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Engineering Behaviour of Alluvial Rockfill Material

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Abstract. Rockfill dams are commonly being constructed to store the natural river water for using to generate the electricity, irrigation, drinking and industry etc. Rocfill material consisting of gravel, cobbles and boulders obtained either by natural riverbed and blasting the rock quarry. These materials are being used because of their inherent flexibility, capacity to absorb large seismic energy, reduce pore water pressure and adaptability to various foundation conditions. The engineering behavior of Rockfill material affects due to mineral composition, particle size, shape, surface texture, confining pressure, gradation etc. Rockfill materials consist of particles of large size more than 1200 mm and this cannot be tested directly in the laboratory. Some kind of modeling technique is often used to scale down the size of particles so that the specimen prepared with smaller size particles can be tested in the laboratory. Among all modeling techniques, the parallel gradation technique is most commonly used and the same has been used in the present study.

The alluvial riverbed rockfill material is obtained from a hydropowerproject inJammu & Kashmir. The maximum particle size used in the dam is 600 mm. For testing, the maximum particle size (d_{max}) is scaled down to 25, 50 and 80 mm by parallel gradation technique. All the d_{max} are tested for 87% relative density. Large size drained triaxial tests are carried out with a specimen size of 381 mm diameter and 813 mm height with varying confining pressures from 0.6 MPa to 1.8 MPa. Engineering behavior means stress-strain-volume change behavior of all the d_{max}under different confining pressures are studied and presented.

Keywords: Rockfill, Modeling technique, Stress-strain-volume.

1 Introduction

River valley projects are being designed and constructed in India/ abroad to store the natural water flowing in the rivers and use it latter for different purposes viz. power generation, irrigation and flood control. Rockfill material is being used in the Earth core rockfill dam (ECRD) & Concrete faced Rockfill dams (CFRD) because of its inherent flexibility, ability to absorb large seismic energy and adoptability to various foundation conditions. In laboratory large size rockfill materials cannot be testeddirectly. Various kinds modeling technique is often used to reduce the particles size so that the specimens prepared with smaller size particles which can be tested in laboratory.

Engineering behaviour of rockfill materials has been reported by many researchers [1], [5],[6],[8] and [10] have carried out laboratory tests on various rockfill materials and concluded that stress-strain behaviour is non-linear and stress level dependent. They had also observed that for alluvial (riverbed) rockfill material, the angle ofinternal friction increases with increase in particle size (d_{max}) [2], [3], [12].

This paper deals with the testing of the alluvial rockfill material obtained from a project site in J&K.

2 Experimental Investigations and Discussion

2.1 Material used

For the present research work rockfill material collected from a hydropower Project inJammu & Kashmir. The d_{max} of the material is 600 mm and gradation of the material is shown in Fig.1. For testing in a large size triaxial cell of 381 mm diameter and 813 mm height, the material has been modeled to maximum particle sizes of 80, 50, and 25 mm by parallel gradation technique as shown in Fig 1[4].

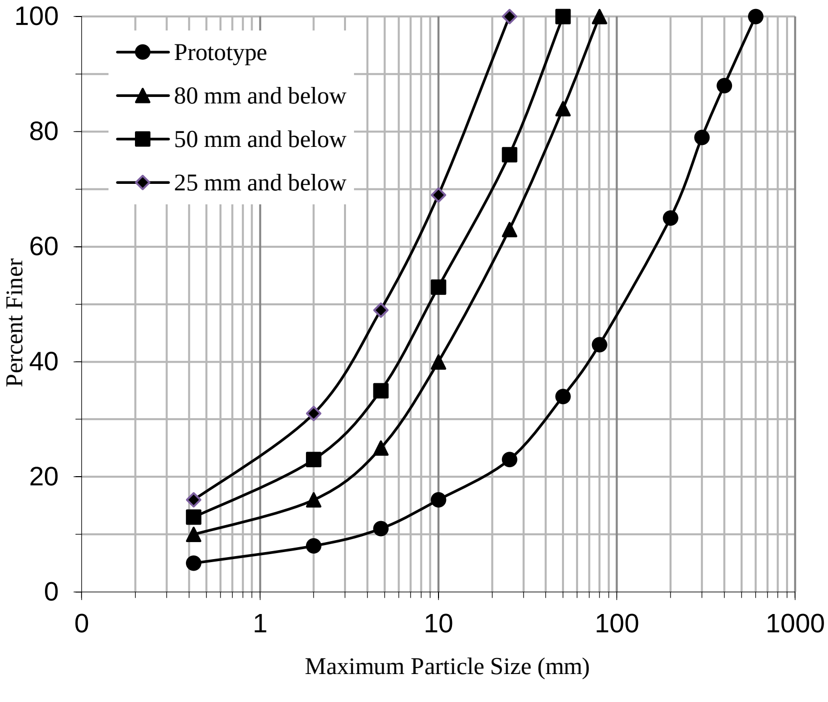

Fig. 1. Prototype and modeled grain size distribution curves

2.2 Experimental Programme

Drained triaxial tests: Consolidated drained triaxial tests have been conducted on the modeled materials at various confining pressures (0.6,1.2 and 1.8 MPa) at Central Soil & Materials Research Station, New Delhi. The stress-strain-volume change response for d_{max} of 80 mm tested with 87% relative density has been presented in Figs. 2 and 3.

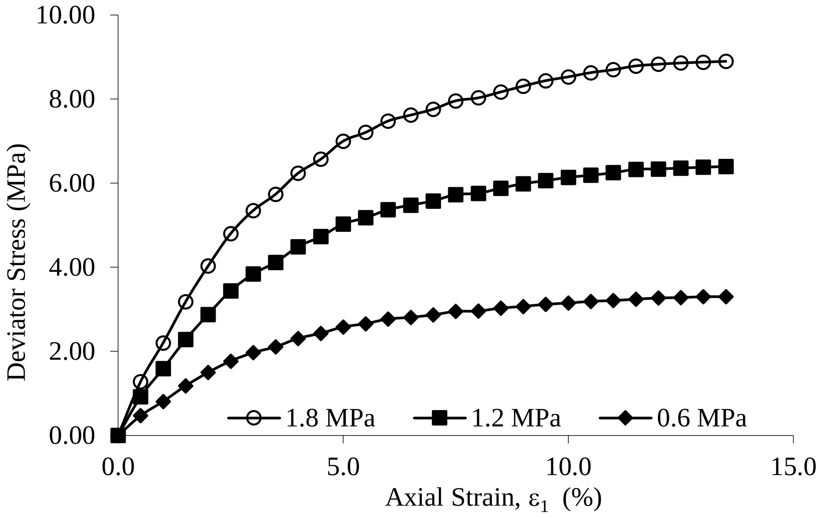

Fig. 2. Stress-Strain Relationship of 80 mm Maximum Modeled Rockfill Material

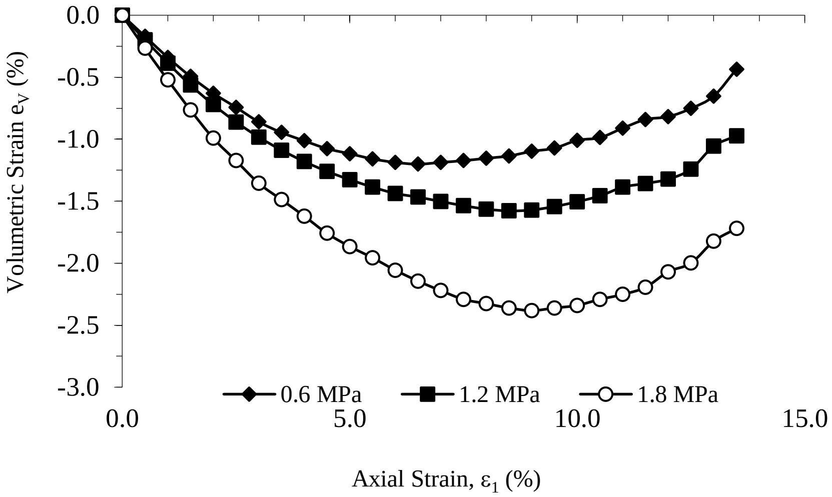

Fig. 3. Volumetric and Axial Strain Relationship of 80 mm Maximum Modeled Rockfill Material

The behaviour of rockfill material for arelative density is observed to be non-linear and stress dependent. The volume change response shows compression in the initial part of shearing and dilation is noted on further shearing of the specimen.

The value of initial tangent modulus is determined from the stress-strain response using Kondner's (1963) hyperbolic relationship,

$$\sigma_1\text{-}\sigma_3 = \frac{\varepsilon 1}{a + b\varepsilon 1}\text{....................}(1)$$

where,

$(\sigma_1\text{-}\sigma_3)$ = deviatoric stress

ε_1 = axial strain

a = constant, inverse of initial tangent modulus, E_i

b = constant, inverse of ultimate strength, $(\sigma_1\text{-}\sigma_3)_{ult}$

The values of $[\varepsilon_1/(\sigma_1\text{-}\sigma_3)]$ are calculated from the initial part (Initial straight line points) of the stress-strain curves and are plotted against ε_1 (Fig 4). The intercept of the best fit line in the transformed plot is obtained as the value of the constant a. The reciprocal of the constant a gives the initial tangent modulus. The values of E_i for the riverbed rockfill materials are given in Table 1.

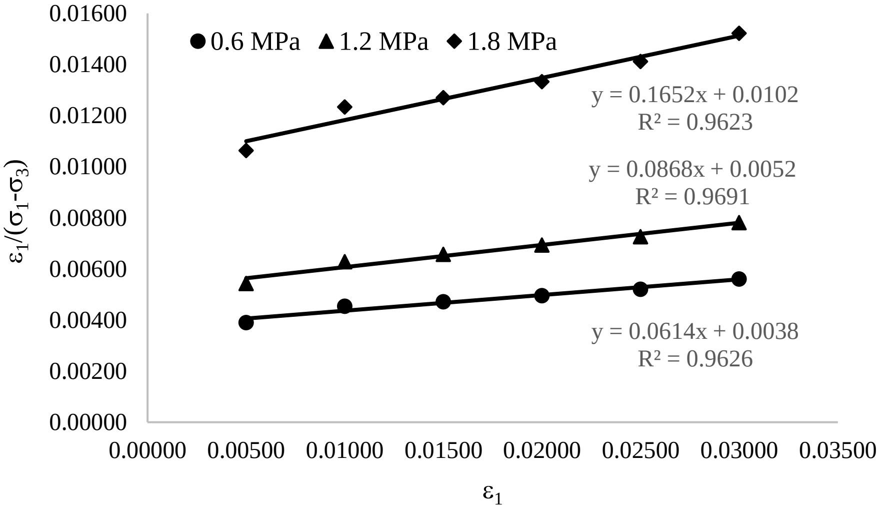

Fig. 4. Typical Hyperbolic Representation by Straight Line in TransformedAxis for Riverbed Rockfill Material collected from a hydropower. Project in Jammu & Kashmir (d_{max} = 80 mm)

Typical variation of the initial tangent modulus with the maximum particle size at different confining pressures are also represented in Fig.5 for riverbed rockfill material collected fromproject sitein J&K.. Similar relationships have been obtained for other riverbed rockfill materials[7], [9], [10], [11].

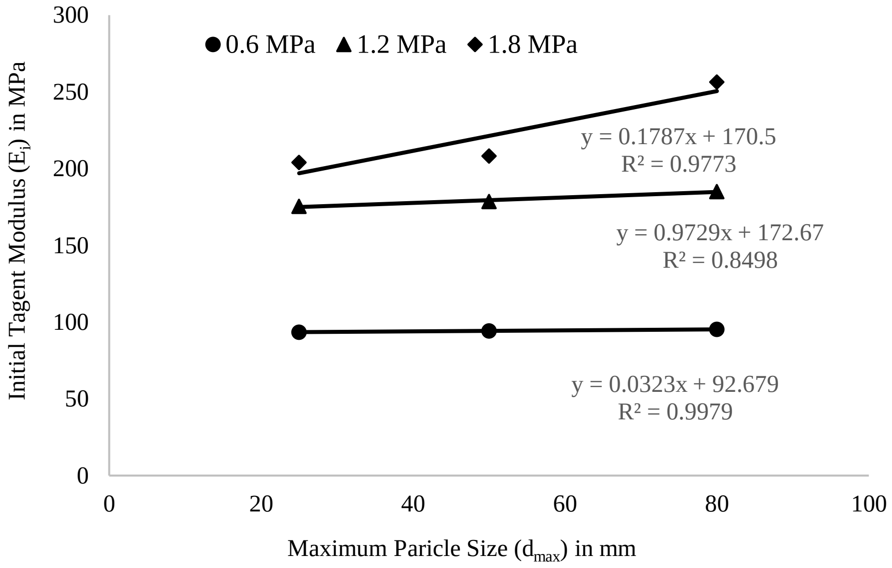

Fig. 5. Variation of Initial Tangent Modulus with Maximum Particlesizefor Riverbed Rockfill Material collected from a hydropower. Project in Jammu & Kashmir

The dilation behaviors, Initial Tangent Modulus and Shear Modulus of materials were also determined different confining pressure and presented in Table 1, 2 and 3.

Table 1. Dilation Angle, Initial Tangent Modulus and shear Modulus for the Riverbed Rockfill Materials of 25 mm particle (d_{max})

Properties		25 mm	
Confining Pressure (MPa)	0.6	1.2	1.8
Angle of Shearing Resistance (deg)		45.2^0	
Dilation Angle (deg)	14.79	14.36	13.98
Initial Tangent Modulus (MPa)	93.46	175.44	204.08
shear Modulus (MPa)	36.20	69.41	85.66
Poisson ratio	0.291	0.264	0.191

Table 2. Dilation Angle, Initial Tangent Modulus and shear Modulus for the Riverbed Rockfill Materials of 50 mm particle (d_{max})

Properties	50 mm		
Confining Pressure (MPa)	0.6	1.2	1.8
Angle of Shearing Resistance (deg)		45.4^0	
Dilation Angle (deg)	14.63	14.41	14.04
Initial Tangent Modulus (MPa)	94.34	178.57	208.33
shear Modulus (MPa)	38.23	68.47	78.94
Poisson ratio	0.319	0.304	0.234

Table 3. Dilation Angle, Initial Tangent Modulus and shear Modulus for the Riverbed Rockfill Materials of 80 mm particle (d_{max})

Properties	80 mm		
Confining Pressure (MPa)	0.6	1.2	1.8
Angle of Shearing Resistance (deg)		45.9^0	
Dilation Angle (deg)	14.31	13.87	13.77
Initial Tangent Modulus (MPa)	95.24	185.19	256.41
shear Modulus (MPa)	35.51	70.29	102.44
Poisson ratio	0.341	0.317	0.252

3 Conclusions

From the study, it is observed that the stress-strain behavior of tested rockfill material found non-uniform, non-ealstic and stress path dependent. The axial strain and deviator stress increases with increase in confining pressure for all the tested materials (d_{max}). From axial strain-volumetric strain behavior, it is observed that the material compress during initial shearing and later shows dilation phenomenon.The effect of dilation decreases with increase in d_{max} and confining pressures for all the materials. Initial tangent modulus increases with increase in confining pressure and d_{max}. Angle of shearing resistance (ϕ) of the tested alluvial rockfill material, increases with increase in d_{max}, decrease with increase in confining pressure.

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