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Effect of RBI Grade 81 on strength characteristics of clayey subgrade

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Abstract

The present study deals with the effect of Road Building International Grade 81 (RBI Grade 81) on strength characteristics of the clayey subgrade. A wide range of tests was conducted on various percentages of RBI Grade 81 subgrade mixtures such as Atterberg limits, compaction characteristics, California Bearing Ratio (CBR) and Unconfined Compression Strength tests (UCS). It can be noticed that the CBR of clayey subgrade has increased significantly with the addition of RBI Grade 81. Similarly, the maximum dry density (MDD) has decreased and the optimum moisture content (OMC) has increased with RBI Grade 81 addition to subgrade. The strength of clay subgrade at 8% of RBI Grade 81 has improved 3–3.5 times as compared to the natural clayey subgrade. Overall, it can be concluded that RBI Grade 81 is suggested as a potential stabilizing agent especially for clayey subgrades.

Keywords: Clayey subgrade, Unconfined compressive strength, California bearing ratio, RBI Grade 81

Introduction

Clayey subgrade soils are known as troublesome soils in causing damages especially to the buildings and highway pavements. The damages caused to the structures particularly the lightweight buildings and pavements due to expansive clay soils are comparable to the damages caused due to the natural hazards of earthquakes and floods. Worldwide the expansive clay soils are considered to be problematic and pose several challenges for engineers when involved in construction activities. To avoid such problems, these soils are required to treat or stabilize before the commencement of the construction project. Soil stabilization is one of the viable and technically feasible options to improve the physical and engineering behaviour of the expansive subgrade. Also, soil stabilization enhances the shear strength and improves the bearing capacity of soil as well as the project requirements [1]. It also enables the soil to fit the requirements under specific weather and traffic conditions especially the highway pavements. In most of the cases, in-situ soil would not be able to bear traffic/wheel loads coming on it and many roads fail due to poor soil subgrade.

In the recent past, one of the trending stabilizers which have been considered by the engineers is Road Building International Grade 81 (RBI Grade 81). It is a natural inorganic soil-stabilizer that can modify the properties of soil to strengthen the subgrade of highway pavements. RBI Grade 81 is a worldwide patented additive which includes

India. It is a combination of naturally occurring compounds that provides a good solution to create low-cost roads and foundation layers of motorways. It encourages faster application periods as the road can be opened to traffic within 24 h of final compaction and it provides a dust free surface. If the nature of the soil changes for different depths, most of the methods for stabilization cannot be used but it has a wide range of response spectrum being an eco-friendly material that has many advantages over the other stabilizers used. It can reduce 30–40% of the construction cost, drastically increases the strength of the pavements, and reduce transport and earth moving costs by 60%.

Apart from the previous investigations it is evidently proven that unconfined compressive strength (UCS); soaked California Bearing Ratio (CBR) increases in addition of RBI Grade 81. It is also noticed from the literature that it is suitable to improve the performance of the soft soils acting as a good stabilizer. Similarly, UCS and CBR are also reduced with increasing the dosage of sodium silicate which pose the limitation to be used as a stabilizer. There was a considerable decrease in the liquid limit and swell index with the increased dosage of the stabilizer. Furthermore, it is also evidenced that there was an increase in the CBR and UCS of soils with the increase in the dosage of the stabilizer [2, 3]. Soil admixed with RBI Grade 81 has shown a reduction in Plasticity Index (PI) of soil. Increase in UCS corresponds to the increase in RBI Grade 81 content and it was found to be significant at 6% of RBI Grade 81 and further addition makes a fair increase in UCS. There was a drastic change in soaked CBR with RBI Grade 81 and it was found to be significant at addition of 6% stabilizer for unsoaked and 4 days of soaking as it achieves the required value as per the Indian Road Congress (IRC) standards [4, 5]. Fatigue life test results indicate a high fatigue life for all treated soils when subjected to repeated loading (considering 1/3 of UCS) as compared to the untreated soils [6]. A wide range of variation was observed in addition of RBI Grade 81 for lateritic (red soil) and black cotton soil [7]. The UCS of specimens treated with RBI Grade 81 increased approximately by 250% for a curing period of 28 days as compared to virgin soil and the CBR value improved approximately by 400%. An increasing trend in soil strength behaviour with increasing percentage of RBI Grade 81 suggested its potential applications in soil stabilization [8]. Heavy compaction influence has been noticed on fly ash treated granular sub-base and also $CaCl_2$ treated swelling soils [9, 10]. The different percentages of RBI Grade 81 varying from 2 to 8% were added and test results indicated 42% reduction in plasticity index for kaolinite, 4% for red soil and 116% for lateritic soils. Similarly, OMC increased and MDD decreased with the addition of RBI Grade 81 for red and kaolinites [11]. The stabilized UCS sample increases with increase in the period of curing but the increased percentage in strength was more upon lime addition compared to RBI Grade 81 [12]. From these aforementioned review of the literature, an attempt is made in this investigation to understand the effect of RBI Grade 81 on strength characteristics of the clayey subgrade. Further details of the study are furnished in the following sections.

Experimental program

Materials used

Soil

The soil used in this study was collected from open pits near Patancheru area, Hyderabad, India. After the collection, soil was processed and stored in an airtight containers in the laboratory. The basic tests were conducted according to the Indian

Standard Code of Practice of testing of soils. The basic properties of soil and the gradation curve are presented in Table 1 and Fig. 1, respectively. From this figure, it can be noticed that the soil has 3% of gravel and 44% of sand. The fines content (passing 0.075 mm sieve) present in the soil is 53%.

RBI Grade 81

RBI Grade 81 accredited by Central Road Research Institute (CRRI), New Delhi was collected from the local construction industry. Response spectrum is the range of soils for which a particular stabilizer can be used. The range over which a soil stabilizer can be used is not the only criteria for its acceptability; the durability, cost, and ease of application also requires an intellectual consideration. The wide range of RBI Grade 81 spectrum is shown in Fig. 2. The physical and chemical properties of RBI Grade 81 are presented in Tables 1 and 2 respectively.

Tests conducted

Different laboratory tests were conducted on the soil samples as per Indian Standard Code of Practice for Testing of Soils. The liquid limit (LL) and plastic limit (PL) tests

Table 1 Basic index properties of soil

S. no.	Property	Value
1	Liquid limit (LL), %	48
2	Plastic limit (PL), %	21
3	Plastic index (PI)	27
4	California Bearing Ratio (CBR)	3
5	Unconfined compressive stress (kPa)	100
6	Maximum dry density, MDD (kN/m^3)	17.5
7	Optimum moisture content, OMC (%)	17.5
8	Cohesion, c (kPa)	50
9	UCS failure strain (%)	10

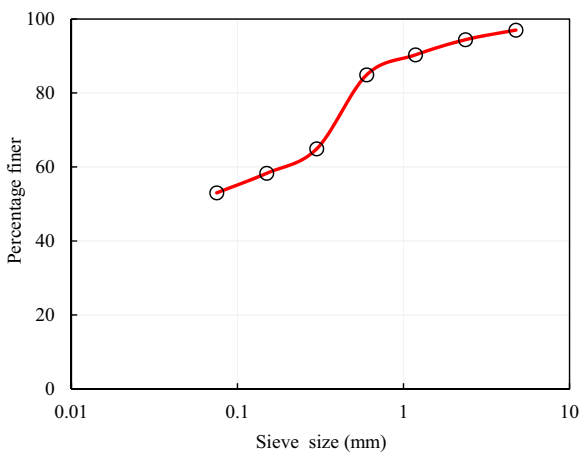

Fig. 1 Grain size distribution curve of clayey subgrade

were conducted as per IS: 2720 (Part 5)-1985 [13]. Grain size distribution is as per IS: 2720 (Part 4)-1985 [14]. Standard proctor compaction test was carried out according to IS: 2720 (Part 8)-1983 [15]. The California Bearing Ratio (CBR) test was carried out as per the IS: 2720 (Part 16)-1987 [16]. The UCS test was carried out as per the IS: 2720 (Part 10)-1973 [17]. The specific gravity of soil was carried out as per the IS: 2720 (Part 3/Set I)-1980 [18]. Determination of Free Swell Index (FSI) of soil was carried out as per the IS: 2720 (Part 40)-1977 [19].

Discussion of results

Liquid limit and plastic limit

Liquid limit and plastic limits are well known as Atterberg limits and are very useful to assess the consistency of fine-grained soils. In general, clay poses a lot of construction problems in the presence of moisture content. If the natural moisture content (NMC) of clay is very close to its LL, the soil will behave like a soft consistency and can be prone to excessive settlement and finally leads to strength reduction.

The variation of Atterberg limits with RBI Grade 81 is presented in Fig. 1. From this figure, it can be seen that as the percentage of RBI Grade 81 increases from 0 to 8%, LL is decreasing linearly, whereas the PL is seen increasing almost linearly and the LL and PL both are meeting at a point corresponding to 8% of RBI Grade 81. PI (it is the numerical difference between LL and PL) is gradually decreasing and showing almost a non-plastic range values. At 8% RBI Grade 81, the PI is almost less than 1. Hence the addition of RBI Grade 81 to clay soil a drastic decrement in PI and consequently turning the soil behaviour into non-plastic (Fig. 3).

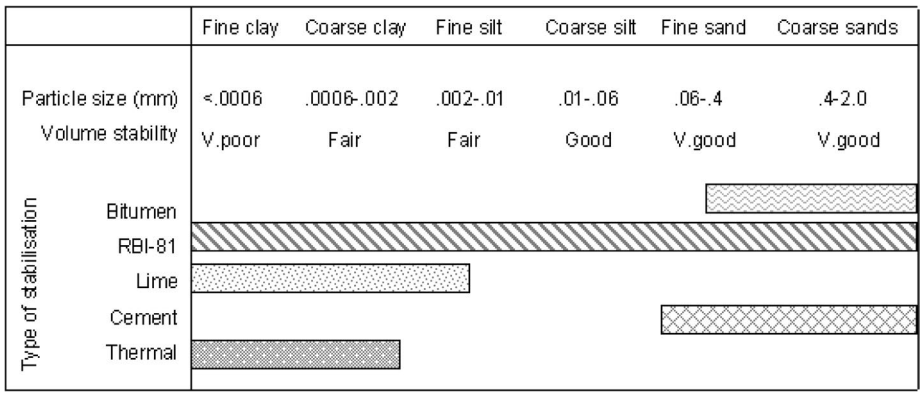

Fig. 2 Spectrum range of RBI Grade 81

Table 2 Physical properties of RBI Grade 81

Physical properties	Average value
Odor/color	4.2
Loss on ignition	2.5
Specific gravity	2.5
% passing through 75 μ	98
Polyester fiber (%)	0.23

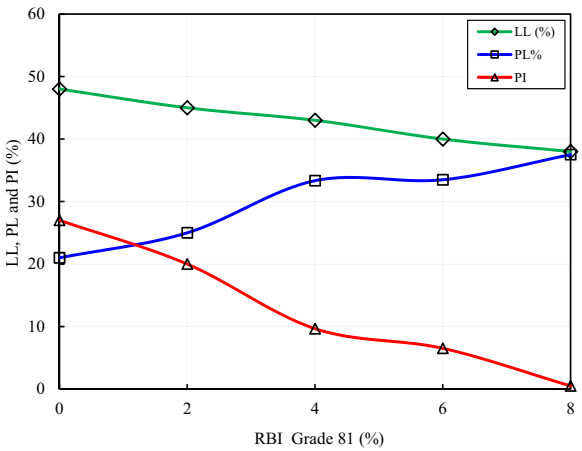

Fig. 3 Variation of LL, PL and PI with RBI Grade 81

Compaction characteristics

Compaction is a mechanical process in which can be carried out mainly to improve the soil density, strength and to reduce the unwanted settlements of the subgrade. In highway projects, compaction characteristics of the subgrade such as optimum moisture content (OMC) and maximum dry density (MDD) are the key parameters, especially in quality control process. So these values can be considered as key quantities for laying the pavement subgrade and must be maintained to attain the stable structure. The compaction curves for the addition of different percentages of RBI Grade 81 mixtures are presented in Fig. 4.

The compaction curves show that as the percentage of RBI Grade 81 increases from 0 to 8%, the peaks are shifting forward right. Almost all the curves are following the similar trend with the addition of the additive. From these curves, it can be further noticed that as the increase in the percentage of RBI Grade 81, the MDD of soil decreasing with the increment of moisture content. This decrease in MDD can be attributed to the replacement of soil with lightweight admixtures such as RBI Grade 81. This replacement of soil by RBI Grade 81 imparts strength to the soil mixtures due to the formation of cementitious compounds; in turn, it develops a good bonding and hence there is an improved stability to the subgrade (Table 3).

Mechanisms governing the compaction characteristics can be better understood from the results as presented in Fig. 5. It can be seen from the above figure that, a decrease in MDD due to the flocculation as a result of physicochemical interaction between the particles and its groups. It is known that flocculated structure as a result of the formation of cementitious bonding makes the compaction more difficult owing to the greater shear resistance at particulate level. Also, the RBI Grade 81 simply replaces the clay particles and the behavioural pattern is nearly governed by itself. The OMC values are also increasing with the RBI Grade 81. This is due to the addition of RBI Grade 81 causing the formation of the matrix; owing to the greater placement of water content is required to obtain the MDD.

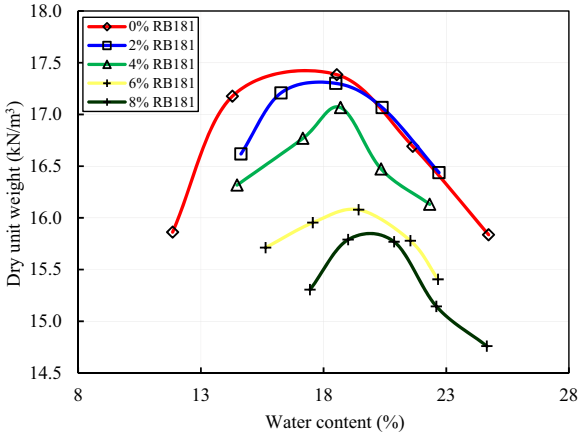

Fig. 4 Compaction curves for admixed soil mixtures

Table 3 Chemical properties of RBI Grade 81

Chemical properties	Average value (mg/l)
$NaHCo_3$	96
$CaSo_4{\cdot}2H_2O$	60
$MgSo_4$	60
kcl	4
pH	8

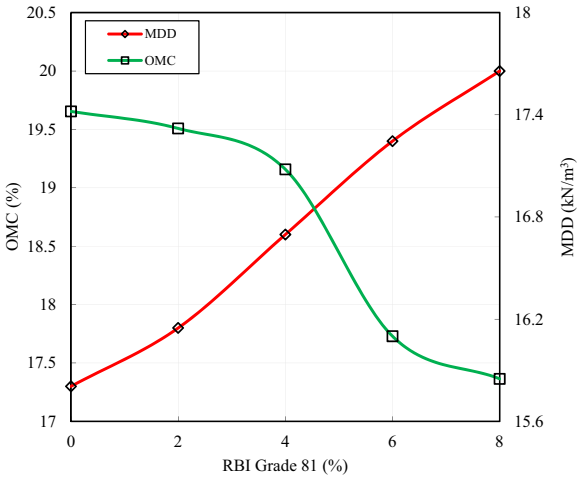

Fig. 5 Variation of OMC and MDD with RBI Grade 81

Effect of RBI Grade 81 on UCS

The stress–strain curves for various percentages of RBI Grade 81 mixtures are presented in Fig. 6. From these curves, it is observed that the curves are following a similar trend, but the failure strain is decreasing as the addition of RBI Grade 81. About 1–2% of strain, the curves are following the linear trend and thereafter the curves changed to curvilinear

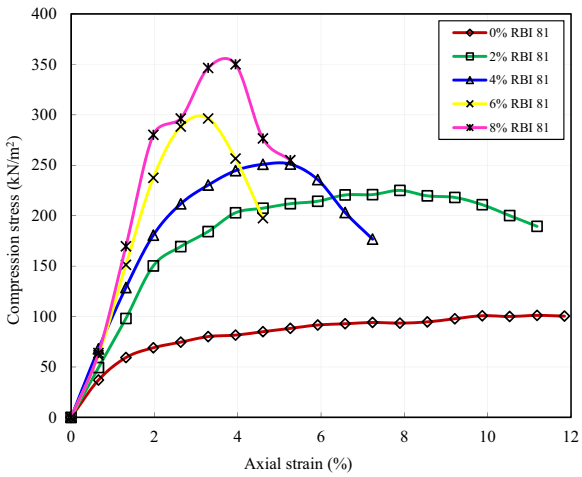

Fig. 6 Stress–strain curves of admixed soils

trend. Further, increase in dosage of RBI Grade 81 causing the soil to fail by brittle nature instead of plastic failure.

The above figure might be helpful to the designers in selecting the respective value of unconfined compression stress (UCS) and strain for a given dosage of RBI Grade 81. The variation of UCS with RBI Grade 81 is presented in Fig. 7. From this figure, it can be seen that the UCS is increasing linearly with the increase in RBI Grade 81. This increment in UCS at 8% RBI Grade 81 is 3.5 times as compared to the untreated soil. It can be observed that addition of RBI Grade 81 imparting an improvement in the soil subgrade strength. Also, the similar improvement is noticed for the cohesion of soil.

Effect of RBI Grade 81 on CBR

The CBR of highway stratigraphy plays a vital role in the design of flexible pavement [20]. The load-penetration curves of CBR tests for the various dosage of RBI Grade 81 are presented in Fig. 8. From this figure, it is noticed that all the curves are following a

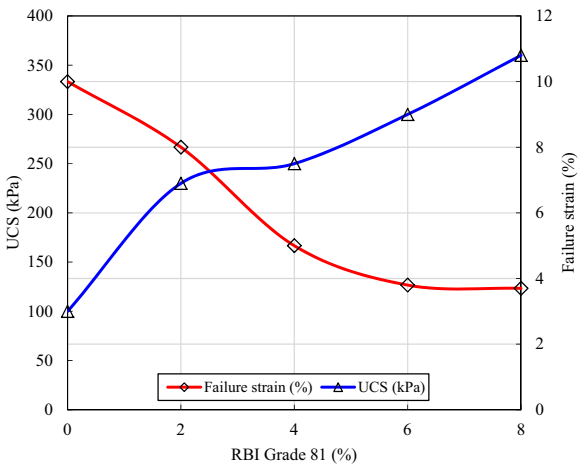

Fig. 7 Variation of failure strain and UCS of admixed soil

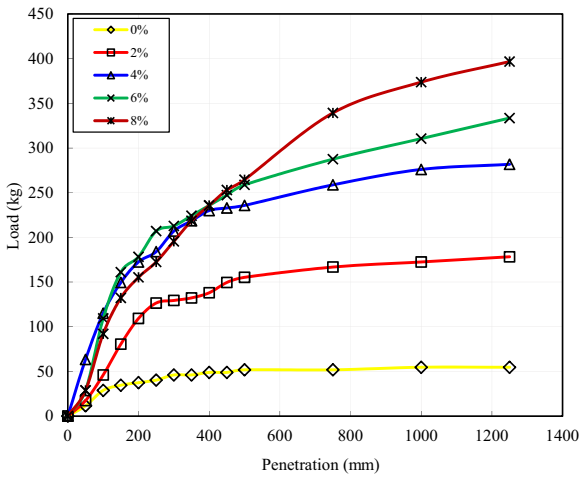

Fig. 8 Load-penetration curves of admixed soil

comparable trend. The load per unit penetration is increasing gradually as RBI Grade 81 increases from 0 to 8%. In addition, further addition of RBI Grade 81 developing rigid matrix in the presence of moisture equivalent to OMC and hence taking more load for a specified penetration in the CBR mould.

Relating curves between CBR and soil basic properties

To read or select the other properties along with the CBR such as MDD, OMC, UCS and cohesion for a various percentage of RBI Grade 81 mixed with soil subgrade are presented in Figs. 9, 10, 11 and 12. From these figures, for a given dosage of RBI Grade 81, it is possible to read or select the required information such as OMC, MDD, UCS, and Cohesion of clay soil. For instance, corresponding to 6% RBI Grade 81, the soil properties noticed are CBR is 14%, UCS is 300 kPa, cohesion is 150 kPa, OMC is 19% and MDD as 15.85 kN/m^3.

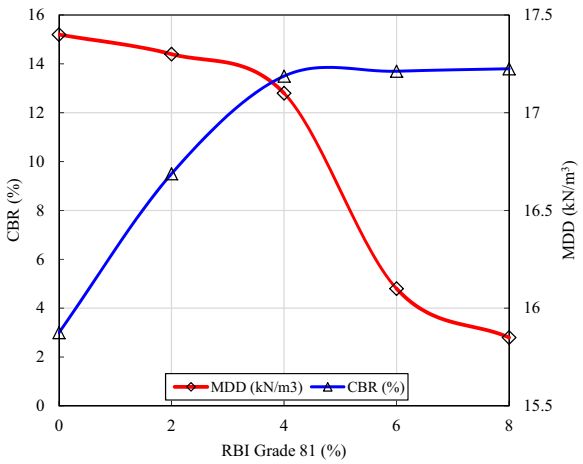

Fig. 9 Variation of CBR and MDD with RBI Grade 81

Conclusions

A stable and durable pavement is the one which provides a safe, comfortable and economical movement of the traffic flow. If the existing ground has no adequate strength, either replacing the soil from other sites or the existing soil stabilized with various techniques to attain the required strength to bear the wheel/traffic loads. In view of the expected improvements in the soil subgrade, the locally available clay soil stabilized with RBI Grade 81 significantly improved the geotechnical properties of the subgrade. From the above results and discussions, the following key conclusions are drawn.

Atterberg limits such as LL, PL, and PI have shown marked changes in soil treated with RBI Grade 81. LL has decreased linearly, whereas PI increased almost linearly and LL and PL both are reached the same point at 8% of RBI Grade 81.

The OMC has increased with the increase in dosage of RBI Grade 81, whereas the MDD is decreased. The UCS has increased linearly with RBI Grade 81 and at 8% of

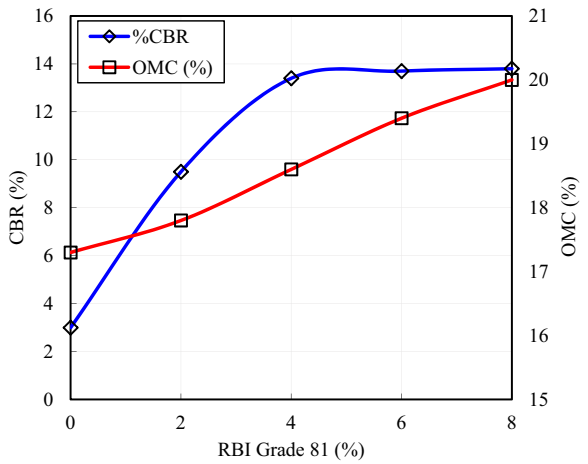

Fig. 10 Variation of CBR and OMC with RBI Grade 81

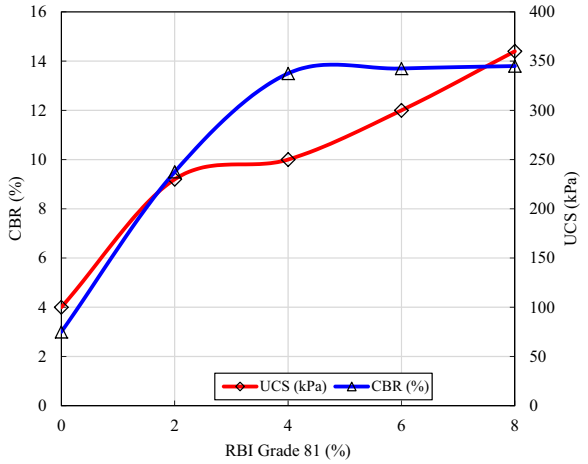

Fig. 11 Variation of CBR and UCS with RBI Grade 81

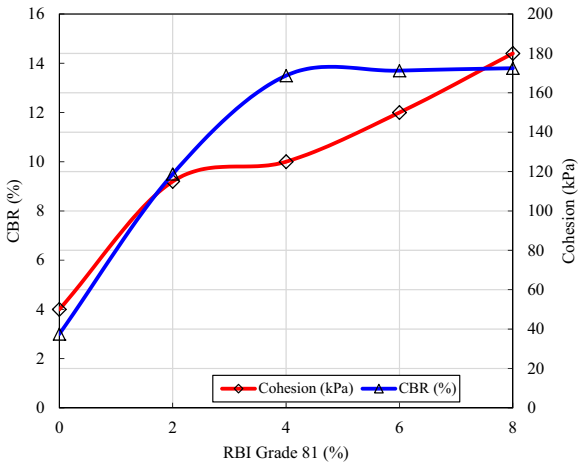

Fig. 12 Variation of CBR and cohesion with RBI Grade 81

RBI Grade 81, it is 3.5 times higher as compared to the untreated soil. Also, the failure strain in the stress–strain curves became lower with the increased dosage of RBI Grade 81.

CBR of clay soil has increased with RBI Grade 81 and this improvement is observed up to 4% of RBI Grade 81 and thereafter no marked improvement is noticed.

Authors' contributions
Both authors involved in compiling the whole manuscript write-up and finally read and approved for the submission. Both authors read and approved the final manuscript.

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Competing interests
The authors declare that they have no competing interests.

Ethics approval and consent to participate
Not applicable.

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