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Review of CBR Value Enhancement Using Geosynthetics

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Abstract- Subgrade is the foundation layer which provide strength and stability to the structures above it. Subgrade soil often exhibits variability in strength, moisture susceptibility and compressibility, leading to potential failure like rutting and settlement. Various improvement techniques like chemical stabilization, mechanical stabilization and geosynthetics are used to enhance the strength and durability of the subgrade soil. This article summarizes the research on the use of geosynthetics for the stabilization of subgrade soil. Geosynthetics act as a reinforcement and increases the load bearing capacity of the soil. It acts as an environment friendly, cost effective and sustainable solution for soil stabilization. An attempt is made herein to compare the effect of geosynthetic reinforced soil in terms of California Bearing Ratio (CBR) value, an key parameter in the design of pavement.
Keywords: Geosynthetics, Geogrids, Geotextile, CBR, Pavement thickness, Soil Stabilization

1. INTRODUCTION

Pavement provide access to safe, easy, and economical path for mobilization. There is a vast development in roads from Roman era to Macadam era which makes pavement construction economical and durable with time. Road performance largely depends on subgrade soil type and properties. Poor subgrade soil affects the pavement strength and require maintenance frequently. Soil stabilization increases the load carrying capacity of soil (q). With modernization in transport engineering, geosynthetics are widely used as a versatile solution in revolutionizing traditional practices. Geosynthetics are used for improve the weak and unsuitable soil subgrade. It acts as reinforcing layer which increases the value q. Geosynthetics are available in different shapes and forms which are listed in Fig. 1. Amongst them the most used in pavement construction include geotextile and geogrids as shown in Fig. 2.

2. LITERATURE REVIEW

Mir et al. [1] studied the effect of uniaxial and biaxial geogrids with ultimate tensile strength of 40 kN/m and 60 kN/m, respectively. Four different types of geogrids were tested in both single- and

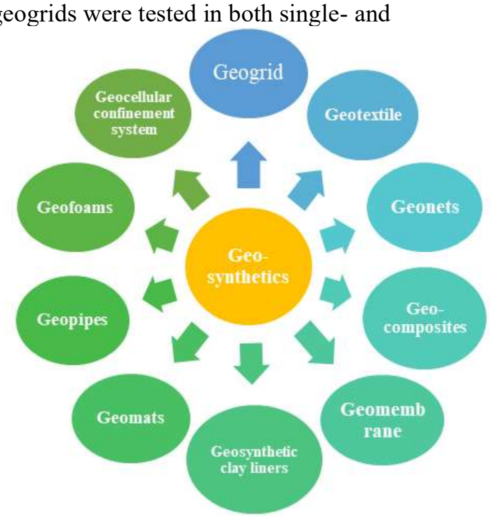

Figure 1: Different forms of Geosynthetics

Figure 2: Geogrid

double-layer configurations to evaluate the unsoaked CBR (US-CBR) and soaked CBR (S-CBR) of three different clay-containing soils in different proportions. The reinforcement layers were placed at various depths from the top of the soil specimen, where H/4, H/2, and 3H/4 for single-layer reinforcement and H/4 and 3H/4, H/3 and 2H/3 for double-layer configurations. Results indicated that the highest CBR value were consistently achieved at H/4 for single layer, and H/3 and 2H/3 for double layer reinforcement, regardless of geogrid type. Notably, the B-60 geogrid demonstrated the best performance across all depths in both soaked and unsoaked conditions. Additionally, this research included an analysis of pavement thickness and construction costs, using empirical equation computed by Bezabih to estimate the cost of construction based on CBR value and traffic load (msa). The findings suggest that strategic placement of geogrids near the top of the subgrade can significantly enhance load-bearing capacity and pavement strength, potentially reducing construction costs by 10% to 23%.

Baadiga and Balunaini [2] studied the effective modulus of the soft subgrade was enhanced by utilizing locally sourced soil materials in combination with biaxial geogrids designated as PP30 (ultimate tensile strength of 30 kN/m) and PET100 (ultimate tensile strength of 100 kN/m). They considered the two subgrade layers, in which subgrade layer II as an existing layer having the CBR value of 2, 5 and 7 %. Similarly, Subgrade layer I having different CBR value 8, 14 and 20 %. Locally available clayey sand (SC) was used as subgrade layer II and well graded gravel (GW) mixed with soil were considered as subgrade layer I. Plate load tests were performed on both unstabilized and stabilized two-layer systems to determine the elastic modulus by plotting the bearing pressure against the settlement curve. The curve indicated that the subgrade with an initial CBR of 2%, placed over a prepared layer with a CBR of 20%, achieved the highest improvement factor when reinforced with the PET100 geogrid. Similarly, existing subgrade having CBR 7 % reduced with increase in CBR. The study found that using a high-stiffness geogrid (PET100) significantly enhanced the subgrade's effective CBR, reaching up to 12.8%, compared to 4.9% for the unstabilized section. Improved CBR value reduces the pavement layer thickness and decreases the cost of pavement construction. The study concluded that use of PP30 geogrid-stabilized subgrade layer I lead to a decrease of 48 % in the cost when compared to cement stabilized subgrade layer I.

Serin and Gonul [3] examined the bearing capacity of crushed basalt stone used as road- subbase material with combination of geogrids. The physical properties of subbase material were determined. According to test results, maximum dry density (MDD) was 2.08 g/cm^3 and optimum moisture content (OMC) was obtained as 11.3 %. Natural jute fiber geogrid, basalt geogrid and jute geogrid coated with bitumen were considered as reinforcement which were placed at 0.33H distance from the top of sample height. The experimental findings showed that adding natural fibers improved the CBR values by 39.7% and 48.5% for control samples of 2.5 mm and 5 mm, respectively. Bitumen-coated natural fiber geogrids demonstrated a 20% improvement, while basalt geogrids exhibited a 5.5% increase compared to the reference sample. Among all tested materials, natural fiber geogrids provided the most significant enhancement in ground bearing capacity and offered superior environmental sustainability, followed sequentially by bitumen-coated geogrids, basalt geogrids, and the untreated control.

Pandey et al. [4] studied the behavior of geotextile in the q value with samples reinforced at different heights. The S-CBR and US-CBR value of two soil samples with geotextile positioned at heights 0.25 H, 0.5 H and 0.75 H are compared. The findings of the research indicated that sample 1 have highest q value without geotextile in both soaked and unsoaked condition. Similarly, in sample 2 maximum q was attained at 0.25 H distance from the top in unsoaked and soaked condition. US-CBR and S-CBR increases by 14.28 % and 15.94 % respectively when compared with samples without geotextile. They concluded that geotextile is more effective when placed near the top which can distribute the stresses more evenly. The compressibility and shear strength of the fine sand increases further leading to the increase in the q value with the use of geotextile.

Lone and Sachar [5] focusses on the bearing strength of four different types of soil with geogrid and geotextile reinforcing material. Black cotton soil, marine clay, granular soil, and red laterite soil were considered. The study concluded that implementation of geogrid in black cotton soil tripled the strength of soil and can be used to build low volume roads at lower cost. Granular soil doubled the CBR value with the inclusion of geogrid. Geogrid shows better outcome than geotextile for all the soils. Geotextile can be used to treat clayey soil having lot of moisture in them as geotextile can absorb water and provide favorable outcome and improve the q value.

Cicek and Buyukakin [6] investigated the impact of various geotextile types on soil CBR values, bearing capacity ratio, pavement layer thickness, and pavement cost analysis. Granular soil sample was used along with fourteen different geotextile samples made of polypropylene and polyester to provide reinforcement. Particle size distribution of the granular soil indicated soil as well graded sand (SW). Geotextiles were divided into the groups for the analysis. First group contains Geotextile 1, 2 and 3 all made of polypropylene. Another group contains geotextile 4, 5 and 6 made of polyester. Then, geotextile 7, 8, 9, 10 and 11 as another group made of polyester and are made of recycled materials. Final group contains geotextile 12, 13 and 14 made of polypropylene with different physical and technical features when compared to first group. For the determination of CBR value different layer of reinforcement was placed at different depths for the effective number of reinforcements on model of geotextile 1. For, one layer reinforcement different placement of depths is examined at 0.75H, 0.25H, and 0.5H where H is the total model height. For, two-layer reinforcement system depths were considered at 0.25H and 0.75H. Similarly, for three-layer reinforcement system depths were considered at 0.25H, 0.5H, and 0.75H. CBR value of unreinforced sample was found to be 38.6 %. The findings of the research indicated that maximum CBR value (CBR_{max}) was attained at 0.25H in single layer geotextile model that is 88.3 % which is higher than two-layer system. Similarly, two-layer shows slightly higher results than three-layer system. It represents that introducing several reinforcement layers weakens the pavement natural structure and leads to separation of layer which decreases the bearing capacity of soil. CBR value of remaining geotextile were tested at 0.25H depth in single layer reinforcement. Macroscopic analysis was conducted to find out the best performing geotextile and stress-penetration curves were plotted for differentiation. From the first group, geotextile 1 and 2 showed similar results having CBR value as 88.3 % and 81.8 % respectively and represented the knitted method of geotextile. Then, from the second group, model having geotextile 6 showed best performance amongst others having 66.5 % CBR value. Similarly, from group third, geotextile 9 and 10 showed best performance having CBR value as 87.6 % and 66.4 % respectively and in group 4 geotextile 12 has the larger CBR value among others in the group that is 58.2 %. From all the fourteen geotextiles, Geotextile 1 and 9 performed better than others and have less thickness and tensile strength. For the cost analysis, 1 km length of the pavement is considered for sub base and base layer. It was observed that when geotextile 1 and 9 were used the pavement thickness reduced by about 2.5 times when compared to the unreinforced sample. It was interesting to note that the geotextiles with lesser thickness mixes well with the soil and CBR value increases when compared to their counterpart thick geotextiles. Among all the fourteen geotextiles considered in the study, the one having higher bearing capacity and the cost-effective was Geotextile 9. The Geotextile 9 bears larger bearing capacity leading to significant decrease in the layer thickness.

Mukherjee and Ghosh [7] examined the outcome of using rice husk ash (RHA) with lime and fly ash with geotextile on q and compared the recycled pavement thickness with conventional pavement thickness using IITPAVE software with different traffic intensities. At first, they evaluated the performance of lime (2 %, 4 %, 6 %, 8 % and 10 %) and RHA (0 %, 3 %, 6 %, 9 % and 12 %) through CBR testing at different percentage mixes which concluded that 6 % lime with 9 % RHA obtained CBR_{max} of 28.25 % under unsoaked condition whereas 6 % lime with 6 % RHA obtained 29.82 % CBR value under soaked condition. Furthermore, they evaluated the performance of fly ash composite mix with geotextile. Silty clay soil was used for investigation based on fly ash-soil matrix having thickness ratio of 1:2, 1:1 and 2:1 inclusion with geotextile. It concluded that 2:1 thickness ratio shows higher CBR value at different OMC for both light and heavy compaction test. It showed that as the thickness ratio increases CBR value increases but CBR value reduces with the increment in molding water content. CBR value having thickness ratio 2:1 decreases from 18.5 to 8.12 % as water molding capacity increases from 16 to 34 % in standard proctor test and value decreases from 23.58 to 8.25 % having water molding capacity from 12 to 36 % in modified proctor test. In this research, analysis of pavement thickness was carried out with the help of IITPAVE software where two categories (PT1 and PT2) of pavement were considered. Different iteration was performed at six different subgrade type including different traffic intensity which concluded that 80 MSA and 15 MSA achieved maximum reduction in pavement thickness in both the categories. The study concluded that fly ash – soil matrix proves to be better stabilization method in worst case scenario than lime with rice husk ash and recycled pavement proves to be more economical than conventional pavement.

Singh et al. [8] investigated the bearing strength of soil with coir geotextile (CG) in single layer and combination of two layer from top surface of soil with replacement of soil by marble dust (MD). The CBR value was assessed by embedding a single layer of CG at depths of 0.5H, 0.33H, and 0.67H measured from the top surface of the soil specimen. For the two-layer configuration, different combinations of placement depths were considered, including 0.33H and 0.5H, 0.5H and 0.67H, as well as 0.33H and 0.67H from the top surface. Silty sand soil is taken into consideration. An increase in MD content leads to a rise in the OMC and a reduction in the MDD. Result for unreinforced soil in US-CBR and S-CBR came out as 4.81 % and 2.77 % respectively. CBR_{max} was observed when a single layer of CG was positioned at a depth of 0.33H from the upper surface of the soil specimen. The US-CBR and S-CBR for 0.33H placement of CG is 9.09 % and 6.76 %

respectively. For combination of CG layer CBR_{max} was attained at depth 0.33H and 0.67H placement from the top of soil sample. The value attained as 12.79 % and 10.21 % for US-CBR and S-CBR respectively. CBR tests were also performed by replacing soil with MD with proportion of 10 to 25 % in increments of 5 %. CBR value of soil with MD increases till 20 % replacement of soil. Further replacement of soil with MD decreases the CBR value. Now CBR value was obtained with the placement of CG and replacement of soil with 20 % MD. With the combination of MD and single layer CG CBR_{max} was attained at 0.33H depth from top of soil surface which is obtained as 11.72 % and 8.34 % in US-CBR and S-CBR respectively. Maximum US-CBR and S-CBR for 20 % MD and combination of two-layer CG at 0.33H and 0.67H placement was obtained as 12.91 % and 10.44 % respectively.

Thakur et al., [9] examined the effect of CBR value on clayey soil having high plasticity with inclusion of non-woven geotextile (NW 8, 10, 21 and 30) and superior needle- punched non-woven geotextile (SNW 14, 25, 62 and 75) based on their tensile strength. The geotextiles were positioned at 0.5 H for CBR testing. CBR_{max} was obtained with the inclusion of NW 30 geotextile with the increase of 52.63 % in CBR value compared with unreinforced sample. SNW geotextile prevents intermixing of different soil layers and filters out fluids from soil particles. It concluded that among NW and SNW geotextiles NW 30 was more effective in increasing the value q.

Muhmood and Khudhur [10] explored on reducing the sub-base thickness with the help of non-woven geotextile. Recycled aggregates from a demolished building were used as sub-base layer of the road in two layers and clay soil as subgrade layer of road pavement in three layers. Five layers were made for the CBR investigation and geotextile were placed at different locations in between the layers. Different percentage of clay were mixed in waste aggregate. Type A specimen contains 5 %, 6.4 %, 7.3 % and 8.7 % clay content. Type B specimen contains 10 %, 12 %, 14.3 % and 16.6 % clay content. CBR_{max} was attained in type B aggregate with 14.3 % addition of clay without geotextile that is 156 % and 120 % in US-CBR and S-CBR respectively. Similarly, in type A maximum value was attained at 7.3 % added clay content without geotextile which was obtained as 58 % and 56.6 % in US-CBR and S-CBR respectively. The result showed that when 50 % clay and 50 % recycled aggregates were used for the investigation maximum increase in CBR value was achieved among all other variations in both type A and B aggregate.

Jayakumar et al. [11] studied the stabilization of subgrade soil using geogrid and non-woven geotextile as a reinforcing layer at top and middle of the soil layer. Clay soil was used for the investigation having MDD 1.69 g/cm^3 and OMC value as 18 %. CBR test were performed by placing geogrid at top and middle position and the grouping of geogrid and geotextile at top and middle position. CBR value was obtained on unreinforced and reinforced sample. The CBR value of unreinforced sample was 3.54 %. The value was increased by placing the geogrid at top and middle as 4.01 % and 5.56 % respectively. The CBR value of soil sample when combining geogrid and geotextile and placing at top and middle was 6.31 % and 6.90 % respectively. The research concluded that maximum q value was attained by the combined action of geogrid and NW geotextile at middle of the soil sample instead of placing the geogrid alone.

Sai et al. [12] examined the application of geogrid in black cotton soil as a reinforcing material to increase the q value. The CBR values were obtained while placing the geogrid at various depths in soaked as well as unsoaked conditions. The geogrid was placed at 0.20H, 0.40H, 0.60H and 0.80H from top surface of the specimen mould. The inclusion of geogrid increases the CBR value of black cotton soil. CBR_{max} was attained at 0.20H that is 10.48 % and 8.7 % compared with other placement and unreinforced soil in unsoaked and soaked condition respectively. The CBR value calculated as 5.9 % and 2.8 % for unreinforced soil, 9.53 % and 6.9 % for 0.40 H, 8.7 % and 5.1 % for 0.60 H and 7.5 % and 3.0 % for 0.80 H in unsoaked and soaked condition respectively where H is the height of mould.

Venkatesh and Suluguru [13] performed the CBR test to estimate the resilient modulus (MR) of optimum CBR specimen on black cotton soil. The research emphasis on geocell (vehicle tyre having aspect ratio 0.75, 1 and 1.5), geogrid (uniaxial, biaxial and triaxial) and CG as soil reinforcement in black cotton soil at different depths 0.33H, 0.5H, and 0.67H from top of CBR mould. Geocell having 1.5 aspect ratio attains the CBR_{max} at 0.33H distance from top of CBR mould which was determined as 3.941 % compared with the others. Triaxial geogrid was considered as effective in increasing the CBR value as 3.654 % rather than other type of geogrid. The MR of Geocell of aspect ratio 1.5, Triaxial geogrid and geotextile was determined as 26.91, 32.841 and 35.469 respectively. It concluded that effective height was measured at 0.33H distance from top of CBR mould irrespective of the geosynthetic used.

Negi and Singh [14] studied the effect of non-woven and woven geotextile piled up with SP-SM and CI soil types. The geotextiles were placed at different depths that is 0.167H, 0.5H and 0.833H in single, double (0.167H and 0.5H, 0.5H and 0.833H, 0.833H and 0.167H) and triple reinforcement layers. Seven cases were formed and CBR testing was performed on two different soils with two different geotextiles. The results showed increase in CBR with addition of geotextile in soil in every case but showed significant increase with clay soil. CBR_{max} was attained at combination of 0.167H and 0.5H woven geotextile in both Soil SP-SM and CI. The S-CBR and US-CBR was obtained as 27.55 % and 28.41 % respectively in SP-SM. Similarly, in CI maximum soaked CBR value was obtained as 4.87 %. The research concluded that woven geotextile showed better performance with respect to non-woven geotextile due its more tensile strength. An increase in the CBR generally raises the q value, which subsequently results in a decrease in pavement thickness and lowers the overall cost of pavement construction.

Chaitanya and Neeharika [15] made an attempt to use steel fibres as a geosynthetic reinforcing material in black cotton soil and sedu soil. With the addition of steel fibres liquid limit (LL) and plastic limit (PL) decreases with increase in the MDD of black cotton soil. The OMC of soil is decreased with addition of steel fibres. Similarly, with the addition of 0.25 % and 0.5 % of steel fibres by weight of soil the MDD is decreased but with the addition of 0.75 % and 1.0 % MDD is increased in sedu soil. Steel fibres were added to the black cotton soil in the range of 0.25 % to 1.0 % with an increment of 0.25 %. For every increment of 0.25 % in the steel fibre the CBR was found to be increase by 91.75 %, 117.5 %, 197.25 % and 117.5 % respectively. Similarly, the CBR value of sedu soil increased with the addition of steel fibres. The research concluded that with the addition of steel fibres the shear strength and q value is improved. The design thickness of flexible pavement was decreased after stabilization of soil by steel fibres by 200 mm from the original thickness and cost after stabilization decreased by 7.37 %.

Singh et al. [16] evaluated the performance of different types of geosynthetics on Silty Sand (SM). The experiment was performed by placing the geosynthetic material at single (0.5H, 0.33H, and 0.25H) and double layer (0.25H and bottom) reinforcement depths where H is the CBR sample height. Glassgrid, Tenax 3D geogrid and Tenax multimat geomat were used as geosynthetic reinforcement. The investigation showed that Tenax 3D grid performed better in case of single layer reinforcement and Tenax multimat performed better in double layer reinforcement. The maximum increase in CBR value in case of single layer reinforcement was obtained as 25.30 % at 0.33H and 22.89 % at 0.25H. In case of 0.5H depth and double layer maximum increase obtained by Tenax multimat as 58.43 % and 324.70 % respectively with respect to unreinforced sample. The optimum location of Tenax 3D grid was found to be in the range of 0.3 H to 0.36 H whereas for glass grid and Tenax multimat reinforcement layer the optimum location varied between 0.41 H and 0.62 H.

Ogundare et al. [17] examined the stabilization of lateritic (Soil A) and clay soil sample (Soil B) with the geotextile as a reinforcing layer at 0.25H and 0.75H from the top of the soil surface. The CBR values increased with the application of geotextile in both the cases in soil B but was found to be much higher in case of 0.25H from base of the soil sample. The CBR value of unreinforced soil sample A and B was 4% and 7 % respectively. CBR_{max} of samples A and B was found out to be 15 % and 21 % respectively when the soil sample was strengthened with NW geotextile introduced at a height of 0.25H from the base of the soil sample. The pavement thickness of soil sample B when unreinforced was calculated as 17.5 cm and with non-woven geotextile it was calculated as 9 cm. The result concluded that with the increase of CBR value, pavement thickness decreases thereby reducing the cost of pavement construction.

Adams et al. [18] presented an experimental investigation on lateritic soil reinforced with geogrid. Three sample of soil having different plasticity and gradation were tested with and without geogrid placement at different positions. In lateritic soil, clay was added as admixture in proportions of 0 %, 10 % and 20 % by weight to modify the plasticity and gradation. Sample S20 (having 20 % clay admixture) was most plastic while S0 (having 0 % clay admixture) was least. A biaxial geogrid was employed as reinforcement, positioned either as a single layer (at the top of Layer 1 or Layer 2) or as a double layer (at the top of Layer 2 and Layer 4) for the purpose of strength evaluation. Plasticity and Plasticity index (PI) of soil S0, S10, S20 was calculated as 25, 14 and 22 and 19, 19 and 21 respectively. The ratio of CBR value of reinforced to unreinforced sample was defined as strength ratio. The result of unsoaked and soaked sample indicated that there was a drastic loss of strength of about 50 % in soaked condition (with or without geogrid) when compared to unsoaked condition. With the placement of geogrid, CBR values increases for every placement depth. Based on test results, it indicated that as the fraction of coarse aggregate increased in the soil (having low PI), significant improvement in CBR was observed. It was observed that introducing 2-layer geogrid reinforcement has a significant effect on the strength over 1-layer geogrid reinforcement.

Kamel et al. [19] considered two types of geogrids with different stiffness. The influence of a single geogrid layer was examined under both static and cyclic loading conditions in three different soil types Soil A (SP), Soil B (CL), and Soil C (ML). CBR, Unconsolidated Undrained triaxial (UU) and unconfined compression tests were conducted to attain the desired position of geogrid placement. Soil A, Soil B, and Soil C exhibited maximum dry densities (MDD) of 1840 kg/m³, 1740 kg/m³, and 1660 kg/m³, respectively, with their optimum moisture contents (OMC) measured at 11.7%, 13%, and 19%. A single layer of geogrid was positioned at various depths, specifically at 0.2H, 0.4H, 0.6H and 0.8H measured from the top surface. The results indicated that geogrid reinforcement led to an increase in CBR values and higher deviator stress at failure. The result showed that the highest value of CBR and modulus attained at 0.8H with the placement of geogrid-1 having more stiffness than geogrid-2. This indicates that desired position of geogrid was obtained when placed at a depth of 72-76% of specimen height for the desired results. The result also indicated that with the inclusion of a geogrid as reinforcement helped to reduce the formation of rut in the range of 7-16%. This reduction in the rut formation was found to depend on the strength of the geogrid used.

3. CONCLUSION

- Geotextiles and geogrids are the primary types of geosynthetics frequently utilized in road construction. Certain types of geosynthetics also serve as sustainable solutions for enhancing the strength of subgrade soils.
- With utilization of geosynthetics as a reinforcing material, pavement thickness can be reduced significantly.
- Geogrids perform better than geotextile in road construction because of its strength and load bearing capacity.
- Geotextiles enhance the strength of soils with high moisture content by absorbing water and improving the load-bearing capacity of structures.
- The addition of geogrids generally leads to an increase in the soil's CBR value.This leads to the increase in the q value which further leads to reduction in pavement thickness and cost of pavement construction.
- The maximum increase in CBR value was reported at locations 0.5H [1, 4, 6, 8, 10, 13, 15], 0.33H [2, 7, 12] and 0.25H [3, 5, 16] from the top of soil specimen in the literatures.
- From all the above paper reviewed, it can be concluded that Geosynthetics should be placed at 0.5H, 0.33H or 0.25H depth from the top of soil specimen (as shown in Fig. 3) for significant improvement in the desired strength.

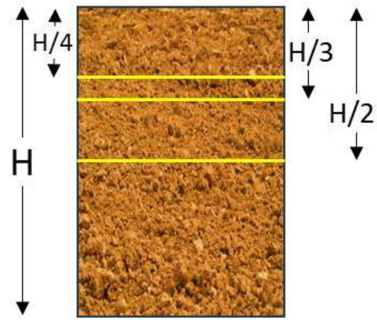

Figure 3: Effective location of Geosynthetic

4. LIMITATIONS OF THE STUDY

This literature review specifically focuses on examining how geosynthetics and their placement affect the CBR value of geosynthetic-reinforced soil.

5. FUTURE SCOPE

This study opens avenues for further research aimed at optimizing the placement of geosynthetics to improve the performance of weak soil subgrades. Future investigations can focus on enhancing the load-bearing capacity of subgrades through the strategic use of geosynthetics, ultimately contributing to extended pavement lifespan.

Additionally, the sustainable and cost-effective nature of geosynthetics offers potential for reducing pavement thickness and overall construction costs. Further studies may also explore different types of geosynthetics, soil conditions, and loading scenarios to develop more efficient and durable pavement design strategies.

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