Effect of Clinker and Fibre content on Geotechnical Properties of Sandy soil

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Abstract- *Scarcity of suitable land and unavailability of good quality construction soil lead to the implementation of various ground reinforcement techniques. The strength of soil can be improved by adding conventional continuous reinforcement inclusions in desired directions in a defined pattern, or by mixing short discrete fibres randomly within the soil mass. This study is conducted to investigate the variation in optimum moisture content, maximum dry density and shear strength parameters of two different types of sand treated with clinker residue, reinforced with randomly distributed glass fibres (length 12 mm) by carrying out Standard Proctor test and Direct Shear test. Five combinations of soil-clinker-fibre composite are prepared and analysed. The result of laboratory tests shows an increase in internal friction angle and slight variations in cohesion. The OMC decreased up to a certain ratio and then increased, and MDD value first increased rapidly and then gradually decreased.*

Keywords- Synthetic fibres; Stabilization; Orientation; Friction angle; Cohesion

I. INTRODUCTION

Soil has been used as a construction material for a long period of time. Being poor in mechanical properties, it has been putting challenges to civil engineers to improve its properties depending upon the requirement which varies from site to site. Soil stabilization is the process of altering properties of soil by changing the gradation by mixing it with different admixtures to improve strength and durability.

Mechanical properties of granular materials depend on the material properties of solid particles, the nature of the contacts between their solid particles and the interaction between void, solid and liquid phases. Fibre reinforcement causes significant improvement in tensile strength, shear strength, and other engineering properties of soil. Shear strength of granular material is provided by cohesion and frictional resistance at the particle interfaces. Chemical stabilization offers better strength and improved soil quality. A considerable reduction in consolidation settlement and improved compressibility characteristics were observed in chemical stabilization.

The main objective of this study is to investigate the behaviour of two types of sand with different particle sizes, reinforced by randomly distributed glass fibre and treated with clinker residue. It should be noted that earlier studies on composite materials (soil-fibre-clinker) are very limited in terms of shear strength improvement. In order to find the effect of variation in clinker-fibre content on the shear strength of poorly graded sandy soils, a series of direct shear tests were carried out.

II. LITERATURE REVIEW

Ahad Ouria., (2016) conducted study on Shear strength of fibre reinforced silty sand. In this study the shear strength of silty sand reinforced by glass fibres is investigated in the laboratory. The effect of fibre content and fibre length on the cohesion and friction angle of the improved soil was investigated using large scale direct shear test. The results of the laboratory tests indicate that the addition of glass fibres increases the shear strength of the soil increasing both cohesion and internal friction angle.

Patel et al., (2017) conducted the study on the Shear strength response of glass fibre-reinforced sand with varying compacted relative density. Triaxial compression tests were conducted to investigate the response to loading of glass fibre-reinforced sandy soil of varying relative densities (35, 65 and 85%). The strength of specimens increases up to an optimum fibre content value of 3 or 4% depending on length.

Sun et al (2018) studied on the Strength Characteristics of Glass Fibre-Reinforced Sand. The strength characteristics of glass fibre-reinforced sand composite are influenced by the controlling parameters of fibre content and confining pressure. A series of triaxial experiments were carried out to study on the behaviours of unreinforced and glass fibre-reinforced sand. The results show that glass fibres insertion can prevent the formation of the strain localization, provide an increase in strength and shearing strength parameters. The cohesion changed more significantly than internal friction angle due to the glass fibres insertion. It is shown that the inclusion of fibres increases the contact surface between soil particles and fibres, but it has not a strong influence on the roughness and staggered arrangement of soil particles.

Shukla et al (2019) studied about the Use of Fibre Reinforcement in Soil for Sustainable Solution of Infrastructure. Roads are an inevitable component of the economic development of the city and fetch important social benefits. It shows that effective construction and maintenance of road infrastructure is essential to preserve and enhance those benefits.

Bouaricha et al., (2018) conducted a laboratory investigation on shear strength behavior of sandy soil - effect of glass fiber and clinker residue content to investigate the shear strength parameters of treated sands reinforced with randomly distributed glass fibres by carrying out direct shear test after seven days curing periods. The test results show that the combination of glass fiber and clinker residue content can effectively improve the shear strength parameters of soil in comparison with unreinforced soil. For instance, there is a significant gain for the cohesion and friction angle of reinforced sand of Chlef. Compared to unreinforced sand, the cohesion for sand reinforced with different ratios of clinker residue increased by 4.36 to 43.08 KPa for Chlef sand and by 3.1 to 28.64 KPa for Rass sand.

III. MATERIALS

A. Sand

TABLE 1
Properties of Sea sand

Properties	Result
D_{10} (mm)	0.300
D_{60} (mm)	0.460
D_{30} (mm)	0.370
Uniformity Coefficient, C_U	1.533
Coefficient of Curvature, C_C	0.992
Specific Gravity	2.64
Optimum Moisture Content	8%
Maximum Dry Density (g/cc)	1.68
Angle of Shearing Resistance	39^o
Cohesion (kg/cm^2)	0.2
Classification of soil	SP

TABLE 2
Properties of River sand

Properties	Result
D_{10} (mm)	0.175
D_{60} (mm)	0.390
D_{30} (mm)	0.252
Uniformity Coefficient, C_U	2.228
Coefficient of Curvature, C_C	0.930
Specific Gravity	2.54
Optimum Moisture Content	10.26%
Maximum Dry Density (g/cc)	2.11
Angle of Shearing Resistance	40^o
Cohesion (kg/cm^2)	0.09
Classification of Soil	SP

River sand (RS) and sea sand (SS) are used in this study. River sand was collected from the banks of the river Neyyar and sea sand was collected from Kazhakuttom in Thiruvananthapuram district, Kerala. The properties of soil are determined using standard procedures and the results are tabulated in table 1 and 2. From the test results, the soil can be classified as poorly graded sand according to Indian Standard Classification system.

B. Glass fibre

TABLE 3
Properties of Glass Fibre

Properties	Value
Colour	Whitish
Length (mm)	12
Diameter (mm)	0.15
Aspect ratio	80
Specific gravity	2.57
Number of fibre (million/kg)	235
Composition	SiO_2,Al_2O_3,CaO

Glass fibre is collected from Malaika International, Jaipur. It is a material consisting of numerous extremely fine fibres of glass. It is an ideal product for construction and stone industry, easy to handle and use. It does not emit toxic and harmful substances. Glass fibres are therefore used as reinforcing agent for many polymer products. This material contains little or no air or gas, is denser. It can also be used as a reinforcement material with high tensile strength, resistant to alkalis, fire resistant, good chemical properties, and excellent durability, anti-leakage performance, lower price, does not decompose and will not rust over time.

The primary objective of using fibre as soil-reinforcement is to improve the bearing capacity by improving the shear strength of the soil. Soil can be reinforced in many ways by mixing different types of fibre. Many investigations were carried out to study the influence of various types of fibre on shear strength of soil. Vidal (1969) first gave the concept of soil reinforcement. He showed that the shear resistance of fibre reinforced soil mass is a function of friction between soil particle and the fibre.

C. Clinker residue

Powdered clinker residue obtained from a local supplier was used throughout this investigation. They are dust that comes from rotary furnace, obtained after crushing and homogenization of raw materials (limestone (80%) and clay (20%)). The clinker dust accumulates in great amounts in environment. It is cost-competitive compared to other materials and are simply added and mixed with the soil, much like cement, lime, fly ash or treated using other chemical stabilization methods.

TABLE 4
Properties of Clinker residue

Properties	Result
Colour	Dark greyish
Size (mm)	0.1mm- 2mm
Specific gravity	3.26
Type	Type 1 Portland cement clinker
Grade	43
Composition	SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, SO_3

IV. METHODOLOGY

The index properties of soil were determined as per the respective IS Codes. The additives consists of powdered clinker residue and glass fibre of length 12 mm and diameter 0.15 mm. Five combinations of clinker and fibre content in ratio is taken (0%C:0%F, 3%C:1%F, 6%C:0.75%F, 9%C:0.5%F, 12%C:0.25%F). For determining the shear parameters of the soil oven dried soil was mixed with the required amount of additive ratios, filled onto the shear box for direct shear test. A clinker- fibre ratio parameter (CFR) is derived and graphs are plotted on the variation of compaction characteristics and shear strength parameters with respect to that ratio.

$$CFR = \frac{Percentag}{Percentaj}$$

V. RESULTS AND DISCUSSIONS

A. Compaction characteristics

In the present investigation a series of compaction tests were carried out by varying clinker fibre ratios and its effect on OMC and MDD are shown in Fig.1 and 2. The data from the test indicates that the optimum moisture content of stabilized sand are less than that of raw sand. Five combinations of clinker – fibre content in percentages is added to the raw sample such as 0%C:0%F, 3%C:1%F, 6%C: 0.75%F, 9%C:0.5%F and 12%C:0.25%F. Addition of additives leads to a decrease in the optimum moisture content which can be taken as optimum value. Figure 2 shows the variation of maximum dry density of both the sands with clinker fibre ratio. Maximum dry density increased with additive content and then decreased after a particular ratio. This ratio can be taken as optimum value of maximum dry density. Increase in MDD may be due to the dense packing of clinker between the poorly graded soil grains.

TABLE 5
Variation in compaction characteristics

Clinker-Fibre ratio (CFR)	Soil sample	OMC (%)		MDD(g/cc)	
		RS	SS	RS	SS
0	RS+0%C+ 0%F	10.26	8	2.11	1.68
3	RS+3%C+ 1%F	10.1	7.5	2.3	1.75
8	RS+6%C+ 0.75%F	8.5	6.5	2.65	2.09
18	RS+9%C+ 0.5%F	9.4	7	2.55	2.02
48	RS+12%C+ 0.25%F	10	7.5	2.32	2.01

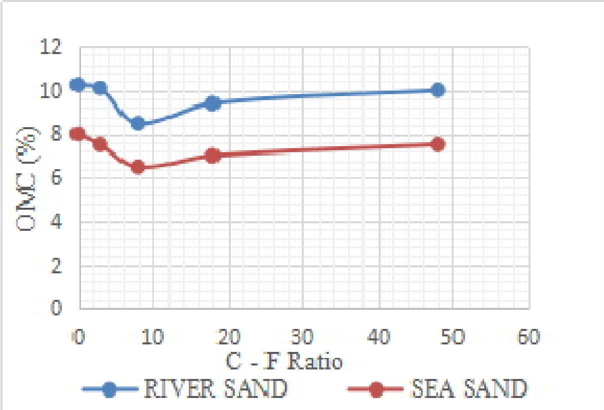

Fig. 1 Variation on OMC with different Clinker-Fbre Ratio

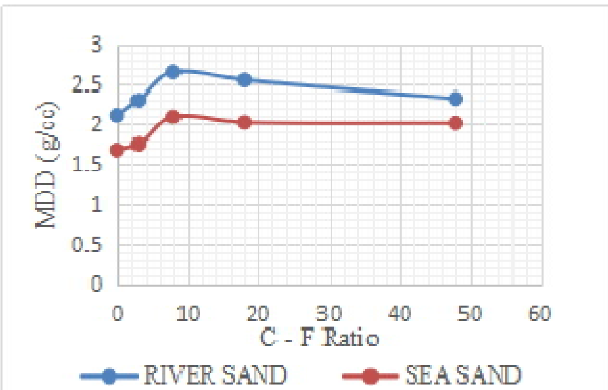

Fig. 2 Variation on MDD with different clinker-fibre ratio

B. Shear strength characteristics

TABLE 6
Variation in shear strength characteristics

Clinker-Fibre ratio (CFR)	Soil sample	Friction angle(degrees)		Cohesion (Kg/cm2)	
		RS	SS	RS	SS
0	RS+0%C+ 0%F	40	39	0.09	0.2
3	RS+3%C+ 1%F	46	43.7	0.21	0.31
8	RS+6%C+ 0.75%F	47.3	44.6	0.3	0.38
18	RS+9%C+ 0.5%F	47.8	44.9	0.28	0.37
48	RS+12%C +0.25%F	48	45	0.27	0.36

It is noted from the study that the shear parameters are affected by the addition of clinker fibre composite on to the sand. The angle of shearing resistance (φ) increased with and cohesion (c) was noted to vary with additive content.

Ahad et al., evaluated the response of fibre on the strength of reinforced silty sand. They reported that the cohesion increases with the increase in fibre content. Higher fibre content increase number and surface of fibre-sand particle contact, so that strength parameters of the composite material are larger. The increase in angle of friction was noted to be increased with the addition of the fibre content for both the sea and river sand. The increase in angle of friction is due to the increased contact and friction between the particles of sand and clinker fibre mixture. After a particular amount of fibre content, presence of high amount of fibre cause localized lumps to form during mixing which in turn affects proper compaction of soil sample. Slight reduction in cohesion may be caused by formation of lumps during mixing.

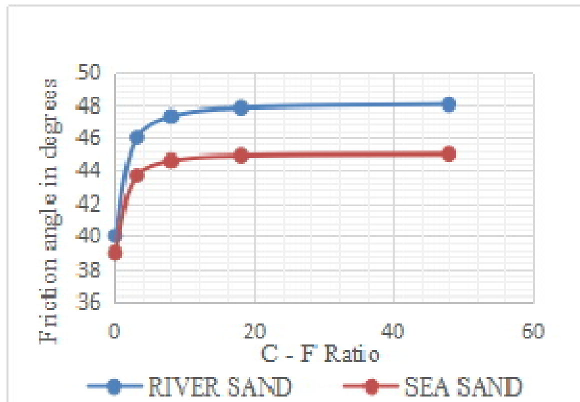

Fig. 5 Variation of Angle of friction with C-F Ratio

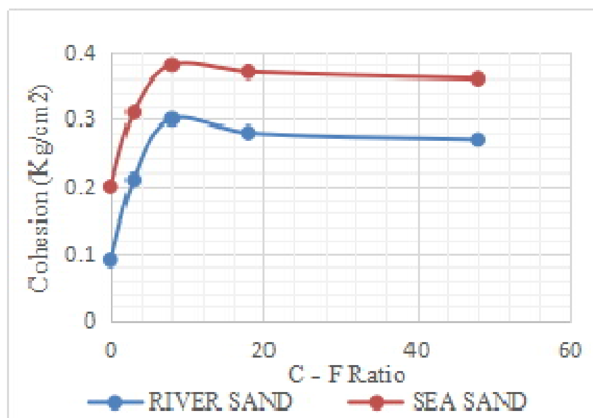

Fig. 6 Variation of Cohesion with C-F Ratio

VI. CONCLUSION

From the test results it was noted that:

- OMC decreased with increase in clinker fibre ratio up to 6%C: 0.75%F, then increased. As the clinker enters into the voids between soil particles, entrapping of water decreases which reduces the optimum moisture content.

- MDD value increased and then decreased at a particular clinker fibre content.
- Angle of internal friction increased with increase in C-F ratio. Cohesion value shows slight variations, it increased rapidly and then gradually decreased.

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