International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 10, October- 2014

Stress-Strain Behaviour of Fine Grained Soils with Varying Sand Content

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***Abstract*-The behaviour of clay is affected by the content of sand particles. How and to what degree the sand content affects on shrinkage limit, compaction characteristics, stress-strain behaviour, shear parameters (angle of internal friction and cohesion) and coefficient of consolidation studied in detail. In this paper, fine grained soil like BC soil and shedi soil with different percentage of sand (10% to 60%) was prepared and compacted with water content at optimum and a systematic series of UU-Triaxial test is conducted. Results of the laboratory tests shows that at optimum content 10% to 60% of sand, the results reveal that undrained shear strength, as the sand content increases in fine soil mixture the cohesion of soil decreases with increases in frictional angle at optimum content. The percentage increased in friction angle increased at steady state from 13^0 to 28^0 and the cohesion decreased from 0.71 to 0.39 kg/cm^2 with increasing sand content.**

Key words-Black cotton soil, Consolidation of soil, Index properties, Shedi soil, Triaxial shear test.

I. INTRODUCTION

Fine-grained soils comprising silt and clay are the most complicated engineering material in soil. it is of great importance in geotechnical engineering to make realistic predictions of the behaviour of soil under various conditions. Most geotechnical engineers consider the behaviour of fine soil as being somewhere between the behaviour of sand at one extreme, sands have modes of behaviour that are distinctly different in a number of respects, and the widely used concept of interpolating between them does not provide a realistic approach to deal with the behaviour of silts. Soils have characteristics in common with both sands and clays. They are subjected to more compression by static pressures than sands, and are subjected to more densification by vibrations than clays. Similarly understanding the behaviour of clay is not easy, as slight variations in the existing conditions will result in enormous changes in the stress, strain and strength response.

Reduction in water content during sample disturbance would result in gain in strength. Also increase in disturbance would result in decrease in strength. The quantity of plastic and non plastic fines in sand influences the stress strain behaviour. Soils behaviour is complex because it is heavily dependent on numerous factors. Strength of soil is the result of the resistance to the movement (failure) of molecules connected with each other, thus failure is related to the shear strength which is one of the most important engineering properties of a soil.

II. MATERIALS AND METHODOLOGY

A. *Sand*

- Locally available river sand was used in the present study. Sieve analysis was done on the sand used in the experiment, and found that sand is well graded and is clean with little or no fines. For the experimental work, sand is considered which is passing through 1 mm sieve and retained on 425 micron sieve.

B. *Black cotton soil*

- Expansive soils are those which show volumetric changes in response to changes in their moisture content. Such soils swell when the moisture content is increased and shrink when the moisture content is decreased. Consequently, expansive soils cause distress and damage to structures founded on them. Black cotton soil is collected from the Navanagar area of Bagalkot district; Karnataka (is located at *Latitude of* 18° 10' 32.55N and *Longitude* 71° 39' 29.88E).

C. *Shedi soil*

- Shedi soils are commonly found in south-west coastal belt in India. These soils typically exhibit moderate to high plasticity, low to moderate strength. Shedi soil is collected from Haliyal road of Dharwad city. At the time of collection of sample care has been taken to avoid the mixing of unwanted materials like wastes, roots and minerals. The soil is collected at a depth of 2 m from ground level at the site. Shedi soil so obtained is air dried and tested in laboratory to find its index and engineering properties according to IS codes.

IV EXPERIMENTAL PROGRAM

D. Shrinkage limit

- Test was performed in general accordance with the procedure described in IS 2720 part 5, 1985. For determination of shrinkage limit in the present studies, about 50 gm of soil passing at 425 microns sieve was taken and mixed with water to make creamy paste, in investigating soil the sand content was adding with different percentage. As 10%, 20%, 30%, 40%, 50%, and 60%.

E. Compaction test

- Test was performed in general accordance with the procedure described in IS 2720 part 7, 1980. The laboratory compaction test was conducted on investigating fine grained soils at different sand content like 10%, 20%, 30%, 40%, 50% and 60%.

F. Triaxial shear test

- Test was performed in general accordance with the procedure described in IS 2720 part 12, 1981. The sample was prepared with their optimum moisture content, by adding different content of sand like 10%, 20%, 30%, 40%, 50%, and 60%, the soil sample extruded from the sampling tube, in which it has been stored, and trimmed to suit a split mould of the required sample size.
- Stress-strain curves from UU tests on BC soil and sand specimens at confining pressures up to 0.5 kg/cm^{2,} 1 kg/cm^{2,} 1.5 kg/cm^2 at strain rate of 0.625mm/min.

Table I Specifications of Specimen

SL	Specifications	Dimensions (cm)
1	Diameter of the Sample	3.4
2	Height of the sample	7.0

G. Consolidation test

For a soil sample, substantial or inherent characteristics could be presented quantitatively by plasticity indices and specific gravity and other properties. Therefore in order to taking into account of these two main factors, conventional one dimension consolidation tests were conducted on each soil samples. To do this about two type of soil sample were prepared and tested with containing different percentage of sand such as 10, 20, 30, 40, 50 and 60% with their soil density. The specimens with initial water content 2 times OMC had slurry state and were filled in the fixed ring, taking care to prevent over topping. Filter papers were placed between specimen and saturated porous stones to prevent from movement of particles into the porous stone. After trimming top of the specimens and displacement of the upper porous stone and filter paper, the setting load (about 5 Kpa) was applied and the set was left for 24 hours for fully saturation of the specimen. Other procedures were made according to the standard test method. Then load increment 0.05, 0.1, 0.2, 0.4 and 0.8 Kg/cm^2 were applied. The corresponding deformations in the dial gauge were noted in the time intervals as required for square root time fitting method. Then a graph of time v/s dial gauge for a particular loading was plot and C_v was determined adopting square root time fitting method. Same procedure was fallowed for all specimens.

V. RESULTS AND DISCUSSION

H. Shrinkage limit (SL)

- The effect of sand content at different percentage on shrinkage limit of investigating soils have been presented in Table 3.1 it is observe that shrinkage limit decreases with increases sand content in investigating soil.

Fig.I Shrinkage samples (BC and shedi soil)

Table II Effect of shrinkage limit in BC soil with varying sand content

Sl	Sand content (%)	BC Soil Shrinkage limit (%)	Shedi Soil Shrinkage limit (%)
1	0	14.60	21.38
2	10	13.5	21.20
3	20	12.08	20.85
4	30	10.86	20.44
5	40	9.87	20.38
6	50	9.46	20.25
7	60	8.98	20.05

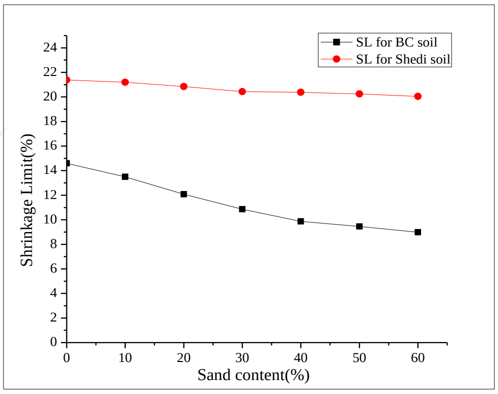


Fig. II Variation in shrinkage limit with different content of sand

From the Fig. 3.2 it is observe that in BC soil shrinkage limit decreases significantly as sand content increases. In case of shedi soil there is marginal change in shrinkage limit as the sand content increases.

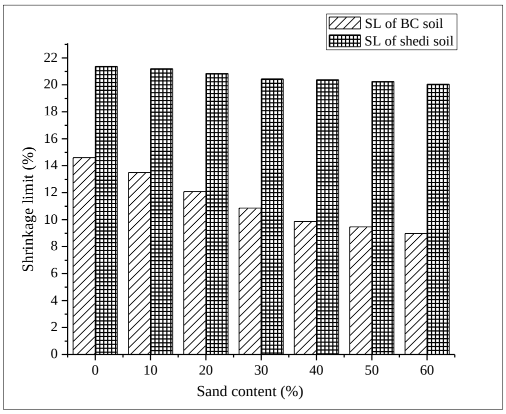


Fig.III Percentage decreased in shrinkage limit with different content of sand

From fig 3.3 at 10% sand content in BC soil the percentage decrease in shrinkage limit was 7.5%. In case of shedi soil at 10% sand content the percentage decrease in shrinkage limit was 0.08%. It indicates that as sand content increases in BC soil shrinks more than shedi soil. Based on experimental study of shrinkage limit, as the sand content increases in soil there is decrease in shrinkage limit and by comparing black cotton and shedi soil as the sand content increases, black cotton soil shrinks significantly about 32% and shedi soil shrinks marginally about 5%.

I. Effect of sand content on compaction characteristics

- The effect of sand content at different percentage on compaction properties of investigating soils have been presented in Table 3 and 4; it is observe that as the sand content increases in investigating soils there increases in maximum dry density and decreases in optimum moisture content.

Table III Variation in optimum moisture content and maximum dry density of BC soil

SI	% of sand	OMC (%)	MDD(gm/cc)
1	0	15.70	1.80
2	10	14.80	1.95
3	20	14.20	2.10
4	30	13.60	2.20
5	40	13.00	2.30
6	50	12.40	2.30
7	60	12.10	2.40

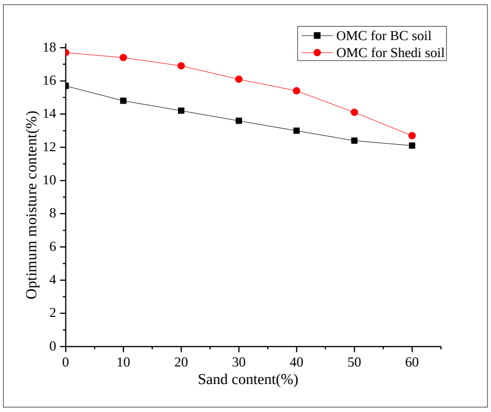


Fig.IV Variation in optimum moisture content of black cotton and shedi soil with varying sand content

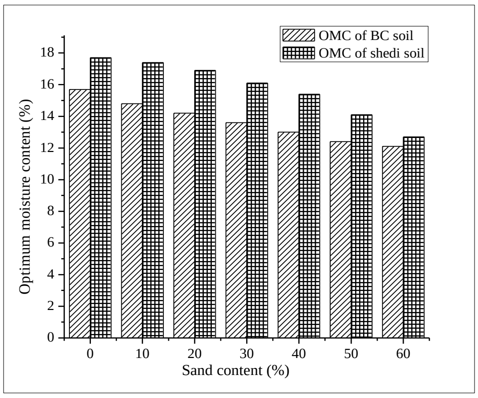


Fig.V Percentage decreased in optimum moisture content of investigating soils with varying sand content

From the fig V as the sand content increases in black cotton and shedi soil there is decrease in optimum moisture content. From fig 4.5 the total percentage decreased in optimum moisture content of BC soil was 18% where as in case of shedi soil the factor reduction in optimum moisture content was 27% as sand content varies from 10% to 60% Based on experimental study the percentage decreased in OMC was found to be 18-27% as the sand content varies from 10% to 60%.

SI	% of sand	OMC (%)	MDD (gm/cc)
1	0	17.70	1.74
2	10	17.40	1.80
3	20	16.90	1.89
4	30	16.10	1.92
5	40	15.40	1.97
6	50	14.10	2.20
7	60	12.70	2.40

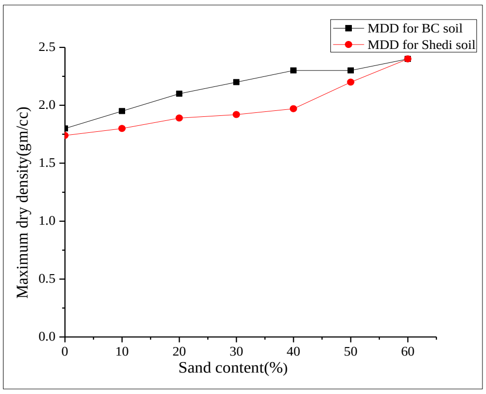


Fig.VI Variation in maximum dry density of black cotton and shedi soil with varying sand content

As the sand content increases in black cotton and shedi soil there is an increase in maximum dry density of soil. From fig VI the percentage increase in maximum dry density of BC soil was 25% where as in case of shedi soil the % increase in maximum dry density of shedi soil was 27%. But at the optimum level of sand content at 60% the

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 10, October- 2014

MDD was almost same in both BC and shedi soil. This is because due to at low fine content the soil structure reside in largely empty void spaces and have little effect on the entire soil behaviour, as the sand content increases the fine particles are closely compact to the sand particles with respect to water content. Based on experimental study the percentage increased in MDD was found to be 19-25%.

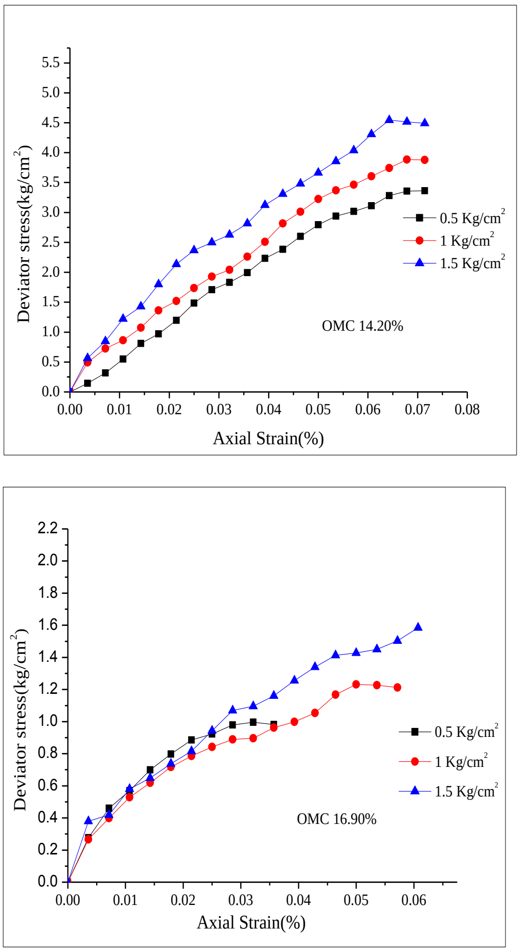
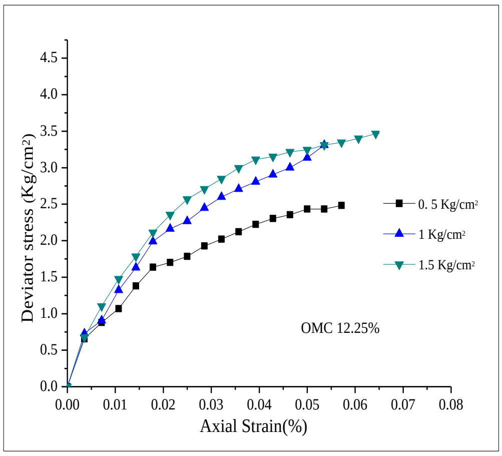


Fig. VII Stress-strain behaviour of BC and shedi soil with 10% of sand content



Stress-strain behaviour shows high deviator stress at 40% of sand content in shedi soil specimen. The specimen of shedi soil and sand content when conducting the experiment under deviator stress and confining pressure the sample fails very quickly compared to BC soil. With increasing order of 10% sand content in each specimen has higher deviator stress. This indicates that cohesion is enhancing the dilatancy and shear strength of sand when sand particles are in close contact during shearing process. This means the behaviour of sand with fines is more compressive and also indicate more compressible in nature

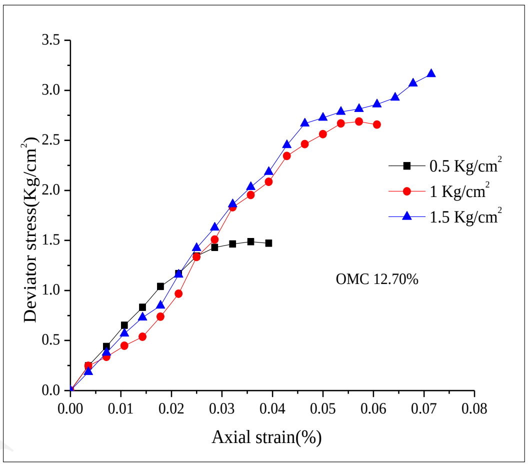


Fig. VIII Stress-strain behaviour of BC and shedi soil with 60% of sand content

By comparison it is evident that the BC soil and sand content specimens are stiffer, stronger and more brittle than shedi sand mixture the BC soil and sand content have a greater tendency to exhibit increases in strength at very high strain levels. For a given compactive effort and dry density, the soil structure in compacted BC soil tends to be stronger than shedi soil. The stress-strain behaviour of soils in the UU test also depends on the confining pressure that is used. The steepness (taking vary less strength) of the initial portion of the stress-strain curves and the strength values both increase as the confining pressure employed in the tests increases. For BC soil samples with containing sand content, the deviator stress increase with increasing confining pressure compared to shedi soil with sand content

Table V Shear parameters of BC soil with varying sand content

SL No	% of Sand	Cohesion(c) (Kg/cm^2)	Frictional angle (Degrees)
1	0	0.71	9.83
2	10	0.47	15.46
3	20	0.47	19.20
4	30	0.49	22.73
5	40	0.50	24.62

ISSN: 2278-0181
Vol. 3 Issue 10, October- 2014

Table VI Shear parameters of shedi soil with varying sand content

SL No	% of Sand	Cohesion(c) (kg/cm^2)	Frictional angle (Degrees)
1	0	0.62	8.88
2	10	0.52	12.89
3	20	0.39	17.74
4	30	0.50	20.29
5	40	0.50	21.62
6	50	0.48	24.37
7	60	0.45	26.29

Variation of frictional angle and cohesion of soil with varying sand content

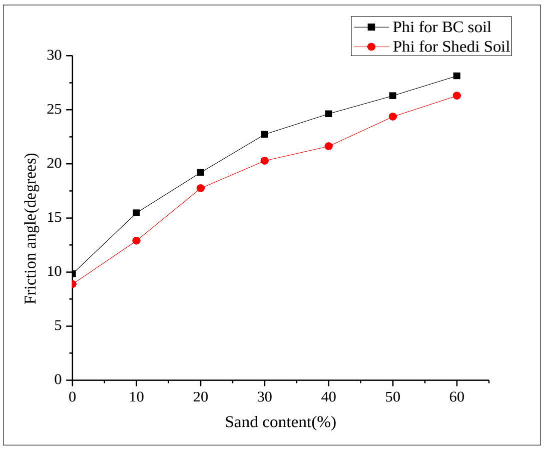


Fig.IX Variation in friction angle of investigating soil with different percentage of sand content
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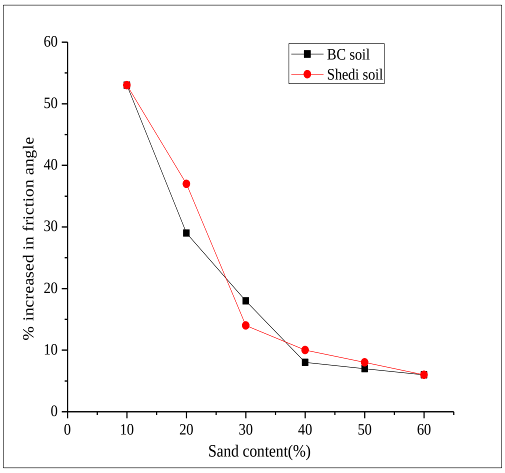

Fig. X Percentage increased in friction angle of investigating soil with varying sand content

- It is well known that shear strength is a function of cohesion and friction angle. Therefore to investigate the shear strength of black cotton and shedi soil with varying sand content. The shear strength parameters (C and Ø) were plotted against the sand content as shown in fig IX and X.

- The fig 4.24 shows the variation of sand content with friction angle indicates that as the sand content increases there is an increase in friction angle .
- From the fig X shows the variation of sand content with cohesion of soil indicates that as the sand content increases there is decrease in cohesion of both black cotton and shedi soils. From fig IX and X at 10% of sand content in both soils the percentage increased in frictional angle was 53% and sand content varied from 50% to 60% in both soil it was found to be 6%. Based on experimental study the percentage decreased in cohesion of soil was found to be 20.2-25.5% as the sand content varies from 10% to 60%.
- From the test results, the frictional angle and cohesion is more in BC soil compared to shedi soil.

Coefficient of consolidation with varying sand content

Table VIII Effect of coefficient of consolidation in BC soil with varying sand content

Sl. No	Sand content (%)	Coefficient of consolidation (Cv) cm^2/min	Coefficient of consolidation (Cv) cm^2/min
1	0	0.09815	0.07432
2	10	0.09669	0.07169
3	20	0.08134	0.06891
4	30	0.06915	0.06652
5	40	0.06137	0.06608
6	50	0.07396	0.06697
7	60	0.07752	0.06714

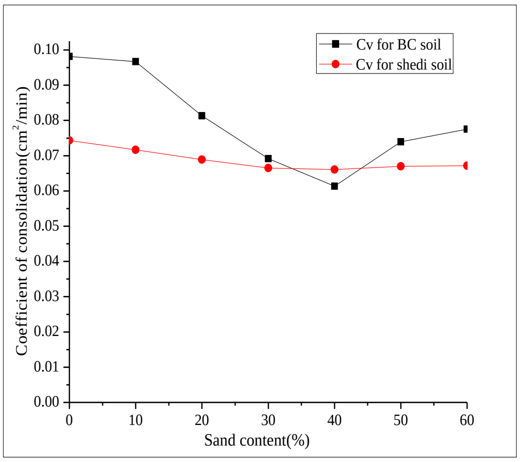

Fig. XI Variation in coefficient of consolidation of investigating soil with varying sand content

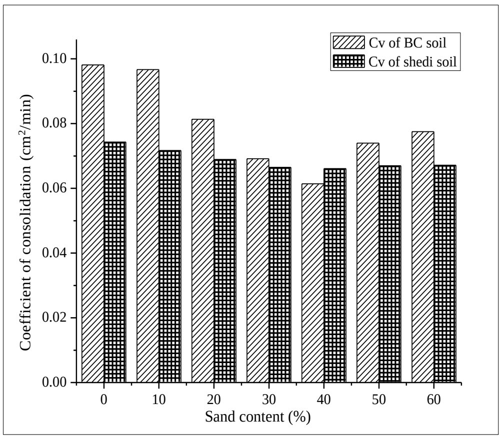

Fig. XII Percentage decreased in coefficient of consolidation of investigating soil with varying sand content

From fig XI as the sand content increases in soil there is decrease in coefficient of consolidation in soil up to specimen containing 40% of sand. A large amount of compression occurred within the first minute of loading, followed by very little compression in subsequent minutes. From table VIII the time-compression behaviour for specimens for BC soil containing 40% of sand it was 0.06137 cm^2/min and the time-compression behaviour for specimens for shedi soil containing 40% of sand it was 0.06608 cm^2/min. based on experimental study the compression chacteristic more in BC soil than shedi soil. At 50% and 60% sand content in both BC and shedi soil the coefficient of consolidation was increases. The result reveal that as sand content increased from 40% there is increase in the compression characteristics of fine soil like BC and shedi soil as shown in fig 12. The percentage decreased in coefficient of consolidation of black cotton and sand mixture was found to be 36.4% and in case of shedi soil with sand content was found to be 7.34% as the sand content varies from 10% to 40%.

V. CONCLUSIONS

Based on the tests conducted, the following conclusions have been drawn which are applicable only to materials used and test conditions adapted in this study.

- Based on experimental study of shrinkage limit, increase in sand content causes decrease in shrinkage limit of soil. By comparing black cotton and shedi soil as the sand content increases, the percentage decrease in shrinkage limit of black cotton soil significantly about 32% and shedi soil marginally about 5% at sand content 60%.
- For both black cotton and shedi soil the Maximum dry density increases and optimum moisture content decreases by adding different percentage of sand content.
- Based on experimental study the percentage increased in MDD was found to be 19-25% and the percentage decreased in OMC was found to be 18.6-27.4% as the sand content varies from 10% to 60%.
- The failure stress increases with increase in sand content from 10% to 40%. And further increase in sand content, the failure stress remains same.
- Based on experimental study the sand content at 10% in both soils the percentage increased in frictional angle was found to be 53% and sand content at 60% in both soils the percentage increased in friction angle was found to be 6%.
- Based on experimental study the percentage increased in friction angle was found to be 45.4-50.7% at 60% of sand content.
- The percentage decreased in cohesion of soil was found to be 20.2-25.5% at 60% of sand content.
- Based on experimental study, as the sand content increases in soil there is decrease in value of coefficient of consolidation up to sand content of 40% in soil. Beyond that addition of sand content in both soils there is significant increase in the value of coefficient of consolidation.
- The percentage decreased in coefficient of consolidation of black cotton and sand mixture was found to be 36.4% and in case of shedi soil with sand content was found to be 7.34% at 40% sand content.

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