Design Value of Shear Parameters of Large Size Material

by

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Introduction

The materal used in the construction of modern high earth and rockfill dams comprises particles as large as 450 mm or more. The literature indicates that the ratio of specimen size to maximum particle size varies from 3 to 40 (Table II, Marachi et al 1972). Though the tests conducted elsewhere (U.P. I.R.I, 1978) in 30×30 cm direct shear machine on sand gravel mixtures compacted at various relative densities indicate that this ratio is about 10 to 12 revealing the need of quite large size direct shear machine and consequently application of abnormally high stresses on the specimen. Both these requirements are difficult to attain in the laboratory as well as in the field. So this size of material can hardly be tested in conventional direct shear or triaxial shear machines.

Therefore practical suitability of indirect methods of viz., parallel gradation modelling technique and replacement techniques is judged and recommended on the basis of laboratory experimentation to evaluate design value of shear parameters. The tests have been carried out on the material having much smaller maximum particle size and the prediction of shear parameters of large size prototype material is done. The main aim of the study was to find out the design value of shear parameters of Tehri dam material.

The material used for laboratory testing should simulate the density of packing, shape, elasticity, surface roughness or crushability with the prototype material (Melkote, 1976) as far as possible to minimize the errors in test results. These requirements should invariably be ensured in the investigations, otherwise these are likely to affect the test results appreciably. In the present investigations most of these conditions are suitably satisfied by taking the testing material of the same origin as that of prototype material.

Modelling Techniques

These indirect methods viz., parrallel gradation modeling technique and replacement techniques may prove quite useful to predict the design value of shear parameters of large size material. In the former case (Lowe, 1964) the prototype material is screened into various fractions. The material greater than the maximum particle size which can not be tested in conventional shear box, is rejected. The remaining fractions are mixed in different proportions so as to give gradation curves of the various samples parallel up to about coarser 80 per cent to the gradation curve of the prototype material. Each of the samples is then prepared and tested. The shear parameters of the prototype material can be conveniently computed

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by extrapolating the curve drawn between maximum particle size and shear parameters. In this technique, elasticity, surface roughness, bulk density and uniformity coefficient of the prototype and modelled material will be the same.

In the replacement techniques (Frost. 1973), the tests are carried out by replacing the oversize fraction, which cannot be tested in shear machines by the amount of relatively finer but still corser fraction in the sample on the basis that the later will have either (*i*) the same weight or (*ii*) the same cross sectional area.

Material Testing

Parallel Gradation Modelling Technique

The laboratory gradation curves parallel to that of the prototype curve up to about coarser 80 per cent were drawn with maximum size of 25 mm, 19 mm, 12.7 mm and 6.3 mm (Figure 1). The different fractions from the prototype material were seperated by sieving. The testing specimens were prepared by mixing the screened material according to the percentage of various fractions determined from the gradation curves.

Weight Replacement Technique

In this technique, the oversize fraction greater than 25 mm (the size which can't be tests in 30×30 cm direct shear box) was replaced by finer fraction but still coarser in the testing material having same weight. Four trials were made to arrive at the best replacing fraction which ranged between 19 to 25 mm, 12.7 to 25 mm, 6.3 to 25 mm and 4.75 to 25 mm. The gradation curves of the material tested after replacement is shown in Figure 2.

Cross Section Area Replacement Technique

In this technique, the following analytical expression (Equation 1), can be drawn to calculate the amount of replacing fraction having the same cross sectional area as that of replaced fraction.

$$p = \frac{d}{D} P \qquad \text{...(1)}$$

By applying this Equation 1, the percentage P of the coarser fraction having average diameter D to be replaced by the percentage P of the finer fraction of average diameter d.

Because of the limitation imposed by the maximum particle size, the replaced fraction ranged from 25 to 450 mm and replacing fraction tried varies from 19 mm to 25 mm. Although the weight of replacing fraction can be directly computed by utilizing Equation 1 yet better results can be expected if we make use of the equation by dividing replaced fraction in number of ranges of diameter of spheres as shown in Table 1.

The Table 1 indicates that 70 per cent coarser faction is replaced by 14 per cent finer fraction so as to give same cross sectional area. The experimentation was done by taking the finer fraction to range between 19.0 to 25 mm, 12.7 to 25 mm, 6.3 to 25 mm and 4.75 to 25 mm. The gradation

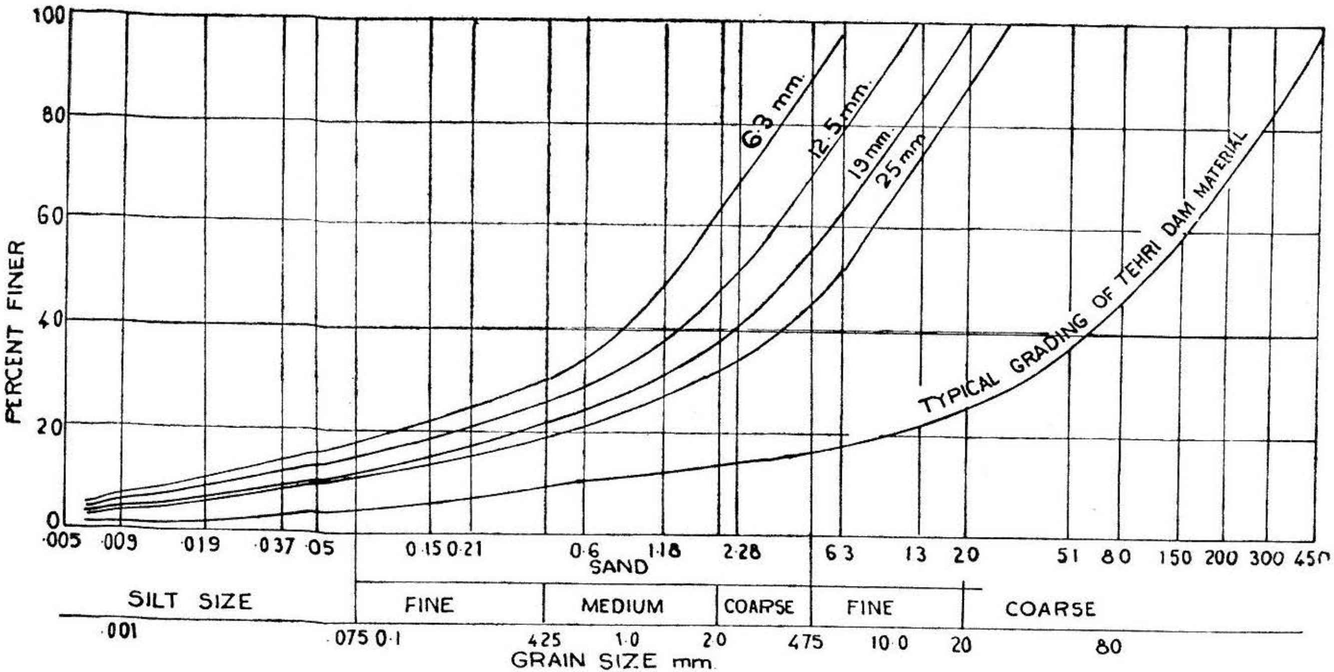

FIGURE 1 Gradation curves of material for Tehri dam material and parallel gradation modelling technique

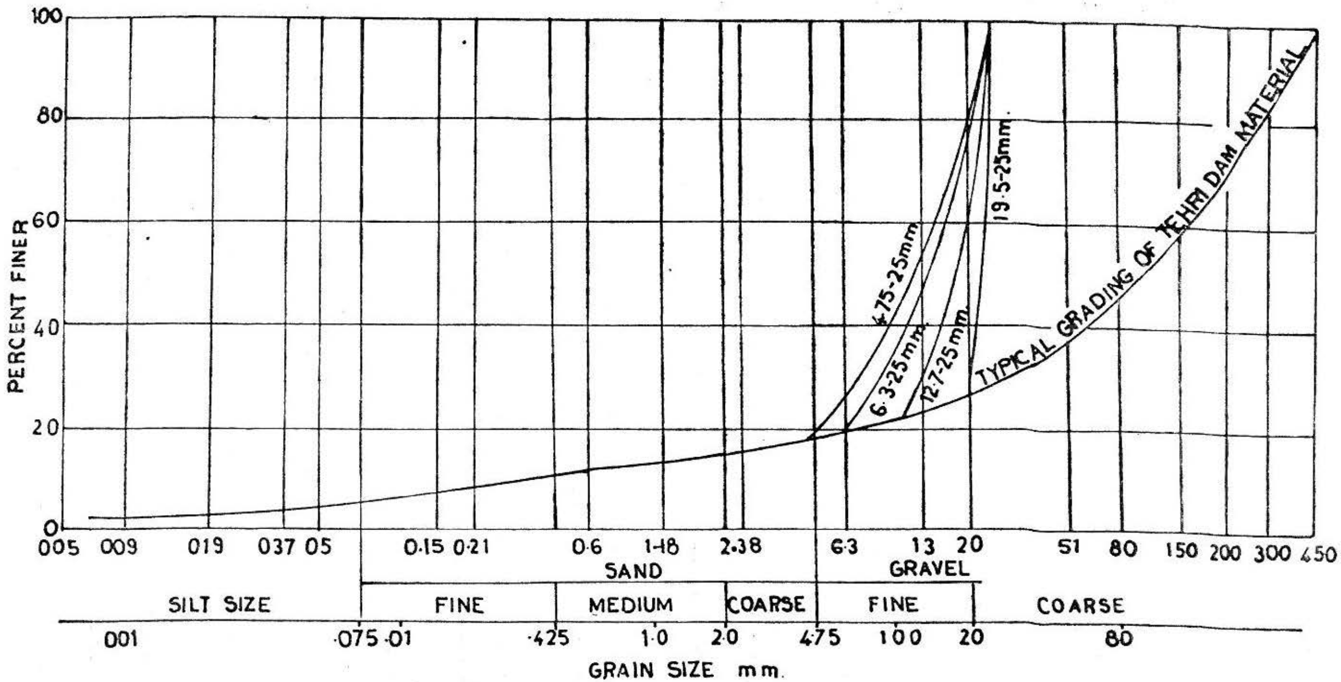

FIGURE 2 Gradation curves of samples for weight replacement technique

TABLE 1

Particle range to be replaced (mm)	Per cent of fraction to be replaced from Figure 1	Average diameter D in mm	Average diameter d of replacing fraction (mm)	Percentage p
025 – 050	08	038.0	22	4.63
050 – 080	07	065.5	22	2.35
080 – 150	14	115.0	22	2.68
150 – 200	13	175.0	22	1.63
200 – 250	08	225.0	22	0.78
250 – 300	05	275.0	22	0.40
300 – 350	05	325.0	22	0.34
350 – 400	05	375.0	22	0.30
400 – 450	05	425.0	22	0.26
			Total	13.37
			Say	14 per cent

curves of the testing samples after applying replacement technique are shown in Figure 3.

Tests Performed

The amount of soil needed to fill the direct shear box of size 30×30 cm at a density of 2.13 g/cm^3 was computed. The soil divided into three equal parts and was thoroughly mixed with the 5 per cent of moisture content. Each portion of the soil was compacted to 5 cm lift of the shear box with the help of 2.6 kg., standard light compaction hammer. All the three batches are thus compacted to fill the shear box completely. The shear tests were performed on four specimen of each sample at various normal stresses up to 3 kg/cm^2 and at a speed of 0.01 mm per minute.

Test Results and Discussions

Parallel Gradation Modelling Technique

The values of shear parameter of various samples with gradation parallel to the prototype material are shown in Table 3. This indicated that the angle of internal friction increased from 31° to 36.5° with the increase in the maximum size of gravel from 6.3 mm to 25.0 mm. This investigation is in accordance with the findings of Holtz and Gibbs (1956), Lewise (1956) and Rao and Katti (1975). The increase in the angle of internal friction may be attributed to the increase in the gravel content and decrease in the finer fraction with increasing maximum particle size. As would be seen from Figure 1, the percentage of gravel for various samples having maximum particle size 25,19,12,7 and 6.3 mm are 55,42,30

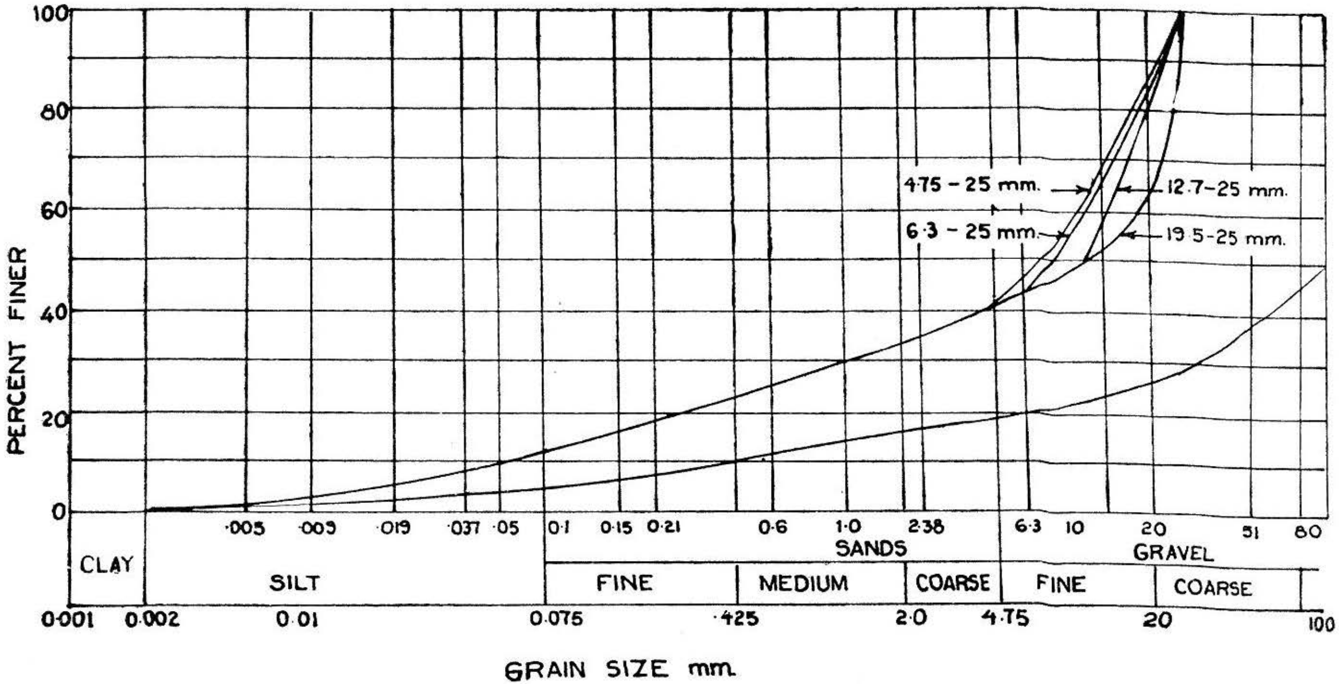

FIGURE 3 Gradation curves for samples (Cross sectional area replacement)

TABLE 2

Maximum Value of Ratio of Specimen Size to Maximum Particle Size

Name	D/d_{max}	Remarks
Bishop (1948)	12	—
Lewis (1956)	30-30	–
Zeller (1957)	05	—
Fagnoul et. al (1969)	05	—
Lee (1969)	05	—
U.S.B.R. (1965)	03	For coarse grained soils ranging 19-75mm
	08	For soils ranging 4.75-19 mm
	18	For fine grained soils having particle size less than 4.75 mm.
Marachi et. at (1969)	06	
Marsal (1969)	10	
Nitchiporovitch (1969)	05	
Leslie (1969)	10	
UP IRI (1979)	10-12	For maximum particle 25 mm.

TABLE 3

Experimental and Computed Values of ϕ using Parallel Gradation Technique

Maximum particle size in the modelled material (mm)	ϕ Value of modelled material (degree)	ϕ Value obtained by extrapolation for prototype material of 450 mm by experimental correlation.
25.0	36.5	44.5
19.0	35.0	44.0
12.7	23.0	43.5
06.3	31.0	43.5

and 8 percent respectively. The finer fraction less than 0.075 mm. has decreased from 18 to 10 percent as the maximum particle size has increased from 6.3 mm to 25 mm. The particles have also not shown any appreciable crushing during tests due to the low stress level testing.

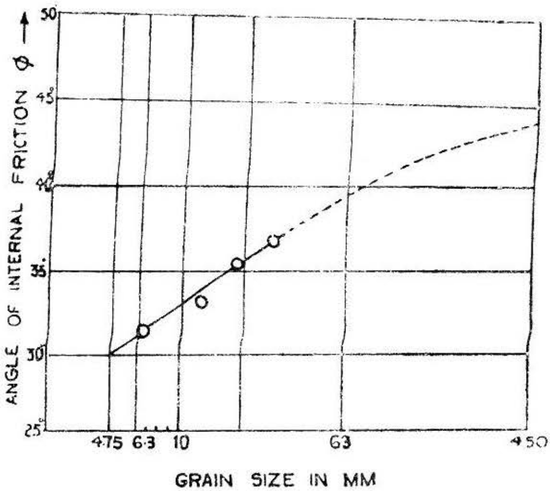

FIGURE 4 Extrapolation of ϕ values against maximum particle size

The angle of internal friction is plotted in Figure 4 against maximum particle size. The trend of the curve indicates that the design values of angle of internal friction of the large size material having maximum particle size of the order of 450 mm or more can be predicted by extrapolation of this curve by testing small size material having maximum particle size of 25mm in conventional direct shear box of 30 x 30 cm size. Another useful attempt is made to derive an empirical correlation between the increase in angle of internal friction ($\triangle \phi$) as a result of increase in the value of D/d, the ratio of maximum particle sizes of the prototype and modelled samples. Out of the all the samples tested, the maximum particle size i.e. 25 mm of the specimen which could be tested in the shear box was taken as the maximum size of prototype material D and the other maximum particle sizes for various samples were taken as maximum particle sized of modelled material and their ratio D/d was computed for different samples tested. The increase in the values of angle of internal friction ($\triangle\phi$) was computed. These values are plotted in Figure 5 with D/d as abscissa and $\triangle\phi$ as ordinate. The results obtained by Lewis (1956), Leslie (1969), and Rao and Katti (1975) to a maximum particle size 100 mm and maximum stress level of 4.0 kg/cm² are also plotted alongwith to observe the validity of this curve. It is seen that all the points lie on the following exponential curve.

$$\phi_1 \phi_2 = \triangle\phi = -\frac{1}{0.15} \log \frac{D'}{d} \qquad \ldots (2)$$

The more computations are also carried out to predict the ϕ value of 25 mm size material considered as prototype material from the modelled samples of lower maximum size material tested in order to find out the validity of the equation. It is observed that the predicted values are almost the same as obtained by testing which confirms that the equations can be used for predicting the ϕ value of large size prototype material by testing the small size modelled material. This equation can be utilized further to predict the values of the Tehri dam material. In this case,

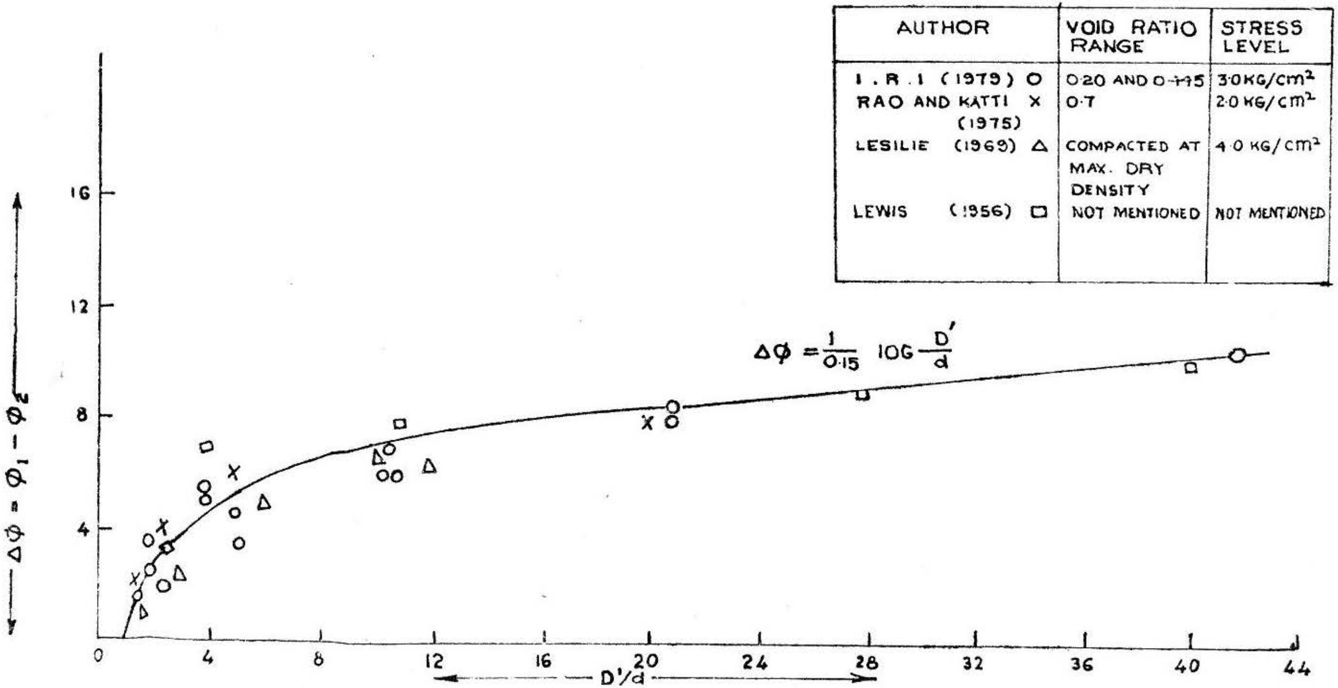

FIGURE 5 Increase in the value of angle of intennal friction ($\triangle\phi$) of prototype material (D') by testing a small size material (maximum size d)

the maximum size of the modelled specimen tested are 6.3, 12.7, 19.0 mm and 25 mm and that of prototype material is of the order of 450 mm.

Replacement Techniques

The angle of internal friction obtained by replacement of oversize fraction by finer but still coarser fraction by same weight are given in Table 4. It is seen that angle of internal friction is within a narrow range of 41 to 42.5 and maximum angle is obtained by replacing the coarser fraction by finer fraction of 19-25 mm.

TABLE 4

Experimental and Computed Values of ϕ using Replacement Technique

Particle range by which oversize fraction was replaced (mm)	ϕ Value of prototype material of 450 mm by weight replacemen, (degree)	ϕ Value of prototype material of 450 mm by cross-sectional area replacement (degree)
19.00-25	42.5	34.0
12.70-25	41.5	33.5
06.30-25	41-0	33.5
44.75-22	41.0	32.5

The value of angle of internal fraction obtained by cross-sectional area replacement method, vary between 32.5° to 34° (Table 4) which is lesser than those obtained by weight replacement method. Such low values may be attributed to the fact that due to 70 percent replacement of coarser fraction by 14 percent of the finer fraction, the percentage of sandy and silty material is increased to a larger amount. A comparison of gradation curves in Figure 2 and 3 reveals that in the weight replacement method, the sample have about 80 percent of gravelly material while in the cross-sectional area replacement method, this gravelly content is reduced to 60 percent and has increased the sand content from 16 to 30 percent and silt content from 4 to 10 percent. This increase in silt and sand content in place of gravelly material reduced the angle of internal friction in cross-sectional area replacement method as compared to weight replacement method.

It is observed that the three techniques used have yielded varying results. The values given by weight replacement technique are within 4 to 5 percent of that given by parallel gradation techniques while the value given by cross-sectional area replacement method have been found to be 23 to 25 percent less than that yielded by parallel gradation technique. However the ϕ values obtained by weight replacement technique vary from 41 to 42.5° while that found by empirical correlation developed from test results of parallel gradation method vary between 43.5 to 44.5°. It indicates that the ϕ values obtained for the prototype material by weight replacement technique and empirical co-relation developed from the test results of parallel gradation technique lie within the same range. Thus a design value ϕ of proper type material can determined by applying any of these two methods.

Conclusions

The following conclusions are drawn based on the laboratory testing of granular soils in direct shear box of size 30×30 cm and a stress level of 3.0 kg/cm².

The parallel gradation modelling technique is quite useful and fairly satisfactory to predict the shear parameters of prototype material. A co-relation is developed between increase of angle of internal friction and ratio of maximum particles sizes of prototype and modelled material and can be utilized to predict the value of large size prototype material from test conducted on modelled material. The co-relation has also been checked by the existing observational data of Rao and Katti (1975), Leslie (1956) and Lewis (1956) at a maximum stress level of 4.0 kg/cm² and maximum particle size of 100. The same weight replacement technique is equally useful to estimate the shear parameters of prototype while the material same cross-sectional area replacement technique provides the misleading results owing to undue increase of finer material in the testing samples.

Acknowledgement

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Notations

D = Minimum of the length and breadth of the specimem

d_{max} = Maximum particle size

ϕ = Angle of internal friction

D' = Maximum particle size of prototype material

d = Maximum particle size of modelled material

ϕ_1 = Angle of internal friction of the prototype material having maximum particle size D'

ϕ_2 = Angle of internal friction of the testing material having maximum particle size d.