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Mitigating the Problematic Behaviour of Expansive Soils Using Zycobond and Stone Dust

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Abstract. Expansive Soils are predominantly constituted of hydrophilic clay minerals with swelling and shrinkage properties. The seasonal moisture changes result in the extensive shrink-swell processes causing severe damage to the structure founded on them. Several ways are in use to improve the problematic Expansive Soils and the most common method is mechanical stabilization. Research revealed that partially replacing problematic soils with waste materials and modifying them mechanically or chemically. Hence, an attempt has been made to use waste material, Stone Dust (SD) and a Binder, Zycobond (ZB) to mitigate the behaviour of problematic Expansive Soil. This paper presents the results and analysis of the various tests conducted on the expansive soil before and after blending it with different percentages of Stone Dust and Zycobond. The Expansive Soil is partially replaced with Stone Dust from 0 to 30% with an increment of 5% and further Zycobond is added with 0 to 2% with an increment of 0.5% to the optimum mix of Stone Dust and Expansive Soil. The results yielded that Stone Dust and Zycobond blends had effectively improved the problematic behaviour of the Expansive Soil with an optimum of 25% Stone Dust as replacement and 1.5% Zycobond as additive respectively.

Keywords: Expansive Soils (ES), Stone Dust (SD), Zycobond (ZB).

1 Introduction

The impact of Expansive Soils in the construction of superstructures or pavement, subgrade plays a pivotal role. Expansive Soil is a kind of soil that experience considerable volume changes in response to change in water content. As a result of these changes, construction of super structures on Expansive Soil is risky and Poor performance of Expansive Soils leads to high construction cost for the reason that such soils are liable to differential settlements because of the low shear strength and high compressibility. It was found that the utilization of the solid mineral waste like Stone Dust (SD) is an alternative to stabilize the soil for various construction purposes. When an activator like Zycobond (ZB) is blended to the Stone Dust (SD), the results are very encouraging. As a result, stabilization procedures are required to ensure the better stability of problematic soils. The present paper evaluates the parametric study on the efficiency of an eco-friendly mineral waste as Stone Dust (SD) and a chemical as Zycobond (ZB) used for the stabilization, to mitigate the problematic behaviour of expansive soil through laboratory tests.

1.1 Usage of Waste Materials

However, the current condition of environmental pollution is significant, must consider how to dispose of waste materials created as a by-product. In every country, solid waste creation, and disposal are becoming serious challenges. Solid wastes that are solid in form and remain where they are disposed off. Mineral Solid wastes are produced as a result of mining activities or the extraction of rocks and minerals.

1.2 Need for the Study

To resolve these problems, new materials plus different approaches have been developed to minimize the variability in soil characteristics have been constantly studied. Therefore, the current experimental research has been undertaken to attain both the needs of improving the problematic behaviour of expansive soil and similarly, to utilize the mineral wastes as effectively as feasible. By partially replacingthe Expansive Soil with Stone Dust (SD), a comparative new mineral waste, and additional blending it with Zycobond (ZB) to mitigating the problematic behaviour of Expansive Soil.

2 Review of Literature

Research carried out by Rahul Phonsa et al., (2019) investigated the performance of Stone Dust (SD) in improving the parameters of the Soil. Prasad et al (2017) they studies the addition of the Quarry Dust and Tile Waste improved the geotechnical qualities of the expansive soil. Thrumalai et al., (2017) they stated that recently following the stabilization of expansive soils employing industrial waste such as (granite, quarry dust, CKD Cement Kilin Dust, RHA, silica fume) are employed to reduce environmental danger. Indiramma and Sudharani (2016) they research reported that the study is conducted to check the improvement in problematic soil characteristics with the addition of quarry dust. Naman Aggrawal et al., (2015) states that the influ- ence of randomly dispersed stone dust has a significant impact on expansive soil properties.

Padmavathi et al., (2019) their research focuses on the use of Nano-materials as an admixture, such as Terrasil, Zycobond, and Cement to increase the strength characteristics of expansive clay. The addition of Terrasile to the foundation clay increased the products water tightness, and when Zycobond and Terrasile were employed as additives alone and in conjunction with cement, significant increase in the strength qualities was seen. Raghavendra et al., (2018) has proven the efficiency of Terrasile and Zycobond was much better in improving the expansive soil properties. Roopika et al.,

(2015) the feasibility of using nana compounds to stabilize black cotton soil was observed. Research demonstrated that UCS values increase with curing time and the addition of various dosages of Terrasil and Zycobond.

The present report entails of an investigational research to evaluate the influence of the Stone Dust (SD) as a replacement material to mitigate the problematic behaviour of Expansive Soil. To the enhancement in the characteristics of the stabilized prob- lematic soil is not as expected so, and hence Zycobond (ZB) is used as an additive in Stone Dust (SD) replaced Expansive Soil.

3 Methodology

The arrangement of stabilized Expansive Soil samples was prepared by moderately replacing the problematic Expansive Soil by different percentages of Stone Dust (SD) and Zycobond (ZB). The following proportions are taken in this research was displayed in the Table 1.

Table 1. Variables and Percentages Considered.

Name of the Stabilizer	Percentages Varied
Stone Dust as replacement to the Expansive Soil	0, 10, 15, 20, 25, 30
Zycobond (ZB)	0, 0.5, 1, 1.5, 2

3.1 Materials Used

Expansive Soil. The Expansive Soil utilized for this research was obtained from a dredging site, where dredging was carried at a depth of about 2.0 meters beneath the ground level at the zone Odalarevu, near Amalapuram in East Godavari District, Andhra Pradesh, and India. The collected soil has a DFSI of 120%, which confirms that soil is having a high degree of expansiveness. The physical properties of Expansive soil are represented in the Table 2.

Table 2. The Physical Properties of the Expansive Soil.

Properties	Values
Differential Free Swell Index (%)	120
Specific Gravity (G)	2.63
Sand (%)	6.0
Silt (%)	25
Clay (%)	69
Liquid Limit (%)	78
Plastic Limit (%)	33.42
Plasticity Index (%)	44.58
Classification of Soil as per IS	CH
Optimum Moisture Content (%)	27.24
Maximum Dry Density (g/cc)	1.514
Soaked CBR (%)	1.34

Unconfined Compressive Strength (kPa)	74

Stone Dust. The Stone Dust (SD) is a solid mineral waste which is the by-product of quarry stone in the form of powder from the crushing of the quarry aggregates. The crushed stones with Stone Dust in it are highly compactable; it is commonly used as a foundation for construction. It is typically found at the bottom of the road, structural foundation, retaining wall base, where require a solid foundation. The SD used throughout this report was obtained from Quarry near Rajahmundry, East Godavari District, Andhra Pradesh, and India. The collected SD was dried and pulverized and it has been sieved through a 1.18 mm IS Classification Sieve in order to remove the larger size particles. It is usually less expensive than other alternatives. The stabiliza- tion of the Expansive Soil depends on these crucial properties. Based on the environ- mental friendly perspective and a desire to utilize the Stone Dust (SD). The physical properties of the Stone Dust (SD) are represented in the Table 3.

Table 3. The Physical Properties of Stone Dust (SD).

Properties	Values
Specific Gravity (G)	2.78
Coarse Sand (%)	8.0
Medium and Fine Sand (%)	78
Silt (%)	14
Clay (%)	0
Maximum Dry Density (g/cc)	1.853
Optimum Moisture Content (%)	12.44

Zycobond. Zycobond (ZB) is a liquid acrylic Co-polymer emulsion that is delivered as a ready-to-use bonding solution. It is used as a bonding primer and porosity filler material during Expansive Clay treatment with admixture material (Stone Dust) when they are mixed with water, and it is manufactured by Zydex Industries and available in the local markets. It provides water resistance, a strong connection, and flexibilityto the clay surface. It provides erosion protection for unpaved roads and shoulders,and it keeps wet CBR into dry state. It maintains friction values between silt, sand, and clay particles, allowing for strength and deformation resistance management. Zycobond increases the alkalinity of the clay so, it improves its properties.

3.2 Preparation of Sample and Laboratory Testing

Prior to testing, laboratory studies were carried out on the Expansive Soil was air dried initially. After that, soil was pulverized before being passes through an IS 4.75 mm Sieve. To explore the behaviour of problematic Expansive Soil, laboratory investigations were carried out on pulverized Expansive Soil, both before and after treatment with the required amount of Stone Dust (SD) and with a certain amount of Zycobond (ZB). The IS Code of Practice was followed during the experimentation. Different experiments were carried out through laboratory tests by replacing Expansive Soil with different percentages of Stone Dust (SD) as an Admixture and stabilizing it with Zycobond (ZB) as a binder.

4 Results and Discussion

With an estimate, DFSI, Liquid and Plastic Limits, Plasticity Index, Compaction, and CBR, UCS experiments were conducted on the SD Expansive Soil mixture to determine the ideal percentage of Stone Dust (SD) replacement combination.

4.1 Effect of Stone Dust (SD) as Replacement in Expansive Soil

From Figure 1 we can see that the Expansive Soil has replaced the declining differential free swell index with a raise in percentile Stone Dust (SD). The DFSI falls from 120 to 62 when the percentile of SD replaced in the Expansive Soil increases. From Figure 2 we can notice the variation in Liquid Limit, Plastic Limit, and Plasticity Index of stabilized Expansive Soil mixture, according to the Stone Dust (SD) re- placement rate in Expansive Soil, Liquid Limit fell from 78 to 57.47 and the Plastic Limit from 33.42 to 29.11 and the Plasticity Index fell from 44.58 to 28.36 with the proportion of SD being replaced increasing in the stabilized soil combination. From Figure 3 with the increment in the proportion of SD replaced in Expansive Soil the MDD increased from 1.514 to 1.643. From Figure 4 we can observe with the gradual- ly increasing in the percentage of SD replacing with expansive soil the OMC is grad- ually decreased from 27.24 to 23.39. This phenomenon is due to the significant re- placement of non-plastic mineral waste material with plastic soil.

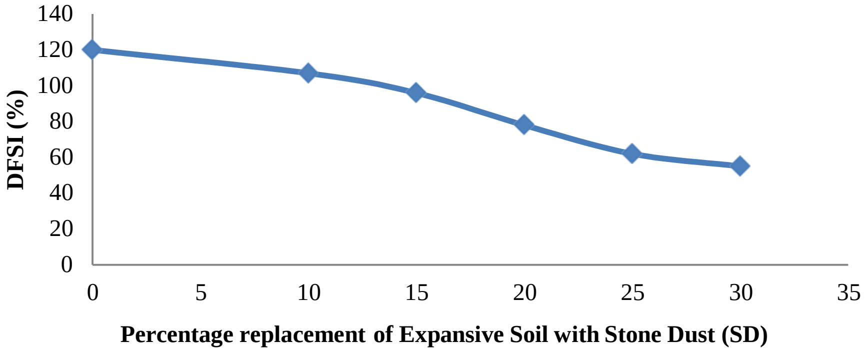

Fig. 1. Plot showing the Variation of Differential Free Swell Index values with the Percentage replacement of expansive soil with SD.

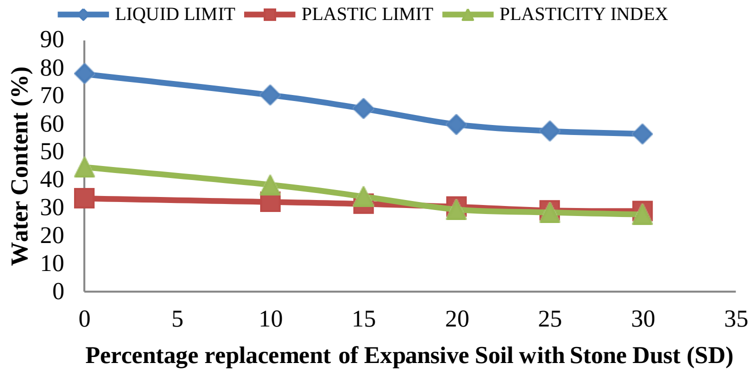

Fig. 2. Plot showing the Variation of Liquid Limit, Plastic Limit and Plasticity Index values with the Percentage replacement of expansive soil with SD.

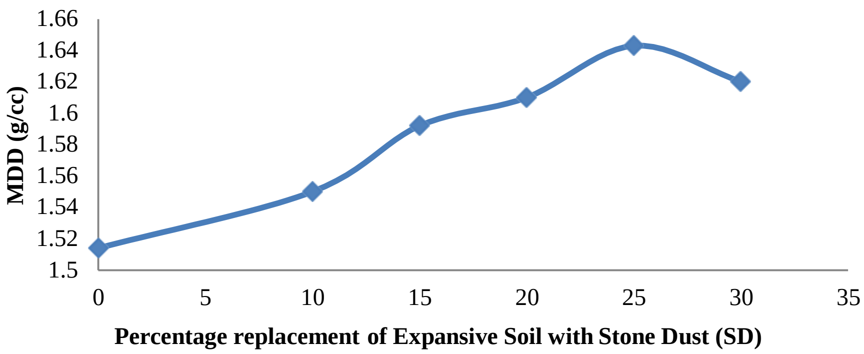

Fig. 3. Plot showing the Variation of Maximum Dry Density values with the Percentage replacement of expansive soil with SD.

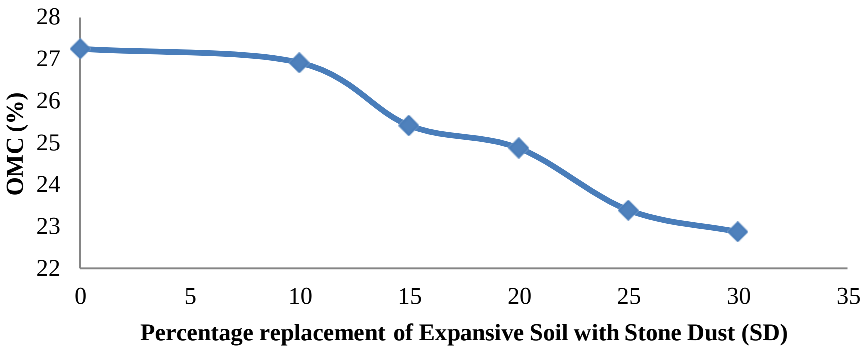

Fig. 4. Plot showing the Variation of Optimum Moisture Content values with the Percentage replacement of expansive soil with SD.

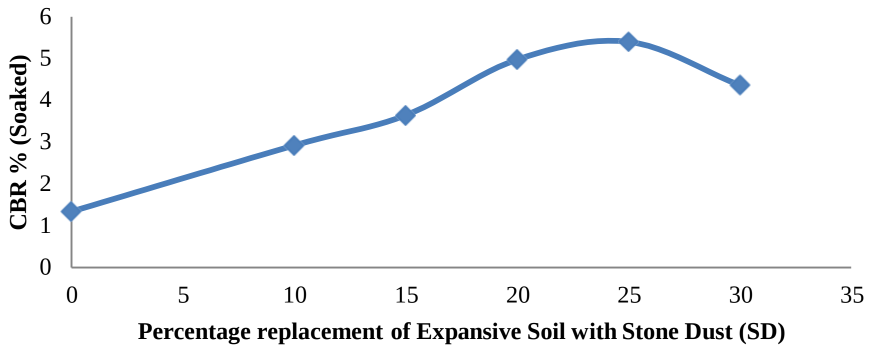

Fig. 5. Plot showing the Variation of Soaked CBR values with the Percentage replacement of expansive soil with SD.

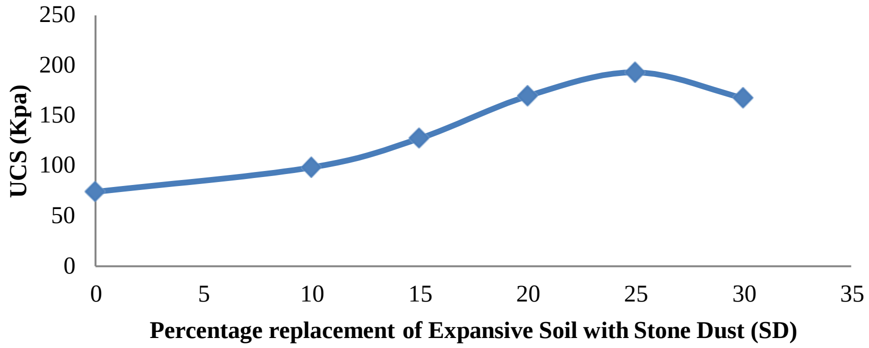

Fig. 6. Plot showing the Variation of Unconfined Compressive Strength values with the Percentage replacement of expansive soil with SD.

CBR variation Figure 5 shows the soaked value with the SD replacement percentage in Expansive Soil. As can be seen, the replacement of 25% of the SD in Expansive Soil results in the maximum penetration values for Soaked CBR being obtained. Figure 6 illustrates how Unconfined Compressive Strength changes as a function of the SD replacement percentage in the Expansive Soil. 25% of SD is used as a re- placement in Expansive Soil to attain the maximum penetration values of Unconfined Compressive Strength (UCS).

The test results demonstrations that there is a magnificent improvement of about 302.98% in soaked CBR values correspondingly, up to 25% SD, as replacement and additional replacing of SD there is a marginal decrease in the values. A same variation was shown in the strength results with an improvement of 160.86% for 25% SD. This may be used to fill the voids in Expansive Soil and reduce the volume change due to swell and also observe water content in Expansive Soil and increase in strength as it is the non-expansive nature of the material. Hence, from the above considerations, the optimum percentage of Stone Dust (SD) as a replacement material in the Problematic Expansive Soil is 25%.

4.2 Effect of Zycobond (ZB) on the Stone Dust (SD) Modified Expansive Soil

Figures 7 to 12 shows the variation of unique components of 25% SD as a partial replacement material in the expansive soil and varied with various proportions of Zycobond (ZB). The influence of the Zycobond (ZB) is as liquid acrylic co-polymer emulsion which is ready to use as a bonding solution which is available as a chemical stabilizer on the behaviour of Stone Dust (SD) treated problematic expansive soil. With a 0.5% increase in percentage, the range of ZB was from 0% to 2%. In the Stone Dust (SD) Expansive Soil mixture, it can be shown that the differential free swell index decreases as percentile of ZB increase, as illustrated in Figure 7. Due to the 1.5% increase in ZB, the DFSI value dropped from 62 to 30. From the graph, it can be observed that the addition of ZB by 1.5% had reduced the DFSI by about 51.61% and the values of plasticity index decreased from 28.36 to 16.51. From the graph, it can be noticed that with the addition of ZB by 1.5% the plasticity index reduced by 41.78%. This demonstrates how the problematic Expansive Soil can be improved by replacing a percentage of it with a non-expanding mineral waste material SD, and combining it with a binder, Zycobond (ZB). And MDD value increased from about 1.643 to 1.791 with the addition of ZB by 1.5%. From the graph it can be observed that the addition of ZB by 1.5% had improved the MDD by about 9.00%. The OMC values decreased from about 23.39 to 19.71 with the addition of ZB by 1.5% and further it reduced. From the graph it can be observed that the addition of ZB by 1.5% had decreased the OMC by 15.73% and further it reduced. With the gradual increment in ZB percentile in the SD Expansive Soil mixture, the Conclusion demonstrates an enhancement in the penetration properties and strength characteristics. The CBR values of Soaked had increased by 53.51% with 1.5% of ZB. The penetration values of Unconfined Compressive Strength (UCS) had improved by around 62.40% when 25% SD replaced Expansive Soil with the 1.5% Zycobond (ZB).

Thus, the properties of problematic Expansive Soil are therefore improved when 25% SD is substituted for it and then combined with 1.5% ZB, as can be seen from the discussion above.

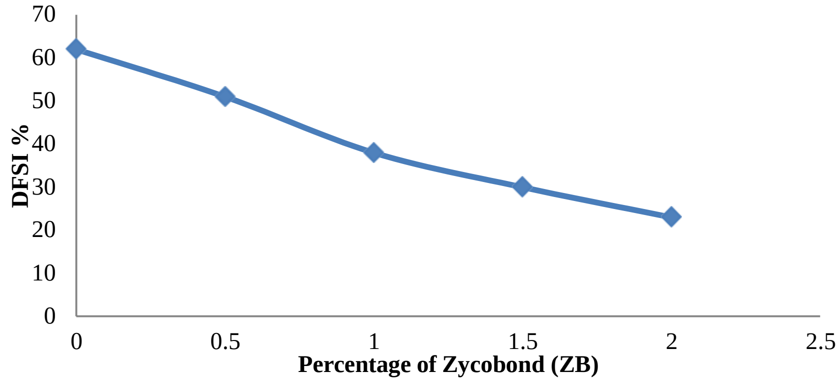

Fig. 7. Plot showing the Variation of Differential Free Swell Index values with the Percentage of Zycobond (ZB) blended to 25% SD treated Expansive Soil.

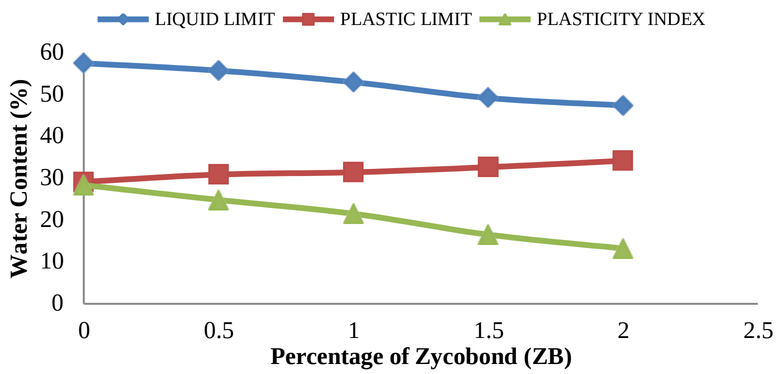

Fig. 8. Plot showing the Variation of Liquid Limit, Plastic Limit and Plasticity Index values with the Percentage of Zycobond (ZB) blended to 25% SD treated Expansive Soil.

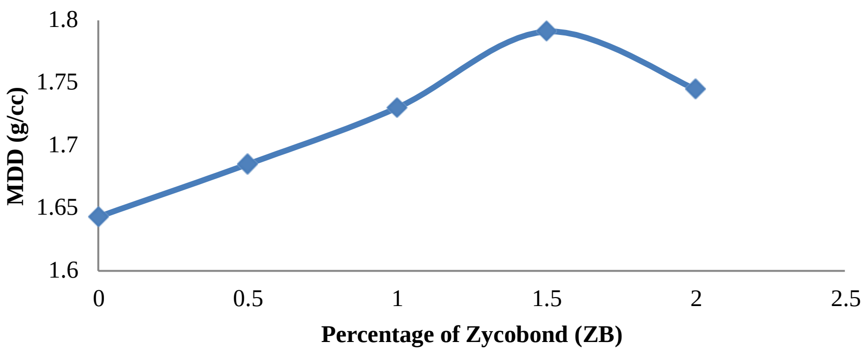

Fig. 9. Plot showing the Variation of Maximum Dry Density values with the Percentage of Zycobond (ZB) blended to 25% SD treated Expansive Soil.

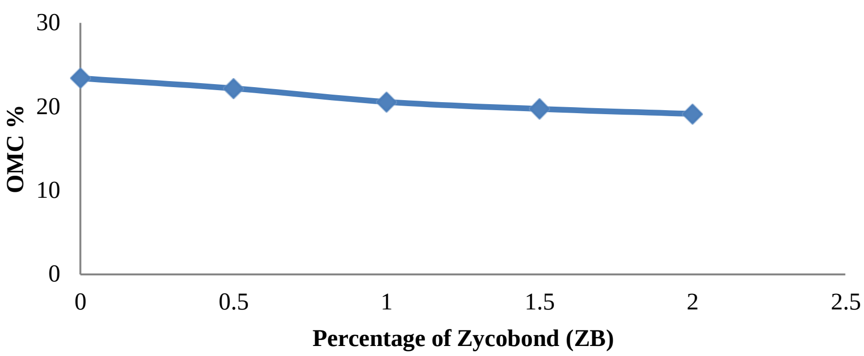

Fig. 10. Plot showing the Variation of Optimum Moisture Content values with the Percentage of Zycobond (ZB) blended to 25% SD treated Expansive Soil.

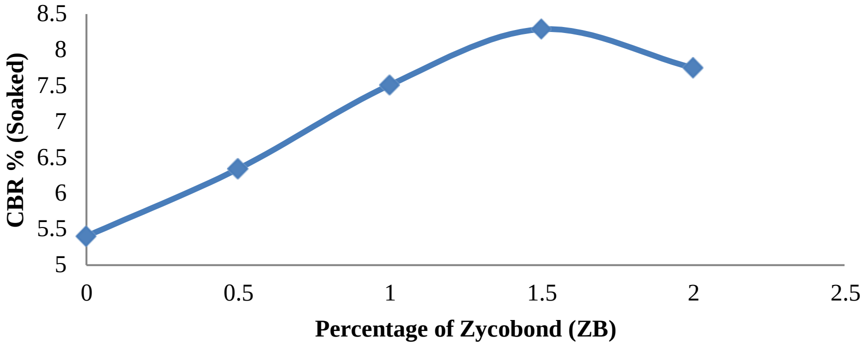

Fig. 11. Plot showing the Variation of Soaked CBR values with the Percentage of Zycobond (ZB) blended to 25% SD treated Expansive Soil.

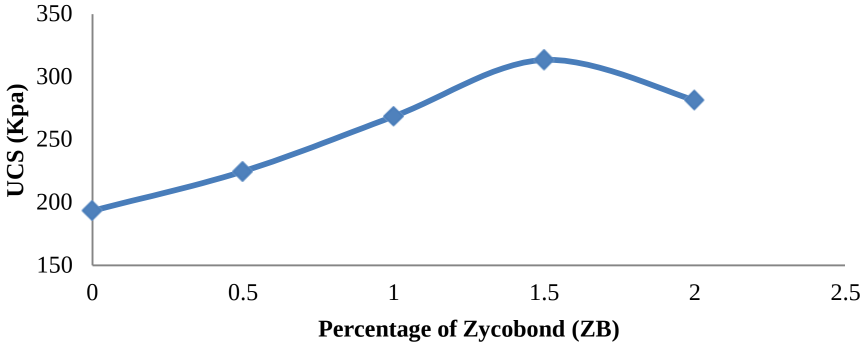

Fig. 12. Plot showing the Variation of Unconfined Compressive Strength with the Percentage of Zycobond (ZB) blended to 25% SD treated Expansive Soil.

4.3 Curing Studies On SD Modified Expansive Soil Mixed With Optimum Zycobond

Figures 13 and 14 shows the results of curing studies on samples prepared using 25% SD + 1.5% ZB as a substitute in the problematic Expansive Soil. Overtime, it was seen from these results that the treatment had magnificently improved the problematic behaviour of Expansive Soil. After 28 days of curing period, Figure 13 shows a noticeable improvement of about 27.26% in the penetration characteristics of soaked CBR. The same trend continued in the penetration properties of Unconfined Compressive Strength (UCS) values with a significant improvement of 29.75%.

In conclusion, the preceding discussion shows that there is a greater improvement in all the properties of problematic behaviour of Expansive Soil with the increment in percentage of SD as a replacement and ZB as additive respectively. Significantly there was considerable changes and enhancement in the soil values.

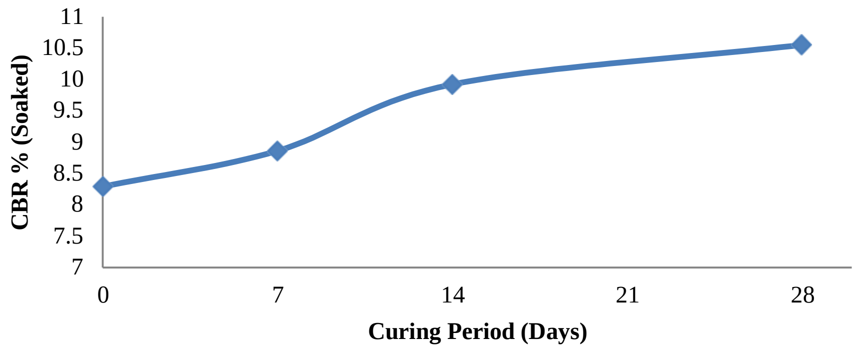

Fig. 13. Plot showing the variation of Soaked CBR values of Sample Prepared with 1.5% Zycobond (ZB) + 25% SD as a Replacement in Expansive Soil with Curing Period.

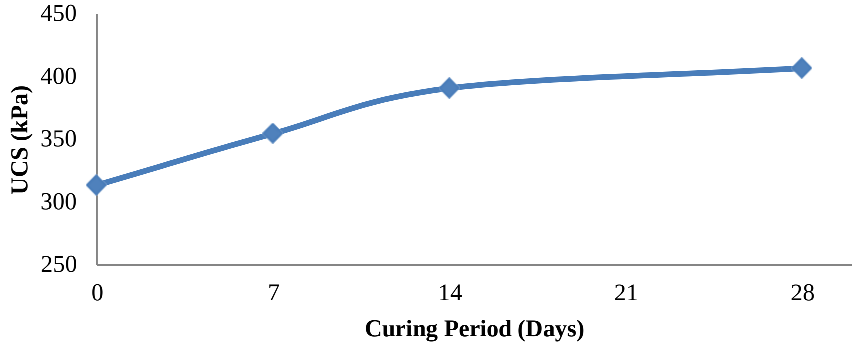

Fig. 14. Plot showing the variation of Unconfined Compressive Strength values of Sample Prepared with 1.5% Zycobond (ZB) + 25% SD as a Replacement in Expansive Soil with Curing Period.

5 Conclusions

The following conclusions may be drawn based on the laboratory experimental re- sults.
[1] It is evident that the DFSI is decreased by 48.33% with the 25% Stone Dust (SD) as a replacement material in the problematic Expansive Soil. It has been further decreased by 51.61% with the addition of 1.5% of Zycobond (ZB).
[2] It is clear that the 25% Stone Dust (SD) as a replacement had decreased the virgin plasticity index of the expansive soil by around 36.38% and on additional add- ing Zycobond (ZB) of 1.5% it had further decreased by nearly 41.78%. This is due to the replacement of plastic soil with a non-plastic mineral waste material and acrylic co-polymer chemical reaction with replaced expansive soil.
[3] It is evident that the MDD value had increased by about 8.52%, respectively, with 25% SD as replacement and with further adding of ZB by 1.5%, the value had further increased by 9.00%.

[4] The OMC values reduced by about 14.13%, respectively, with 25% SD as replacement and with further addition of ZB by 1.5%, the value reduced by about 15.73%.
[5] It is evident that the Soaked CBR values had improved by about 302.98%, respectively, with 25% SD as replacement and with further addition of ZB by 1.5%, the value had further improved by about 53.51%, respectively.
[6] It is clear that penetration values of Unconfined Compressive Strength are improved by about 160.91%, with 25% of SD replace in expansive soil. The value had further improved by 62.36% with the addition of ZB.
[7] Overall, it is concluded that the present paper report on the problematic behaviour expansive soil was magnificently improved with a sustainable solution by reusing the mineral waste material.

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