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Impact of Affecting Parameters on Shear Behavior of River Sand

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Abstract. In this research paper, significant parameters that affect the shear behavior of river sand collected from Rishikesh (Uttarakhand) are studied. Classification and geotechnical properties of river sand are found as per standard codes. The effect of the height of fall and time of shaking on the relative density of river sand is found. After that effect of the size of the specimen, relative density and strain rate on shear properties are studied. Relative density is found up to 16 minutes of vibration with a step increment of 2 minutes. Direct shear test results of 300 mm and 60 mm shear boxes are compared to study the specimen size impact. The strain rate of 1.25, 0.625 and 0.25 mm/min are considered to analyze the strain rate impact. Three relative densities at 50, 70 and 85% of direct shear test specimens are considered. Relative density becomes constant after a particular point of the fall height and time of vibration. Shear properties of sand are affected significantly by different test scales, strain rates and relative densities of river sand specimens.

Keywords: River sand, shear behavior, geotechnical properties, direct shear test

1 Introduction

Shear properties of soil are primary governing parameters in design consideration of earth pressures in flexible or rigid retaining walls, bearing capacity of foundations and slope, embankment and dam stability. The direct shear test is performed in the present study for accessing shear parameters. The significant factors affecting shear strength are soil properties and driving equipment settings. In soil properties, relative density and soil gradation are and in equipment setting, the strain rate and box size can govern for variation in shear strength behavior. [1], [2].

Mamo et al. [3] studied the effect of strain rate on shear parameters. The friction angle is found to increase with the increase in strain rate. The peak shear strength was also found to vary with strain rate, which led to varied strain at failure.

The large shear test results are compared with the small-scale shear test to find the impact of confinement of boundaries of the shear box [4], [5]. The shear strength is found to be on the lower side in the case of a large shear test. Li et al. [6] performed 35 direct shear tests under different test conditions to analyze the sensitivity of governing parameters and found that high normal stress and low shearing rate produced a small void ratio in the shear zones, facilitating volumetric contractions.

2 Material and Experimental Program

2.1 Material

In the present study, the soil sample is taken from the bank sides of river Ganga located in the Rishikesh district of Uttrakhand state, India (Figure 1a). The physical appearance of the river sand sample is shown in Figure 1b. The specific gravity of the sample is found to be 2.63 as per IS 2720 Part 3 [7]. Gradation and classification of soil particles are done as per IS 2720 Part 4 [8] (refer Figure 2). Index and engineering properties of soil samples are found as per Indian codes.

Figure 1. a) Location of sample collection and b) Physical appearance of river sand

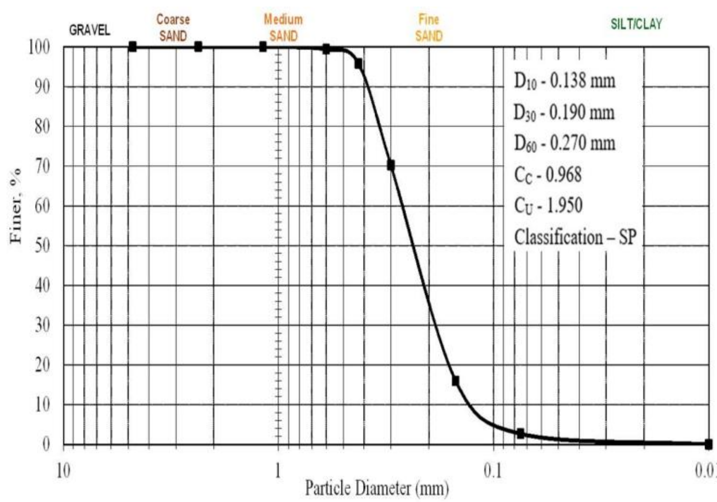


Figure 2. Gradation properties of river sand

2.2 Relative density test

The relative density test is done following IS 2720 Part 14 [9] and the effect of height of fall and vibration time on soil density is studied. The sample is poured into a standard mold of 3000 cc. The minimum height of fall is considered as 150 mm and the maximum is taken until the increase in density becomes insignificant. Density can be increased to a certain value by increasing the fall height; for a denser layer, the vibration method is used for sands.

As per the code, a standard vibration time of 8 minutes is given for all types of sands. Shaking accelerates the particles to fill voids. In the present study, the density value is noted after every 2 minutes of vibration until it becomes constant.

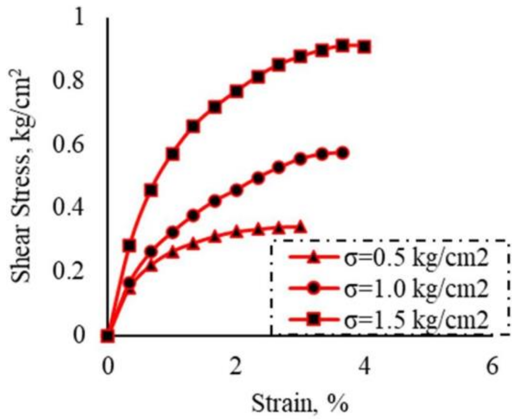
2.3 Direct shear test

In the present study, shear parameters are computed using a direct shear test apparatus following IS 2720 Part 13 [9]. Strain rate, size of the test specimen and density of specimen are dominant factors in the computation of shear parameters. Variation of shear stress to strain under different normal stresses is shown in Figure 3. Peak shear strain also increases with an increase in normal stress.

For comparison of results based on different specimen sizes, a small box of 60*60mm and a large box of 300 * 300 mm cross-sectional area are used. Different cases are studied by varying these parameters

(Table 1).

Test Scale	Relative density (%)	Strain Rate (mm/min)
Large Shear Box of 300 mm	50	1.25
Small Shear Box of 60 mm	50	0.25
	50	0.625
	50	1.25
	70	1.25
	85	1.25



7 **Figure 3.** Typical stress-strain behavior

3 Results

3.1 Effect of the height of fall on dry density

The variation of density with the height of fall is shown in Figure 4. The effect of fall height is found to be insignificant after a height of 0.5m. This curve can be used to achieve a particular density value in the case of sand.

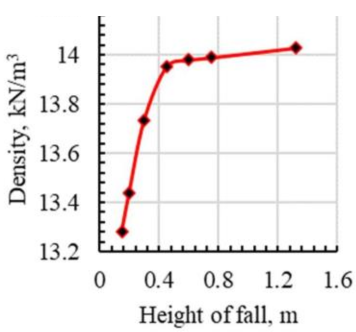


Figure 4. Variation of density with the height of fall

3.2 Effect of time of vibration on relative density

A vibration time of 6 minutes is found to be enough to achieve maximum density for river sand (Figure 5). After this threshold time, density becomes constant as it attains to minimum value void ratio.

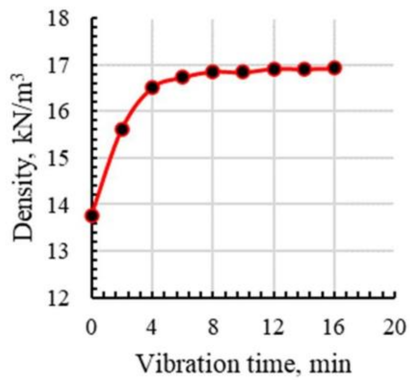
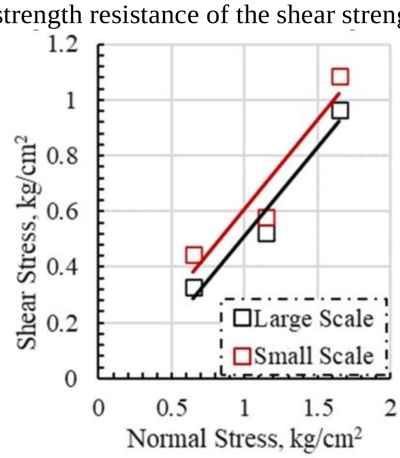


Figure 5. Variation of density with vibration time

3.3 Effect of test scale on DST

The value of the angle of friction for large-scale direct shear is smaller than the small-scale test (Figure 6). In a large shear test, there is a lesser amount of confinement from the boundaries of the shear box and the same normal load is distributed to more area, leading to low shear strength resistance of the shear strength



(Table 2).

Figure 6. Effect of test scale on the angle of friction

Table 2. Effect of test scale on the angle of friction at a strain rate of 1.25 mm/min.

Test Scale	RD (%)	Peak shear strength values corre-sponding to normal stress (kg/cm²) 0.65	1.15	1.65	R^2 of lin-ear curve	ϕ (0)
Large	50	0.3291	0.5238	0.9653	0.9518	32.450
Small	50	0.4467	0.5798	1.0850	0.985	34.779

3.4 Effect of strain rate on DST

The results reveal that increment in the experimental strain rates leads to a progressive increase in the angle of internal friction of the sand sample keeping relative density constant at 50% (Figure 7). The value of the angle of friction increases by 4.6% and 7.35% when the strain rate increases to 0.625 and 1.25 mm/min from 0.25 mm/min, respectively (Table 3). At a lower strain rate, s[illegible]ge themselves in a denser state.

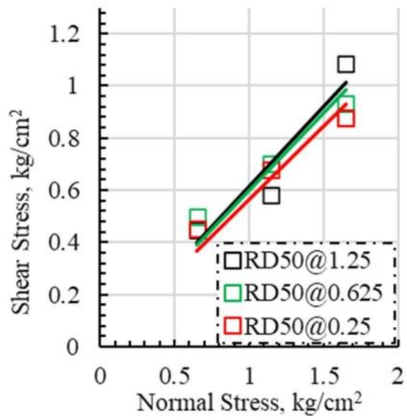


Figure 7. Effect of strain rate on the angle of friction with relative density of 50%

Table 3. Small direct shear test results for different strain rates at a relative density of 50%

Displace-ment rate (mm/min)	Peak shear strength values corre-sponding to normal stress (kg/cm^2)			R^2 of linear curve	ϕ (^{0})
	0.65	1.15	1.65		
1.25	0.4467	0.5798	1.0850	0.985	34.779
0.625	0.4996	0.7033	0.9329	0.979	33.908
0.25	0.4544	0.6809	0.8754	0.981	32.399

3.5 Effect of relative density on DST

Besides strain rate, relative density also affects the resulting shear parameters obtained from direct shear tests. From the results (Figure 8), it can be shown that the angle of friction decreases with a decrease in relative density. A denser medium provides more resistance to shear force (Table 4).

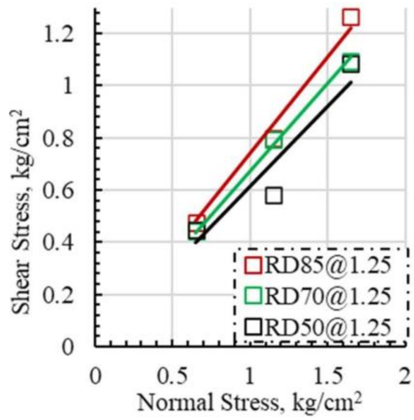


Figure 8. Effect of relative density on the angle of friction at a strain rate of 1.25 mm/min

Table 4. Small direct shear test results for different relative densities at a strain rate of 1.25mm/min

RD (%)	Peak shear strength values corresponding to nor-mal stress (kg/cm^2)			R^2 of linear curve	ϕ (0)
	0.65	1.15	1.65		
85	0.4751	0.7988	1.2637	0.998	39.946
70	0.4495	0.7959	1.0924	0.998	37.202
50	0.4467	0.5798	1.0850	0.985	34.779

4 Conclusion

The present study will be helpful in designing various geotechnical structures. It attributes the behavior of river sand under certain loading conditions. From the present study following conclusions can be made:

- It is found that the height of a fall has no significant effect on density after 0.5m of height.
- Vibration for 6 minutes is found to be sufficient to get a minimum void ratio.
- Shear behavior is comparable for small and large-scale shear tests. The value of the angle of friction is slightly less by 2° in the large-scale test.
- Value of the angle of friction increases by 4.6% and 7.35% when the strain rate increases by 2.5 times and 5 times, respectively.
- The friction angle value changes from 34.77° to 39.94° by changing relative density from 50% to 85%.

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