EFFECT OF RICE HUSK ASH AND RBI GRADE 81 ON GEOTECHNICAL PROPERTIES OF CLAYEY SOIL

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Highlights

- *The combination of clayey soil, RHA and stabilizer reduces the water absorption, optimum mix identified as 86%clay, 10%RHA and 4% stabilizer (RBI Grade 81)*
- *The combination of clay with RHA and stabilizer increases the compressive strength with the age*
- *The relation establishes between modulus of elasticity and unconfined compressive strength,* $E = 0.038qu + 0.033$
- *The SEM images indicates the formation of CSH and CAH gel, which helps to increase the strength and reduce the compressibility of clayey soil.*

Abstract

Rice husk ash (RHA), RBI Grade 81 (stabilizer), and their combinations are used variously as stabilizers in different proportions maximum up to 20%, to understand and evaluate stabilized clayey soils.The effect of rice husk ash and dosage of stabilizer on fresh and mechanical properties are evaluated through consistency limits, light compaction test, unconfined compressive strength (UCS), modulus of elasticity and California bearing ratio (CBR) test. The chemical reaction identification tests like scanning electron microscopy (SEM) and Energy dispersive spectrum(EDS) are conducted on pure clay and optimum mix of clay, RHA and stabilizer. Optimum mix obtained from the Atterberg's limits tests is 86:10:04(Clay: RHA: RBI grade 81). UCS and CBR tests were conducted on the optimum mixfor 3, 7 and 28 days curing periods. Comparatively with clay optimum mix shows increased in percentage i.e. 782% and 166% in UCS and CBR respectively. Correlation between strength, modulus of elasticity, and CBR test are also established. The SEM and EDS images show that formation of impermeable CSH and CAH gel which fills the void spaces and due to that reduction in the compressibilityof clayey soils. The optimum mix which was developed stabilized soil has shown satisfactory strength and durability characteristics and can be used for rural and low cost construction road infrastructures.

***Keywords**: Rice Husk Ash, RBI grade 81, Stabilization, UCS, modulus of elasticity, CBR.*

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1. INTRODUCTION

Clayey soils are those that change significantly in volume with changes in water content. The swelling and shrinkage lightly loaded civil engineering structure like residential buildings, pavements and canal linings are severely damaged. It is necessary to mitigate the problems posed by clayey soils and prevent cracking of structures. Soils with low shear strength and higher compressibility can be strengthened economically for build roads infrastructures through the process of soil Stabilization using various additives [1]. Compressible clayey soils can be stabilized by mixing the various proportions of RHA and Portland cement, increasing the static properties like compaction, shear strength and cohesion of natural soil [2]. Scientific techniques of soil stabilization have been introduced in recent times and the use of potential industrial waste cementitious materials like fly ash, pond ash, slag, RHA, cement kiln dust as stabilizers is common [3-5]. The commercial material like lime, RBI Grade 81, sodium silicates, portland cement have been used for the improvement of the low bearing capacity and compressible soils [6-12]. The calcium and silica content pozzolanic materials can bind soil particles together and reduce of the water absorption capacity. Stabilized soils are useful as many of the areas of the construction, especially locally available industrial waste products. Rice husk ash (RHA) found abundantly in India. India is a large scale rice producing country, about 20 million tons of rice husk ash produced annually. The rice husk ash is a great environmental threat which can cause damage to the land and the surrounding area in which it is dumped. RHA is rich in silica (SiO_2) compound; it can be used as pozzolanic material for the stabilization of soil which improves the properties of soil.

RBI means Road Building International, RBI 81 is natural stabilizer which is cost effective and environment friendly. RBI grade 81 was collected from Alchemist technologies ltd, New Delhi. RBI grade 81 contains fibers in it, which reinforced the soil. It is an odorless powder. It is insoluble in water and works by hydration reaction and is chemically stable. It improves the strength of soil. It is particularly effective with clay having low geo - mechanical qualities.

2. EXPERIMENTAL INVESTIGATION

2.1 Materials

To achieve the objectives of the research, the rice husk ash and stabilizer (RBI Grade 81) used forinvestigation were supplied by local companies.The stabilizer was collected from Alchemist technology, New Delhi. The chemical composition of RHA and stabilizer (RBI Grade 81) are presented in Table 1. A locally available clayey soil was collected, and its engineering properties in terms of Atterberg limits, soil classification and compaction characteristics are presented in Table 2. Soil was classified as highly compressible according to IS classification plasticity chart is presented in Fig.1

2.2 Proposed Combination Schemes for Stabilized Soil Mixtures

A series of laboratory tests was conducted on the collected clayey soil mixed with the various percentages of RHA and stabilizer (RBI Grade 81). The geotechnical tests measured Atterberg's limits, standard proctor compaction, unconfined compressive strength (UCS), modulus of elasticity, California bearing ratio (CBR) and chemical reaction identification tests scanning electron microscopy images (SEM) energy dispersive spectrum. The summary of combination of schemes of stabilized soil mixtures are presented in Table 3. The clayey soil has been mixed with RHA from 0% to 20% at an increment of 5% and RBI grade 81 from 0% to 6% at an increment of 2%. Testing was conducted as per the IS 2720 code. A total of thirteen combinations of mixed stabilizers were studied.

2.3 Sample Preparation and Testing

Oven dry soil was mixed with hand thoroughly with each combination of stabilizers in big try in a dry state. The mixing was carried out in a laboratory mixer for at least 3min after adding water (required for Atterberg limits determination). Liquid limit (LL), plastic limit (PL) and plasticity index were determined for different mixtures as per the IS 2720 (part 5).

The maximum dry density and optimum moisture content for different percentages of stabilizers were determined by the light compaction test (IS 2720 part7).

Cylindrical specimens (38mm diameter and 78mm length) were used for unconfined compressive strength (IS 2720 – 10) and modulus of elasticity. The compressive strength were determined on hydraulic testing machine under strain control at a loading speed of 1.0mm/min.

The CBR test on stabilized soil specimen was conducted at unsoaked condition (IS 2720 – 16). The specimens were made in the CBR mold with the same compactive energy per volume as in the light compaction test. The diameter of the plunger used to determine the penetration values is 50mm. The rate of penetration is 1.27mm/min. The CBR value determined corresponding to 2.5mm penetration.

3. RESULTS AND DISCUSSIONS

3.1 Atterberg's Limits

From Table no.4 and Fig .1 results shows that the liquid limit decreases when increasing the RHA component upto 10% and RBI Grade 81 upto 4%. Liquid limit increase with increase of the RHA and RBI Grade 81 components. The plastic limit increases with increase in RHA and RBI Grade 81 component upto the 86: 10: 4. Plasticity index will follow the same pattern like liquid limit. Reason may be the pozzolanic reaction between the silica, calcium presented in the RHA and RBI Grade 81.

3.2 Moisture–Density Relationship

The MDD of stabilized soil decreases with increase in RHA. The MDD and OMC for clay soil are 1.87 Kg/mm^3 and 11% respectively. The MDD and OMC for the optimum mix are 1.6 g/cc and 20%, respectively. The optimum mix is determined from the consistency's limit test which was discussed in previous. The OMC increases from 11% to 20% and the MDD decreases from 1.87 to 1.6g/cc from virgin soil to stabilized clay soil. The increase in OMC (from 11% to 20%) is observed at 10%RHA, 4% of RBI grade 81 and 86%of clay. Reason may be flocculation and agglomeration.

3.3 Unconfined Compressive Strength

The optimum mix having highest UCS values for the different curing periods i.e 3, 7, 28 days. The compressive strength of treated soil is greater than untreated soil. For different curing periods, the strength of the stabilized soil increases with increase in curing periods. The UCS value of the stabilized mix increases from 85 kPa to 750 kPa at 28 days curing for 10% of RHA and 4% of RBI grade 81 with 86 % of clay. Typically, for 86: 10: 04 (Clay: RHA: RBI 81) mix, the UCS value increases from 85 to 415 kPa, 550 kPa and 750 kPa for 3, 7 and 28 days of curing periods, respectively. The increase in compressive strength is due to pozzolanic action, the fibre content in RBI 81 causes frictional resistance and cohesion in the clay. The stress–strain curve for UCS tests for the optimum mix at different curing days has drawn from the obtained UCS values.

Figure4.shows the stress strain relationship, stress is taken as deviator stress $\sigma_3 = 0$ and strain taken is an axial strain. The graphical presentation shows the comparison between 100 % clay and optimum mix of 3, 7 and 28 days curing periods. The pure clay curve shows that increase of deviator stress with axial strain. This shows that pure clay possessing ductile in nature because of no additives. In the case of optimum mix at curing period of 3, 7, 28 days there is increase in deviator stress with slightly lower axial strain. The curve of optimum mix and sample failure indicates brittle failure in nature. There is higher increase in 28 days values as compare to 3 days and 7 days.

Figure5. shows the compressive strength of mix having 10 % RHA with 2 %, 4 %, 6 % of RBI grade 81 for different curing periods of 3, 7 and 28 days. The 2 % curve shows

that there is little increase in the compressive strength as the days of curing increases. The 4 % of RBI shows much increase in the values as compared to 2 % addition of RBI grade 81. The best result has given by 4 % addition of RBI grade 81. In 6 % addition there is increase in the compressive strength as the curing days increase but it is less than addition of 4 % of RBI grade 81.

Figure. 6 shows the graph of modulus of elasticity of mix having 10 % RHA with 2 %, 4 %, 6 % of RBI grade 81 for different curing periods of 3, 7 and 28 days. The 2 % graph shows that there is very small increase in the young's modulus value as the days of curing increases. The 6 % addition of RBI grade 81 also leads to less increase in the compressive strength as the curing days increases. The modulus of elasticity at 4 % addition of RBI shows better result, there is little increase in the values till 7 days after that there is higher increase in the modulus of elasticity value.

Fig 7. shows graph of optimum mix of Clay: RHA: RBI 81 (86: 10: 04) between Young's modulus and curing days. According to this graph as the curing days increase from 3 days to 28 days the young's modulus value of optimum mix also increases.

From Fig 8.Modulus of elasticity is directly proportional to compressive strength. The relation between modulus of elasticity and compressive strength shows that with the increase of compressive strength modulus of elasticity value increases. The relation between these more clearly define by the equation given below:

$$E = 0.038q_u + 0.033 \qquad (1)$$

Here, E = Modulus of elasticity (MPa)
q_u = Compressive strength (kPa)

With the help of this relation modulus of elasticity value can easily found if compressive strength value known.

3.4 California Bearing Ration Test

The CBR tests were carried out on pure clay soil and optimum mix proportion (86%: 10% : 4%) The un-soaked CBR values are obtained1.35% and 3.6% for pure clayey soil and optimum mix respectively. From the CBR values the author calculated the modulus of elasticity according to IRC 37: 2000 code, the values are 16 MPa and 36.5 MPa for untreated and treated soils respectively.Author compares the modulus of elasticity values from UCS and CBR test results, the observed values are tabulated in table no. 4 and Fig. 9

The difference in modulus elasticity values the reason may be due to CBR modulus of elasticity values determined from the empirical relation (IRC 37: 2000) which indicates higher values whereas the UCS values are from the test.

3.5 Scanning Electron Microscopy

The SEM images investigate the morphology of the reaction of RBI grade 81 and RHA into the clayey soil. The SEM image of the 100 % Clay and the optimum mix (86:10:04) has done under the resolution of 5000 and optimum mix SEM image at 10000 magnification level as shown in Fig. 10 to 13 obtained from CBR and UCS tests.

Fig 10 and 13 show the bonding between the clay particles due to addition of RHA and RBI grade 81 and also show the reaction occurs between them. Images indicate the formation of CSH and CAH gel formations due to the long term pozzolanic reaction.Images prove the strength development due to the formations of impermeable gel.

Concluding Remarks

1. The optimum mix obtained from consistency limits test 86% of Clay+ 10% of RHA 04% of RBI 81.
2. The maximum dry density decreases and optimum moisture content increases with increase in percentage of addition Rice husk ash and RBI 81 into the clayey soil.
3. The stress – strain behavior of optimum mix at different curing periods shows that the deviator stress of the mix increases with the increase in axial strain as the curing period increases.
4. The unconfined compressive strength increases with the increase in curing days of optimum mix.
5. The elasticity of optimum mix of 86%Clay: 10%RHA: 4%RBI has obtained 28.52 MPa at 28 days curing days which is much higher than the pure clayey soil.
6. The comparison of elasticity as per CBR and UCS shows the CBR test higher than UCS test.
7. SEM micrographs show the changes in the microstructures of the treated soil and reduction in pore spaces which explain the increase the strength.

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TABLES

Table 1: Chemical composition of RHA and RBI grade 81

Constituent	RHA (%)	Stabilizer (RBI
Silica (SiO_2)	86	19
Alumina (Al_2O_3)	5	7
Iron Oxide (Fe_2O_3)	2	3
Calcium Oxide	6	52
Magnesia (MgO)	2	2
Loss on ignition	4	-
Fibres	-	0 – 1

Table 2: Properties of Clay

Physical Properties	Value
Specific gravity	2.71
Liquid Limit (%)	50.4

Plastic Limit (%)	29.1
Plasticity-Index	21.3
Soil classification (IS)	CH
Optimum Moisture Content (%)	11
Maximum Dry Density (g/cc)	1.76
UCS (kPa)	85
CBR (%)	1.6

Table 3: Stabilizer Combination Scheme for Stabilized Soils

Combinations	Designation
Single clayey soil only (0RHA 0S)	
Mixed stabilizers (12 combinations – total 12 mixes	
5%RHA+2%S,	5RHA2S
10%RHA+2%S	10RHA2S
15%RHA+2%S	15RHA2S
20%RHA+2%S	20RHA2S
5%RHA+4%S,	5RHA4S
10%RHA+4%S	10RHA4S
15%RHA+4%S	15RHA4S
20%RHA+4%S	20RHA4S
5%RHA+6%S,	5RHA6S
10%RHA+6%S	10RHA6S
15%RHA+6%S	15RHA6S
20%RHA+6%S	20RHA6S

Note: RHA = Rice husk ash; S = stabilizer (RBI Grade 81). Numeric in the designation represent the percentage of stabilizer by total mass of the mixture.

Table 4: Variations of LL, PL and PI for various proportions of Clay, RHA and RBI grade 81

Clay: RHA: RBI 81 (%)	L.L (%)	P.L (%)	P.I	MDD g/cc	OMC (%)
100 : 0 : 0	50.4	25	25.4	1.87	11
93 : 5 : 2	48.1	26.1	20	1.81	7
88 : 10 : 2	48	26.5	21.5	1.76	15
83 : 15 : 2	46	26.8	19.2	1.73	15
78 : 20 : 2	44	27	18	1.63	20
91 : 5 : 4	43	27.7	15.3	1.66	11
86 : 10 : 4	41	28.57	12.43	1.6	20
81 : 15 : 4	42	27	15	1.63	18
76 : 20 : 4	42.8	26.8	16	1.65	19
89 : 5 : 6	43	25	18	1.76	15
84 : 10 : 6	41	23	21	1.77	20
79 : 15 : 6	45	22.8	22.2	1.67	18
74 : 20 : 6	43	25	18	1.66	16

Note: L.L = Liquid limit, P.L = Plastic limit, P.I = Plasticity index, MDD=max.dry density, OMC = optimum moisture content.

Table 5: Variation of UCS and modulus of Elasticity (E) for various proportions at 3, 7 and 28 curing Days

Clay: RHA: RBI Grade 81 (%)	UCS (kPa) at different curing days			E values (MPa) at different curing days		
	3 days	7days	28 days	3 days	7days	28 days
100 : 0 : 0	85	85	85			
93 : 5 : 2	90	130	200			
88 : 10 : 2	130	180	280			
83 : 15 : 2	170	250	400			
78 : 20 : 2	270	350	485			
91 : 5 : 4	300	400	540			
86 : 10 : 4	415	550	750	15.8	16.7	28.52
81 : 15 : 4	315	450	650			
76 : 20 : 4	280	345	520			
89 : 5 : 6	250	300	450			

84 : 10 : 6	225	280	350			
79 : 15 : 6	200	230	280			
74 : 20 : 6	185	210	250			

Table 6: Comparison between modulus of elasticity obtained from UCS andCBR

Clay: RHA: RBI Grade 81 (%)	Modulus of Elasticity (MPa)	
	UCS	CBR
100: 00: 00	5.6	16
86: 10: 4	28.52	36.5

FIGURES

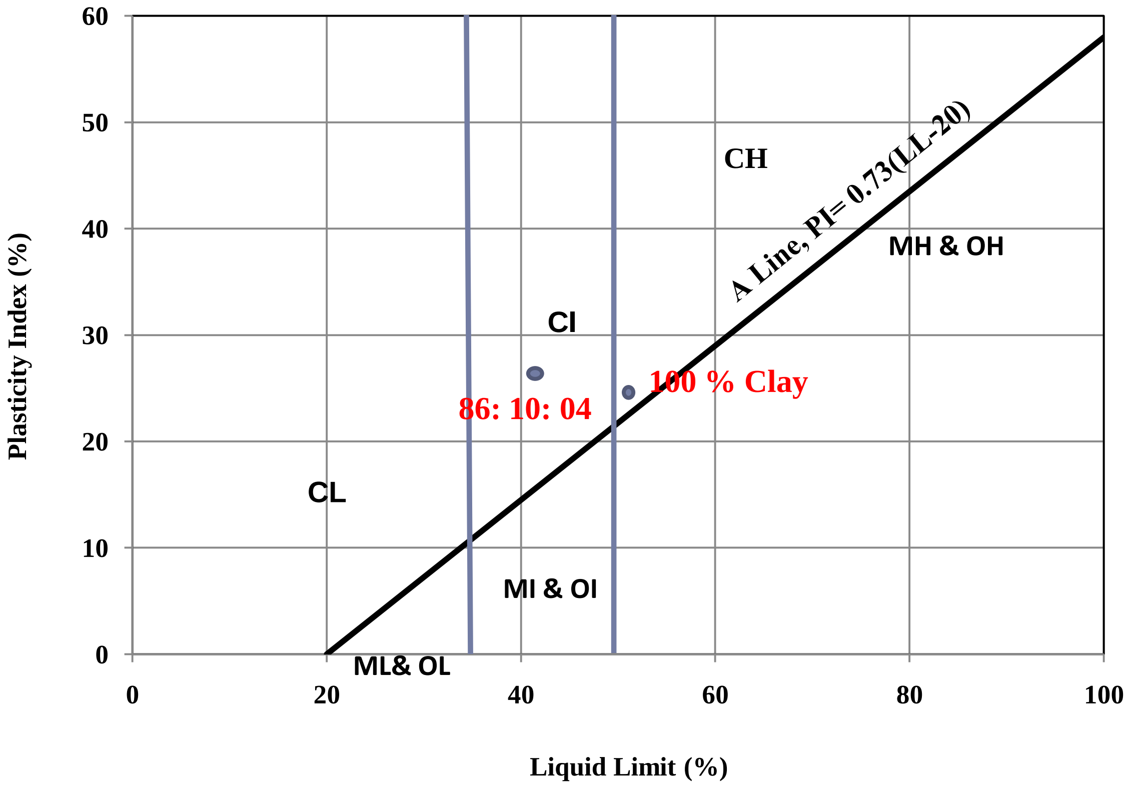

Fig.1 Plasticity shows soil classification before and after treatment

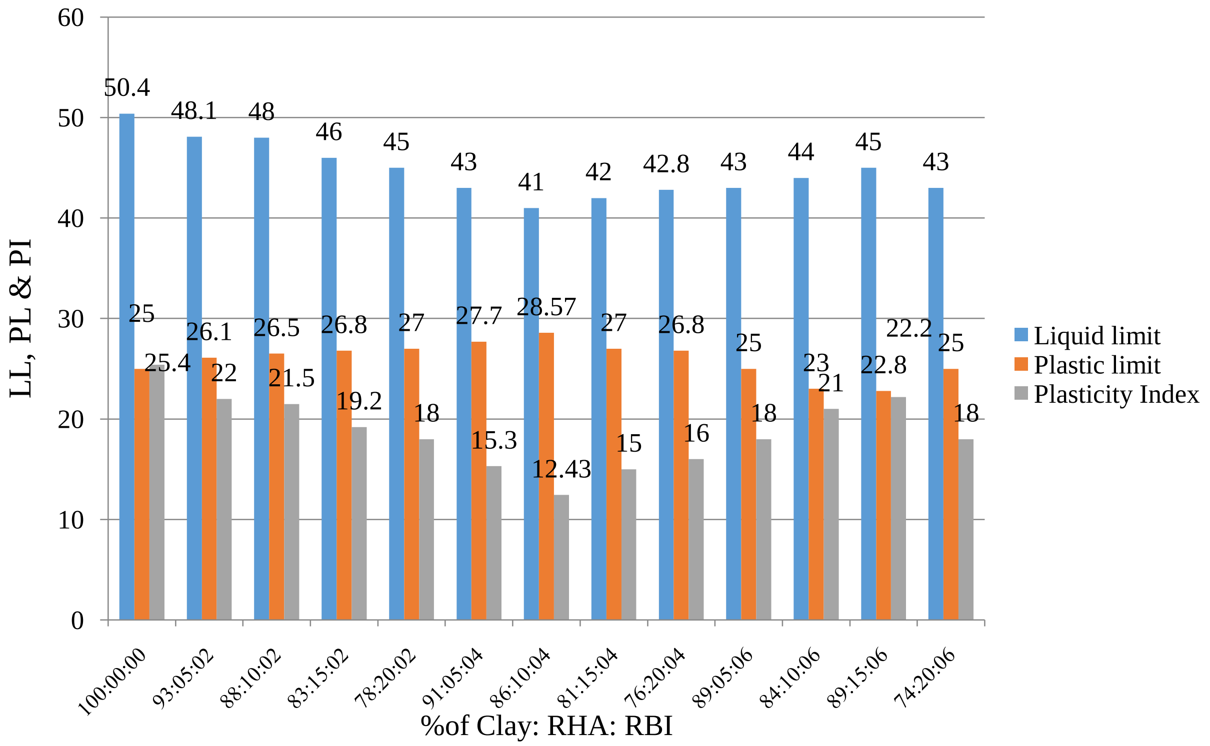

Fig. 2 Consistency limits graph for the various proportions

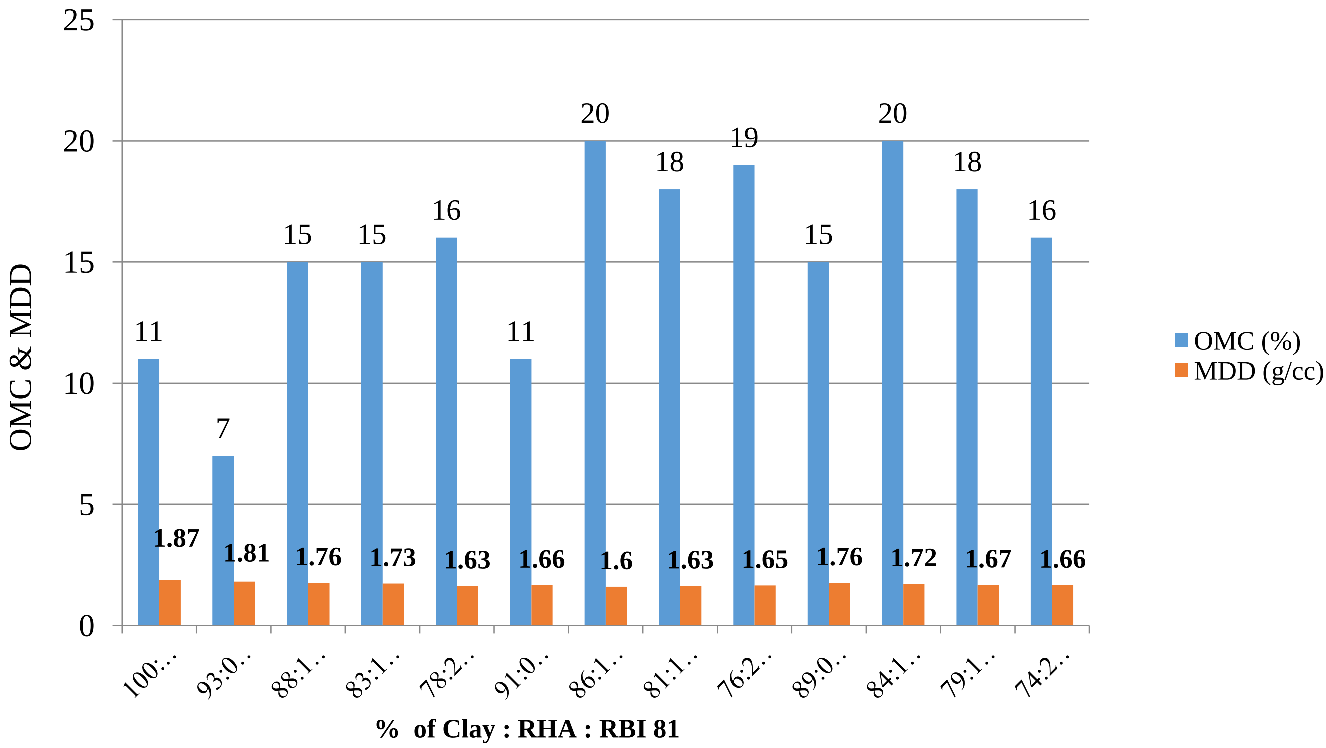

Fig. 3OMC &MDD v/s proportion of RHA with RBI Grade 81

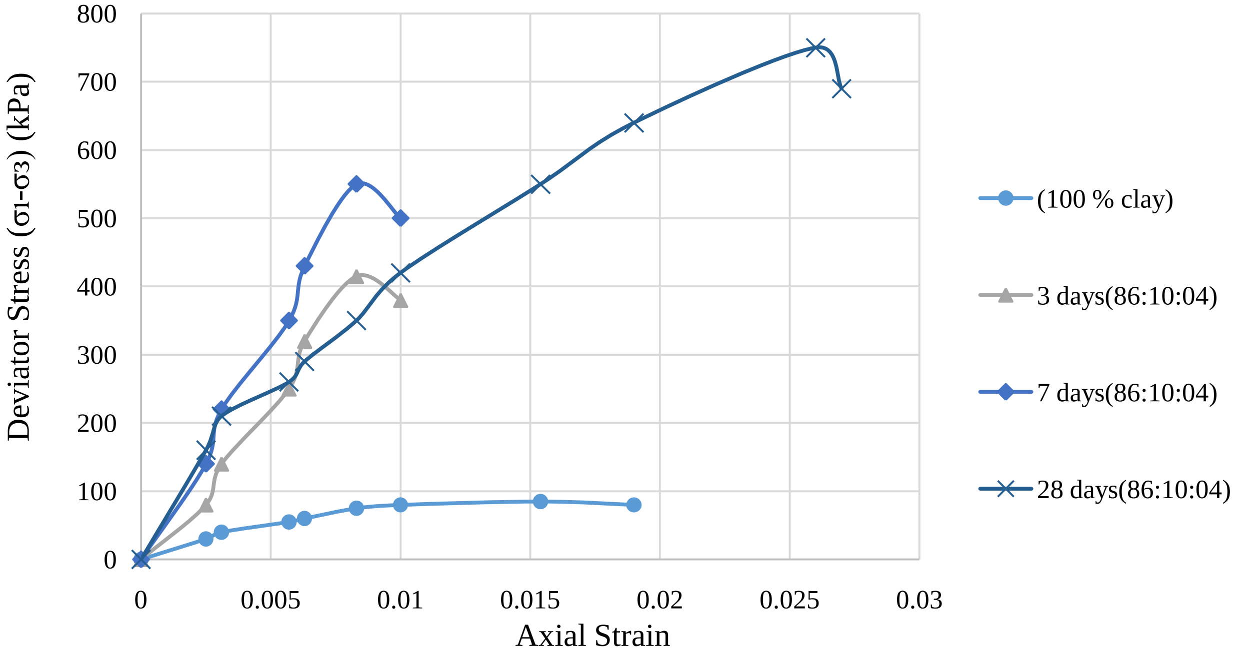

Fig. 4 Deviator Stress vs. Axial Strain of optimum mix under 3, 7 and 28 days

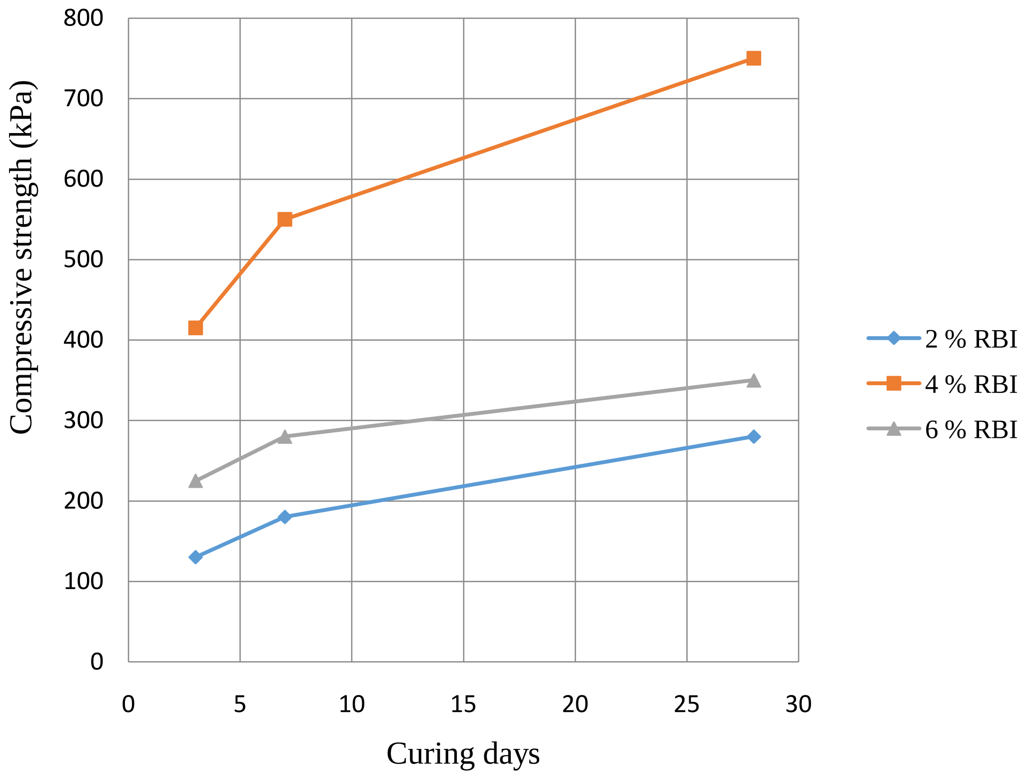

Fig. 5: Compressive strength v/s curing days of 10 % RHA with 2, 4, 6% of RBI

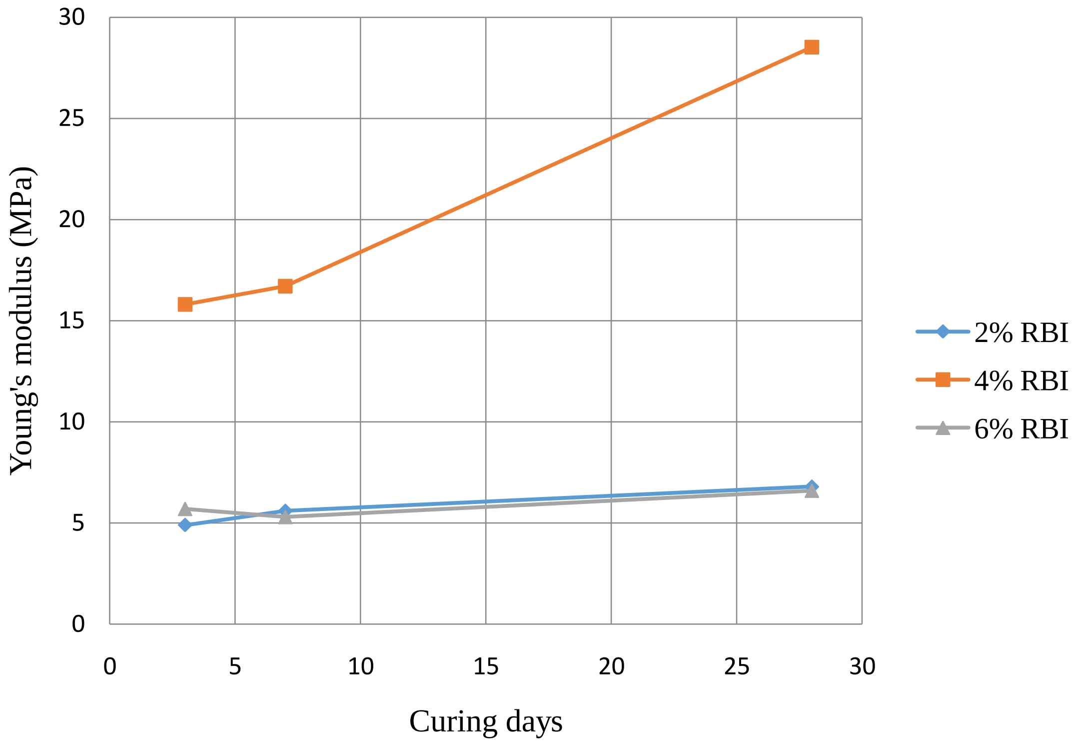

Fig. 6: Modulus of Elasticity vs. curing days of 10 % RHA with 2%, 4%, 6% of RBI

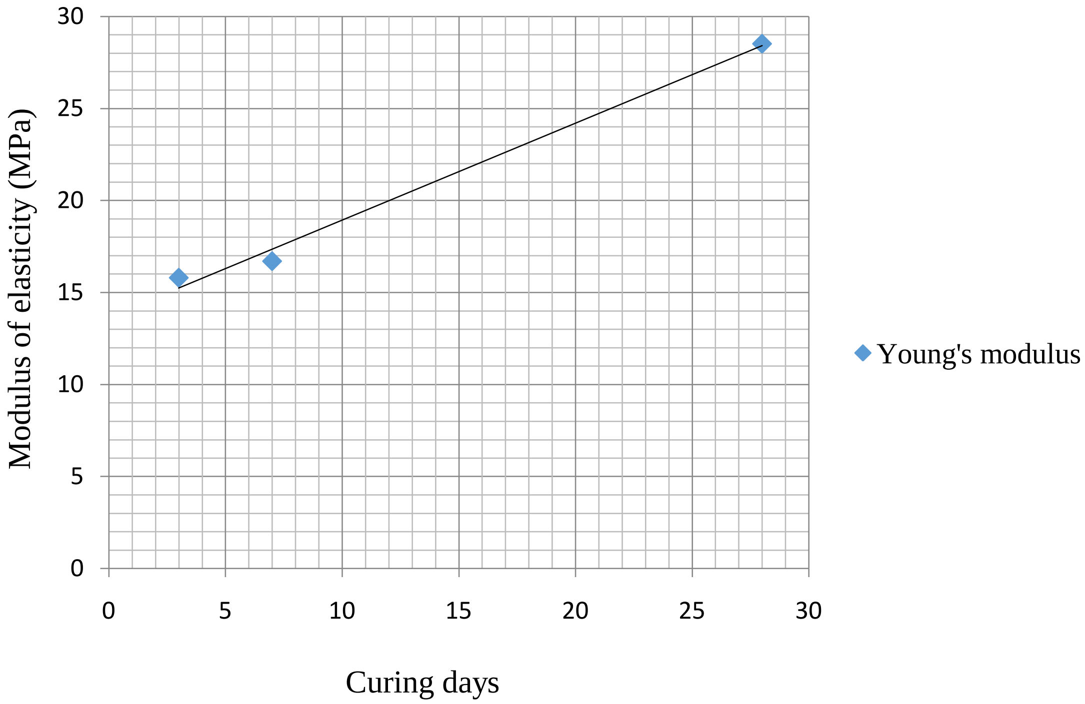

Fig. 7: Modulus of Elasticity vs. curing days of optimum mix (86:10: 04)

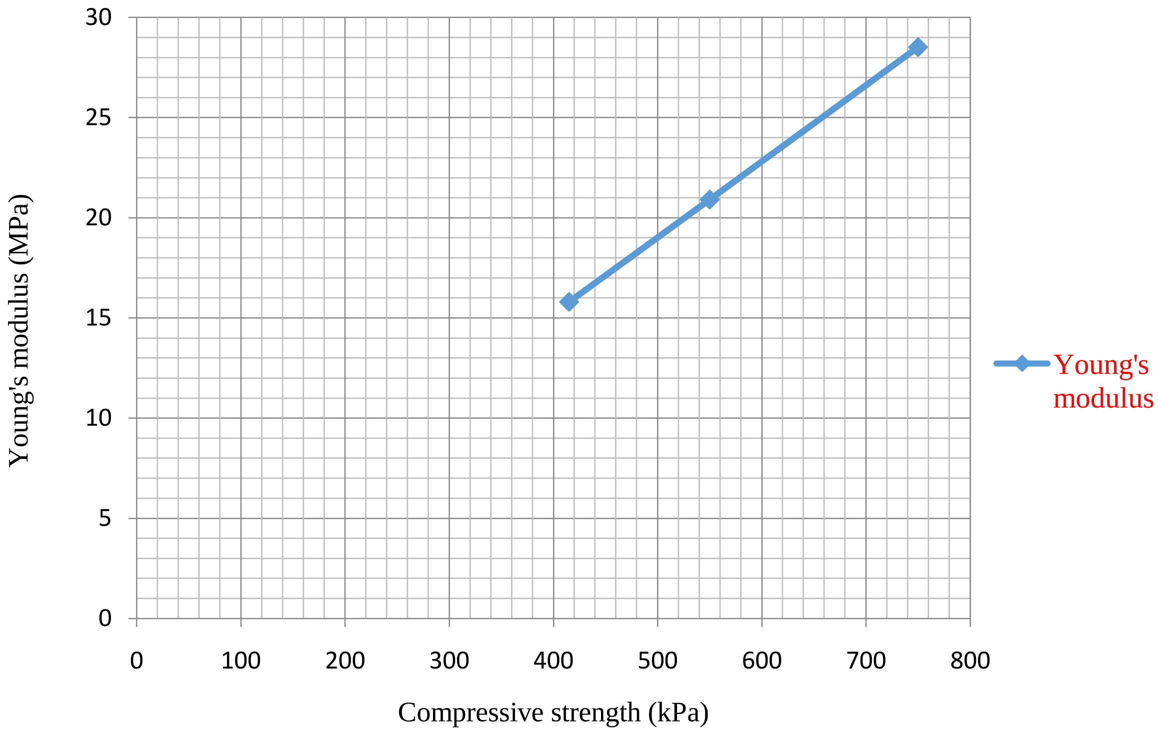

Fig. 8 Relation between modulus of elasticity and compressive strength of optimum mix at 3, 7 and 28 days

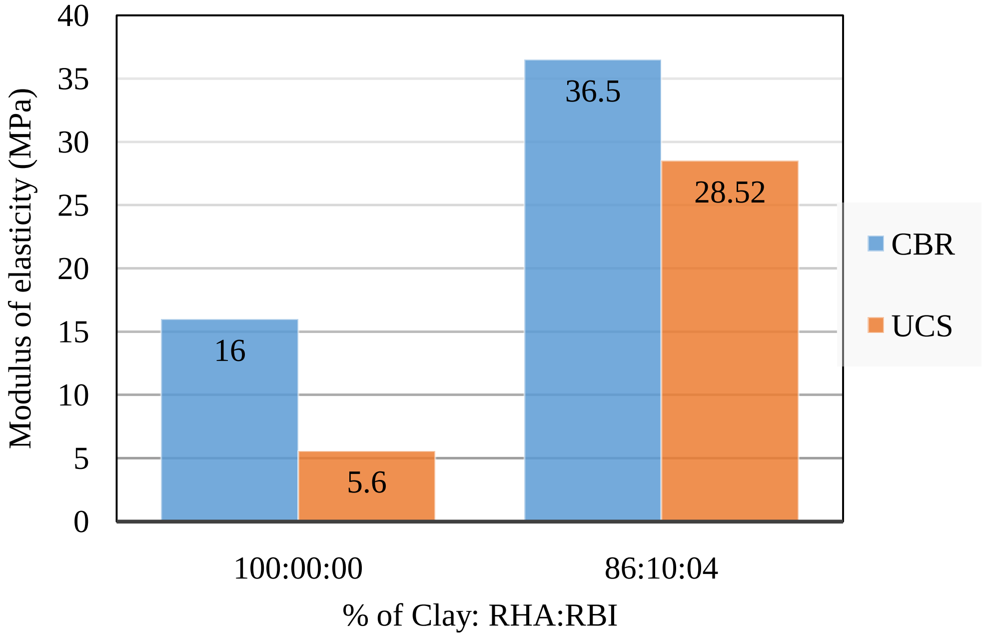

Fig. 9 Comparison between Modulus of Elasticity value of pure clay and optimum mix

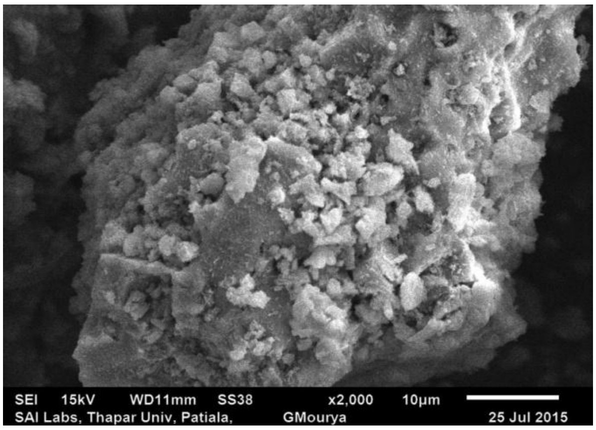

Fig. 10 Particle arrangement of 100% Clay at 5000 magnification level

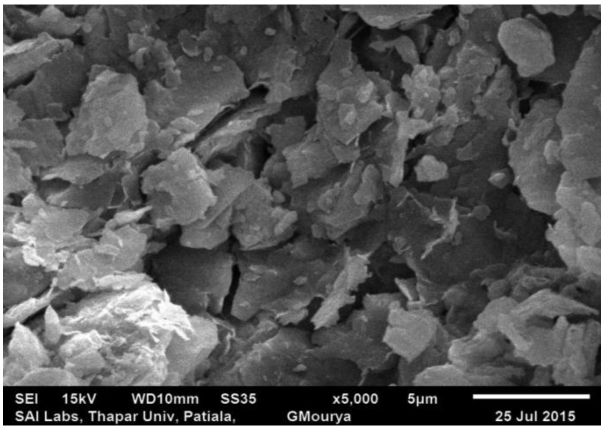

Fig. 11 Particle arrangement of optimum mix (86:10:04) at 2000 magnification level at 28 days curing days

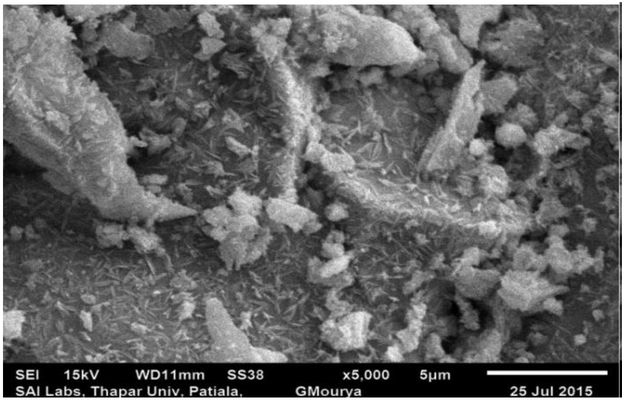

Fig. 12 Particle arrangement of optimum mix at 5000 magnification level at 28 days curing

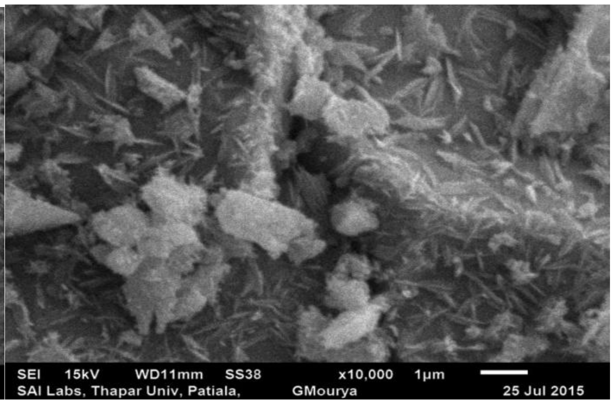

Fig. 13 Particle arrangement of Optimum mix at 10000 magnification level at 28 days curing