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Effect of Sand Content on Compaction Characteristics of Fine-grained Soil

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Abstract—*This paper deals with an experimental investigation on the effects of sand content on compaction characteristics of fine-grained soil. A fine-grained soil and sands of three different gradations: fine, medium, and coarse sand are taken for this study. The fine-grained soil is mixed with varying amounts of sand contents (ranging from 5%-30% of dry fine-grained soil) of different gradations and their compaction characteristics are investigated. All experiments are carried out conforming to the guidelines laid down in Indian standards. Compaction curves of parent soil and soil mixed with sand are presented and key aspects are highlighted. It has been observed that maximum dry density (MDD) of fine-grained soil consistently increases with increase in sand content and fine sand leads to the highest MDD. For soil containing 30% fine sand, MDD of 1705 kg/m^3 is achieved against the untreated value of 1520 kg/m^3, showing an increase of around 12%. In contrast, optimum water content (OMC) decreases with sand content. However, the diminishing trend is not consistent with the gradation of sand. Minimum OMC is obtained in case of soil containing 30% fine sand (18.6%) which is nearly 24% less than the untreated value.*

1. INTRODUCTION

Compaction is the process of application of mechanical energy to soil in order to rearrange its particles causing reduction in void ratio. The primary objectives of compaction are to increase the shear strength and bearing capacity, to decrease settlement, and to decrease the permeability of soil. Compaction is chiefly governed by water content, soil type, compactive effort imparted during compaction, and type of admixture used, if any. Soil is composed of particles of different sizes (clay, silt, sand, gravel etc.) and sizes of the constituent particles play an important role in the compaction process. Gravel and sand belongs to coarse-grained soils, whereas silt and clay falls in the category of fine-grained soils.

A good deal of research has been carried out on the effects of admixtures on soils. Some typical clayey soil properties like plasticity index, compressibility, unconfined shear strength etc. can be sufficiently improved by addition of admixtures [1-5]. However, soil stabilized with admixtures exhibits a lower maximum dry density (MDD) and higher optimum water content (OMC) than untreated soil with this trend more pronounced as admixture content increases [1, 3, 4, 6].

Several investigations have been carried out to study the effect on compaction characteristics of soils due to the addition of fines. Kim et al. [7] performed compaction tests on decomposed granitic soil and noted that MDD decreases and OMC increases with increase in fine aggregate content. Similar compaction characteristics were observed by Osinubi et al. [8] in their investigation on the effect of fines on reconstituted lateritic soils. A study on heavy compaction test on coastal dune sand with different proportions of plastic fines [9] shows that addition of 10% fines substantially increases the MDD of soil. In this investigation, the optimum value of fines to sand ratio is found to lie in the range of 0.2 to 0.3. Deb et al. [10] studied the effects of fines on compaction characteristics of poorly-graded sands. This study shows that the addition of fines up to a certain extent increases the MDD of poorly-graded sands and the uniformity coefficient of sand governs the critical amount of fines. Prasad and Pandey [11] conducted a study on the effects of fines on the mechanical behaviour of sands. It was found that addition of fines up to 30% causes increase in MDD and decrease in OMC of sand. Mujtaba et al. [12] carried out standard and modified Proctor tests to study the effect of finer content on compaction characteristics of sands. It was observed that, in general, MDD increases and OMC decreases with increase in finer content. However, MDD reaches its maximum value at a finer content of nearly 35% and beyond that it shows a diminishing trend.

On the other hand, very few attempts have been made to study the effect of sand on compaction characteristics of fine-grained soil. This issue was partly addressed in the investigations on the effect of sand content on engineering properties of fine-grained soil [13] and on effect of coarse-grained fraction on compaction characteristics of fine-grained soil [14]. It either of these studies, it was noted that addition of sand increases the MDD and decreases the OMC of fine-grained soil. Nevertheless, these two studies are not extensive and complete in all respect. Percentage increase/decrease in MDD and OMC of treated soil with respect to those of untreated soil, effect of gradation of sand etc. are yet to be studied. This pin-points the necessity of a further study in the domain.

In view of the above, an experimental investigation is carried out to study the effect of sand content on the compaction characteristics of a fine-grained soil. Sands of three different gradations: fine sand, medium sand, and coarse sand are taken in this study. The fine-grained soil is mixed with varying percentages of sands and the compaction characteristics are investigated. The percentage increase/decrease in MDD and OMC of treated soil with respect to the untreated soils are presented and salient observations are summarized.

2. MATERIALS AND METHODS

A locally available fine-grained soil sample is chosen for this study and its geotechnical parameters are furnished in Table 1. Specific gravity test, liquid limit and plastic limit, IS light compaction test (equivalent to standard Proctor test) are carried out conforming to the guidelines of relevant Indian standards [15-17]. Based on Indian standard plasticity chart of IS-1498: 1970 [18], the soil is classified as CI (clay of intermediate plasticity).

Table 1: Characterization of fine-grained sample

Parameter	Notation	Value
Specific gravity	G_s	2.71
% Finer	--	92.4%
% Sand	--	7.6%
% Gravel	--	0%
Liquid limit	LL	43.3%
Plastic limit	PL	22.6%
Plasticity index	PI	20.7%
Optimum water content	OMC	24.6%
Maximum dry density	MDD	1520 kg/m^3

Sand samples of three different gradations, i.e. fine sand (FS), medium sand (MS), and coarse sand (CS) are taken for this study. Sand samples of different gradations (FS: 0.075-0.425mm, MS: 0.425-2mm, CS: 2-4.75mm) were prepared by sieving sand on respective sieves [18]. Specific gravity tests are performed on these samples as per IS: 2720 (part 3)-1980 [15]. The grain-size distribution curves of fine and medium sands are depicted in Fig. 1. Grain-size distribution of coarse sand could not be incorporated as there is no intermediate sieve in between 4.75mm and 2mm.

The specific gravities (G_s) of these samples, their co-efficient of uniformity (C_u) and co-efficient of curvature (C_c) values are furnished in Table 2. All these three samples fall under the category of poorly-graded sand (SP) as per IS: 1498-1970 [18], owing to the fact that they do not contain particles of all sizes.

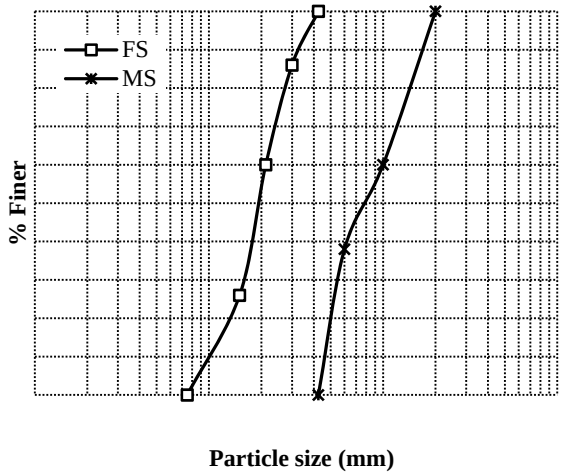


Fig. 1: Grain-size distribution curves of fine and medium sand

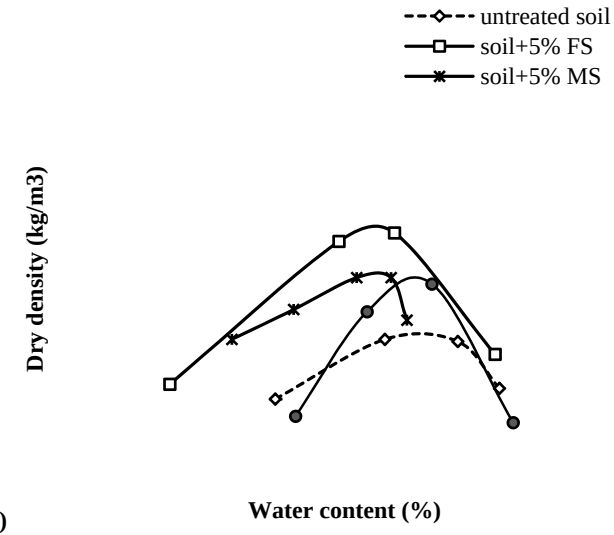
Table 2 Characterization of sand samples

Sand types	G_s	C_u	C_c	Group
Fine	2.65	2.10	1.22	SP
Medium	2.63	2.17	0.68	do
Coarse	2.62	--	--	do

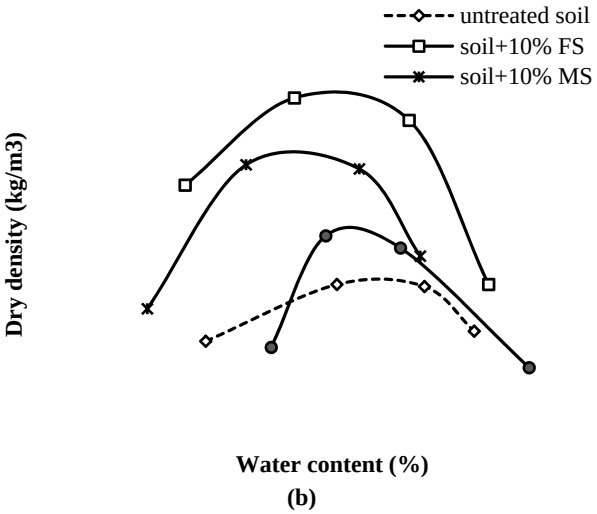
The compaction characteristics of the fine-grained soil is first determined by performing IS light compaction test [17] as shown in Table 1. In the subsequent step, sands of varying amounts (5%, 10%, 15%, 20%, and 30% of weight of dry fine-grained soil) are thoroughly mixed with the parent soil and compaction tests were carried out. Finally, the compaction characteristics of untreated sample and samples blended with different proportions of fine, medium and coarse sands are compared and key aspects are highlighted.

3. RESULTS AND DISCUSSIONS

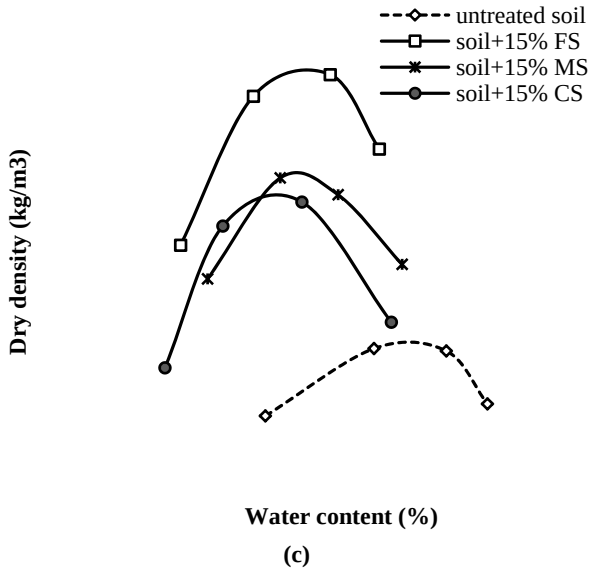
IS light compaction tests were carried out on the sand treated samples as per the methodology discussed in previous section. The compaction curves of untreated soil sample and sand mixed samples are presented in Figures 2(a)-(e). The corresponding MDD and OMC values as obtained from the compaction curves and furnished in Table 3.



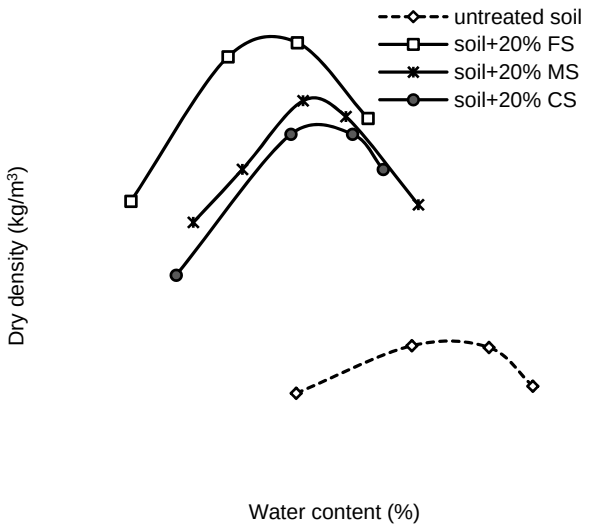
(a)



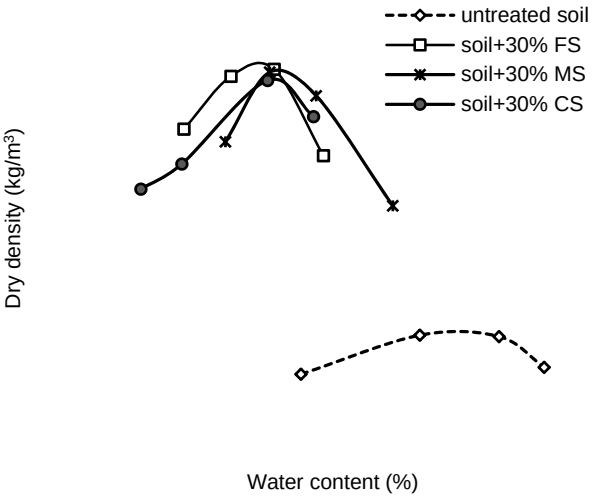
(b)



(c)



(d)



(e)

Fig. 2 Compaction curves of untreated soil and soil mixed with (a) 5% sand (b) 10% sand (c) 15% sand (d) 20% sand (e) 30% sand

Table 3: MDD and OMC values of untreated soil and soil mixed with sand

Soil	**MDD (kg/m^3)**			**OMC (%)**		
Untreated	**1520**			**24.6**		
With sand	FS	MS	CS	FS	MS	CS
5% sand	1564	1544	1540	23.1	23.1	24.3
10% sand	1605	1580	1540	23.4	22.2	23.7
15% sand	1626	1584	1574	21.0	20.7	20.4
20% sand	1686	1650	1635	19.0	20.4	20.6
30% sand	1705	1700	1695	18.6	19.2	19.0

It is apparent that increase in sand content results in consistent increase in MDD of fine-grained soil. For example, mixing with 30% fine sand, the MDD of soil increases to 1705 kg/m^3 against its untreated value of 1520 kg/m^3. Increase in MDD is maximum due to the addition of fine sand followed by medium and coarse sands. This implies that finer the sand particles, higher will be the MDD of treated soil and vice-versa. In contrast, OMC decreases with increase in sand content. For example, increase in fine sand fraction up to 30% reduces the OMC to 18.6% against the untreated value of 24.6%. However, the trend of decrease in OMC is not consistent with the gradation of sand. The percentage change in MDD and OMC of sand mixed soils are computed with respect the untreated values and are presented in Fig. 3.

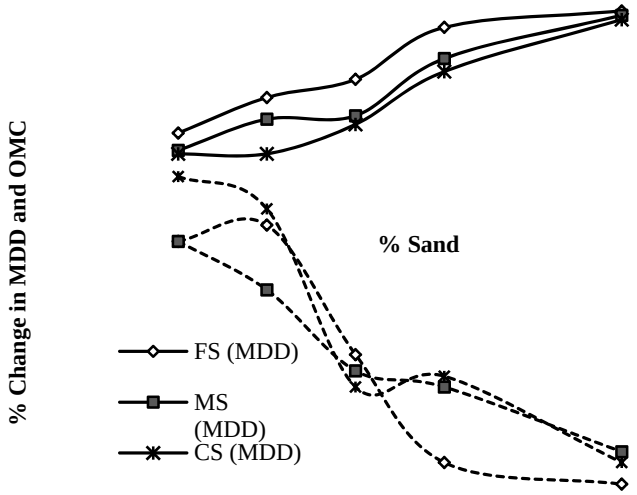


Fig. 3: Percentage change in MDD and OMC of untreated sample and samples treated with sand

It is evident that % increase in MDD consistently increases with increase in sand content. For finer sand particles, higher % increase in MDD is achieved, in general. For example, the MDD of soil containing 30% fine sand is nearly 12% more than that of untreated soil. On the other hand, % decrease in OMC increases with increase in sand content. For soil mixed with 30% fine sand, decrease in OMC is around 24% with respect to its untreated value.

4. CONCLUSIONS

An experimental investigation is carried out in this study on the effects of sands of different gradations on compaction characteristics of fine-grained soil. Salient observations of this study can be summarized as follows:

Addition of sand increases the MDD and the amount by which MDD increases is governed by the gradation of sand. In general, fine sand leads the highest MDD followed by medium and coarse sands. For soil containing 30% fine sand content, the MDD is 1705 kg/m^3 against the untreated value of 1520 kg/m^3 showing an increase of around 12%.

In contrast, OMC decreases with the increase in sand content. However, trend of decrease in OMC is not consistent with the gradation of sand. Lowest value of OMC is obtained in case of soil containing 30% fine sand (18.6%) which is nearly 24% less than the untreated value.

It can be concluded that with the addition of sand, fine-grained soils can be compacted to a higher degree requiring less amount of water. Further investigation can be carried in the domain by altering the type of fine-grained soil and using sands of varying uniformity coefficients.

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