

Effect of Cement Kiln Dust and Chemical Additive on Expansive Soil at Subgrade Level

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ABSTRACT: Day by day increasing the demand of cement results in intense collection of kiln dust from cement manufacturing plants. The disposal of this fine dust becomes an environmental threat. In order to overcome this problem, research is being carried out in different parts of the world to find out the economical and efficient means of using cement kiln dust (CKD) various applications like soil stabilization, cement production, pavements, waste product stabilization, and agriculture and cement products, etc. The present investigation includes the study of engineering properties of expansive soil using CKD and chemical additive RBI grade 81 (Road Building International grade 81) at various percentages and for different curing periods. RBI grade 81 is an odorless beige powder that is composed of number of naturally occurring compounds. It works by hydration reaction and it is insoluble in water, non UV degradable, inert and chemically stable. Atterberg's limit, Compaction, California Bearing Ratio (C.B.R.), Unconfined Compressive Strength (U.C.S.) tests were carried out on the samples of soil and soil with stabilizers. Reduction in the PI is 67.80%. Addition of the chemical additive RBI grade 81 and CKD contributes the strength development to the soil. From the UCS test, it is found that the UCS value of soil is improved by approximately 450%. The optimum mix Obtained is soil: CKD: RBI Grade 81 in proportions of 81:15:04.

KEYWORDS: Compaction Characteristics, Consistency Limits, UCS, Undrained Shear Strength (C_u), CBR, CKD, RBI Grade 81.

I. INTRODUCTION

Soils with low-bearing capacity can be strengthened economically for building purposes through the process of "soil stabilization" using different types of stabilizers. An expansive soil is mostly covers nearly 20% of the land in India and includes approximately the entire Deccan Plateau. Expansive soils are the soils which swell when come in contact with moisture and shrink when it becomes dry. Because of this behavior of soil, lot of damage occurs to different Civil engineering structures founded on them. There are sufficient techniques available to improve the engineering properties of expansive soil to make it suitable for construction. Stabilization of expansive soil by using waste material like Cement Kiln Dust and natural soil stabilizer which have been successfully utilized for stabilization of expansive soil. Because these soil can cause more damage to structures than any other natural hazard including earthquakes and floods.

II. LITERATURE REVIEW

A. Cement Kiln Dust (CKD): Cement kiln dust (CKD) is a finely divided particulate material similar in appearance to Portland cement. During the manufacture of Portland cement, a large amount of dust is collected from kiln exhaust gases and disposed in landfills. The Indian cement industry is directly related to the country's infrastructure sector and thus its growth is paramount in determining the development of the country. With a current production capacity of around 366 million tonnes (MT), India is the second largest producer of cement in the world and fueled by growth in the infrastructure sector, the capacity is expected to increase to around 550 MT by FY20. The problem of disposing and managing solid waste materials in the industrial countries has become one of the major environmental, economical and social issues. During manufacturing of cement a waste by product, known as cement kiln waste (CKD) is generated

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 4, Issue 6, June 2015

which accounts for 15-20% of the cement clinker production. In year 2012, 3,400 million metric tons of clinker was produced worldwide resulted in approximately 510-680 million metric tons of CKD generation.

The Cement Kiln Dust (CKD) has cementitious properties that make it an effective stabilizer for certain soil types. CKD represents a potentially useful and cost-effective. CKD is being used increasingly for soil stabilization. CKD has been used as a soil additive to improve the texture, increase strength and reduce swell characteristics. Treatment with cement kiln dust was found to be an effective option for improvement of soil properties, based on the literature review as a part of this research. Strength and stiffness were improved and plasticity and swell potential were substantially reduced. CKD treated samples performed very well in strength gains and in many cases showed additional reductions in plasticity. It is recommended based on the literature review of this research that cement kiln dust be considered a viable option for the stabilization of sub grade soils.

Pranshoo Solanki et al. (2007) studied the effect of cement kiln dust on silty-clay. Authors observed an increase in OMC and decrease in MDD were observed with increasing amount of CKD. Higher the CKD content, higher the M_E and UCS values with a linear relationship between modulus of elasticity (M_E) and UCS. Mixture of silty-soil with 15% CKD substantially improved Resilient modulus (M_R) values up to 35% - 425%.

Khandaker M. Anwar Hossain (2011) studied the effect of cement kiln dust and rice husk ash on clayey soil. Author observed that stabilized soil exhibit enhanced mechanical properties such as strength (compressive and tensile), modulus of elasticity, and CBR as well as durability in terms of water resistance, water sorptivity and shrinkage. CKD stabilized soils shows higher strength/elastic modulus/ CBR/water resistance/shrinkage values and lower water absorption/sorptivity compare to their RHA counterparts.

G.K. Moses and A. Saminu (2012). Author observed that natural soil treated with CKD gave a peak 7 day UCS value of 381 kN/m² and 410 kN/m² at 12% and 8% CKD content at BSL and WAS energy level respectively. Peak CBR values of 5 and 7% were obtained at 12% CKD content at the energy levels of BSL and WAS.

J.B. Oza and Dr. P.J. Gundaliya (2013) studied the effect of cement waste dust and lime on black cotton soil. Author observed that comparing three groups (Soil, Soil+CKD, Soil+CKD+Lime), Cement dust provides substantial and durable benefits when used as stabilizing agent for BC soil. Significant change in plasticity index of BC soil used with cement dust.

B. RBI Grade 81: RBI grade 81 is an odorless beige powder that is composed of number of naturally occurring compounds. It works by hydration reaction and it is insoluble in water, non UV degradable, inert and chemically stable. It improves the structural properties of a wide range of soil. It is particularly effective with silty clay soil with low geomechanical qualities.

In India RBI Grade 81 has been tested by many leading institutions including IIT Madras, Kharagpur, and Roorkee, the Central Road Research Institute (CRRI), New Delhi, India, and the Centre for Road Technology, Bangalore to name a few.

K.V. Madurwar, P.P. Dahale and A.N. Burile (2013). Free Swell Index decreases as the addition of RBI Grade 81 increases and it goes on increase with addition of sodium silicate. Similarly, UCS and CBR also reduce with increasing dosage of sodium silicate in soil pose limitation of sodium silicate used as stabilizer.

B.M. Patil and K.A. Patil (2013) studied the effect of RBI Grade 81 and pond ash on clayey soil. Author observed that RBI Grade 81 and pond ash help to reduce the swelling characteristics of clayey soil as the DFS index reduces. Soaked CBR value of sub grade clayey soil and grade-III material improved by addition of Pond ash and RBI Grade 81 and therefore it is possible to reduce the thickness of road. RBI Grade 81 work as a good clayey soil stabilizer.

Manisha Gunturi et al. (2014). Failure patterns of the treated sample shows the alteration in the property of soil into a brittle material. XRF results indicate the formation of cementitious compound C-A-H & C-S-H. SEM micrographs reveal the change in microstructure of the treated soil sample by the formation of cementitious material.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 6, June 2015

III. MATERIAL

Expansive Soil: Soil for the work was collected from Sundernagar, District Mandi (Himachal Pradesh). Tests were carried out to determine the various properties of soil and the results are tabulated in table 1.

TABLE 1

PROPERTIES OF SOIL

Physical Properties	Value
Specific gravity	2.5
Liquid Limit (%)	64
Plastic Limit (%)	31.7
Plasticity-Index (%)	32.2
IS Soil Classification	CH
Optimum Moisture Content (%)	20
Maximum Dry Density (g/cc)	1.68
Unconfined Compressive Strength (kPa)	88.3
California Bearing Ratio (%)	
Unsoaked	1.65
Soaked	1

Cement Kiln Dust (CKD): Cement kiln dust is collected from ACC cement plant Barmana (Himachal Pradesh). The chemical Composition of CKD is given in the table 2.

TABLE 2

CHEMICAL PROPERTIES OF CEMENT KILN DUST

Sr. No	Chemical Composition	Cement Kiln Dust
	Oxide Compounds	%
1	CaO	52.52
2	SiO ₂	11.9
3	Al ₂ O ₃	9.9
4	Fe ₂ O ₃	3.4
5	SO ₃	1.48
6	MgO	1.7
7	Na ₂ O	0.5
8	K ₂ O	0.1
9	Loss on ignition	4.7

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 6, June 2015

RBI Grade 81: RBI Grade 81 Natural Soil Stabilizer is a unique and innovative product that was developed for the stabilization of a wide spectrum of soils in an efficient and least-cost manner. Material for the testing work is received from M/S Alchemist Technology Limited, India. Chemical compositions of RBI Grade 81 are given in table 3.

TABLE 3
CHEMICAL COMPOSITION OF RBI GRADE 81

Sr. No	Chemical Composition	RBI Grade 81
	Oxide Compounds	%
1	CaO	52
2	SiO ₂	19
3	Al ₂ O ₃	7
4	Fe ₂ O ₃	3
5	SO ₃	11
6	MgO	2
7	Mn, K, Cu, Zn	0-3
8	Fibers (Polypropylene)	0-1
9	Additives	0-4
10	H ₂ O	1-3

IV. SAMPLE PREPARATION AND METHODOLOGY

Initially, oven-dry soil was thoroughly hand mixed with each stabilizer or combination of stabilizers in a large tray in a dry state. Thereafter, mixing was carried out for at least 6 min after adding water (required for the intended moisture content), and finally, the air was squeezed out by hand. The optimum moisture content and dry density for soil with different percentages of stabilizers were determined by the standard Proctor compaction test.

All test specimens were prepared with the static compaction method at the optimum moisture content. The specimens were wrapped in thin plastic film until testing at 3, 7, 14 and 28 curing days. Total 109 specimens were made for UCS test for each type of soil mixture. Cylindrical specimens (L/D ratio is 2) were used for unconfined compressive strength. All samples were kept for curing in humidity chamber for 3, 7 and 28 days. The compressive strengths were determined on UCS testing machine.

V. RESULT AND DISCUSSION

Initially liquid limit and plastic limit test was performed to classify the soil and specific gravity test was performed for soil, RBI and CKD. Liquid limit and Plastic limit of the soil was found out to be 64% and 31.7%. Standard proctor test was also performed on clayey soil. The OMC and MDD of the soil were found out to be 20 % and 1.68 gm/cm³ respectively. The specific gravity of clayey soil and CKD were found out to be 2.5 and 2.68 respectively. Liquid limit and plastic limit test was performed for samples mixed with different percentage composition of CKD and RBI Grade 81 at different intervals. Standard proctor test was also performed for samples mixed with different percentage composition of CKD at an interval of 5% and on various mixed proportion of Soil: CKD: RBI to find out OMC and MDD. Samples were prepared by mixing CKD with different percentage at an interval of 5% and with stabilizing agent RBI grade 81 with increasing percentage as

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 6, June 2015

0%, 2%, 4% and 6%.

Stabilized samples were prepared mixing CKD and RBI with different percentage i.e. CKD with increasing percentage of 5% and RBI grade 81 with increasing percentage as 0%, 2%, 4% and 6%. The samples were then subjected to unconfined compressive test after 3, 7 and 28 days of curing. Unsoaked CBR test was also performed for different percentages of CKD and combination of CKD and RBI Grade 81. Summary of test results are given in table 4.

TABLE 4.

Soil:CKD:RBI	LL (%)	PL (%)	PI (%)	OMC (%)	MDD(g/cc)	UCS(kPa)			C _u (kPa)	CBR (%)
						3days	7days	28days		
100:00:00	64	31.7	32.3	20	1.68	88.3	88.3	88.3	44.15	1.65
95:05:00	54.2	31.3	22.9	21.5	1.67	91.2	99.2	107.5	53.75	2.41
90:10:00	52.5	31	21.5	22	1.65	93.9	102.5	125.7	62.85	3.88
85:15:00	55.9	31.5	24.4	24	1.64	95.8	111.5	139.5	69.75	4.35
93:05:02	47	30.5	16.5	19.78	1.69	102.4	127.5	181.25	90.63	4.68
88:10:02	45.8	29.8	15.7	19.53	1.70	112.5	153.6	210.3	105.15	6.36
83:15:02	44.2	29	15.2	19.3	1.72	129.4	206	266.05	133.02	8.03
91:05:04	40	26.5	13.5	19.28	1.73	146	241.8	388.8	194.4	11.11
86:10:04	36.8	27.7	9.1	18.8	1.74	169.8	283.5	467.8	233.9	13.32
81:15:04	35.4	25	10.4	18.1	1.76	228.8	338.4	572.7	286.4	17.14
89:05:06	38.5	28.43	10.07	19.5	1.72	298	361	662.25	331.12	19.02
84:10:06	37.05	28.33	8.72	19.9	1.685	308.7	382	770.5	385.3	20.02
79:15:06	37.4	30.63	6.77	21	1.67	384	444.4	976	488	21.7

A. *Consistency Limit*: The variation of liquid limit, plastic limit and plasticity index with CKD is shown in figure 1. The LL, PL and PI decrease with the addition of CKD up to 10% and then increase slightly with further increase in the addition of CKD. The initial reduction may be attributed to the cementitious properties of CKD due to high content of calcium oxide (CaO) which aid flocculation and aggregation of the soil particles. The increase in LL, PL and PI beyond 10% CKD content is attributed to the extra water required to turn the soil-CDK mix to fluid.

It is observed that the LL, PL of soil treated with 2% RBI Grade 81 and different percentage of CKD is decreases due to chemical reaction between soil, CKD and RBI Grade 81, also CKD absorbs more amount of water. Similarly soil is treated with 4% and 6% RBI Grade 81 and different proportions of CKD referring to the results shown in Table 4. Figure 2 shows that, the LL, PL of 4% RBI Grade 81 and 15% CKD decreases for 8:15:04 proportions as compared to untreated soil. As the percentage of CKD and RBI increases in the mix, the PI of soil decreases. The RBI Grade 81

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 6, June 2015

contains fibers due to which for more percentage of it reduces. Also the further increase in CKD and RBI percentage LL, PL increases and PI reduces.

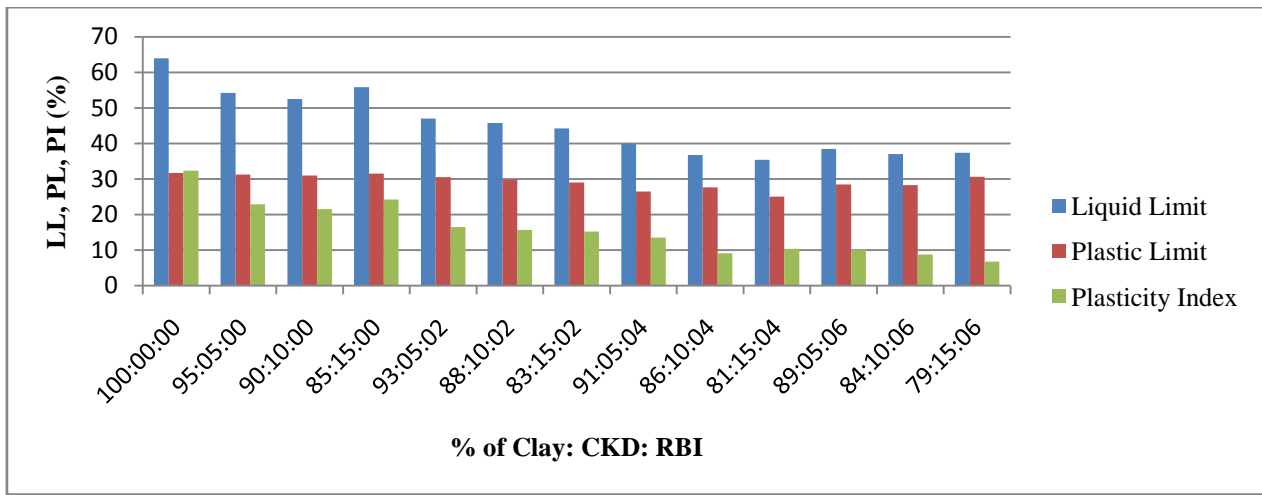


Figure 1: Effect of CKD and RBI Grade 81 on LL, PL and PI of soil

B. Compaction Characteristics: The relationship between the dry density, moisture content and %CKD for treated soil using modified compaction test is shown in figure 3. It is noted that increasing the amount of CKD content MDD decreases and OMC increases. The decrease in dry density with addition of CKD can be attributed to the increased

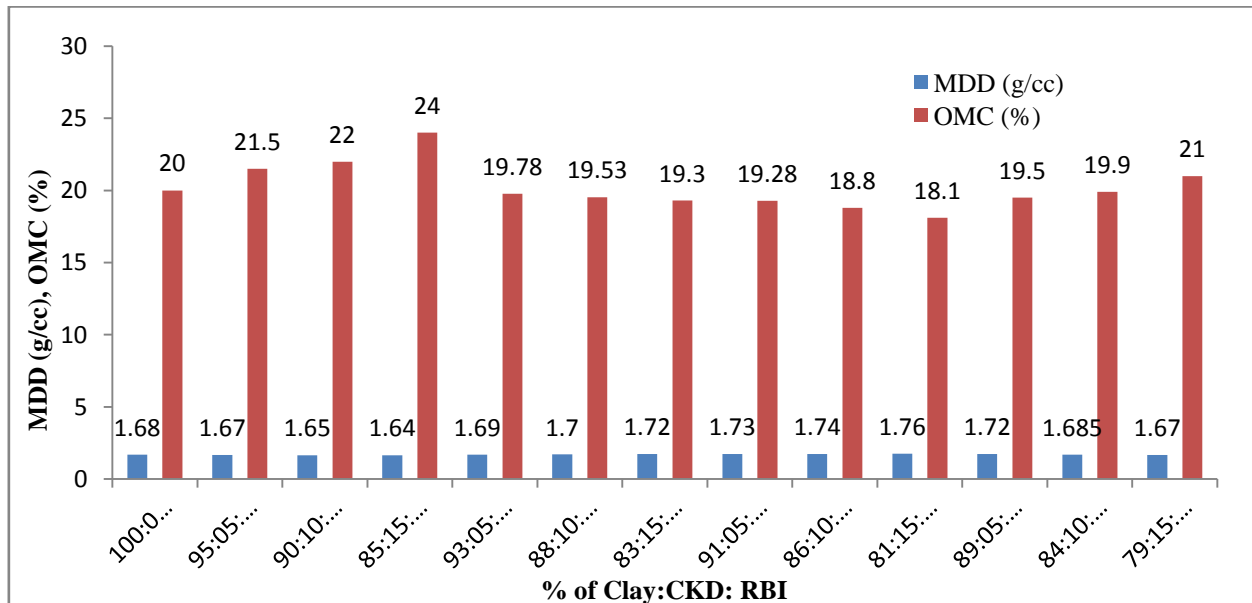


Figure 2: Effect of CKD and RBI on MDD and OMC of soil

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 6, June 2015

number of fines in the mix due to the addition of CKD. The other reason for subsequent reduction in MDD may be probably due to the fact that for any soil there is always a water content to produce maximum strength. The increase in OMC with the addition of CKD is attributed to the extra water required for higher fineness and subsequent enhanced hydration. The relationship between the dry density, moisture content with different proportions of materials using modified compaction test is shown in figure 4. It is noted that increasing the amount of CKD and RBI content MDD increases and OMC reduces. The RBI Grade 81 reacts chemically with soil particles and binds them together and reduces the pore spaces and help to increase the MDD of soil. The RBI Grade 81 contains fibers due to which the increase in MDD is less and if the percentage of RBI Grade 81 increases the MDD of soil reduces. The subsequent decrease in OMC with increase in RBI content might be due to cation exchange reactions that causes the flocculation of clay particles.

C. Unconfined Compressive Strength: Initially UCS of stabilized soils using both the stabilizer i.e. CKD and combination of CKD and RBI increases with increasing the percentages of stabilizer and with increasing the days of curing. The increase in UCS value could be attributed to ion exchange at the surface of clay particles. The Ca^{2+} in the additives reacts with the lower valence metallic ions in the clay microstructure which resulted in agglomeration and flocculation of the clay particles. The gain in strength of specimen with age was done primarily to the long term hydration reaction that resulted in the formation of cementitious compounds.

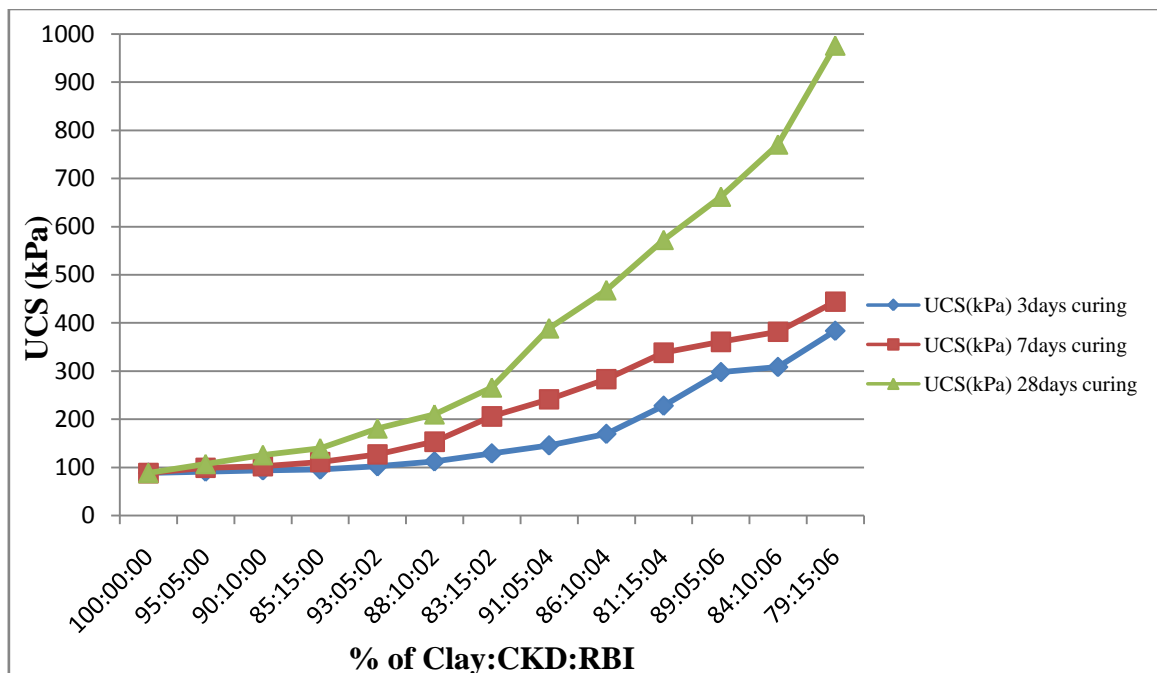


Figure 3: Effect of CKD and RBI on UCS value of soil

D. Undrained Shear Strength (c_u): A series of unconfined compressive strength tests were conducted to determine the strength characteristics of expansive soil treated with various percentages of Cement Kiln Dust and RBI Grade 81. It has been observed that undrained shear strength (c_u) increases with increase in percentages of CKD and RBI. The increase may be attributed to the long term hydration reaction that resulted in the formation of cementitious compounds.

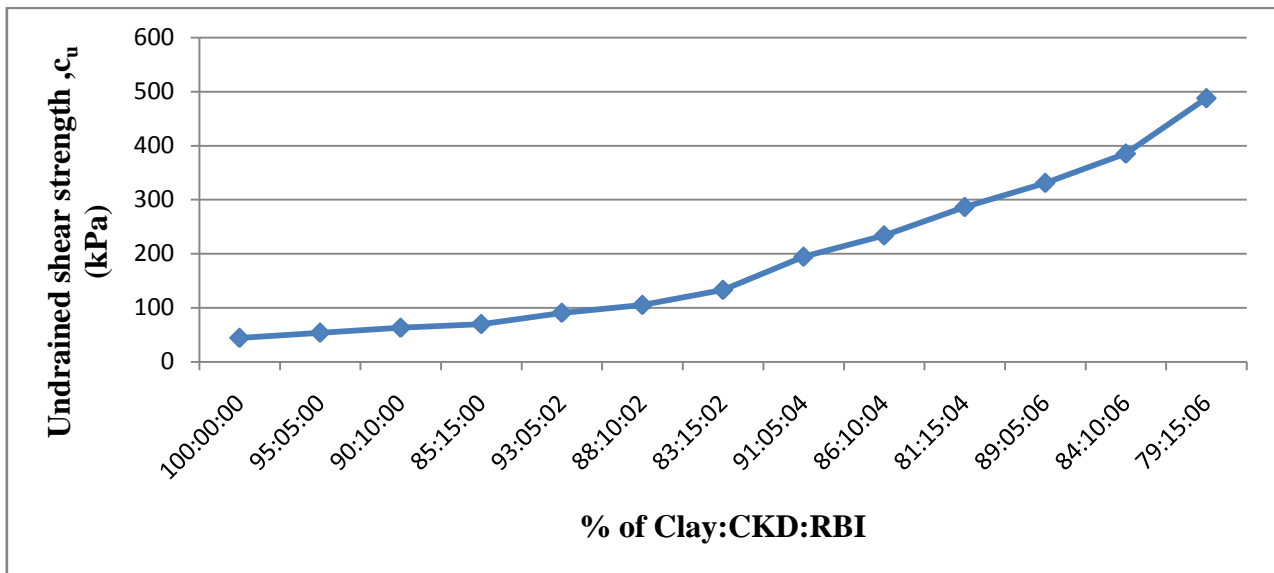


Figure 4: Effect of CKD and RBI on C_u value of soil

E. California Bearing Ratio: The CBR value of soil increases with increasing percentages of combination of CKD and RBI as compare to CKD alone. The content of RBI Grade 81 having binding property due to which the soil particles bind together and the CBR value of mix increases. Other reason for increase of CBR value is due to fibers present in RBI Grade 81.

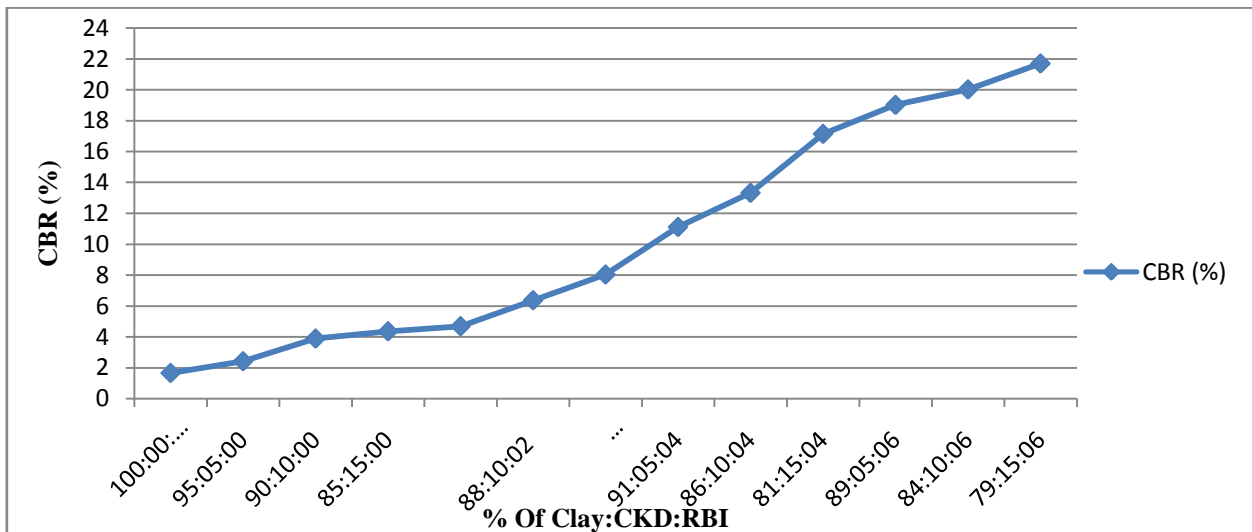


Figure 5: Effect of CKD and RBI on CBR value of soil

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 6, June 2015

VI. CONCLUSION

1. The liquid limit, plastic limit, plasticity index are decreasing by the addition of CKD up to 10% and then further increases with the increase in CKD percentage.
2. The optimistic mix proportion based on the LL, PL, PI is 81: 15: 4 (Clay:CKD:RBI Grade 81)
3. The Maximum Dry Density is decreasing and Optimum Moisture Content is increases with increase in percentage of CKD at different proportions may be due to water adsorption reduction.
4. The MDD is increasing and OMC is decreasing at the combination of 4% RBI Grade 81 and 15% CKD content. It gives the optimum value at 81:15:04 (Soil: CKD: RBI) proportion.
5. The unconfined compressive strength of stabilized samples increases with increase in percentage of CKD and RBI grade 81.
6. The unconfined compressive strength of stabilized samples increases with increase in 3, 7 and 28 days of curing.
7. The shear strength cohesion values are increasing for combinations of CKD and RBI Grade 81.
8. Unsoaked CBR value of soil increases with increasing the percentages of CKD and RBI Grade 81.

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