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A Review: Effect of Geo-grid reinforcement on soil

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Abstract

Road pavements are vulnerable (weak) to soil performance because the foundation of the pavement is a road's most important element. And if the sub grade layer of pavement consists of expansive soil (black cotton soil), due to changes in moisture content and subsequent shrinkage and swelling, it undergoes failure. Thus, for the construction on such type of soil it is required to improve the engineering properties of soil or to replace the soil itself. Replacing the existing soil might not be a practical and feasible option, thus it is required to stabilize the soil with suitable stabilizer. However the selection of stabilizer depends upon the type of sub-grade soil, type of soil improvement desired, availability of stabilizer, the required strength and durability of stabilized layer, various stabilizing techniques, environmental conditions and the most important cost factor. This paper reviews the work of various researchers on stabilization of soil and use of geo-synthetic materials in improving its strength.

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Index Terms— Expansive soil, Stabilization, CBR, geo-synthetic reinforcement, Strength of soil.

INTRODUCTION

In India large area is occupied by black cotton Soil, which absorbs water, swells, becomes soft and loses strength. This type of soil is easily compressible when wet; when dry, it shrinks in volume and develops cracks. These properties of soil make the soil poorer for construction work. Techniques are being used worldwide for stabilization of such weak soil using various admixtures. Extensive laboratory / field tests have been carried out by various researchers and have shown promising results for application of such expansive soil after stabilization with additives such as sand, silt, lime, fly ash, cement kiln dust, slate dust, rice husk ash, geo-synthetics etc.

On many construction sites, good quality materials and additives are unavailable or they are in shortage. Because of this reason, engineers are often forced to search alternative designs using substandard materials, commercial construction aids, and innovative design practices. One category of commercial construction aids is geo-synthetics, which is a man made material made from various types of polymers and used to enhance geotechnical properties of soil. Various types of geo-synthetics are: geo-textiles, geo-grid, geo-nets, geo-foam, geo-membranes, geo-composites etc. The polymeric nature of the products makes them suitable for use in the soil where high levels of durability are required. Geo-synthetics perform five major functions such as separation, reinforcement, filtration, drainage, and moisture barrier. One category of geo-synthetics in particular is geo-grids, which is used for improving the engineering properties of soil.

Geo-grid:

Geo-grids represent a small but rapidly growing segment of the geo-synthetics area. Rather than being a woven, nonwoven or knit textile (or textile-like) fabric, geo-grids are plastics formed into a very open, grid like configuration, i.e., they have apertures greater than 1/4" to allow interlocking with surrounding soil, rock, earth and other surrounding materials. Often they are stretched in one or two directions for improved physical properties. By themselves, there is a list of application areas like under parking lots, airport runways, gravel construction roads, highways, earth retaining wall construction, Steepened Slopes, dam and railroad tracks etc. It functions in two ways: reinforcement and separation which are the techniques of improving poor soil with geo-grid, to increase the stiffness and load carrying capacity of the soil through frictional interaction between the soil and geo-grid material.

Soil Reinforcement:

To give reinforcement to the soil there are three methods. First is by physical method which is done by vibration, thermo-electrical, freeze and thaw. Second is by mechanical method using fibrous materials from Geo-synthetic family (Geo-grid, Geo-textile, Geo-composite, Geo-net, Geo-cell). The third is by chemical method using conventional materials, enzymes & polymeric resins. Reinforcing soil is a very old and effective technique.

REVIEW OF LITERATURE

Roads constructed on poor sub-grade soil requires a larger thickness of pavement which can be reduced by inclusion of Geo-grid. Which increases the bearing capacity of the sub-grade, reduce the differential settlement of the pavement, increases the life of the pavement and also reduces the cost due to saving incurred in the reduction of the special fill material. Geo-grid can be placed in one or more layers in subgrade soil. Geo-grid reinforcement can be used to prevent or reduce rutting caused by the bearing capacity failure of the base or sub-grade and by the lateral movement of base course or sub-grade material.

S. A. Naeini & R. Ziaie Moayed[2] in their study prepared three types of soil sample with different percentage of bentonite on which California Bearing Ratio tests were carried with or without geo-grid reinforcement in one or multilayered. The result shows that increase in the plasticity index decreases the California Bearing Ratio value in both soaked and un-soaked condition. California Bearing Ratio can be considerably increased by using geo-grid reinforcement in two layers when compared with unreinforced, but less value when compared with single layered reinforcement.

By placing geo-grid at layer 2 there is a considerable increase in California Bearing Ratio value compared with unreinforced soil in both soaked and un-soaked conditions. By using two layers of geo-grid at layer 1 and 3, un-soaked California Bearing Ratio value increases compared with unreinforced soil. However, this increment is much less when compared to the case when Geo-grid is placed on layer 2. Further, the soaked California Bearing Ratio value is higher than the value obtained for both single and no layer of geo-grid.

It is noteworthy to understand that the author had discussed the effect of PI along with geo-grid which do affect the California Bearing Ratio. Perhaps this could be the reason for getting different results for soaked and un-soaked sample under the same condition of Geo-grid; and the soaked condition is prevailing in the field. So, there needs to confirm the result through more experimentations.

Hossein Moayedi et.al [3] provides geo-grid reinforcement into paved road to improve the performance of the transportation. He in his experimental work provides Geo-grid reinforcement at three different positions (i.e. at a distance of 0.5m, 0.25m and at 0.05 from the bottom of the model. He found that maximum shear stress and normal stress increases when the geo-grid is placed at a distance of 0.5m from the bottom. He also observed that the vertical deflection under the centre of the load reduces with the use of geo-grid just under the asphalt layer and hence concluded that the effectiveness of geo-grid is more pronounced when it is placed at the bottom of the asphalt concrete improved if an effective bending is maintained between the asphalt concrete and geo-grid.

The author had used FEM model for AC pavement and did not show any analytical correlation for the obtained results. The Author has not validated results by testing it on sub-grade soil nor it has been experimentally verified using tests like California Bearing Ratio.

J.G. Zornberg et.al [4] shared his field experience on pavement over expansive soil in Milam country, Texas. Extensive network of longitudinal cracks was observed on the pavement section. Use of reinforcement was considered using a layer of geo-grid at the interface between the base and sub-grade along with lime treated sub-grade and asphalt seal coat on the top. Two geo-grid reinforcement sections were constructed in addition with a controlled (unreinforced) section to evaluate the effect of geo-grid. While falling weight deflectometer (FWD) testing was conducted to try to quantify the pavement performance. Visual inspection of the pavement results that the control section was found to develop longitudinal cracks with in very short period where as the two geo-grid reinforced section were found to perform well, without any evidence of longitudinal cracking.

Dr. D.S.V. Prasad et.al[5] prepared a model of flexible pavement consisting of expansive soil sub-grade of 0.5m at bottom compacted in 10 layers and gravel sub-base laid in two layers, each of 0.07m compacted thickness using a layer of different reinforcing material like Geo-grid, bitumen coated chicken mesh, bitumen coated bamboo mesh for reinforcement with waste plastic and waste tire rubber was mixed uniformly throughout. The sub-base material on which two layers of WBM-II each of 0.075m compacted thickness was laid. To find the best alternative reinforcement in flexible pavement, the cyclic plate load test was carried out. It was found that the total and elastic deformation values of the flexible pavement system are decreased by the provision of providing different reinforcing material. The maximum load carrying capacity followed by less value of rebound deflection obtained for geo-grid reinforcement is more than any other reinforcement provided.
The work of the author essentially is about the usage of geo-grid along with other reinforcing elements like chicken mesh, bamboo mesh and waste plastic. The results, thus obtained are not giving a clear picture about which reinforcing elements contributed towards the improvement in strength of the sub-base.

Omid Azadegan and Gh. R. Pourebrahim [6] studied the effect of geo-grids on compressive strength and Elastic Modulus of Lime/ Cement treated soil in order to find out the effect of geo-grid applications, on the geotechnical behavior of lime /cement treated soil used as base, sub-base or structural foundation materials. Study has been performed on compressive treated soil sample with or without geo-grid layers and found that when there is an increment in modulus of elasticity and the cohesion, produced by pozzolanic reaction of lime and cement, side deformation of the cylinder decreases and therefore the tension produced in reinforcement and the confinement

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forces would decrease too. To have appropriate interaction the mix design should comprise enough ductility and side deformation for which, L/C ratio should be greater must be selected and total amount of applied cement must be lower than 5 percent. The author has used Unconfined Compression Test using cylindrical sample and observed that the deformation prior to the reinforcement of the geo-grid and did not correlate with California Bearing Ratio. The author has quantified the deformation using equation 1 & 2.

$$v = \frac{Lateral\ Strain}{Axial\ Strain} \quad \text{Eq. (1)}$$

$$v = -\frac{\varepsilon_{2,3}}{\frac{\sigma}{E}} \quad \text{Eq. (2)}$$

where,

$\varepsilon_{2,3}$ is the strain on sides,

σ is the compressive stress in kgf/cm^2,

E is the modulus of elasticity in kgf/cm^2, and

v is Poison ratio.

Moreover the author fails to mention about specific mix design of pavement which is the governing factor for the interaction between used of geo-grid and stabilized soil.

The author has studied the effect of geo-textile on already treated and stabilized soil with lime/cement. The author has used Unconfined Compression Test and correlated the results with California Bearing Ratio. Moreover, the author has failed to mention about the specific mix design of pavement which is the governing factor for the interaction between the Geo-grid and stabilized soil.

Sarika Dhule et.al [7] in her experimental work tries to modify the properties of weak sub-grade soil and soft murrum by addition of geo-grid in different percentage i. e. 1%, 2%, 2.5% and 3% separately and found that the California Bearing Ratio value increases with addition of geo-grid. Again with addition of this work she also found the effect on California Bearing Ratio value of murrum with 2% cement and different percentage of geo-grid. The California Bearing Ratio value found by addition of 2.5% geo-grid is more. The author used compacted soil for further California Bearing Ratio tests. The author also mentioned that the shear strength and low permeability are the affecting properties on compaction characteristics. Therefore, the results are dependent on compaction of the soil under consideration.

A.K. Choudhary et.al [8] placed multiple layers of reinforcement namely geo-grid and jute geo-textile within the sub-grade. He found that the expansion ratio decreases when the soil is reinforced with single layer and goes on decreasing with an increase in number of reinforcing layer, but this decrease is significant in case of jute Geo-textile and marginal in the case of Geo-grid which means the insertion of reinforcement controls swelling of the soil. The California Bearing Ratio value of the soil also increases with increase in number of reinforcing layers. It is found that geo-grid offer better reinforcing efficiency than jute geo-textile but it can be gainfully exploited in low cost road project.

Pradeep Singh and K.S. Gill [9] carried out experimental work to determine the optimum position of providing geo-grid reinforcement in sub-grade soil by conducting California Bearing Ratio test and unconfined compressive test . He found that by providing geo-grid reinforcement at 0.2H from top give considerable improvement in California Bearing Ratio value and stress strain behavior of sub-grade soil.

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Dr. P Senthil kumar & R. Rajkumar [10] studied the effect of introducing geo-textile layer between sub-grade soil and base course layer and found that the resistance to penetration increases with the introduction of geo-textile layer. He used the equation given by (Koerner, 2005) for calculating the reinforcement ratio i.e. load with geo-textile to load without geo-textile and found that the reinforcement ratio is more than one throughout the test. Hence concluded that the use of geo-textile is most advantages in road with soft sub-grade at higher penetration. The author used the term Reinforcement Ratio suggested by Koerner (2005).

$$Reinforcement\ Ratio = \frac{Load\ with\ Geo-Textile}{Load\ without\ Geo-Textile}$$
Eq. (3)

But the author had performed the test essentially on soil of class CH having a Maximum Dry Density of 1.562 moreover, he has mentioned the woven and non-woven Geo-textile but he has not mentioned the percentage of Geo-textile reinforcement neither its aperture size and its thickness. Hence the results were not validated.

Evangelin Ramani Sujatha et.al [11] provide geo-grid reinforcement to improve the strength of weak soil The author conducted California Bearing Ratio tests on soil with geo-grid introduced at different depths within the sample, in single, double and triple layer and found that the best performance in the single layer occurs when geo-grid is placed at 2/3 distance from the base. And found that the California Bearing Ratio value of 3 layers of Geo-grid is lesser than 2 layers, but higher than single layer and hence concluded that Geo-grid increases the strength of the sub-grade soil in both soaked and un-soaked condition and proved that Geo-grid reinforcement provided in a single or multilayer to the sub-grade increases the strength of the soil and thus reduces the thickness of the pavement.

Mihai Iliescu and Ioan Ratiu [12] devised a new design methodology for stabilizing road sub-grade using geo-grid reinforcement. In their experiments, they found out that geo-grids can improve the performance of the Sub-grade soil. They carried out extensive static and dynamic plate bearing tests on different conditions based on the results of trial and the membrane theory of Giroud & Noiray, they developed design graphs for multifunctional geo-grids in unpaved and temporary road.

Rakesh Kumar and P.K.Jain [13] in their study of ground improvement techniques found that the construction of granular piles in expansive soil improves the load carrying capacity of the soil. They further made an attempt to investigate the improvement of load carrying of granular pile with and without geo-grid encasement through Laboratory model tests and found that the load carrying capacity of granular pile increases by casing the pile with geo-grid.

Prof Mayura Yeole and Dr. J.R. Patil [14] carried out a laboratory California Bearing Ratio test on granular soil with or without geo-textile which was placed in one or two layer in the mould. The single layer of geo-textile was placed at the depth of (25, 50, 100mm) from the top of the mould , the maximum California Bearing Ratio obtained was at 25mm and when the geo-textile was placed in two layers at { (25 &75 mm),(50 &75 mm), (50 &100 mm)} California Bearing Ratio was increased and it was maximum at 25 & 75mm geo-textile layer by 38.21% when compared with the California Bearing Ratio of no geo-textile.

By extending the available literature and techniques the author(s) have done work on stabilization of soil having poor in-situ engineering properties for further application of geo-synthetic materials to improving the strength [1].

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Table No. 1 Properties of material used by the researchers (Sarika Dhule et.al, A. K. Choudhary et.al, S.A. Naeini et.al, Pradeep Singh et.al)

Soil Sample	Sarika Dhule et.al	A K Choudhary et.al	S A Naeini et. al	Pradeep Singh et.al
Specific Gravity	2.32	2.72	2.62	2.6
Liquid limit Percent	71.13	59	25.5	28
Plastic limit percent	27.9	34	15.5	15
Plasticity Index	NA	35	10	13
Free swelling Index	NA	62.5	NA	NA
Optimum moisture content %	25	18.2	11.4	16
Maximum Dry Density gm/cc	1.4	17.1	19.4	1.7
Soaked California Bearing Ratio	2.06	NA	4.4	2.9

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Geo-grid				
Classification	KGR 60	NA	GS-50	Grid
Material composition	PET	Poly-propylene	LDPE	NA
Mesh aperture size (mm)	20/20	1.47	2	22/22
Thickness (mm)	NA	0.27	1	NA
Tensile strength (Breaking) kN/m	60/30	4	0.91	5.2 to 5.8

CONCLUSION

Although the research that has been performed on geo-grid reinforced soil gives wide variety of results on several issues from which the following qualitative conclusions can be drawn:

- A geo-grid reinforced soil is stronger and stiffer and gives more strength than the equivalent soil without geo-grid reinforcement.
- Geo-grids provide improved aggregate interlock in stabilizing road infrastructure through sub-grade restraint and base reinforcement applications.

- Geo-grid reinforcement provided between the base course and sub-grade soil carries the shear stress induced by vehicular loads.
- Geo-grid reinforcement in a pavement system ensures a long lasting pavement structure by reducing excessive deformation and cracking.
- Maintaining the same thickness of pavement, the designed life can be increased substantially with the inclusion of geo-grid layer.
- The geo-grid reinforcement of base course layer results in reducing the lateral strains within the base course and sub-grade layers.
- With increasing number of geo-grid reinforcement layers there is an increase in the bearing capacity ratio value up to the depth 0f 1.5B thereafter it cannot significantly increase the bearing capacity.
- The introduction of geo-grid reinforcement in soil leads to decrease surface penetration and deformation and improves the stress distribution on the soil sample.
- The development of longitudinal cracks in pavement section is precluded when reinforced with geo-grid.
- Geo-grid reinforcement provided in a single or multilayer to the sub-grade increases the strength of the soil and thus reduces the thickness of the pavement.
- Geo-grid reinforcement improves the service life of pavement with reduced structural section.

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