Int. J. of GEOMATE, April, 2016, Vol. 10, No. 2 (Sl. No. 20), pp. 1743-1750
Geotech., Const. Mat. and Env., ISSN: 2186-2982(P), 2186-2990(O), Japan

CBR VALUE OF SANDY SUBGRADE BLENDED WITH COARSE AGGREGATE

Kesharwani R.S.[1] Sahu A. K. [2] Khan N.U.[3]

[1,3]Department of Civil Engineering, Jamia Milia Islamia, New Delhi,India

[2,]Department of Civil Engineering, Delhi Technological University, Delhi, India.

ABSTRACT:-In several parts of India, soil deposits consist of a matrix like soil with inclusions of coarser aggregates of various sizes. The CBR test is used for the design of sub grade for highways & pavement. Therefore in the present investigation, the CBR tests were carried out on the sand blended with coarse aggregates of various sizes and proportions. To strengthen the sub grade strata, coarse aggregates of 10mm and 20mm sizes were mixed in the sand, in various proportions. The soil samples were prepared and tested first without coarse aggregates, then by mixing coarse aggregates in varying percentages by weight, starting from 5% to 30%. The results of CBR tests shows that with the increase in the percentage of coarse aggregates, the CBR value of the soil increases. It is observed that the percentage improvements in the CBR values ranges from 20.99 % to 115.83% and 31.30% to 151.94% for 10mm and 20mm coarse aggregates respectively at OMC. In soaked condition, this improvement ranges from 23.20% to 202.48% and 31.35% to 233.17% for 10mm and 20mm coarse aggregates respectively.

Keywords: *Soil, Coarse aggregates, CBR, Subgrade*

1. INTRODUCTION

In engineering practice, the earth construction requires compactions of existing sub grade by improving the density & strength of the strata. All types of earth structures i.e. highways, pavements etc. rest directly on the soil beneath them. The safety of these entities depend upon the strength/bearing capacity of the soil over which these are constructed. Therefore, a proper analysis of the soil properties and the design of their compression parameter become necessary to ensure that these structures remain stable and are safe against unequal settlements. To determine the suitability of any soil type for use as sub grade, sub base or base material, one of the parameter generally used is the California bearing ratio (CBR).

CBR is frequently used as test value for civil engineers particularly to those who are in pavement construction to access the stiffness modulus and shear strength of the sub grade. It is actually an indirect measure which represents the strength of a crushed rock as a percentage value. Usually the CBR values are used by the pavement engineers to design the thickness of the pavement to be laid on the sub grade.

The thickness of the pavement will be more for the sub grades having lesser value of CBR and vice versa. In other words the designed thickness of the pavement is very much depending upon the CBR value of the sub grade soil. Different types of soils give different values of CBR even though these were compacted to same amount of energy and rate of penetration. To enhance the strength of sub grade soil, several techniques like compaction, mechanical/electrical/thermal stabilization, addition of geotextile, geosynthetic, fly ash or randomly distributed discrete fibers are used. In the present study, the variation in CBR value or sub grade strength of soil is carried out due to the addition of coarse aggregates. The coarse aggregates are the rock fragments usually restricted to round or sub rounded particles. The review of literature is carried out for the improvement to the CBR value by various technique.

Srivastava et al [1] reported that the CBR of the soil increases when the geotextile layer intercepts the pressure bulb generated due to the application of the applied load and further by using geotextile in layers the thickness of road pavement can be reduced by virtue of increased failure stresses. Jain et al [2] observed that with the addition of 4% discrete natural fiber in sand at a density of 16.60 KN/m^3 there is 114% and 80% increase in the CBR value of soil both in unsoaked and soaked conditions. While the direct shear test indicates that there is increase in the cohesion of the soil. Pandian et al [3] while working on soil, fly ash mixes reported that with the addition of 20% fly ash in black cotton soil the CBR value of black cotton can be improved while the CBR of fly ash can be improved with the addition of 30% black cotton soil. The study also indicate that the low value of CBR of black cotton soil or fly ash is due to poor gradation, thus, the gradation and the compacted strength can be significantly improved by mixing the two materials in proper proportions.

Singh & Kumar [4] studied the effects of surcharge and the compaction on the CBR value of alluvial soil and concluded that the surcharge load and the compacting effort both influences the CBR value of the soil i.e. the CBR value of soil increases with the increase in surcharge load as well as the compacting effort. Amu et al [5] observed that up to 60% stabilization the CBR value increases and beyond which it starts decreasing. At 60% stabilization, the CBR value obtained was highest at 110.73% for lime and 92.26% for wood ash. The CBR values of soil samples were found better when stabilized with lime and when stabilized with wood ash the maximum dry density of the soil sample was found better.

Duncan-Williams & Attoh-Okine [6] show that the soil having low CBR values benefited more as compared to soil having higher CBR values both in un-soaked and soaked conditions when reinforced with geosynthetic though the improvement in strength and the CBR value depends upon the characteristics of the geo-synthetic used. Naeini & Mirzakhanlari [7] used geotextile as a reinforcing material and reported that though it improves the CBR value, its inclusion in soils leads to decreased penetration and deformation thus improving the stress distribution of the soil sample. Duncan-williams and Attoh-Okine[6] also concluded similar results. The strength and the CBR value increases when its layer is placed in the middle of the granular soils but the same decreases when used in the fine grained soils.

Modak et al [8] studied the combined effect of lime and fly ash in black cotton soil and concluded that with increasing the percentage of lime and fly ash in black cotton soil, (CBR) and maximum dry density (MDD) values are also increases. Mehta et al [9] stabilized black cotton soil using lime .The CBR value of the lime stabilized clayey soil was improved due to decrease in the plastic behaviour of the soil.Mudgal et al [10] studied the effects of lime & stone dust on CBR value of black cotton soil with the addition of 9% lime and 20% stone dust by weight with black cotton soil,the CBR value increased.

A review of the literature reveals that most of the work has been carried out using either fly ash/geo-textile/lime or rice husk ash as a reinforcing material to enhance the CBR value of the soil and very few or none studies have been carried out using coarse aggregates as a reinforcing material in the soil to enhance its properties. Hence study is needed to evaluate this aspect too since in areas where coarse aggregates are available in abundance and procuring of other reinforcing materials proves to be uneconomical, adding coarse aggregate will be a suitable option.

Table 1.Geotechnical properties of soil.

Particulars	Values
Natural Moisture Content	4.26%
Bulk Density (KN/m^3)	17.2
Specific Gravity	2.65
Uniformity Coefficient (Cu)	2
Coefficient of Curvature (Cc)	1.14
Maximum Dry Density (MDD) (KN/m^3)	17.7
Optimum Moisture Content (OMC)	11.41%
Cohesion	0
Angle of internal friction	32^0
Classification of soil	SP

2. MATERIALS& METHODOLOGY USED

2.1 Sandy Soil:

The sandy soil used in the study is procured from river basin transported by stream etc. The different geotechnical properties of soil are summarized in Table-1 and the particle size distribution curve is shown in Fig-1.

2.2 Coarse Aggregates:

The coarse aggregates obtained in this study are the same as used for making plain cement concrete. The different physical properties of the coarse aggregates used are given in Table-2.

2.3 Water

The CBR tests in the study have been carried out in the laboratory. Therefore, water used for mixing during the preparation of the samples is taken as available in the laboratory which is an ordinary tap water. The various physical properties of water used are given in Table-3.

3. EXPERIMENTAL INVESTIGATION

3.1 Introduction

The bulk quantity of sand and aggregates of 20 mm & 10 mm nominal sizes are procured in the laboratory and stored properly. The collected sample of sand and coarse aggregate were characterized in the laboratory. The tests were carried out to determine the physical and chemical properties of the material. The Proctor's compaction test were performed on the sand to determine the optimum moisture content and maximum dry density of the sand. The coarse aggregate of 20 mm & 10 mm sizes in various proportions (5% to 30% by weight) are mixed with the sand and the CBR values of each mixes were determined under soaked and un-soaked condition.

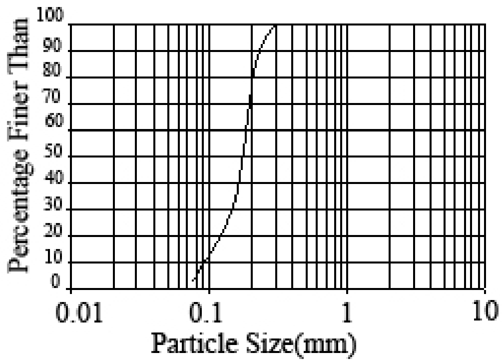

Fig. 1. Particle size distribution curve.

Table 2. Physical properties of coarse aggregates.

Particulars	Values
Aggregate Crushing Value (ACV)	11.21%
Aggregate Impact Value (AIV)	9.86%
Specific Gravity (G)	2.64
Water Absorption	2.36%
Fineness Modulus	7.36

3.2 Details of Test Conducted

The details of experimental programs are summarized in Table-4.The tests were performed conforming to Indian standard specifications listed in the reference. A known quantity of coarse aggregates was mixed in the soil with the water contents corresponding to the maximum dry density of the soil. The prepared soil coarse aggregate mix was then kept in a sealed polythene bag for maturing for 24 hours. The re-moulded samples were then prepared by compacting matured soil coarse aggregate mix in the CBR mould in three equal layers giving each layer 56 blows of rammer weighing 26 N, using dynamic compaction method at maximum dry density. For each test, two samples were prepared first for immediate penetration test at OMC and the second one was soaked in water before the penetration test for 96 hours for free accesses of water from the top and bottom of the mould with a surcharge weights 50 N. The test on soaked sample serves as a precaution to allow for the increase in moisture content due to either rise in water table or floods in the region and the surcharge weight simulates the effect for the thickness of the road pavement overlaying the base course.

3.3 CBR Tests

California bearing ratio tests on soil coarse aggregate mixes were conducted at OMC and soaked conditions using the standard method as described in IS: 2720 (Part 16) – 1979.

Table 3. Physical and chemical properties of water.

Particulars	Values
pH value	6.87
Dissolved Solids	32.00 mg/l
Suspended Solids	144.00 mg/l
Sulphates	86.00 mg/l
Chlorides	128.00 mg/l
Turbidity	3.50 NTU
Alkalinity	25.00 mg/l
Hardness	74.00 mg/l

The experimental setup for penetration test consists of a loading machine of 50 KN capacity equipped with a movable base enabling the plunger of 50 mm dia. to penetrate into the test specimen at a rate of 1.25 mm per minute, proving ring of 50 KN capacity for measuring the load, a metal mould of 150 mm internal diameter and 175 mm in height fitted with 60mm high collar and a perforated base plate, Two annular weights each of 25 N, spacer disc, a metal rammer weighing 26 N and dial gauge for recording penetration of plunger up to 25 mm.

4.RESULTS AND DISCUSSION

4.1 Geotechnical Properties of Soil

The particle size distribution curve obtained by plotting the result of sieve analysis indicates that the soil contains nearly 96.40% particles passing through 4.75 mm IS sieve and larger than 75 micron IS sieve. This shows that the soil falls in the category of sand. Since the uniformity coefficient is

2.1 and the coefficient of curvature is 1.18, therefore the soil is designated as SP, i.e. the poorly graded sand.

Table 4. Experimental program me

Material	Details of The Experiments
Sandy Soil	Natural Moisture Contents, .Bulk Density, Specific Gravity, Grain size distribution, Compaction Characteristics, CBR Tests (As per IS: 2720,various parts)
Aggregates	Aggregate Crushing Value, Aggregate Impact Values, Specific Gravity , Water Absorption, Fineness Modulus(as Per IS:383 & IS:2386, Various Parts)
Water	pH, Dissolved Solids, Suspended Solids, Sulphates, Chloride, Turbidity, Alkalinity, Hardness(Standard Methods)
Sand mix with aggregates	CBR Tests

The moisture content-dry density relation revealed that due to addition of water the dry density increases uniformly to a maximum value of 17.70 KN/m^3 at 11.41% moisture content thereafter shows a declining behavior. On the basis of the results obtained from direct shear test, the angle of internal friction is 32^o which shows that there is better mobilization of shear strength through interlocking of soil particles and the soil will fail by local shear failure. Since the value of cohesion is zero, the shear strength in the soil will result from intergranular friction alone. The geotechnical properties of the soil under investigation are presented in Table 1.

4.2 Physical Properties of Coarse aggregates

The 20 mm & 10 mm nominal sizes of coarse aggregates were taken as per IS:383-1970.The aggregates having impact value 9.86% and crushing value as 11.21 % shows that the coarse aggregates collected can withstand relatively larger heavy loads. The physical properties of coarse aggregates are shown in Table – 2.

4.3 Physical& Chemical Properties of Water

The pH value of the water obtained is 7.24 which is greater than 7, therefore, it is alkaline. The presence of sulphate in water affects the durability and strength of mix and chlorides produces efflorescence. The tests on water indicate that the sulphate content in water is 86 mg per liter and chlorides 128.00 mg per liter, which is within acceptable limits. Table – 3 shows the properties of water being used in the study. These properties of water shows that the water is potable and is fit for drinking purposes and hence can be used for the present experimentation.

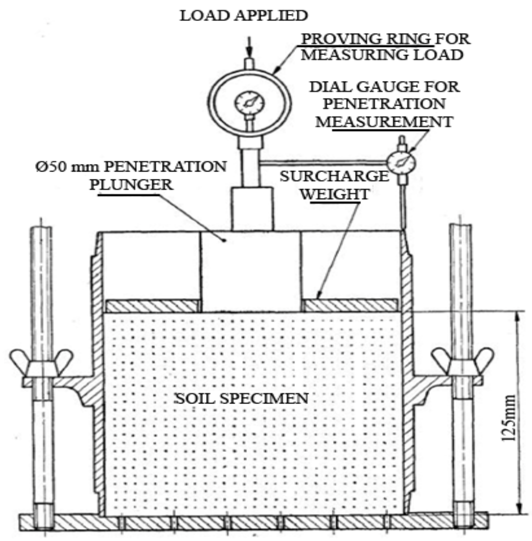

Fig. 2. Experimental setup for CBR test.
Source: IS: 2720 (Part 16) "Methods of Test for Soils: Part-16, Laboratory Determination of California Bearing Ratio"

4.4 CBR Values of Sand Mixed With Coarse Aggregates

CBR tests have been carried out on the soil samples, at OMC as well as in soaked condition, first without mixing coarse aggregates and then by mixing coarse aggregates in varying percentages ranging from 0% to 30% by Weight of the dry soil at a constant optimum moisture content of 11.41%. The results obtained are presented in graphical form:

A) CBR value of soil without mixing coarse aggregates:
   At OMC: 26.78%
   In Soaked Condition: 18.15%
B) CBR value of soil mixed with coarse aggregates(by Weight) in varying percentages:

The load penetration curves for the soil mixed with various percentages of coarse aggregates are shown in Fig.-3 to Fig.-9 for various conditions of the soil such as at OMC and at soaked condition. The load increases with the various penetration values in both at OMC and at soaked conditions of the soil. After a certain value of the load, penetration increases at a constant load condition in each case. The CBR values of the soil samples containing different percentages of coarse aggregates are shown in Table – 5. CBR value of soil without coarse aggregates is found to be 26.78% and 18.15% at OMC and in soaked condition respectively. The CBR value of soil is contributed due to the apparent cohesion and friction. The soil used in this present study is cohesion less; therefore due to the coarser particles of sand, friction alone contributes to the mobilization of the strength. From Table –5, it is revealed that the CBR value of soil increases with the addition of the coarse aggregates. The CBR values increases to 35.19% & 32.40% at OMC and 23.84% & 22.36% in soaked condition for 20mm & 10mm size coarse aggregates respectively by adding 5% coarse aggregates and enhanced to 67.47% &57.80% for 20mm and 60.47% &54.90% for 10mm size at OMC and in soaked condition when mixed with 30% coarse aggregates.

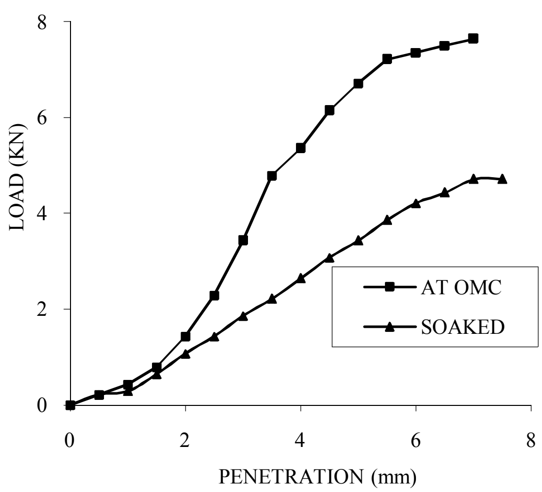

Fig.3.Load penetration curve for soil mixed with 0% coarse aggregates.

The load carrying capacity of soil mix is more at OMC than at soaked condition. With the increase in the percentage of coarse aggregates in the soil mix, the load carrying capacity increases at any level of penetration. This increase in strength of the soil coarse aggregates mixes is attributed to the increased weight per cubic meter due to the inclusion of more dense coarse aggregates in to the soil. The 20mm coarse aggregates has the ability to take greater loads as compared to the 10mm coarse aggregates. This increase in CBR values is attributed to the density of the coarse aggregates added and the interlocking of soil particles with them. With the increase in the coarse aggregate percentage, the CBR of the soil further increase. Fig. 10 shows the relationship between percentages of coarse aggregates added and corresponding CBR values at OMC and in soaked condition. From this, it seen that the relation is linear up to 15% inclusion of 20 mm coarse aggregates.

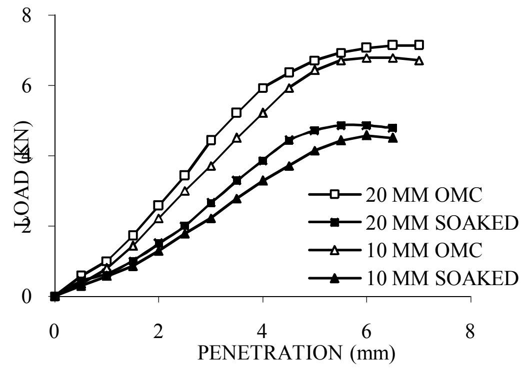

Fig.4. Load penetration curve for soil mixed with 5% coarse aggregates.

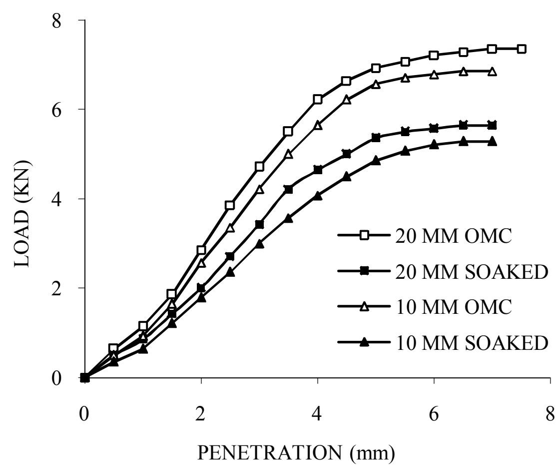

Fig.5. Load penetration curve for soil mixed with 10.0 % coarse aggregates.

At 15% to 20% inclusion of coarse aggregates, there is sudden increase in the CBR value and there after it again becomes linear. In the case of 10mm coarse aggregates also, the relation remains linear up to 15% inclusion of coarse aggregates and at 15 % to 20% there is sudden increase in the CBR value thereafter the relation again become linear. This accumulation of the strength is attributed to the improvement in the frictional resistance of the soil coarse aggregate mix. From this table it is observed that the percentage variation in the CBR values improved from 20.99% to 115.83% and 31.30% to 151.94% for 10mm and 20mm coarse aggregates respectively at OMC. In soaked condition this improvement ranges from 23.20% to 202.48% and 31.35% to 233.17% for 10mm and 20mm coarse aggregates respectively.

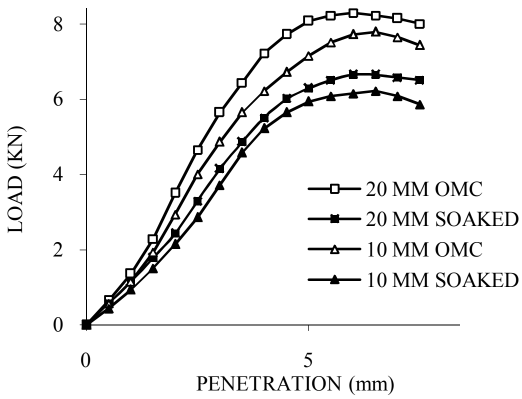

Fig.6. Load penetration curve for soil mixed with 15.0 % coarse aggregates.

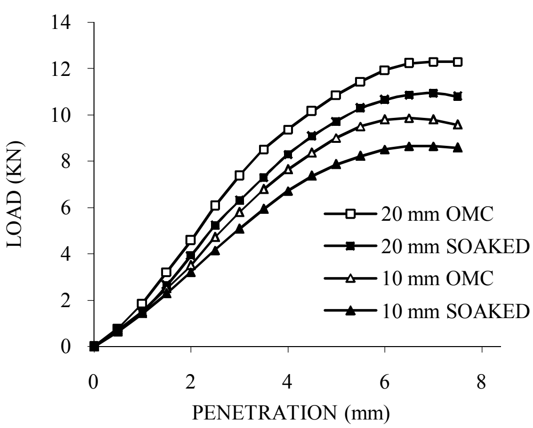

Fig.7. Load penetration curve for soil mixed with 20.0 % coarse aggregates.

The percentage increase in the CBR values with the addition of coarse aggregates is given in Table 5.

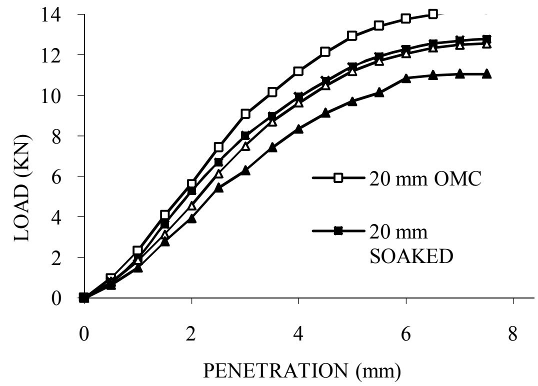

Fig.8. load penetration curve for soil mixed with 25.0 % coarse aggregates.

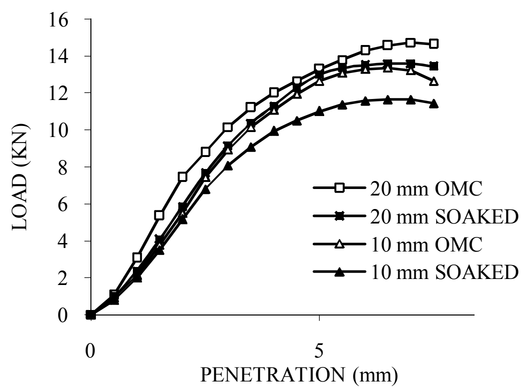

Fig.9. Load penetration curve for soil mixed with 30% coarse aggregates.

Table 5. Percentage increase in the CBR values with the addition of coarse aggregates.

% of coarse aggregate	CBR Values (%)			
	At OMC		In Soaked Condition	
	10 mm	20 mm	10 mm	20 mm
0	26.78	26.78	18.15	18.15
5	32.4	35.19	22.36	23.84
10	34.46	38.44	26.48	28.3
15	37.01	40.86	30.83	34.1
20	46.44	59.98	43.54	49.48
25	51.88	64.33	49.09	56.11
30	57.8	67.47	54.9	60.47

As expected, the CBR values of the soil mixes obtained with the inclusion of 10mm coarse aggregates remains lower than that obtained with the 20mm. This is attributed to the strength of the coarse aggregates since the strength of small coarse aggregates is less as compared to the larger particles, therefore the CBR of the soil remains low with 10mm coarse aggregates as compared to the 20mm.

Table 5. CBR values of soil Mixed with Different % of Coarse Aggregate (By Weight).

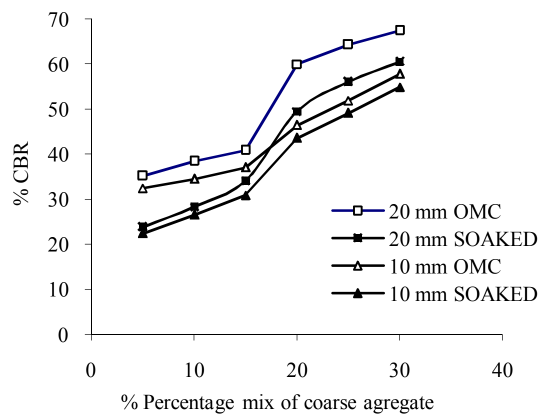

Fig.10.Variation of CBR Value with Percentage of Coarse aggregates.

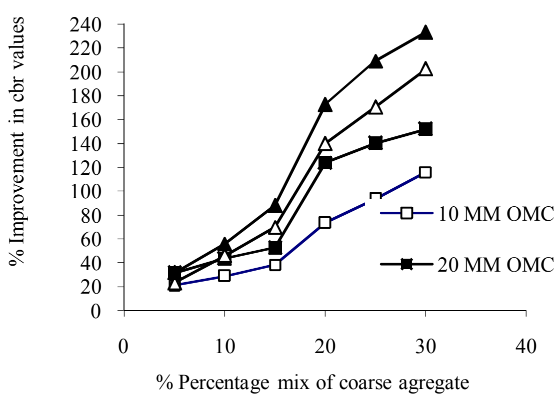

Fig.11.Percent improvement in CBR values for various mix of coarse aggregates.

It is evident from the Fig 3 to Fig 11and the Table 5 to Table 6, that soaking of the sample causes a decrease in the CBR value of the soil both with and without mixing of coarse aggregates but the behavior of increase in CBR is same in soaked condition as well as at OMC for the increase in the percentage of the added coarse aggregates. This decrease in CBR value is due to increase in the moisture content of the mixes above OMC during their soaking period thus making the soil soft and a decrease in the effective stresses. More over the particles are also mobilized therefore the load carrying capacity decreases due to soaking. The coarse aggregates used in the study have good interlocking and frictional properties which provides resistance to the lateral movements and improves the strength of the soil sample.

Table 6.Percentimprovement in CBR values of soil mixed with different % of coarse aggregate (by weight)

Percentage Improvement of CBR Values for addition of Aggregate				
% of Aggregate	At OMC		In Soaked Condition	
(By Weight)	10 mm	20 mm	10 mm	20 mm
5	20.99	31.3	23.2	31.35
10	28.68	43.54	45.9	55.92
15	38.2	52.58	69.86	87.88
20	73.41	123.97	139.89	172.62
25	93.73	140.22	170.47	209.15
30	115.8	151.94	202.48	233.17

5. CONCLUSIONS

The experimentation conducted shows favorable results as the CBR of soil enhanced by the inclusion of coarse aggregates. However with the increase of coarse aggregate percentage, the problem of workability was experienced during the experimentation because the coarse aggregate replaces the soil mass with their increased density. However following specific conclusions are made from this study:

1. The CBR value of soil increases with the increase in coarse aggregate percentage.
2. The CBR value of soil when mixed with 20mm size coarse aggregates is more than that with 10 mm sized coarse aggregates.
3. With the increase in the percentage of coarse aggregates in the soil, the workability is affected and will be uneconomical.

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Int. J. of GEOMATE, April, 2016, Vol. 10, No. 2 (Sl. No. 20), pp. 1743-1750.

MS No. 48585 received on Sept. 11, 2015and reviewed under GEOMATE publication policies.

Pertinent discussion including authors' closure, if any, will be published in Dec. 2016 if the discussion is received by June 2016.

Corresponding Author: Kesharwani R.S.