Geoanalytical Approach of using Geotextiles in Flexible Pavement

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Abstract

Soil is enough powerful in compression and relatively weak in tension. To increase stability and reduce deformation tensile elements are inserted into the soil as part of the soil reinforcement. The primary purpose of the geotextiles, which are used as reinforcement, is to give soil tensile strength at a strain level consistent with the functionality of the soil structure. Geotextiles are employed as reinforcement in paved roads, railway tracks, earth retaining walls, mining subsidence protection, and embankments of shallow weak soils. This study describes the assessment to analyze the properties of soil, the geotextile-soil characteristics due to direct shear test. Also, to study the CBR values at 2.5 mm and 5 mm penetration in soil system without and with geotextile (woven and non-woven) layer at the interface of the two soil layers. Four types of geotextiles are used (two woven and two non-woven geotextiles). Geotextiles are placed at H/3 height from the bottom of the CBR mould. The results show an increase in the CBR values of the unreinforced soil and there is an increase of 28.12% and 44.6% in case of non-woven and woven geotextiles, respectively at 2.5 mm penetration and 3.46% and 9.64% in case of 5 mm penetration. The result also shows percentage decrease in thickness of 10.136% and 3.74% in the flexible pavement with the inclusion of woven and non-woven geotextiles, respectively.

Keywords: Woven Geotextiles, Non-woven Geotextiles, CBR Test, Reinforced Soil

1. Introduction

1.1. Introduction

Reinforcing soil is a technique that involves inserting tensile elements into the soil to improve stability and control deformation. Soil reinforcement can be through many techniques like mechanical stabilization, grouting, stone columns, vertical drains, geosynthetics etc. Geotextiles are employed as underpinning; their primary function is to give tensile strength to soil at strain situations suitable with soil structure performance. fabrics, in the form of fibres and fabric forms similar as woven, knitted, andnon-woven, are used as underpinning.

There are several studies in the literature where the response of corroborated soil with geosynthetics is analyzed. (KittureS.P., etal.) studied that geosynthetic material consists of synthetic fibers and are composed of yarns. These fibers are mostly made up of polypropylene or polyester resins. They're well known for their unique parcels like non-biodegradable and long- life span. (SinghT., etal.) examined the increase in strength of soil by adding geotextile through experimental disquisition. The main ideal of their study was to drop the pavement consistence and to rise the strength of pavement structures by using geotextile as underpinning material.

The use of geosynthetics to ameliorate roads was examined by (GiroudJ.P., etal.), and also describes the design styles used to increase the strength of geosynthetics used in unpaved and paved roads and to break grueling road problems. The planar fashion of beach underpinning exploitation geosynthetic layers was tried by (ChandrasekaranB. etal.). (VinothS., etal.) give a review of using geosynthetics for perfecting the life of pavement and also give the design guidelines, material specifications, performance norms, and construction processes.

(GuraraM.J., etal.) did an experimental and logical examinations to estimate the relative performance of pavements with and without geosynthetic stabilization. This was fulfilled by the testing of an aggregate of 8 pavement core samples and 11 CBR test sections which could be classified into two different types one which was constructed without geosynthetics and one with one of two geomembranes or a geogrid. According to (ManojS., kumarS.), he delved the road- strengthening system. The geogrid greatly increases the strong point of poor soils, which is imaged in the problematic CBR values. It concludes that sticking the geo- grid at different strata and in adding figures has a significant favorable impact on the subgrade strength. The use of geo- grids as soil underpinning restores the strength of depleted soils.

The present study focuses on using the geotextile with the soil in between subgrade and the base course subcaste. Generally made from polypropylene or polyester, geotextile fabrics come in two introductory forms woven and nonwoven.Generally, geotextiles are placed at the pressure face to strengthen the soil. Geotextiles generally laid in the direction of construction business. It must be lapped both side to side and end to end in the direction of aggregate placement. Laboratory CBR test have been conducted on natural soil as well as soil reinforced with Geotextiles (two woven and two non-woven geotextiles). The effect of percentage increase in CBR is discussed.

1.2. Literature Review

- **Vinoth S., et al. (2022)** gave a review of using geosynthetics for perfecting the life of pavement and also give the design guidelines, material specifications, performance norms, and construction processes. Geosynthetics act as underpinning and increases the performance of the bearing capacity of the soil. According to the findings of expansive study, geogrids offer more implicit for buttressing flexible pavements than geotextiles. This study shows that there in inclusion of geosynthetics, the maximum California bearing rate can be attained and it'll also help the masterminds and contractors in selection of accoutrements for better result and frugality.
- **Kitture S.P., et al. (2021):** A Geosynthetic material consists of synthetic fibers and are composed of yarns which are made up of polypropylene or polyester resins. They're well known for their unique parcels like non-biodegradable and long- life span. In road pavement, there are different layers and these geo-synthetic accoutrements can be used to make them more durable and sustainable. In country like India, they can be proved to be more effective and useful in construction practices. Geosynthetic accoutrements are proved to be an effective result to the problems of road sinking, pothole circumstance etc. It’s also a cost-effective result and helps to achieve frugality in the construction. The results handed to the affected road can be applied effectively to rejuvenate its condition.

- **Shirazi M.G., et al. (2020):** This composition concentrated on the number and position of the natural geotextiles inside the soil mass. The advantages of utilising the biodegradable accoutrements as natural geotextile underpinning for bearing capacity enhancement was presented. The addition of natural geotextiles as an underpinning lead to a significant increase in the bearing capacity of the soil foundation. The effectiveness of geotextiles (e.g., knaf, coir, bamboo) was set up to be dependent upon (1) the position of the first geotextile subcaste (top subcaste distance) within the soil mass; (2) the perpendicular distance between the underpinning layers; (3) the number of mounts, and (4) the length of the mounts. The soil bearing capacity enhancement only exists when the natural underpinning subcaste is placed within the distortion zone. Generally, the bearing capacity of the soil increases with a drop in the perpendicular distance of the geotextile underpinning. With the increase in the embedment depth of the underpinning subcaste, the CBR decreases. The geotextile- reinforced soil displayed a ductile curvewhere strain hardening goods were observed, indeed at large agreements. The optimum number of underpinning layers was recommended in the range of 3 to 4. The bearing capacity increased appreciably with an increase in the length of natural geotextiles up to the length rate of 3.
- **Singh T. et al. (2020)** examined the strength improvement with the help of experimental disquisition. The main ideal of their disquisition was to drop the pavement consistence and to rise the strength of pavement structures by using geo- cloth as underpinning material and in their trials, they also included the study on the effect of type of geo- cloth used for underpinning, effect of position of underpinning subcaste, effect of number of layers of underpinning, vaticination of CBR values using ANN and M5P, vaticination for woven geo- cloth, vaticination for non- woven geo- cloth.
- **Sugandini S., Madhuri M. (2017)** suggested that geosynthetics considerably used during the many decades in the construction of the road's conformation, trace dam, earthen heads and retaining walls. This paper presents soil geosynthetics commerce parcels for different types of soil, four types of soils were used with geocomposite corroborated accoutrements for conducting CBR test to chancing the viscosity of soil samples and mechanical strength of subgrade soil.

2. Material and Methodology

2.1. Materials

Soil

The soil used in present study is collected from Jammu district of Jammu & Kashmir, India.

Index properties of collected soil are determined in laboratory as per Indian standards. Grain size distribution, free swell index, moisture content and compaction parameters were determined as per IS: 2720 (Part IV) -1985, IS:2720, Part-40, IS: 2720 (Part II)-1973and IS: 2720 (Part- VII)-1980 respectively.

Table 1: Geotechnical Properties of Soil

S.No.	Properties	Values
1	Grain Size Analysis of Soil as per IS 2720, Part-4.	Gravel = 4.80% Sand = 65.80% Silt & Clay = 29.40%
2	Specific Gravity Test as per IS 2720, Part-2.	2.65
3	Liquid Limit determination as per IS 2720, Part-5.	20.60 %
4	Free Swell Index as per IS 2720, Part-40.	0%

5	Modified Proctor Compaction Test as per IS 2720, Part-8.	MDD =1.985gm/cc OMC = 10.68%
6	Direct Shear Test as per IS 2720, Part-13: 2009	Φ° = 32 ° C = 0
7	CBR Test as per IS 2720, Part-16.	2.5 mm = 14.07% 5 mm = 20.86%

Geotextiles

Woven and non-woven Geotextiles has been purchased online from Virendera Textiles and Gupta Non-woven Textiles through Indiamart.com.

Following are the properties of online purchased non-woven geotextile:

Fig. 1: Non-woven Geotextiles

Table 2: Properties of Non-woven Geotextiles

Property	Values	Values
Thickness	2.0 mm	1.7 mm
Pattern	Plain	Plain
Colour	White	White
Material	Polyester	Polyester
GSM	150 GSM	100 GSM

Following are the properties of online purchased woven geotextile:

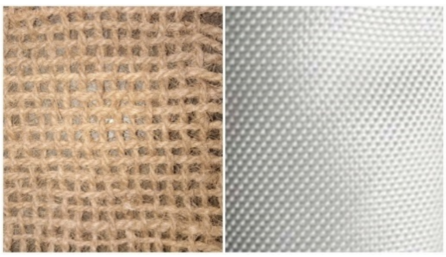


Fig. 2: Woven geotextiles

Table 3: Properties of Woven Geotextiles

Property	Values	Values
Thickness	3.0-7.0 mm	0.9-5.0 mm
Pattern	Plain	Plain
Colour	Natural Brown	White
Material	Jute Fiber	Multifilament Polyester
Apparent Size Opening	< 80 micron	< 75 micron

Setting of Samples using Geotextiles

Non-woven Geotextiles

Sample is made by placing non-woven geotextile at H/3 height from bottom of the mould.

And the soil is placed in 3 equal layers then compacted with 55 blows by 2.6 kg hammer.

Fig. 3: Sample Preparation using Non-woven Geotextiles

Woven Geotextiles

Sample is made by placing woven geotextile at H/3 height from bottom of the mould.

And the soil is placed in 3 equal layers then compacted with 55 blows by 2.6 kg hammer.

Fig. 4: Sample Preparation using Woven Geotextiles

2.2. CBR Testing

Laboratory CBR test is conducted to know the bearing capacity of the soil and CBR test with the inclusion of different types of geotextiles are conducted to calculate the percentage increase in CBR test and to check the improvement in strength of the reinforced soil. CBR testing is done as per the standard procedure mentioned in IS 2720, Part-16**.**

2.2.1. CBR Test on soil with Non-Woven Geotextiles

Non-Woven Geotextiles are placed at a height of H/3 from the bottom of CBR mould. The strength improvement of the reinforced soil is quantified through a non-dimensional parameter i.e., Bearing Capacity ratio (BCR). It is defined as the ratio of CBR of reinforced soil ($CBR_{r)}$ to the CBR of unreinforced soil ($CBR_{u).}$

$$BCR = \frac{CBR\,r}{CBR\,u}$$

Table 4: CBR Test using Non-woven Geotextile (Type-1)

CBR: Non-woven 1			
Test Specimen	**CBNW1A**	**CBNW1B**	**CBNW1C**
Corrected Load (kg) at 2.5 mm	240.983	248.709	251.1758
Corrected Load (kg) for 5.0 mm	436.9135	433.3995	460.1145
CBR% (2.5 mm)	17.59	18.154	18.334
Average CBR (2.5 mm)	18.026		
Percentage Increase (%)	28.12		
CBR% (5 mm)	21.261	21.09	22.39
Average CBR (5 mm)	21.581		
Percentage Increase (%)	3.46		

Table 5: CBR Test using Non-woven Geotextile (Type-2)

CBR: Non-woven 2			
Test Specimen	**CBNW2A**	**CBNW2B**	**CBNW2C**
Corrected Load (kg) at 2.5 mm	220.864	227.32	279.328
Corrected Load (kg) for 5.0 mm	428.736	448.1955	448.224
CBR% (2.5 mm)	16.12	16.6	20.39
Average CBR (2.5 mm)	17.703		
Percentage Increase (%)	25.82		
CBR% (5 mm)	20.86	21.81	21.81
Average CBR (5 mm)	21.49		
Percentage Increase (%)	3.02		

Table 6: BCR Values for Non-woven Geotextiles

BCR	**NW1**		**NW2**	
	2.5 mm	5 mm	2.5 mm	5 mm
	1.28	1.034	1.25	1.030

2.2.2. CBR Test on Soil with Woven Geotextiles

Table 7: CBR Test using Woven Geotextile (Type-1)

CBR: Woven 1			
Test Specimen	**CBW1A**	**CBW1B**	**CBW1C**
Corrected Load (kg) at 2.5 mm	272.219	290.714	273.452
Corrected Load (kg) for 5.0 mm	492.58	464.84	452.511
CBR% (2.5 mm)	19.87	21.22	19.96
Average CBR (2.5 mm)	20.35		
Percentage Increase (%)	44.6		
CBR% (5 mm)	23.97	22.62	22.02
Average CBR (5 mm)	22.87		
Percentage Increase (%)	9.64		

Table 8: CBR Test using Woven Geotextile (Type-2)

CBR: Woven 2			
Test Specimen	**CBW2A**	**CBW2B**	**CBW2C**
Corrected Load (kg) at 2.5 mm	267.561	274.342	274.342
Corrected Load (kg) for 5.0 mm	473.698	431.94	484.877
CBR% (2.5 mm)	19.53	20.025	20.025
Average CBR (2.5 mm)	19.86		
Percentage Increase (%)	41.15		
CBR% (5 mm)	23.051	21.019	23.595
Average CBR (5 mm)	22.55		
Percentage Increase (%)	8.125		

Table 9: BCR Values for Woven Geotextiles

BCR	W1		W2	
	2.5 mm	5 mm	2.5 mm	5 mm
	1.44	1.09	1.41	1.08

2.2.3. Thickness from CBR Test

The percentage decrease in the thickness of the pavement is tabulated in table 20. Thickness from the CBR test is calculated by the formula:

$$\text{Thickness (cm)} = \sqrt{\left(\frac{1.75P}{CBR\%} - \frac{P}{\pi p}\right)}$$

Where P = wheel load = 4085 kg (standard value)
p = contact pressure = 7 kg/cm^2 (standard value)

Table 10: Thickness from CBR Test

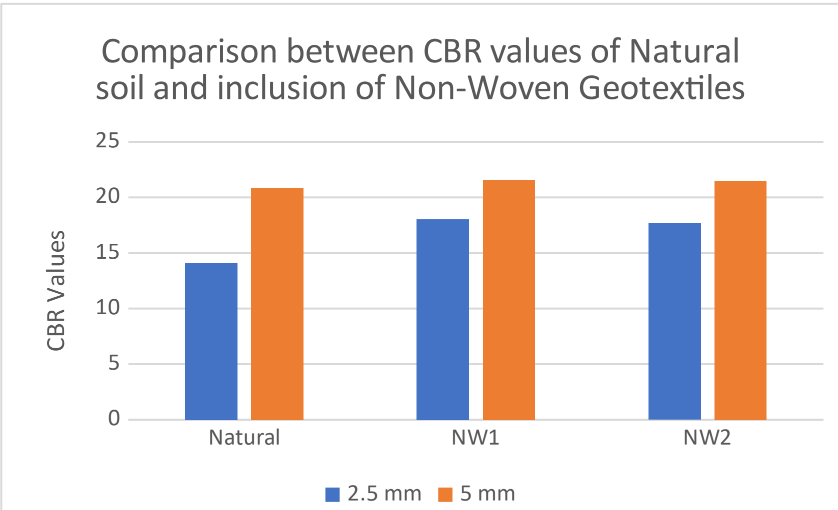
	Wheel Load (P): 4085 kg		Contact Pressure: 7 k/cm^2		
Sample	CBR1	CBW1	CBW2	CBNW1	CBNW2
Thickness (cm)	12.53	11.26	11.46	12.062	12.12
Percentage decrease in thickness (%)		10.136	8.53	3.74	3.27

3. Results and Discussion

The results from the experimental studies shows that Geotextiles can be successfully used as a reinforcing material in subgrade soil. The increase in the CBR values of the soil is seen by reinforcing it with Geotextiles. It is also found from table 6 and table 9 that Woven Geotextiles always gives more BCR than a Non-Woven Geotextiles.

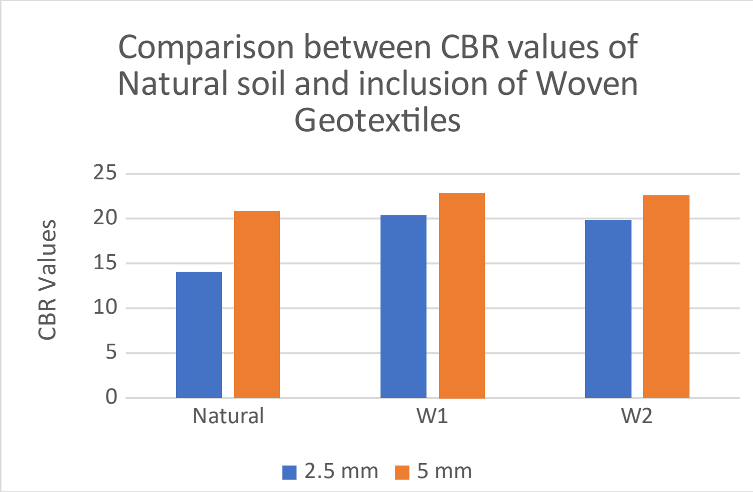
The comparison of CBR values of Natural soil and soil reinforced with Non-Woven Geotextiles is shown in Chart 1.

Chart 1: Comparison between CBR Values of Natural Soil and inclusion of Non-woven Geotextiles



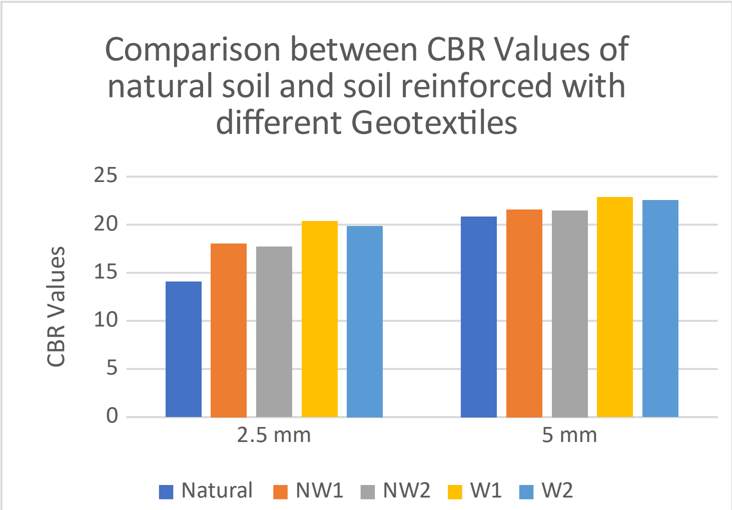
The comparison of CBR values of Natural soil and soil reinforced with Woven Geotextiles is shown in Chart 2.

Chart 2: Comparison between CBR Values of Natural Soil and inclusion of Woven Geotextiles



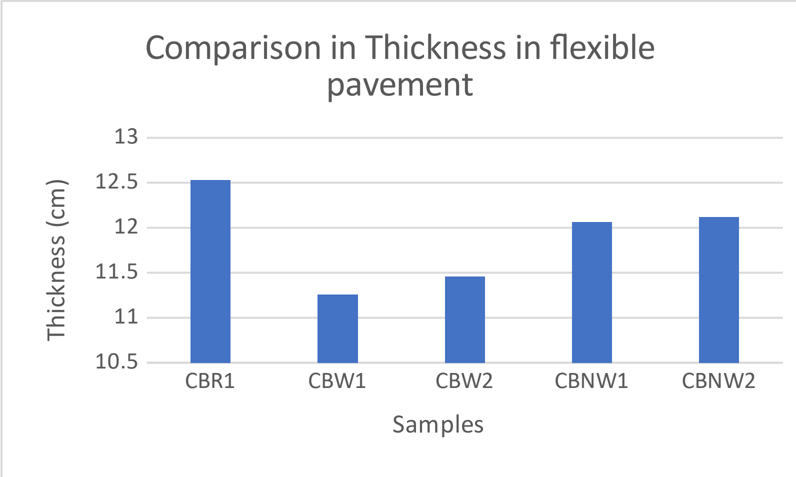
The overall comparison between the Natural soil and different Geotextiles is shown in Chart 3. It is found that the woven geotextiles proved to give better percentage increase in CBR values as compared to the non-woven geotextiles.

Chart 3: Comparison between CBR Values of Natural Soil and Soil Reinforced with different Geotextiles



The results also showed the decrease in the thickness in flexible pavement due to the inclusion of different geotextiles. It is found from chart 4 that Woven Geotextile proved to give better percentage decrease in the overall thickness of the pavement.

Chart 4: Comparison in Thickness in Flexible Pavement



4. Conclusion

- The use of geotextiles in soil reinforcement has given positive results in terms of California Bearing Ratio values. Utilization of geotextiles such as woven and non-woven provides a cost-effective and efficient solution for enhancing the properties of the soil. The different values of CBR tests are determined by placing the geotextile layer at a height of H/3 from the bottom of the mold.
- The use of non-woven geotextile in soil improves the CBR values and hence the strength of the soil. It is found that non-woven geotextile with less thickness (NW2) gives relatively lesser strength as compared to the non-woven geotextile with high thickness (NW1). But both of them gives positive results as compared to the normal CBR values. It is found that the percentage increase in using the non-woven geotextile is 28.12% and 3.46 % at 2.5 mm and 5 mm penetrations, respectively for the NW1 and the percentage increase is 21.49% and 3.02% at 2.5 mm and 5 mm penetrations, respectively for NW2.
- The use of woven geotextile in soil improves the CBR values and hence the strength of the soil. It is found that woven jute fiber geotextile (W1) gives relatively more strength as compared to the woven multifilament polyester geotextile (W2). But both of them gives positive results as compared to the normal CBR values. It is found that the percentage increase in using the woven jute fiber geotextile is 44.6 % and 9.64 % at 2.5 mm and 5 mm penetrations, respectively for the W1 and the percentage increase is 41.15 % and 8.125 % at 2.5 mm and 5 mm penetrations, respectively for W2.
- Comparing these findings, it is evident that the inclusion of woven geotextiles in soil at a height of H/3 from the bottom of the mould resulted in higher CBR values as compared to Non-woven Geotextiles and in the absence of geotextiles. Therefore, implementing woven geotextiles proved to be an effective measure in improving bearing capacity of the soil.
- The maximum percentage decrease of 10.136% in thickness is visible in Woven Geotextile (type-1) and the maximum percentage decrease of 3.74% in thickness is visible in Non-Woven Geotextile (type-1).

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