ESTIMATING THE SHEAR MODULUS OF SOILS BASED ON SURFACE ROUGHNESS

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Abstract

The purpose of this paper is to estimate the initial shear modulus of soils based on the surface roughness of materials. Interface shear modulus depends on soil type & gradation and surface roughness of specimens. By considering all the factors, a simple mathematical equation was given by Murugan et al. (2014) for the interface shear modulus between soil and structural material. Interface shear modulus of soil was evaluated by using the mathematical equation given by Murugan et al. (2014).Result indicates that interface shear modulus increases with the increment of the surface roughness of the specimens used in this study. The highest peak shear modulus is achieved when the surface is rough. This study is very important in the field of earthquake geotechnical engineering.

Keywords: *Soil, Interface shear modulus, Initial shear modulus, surface roughness.*

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1. INTRODUCTION

Shear modulus is a most important property for evaluating the dynamic responses of soil structures at different sites. Seismic waves altered as they pass through soil layers, from bedrock to surface, change frequencies and amplitudes and these modifications result in different ground motion characteristics. Therefore, the effects of earthquakes in buildings and earthworks depend on the shear moduli of soil strata underlying the affected sites. In recent years many studies were performed to develop a general model to estimate shear modulus at small strain level. The initial shear modulus (G_0) is a very important parameter for seismic ground response analysis and also for a variety of geotechnical applications. A considerable number of empirical relationships have been proposed for estimating initial shear modulus for different kind of soils: [(Hardin and Black, 1969), (Iwasaki and Taksuoka, 1977), (Biarez et al., 1999)]. Existing models for unsaturated soils are limited on empirical models for initial shear modulus [Mancuso et al., 2002], [Biglari et al., 2010b] because the most of the literature experiments are included in investigating small strain behavior. This paper presents the results of initial shear modulus of soils (sand, gravel and SC soil) based on the empirical model proposed by Murugan et al., 2014.

2. SOIL CHARACTERISTICS

Three different soils were selected. The index and engineering properties of these soils are presented in Table 1 to 3. The soils were classified according to IS: 1498 - 1970.

Table 1. Engineering properties of the sandy soils used in the study

Soil Property	Well graded sand	Poorly graded sand
Grain size analysis: Effective size, D_{10} Coefficient of uniformity, C_u Coefficient of curvature, C_c Classification (unified)	 0.36 mm 6.46 2.08 SW	 0.29 mm 2.14 0.94 SP
Specific gravity, G_s	2.65	2.62
Dry unit weight: Maximum, γ_d(max) Minimum, γ_d(min)	 17.12 kN/m^3 15.72 kN/m^3	 16.81 kN/m^3 15.25 kN/m^3

Table 2. Engineering properties of the gravel soils used in the study

Soil Property	Well graded gravel	Poorly graded gravel
Grain size analysis: Effective size, D_{10} Coefficient of uniformity, C_u Coefficient of curvature, C_c Classification (unified)	 2.52 mm 4.42 1.24 GW	 2.31 mm 3.62 0.92 GP
Specific gravity, G_s	2.68	2.65
Dry unit weight: Maximum, γ_d(max) Minimum, γ_d(min)	 18.86 kN/m^3 16.68 kN/m^3	 18.12 kN/m^3 16.25 kN/m^3

Table 3. Engineering properties of the SC soil used in the study

% Passing			Atterberg Limit			Dry unit weight (kN/m^3)		Type of soil (IS 1498)
4.75mm	425μ	75μ	LL (%)	PL (%)	Ip	γ_d(max)	γ_d(min)	
99	64	49	47	26	21	15.25	13.12	SC

3. SURFACE ROUGHNESS OF SPECIMENS

Three different types of specimens were used for this study; concrete, steel and timber with varying surface roughness. The specimens are shown in Fig. 1 to 3. Surface roughness of the material is one of the important factors that influence the shear strength parameters. Generally, Absolute roughness (R_a) is considered for calculating interface friction between two different materials. It is a measure of the surface roughness of a material. This roughness is generally expressed in units of length as the absolute roughness of the material. Surface roughness of specimens used in the study is given in the Table 4.

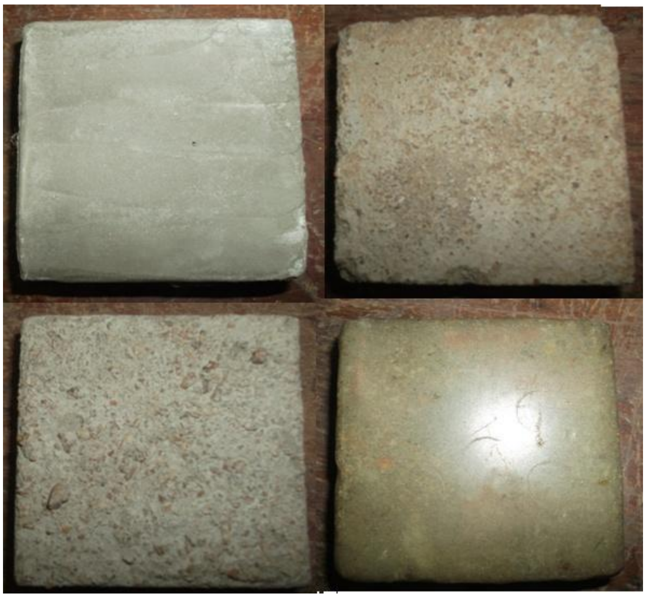

Fig. 1. Concrete specimens used in this study

Fig. 2. Timber specimens used in this study

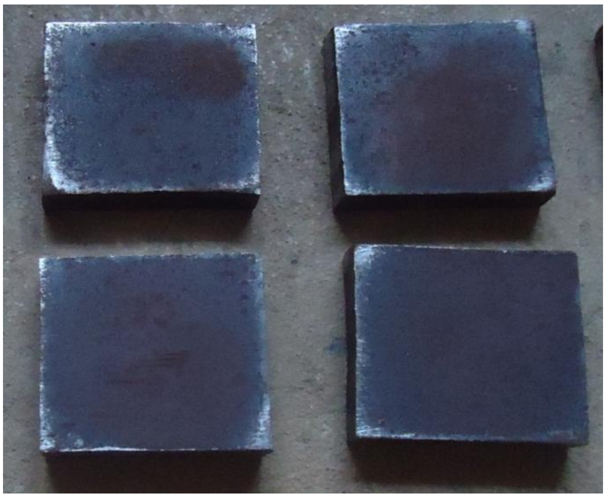

Fig. 3. Steel specimens used in this study

Table 4 Surface roughness of specimens

Steel specimens	Surface roughness, R_a (μm)
Smooth surface concrete	0.62
Medium surface concrete	0.88
Rough surface concrete	1.82
Epoxy coated concrete	0.44
Smooth surface timber	0.48
Medium surface timber	0.70
Rough surface timber	0.86
Epoxy coated timber	0.44
Smooth surface steel	0.51
Medium surface steel	0.76
Rough surface steel	0.92
Epoxy coated steel	0.44

4. AN EMPIRICAL MODEL FOR PREDICTING THE INTERFACE SHEAR MODULUS

Interface shear modulus depends on soil type & gradation and surface roughness of specimens. By considering all the factors, a simple mathematical equation was given by Murugan et al. (2014) for the interface shear modulus between soil and structural material.

Shear modulus between soil and structural material,

$$G = a + b\,(R_a) \quad N/mm^2$$

where,
R_a = Surface roughness of structural material (μm)
a& b are constants depends on soil type & gradation. The values of a & bare tabulated in Table 5.

Table 5 Constants a & b (Murugan et al. (2014)

Type of soil	Constants	
	a	b
Well graded sand	55.32	11.76
Poorly graded sand	51.19	11.67
Well graded gravel	62.24	11.45
Poorly graded gravel	58.55	11.51
Sandy clay	40.34	15.72

5. TEST RESULTS AND DISCUSSIONS

Interface shear modulus against surface roughness of concrete, steel and timber specimens with sand, gravel and SC soil isgiven in Table 6 to 8. It indicates that interface shear modulus increases with the increment of the surface roughness of the specimens used in this study. The highest peak shear modulus is achieved when the surface is rough. This study is very important in the field of earthquake geotechnical engineering to evaluate the performance of soil under dynamic loads.

Table 6. Shear modulus of soil against concrete surfaces

Type of Soil	Constant		Shear Modulus, N/mm^2			
	a	b	Smooth	Medium	Rough	Epoxy coated
Well graded sand	55.32	11.76	62.61	65.67	76.72	60.49
Poorly graded sand	51.19	11.67	58.43	61.46	72.43	56.32
Well graded gravel	62.24	11.45	69.34	72.32	83.08	67.28
Poorly graded gravel	58.55	11.51	65.69	68.68	79.50	63.61
Clayey sand	40.34	15.72	50.09	54.17	68.95	47.26

Table 7. Shear modulus of soil against steel surfaces

Type of Soil	Constant		Shear Modulus, N/mm^2			
	a	b	Smooth	Medium	Rough	Epoxy coated
Well graded sand	55.32	11.76	61.32	64.26	66.14	60.49
Poorly graded sand	51.19	11.67	57.14	60.06	61.93	56.32
Well graded gravel	62.24	11.45	68.08	70.94	72.77	67.28
Poorly graded gravel	58.55	11.51	64.42	67.30	69.14	63.61
Clayey sand	40.34	15.72	48.36	52.29	54.80	47.26

Table 8. Shear modulus of soil against timber surfaces

Type of Soil	Constant		Shear Modulus, N/mm^2			
	a	b	Smooth	Medium	Rough	Epoxy coated
Well graded sand	55.32	11.76	60.96	63.55	65.43	60.49
Poorly graded sand	51.19	11.67	56.79	59.36	61.23	56.32
Well graded gravel	62.24	11.45	67.74	70.26	72.09	67.28
Poorly graded gravel	58.55	11.51	64.07	66.61	68.45	63.61
Clayey sand	40.34	15.72	47.89	51.34	53.86	47.26

6. CONCLUSIONS

Examining the data, it could be seen that, the shear modulus at the interface increases with increase in surface roughness of specimens.The highest peak shear modulus is achieved when the surface is rough. Interface shear modulus also based on the type of soil and soil gradation. This study is very important in the field of earthquake geotechnical engineering to evaluate the performance of soil under dynamic loads.

REFERENCES

[1]. Hardin, B.O. and Black, W.L. (1969), "Closure to vibration modulus of normally consolidated clays". Journal of Soil Mechanics and Foundations Division, ASCE, vol. 95, no. SM6, pp. 1531-1537.

[2]. Iwasaki, T. and Taksuoka, F. (1977), "Effects of Grain size and grading on dynamic shear moduli of sands". Soils and Foundations, vol. 17, no. 3, pp. 19-35.

[3]. Biarez, J.; Gomes Correia, A.; Liu, H. and Taibi, S. (1999), "Stress-strain characteristics of soils interesting the serviceability of geotechnical structures". 2nd International Symposium on Pre-failure Deformation Characteristics of Geomaterials, Torino (in press).

[4]. Mancuso, C., Vassallo, R., and d'Onofrio, A. (2002), "Small strain behavior of a silty sand in controlled-suction resonant column – torsional shear tests". Canadian Geotechnical Journal, Vol. 39, 22– 31.

[5]. Biglari, M., Mancuso, C., d'Onofrio, A., Jafari, M.K., and Shafiee. (2010b), "A. Modelling the initial shear stiffness of unsaturated soils as a function of the coupled effects of the void ratio and the degree of saturation". *Computers and Geotechnics*, DOI:10.1016/j.compgeo. 2011.04.007.

[6]. Murugan, M., Natarajan, C. and Muthukkumaran, K. "Performance of FRP strengthened RC piles subjected to static and cyclic lateral loads", PhD thesis, National Institute of Technology, Tiruchirappalli, 2014.