Predicting The Strength Enhancement Of Subgrade Soil Reinforced With Geotextile Using Artificial Neural Network And M5P Model Tree

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Abstract

Geosynthetics layers are being implemented as reinforcement to enhance the strength of subgrade soil (which is calculated in terms of CBR). Present research work, aims at investigating the strength enhancement in terms of CBR through experimental study. Experiments were conducted on subgrade soil reinforcing it with single and double layer woven and non-woven geotextile layer were placed at depth M/3, M/2 and 2/3M from the top of CBR specimen, where Mis height of CBR specimen. Result indicate that woven geotextile offers more strength to subgrade soil than non-woven geotextile, further as depth of placement of reinforcement increases from top lesser is increase in strength for both the geotextile. Strength also increases when double layer was placed in comparison to single layer for both the geotextile. ANN and M5P was used to predict the CBR value, result suggest improved performance of ANN over M5P for present data.

Keyword:Geotextile, Artificial neural network, M5P model tree, subgrade soil.

1. INTRODUCTION

Various techniques has been reported to increase strength of subgrade soil in road structures which include mechanical processes (replacement of soil, compaction etc), chemical process (using admixtures), injecting a tough material into the soil mass (compaction piles, bamboo strip, etc.). Besides these natural and traditional techniques, the important development of concept of reinforced soil as construction material, was first introduced by French Architect H. Vidal, in the sixties, has acquaint with the modern form of soil reinforcement technique. This practice has been implemented to enhance the strength of subgrade in several structures, e.g. slopes and embankment, road pavements, retaining walls, dams and foundations others and it has been proven by Mitchell [1] that soil reinforcement techniques is most advanced application for enhancing soil strength.

With advancement of construction practices the use of geosynhetic have been gradually increased as reinforcement material for subgrade soil of paved and unpaved road.The benefits of using geosynhetic layers in subgrade soil can be witnessed in performance and economy both.[2]. The theory of using geosynhetic as reinforcement material was introduced in 1970s in paved/unpaved road construction started. Many researcher reported experimental and numerical studies to stating the advantage of using the geosynhetic in road construction [3-4]. As geosynhetic was successful as reinforcing material, several types of geosynhetic have been developed [5]

Numerous investigators have revealed that using geosynthetics layer have been proven useful as reinforcement in case of subgrades soil to increase their performance [6-9]. The placement of the geosynthetics layer at appropriate depth is important factor which influences the performance of subgrade – [10-12]. Reduction in depth of ruts, enhancement in load bearing capacity, prolong the service life, reduction in cost of construction and maintenances and diminish the necessary fill thickness are the several advantages of using geosynhetic as reinforcement [13-17]. Strength of subgrade soil is expressed in CBR and various studies have shown that reinforcement of geosynhetic layer enhances the CBR value [18- 23]. However conflicting result have been reported regarding positioning of geosynhetic some have suggested that it should be placed near the load applied while other suggested that it should be placed at bottom half of CBR specimen [24]. Keeping this in view present work aims to investigate the performance of two different types of geotextile and find the optimum depth of their position.
The use of laboratory and theoretical analysis are labour and computationally intensive, hence the need of alternate approaches to monitor the strength enhancement in subgrade soil is required. Within last two decades many researchers adopted machine learning techniques for various civil engineering problems and found these techniques performing well and requiring less computational resources. [25-28] used artificial neural network (ANN) and established that performance of NN was equally well or better than the existing empirical equations. [29-30] used generalized regression neural network (GRNN) with different civil engineering problems. [31-32] used ANFIS (neuro-fuzzy), which is a combination of NN and fuzzy logic) which has been extensivelyapplied on civil engineering problems due to its reasoning and learning capabilities. These techniques show better results in comparison to empirical relations. Keeping in view the usefulness of various machine learning approaches, present study aims to investigate the usefulness of artificial neural network (ANN) and M5P model tree for predicting the strength enhancement of subgrade soil reinforced with geosynhetic layer.

2. EXPERIMENTAL INVESTIGATION AND METHODOLOGY

Experimental Investigation and Methodology:

Specifics of Experimental Investigation:T
he entire study has been conducted in Geotech Lab of Lingaya's Vidyapeeth Laboratory on the subgrade soil, *i.e.* to analysis the CBR value of Subgrade soil upon reinforcing with Woven and Non-Woven Geotextile at different levels. Detail of soil used for investigation, geotextile used and methodology adopted have been discussed in detail in this section.

Details Subgrade Soil:
The Subgrade Soil which is taken for Laboratory investigation in present study was collected from the adjacent of road in front of Lingaya's Vidyapeeth, Faridabad. The engineering properties of subgrade soil determine in the laboratory in accordance to Indian Standard Code IS 2720 and tabulated in Tab

Reinforcement:
Among various types of geosynhetic, geotextile is the most useful, adaptable and economical ground modification materials and constitute the major component of geosynhetic. Geotextile been widely used these days in civil engineering projects. As per ASTM 19941 geotextile is described as a permeable textile materials applied with connection to soil, rock or any other material associated with geotechnical as an essential part of construction project. Geotextile are of two types woven and non-woven based on their structural composition and the manufacturing processes.

- Woven geotextiles are produced by crossing intricately of warp and weft yarns and these may consist of multifilament, fibrillated, spun or of slit film.
- Nonwoven geotextiles are produced by mechanical interlocking or thermal bonding of fibres/filaments.

Present study involve use of both woven and non-woven geotextile. Selection of geotextile was governed by comparing several parameters such as specification, availability, durability and price. Specification of woven Geotextile (PPMF-30) are given in Table 2. Specification of non-woven Geotextile (SN-30) are provided in Table 3. Geotextile were cut in round shape of size slightly less than CBR mould.

Experimental Investigation:

The main objective of present investigation was to decrease the pavement thickness and to rise the strength of pavement structures by using geotextile as reinforcement material. As CBR value is the measure of strength of material to be used in subgrade so to achieve the objective unsoaked CBR value {as per IS: 270 (part 16)-1979} of parent subgrade soil without reinforcement was calculated and then performance of parent subgrade soil by providing geotextile (woven and non-woven) at different height and combination were investigated. Reinforcement was provided at different depth of CBR namely *M/3, M/2* and *2/3M* from the top as shown in Figure 1, where *M* is total depth of CBR mould from the top. Table 4 provide the different combination of geotextile used. Two test were carried out with each combination and average were taken for accuracy. The loads, for 2.5mm, 5mm and 12.5mm were observed and recorded. This load is given as a percentage of standard load value at a corresponding deformation level to obtain CBR value. In this way total 12 observations were made for woven and non-woven each. The increase in strength was determined by evaluating increment ratio, I_R (%) which is equal to ratio of CBR value of reinforced soil and CBR value of parent soil given in equation 3

I_R = (Increase in CBR of reinforced soil/ CBR of unreinforced soil)*100 (3)

3. Data Set and Details of Ann and M5p

Top of mould (2/3H) were taken as input parameter. Analysis were carried out for woven and non-woven separately. Out of twelve observations of each woven and non-woven, two third (i.e 8 reading) haphazardly selected samples were used as training data and remaining one third (i.e 4 reading) were taken as testing data set. WEKA 3.9 was used for modelling the data. Large number of iteration were carried out to determine the optimal user defined parameters of M5P and ANN. Table 5 shows the value of optimal usertop (H/2) and Number of geosynhetic layer at height of reinforcement two third from defined parameter for M5P and ANN. Coefficient of correlation. (CC) and root mean square error (RMSE) values were used for evaluation of performance of different regression approach,

4. RESULT AND DISCUSSION

Observation from Experimental Investigation:

Figure 2 provide the plot between CBR values of woven and non-woven geotextile corresponding to depth of penetration equal to 12.5mm and position of reinforcement, for three cases single layer of reinforcement was provided at *M/3*, *M/2* and *2/3* M from the top and in one case two layer of reinforcement was provided at *M/3* and *2/3* M from the top. Table 6 gives the value of CBR at each position of reinforcement and Increment ratio at each depth.

Effect of reinforcement:

From Table 6 it was observed that reinforcing parent soil with woven or non-woven geotextile at varying depth increases the CBR value and in turn improves the bearing capacity of subgrade soil. Increment ratio (Table 6) was observed from 87.17% to 188.23% depending upon the location of reinforcement layer, type of geotextile and number of layer of reinforcement. Hence it can be concluded that soil reinforced using geotextile enhances the strength of parent subgrade soil.

Effect of type of geotextile used for reinforcement:
From Figure 2 and Table 6 it can be observed that for both single layer and double layer reinforcement and at all the position of reinforcement, woven geotextile have larger value of CBR than nonwoven geotextile, hence it can be stated that the woven geotextile are more capable of increasing strength of subgrade soil in comparison to non-woven geotextile.

Effect of position of reinforcement layer:
From Figure 2 and Table 6 it can be witnessed that as the depth of placement of reinforcement from top (for both woven and non-woven geotextile) increases, CBR value decreases. Hence, it can be concluded that if position of reinforcement is near to the top *(M/3)* of soil specimen amplifies the strength of parent subgrade soil is more prominent, no significant increase in strength of parent subgrade soil was observed if reinforcement is placed beyond middle of the specimen depth *(M/2)*. Thus, position of reinforcement in important parameter while reinforcing the soil.

Effect of number of layer of reinforcement:
From Figure 2 and Table 6 it can be clearly observed that increment ratio of double layer of reinforcement for both woven and non-woven was greater than respective single layer. Increment ratio increased greatly (188.23%) if two layer of woven geotextile was placed in comparison to two layer of non-woven geotextile (133.96%).

Prediction of CBR values using ANN and M5P:
ANN and M5P was used to predict the CBR value for both woven and non-woven geotextile separately.Both the approaches were tuned to the optimum user defined parameter and then predicted values were recorded. Table 7 gives the value of performance evaluation parameter for both woven and non-woven geotextile.

Prediction for woven geotextile:
Figure 3(a) and (b) provide the plot of actual vs predicted CBR value for training and testing data set using ANN and M5P modelling approach for subgrade soil reinforced with woven geotextile. Comparison of performance evaluation parameter; CC= 0.8976 and RMSE= 3.097 from ANN and CC= 0.9012 and RMSE= 1.3955 from M5P, suggest that prediction from both the approaches were in accordance of experimental results and performance of M5P was slightly better than ANN. Hence it can be concluded that both the approaches can be used to forecast the CBR value if soil is reinforced with woven

Prediction for non-woven geotextile:
Figure 4(a) and (b) gives the plot of actual vs predicted CBR value for training and testing data set using ANN and M5P modelling approach for subgrade soil reinforced with non-woven geotextile. Comparison of performance evaluation parameter; CC= 0.9172 and RMSE=2.5564 from ANN and CC= 0.4897 and RMSE= 5.4371 from M5P, submit that prediction from ANN approaches were in agreement with experimental results and performance of ANN was superior to M5P. Hence it can be inferred from investigation that only ANN can be used to forecast the CBR value if soil is reinforced with non-woven geotextile.

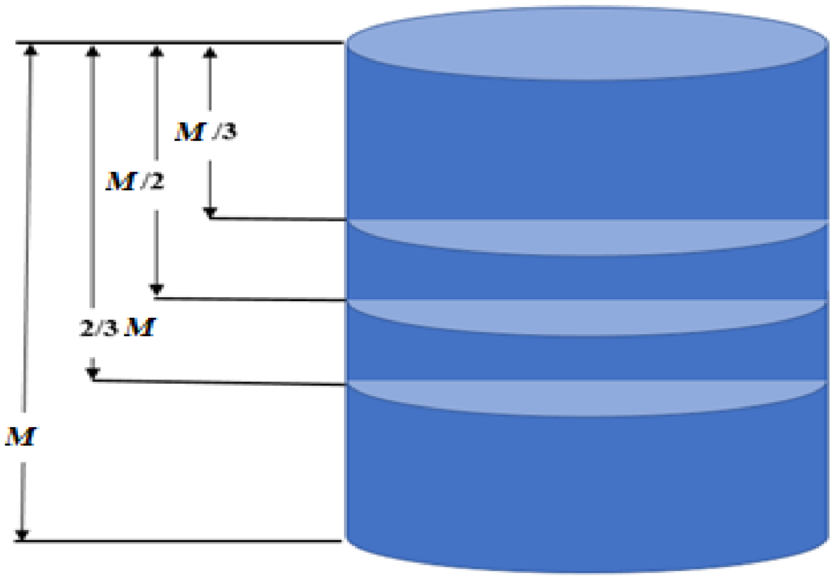


Figure 1: Diagrammatic representation of position of reinforcing layer

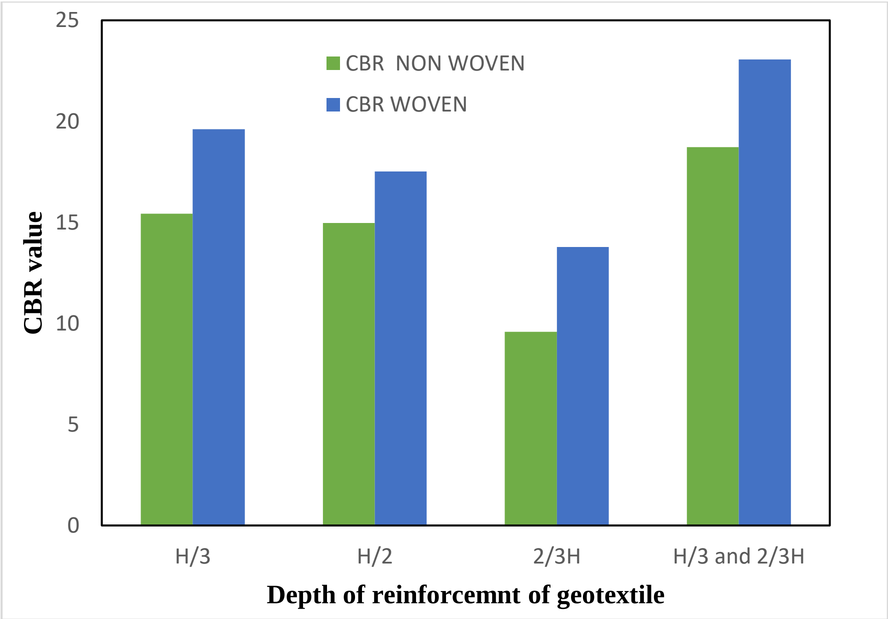
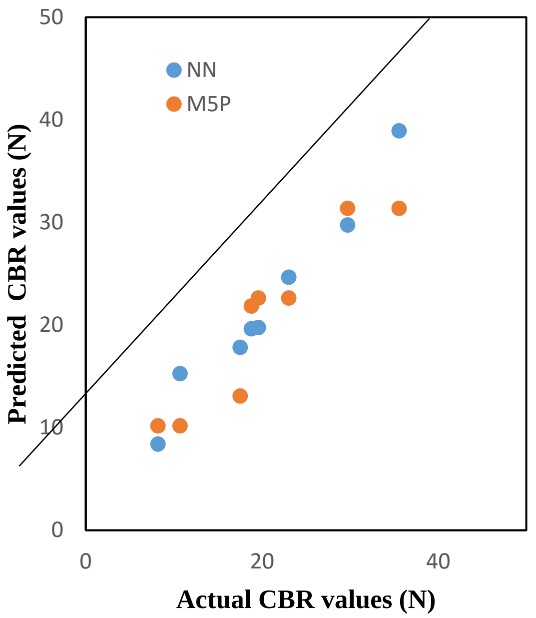


Figure 2 Plot of CBR values vs position of reinforcement



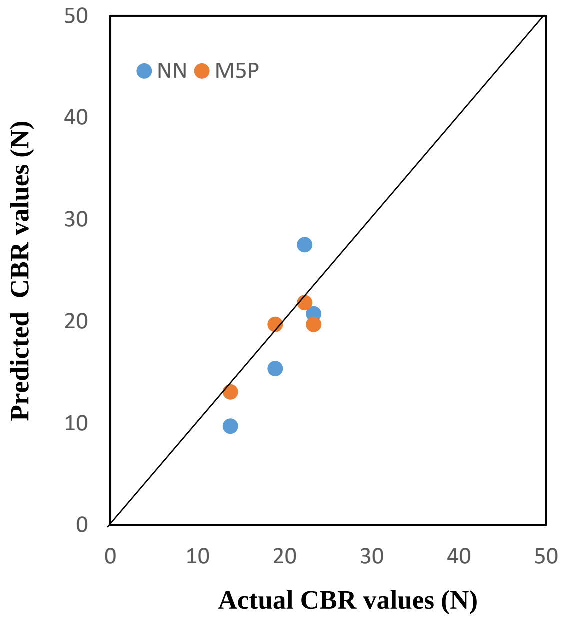
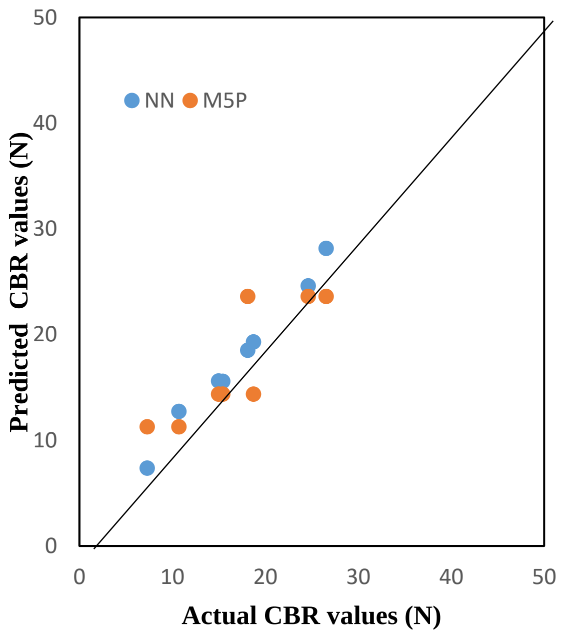


Figure 3 (a) **Figure 3(b)**

Figure 3 Actual vs Predicted value of CBR for for subgrade soil reinforced with woven geotextile, Figure 3(a) and (b) is for training data and testing data set respectively.



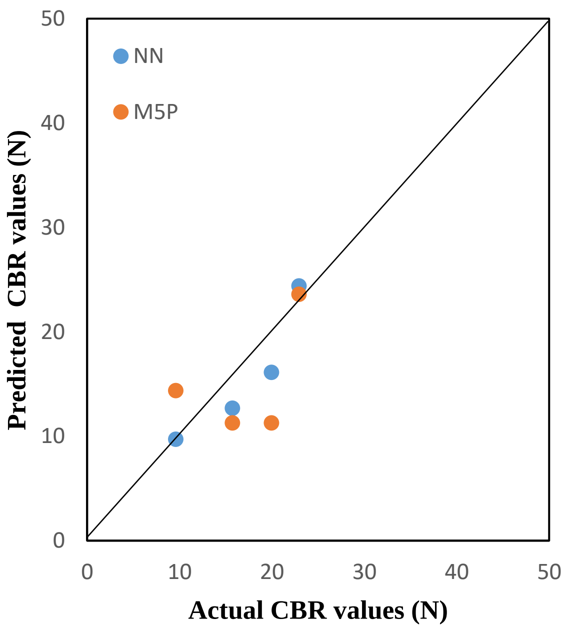


Figure 4 (a) **Figure 4(b)**

Figure 4 Actual vs Predicted value of CBR for subgrade soil reinforced with non-woven geotextile, Figure 4(a) and (b) is for training data and testing data set respectively.

Table I . Engineeringpropertiesofsubgradesoil.

Index Property	Experimental Value
Liquid Limit	52.92 %
Plastic Limit	33.02 %
Plasticity Index	19.9 %
Specific Gravity	2.4
Optimum Moisture Content	17 %
CBR (%)	7%

Table II. Specification of Woven Geotextile (PPMF-30)

Properties	Test Method	Unit	Values
Physical/Mechanical			
Mass Per Unit Area	EN ISO 9864	g/m^2	300
Thickness		Mm	0.6 mm
Tensile Strength (5 x 20 cm strip),Warp	EN ISO 10319	Kgf	317
Tensile Strength (5 x 20 cm strip), Weft	EN ISO 10319	Kgf	285
Elongation at break, Warp	EN ISO 10319	%	40
Elongation at break, Weft	EN ISO 10319	%	36
Bursting Strength -	--	Kgf/cm^2	53
Air Permeability at 1.22 WC	--	--	0.32

Table III. Specification of non-woven geotextile (SN-30)

Properties	Test Method	Unit	Values
Physical			
Mass Per Unit Area	ASTM D 5261	g/m^2	300
Thickness	ASTM D 5199	Mm	2.8
Mechanical			
Grab Tensile Strength	ASTM D 4632	N	1180
Grab Elongation	ASTM D 4632	%	80
Wide Width Tensile Strength	ASTM D 4595	KN/m	7
Wide Width Tensile Elongation	ASTM D 4595	%	80
Trapezoidal Tear length wise	ASTM D 4533	N	300
Trapezoidal Tear Width wise	ASTM D 4533		550
Mullen Burst Strength	ASTM D 3786	Kpa	2400
Puncture Strength (CBR)	ASTM D 6241	N	3700
Endurance			
UV Resistance @ 500 Hours	ASTM D 4355	%	70

Table IV: Various combination of parent subgrade soil with geotextile.

Sr No.	Combination	No. of Layer	Type of Geotextile
1	CBR Test without Reinforcement.	--	--
2	Soil with Geotextile at a depth of M/3 from Top.	01	Woven
3	Soil with Geotextile at a depth of M/2 from Top.	01	Woven
4	Soil with Geotextile at a Height of 2/3 M from Top.	01	Woven
5	Soil with Geotextile at a Height of M/3 and M/3 H from Top.	02	Woven
6	Soil with Geotextile at a depth of M/3 from Top.	01	Non-Woven
7	Soil with Geotextile at a depth of M/2 from Top.	01	Non-Woven
8	Soil with Geotextile at a Height of 2/3M from Top.	01	Non-Woven
9	Soil with Geotextile at a Height of M/3 and 2/3 M from Top	02	Non-Woven

TableV :Valueofuserdefinedparameter

Modelling approach	User-Defined Parameters	Type of Geotextile
M5P	Number of training examples allowed at a terminal node=4	Woven
ANN	Learning rate =0.5, momentum =0.3, number of iterations =100, number of hidden layer=8	Woven
M5P	Number of training examples allowed at a terminal node=4	Non-Woven
ANN	Learning rate =0.3, momentum =0.2, number of iterations =100, number of hidden layer=8	Non-Woven

Table VI: CBR value and Increment Ratio I_R (%) at each position of reinforcement for woven and non-woven geotextile

Position of Reinforcement	Type of Geotextile	CBR	Increment Ratio I_R (%)
M/3	Woven	19.61	145.19
M/2	Woven	17.52	118.98
2/3M	Woven	13.78	72.19
M/3 and 2/3M	Woven	23.06.	188.23
M/3	Non- woven	15.42	92.78
M/2	Non- woven	14.97	87.17
2/3M	Non- woven	9.58	19.79
M/3 and 2/3M	Non- woven	18.72	133.96

5. CONCLUSION

Effect of reinforcing woven and non-woven geotextile at different depth of reinforcement in single and double layer in terms of CBR value were examined in present study. Further for prediction of CBR, ANN and M5P modelling approaches were used. Vital outcomes of this research are listed below:

- Strength of subgrade soil was enhances upon reinforcement with both woven and non-woven geotextile.
- Rise in strength with reference to parent soil was noticed from 19.79% to 188.23% depending on the position of reinforcement, type of geotextile laid and number of layer of reinforcement.

- Subgrade soil reinforced with woven geotextile gives better result when reinforced with to non-woven geotextile for all position of reinforcement and for both single and double layer.
- Optimum benefit of reinforcement wasmarkedonly if position of reinforcement of geotextile layer is at *M*/3 and *M*/2 for both woven and non-woven geotextile.
- Increment ratio of double layer of reinforcement for both woven and non-woven was greater than of respective single layer.
- Performance of M5P predict the CBR value for woven was better than ANN
- Performance of ANN to predict the CBR value for non-woven was better than M5P.

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