APPLICATION OF FIBERS FROM SABAI GRASS IN CONSTRUCTION OF SUBBASE OF ROADS IN CONJUNCTION WITH SANDS

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ABSTRACT

In many parts of the world, large amount of construction of roads are going on. Such constructions require massive quantity of good brickbats for subbase in conventional construction of road. But the production of bricks is being limited due to non-availability of suitable soils and dearness of energy. In view of this there is growing need for use of alternate materials for making sub base in place of brickbats. In this context, use of sand as an alternate material may be advocated. However, to improve the strength of such laid sands, further, random mixing of some Geotextile fiber are also suggested. Natural fibers from sabai grass are biodegradable, eco-friendly and are available in abundance in many countries at very low cost. It can be used as additive material in the sub base course employing sand to result possible increase in strength and decrease in deformability. A systematic experimental program has been undertaken for improvement of compactibility of sands, and increase in California Bearing Ratio (CBR) of such laid sand layers on mixing these geo-natural fibers in various proportions and lengths. The present investigation highlights the efficacy of construction of sub-base with sand and Sabai grass fibers composite system, as alternate material of construction.

Keywords: Sub-base, alternate material, random mixing, eco-friendly.

INTRODUCTION

Elaliopsis Binata, locally known as “Sabai grass” belongs to the family Poaceae, is very new-fangled fiber to be used as inclusive with soil for the improvement of soil strength. Sabai grass is spread in China, India, Pakistan, Nepal, Bhutan, Mayanmar, Thailand, Malaysia and Phillipines. In India it is mostly grown in the eastern part of the country embracing the states like West Bengal, Bihar, Jharkhand, Orissa etc. Thin and long leaves of the plant with high quality fiber constitute a major raw material for paper industries, also the flexibility and strength properties of the leaves are utilized for making ropes and other rope based utility items.

In flexible pavement, sub-base is conventionally constructed with brickbats. However due to scarcity of good clays to make brick, use of brick bats in construction of road subbase is being discouraged. Different locally available alternate materials are used for subbase construction of rural areas. But they may not be available in many areas. In this regard, sand may be used as alternate material for the construction of subbase (Singh and Prasad, 2004). To enhance the compactibility of sand as subbase material, some innovative methods are required to improve the mechanical properties of sand. Among the recent techniques, reinforcement in different forms is added to soils in order to improve their mechanical properties. Randomly distributed fibers in soil, is one of the latest techniques in which fibers of desired quality and type are added to the soil. In this technique the mixing of reinforcement in the soil is very easy and no special skill is required.

In this regard preliminary research of using locally available natural sabai grass fiber reinforced sand shows possibility to improve the compactibility of the sand, to develop high CBR value and to sustain the compactness.

REVIEW OF PAST WORKS

Improving properties of soils with inclusion of reinforcements of different forms, texture and stiffness, is now well accepted practice in civil engineering construction after Vidal (1969) established the principle of reinforced earth. Materials of earth reinforcements of low modulus included to effect overall engineering properties of soils, generally consist of natural and synthetic fibers and used in the form of fabrics of various variety, manufactured specifically to suit different situations in the field. Technology of application of such reinforcements are now well established and large body of technical literature in the area, is available and oriented fabric layer of geotextile are now widely used in engineering practice (Gray and Al-Refeal,1986). On the contrary use of random fibers in soil is sparsely represented though use of such reinforcement probably started from the beginning of construction of mud shelter houses in early days of civilization at many places of the world.

Varghese et al. (1989) investigated the possibility of increasing the bearing capacity of cohesionless soils by reinforcing with coconut fibres through model studies. It has been observed that the bearing capacity of foundation soil will be maximum when the reinforcement is kept at a depth of 0.41 times the width of the foundation. Fiber stabilization technique in sand has been introduced for air field and road construction. Laboratory and field studies to quantify the effects of numerous variables on the performance of fiber stabilized sand layers where sand was mixed with fibres randomly, had shown improvement in load carrying capacity, and improvement is shown to depend on material of fiber, aspect ratio of the fiber included etc. (Santoni and Webster, 2001). Rao and Balan (2000) after conducting Drained triaxial test on specimens of sand reinforced with coir fibres (25 mm and 50 mm) up to 1% reported a significant gain in strength parameters and stiffness.

Full scale field test on discrete fibre reinforced sand, conducted by Tingle et al (2002) indicated that fiber stabilized sands are viable as an alternate to traditional road construction materials for low volume roads.

The escalating costs of materials, energy and lack of resources have motivated engineers to opt for new alternate materials in new constructions or major works. Reinforcing the soil with short fiber appears to have great potential for application in roads when alternate materials are also used. Fiber reinforced flyash can be used as subbase in rural roads. Sreedhar et al (2009) reported experimental study on effect of including geotextile fibres in dry sand as random distributed. They observed phenomenal improvement on CBR value of sand when mixed randomly with such fiber of all length of different aspect ratios. However maximum improvement was noted in the order of 68% to 87% when 1.50% fiber was added with an aspect ratio of 10.

In the present investigation, efficacies of using natural sabai grass fiber in locally available sand have been studied. Results of the experimental study made with various length and proportion of above fiber mixed with different types of sand are reported in this paper.

MATERIALS AND TEST PROGRAMME

Sand

Locally available fine brown sand, medium brown sand, and Silver sand were used in this experimental study. The reason for choice of these types of sand was mainly for their easy availability in many parts of the world for possible use in practice.

Grass Fiber

Natural sabai grass fiber was collected from local market and processed by cutting into small pieces of length 5mm, 10mm and 20mm for use as fiber material and are shown in Figs 1 and 2. Fibers were randomly mixed in sand to form homogeneous mixture.

Fig. 1 Sabai grass was taken from field

To investigate the effect of inclusion of these natural fibers of various lengths and proportion, in different sands taken, a series of Standard Proctor tests and CBR tests have been conducted using Proctor mould and CBR mould as per I.S. codal provision. Different parameters considered in the experiments are given in the Table 1. The summary of the physical properties of sands and fibers are given in Tables 2 and 3, respectively.

Fig. 2 Sabai grass fiber cut into pieces of definite length.

Table1 Different parameters considered in the experiments

Type of fibres	Type of sands	% fiber	Fiber length (mm)
Sabai grass	Fine brown sand, Medium sand, and Silver sand	0.5, 1.0, 1.5, 2	5, 10, 20.

Table 2 Summary of physical properties of sands

Properties	Fine brown Sand	Medium brown Sand	Silver sand
Classification (IS)	SP	SP	SM
Specific gravity	2.632	2.65	2.542
Coefficient of uniformity, C_u	2.09	2.18	2.47
Maximum dry density (gm/cc)	1.623	1.625	1.588
Optimum moisture content (%)	15.3	14.5	15.5
California bearing ratio (%)	8.4	9.1	7

Table 3 Summary of physical properties of Sabai grass fibers

Tests	Sabai grass
Density (g/cc)	0.639
Diameter (mm)	0.955 (av.)

SAMPLE PREPARATION

The mixing of fibers and sand was done manually with proper care for preparing homogeneous mixture at each stage of mixing. It was found that the fibers could be mixed with soil more effectively in the moist state than in the dry state. The tests were performed for various combinations of soil fiber mixtures are given in Table 4.

RESULTS AND DISCUSSIONS

Standard Proctor tests and Unsoaked CBR tests have been conducted in the Laboratory. The results of these tests are given in the Table 5.

Effect of Fibers Inclusion on Standard Proctor Tests

The value of MDD and OMC obtained from the laboratory tests are given in Table 4 for sabai grass fibers.

Effect of Fiber Content on MDD for Different

Types of sand

The variation in MDD vs Fiber content curve are plotted for different types of sand mixed with various percentage of natural sabai grass fiber of varying length are shown in Fig. 3 to Fig. 5. The results show that as the fiber content increases, the maximum dry density decreases for all fine brown sand, medium brown sand, and silver sand.

Effect of Fiber Content on OMC for Different

Types of sand

The variation in Optimum moisture content vs Fiber content curve are plotted for different types of sand mixed with various percentage of natural sabai grass fiber of varying length are shown in Fig. 6 to Fig. 8. The results show that as the fiber content increases, the optimum moisture content increases for all fine brown sand, medium brown sand, and silver sand.

Effect of Fiber Length on MDD for Different

Types of sand

The variation in MDD vs Fiber length curve are plotted for different types of sand mixed with various length of natural sabai grass fiber of varying percentage are shown in Figs. 9 to 11. The results show that as the fiber length increases, the maximum dry density decreases for all fine brown sand, medium brown sand, and silver sand.

Table 4 Details of sand fiber mix

Type of Sand used	Length of Sabai grass Fiber	Fiber Content (with respect to weight of dry sand)
Fine brown Sand	20mm	0.5%, 1.0%, 1.5% & 2.0%
	10mm	0.5%, 1.0%, 1.5% & 2.0%
	5mm	0.5%, 1.0%, 1.5% & 2.0%
Medium brown Sand	20mm	0.5%, 1.0%, 1.5% & 2.0%
	10mm	0.5%, 1.0%, 1.5% & 2.0%
	5mm	0.5%, 1.0%, 1.5% & 2.0%
Silver sand	20mm	0.5%, 1.0%, 1.5% & 2.0%
	10mm	0.5%, 1.0%, 1.5% & 2.0%
	5mm	0.5%, 1.0%, 1.5% & 2.0%

Table 5 Summary of results of standard proctor tests and unsoaked CBR tests

Fiber length	% of Fiber	Fine brown sand		
		MDD	OMC	CBR
No fiber	0.0%	1.613	15.2	8.4
Sabai grass 0.5cm	0.5%	1.584	15.9	10.5
	1.0%	1.571	16.5	11.3
	1.5%	1.557	16.9	10.7
	2.0%	1.549	17.2	9.8
Sabai grass 1.0cm	0.5%	1.58	16	10.3
	1.0%	1.567	16.6	11
	1.5%	1.552	17.2	10.5
	2.0%	1.543	17.6	9.5
Sabai grass 2.0cm	0.5%	1.578	16.1	10.1
	1.0%	1.564	16.7	10.5
	1.5%	1.55	17.3	9.9
	2.0%	1.54	17.8	8.7
Fiber length	% of Fiber	Silver sand		
		1.588	15.6	7.2
Sabai grass 0.5cm	0.5%	1.572	16.1	8.8
	1.0%	1.563	16.8	9.3
	1.5%	1.554	17.5	8.7
	2.0%	1.542	17.8	7.7
Sabai grass 1.0cm	0.5%	1.569	16.2	8.6
	1.0%	1.558	16.9	9.2
	1.5%	1.549	17.6	8.4
	2.0%	1.538	17.9	7.5
Sabai grass 2.0cm	0.5%	1.566	16.4	8.4
	1.0%	1.553	17.2	9
	1.5%	1.545	17.6	8.1
	2.0%	1.534	18	7.3
Fiber length	% of Fiber	Medium brown sand		
		1.625	14.5	9.1
Sabai grass 0.5cm	0.5%	1.604	15.3	9.3
	1.0%	1.596	15.9	9.4
	1.5%	1.582	16.3	8.7
	2.0%	1.574	16.8	8.2
Sabai grass 1.0cm	0.5%	1.6	15.5	9.2
	1.0%	1.591	16.1	9.2
	1.5%	1.578	16.7	8.5
	2.0%	1.566	17.3	7.7
Sabai grass 2.0cm	0.5%	1.598	15.7	9.2
	1.0%	1.586	16.3	9.1
	1.5%	1.573	16.9	8.2
	2.0%	1.561	17.5	7.5

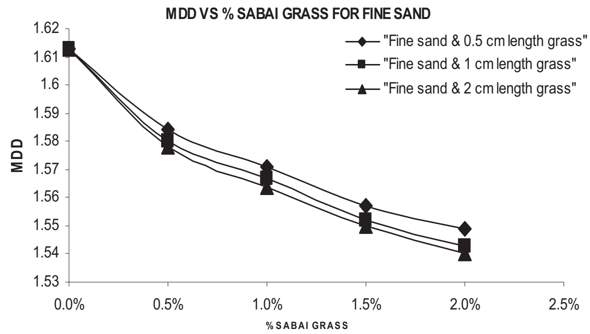

Fig. 3 Effect of fiber content on MDD for fine brown sand

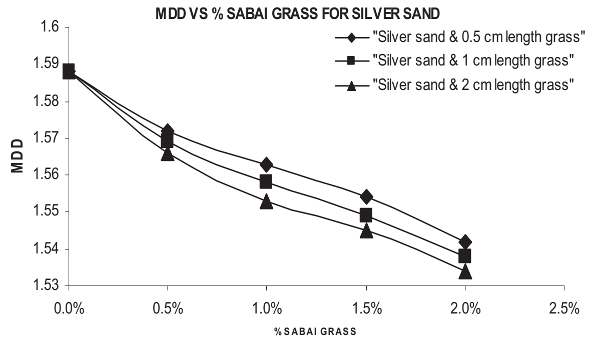

Fig. 4 Effect of fiber content on MDD for silver sand

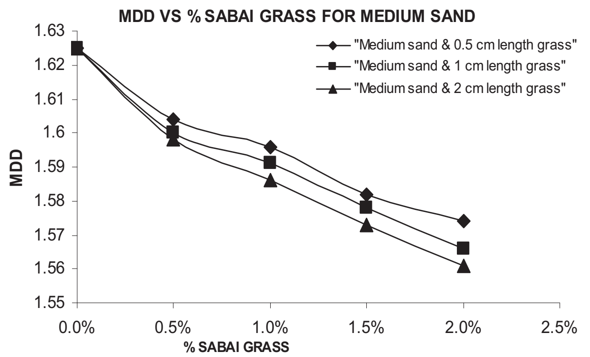

Fig. 5 Effect of fiber content on MDD for medium brown sand

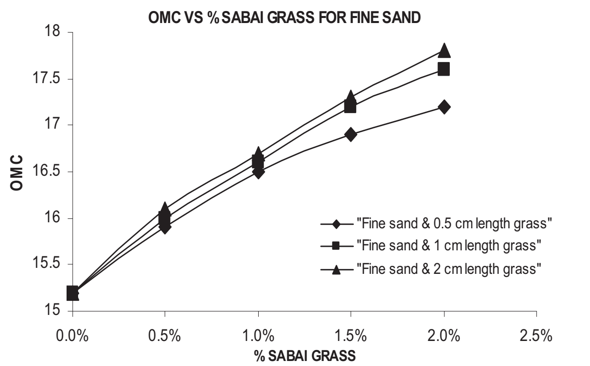

Fig. 6 Effect of fiber content on OMC for fine brown sand

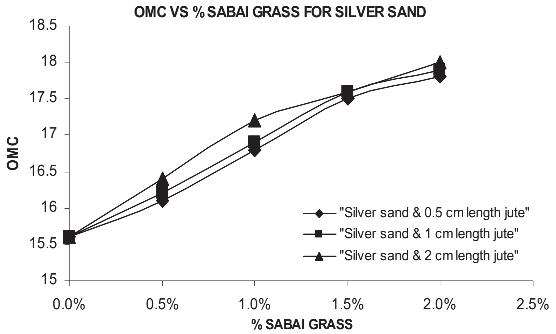

Fig. 7 Effect of fiber content on OMC for silver sand

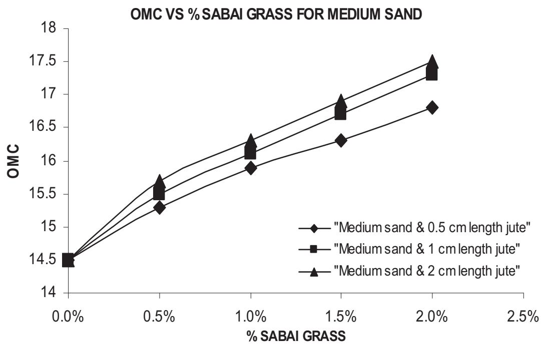

Fig. 8 Effect of fiber content on OMC for medium brown sand

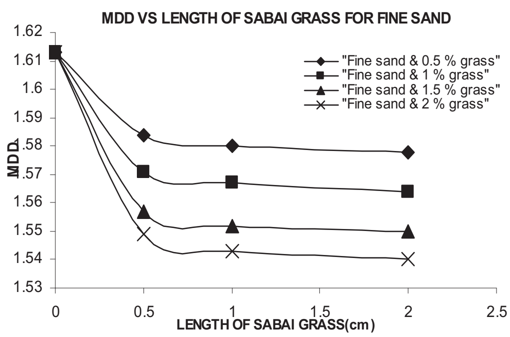

Fig. 9 Effect of fiber content on MDD for fine brown sand

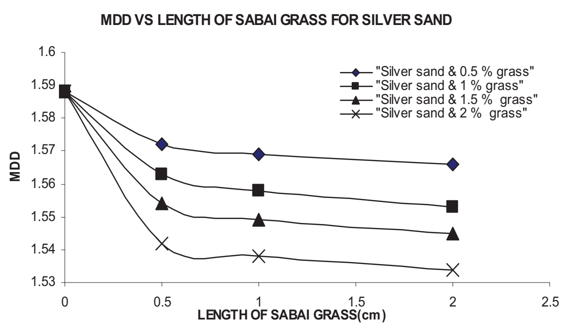

Fig. 10 Effect of fiber length on MDD for silver sand

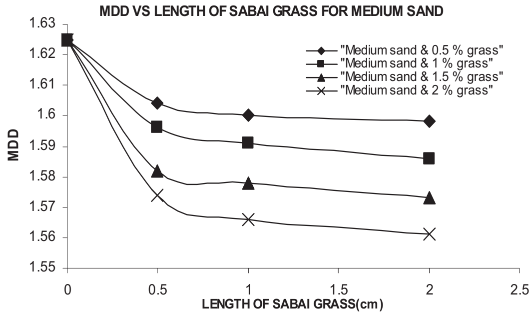

Fig. 11 Effect of fiber length on MDD for medium brown sand

Effect of Fiber Length on OMC for Different Types of Sand

The variation in OMC vs Fiber length curve are plotted for different types of sand mixed with various length of Sabai grass fiber of varying percentage are shown in Figs. 12 to 14. From figures as the fiber length increases, the optimum moisture content increases for all fine brown sand, medium brown sand, and silver sand.

The decrease in density is most likely a result of the fiber having less specific weight in comparison with the sand grains. The increase in moisture content is most likely the result of the fibers having a greater water absorption capacity than the surrounding sand.

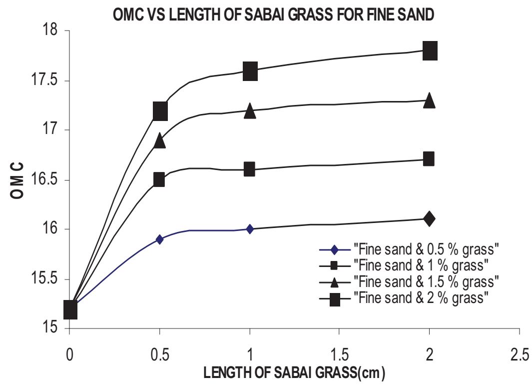

Fig. 12 Effect of fiber length on OMC for fine brown sand

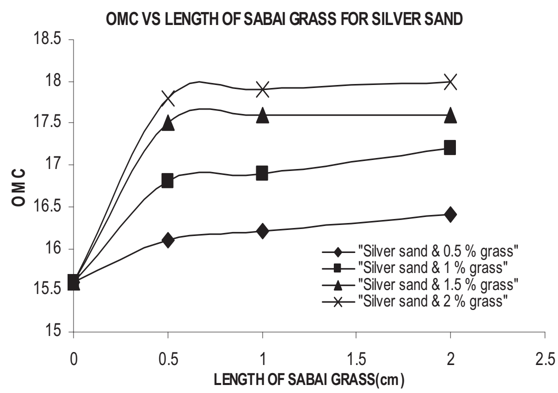

Fig. 13 Effect of fiber length on OMC for silver sand

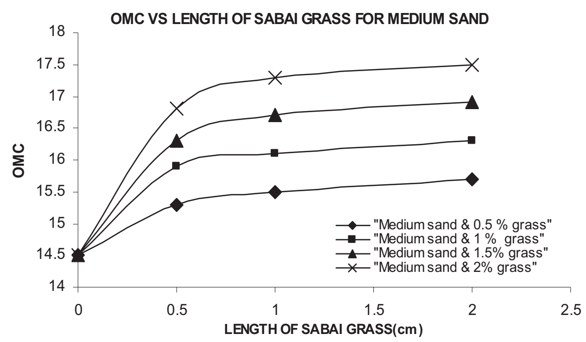

Fig. 14 Effect of fiber length on OMC for medium brown sand

Effect of Fibers on California Bearing Ratio Test

The CBR values obtained from laboratory tests are given in Table 4.

Effect of Fiber Content on CBR for Different Types of Sand

The CBR vs sabai grass fiber content curve for different types of sand mixed with various percentage of natural sabai grass fiber of varying length are shown in Figs. 15 to 17. From the CBR results, it can be observed that the CBR values increases with the increase in fiber inclusion (%) up to a maximum limit, after that it decreases for all fine brown sand, medium brown sand, and silver sand. CBR value is maximum for 1.0% of fiber inclusion of the dry weight of sand for all three types of sand.

The decrease of CBR value above optimum content may be due to the fact that, at that fiber content, fiber quantities are higher enough to effect more fiber-fiber interaction than fiber-sand interaction.

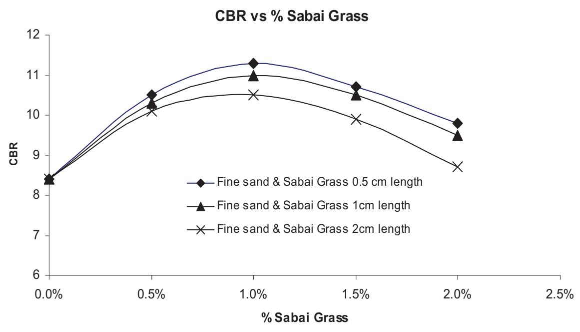

Fig. 15 Effect of fiber content on CBR for fine brown sand.

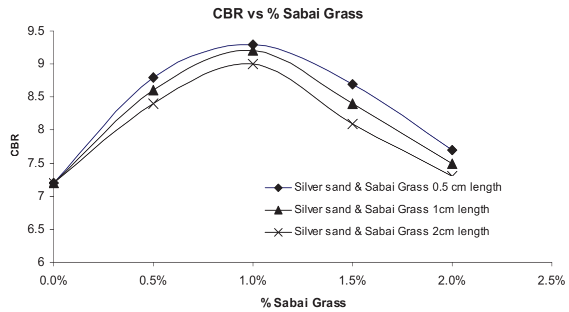

Fig. 16 Effect of fiber content on CBR for silver sand.

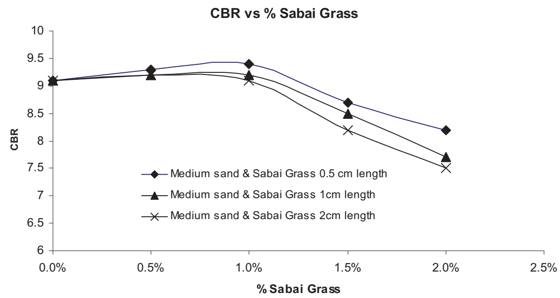

Fig. 17 Effect of fiber content on CBR for medium brown sand.

Effect of Fiber Length on CBR for Different Types of Sand

The CBR vs length of sabai grass fiber curve for different types of sand mixed with various length of natural sabai grass fiber of varying percentage are shown in fig. 18 to fig. 20. From the CBR results, it can be observed that the CBR values increases with the increase in fiber length of 5mm, after that it decreases for all fine brown sand, medium brown sand, and silver sand. This increase is more predominant for silver sand.

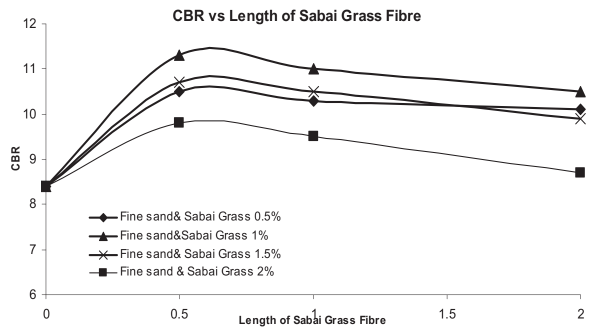

Fig. 18 Effect of fiber length on CBR for fine brown sand.

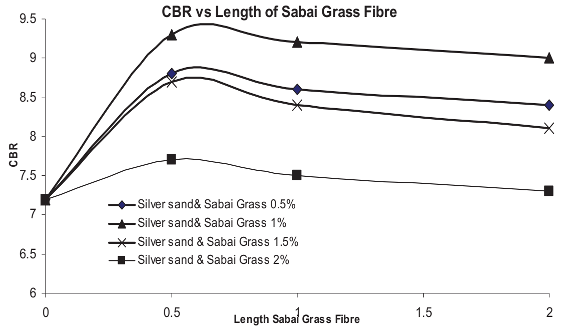

Fig. 19 Effect of fiber length on CBR for silver sand

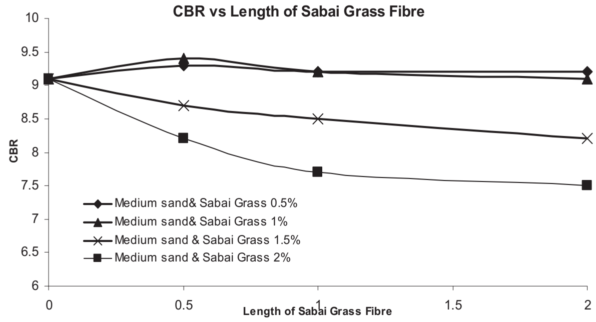

Fig. 20 Effect of fiber length on CBR for medium brown sand.

Improvement in CBR by CBR Ratio

The improvement in CBR values due to inclusion of fiber has been expressed by the ratio of $\left(\frac{\text{CBR with fiber}}{\text{CBR without fiber}}\right)$. The $\left(\frac{\text{CBR with fiber}}{\text{CBR without fiber}}\right)$ ratio vs fibre content for fine brown sand, silver sand, and medium brown sand are shown in fig. 21, fig. 22 and fig. 23 respectively.

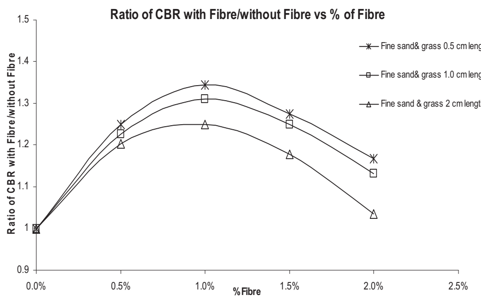

Fig. 21 Effect of Fiber content on CBR ratio for Fine brown sand

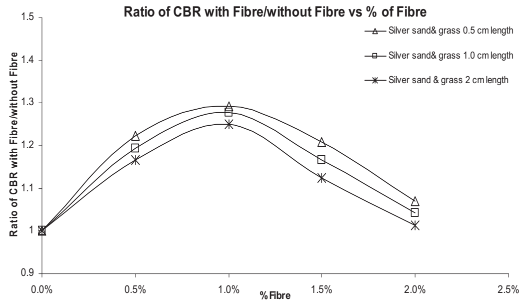

Fig. 22 Effect of fiber content on CBR ratio for silver sand

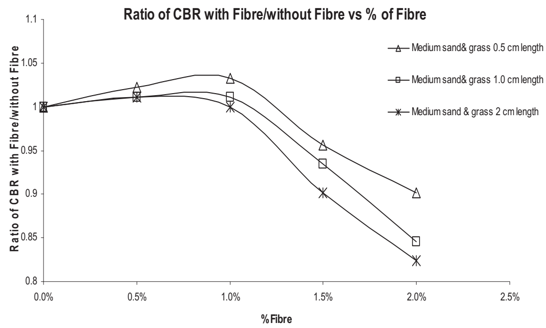

Fig. 23 Effect of fiber content on CBR ratio for medium brown sand

REGRESSION ANALYSIS

Regression analysis is a statistical technique for modeling the relationship between two or more variables. A number of techniques can be used to indicate the adequacy of a multiple regression model. One of these technique for multiple regression may be carried out with R-squared values. During regression analysis, a regression model with higher R-squared value is usually accepted.

For studying the effect of inclusion of Sabai grass fibers in different sands, regression analysis was carried out to correlate different compaction characteristics like Maximum dry density, Optimum Moisture content and CBR value of such sands.

Effect of Fiber on MDD for Different Types of Sand

The multiple linear regression equations generated to predict Maximum Dry Density (MDD) value in gm/cc with certain fiber content and fiber length for fine brown sand, silver sand, and medium brown sand (with R^2 value ranging from 0.965 to 0.993). The relevant equations are as given below,

For fine brown sand:
MDD = 1.6044 – 2.77349 (% of fiber) – 0.00067 (length of fiber in mm) ------ (1)
For silver sand:
MDD = 1.58642 – 2.086(% of fiber) – 0.00057(length of fiber in mm) ------ (2)
For medium brown sand:
MDD = 1.62205 – 2.38512(% of fiber) – 0.00068(length of fiber in mm) ------ (3)

Effect of Fiber Content on OMC for Different Types of Sand

The multiple linear regression equations generated to predict Optimum Moisture Content (OMC) value with certain fiber content and fiber length for fine brown sand, silver sand, and medium brown sand are given in the following form (with R^2 value ranging from 0.978 to 0.987) respectively as given below,
For fine brown sand:
OMC = 15.24419 + 104.13953(% of fiber) + 0.02289(length of fiber in mm) ------ (4)
For silver sand:
OMC = 15.58605 + 111.53488(% of fiber) + 0.01608(length of fiber in mm) ------ (5)
For medium brown sand:
OMC = 14.53721 + 113.90698(% of fiber) + 0.03379(length of fiber in mm) ------ (6)

Effect of Fibers on California Bearing Ratio Test

The regression equations generated to correlate California bearing ratio (CBR) value with fiber content are given in general form as below-

$$CBR = \alpha .\, P^2 + \beta .\, P + \gamma$$

where P= Fiber content in percentage, CBR = California bearing ratio and α, β and γ are three constants.

To obtain α, β and γ values for different fiber lengths, the regression equations generated correlating α, β and γ values with fiber length, are given below for different fiber-sand mixes.
Sabai grass and fine brown sand mix:
$\alpha = -11.433x^2 + 400.1x - 22858$ ------ (7)
$\beta = 0.1219x^2 - 8.801x + 523.82$ ------ (8)
$\gamma = 8.4$
Sabai grass and silver sand mix:
$\alpha = 13.335x^2 - 371.46x - 4761.8$ ------ (9)
$\beta = 0.1047x^2 - 6.999x + 410.38$ ------ (10)
$\gamma = 7.0$
Sabai grass and medium brown sand mix:
$\alpha = -1.9x^2 + 199.9x - 18952$ ------ (11)
$\beta = -0.0667x^2 + 0.0286x + 79.238$ ------ (12)
$\gamma = 9.1$

CONCLUSIONS

From the experimental investigation reported above, following conclusions may be drawn.

1. In all the types of sands used in the investigation the value of MDD decreases and value of OMC increases with the increase of sabai grass fiber content mixed randomly.
2. There is a considerable increase in the CBR value for the all types of sands used i.e. fine brown sand, silver sand and medium brown sand when mixing with randomly distributed natural sabai grass fiber.
3. CBR value is maximum for fiber length of 5mm for Sabai grass fibers used. And the optimum percentage inclusion may be considered as 1.0% of the dry weight of sand.
4. The improvement in CBRI due to sabai grass fiber inclusion is more in fine sand with respect to silver sand.
5. The multiple linear regression equations generated to predict Maximum Dry Density (MDD) value in gm/cc with certain Fiber content and fiber length for Fine brown sand, Medium brown sand, and Silver sand are given in the equation from 1 to 3 with R^2 value range from 0.965 to 0.993.
6. The multiple linear regression equations generated to predict Optimum Moisture Content (OMC) value in percentage with certain Fiber content and fiber length for Fine brown sand, Medium brown sand, and Silver sand are given in the equation from 4 to 6 with R^2 value range from 0.978 to 0.987.
7. The regression equations generated to correlate California bearing ratio (CBR) value with fiber content are given in general form as below

$$CBR = \alpha .\, P^2 + \beta .\, P + \gamma$$

where P= Fiber content in percentage, CBR = California bearing ratio.
The values of α, β and γ for Fine brown sand, medium brown sand, and Silver sand mixed with fiber are given in the equation from 7 to 12.

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