 4%-8% for nonwoven and woven geotextile respectively. Change in optimum moisture content is more as compared to dry density of soil. For normal case, effect of reinforcement on dry density can be neglected.

INTRODUCTION

Soil compaction is a process in which a load is applied onto the loose soil and it causes the expulsion of air from soil pores and leads to the densification of soil. Compaction of soil leads to a change in the volume of the soil mass as it causes the expulsion of air from soil voids [1]. Soil compaction decrease the probability of shrinkage and reduces the voids between soils particle as well, thereby increases the density and consequently load carrying capacity. In most of construction, compaction is required and improperly performed compaction results in cracking, uneven settlements and additional maintenance cost [2]. Almost in all types of construction compaction is achieved by means of mechanical techniques. In cohesive soil, soil particles stick together and high impact loading is required for compaction whereas in case of sandy soils, cohesion forces between particles remain negligible and only vibratory loading is enough for compaction of soil mass. Hatami & Bathurst (2006) [3], and Mirmoradi & Ehrlich (2014) [4] modelled the compaction induced stress on reinforced soil walls and found that surcharge has substantial influence on the performance of retaining wall so engineering should consider the compaction effects on design of retaining wall.

Soil reinforcement is required to strengthen the soil having low bearing capacity. Reinforcing of a weak soil have gained popularity in the construction and geotechnical engineering in the recent years. Reinforcing of soil masses can be achieved by means of sheets of geosynthetic, strips of metal and threads of various material. A number of factors affects the performance and efficiency of reinforced soil such as fibre type, soil type, stress condition, orientation of fibres, quantity of reinforcement, and strength characteristics of geotextiles and strength characteristic of soil mass. Geosynthetic materials have a wide range of applications in civil engineering, especially in soil reinforcement.

Compaction behaviour of virgin soil and soil with reinforcement are different and depend on various factors such as characteristic of reinforcing media, amount and volume of reinforcing material and compaction energy [5]. Compaction behaviour of soil changes with the incorporation of reinforcement as reinforcement provides the additional resistance

to the compaction, and it also affects the density and water absorption capacity of reinforced soil mass.
The effect of reinforcement on soil shear strength have been studied in the earlier by various researchers and the influence of other parameters such as fibre type, fibre characteristic, soil characteristic, orientation of reinforcement, number of reinforcement and type of loading have been studied using various type of test such as direct shear tests, unconfined compression tests and triaxial tests. But only few studies have been conducted to determine the compaction behaviour of reinforced soil.

Dutta and Rao 2007 [6] found that for a given compaction energy, the presence of the reinforcement provides supplementary resistance to the compaction. Relative density of reinforced soil mass decreased with increase in the quantity of fiber. Fletcher and Humphries (1991) [7] found that inclusion of fiber on silty clay leads to a modest reduction in the maximum density of soil. Increase in fiber content caused an increase in optimum moisture content. Similar observation have been made by Ramesh, H.N. (2010 IGC) [8], Kaniraj & Gayathri (2003) [9], Ramesh et al (2010) [10].

Ramesh et al. (2010, 2010, 2011) [8, 10-11] found that incorporation of randomly distributed coir fiber in black cotton soil has decreased the maximum dry density and increased the optimum moisture content of reinforced soil. Chegenizadeh & Nikraz (2011) [12] used fibre reinforced silty sand and found that increase in the length and content of fibers have caused an increase in OMC and decrease in maximum dry density of soil. Laskar & Pal (2013) [13] investigated the effect of waste plastic fiber on consolidation and compaction behaviour of reinforced soil. Incorporation of waste plastic fibers leaded to a less dense packing of reinforced soil for same amount of compaction energy but there is no changes in optimum moisture content of reinforced soil.

Kumar et al., 1999 [14] and Ozkul et al, 2007 [15] found that the effect of the reinforcement on compaction parameters is insignificant. Ibraim & Fourmont, 2006 [16] studied the effect of randomly oriented discrete crimped polypropylene fibers on the compaction and shear parameters of sand samples. Incorporation of fiber reinforcement has caused the less dense packing and more resistance to compaction. With the increase of the fibre content in soil, energy absorption capacity of reinforced soil was increased. Due to extremely low moisture absorption characteristic of plastic strips, optimum moisture content (OMC) of every soil-plastic mix remains constant as optimum moisture content of soil without plastic fibers. Gaw & Zamora, 2011 [17] found that incorporation of coir fibers in the soil caused a decrease in optimum moisture content and dry density of soil.

There are a good number of studies available in the literature, which have discussed the compaction behaviour of reinforced soil but most of studies have considered the randomly oriented fiber as a reinforcing material rather than geosynthetic. Even for fiber reinforced soil, there is no agreement between earlier studies. Few studies have discussed the compaction of soil sample with some soil additives as well but studies on the compaction behavior of geotextile reinforced soil are missing in literature. In this study, an attempt has been made to study the compaction parameters of geotextile reinforced c-φ soil. This study will able us to find that whether compaction of such reinforced soil is beneficial or not and which type of geotextile is most suitable for c-φ soil. Compaction tests have been performed to determine the effects of inclination of geotextile as well.

MATERIAL AND APPARATUS USED IN THE STUDY

A c-φ soil used in present study was collected from Domehar district of Himachal Pradesh, India. Index properties of soil are shown in tabular form in table1. Grain size distribution of soil are shown in figure 1

Table 1: Soil Properties

Properties	Value
Liquid limit	41.80%
Plastic limit	21.85%.
Plasticity Index	20.05%
Effective size (mm)	0.019
Cohesion (kPa)	52.43

Angle of internal friction	8.84^0
OMC (%)	17.11
Max. dry density (gm/cc)	1.73

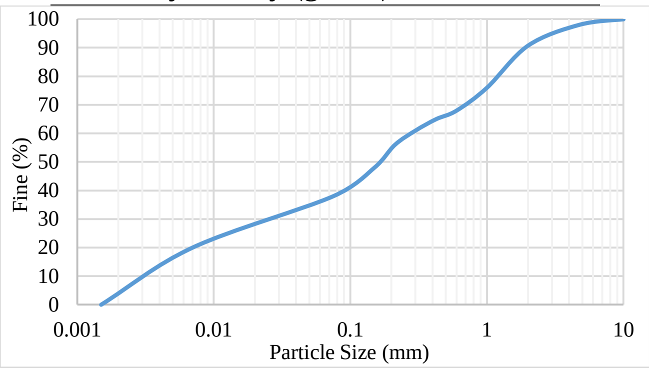
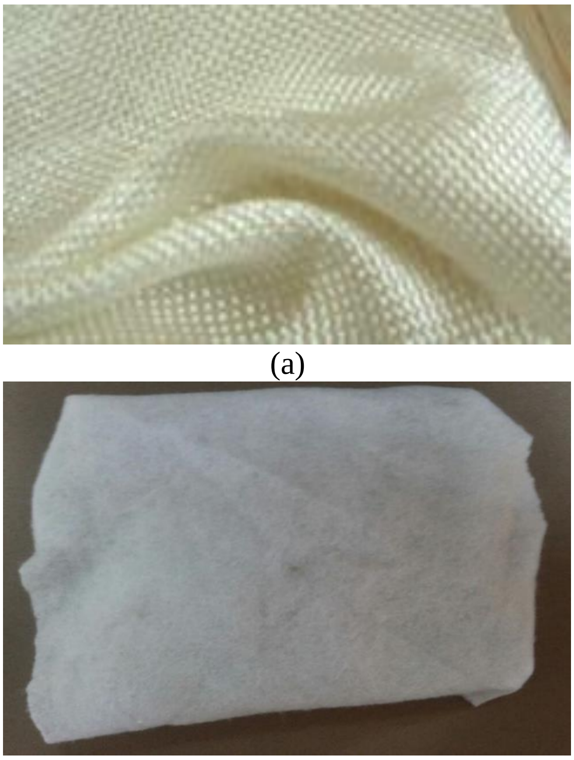


Figure 1: Grain size distribution curve of soil

Woven and nonwoven geotextiles were used in sheet form in this study and are shown in figure 2. The geotextiles were bought from Virendera Textiles, Noida, Uttar Pradesh. Properties of nonwoven and woven geotextiles are shown in table 2. Used geotextiles are having resistant to various chemicals and microorganism found in earth.



(a)

(b)

Figure 2: Geotextiles used in study; (a) Woven Geotextiles (b) Non-woven Geotextiles

Table 2: Properties of nonwoven Geotextiles

Properties	Values
Mass Per Unit Area	120 g/m²
Weight of Fabric	120 GSM
Tensile Strength CD	4.0 KN/m
Elongation	80 %
Grab Tensile Strength CD	.30 kN
CBR Puncture Strength	640 N
Apparent Opening size (AOS)	90 Microns

Table 3: Properties of woven Geotextiles

Properties	Values
Tensile Strength	42 KN/m
Elongation at Break	28 %
Trapezoid rear strength	520 N
Puncture strength	620 N
Water Permeability	9.5
Apparent opening	0.075 mm
Weight of Fabric	240 GSM

All compaction tests were performed in the laboratory using light compaction test. Compaction mould is having diameter of 100mm and 127.3 mm height. Apparatus used in study is shown in Fig 3.

Figure 3: Compaction test apparatus

EXPERIMENTAL PROGRAM AND PROCEDURE

All soil samples were collected from Domehar district of Himachal Pradesh. Index properties of collected soil were determined in laboratory as per Indian standards. Grain size distribution, water content, direct shear test and consistency limit were determined as per IS: 2720, Part IV: 1975 [18], IS: 2700, Part II: 1973 [19], IS: 2720, Part XIII: 1986 [20] and IS: 2720 Part V: 1985 [21] respectively.

The geotextile sheet was cut into a circular shape of diameter 98 mm. Geotextile was used in three layers. A trial and error method was used to determine the initial position and angle of inclination of geotextiles layer in the compaction mould so that after compaction of soil geotextiles layer acquire desirable position and inclination. In trial- error process, the geotextiles were placed at arbitrary height from the base and arbitrary angle with horizontal, and these height values and inclination values were noted down in an observation sheet. The soil sample was compacted in layers using an automatic tamping rod. This automatic tampering rod have an advantage over manual tampering that it transfer same compaction energy in each blow. After compaction process completed, soil sample was detached from mould and final positions (height from base) and angle were again noted down. This procedure was repeated until geotextile sheets get a desirable position and inclination at the end of compaction test. A series of trial tests were performed to get the desirable position. After every trial location and inclination have been checked. After determination of position and inclination of geotextiles a series of compaction tests were performed on same soil with and without reinforcement. The relationship between moisture content and the dry density of unreinforced and reinforced soil specimens were developed using a method described in IS: 2720, Part VIII: 1985 [22].

RESULTS AND DISCUSSION

Optimum moisture content and maximum dry density relations graphs were prepared based on the result of compaction test. Horizontal and inclined geotextiles were incorporated in soil sample. For a constant amount of applied compaction energy, there are change in the density and water content of reinforced soil and virgin soil. Horizontal reinforcement, either woven or non-woven causes a reduction in the optimum moisture content and maximum dry density of soil.

In case of inclined geotextile, the maximum dry density increases with incorporation of woven and non-woven geotextile as well. Incorporation of non-woven type geotextiles have a moderate effect on density and optimum moisture content of soil. Change in OMC are varied between 15%-25% and 4%-8% for nonwoven and woven geotextile, respectively. Changes in maximum dry density and OMC are shown in Table 3. Figure 4 and figure 5 show the effect of woven and nonwoven geotextiles on compaction parameters, respectively. Change in optimum moisture content is more as compared to dry density of soil. For normal cases, effect of reinforcement on dry density can be neglected.

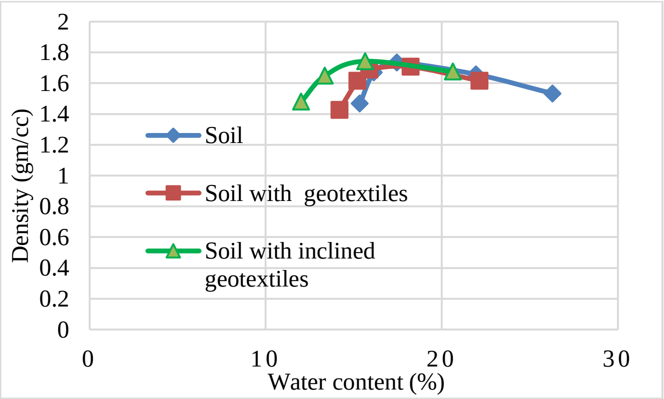


Figure 4: Effect of woven reinforcement in the compaction parameters

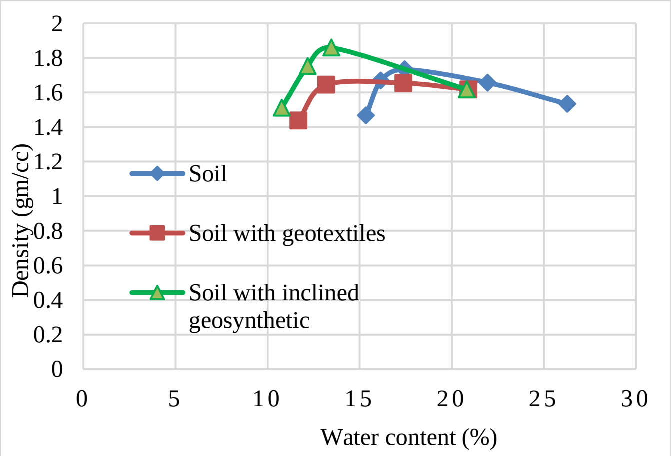


Figure 5: Effect of non-woven reinforcement in the compaction parameters

Table 4: Change in the soil density

Type of geotextiles	Inclination with the horizontal	Maximum dry density	Change in γ_{max} (%)
Soil only		1.7433	-
Woven	0^0	1.700	-2.48%
Woven	30^0	1.7633	1.15%
Non-woven	0^0	1.655	-5.06%
Non-woven	30^0	1.879	7.80%

Table 5: Change in the OMC of soil

Type of geotextiles	Inclination with the horizontal	OMC	Change in OMC (%)
Soil only		17.46	-
Woven	0^0	17.95	2.86%
Woven	30^0	16.13	-7.60%
Non-woven	0^0	14.52	-16.83%
Non-woven	30^0	13.46	-22.85%

CONCLUSION

Compaction tests were conducted with and without incorporation of woven and non-woven geotextiles. Horizontal and inclined geosynthetic were used in compaction testing. Horizontal reinforcement, either woven or non-woven causes a reduction in the optimum moisture content and maximum dry density of soil. Horizontal geotextiles cause a reduction in the maximum dry and optimum moisture content of reinforced soil whereas inclined reinforcement causes the reduction in optimum moisture content and increase in maximum dry density of soil. Compaction parameters are more affected by non-woven geotextiles as compared to woven geotextiles.

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