

# Study of Shear Strength Behaviour of Soil-Rock Mixture

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**ABSTRACT:** In recent years use of soil-rock mixture has significantly increased in many geotechnical projects. Strength is the most important property to be investigated when using in such projects. Shear strength of soil-rock mixture has been studied through many approaches and consequently different results obtained. It is difficult to test the specimen of such a large volume which may affect the result. This thesis work presents the normal loads 0.25 kg/cm<sup>2</sup>, 0.50 kg/cm<sup>2</sup>, 0.75 kg/cm<sup>2</sup> and 1.0 kg/cm<sup>2</sup> for each sample.

Shear strength behaviour of soil-rock mixture by direct shear test using large direct shear apparatus which provide ease to perform with large volume of mix and provide a better result. To perform this test four sample of soil –rock mixture having 5%,10%,15% and 20% of rock particles of size range 4.75- 8mm, 8-16mm, 16-25mm and 25-31.5mm respectively tested under constant normal loads 0.25 kg/cm<sup>2</sup>,0.50 kg/cm<sup>2</sup>,0.75 kg/cm<sup>2</sup> and 1.0 kg/cm<sup>2</sup> for each sample. Results comprise the load deformation behaviour of soil- rock mixture and failure envelope to obtained shear strength parameter.

It is concluded from results that there is increase in peak shear stress of mixture as percentage of rock increased up to 15%, and also increment in value of angle of internal friction with the same which shows that rock particles increase the strength of mix if replaced 15% by weight with sand

**KEYWORDS:** cohesion, angle of internal friction, shear strength, failure envelope.

## I. INTRODUCTION

The safety of any geotechnical structure is dependent on the strength of soil. If the soil fails, a structure founded on it can collapse, endangering lives and causing economic damage. The strength of soils is therefore of paramount importance to geotechnical engineers. The word strength is used loosely to mean shear strength, which is the internal frictional resistance of a soil to shearing forces. Shear strength is required to make estimates of the load bearing capacity of soils, the stability of geotechnical structures, and in analysing the stress-strain characteristics of soils.

The stress induced in soil due to applied loads depends upon its stress-strain characteristics. The stress –strain behaviour of soil is complex and depends upon a large number of factors such as drainage condition, water content, void ratio, rate of loading, level of loads, and stress path. To simplify the problem some assumption are made to analyse stress-strain behaviour and most of the time results are good enough to solve problem usually encountered in field practice.

Every engineering material has property to deform when subjected to loads. Soil is also an engineering material and having property to deform when loaded. Soils are rarely subjected to direct shear and direct tension however the shear stress develops when soil subjected to compression. Shear failure occurs in soil when shear stress induced due to applied load exceeds the shear strength of soil. When loads are exceeded failure occurs by relative movement of the particles. Hence evaluation of shear strength characteristics of soil is solution of many soil problems.

The characteristic of soil shear strength is defined by the angle of internal friction and cohesion. The strength of cohesion less soil, whether wet or dry are most dependent upon, the frictional properties of the material .Granular frictional properties are affected by the surface roughness and interlocking characteristics and the size, shape and

# International Journal of Innovative Research in Science, Engineering and Technology

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strength of particle. In granular material the resistance to sliding on any plane is depend upon the angle of internal friction and normal force acting over it. The interlocking phenomena of sand is contributes significantly in frictional resistance, if the relative density of sand is high interlocking effect will increase appreciably. It is also observed that the relative change in density during shear test.

The stress strain curve for dense sands exhibit a relatively high initial tangent modulus .the stress reaches maximum value at its peak at a comparatively low strain and then decrease rapidly with increasing strain and eventually become constant while the stress strain curve for loose sand exhibits a relatively low initial tangent modulus. At large strain the stress becomes constant.

Usual Methods of Evaluation of shear strength of soil is direct shear test and triaxial test. Triaxial Test more precise to determine stress –strain behaviour with various condition while direct shear test has some limitation.

On other hand there is very less knowledge of shear strength characteristics of soil rock mixture. Soil rock mixture is a non homogeneous material experienced in geotechnical field.

Soil-rock mixture consist soil which may be sand, silt, and clay and rock particles. It may be found in landslide deposit, alluvial deposit, and colluviums deposit. Properties of soil-rock mixture may be different from pure soil and pure rock. The strength of soil-rock mixture depends upon the amount of large particles mixed with the fine matrix.

In past few year very few test has been conducted to evaluate shear strength characteristics of soil rock mixture because it requires a large box to prepare sample which having large rock particles and large loading arrangements to stressed the sample similar to actual field.

Some studies show that oversize particles can increase the friction angle of soil. While there have been some other researches with opposite conclusions indicating reduction in the measured friction angle due to presence of oversize particles in the shear box. Furthermore, it appears that there has not been any specific study on the effect of a single oversize particle on the cohesion and friction angle of mixture soil and rock particle

## II. EXPERIMENTAL INVESTIGATION

To evaluate the behaviour of soil rock mixtures, using big size direct shear apparatus at different normal load. The details of material properties, apparatus and sample preparation are discussed in this chapter.

### Material properties

**TABLE -I PROPERTIES OF MATERIAL USED IN THIS RESEARCH WORK.**

S.N	Material properties	Soil	Rock particle
1	Specific gravity	2.64	2.85
2	Free surface moisture (%)	0.2	0.1
3	Water absorption (%)	1.15	0.55
4	Bulk density (gm/cc)	1.6	-

### Direct Shear Apparatus

Direct shear apparatus is used for determining shear strength of sand and gravel, gravelly clays use in geotechnical field. It is designed for a maximum normal load of 5 kg/cm<sup>2</sup> and maximum shear load of 3000 kg. It is a constant rate of strain type and gives 72 rates of deformation and is suitable for an operation on 450volts, 50cycles 3 phase AC supply.

### Sample Preparation

To evaluate the shear strength characteristics of soil-rock mixture, the direct shear test was conducted on soil and with different percentage of rock chips. Locally available soil and rock particles are used to conduct the test. Sieve analysis of sample is also conducted before direct shear test. Four different sizes of rock particle 4.75- 8mm, 8-16mm, 16-25mm and 25-31.5mm each mix at 5%, 10%, 15 % and 20% with soil were prepared and each mixture was tested under four normal loads 0 .25 kg/cm<sup>2</sup>, 0 .50 kg/cm<sup>2</sup>, 0 .75 kg/cm<sup>2</sup>, 1 .00 kg/cm<sup>2</sup> respectively.

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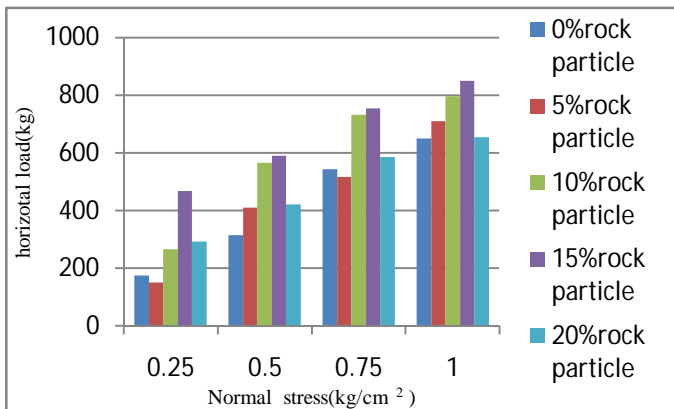
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### III. RESULTS AND DISCUSSION

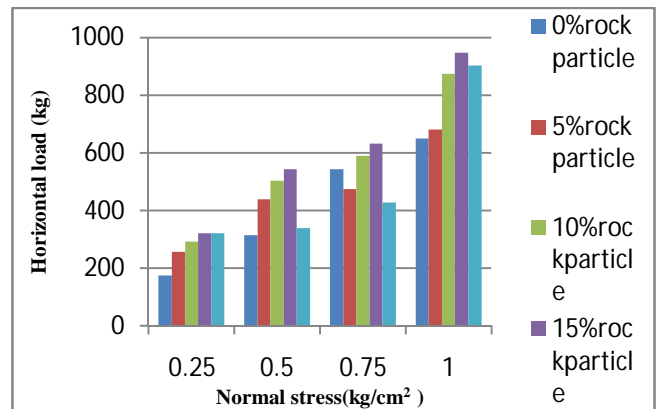
**Table 2: CALCULATED VALUES OF ‘C<sub>u</sub>’ AND ‘C<sub>c</sub>’ FROM GRADATION CURVE**

Size of rock particle		Soil		4.75-8mm		8-16mm		16-25mm		25-31.5mm	
S.N.	%age of rock particle	C <sub>u</sub>	C <sub>c</sub>	C <sub>u</sub>	C <sub>c</sub>	C <sub>u</sub>	C <sub>c</sub>	C <sub>u</sub>	C <sub>c</sub>	C <sub>u</sub>	C <sub>c</sub>
1	5	2`18	1.49	2	1.12	3.03	0.46	2.72	0.48	2.90	1.48
2	10			2	1.09	3.09	0.47	2.78	0.42	3.08	0.73
3	15			1.88	0.98	2.88	0.475	2.73	4.49	3.24	0.75
4	20			1.88	1.04	2.44	0.46	2.64	4.50	3.28	0.72

From table no 2- it has been found that the value of C<sub>c</sub> and C<sub>u</sub> will not give optimized result so doesn't have significance roll in grading of soil when mixed with rock particle



**Fig-1(a)**



**Fig-1(b)**

It is found from figure 1(a) that 15 percent rock particle proportion having highest value of load at failure of samples among all proportion when soil mixed with size range 4.75- 8mm rock particle and also it has been observed that at mix of 5 percent for normal load 0.25 kg/cm<sup>2</sup> and 0.7kg/cm<sup>2</sup>.

From figure 1(b) it is found that the load is increasing as proportion of rock particle of size range 8-16mm increases maximum load at failure increases but only up to 15 percent proportion for each normal stress and after that decreases at 20 percent proportion of rock particle

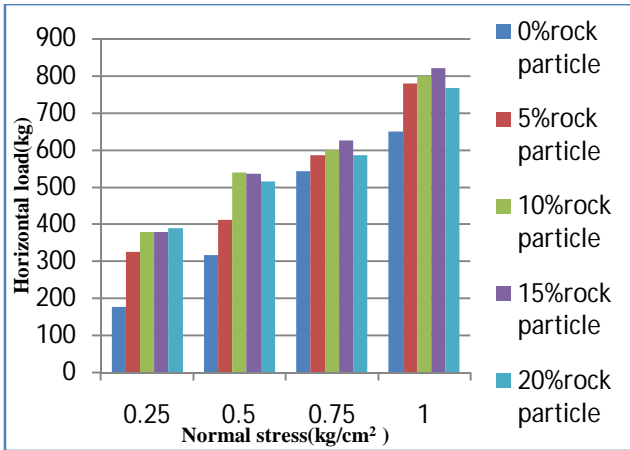


Fig-2(a)

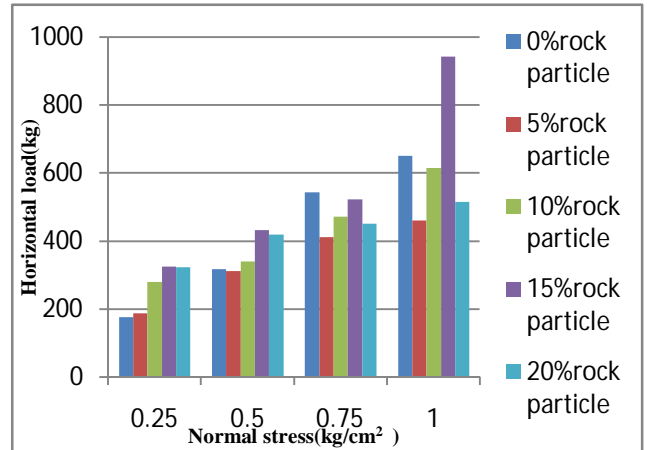


Fig-2(b)

From figure-2 (a) shows that size range 16- 25 mm rock particle mixed with soil at different percentage and giving maximum load at 15 percent for each normal stress and also at 5 percent rock particle it gave lower value of load at failure then that of soil mixed with 0 percent rock particle at normal stress 0.75kg/cm<sup>2</sup> and 1.00 kg/cm<sup>2</sup>. It can be found from Figure-2(b) when soil mixed with size range 25-31.5 mm rock particle horizontal load increase and maximum load achieved at 15 percent rock block proportion than decreases at 20 percent.

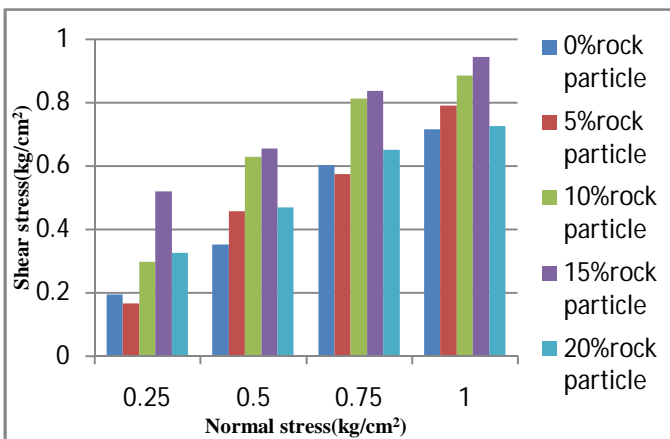


Fig-3(a)

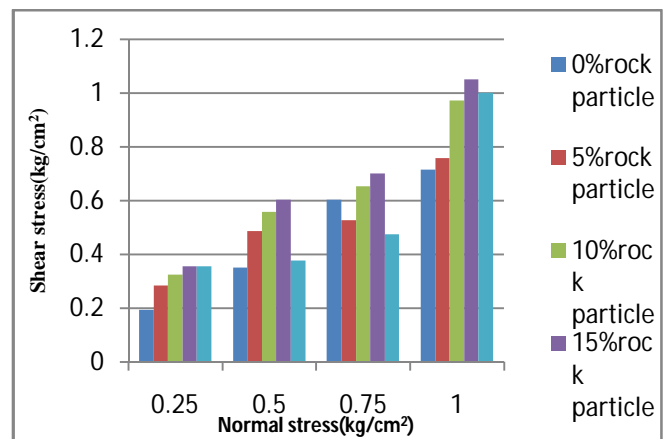


Fig-3(b)

Figure 3(a) shows that maximum shear stress value is increasing as rock block proportion increases of size range 4.75-8 mm at 15 percent it achieved maximum value and also at 0.25 kg/cm<sup>2</sup> and 0.75 kg/cm<sup>2</sup> its having less value than that of soil so by testing number of sample it is optimized that shear strength has maximum value at 15 percent rock block proportion.

From figure 3 (b) it is found that for size range 8-16 mm rock particle at 5%,10%,15%,20% mix with soil and shear strength of soil increasing ,for most of the sample so it can be concluded that at 15% proportion strength is maximum.

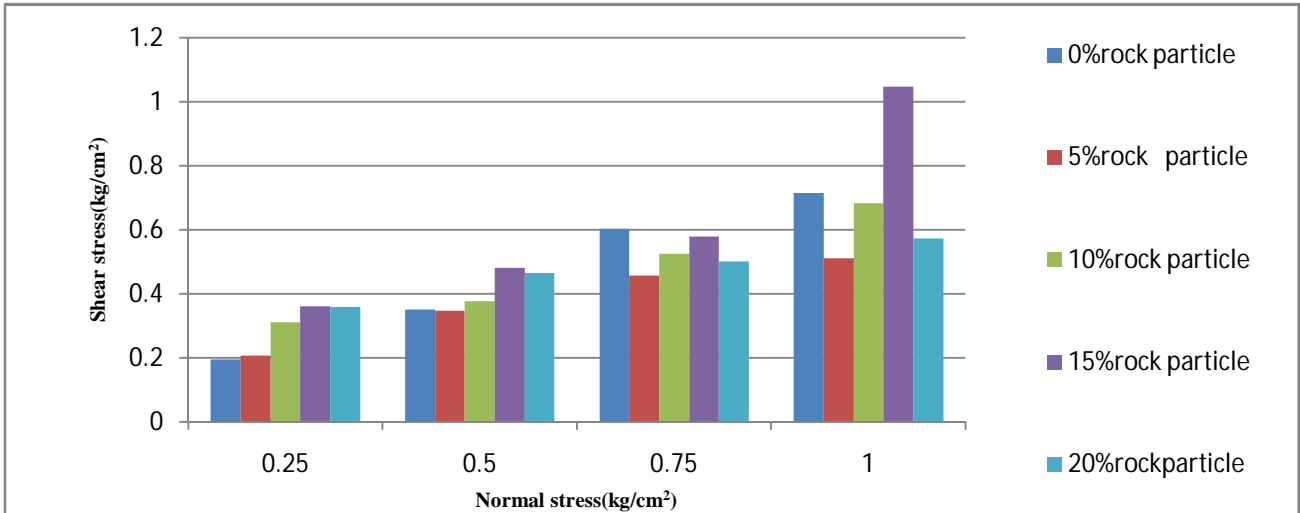


Fig-4(a)

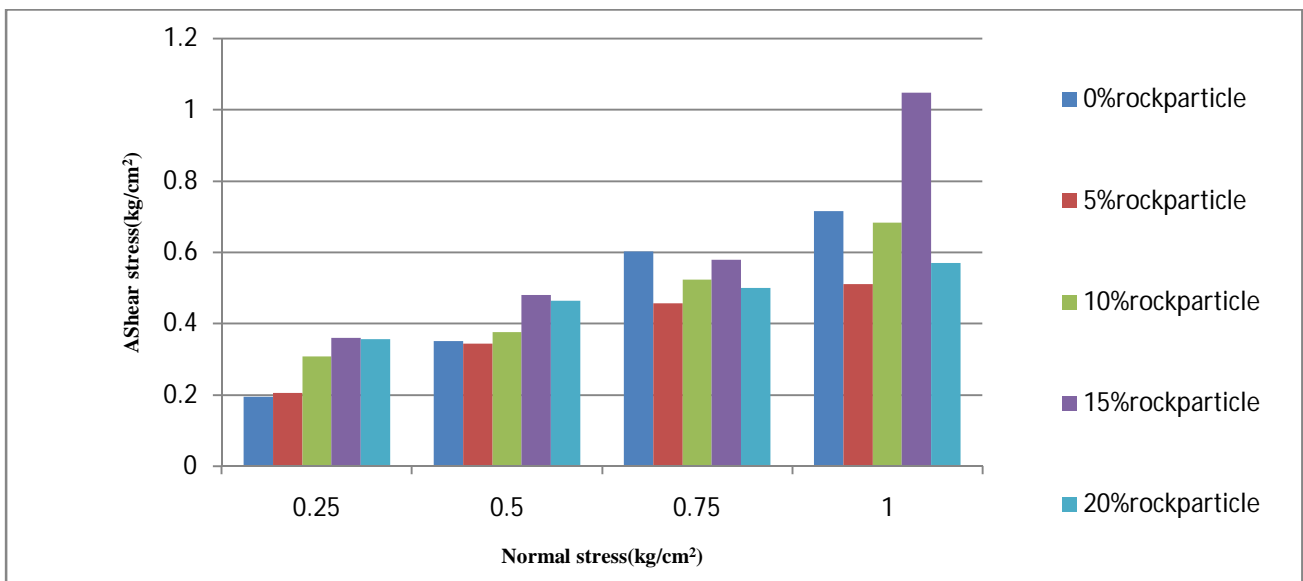


Fig-4(b)

Figure 4(a) shows the result of shear strength of soil when mixed with 16-25 mm rock particles is increasing as rock proportion increasing in most of sample so it can be optimized that at 15% it gives maximum value and then decreasing. From figure -4(b) it can be found that for size 25-31.5 mm rock particles there is a variation in shear strength in 5% proportion which is not sufficient to give any conclusion but for 15% proportion it is clearly shown that it is suitable to get maximum value of shear strength at each normal stress.

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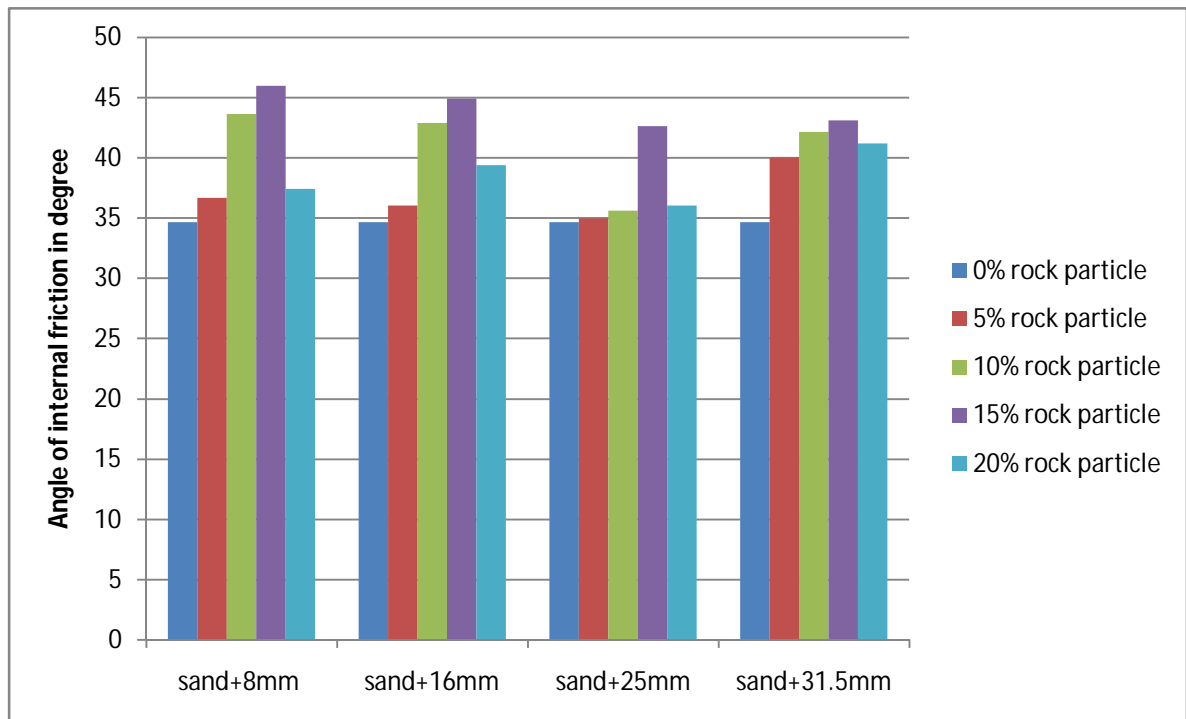
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**Table 2** Calculated values of shear strength parameters

Size of rock particle		4.75-8 mm		8-16 mm		16-25 mm		25-31.5 mm	
Serial No.	%age of Rock particle	C	Ø	C	Ø	C	Ø	C	Ø
1	0	0.110	34.65	0.110	34.65	0.110	34.65	0.110	34.65
2	5	0.100	36.64	0.125	36.21	0.125	34.98	0.125	40.03
3	10	0.130	43.62	0.120	42.89	0.100	35.62	0.100	42.15
4	15	0.130	45.98	0.120	44.89	0.130	42.64	0.100	43.10
5	20	0.100	37.41	0.087	39.38	0.087	36.01	0.100	41.16

Table no-2 shows that the angle of internal friction is increasing as percentage of rock particle increasing for all sample tested, and there is no proper way of changing in cohesion as mixed with rock particles.



**Fig-5** Variation of angle of internal friction with different size range

Figure-5 is the graphical representation of change in angle of internal friction which is increasing as percentage of rock particle increasing and got a maximum value for 15% proportion of rock particle mixed with soil then decreased at 20% proportion.

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## IV. CONCLUSION

The analysis of results indicate that the sensitivity of experiments depends entirely on certain elemental variation and hence the shear strength of sand-rock mixture covers a broad and extensive field of study because the factors involved are numerous and to a large extent unpredictable and thus to incorporate. Under such circumstances, therefore, it is not possible to make generalized conclusions.

However, on the basis of experiments of this work may be concluded:

1. Shear strength acting on soil sample increases when the percentage of soil replaced with rock particle for all size range is increases up to 15% by weight of soil and then decreased.
2. The shear strength of soil sample containing rock particle of size range 4.75-8mm was found higher at 15% replacement as compared to that of soil sample containing rock particle of other size range for normal stress(0.25 kg/cm<sup>2</sup>, 0.50 kg/cm<sup>2</sup>, 0.75 kg/cm<sup>2</sup>). For normal stress of 1.0kg/cm<sup>2</sup> the rock particle size range 8-16mm was found better than other size range. It indicates that for higher normal stress greater size range of particles was found to give higher shear strength.
3. The angle of internal friction of soil sample replaced with rock particles of size range 4.75-8mm by weight of soil was found 32% higher than the that of soil without any rock particles.
4. In soil rock mixture the study of test result (shear strength and angle of internal friction) was found that 15% of rock particle mix with soil by weight may be recommended for optimum for size range 4.75-8mm.

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