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Effect of plasticity index and reinforcement on the CBR value of soft clay

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ABSTRACT: In recent years, soil reinforcement is considered of great importance in many different civil projects. One of the most significant applications of soil reinforcement is in road construction. Sub grade soil and its properties are very important in the design of road pavement structure. Its main function is to give adequate support to the pavement from beneath. Therefore, it should have a sufficient load carrying capacity. One of the most appropriate methods for increasing this parameter of the soil is to reinforce it by means of geogrid which is one kind of geosynthetic materials.Geogrid reinforcement of sub grade soil is achieved through the increase of frictional interaction between the soil and the reinforcement. Further, if the weak sub grade is stabilized and reinforced, the crust thickness required will be less that would be more cost saving. Thus, in this paper the effects of plasticity index and also reinforcing soft clay on CBR values are studied. Three samples of clay with different PI values are selected and tested without reinforcement. Then by placing one and two layer of geogrid at certain depth within sample height, standard CBR tests with ASTN D1883 method are carried out. The result of these tests shows that increase in PI of the clay will decrease the CBR value and reinforcing clay with geogrid will increase the CBR value.

1 INTRODUCTION

Concrete or asphalt pavement can not be constructed on weak soil, because in this case the pavement will be easily cracked. As sub grade soil function is to transfer applied loads from pavement to the layer beneath, it should have a sufficient load carrying capacity. One of the methods for improving the weak sub grade soil strength and stability is to reinforce it with geogrid.

In general, geogrids are sheets made of polymer material whose main characteristic is its invulnerability against corrosive elements in soil. Hence, from this point of view, geogrids have many different applications in geotechnical engineering and improving soil properties.

The presence of high friction not only prevents the sliding between soil and the reinforcement element, but also helps the process of transferring stress from soil into the reinforcement element. Lack of integrity of geogrid in different levels causes some types of interlocking with soil particles. In addition, it's the little stiffness of geogrids that makes it possible to refer the increase in strength properties of soil to tensile strain created in geogrids. Using reinforcements in sub grades can increase safety coefficient of embankment stability and also decrease displacements. Furthermore, if the weak sub grade is stabilized or reinforced, the crust thickness required will be less, which results in less repairs and overall economy.

As it is known, in road construction, one of the most significant parameters for designing road sub grades is CBR value. In some projects, because of soft clay soils, CBR value is low, thus different methods such as reinforcing with geogrids are used to improve soil behavioral characteristics. The purpose of this research is to study and measure the effects of PI and also reinforcing soft clay on CBR values.

2 LITERATURE SURVEY

Rao et. al. (1989), Shetty (1989), Rao and Raju(1990), Gopal Ranjan and Charan(1998) presented the results of series of laboratory CBR tests (soaked and unsoaked) on silty sand (SM) reinforced with randomly distributed polypropylene fibers. The test result showed that CBR value of the soil increase significantly with increase in fiber content. The increase in CBR was observed to be 175% and 125% under soaked and unsoaked conditions, respectively with addition of 3% fibers (by weight).

Cancelli et. al. (1996) Montanelli et. al.(1997), Perkins and Ismeik (1997) analyzed the results of a full scale pavement test conducted on several reinforced sections by use of geogrids with saturated silty clay soil having the in-situ CBR value of about 1% to 8%. The test result showed that multi layer geogrids provide the best base reinforcement results for sub base soil having

CBRs equal to 3% or lower. No major differences were found between different single layer integral geogrids. The higher tensile modulus geogrids have shown better contribution at CBRs 3% or lower. The percent reduction of rutting, between reinforced and unreinforced sections, increases with reducing the sub grade CBR, for all geosynthetics. The Traffic Improvement Factor for road service life increases for deep allowed ruts, lower CBR values and lower pavement structural number.

Gosavi, et. al.(2004), Mittal and Shukla (2001) investigated the strength behavior of locally available black cotton soil reinforced with randomly mixed geogrid woven fabric and fiberglass. CBR value of black cotton soil is 4.9% without geogrid. Soaked California Bearing Ratio test results show considerable increase in the CBR value for black cotton soil when reinforced. CBR value of black cotton soil increases 42% to 55% when 1% woven fabrics and fiberglass, respectively are added randomly. The rate of increase in CBR value with 2% addition of fibers is less and the absolute value of CBR still decrease with more addition of fibers. Increase in % CBR is more for higher aspect ratio of fibers. This may be because of higher tensile strength of the woven fabrics. For addition of 3% woven fabrics the rate of increase in CBR value decreases. Increase in the CBR value is due to the compaction characteristics of the fiber reinforced soil. Higher compaction in their study achieved by addition of fiber with higher aspect ratio up to certain limit. It was concluded that for flexible pavement design, higher value of CBR (percentage) for sub grade soil gives lesser pavement thickness and which proves to be economical solution in the pavement construction.

3 TESTED MATERIAL

Geogrid used as reinforcement was cut in to circular pieces with the same diameter of CBR mould (15.2 cm). It was used as an artificial reinforcement. Properties of the reinforcement are given in Table 1.

Soft clay soil was collected locally from Khatoon Abad (located in Semnan road) and was used for experimental work. Bentonite was used as a material for changing PI of the clay soil samples. Properties of the soil with different percentage of bentonite are given in Table 2.

Table 1. Properties of the reinforcing material (geogrid).

Name	Material	Std.weight g/m2	Mesh Aperture, mm	Mesh Thickness, mm
GS 50	LDPE	300	2	1

4 EXPERIMENTAL WORK

7 kegs of unsoaked soft clay soil (CL) passed through No.40 sieve are mixed with optimum water content of 11.4% (by weight) which is obtained from modified compaction test. The mixture achieved is then hammered in 5 layers within CBR mould and become ready for performing unsoaked CBR test. However, for soaked CBR test, the mould should be placed under water, until it is completely saturated. In the next stage the soil is reinforced at layer 2, in the way that geogrid is put between layer 2 and 3 (from the top). The soaked and unsoaked CBR test is carried out. CBR test is also performed in 2 layers, that in this case geogrid is put at the first and the third layer. Thus, soaked and unsoaked CBR of soil is achieved. By performing activities explained above, required information related to the CBR of soil with PI 16 without any geogrid, with 1 layer of geogrid and 2 layers of geogrid under soaked and unsoaked condition is achieved.

For preparing the next sample, soil is mixed with 10% (by weight) of bentonite, in the way that it becomes 7kgs totally. PI of soil is 16. Optimum water content of 12.2% is added to the soil and is completely blended until the mixture obtained becomes homogeneous and then compacted in CBR mould. CBR test is carried out under soaked and unsoaked and also reinforced and unreinforced condition.

The last sample is prepared by mixing soil with 20% (by weight) of bentonite with total weight of 7 kgs. The soil PI is 23 and 13.9% of optimum water content is added to it. CBR test is carried out under both soaked and unsoaked condition. In addition, the soil CBR is obtained by putting geogrid at layer 2 and also at layer 1 and 3.

5 RESULTS OF TESTS

The results of performing soaked and unsoaked CBR tests and reinforced and unreinforced situation for various PIs are shown in Table 3 and also Figures 1 to 6.

Table 2. Properties of soft clay soil and soils tested.

Soil Type	Color	Maximum Dry density (MDD) KN/m3	Gs	LL %	PL %	PI %
CL	Brown	19.4	2.62	25.5	15.5	10
CL + 10% Bentonite	Light Brown	18.8	2.60	34.9	18.9	16
CL + 20% Bentonite	Gray	18.2	2.57	46	23	23

From Figure 1, it is observed that in unsoaked CBR test with increase in PI, the CBR value decrease, because when soil PI become more, OMC (optimum moisture content) of soil rises and so the water content increases and water particles replace the soil particles and cause the soil to be more ductile. Thus the soil strength decreases and its CBR value declines.

With comparison between soaked and unsoaked CBR test, it is inferred that in saturated condition, the CBR value is remarkably lower compared with unsoaked state. For example, for PI 10, soaked CBR 92% decreases than unsoaked CBR. This trend continues for the rest of PIs. However, soaked CBR decreases with increase in PI. This is shown in Figure 2.

Figure 3 and 4 shows respectively reinforced soil at layer 2 and at layers 1 and 3 in both states soaked and unsoaked condition. As it is expected, in both figures a clear difference is between soaked and unsoaked CBR. For example, for PI of 16 soaked CBR as compared with unsoaked one decreases by 97.6% and 96.9% respectively. This is because of the effect of water in the test.

Now only unsoaked CBR value in different reinforced condition is considered. As it is observed in Figure 5, CBR value for PI = 10 is 55.3 that in case of adding geogrid in the second layer it increased by 39.42%. If geogrid is placed in layer 1 and 3 CBR value becomes 23.69%. Similarly, for plasticity indexes of 16 and 23, CBR value without geogrid is 50.6 and 44.6 which in case of being reinforced in layer 2, it increased by 39.92% and 38.79% respectively. If geogrid is placed in layer 1 and 3, CBR value increases by 29.45% and 40.58% in comparison with the initial state. By putting geogrid at layer 1 and 3 CBR values grow considerably as compared with the state of putting no geogrid. However this growth in comparison with putting geogrid at layer 2 is less, because of by placing geogrid at layer 2 more braced forces is produced in geogrid and interlocking between soil

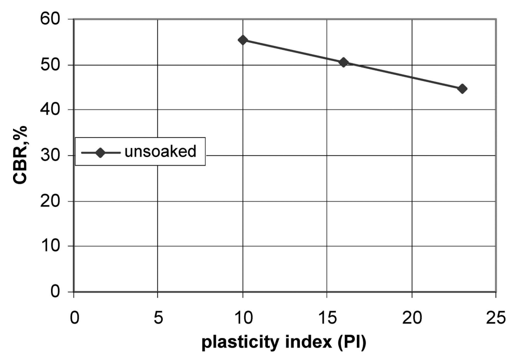

Figure 1. Dipicts unsoaked CBR for various PIs.

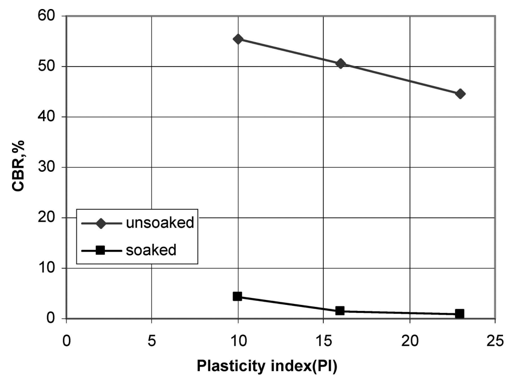

Figure 2. Compare soaked and unsoaked tests without geogrid.

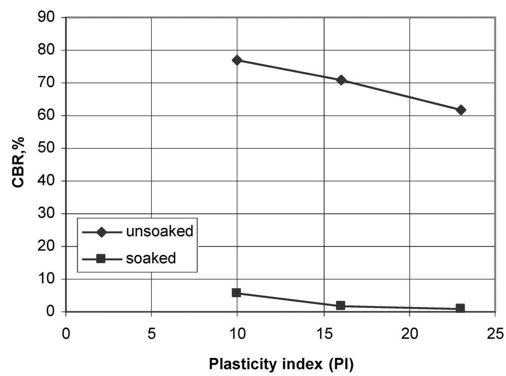

Figure 3. Compare soaked and unsoaked tests with geogrid in layer 2.

Table 3. Summery of the results of the CBR tests performed.

PI	Gs	Maximum Dry density (MDD) KN/m3	Optimum Moisture content (OMC), %	CBR, % (unsoaked)			CBR, % (soaked)		
				No Geogrid	Geogrid in layer 2	Geogrid in layer 1 & 3	No Geogrid	Geogrid in layer 2	Geogrid in layer 1 & 3
10	2.62	19.4	11.4	55.3	77.1	68.4	4.4	5.61	6.00
16	2.60	18.8	12.2	50.6	70.8	65.5	1.5	1.73	2.03
23	2.57	18.2	13.9	44.6	61.9	62.7	0.9	0.92	1.20

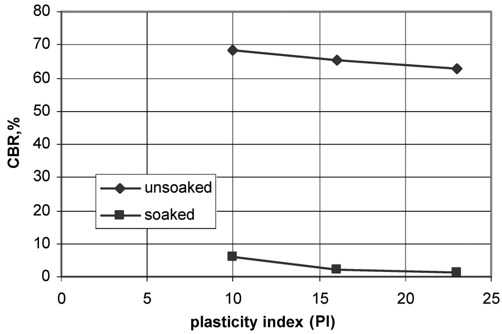

Figure 4. Compare soaked and unsoaked tests with geogrid in layers 1,3.

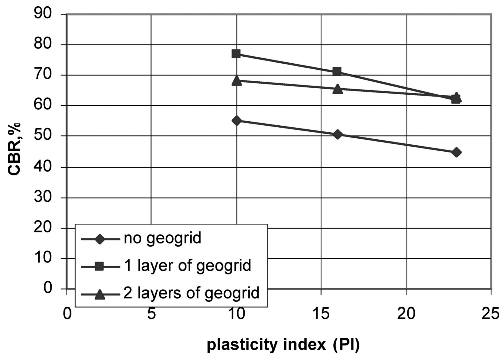

Figure 5. Compare (1), (2) and no layers of geogrid in unsoaked tests.

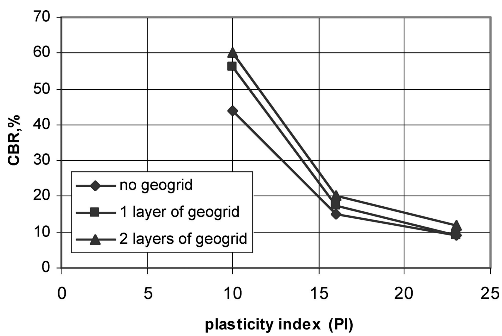

Figure 6. Compare (1), (2) and no layers of geogrid in soaked tests.

and geogrid increases. Thus placing geogrid is more appropriate. See Figure 5.

In Figure 6 only soaked CBR is depicted with different types of reinforcement. It is interesting that with reinforcing at layer 1 and 3 the maximum CBR for various PIs is obtained. This result is opposite to what we had in former test (in which CBR was more at layer 2). It can be inferred that in saturated state because of accumulation of more water in soil the effect of geogrid at layers nearer to the soil layer of themselves are great. As shear strength and braced force of geogrid with soil decreases, only tensile strength is determining that this strength in upper levels is more effective.

6 OMC AND MDD

From Table 3 it is observed that the OMC (Optimum Moisture Content) and MDD (Maximum Dry Density) of clay soil with PI 10 are 11.4% and 19.4 respectively. With increase of the soil plasticity index to number 16, OMC increased by 7% and MDD decreased by 3 %. In the same way, with increase of the soil plasticity index to 23 again OMC increased by 22%.and MDD decreased by 6% compared with the primary state.

It is found that the rate of increase in OMC and decrease in MDD rises by increase in the soil PI. The reason might be that with increase in PI (by adding bentonite to clay soil) the number of fine particles in the mixture become more in comparison with the primary state and require more water to reach to OMC state that this causes increase in soil MDD, because water replace the soil particles.

7 CONCLUSIONS

In this study we had three types of soil with various PIs of 10, 16 and 23 that it is achieved by adding different percents of bentonite to clay soil. The samples were initially tested without geogrid in soaked and unsoaked conditions. Then by placing a single layer of geogrid at the second layer of the sample CBR tests were performed on the reinforced soil. Consequently, geogrid was placed at the first and the third layer and CBR tests were repeated. The results obtained from tests done above are as follows:

1. With increase of PI in all kinds of reinforcements the CBR value of soaked and unsoaked decreases due to the presentation of water through the soil and reduction of its strength. It is obvious that when soil becomes more plastic the penetration piston requires less pressure.
2. From Figure 2, 3 and 4 it is observed that soaked CBR values are lower than unsoaked CBR values. It can be explained that in soaked situation because of more water content soil particles slides easily as water causes less interlock of soil particles with each other. The less the interlocking of the soil (more ductility), the less would be the CBR value such as Figure 2.
3. Using single layer of geogrid at layer 2 causes a considerable increase in CBR value compared with unreinforced soil in both soaked and unsoaked conditions.

4. Using two layers of geogrid at layer 1 and 3 causes an increase in unsoaked CBR value compared with unreinforced soil but this increase is less than the case in which geogrid is placed at layer 2. However the soaked CBR value is more than both single and no layer of geogrid.

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