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A laboratory study on pine needle reinforced soil

Sonu Sharma[1] Akansha Sinha[2]

[1] M. Tech Scholar, Construction Technology & Management, Faculty of Engineering & Technology Rama University, Kanpur, Uttar Pradesh, India

[2] Assistant Professor, Dept. of Civil Engineering, Rama University, Kanpur, Uttar Pradesh, India

***Abstract-* A great interest in the research of naturally available materials had been evoked due to the lack of resources that are environment friendly. Randomly distributed fibre reinforced soils have recently been a source of attraction for Engineers. The present work emphasizes on soil stabilization using pine needles. The pine needles are available as scrap material in abundance and therefore can be used for soil stabilization purpose taking into account both cost as well as easy availability of material. This paper is the partial part of the ongoing research work; hence, the discussion on laboratory tests is limited to only material characterization with or without pine needle & fly ash. From the present study, it is learnt that, inclusion of pine needle reduces both OMC & MDD as well as soaked CBR value irrespective of its aspect ratio. The angle of internal friction and cohesion increases considerably on admixing of pine needle irrespective of aspect ratio. However, the increase of internal friction and cohesion was more pronounced for 53 aspect ratio in comparison to 27 aspect ratio.**

Keywords: soil reinforcement; cohesion; OMC; MDD; CBR; fibre reinforced; soil stabilization; aspect ratio.

I. INTRODUCTION

Historically, there were different recorded trials of reinforcement of soils such as the Romans built reinforced soil roads using fascines and brushwood and in Southeast Asia; bamboo fascines were used for hundreds of years to support low embankments on soft marshy grounds, (Mc Gown et al, 1990). According to various investigators, soil stabilization methods have considerable scope in decreasing initial construction cost of pavements and for stage construction. The effective utilization of locally available soil and other construction materials and stabilizers would enable construction of low cost pavements (Vazirani et al. 1978).

Pine needle is a renewable natural material available abundantly in India, produced at low cost in a processed from. The total amount of needle falls in pine forests ranges from 1000 to 8000 kg/ha per year (Pande, 1996). The nominal cost of pine needle is Rs. 200 per ton (government was fixed this rate for Uttarakhand state) (Manoj Chandran et al. 2011).

However, very few works have been done so far by using natural fibres. So it is a broad field to research as a road embankment slope protection as well as suitability for subgrade construction. The effect of fibre inclusion evaluated as function of shearing strain amplitude, confining stress and number of cycles, fibre content, aspect ratio and modulus Maher (1988). Shear strength of sand increases due to an inclusion of discrete fibres, both synthetic and natural fibres Vasan et al. (1995). Soil reinforcement is defined as a technique to improve the engineering characteristics of soil. Although availability of geosynthetics is there but randomly distributed natural fibre-reinforced soils have recently been a source of attraction for Engineers. The Pine needles are available as scrap material in abundance in hilly areas and therefore can be used for soil stabilization purpose taking into account both cost as well as easy availability of material. Suitability of pine needle reinforced soil for road embankment slope protection is therefore the most important consideration.

II. MATERIAL USED

The following are the materials considered in the present investigation:

1. Soil
2. Fly ash
3. Pine needle.

2.1 Soil

The soil was collected from paddy field of Khanjarpur village, Roorkee, Uttarakhand. Various preliminary tests such as particle size analysis, specific gravity, proctor tests have been carried out with the help of relevant Indian standard codes to identify and classify the soils. The compaction characteristics of reinforced and unreinforced soil, with various fibre doses have been determined by conducting standard Proctor test in accordance with Light compaction. The samples for CBR and Tri axial testing were prepared at optimum moisture content and maximum dry density as obtained from standard Proctor test.

2.2 Fly ash

Fly ash, also known as flue-ash, is one of the residues generated in combustion, and comprises of fine particles that rise with the flue gases. Coal fly ash is a product obtained during combustion of coal which has numerous applications in construction of highway. Fly ash has a non-crystalline, pozzolanic and slightly cementitious behavior. The application of fly ash was first proposed in the first edition of “Fly ash Facts for Highway Engineers” during 1986. After that fly ash has gained importance in various constructions, highway and new applications have been introduced. Fly ash is a by-product obtained from the burning of coal in thermal power plants which is environmentally hazardous solid waste. The fly ash used has been collected from a nearby thermal power station.

Therefore, introduction of fly ash in construction of highway is highly beneficial and also accounts for sustainability.

Figure 1: **Fly Ash dried in oven**

2.3 Pine needles

The pine needles used in the present work were collected from Pithoragarh district, Uttarakhand. Pine needle is a renewable natural material available abundantly in India, produced at low cost in a processed from. The total amount of needle falls in pine forests ranges from 1000 to 8000 kg/ha per year. Pine needle is a natural fiber, dark brown in color throughout its length. Pine needle cross section is semi- circular, uniform and tapers at the ends. The average diameter of pine needle is 0.75mm. The maximum length of pine needle is 270 mm but mostly obtained fibers are between 190 mm to 270 mm in length.

Figure 2: Pine Needles

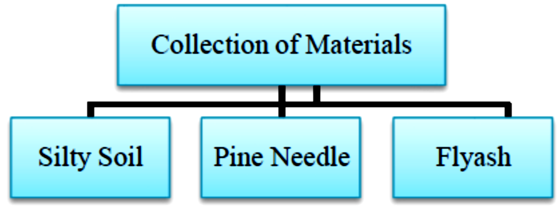
Figure 3: Sample Condition (Pine Needle)

III. LABORATORY STUDY, RESULTS AND DISCUSSIONS.

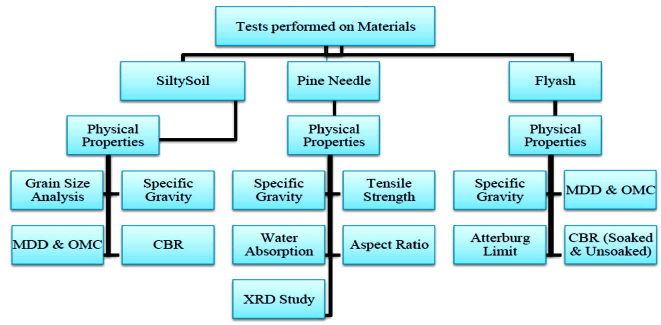
3.1 Methodology adopted and tests performed

In order to carry out the research sequentially, the work has been divided into the following phases.

Phase-I: Collection of Materials



Phase-II: Determination of properties of materials.



Phase-III: This stage is marked by preparation of various mix designations considering different percentages of pine needles with and without adding fly ash. Mix designations considered in the present investigation are presented in Table 1.

The study is conducted for two different aspect ratio i.e.27 & 53 respectively.

Table 1: Mix Designation

Mix Designation		
Fly ash + Silty Soil	**Pine Needle + Silty Soil**	**Pine Needle + Fly ash + Silty Soil**
i) 100% SS **(X1)**	**i)** 1.0% PN + 99.0% SS **(P1)- -27**	**i)** 1.0% PN + 40% FA + 59.0% SS **(Q1)- -27**
ii) 35% FA + 65% SS **(S1)**	**ii)** 1.5% PN + 98.5% SS **(P2)- -27**	**ii)** 1.5% PN + 40% FA + 58.5% SS **(Q2)- -27**
iii) 40% FA + 60% SS **(S2)**	**iii)** 2.0% PN + 98.0% SS **(P3)- -27**	**iii)** 2.0% PN + 40% FA + 58.0% SS **(Q3)- -27**
iv) 45% FA +55% SS **(S3)**	**iv)** 1.0% PN + 99.0% SS **(P1)- -53**	**iv)** 1.0% PN + 40% FA + 59.0% SS **(Q1)- -53**
	v) 1.5% PN + 98.5% SS **(P2)- -53**	**v)** 1.5% PN + 40% FA + 58.5% SS **(Q2)- -53**
	vi) 2.0% PN + 98.0% SS **(P3)- -53**	**vi)** 2.0% PN + 40% FA + 58.0% SS **(Q3)- -53**

Note: PN = Pine Needle SS = Silty Soil FA = Fly Ash

The laboratory tests conducted on the above mentioned mix designations are presented in the following table.

Table 2: Laboratory tests conducted

Laboratory Tests		
Silty Soil + Fly ash	**Pine Needle + SiltySoil**	**Pine Needle + Fly ash + SiltySoil**
i) OMC & MDD ii) CBR(Soaked & Unsoaked) iii) Triaxial Test	i) OMC & MDD ii) CBR (Soaked & Unsoaked) iii) Triaxial Test	i) OMC & MDD ii) CBR(Soaked & Unsoaked) iii) Triaxial Test

Phase-IV: In this stage GEO STUDIO software is used to carry out the slope stability analysis. In Geo STUDIO also a particular module called GEOSLOPE or SLOPE/W is used for analysis of stability of slope. SLOPE/W is the leading slope stability CAD software product for computing the factor of safety of earth and rock slopes. SLOPE/W can effectively analyze both simple and complex problems for a variety of slip surface shapes, pore-water pressure conditions, soil properties, analysis methods and loading conditions.

IV. RESULTS & DISCUSSION

4.1 Material characterizations

Based on the laboratory tests carried out, the local soil collected was found to be silty soil. The engineering properties of soil & fly ash are presented in Tables 3 & 4 respectively. It is also learnt that fly ash collected from Dadri thermal power plant showed OMC of about 1.45 times higher than that of silty soil and about 1.25 times higher in MDD was noted for silty soil in comparison to fly ash used.

The physical and chemical properties of pine needle are presented in Tables 5 & 6 respectively. As can be seen from the Table 6, presence of lignin and holocellulose was about 34.407% and 68.86% respectively. The degradability of such material is depending upon the presence of amount of lignin and holocellulose. Pine needle being one such material which exhibit higher lignin and holocellulose content even higher than coir (lignin=32.8%; holocellulose = 56.3%). This analysis apparently infers that pine needle would offer better resistance against biodegradability.

Table 3: Physical properties and classifications of soil used in the present study.

Properties	Values
Optimum moisture content OMC (%)	15.9
Maximum dry density MDD (g/cc)	1.73
Specific Gravity (G)	2.33
Liquid Limit (%)	30
Plastic Limit (%)	24
Average grain size (D50), (mm)	0.30
Coefficient of uniformity (Cu)	6.55
Coefficient of curvature (Cc)	1.16 (1 to 3 for well graded soil)
Classification as per Indian standard(IS 1498-1970)	ML
Typical soil classification	Silt

Table 4: Physical properties of fly ash, determined in lab are as follows:

Properties	Values
Specific Gravity	2.03
Optimum Moisture Content (%)	23
Maximum Dry Density (gm/cc)	1.38
Liquid Limit (%)	15.3
Flow Index	14.2

Table 5: Physical properties of pine needle used.

Properties	Values
Specific Gravity	0.651
Tensile Strength (kPa)	1.25×105
Water absorption (%)	35.3
Length (mm)	20
Diameter (Avg)	0.75
Aspect ratio	27
Colour (when dry)	Brown

Table 6: Chemical properties of pine needles used.

Properties	Values
Lignin	34.407 %
Holocellulose	68.86 %
Ash	1.61 %
Extractives	15.7 %
Pentosan	10.00 %

4.2 Study conducted on soil mixtures with or without fly ash& pine needle

Tables 7 & 8 clearly indicate that OMC increases with the increase in FA content but MDD decreases on admixing of fly ash into silty. However, the OMC & MDD of the soil mixtures both decreases with the increase in pine needle content. Similarly the OMC & MDD of soil mixtures including both FA as well as pine needle also decreases with the increase in content of FA & PN both.

Table 7: OMC &MDD test results of soil samples on different aspect ratio (Soil + FA)

Mix Designations	Proctor Test (Soil + FA)	
	OMC (%)	MDD (g/cc)
S 1	16.12	1.632
S 2	16.17	1.612
S 3	17.36	1.569

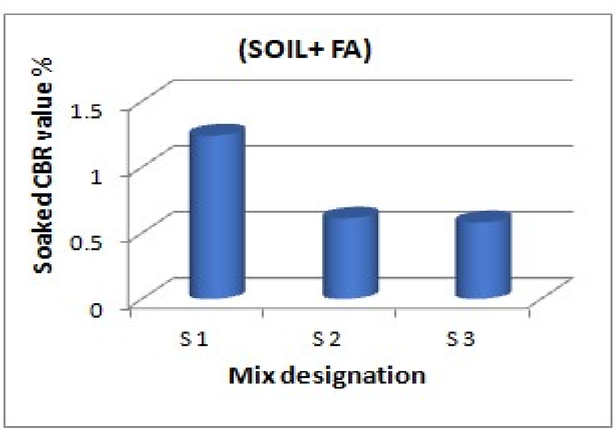
Table 8: OMC &MDD test results of soil samples on different aspect ratio (Soil+ PN)

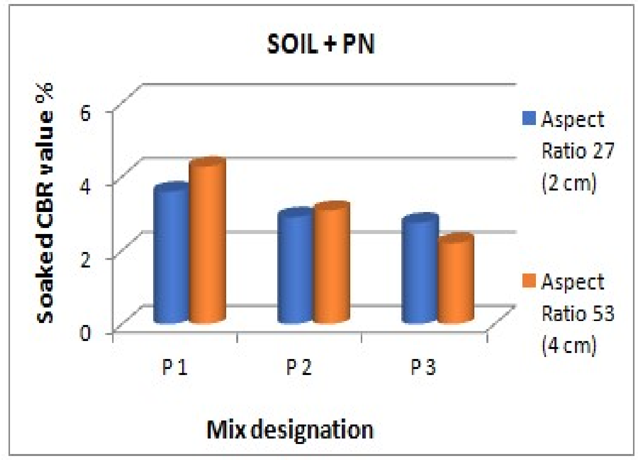
Mix Designations	Proctor Test (Soil+ PN)			
	Aspect Ratio 27 (2 cm)		Aspect Ratio 53 (4 cm)	
	OMC (%)	MDD (g/cc)	OMC (%)	MDD (g/cc)
P 1	15.68	1.633	15.46	1.932
P 2	15.98	1.628	15.00	1.916
P 3	15.35	1.598	15.57	1.874

Table 9: OMC &MDD test results of soil samples on different aspect ratio (Soil+ PN + FA)

Mix Designations	**Proctor Test (Soil+ PN+ FA)**			
	Aspect Ratio 27 (2 cm)		**Aspect Ratio 53 (4 cm)**	
	OMC (%)	**MDD (g/cc)**	**OMC (%)**	**MDD (g/cc)**
Q 1	14.54	1.843	16.26	1.598
Q 2	16.73	1.805	16.29	1.562
Q 3	16.94	1.575	16.70	1.556

Fig 4 shows the soaked CBR values of the different soil mixtures which exhibits a reduction in soaked CBR value with the increase in content of PN & FA. However, in case of soil mixtures having soil + PN + FA with 53 aspect ratio the CBR value increases with the increasing content of both PN as well as FA.





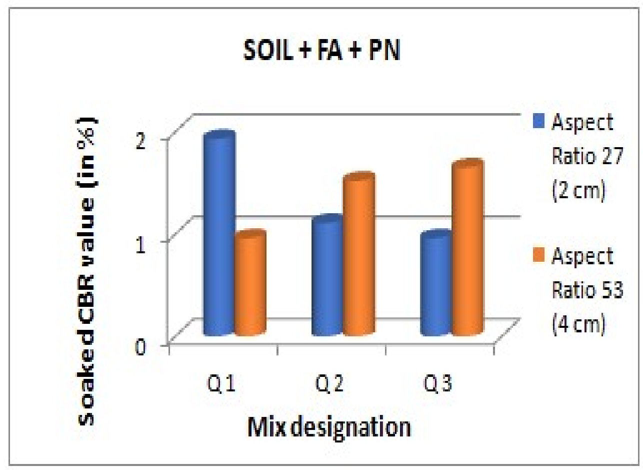
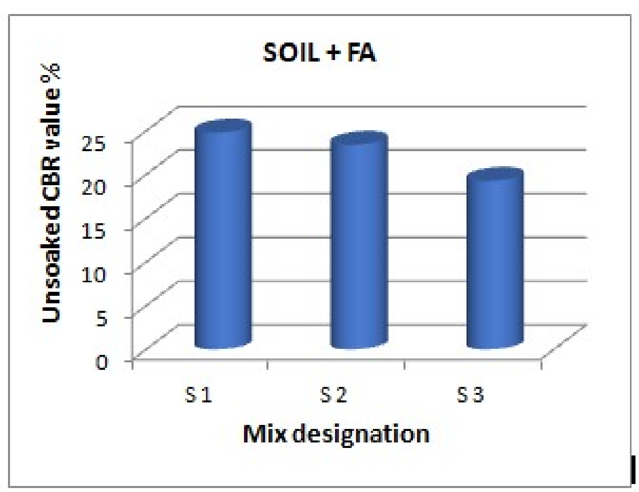


Figure 4: Soaked CBR test results of various soil mixtures designated on aspect ratio 27 & 53

Similarly, Fig 5 shows the unsoaked CBR values of the different soil mixtures which shows a reduction in the CBR value with the increase in content of PN & FA. However, in case of soil mixtures having (soil + PN) with 27 aspect ratio the CBR value increases with the increasing content of pine needle.



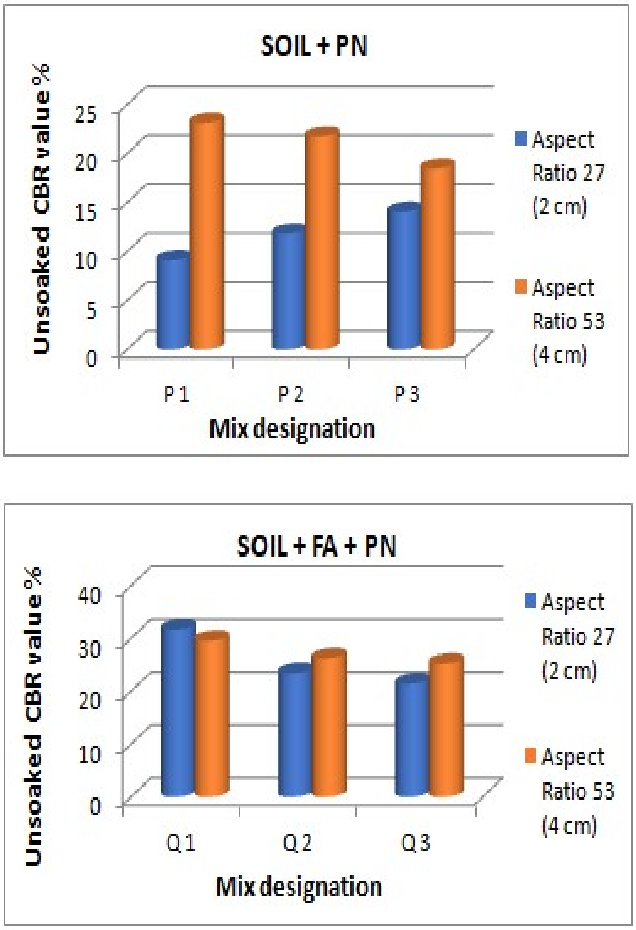
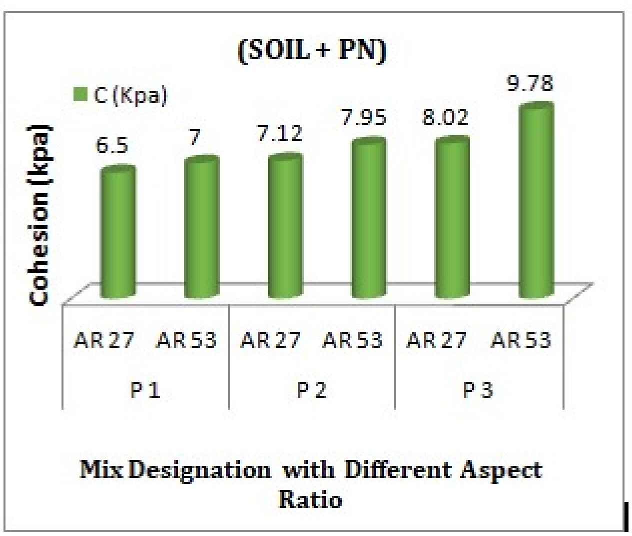


Figure 5: Unsoaked CBR test results of various soil mixtures with aspect ratio 27 & 53.

Fig 6 clearly shows that the cohesion as well as angle of internal friction of the soil mixtures (SOIL + PN) at different aspect ratio (27 & 53) increases with the increase in PN content.



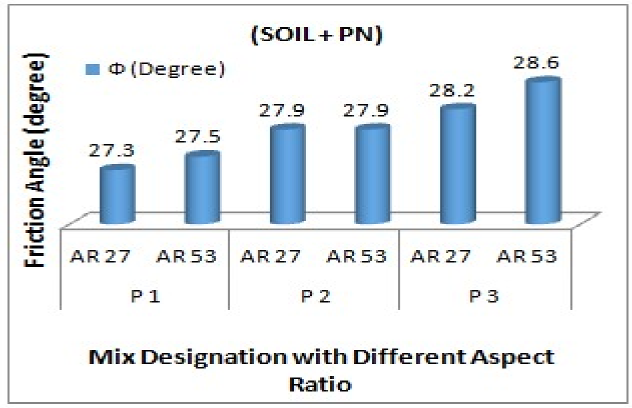


Figure 6: Cohesion & angle of internal friction of soil samples on different aspect ratio (SOIL+PN)

Similarly, Fig 7 also depicts the cohesion as well as angle of internal friction of the soil mixtures (SOIL + PN + FA) with aspect ratio (27 & 53) increases with the increase in PN & fly ash content incorporated in the soil mixtures.

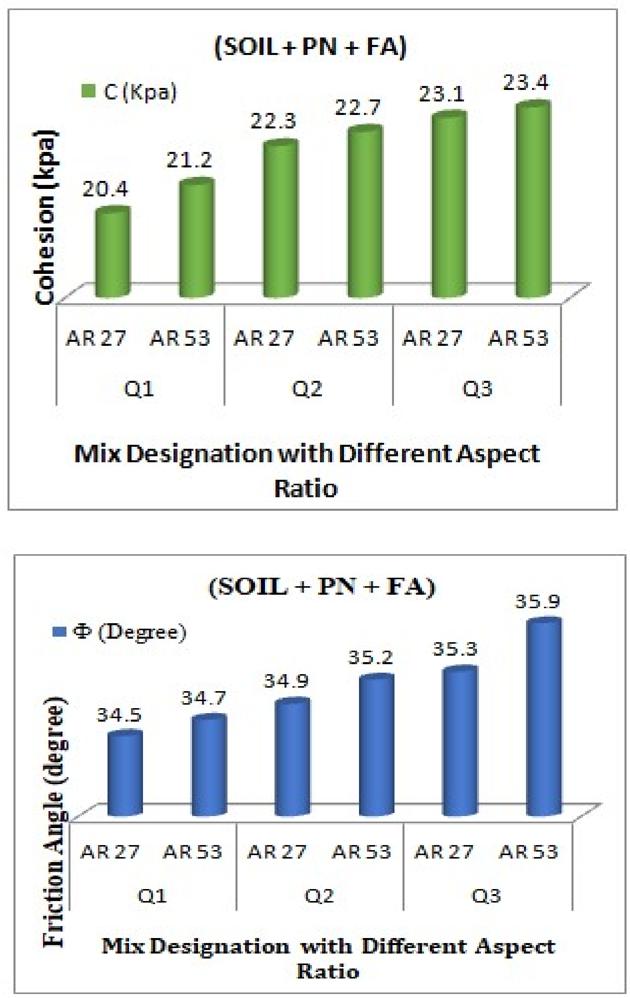


Figure 7: Cohesion & angle of internal friction of soil samples on different aspect ratio (SOIL + PN + FA).

V. CONCLUSION

The following conclusions have been drawn from the present laboratory studies:

Inclusion of pine needle reduces both OMC & MDD as well as soaked CBR value irrespective of its aspect ratio. But in case of soil mixtures having soil + PN + FA with 53 aspect ratio the CBR value increases with the increasing content of both PN as well as FA.

Soil engineering properties like angle of internal friction and cohesion increases considerably on admixing of pine needle irrespective of aspect ratio. However, the increase of internal friction and cohesion was more pronounced for 53 aspect ratio in comparison to 27 aspect ratio.

Substantial improvements in angle of internal friction & cohesion values were observed when both FA & PN are admixed together into silty soil. This analysis clearly infers that inclusion of certain amount of fly ash would be beneficial towards the enhancement of internal friction & cohesion values in pine needle reinforced soil mass.

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