An Experimental Study on Bearing Capacity and Settlement of Rectangular Footing over a Back Cotton Soil Blended With Sand and Layered Black Cotton Soil with Sand

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***Abstract* - In this paper the behavior of black cotton soil results in the swelling and shrinking properties which causes many problems to the building which is constructed on them. It is necessary to improve the bearing capacity and settlement of the BC soil, BC soil is barrowed from the Hassan district. Sand is barrowed from the locally available material near the construction site is used to found out the bearing capacity of the layered BC soil and sand, suitable metal tank is taken which as the size of 40cm length ,28cm width, 40 cm height. For the variation of percentage sand which is mixed to the BC soil to find out the bearing capacity of the blended sand & BC soil, the high load carrying capacity of the soil is obtain for 30% sand + 70% of BC soil and also maximum dry density is obtained and further addition of sand the load carry capacity decreases, this is because the spaced sand particles occupies the place by the BC soil. Bearing capacity and the settlement of layered BC soil and sand is placed to tank at maximum dry density at specified height 5 cm BC soil at top and 35 cm of sand at bottom and s0 on, up to 40 cm BC soil and vice versa. The load carrying capacity is observe red for sand compared to the BC soil, as the height of the layered sand increases the bearing capacity also increases and 40 cm of BC soil as lower load bearing capacity.**

Index Terms – Black Cotton Soil, Unconfined Compression Strength, Bearing Capacity.

I. Introduction

An important and fundamental problem in field of civil engineering is the prediction of bearing capacity and settlement of the super structure. The settlement of the soil is due to load transmitted from the superstructure to the underlying soil. In the field the different types of footings are used, nature of load transmitted also varies; a differential settlement total settlement of the structure has to be ensured to be safe. The settlement of a structure generally processes the decrease in volume and causes damage in the structure. All in all because of the static loading water removal occur which brings about lessening in volume, when the stress us applied to a soil the soil particle which is closely packed get reduction it's bulk volume when soil is saturated with water, water squeezes out of the soil. For the safety purpose the settlement is within the 50 mm of load transmitted to the soil. A settlement depends upon the various type of footing such as capacity, type of soil, particle size, area and shape of footing etc. The size of footing shows different settlement on the same type of doing and the same type of loading condition. Where more knowledge is required for the design of foundation, the settlement of footing. The shape of the footing may also play an important role in settlement of footing, the settlement and the safety against failure of the foundation design.

The Soil classification gives the Information regarding engineering properties of the soil such as permeability, strength, expansion etc. The soil Classified based on the consistency limit and particle size distribution. There are two types of soil classification course Grain soil and fine grained soil. Fine grained soil contains silt and sand while coarse grained soils contain gravel. Generally coarse grained soil has less problematic and have low plasticity to non plasticity, generally fine sand and silty sand process more problematic soil.

II. Objectives

- The fundamental target is to research the geotechnical property of the BC soil and sand.
- To investigate the load Bearing limit and settlement of model rectangular footing resting over layered BC soil and sand.
- To analyze the bearing capacity for the layered soil with depth variation.
- To analyse the comparison characteristic and strength properties of blended BC soil with sand at different percentage.
- Comparison is done between the BC soil and settlement of layered soil and blended soil.

III. Literature Review

PANKAJ & TRIVEDI (2016), this paper displays the investigation of BC soil and its intermittent volume changes with the variety of moisture content. By experiment it is found that the blending of sand and cement in the soil specimen, brings about change of free swell record an incentive from 45.45% to 6%, at last it is lessening to 86.79% with the expansion of 20% sand and 2% cement respectively. By this examination the Atterberg's limits such as liquid limit, plastic limit additionally continues decreasing with increase in sand content. The estimation of the liquid limit decreases up to 30% by the expansion of 20% sand and 2% cement blend. On account of OMC and MDD, Optimum moisture

content decreased from 16% to 10%, at last decreases to 37.5% while most maximum dry density increased from 1.8 to 2.01. Thus, the research in this area will pave the way to build up a design methodology to mitigate the troubles of BC Soil.

KUNDAN & JAIN (2015), Utilization of granular pile in BC Soil demonstrated that the soil quality on wetting could be enhanced essentially. The granular pile is found to enhance the load bearing limit of a footing to shifting degree depends upon the underlying consistency of the soil, consideration of fibers. The decrease in swelling relies on upon the extent of the granular pile and depends on the content in the soil, a larger diameter pile and at low beginning moisture content, more prominent decrease in swelling is observed, greater reduction in swelling is observed. Field application of both the techniques is yet to be studied.

KIRAN & NAGRAJ (2015), this paper displays that the behavior of reinforced sand in enhancing the bearing capacity and settlement under the square footing and circular footing. From the results can be conclude that reinforced sand have 30% more load carrying capacity than unreinforced sand under square footing and 10% more in circular footing. Increase in the number of layer of reinforcement, load carrying capacity of sand increases by 5 % to 10% under both square and circular footing. In the unreinforced and reinforced condition with intrusion of soil layer increases the load bearing capacity of sand by 10% for square footing and 30% under circular footing. The three layer reinforced sand bed as the bearing capacity of 272.27kN/m2 and the sand bed with embedded lateritic have high bearing capacity of 274.51kN/m^2.

NEETU et.al. (2014), in this paper introduces the results of lab tests BC Soil is extremely feeble and does not have enough stability for a development work. The motivation behind this review to decide the optimum measurement of the stabilizer, which enhances the quality of soil (CBR not exactly or equivalent to 2 % to over 7 %) which is appropriate for asphalt structure. Experiment result found that expansion of sand substance in soil brings about the change of soaked CBR extreme from 1.93 % to 7.39 %. The most extreme CBR is acquired while utilizing 40% sand & 2% concrete with the regular soil. The BC Soil after stabilizing with cement and sand for higher MDD & CBR shall be taken for further improvement in CBR value using Geo-textile reinforcement.

IV. Materials & Equipments

A. *Black cotton soil*

The black cotton s0il (BC Soil) was obtained from Hassan district of Karnataka state in India. It is an expansive soil which c0ntains Montmorrilonite as the maj0r mineral. S0il is c0llected from a depth of 1m to 2m below the natural ground level by open excavation. The soil was dried and sieved through 4.75mm IS sieve.

TABLE I
Properties 0f Black Cotton S0il

Sl No.	Properties	Values
1	Specific Gravity	2.63
2	Co-efficient 0f Uniformity, Cu	3.4
3	Co-efficient of Curvature, Cc	1.67
4	Liquid Limit	66.7%
5	Plastic Limit	27%
6	Plasticity index PI	39.8
7	Soil classification	CH
6	Maximum Dry Density in kN/m2	14.3 kN/m^3
7	Optimum Moisture Content in %	16.4%
8	Unconfined Compressive Strength kN/m^2	168.5 kN/m^2
9	Cohesion	14 kN/m^2
10	Angle of Internal Friction	13°

B. *Sand*

Sand used in research work is collected from the nearby construction site. Which was brought from the place called Mandya from Karnataka State. Sand is a natural occurring granular material composed of finely divided rock & mineral particle. The sand is to make it free from grass roots and other organic materials and then the sample is dried in oven. A sand of 4.75mm IS sieve passing of required amount is taken for this work

TABLE II
Properties of Sand

Sl No.	Properties	Value
1	Specific Gravity, G	2.67
2	Co-efficient of Uniformity, Cu	3.4
3	Co-efficient of Curvature, Cc	0.81
4	Maximum Dry Density in kN/m2	15.2 kN/m3
5	Cohesion	0
6	Angle of Internal Friction	43°

C. *Test tank*

Tank size is decided on the some of the results of literatures and on the of IS code. IS 1888-1962 says that minimum size should to be no less than 5 times the width of test footing plate to build up the full failure zone with no interference of side of the tank. For cohesionless soil, Chumar (1972) proposed that the maximum expansion of failure zone will be 2.5 times the width of footing width along the sides and depth of foundation should be 3times the width of footing below the base of the footing. Keeping the above criteria in mind, 40cm long tank with 260mm width and 40cm height has been used for 5cm and 8 cm footing and thickness of 1 cm during experimental work. Due to the tank size, there may be some scale effect which will influence the ultimate bearing capacity of footing resting over sand bed. The tank is made up of 1cm thick mild steel.

Fig. 1: Mild Steel Test Tank

D. Funnel

The funnel is used for raining technique or rainfall technique. A funnel is used to pour the sand into the tank to get the uniform density throughout the tank and also to maintain the uniform density over the depth of the tank. The thread was fixed to the bottom of the funnel to maintain constant height of fall. The sand is poured at different heights to know the maximum and minimum density of sand after that sand is poured by fixing the height of fall to get required density.

E. Bearing ball

A ball is used to transfer the load from loading frame to footing on the layered soil which acts as a hinge between footing and proving ring, which helps the footing to take its own position during failure and also to coincide the footing face with sand surface during failure.

Fig. 2: Ball Bearing

F. Model Footings

Two model footing of size 5cm X 8cm square of 1cm thickness made up of mild steel is used for experimental work. A grove is made at the centre of top face of the footing to place a rigid metallic ball which connects the footing and bottom of proving ring which helps to apply a load. The footing is placed on the sand bed so as to make it rough so that friction between footing and foundation soil can develop during application of load.

Fig. 3: Rectangular Footings

G. Static Loading Unit

An electrically operated static loading unit is used to apply the load on the footing during test. The whole loading unit consists of one electrical motor one loading frame with shaft. Power pack consist of one vertical jack inter connected with electric motor and it also consist of levers to operate by hand also. The loading system applies a load at a strain rate of 2.5mm/min. The frame is supported by a horizontal beam which provide there action to the frame during application of load. In a testing machine, stress is connected to an sample of the material being tried in a way which brings about stress along one axis being not the same as the stress in perpendicular direction. This is commonly accomplished by setting the example between two parallel platens which apply stress in one (normally vertical) direction, & stress in the perpendicular direction applied due fluid pressure to the specimen.

H. Proving Ring

A proving ring has a capacity of 2.5 kN is used to record the applied l0ad on the footing during the experimental work. The least count of this proving ring dial gauge obtained from calibration chart. One small division of proving ring dial gauge is equal to 0.2kN.Top of proving ring is attached with the metallic frame of the set up at top of static loading unit while the bottom is in contact with the metallic ball which is resting on the footing. The rigid metallic ball between the footing and the proving ring acts as a hinge. When load is applied, the load is transmitted from proving ring to the footing through metallic ball.

Fig. 4: Proving Ring

I. Dial Gauge

A dial gauge which can measure the settlement with least count of 0.002mm is used during the experimental work. It is fixed at the top of the tank in which is foundation and the settlement of the footing is recorded in the dial gauge by keeping the needle on top of the footing. A steel bar which is supported by frame is used to support the dial gauge on footing.

Fig. 4: Dial Gauge

V. METHODOLOGY

A. *Experimental Procedure for Blending Of Black Soil and Sand*

1) Basic tests for soil are carried out according to IS 2720 standards.
2) Tank dimension decided as per IS code and some literatures (3 times the width of the footing) of 40cmx26cmx40cm (length, width, height) and footing size 8cmx5cmx1cm has taken during experimental work.
3) Preparation of foundation bed- The soil is free from lumps is taken to 90% of black cotton soil quantity which is mixed with 10% percentage of sand, the calculated amount of water by compaction test which is OMC i.e. 15.55% of 90% BC and 10% sand OMC is added and mixed thoroughly.
4) The soil is spread into the metal tank and compacted with the hammer up to the height of 15-20cm to get the MDD and the procedure is repeated continuously till the soil is reached to the required height of tank i.e. 40cm height of tank.
5) The blended soil is filled at the MDD i.e. 15.2kN/m3 in which the value is obtained from the compaction method.
6) The prepared model footing which is placed below the proving ring and the metal footing which as the size of 5.2cm X 8cmis placed and load setup has to been done.
7) Settlement v/s load is calculated.
8) Curve is drawn and by using tangent intersection method, experimental bearing capacity is extracted.
9) Procedure is repeated for different percentage of BC soil and sand.(80% of BC & 20% of Sand, 70% of BC & 30%, 60% of BC & 40% of Sand)

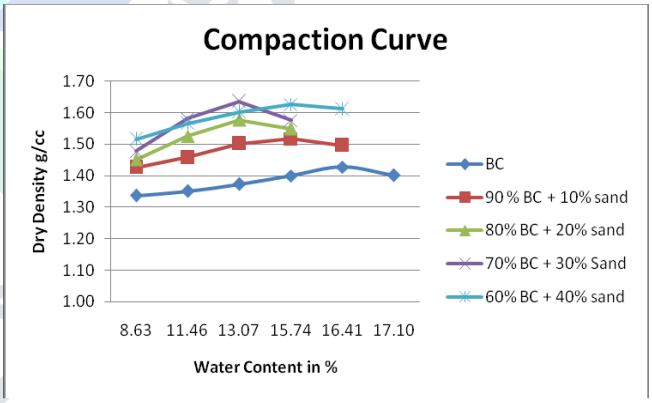
B. *Experimental Procedure for Layered Soil*

1) Basic tests for soil are done according to IS 2720 standards.
2) Tank dimension decided as per IS code and some literatures (width of the footing is 3 times) of 40cmx26cmx40cm (length, width, height) and footing size 8cmx5cmx1cm has taken during experimental work.
3) Preparation of foundation bed- The soil is free from lumps is taken to some quantity on each layer which is mixed with calculated amount of water by compaction test which is OMC i.e. 16.66%.
4) The soil is spread into the metal tank and compacted with the hammer upto the height of 15-20cm to get the maximum dry density and the procedure is repeated continuously till the soil is reached to the required height of tank i.e. 40cm height is calculated (5cm BC soil and remaining 35 cm sand) and the sand is filled at the specified height in a such that the MDD obtain from the Pluviation technique.
5) BC soil is filled at the MDD in which the value is obtained from the compaction method.
6) The prepared model footing which is placed below the proving ring and the metal footing which as the size of 5.2cm X 8cmis placed and load setup has to been done.
7) Settlement v/s load is calculated.
8) Curve is drawn and by using tangent intersection method, experimental bearing capacity is extracted.
9) Procedure is repeated for different height of BC soil and sand. (10cm BC and remaining 30 cm sand, 15cm BC and remaining 25 cm sand, 20cm BC and remaining 20 cm sand, 25cm BC and remaining 15 cm sand, 30cm BC and remaining 10 cm sand, 35cm BC and remaining 5 cm sand, 40cm BC, and vicevarsa)

VI. RESULTS AND DISCUSSION

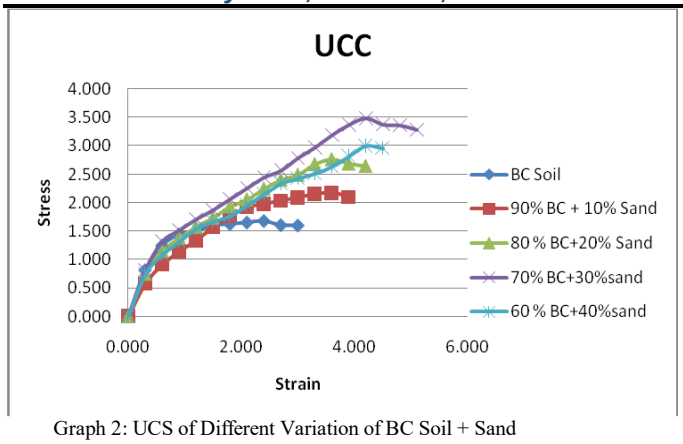
*1) Blending Of Black Cotton Soil & Sand :*It is the process of mixing the same amount of BC soils with sand in order to check the strength properties of the blended soil and load tests have been performed for blended soils on model rectangular footings of size 5.2cm and 8cm breadth and length respectively resting over the blend of BC soil and sand (90% BC soil+10% sand,80% BC soil + 20% sand ,70% BC soil+ 30% sand, 60% BC soil + 40 % sand).

2) Compaction Curve 0f Black Cotton Soil And With Some Percentage Of Sand: Below graph shows the compaction curves of black cotton soil blended with sand variation from 10% to 40% and the optimum moisture content of black cotton soil lessening with the addition of sand. The MDD get for the 30% of sand blend with black cotton soil, this is on account of sand particles are coarser with that of BC soil. Coarser soils require lesser moisture content substance to get the MDD of soil. The density of blend expanded because of good packing of particles together of clay combines with sand particles prompting well grade soil of the blend and sand has more specific gravity.



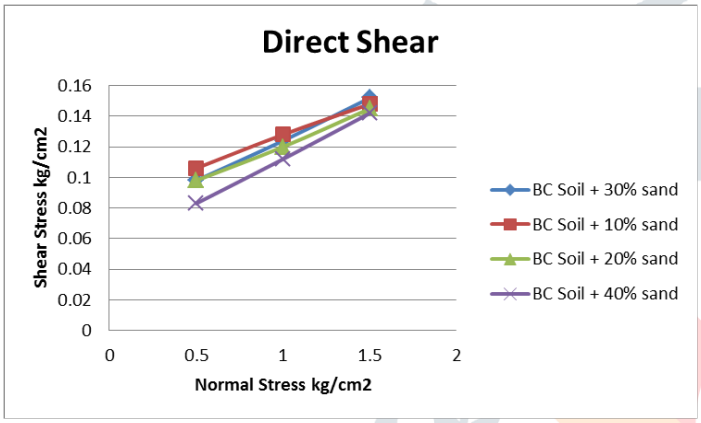
Graph 1: The compaction curves of black cotton soil blended with sand variation from 10% to 40%

3) Unc0nfined Compressive Strength of Black Cotton Soil with some Percentages Of Sand: Unconfined compressive strength test for all composites were conducted in the laboratory using a strain rate of 1.2mm/min. As discussed in above section, with the help of UCS test, optimum mixes for all composites were obtained. UCS of BC soil used in this study was 168.5kN/m2. Due to the addition of sand percentage upto 30% in the soil, dispersed structure aggregation occurs up, so as resulted UCS values increased from 168.5 kN/m^2 to 348.3 kN/m^2 and then the further addition of sand particle, the UCS values suddenly decreased to 299 kN/m2.



Graph 2: UCS of Different Variation of BC Soil + Sand

4) Direct Shear of Black Cotton Soil with Some Percentages of Sand: Graph 3 shows Direct Shear Test of Different Variation of BC Soil + Sand



Graph 3: Direct Shear Test of Different Variation of BC Soil + Sand

5) UCS of Different Variation of BC Soil + Sand: Load tests have been performed on model rectangular footings of size 5.2cm and 8cm breadth and length respectively resting 0ver the blend of BC soil and sand (90% BC soil+10% sand,80% BC soil + 20% sand ,70% BC soil+ 30% sand, 60% BC soil + 40 % sand).

The l0ad deformation behavi0r 0f the BC soil is done by loading in a Triaxial loading at the strain rate of 1.25mm/minute. Loading tests were done on sandy soil & BC soil prepared in tank mould is applied through rectangular model footings resting on the surface of sand and black cotton layers which are filled in three layers are filled in the tank

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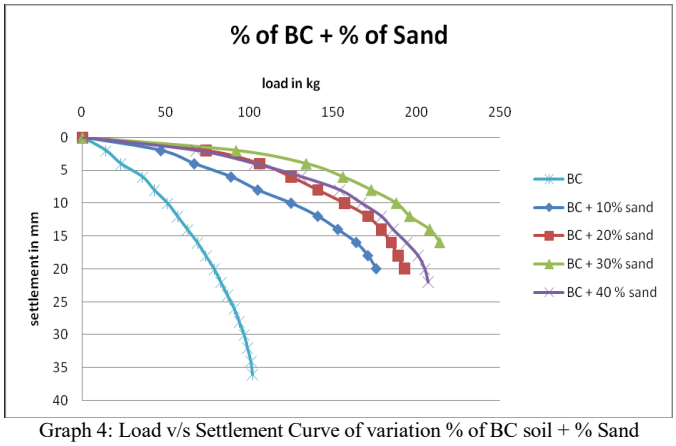
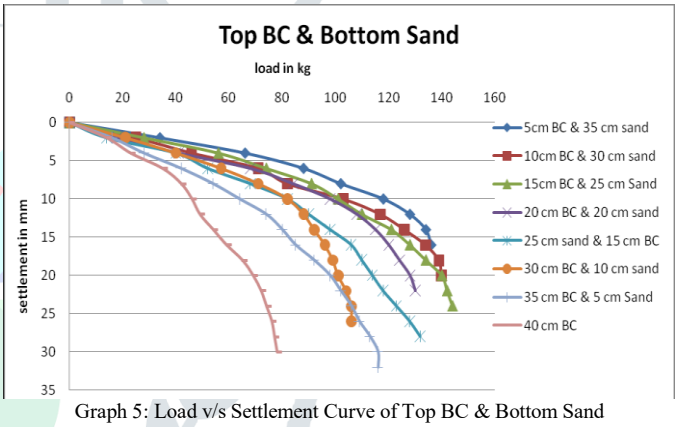


Graph 4: Load v/s Settlement Curve of variation % of BC soil + % Sand

From the above graph we have to know that the load carrying capacity of the rectangular footing is more for 70% black cotton soil and 30 % sand 435.69 kN/m^2 which has settlement of 4.3 mm which is more than the other percentage of sand and BC soil percentage. With further increase in percentage of sand i.e. BC soil of 60 % and 40 % sand lowers the bearing capacity i.e. 390.2 kN/m^2 and settlement found to be 4.9 mm.

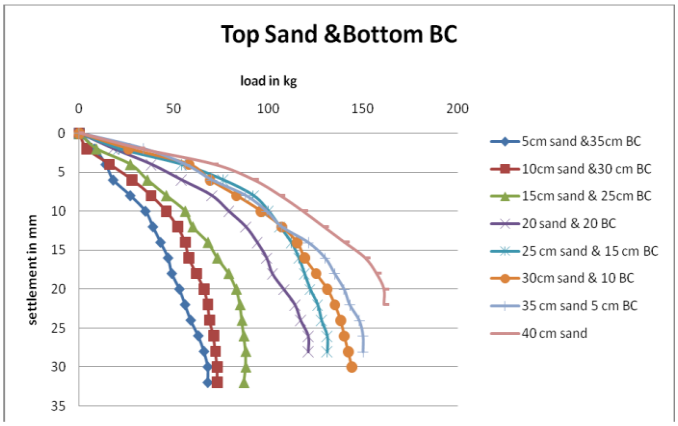
*6) Model Footing Test Results Of Bearing Capacity With Layered Top Black Cotton Soil And Bottom Sand :*Load tests have been performed on model rectangular footings of size 5.2cm and 8cm breadth and length respectively resting over black cotton soil and sand bed (5cm BC and remaining 35 cm sand, 10 cm BC and 30 sand, 15cm BC and 25 cm sand, 20 cm BC and 20 sand, 25 BC and 15 cm sand, 30 cm BC and 10cm sand, 35cm BC and 5 cm sand , vicevarse). The load deformation behavi0r 0f the BC soil is studied by loading in a Triaxial loading frame at a strain rate of 1.25mm/min. Loading tests were performed on sandy soil and BC soil prepared in tank mould is applied through rectangular model footings resting on the surface of sand and black cotton layers which are filled in three layers are filled in the tank.



Graph 5: Load v/s Settlement Curve of Top BC & Bottom Sand

From the above graph we have to know that the load carrying capacity of the rectangular footing is more for sand comparatively less for the BC soil. The bearing capacity of layered soil which is 5cm of BC soil and 35 cm of sand bed under rectangular footing was found to be 293.6kN/m2 and settlement found to be 7.2 mm which have more bearing capacity than the other layered soil. With the further increases of BC soil layer depth the bearing capacity decreases. Lower bearing capacity of layered soil of 40cm of BC soil is found to be 156.21kN/m2 and settlement found to be 14.3mm.

7) Model Footing Test Results Of Bearing Capacity With Layered Top Sand And Bottom Black Cotton Soil: From the graph 6 we have to know that the load carrying capacity of the rectangular footing is more for sand comparatively less for the black cotton soil. The bearing capacity of sand bed of 40 cm under rectangular footing was found to be 330.52kN/m2 and settlement found to be 5.6mm which have more bearing capacity than the other layered soil. With the further increases of sand layer depth the bearing capacity increases. The lower bearing capacity of layered soil of 5cm sand and 35 cm of BC soil is found to be 163.4kN/m2 and settlement found to be 9.1mm.



Graph 6: Load v/s Settlement Curve of Sand at Top & BC at Bottom

VII. CONCLUSION

The following conclusions are drawn from the study conducted on BC soil and sand.

1) The MDD of BC soil and sand mix improved with the addition of sand up to 30% thereafter it decreased and the OMC decreases with the addition of sand.

2) The compressive strength of the plain BC soil is 168.5kN/m2 with mix of 30% sand increases by 15%-25% and thereafter with addition of sand decreases the strength.

3) The cohesion of BC soil decreases with increase in the sand percentage where as angle of internal friction increases with increase in sand percentage.

4) The bearing capacity of the plain BC soil is increased by 12 %- 55 % with mix of sand for different percentage, and there is a reduction in settlement.

5) The plain sand has more load carrying capacity than plain BC soil under rectangular footing.

6) As the depth of the BC soil increases in the layered soil, bearing capacity of the soil decreases by 40%. Similarly as the depth of the sand increases in layered soil the load bearing capacity of the soil increases by 40-50%.

7) The sand bed of 40 cm height have bearing capacity of 330.52kN/m2 and the BC soil mixed with 30% sand which is 435.65 kN/m2 have high bearing capacity and also reduction in the settlement.

8) It is tabulated that the layered BC soil depth increases, the settlement also increases by settlement under rectangular footing by 7.2 mm to14.4 mm, where as in the blending method the BC soil settlement decreases from 14.4 mm to 4.6 mm.

9) Therefore it can be conclude that the earthquake resistance and gravity forces can also minimized by this type of sand addition to the BC soil.

10) After conducting the tests, the following results are observed that the considerable reduction in the settlement using sand.

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