

Experimental Study on the Geotechnical Properties of Local Soil Using Stone Dust

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ABSTRACT: An experimental investigation has been carried out to study the effect of stone dust on the geotechnical properties of the soil. Stone dust is a kind of solid waste material, which is the by-product of crusher industries. The replacement of the natural soil has been done by the stone dust at various percentages, i.e. 10%, 20%, 30% and 40% by weight of the soil. The results obtained from the laboratory tests on the samples have been studied and summarised that the replacement of the soil by 40% of stone dust by weight of the soil, increased the MDD by 14.2% and the corresponding OMC decreased by 26.88% with respect to the natural soil. The LL, PL and SL have been decreased by 15.29%, 25.54% and 34.26% respectively, with respect to natural the soil. The permeability of the soil has been increased by 33.61% with respect to the natural soil after replacing the soil with 40% of stone dust by weight of the soil. The CBR value has been increased by 50.12% in un-soaked condition and 67.56% in soaked condition with respect to the natural soil. The maximum value of UCS of modified soil has been obtained as 4.75 kg/cm² with the replacement of the soil by 30% of stone dust by weight of the soil, which is 102.12% more than that of the natural soil; hence the percentage of stone dust has been optimised at 30% by weight of the soil regarding the strength parameter.

KEYWORDS: CBR, Clayey silt, Compaction, Stone dust, UCS.

I. INTRODUCTION

The stability of a structure depends upon the stability of the supporting soil to the great extent. The supporting soil must be geo-technically sound to take the load from the structures. The clayey soil has the tendency to swell when its moisture content increases and shrink when its moisture content decreases due to the presence of Montmorillonite clay mineral. These soils are known as Black cotton soil or Expansive soil. The moisture may come from rain, leakage from water or sewer lines, seepage from nearby water bodies, earthen drains, variation of ground water table. These soils have high plasticity, high shrinking and swelling characteristics, extremely low shear strength, bearing capacity and high compressibility. These soils are considered as poor soil regarding the engineering purposes.

To achieve the economy and for proper performance of the structures, it is necessary to improve the geotechnical properties of such soil. The methods used to improve the properties of such soil are known as soil stabilization. The process of soil stabilization first involves mixing a suitable additive with the soil which changes its property and then compact the mixture suitably. This method is applicable only for soil in shallow foundations, the base courses of roads, airfield pavement or core of the dams.

Stone dust is a kind of solid waste material which is generated from the crusher industries. It is estimated that a crusher unit produces 15% to 20% stone dust of its total production of stone aggregates. It possesses a great problem of disposal due to the limited land area and environmental issues. The best way to eliminate this problem is to make use of this waste. Stone dust is available at nominal cost in almost all the places. Hence, it gave an idea to use stone dust as a soil stabilizer to enhance the geotechnical properties of local soil by replacing the soil with stone dust at various percentages such as 10%, 20%, 30% and 40% by dry weight of the soil. The main objective of the study is to analyse the effect of stone dust on the geotechnical properties of the local soil.

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II. EXPERIMENTAL INVESTIGATION

2.1 Soil

The soil sample has been taken for this research work from the B.I.T. Sindri campus.

Table 1: Properties of local soil

| Property | Value |
|---|------------------------|
| Specific gravity | 2.46 |
| Sand (%) | 41.64 |
| Silt (%) | 48.74 |
| Clay (%) | 9.62 |
| Coefficient of uniformity (C_U) | 34.78 |
| Coefficient of curvature (C_C) | 2.87 |
| Optimum moisture content (%) | 16.0 |
| Maximum dry density (g/cc) | 1.76 |
| Liquid limit (%) | 34 |
| Plastic limit (%) | 14.8 |
| Plasticity index (%) | 19.2 |
| Shrinkage limit (%) | 9.37 |
| Permeability (cm/s) | 5.308×10^{-6} |
| Unconfined compressive strength (kg/cm ²) | 2.35 |
| CBR in un-soaked condition (%) | 3.38 |
| CBR in soaked condition (%) | 2.25 |

2.2 Stone dust

Stone dust has been taken from a crusher unit in Guludih, near Baliyapur, Dhanbad for this project work.

Table 2: Properties of stone dust

| Property | Value |
|-------------------------------------|-------|
| Specific gravity | 2.84 |
| Coefficient of uniformity (C_U) | 6.67 |
| Coefficient of curvature (C_C) | 0.94 |
| Optimum moisture content (%) | 10.2 |
| Maximum dry density (g/cc) | 2.11 |

To analyse the effect of stone dust on the geotechnical properties of local soil, which is clayey silt in nature, five types of soil samples were prepared. Those samples were tested on various parameters such as, determination of maximum dry density corresponding to optimum moisture content, liquid limit, plastic limit, shrinkage limit, permeability, UCS and CBR in soaked and un-soaked condition. The descriptions of the samples are as follows:

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Table 3: Description of samples

| Sample | Notation | % of soil | % of stone dust |
|----------|-------------------|-----------|-----------------|
| Sample 1 | S _{SD0} | 100 | 0 |
| Sample 2 | S _{SD10} | 90 | 10 |
| Sample 3 | S _{SD20} | 80 | 20 |
| Sample 4 | S _{SD30} | 70 | 30 |
| Sample 5 | S _{SD40} | 60 | 40 |

III. RESULTS AND DISCUSSION

3.1 Moisture content- dry density relationship

Table 4: Results of OMC and MDD of the samples

| SAMPLE | OMC (%) | % variation w.r.t. natural soil | MDD (g/cc) | % variation w.r.t. natural soil |
|-------------------|---------|---------------------------------|------------|---------------------------------|
| S _{SD0} | 16.0 | 0 | 1.76 | 0 |
| S _{SD10} | 14.8 | - 7.5 | 1.86 | + 5.68 |
| S _{SD20} | 13.9 | - 13.13 | 1.91 | + 8.52 |
| S _{SD30} | 12.0 | - 25.0 | 1.97 | + 11.93 |
| S _{SD40} | 11.7 | - 26.88 | 2.01 | + 14.20 |

The values of MDD to the corresponding OMC in the above table show that, as the percentage of stone dust increased in the soil, the maximum dry density also increased and the corresponding moisture content decreased. It implies that the soil can be compacted to a higher density with the less consumption of water, which is very useful in preparing sub-grades for pavements, embankments of railway and highway, core of the dams etc. The variation of OMC and MDD of the samples due to the replacement of soil with stone dust can be understood easily with the help of the following graph:

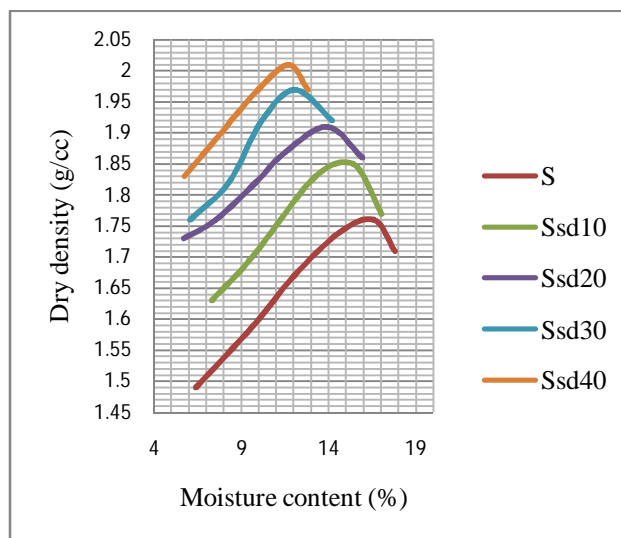


Fig. 1: Variation of OMC and MDD of the samples

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3.2 Atterberg's limit

Table 5: Results of Atterberg's limit of the samples

| SAMPLE | LL (%) | PL (%) | SL (%) |
|-------------------|--------|--------|--------|
| S _{SD0} | 34.0 | 14.80 | 9.37 |
| S _{SD10} | 31.6 | 12.69 | 7.27 |
| S _{SD20} | 30.3 | 11.92 | 6.81 |
| S _{SD30} | 30.0 | 11.89 | 6.40 |
| S _{SD40} | 28.8 | 11.02 | 6.16 |

The values of the Atterberg's limit, i.e. liquid limit, plastic limit and shrinkage limit decreased as the percentage of stone dust increased in the soil. It indicates that the soil become less compressible due to the replacement of the soil with stone dust which is a desirable engineering property of soil regarding any construction on the soil. The swelling and shrinking characteristic of expansive soil due to the variation of moisture content gets arrested as the compressibility of the soil decreases. The variations of LL, PL and SL due to the replacement of soil with stone dust have been shown by the following graph:

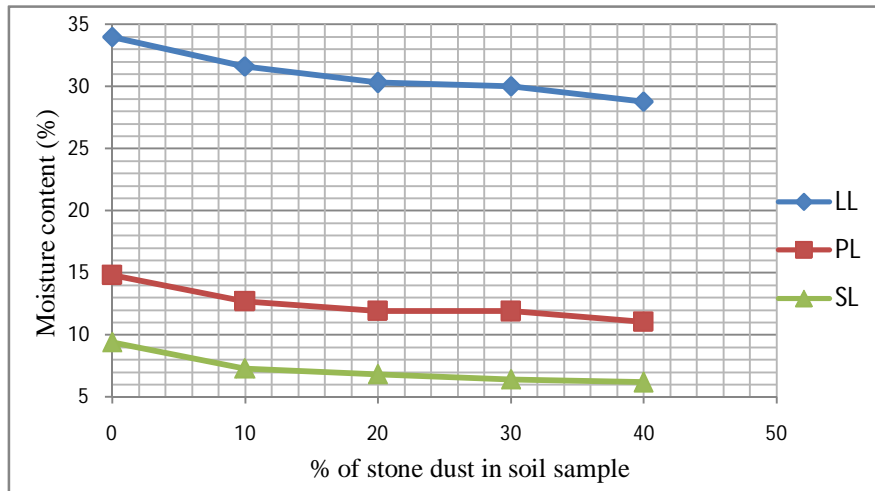


Fig. 2: Variation of Atterberg's limit

3.3 Permeability

Table 6: Results of permeability of the samples

| SAMPLE | COEFFICIENT OF PERMEABILITY (k) (cm/s) | % variation w.r.t. natural soil |
|-------------------|--|---------------------------------|
| S _{SD0} | 5.308×10^{-6} | 0 |
| S _{SD10} | 5.659×10^{-6} | + 6.61 |
| S _{SD20} | 6.204×10^{-6} | + 16.88 |
| S _{SD30} | 6.773×10^{-6} | + 27.60 |
| S _{SD40} | 7.092×10^{-6} | + 33.61 |

The results of permeability state that the permeability of the soil goes on increasing with the increment of percentages of stone dust in the soil. The enhanced permeability of the soil improves the drainage property of the soil which is one

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of the desired conditions for the pavement design. The graphical presentation of the variation of permeability of the samples is shown in the following figure:

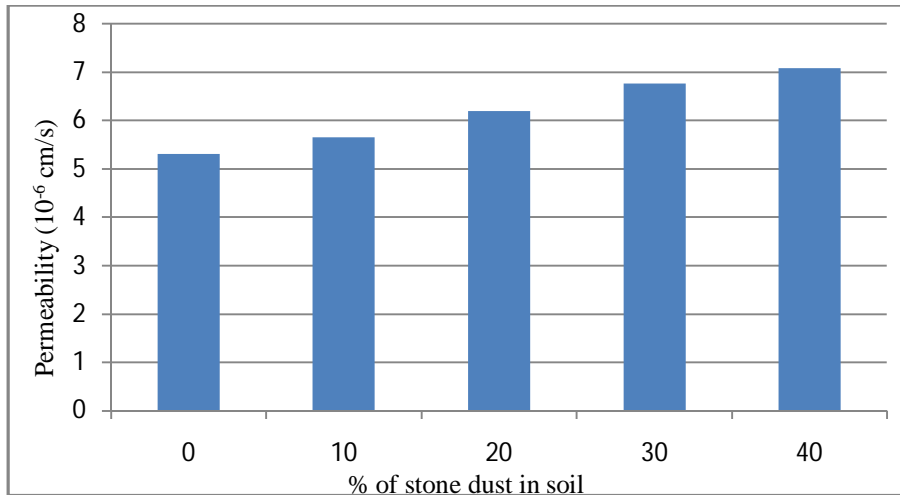


Fig. 3: Variation of permeability of the samples

3.4 Unconfined compressive strength

Table 7: Results of UCS of the samples

| SAMPLES | UNCONFINED COMPRESSIVE STRENGTH (kg/cm ²) | % variation w.r.t. natural soil |
|-------------------|---|---------------------------------|
| S _{SD0} | 2.35 | 0 |
| S _{SD10} | 4.05 | + 72.34 |
| S _{SD20} | 4.58 | + 94.89 |
| S _{SD30} | 4.75 | + 102.13 |
| S _{SD40} | 3.15 | + 34.04 |

The results obtained from tests show that the unconfined compressive strength of the samples increased with the replacement of the soil by stone dust and the soil sample with 30% of stone dust by weight of the soil, gave the maximum value i.e. 4.75kg/cm². As the percentage of stone dust increased further in the soil, the unconfined compressive strength decreased. Hence, regarding the strength parameters of the soil, the percentage of stone dust in the soil has been optimised at 30% by weight of the soil. The sample with 30% of stone dust by weight of the soil gave the UCS value 102% more than that of the natural soil. The variations of UCS of the samples are shown in the following graph:

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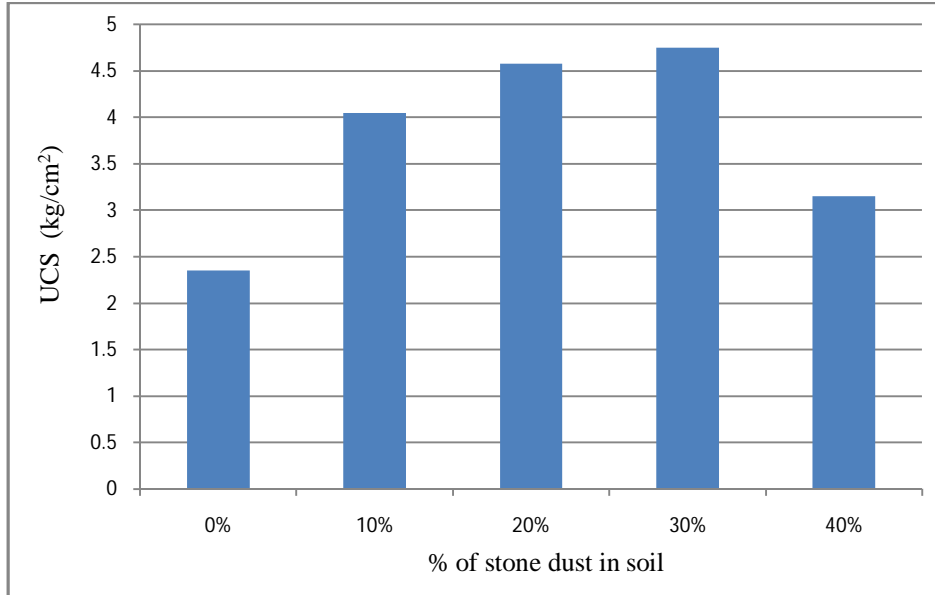


Fig. 4: Variation of UCS of the samples

3.5 California Bearing Ratio

Table 8: Results of CBR of the samples

| SAMPLES | CBR (UN-SOAKED) (%) | % variation w.r.t. natural soil | CBR (SOAKED) (%) | % variation w.r.t. natural soil |
|-------------------|---------------------|---------------------------------|------------------|---------------------------------|
| S _{SD0} | 3.85 | 0 | 2.25 | 0 |
| S _{SD10} | 4.66 | + 21.04 | 2.33 | + 3.56 |
| S _{SD20} | 4.74 | + 23.12 | 3.13 | + 39.11 |
| S _{SD30} | 5.06 | + 31.43 | 3.45 | + 53.33 |
| S _{SD40} | 5.78 | +50.13 | 3.77 | + 67.56 |

The CBR test results interpret that the CBR value in un-soaked as well as in soaked condition has been increased remarkably with the replacement of the soil by stone dust. The replacement of soil with 40% of stone dust by weight of the soil increased the CBR value by 50.13% with respect to the natural soil in un-soaked condition and 67.56% in soaked condition. The variations of the CBR values are represented by the following graphs:

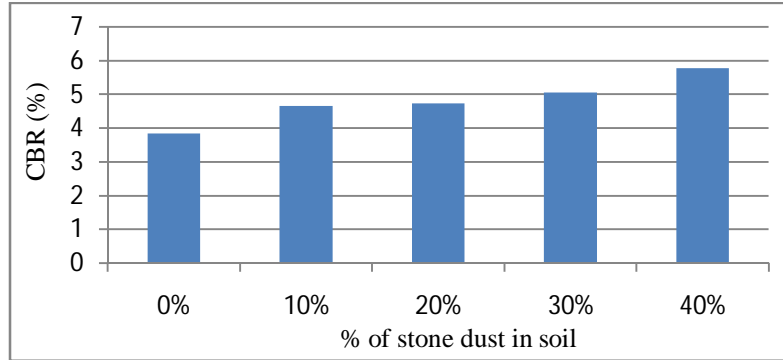


Fig. 5: Variation of CBR in un-soaked condition of the samples

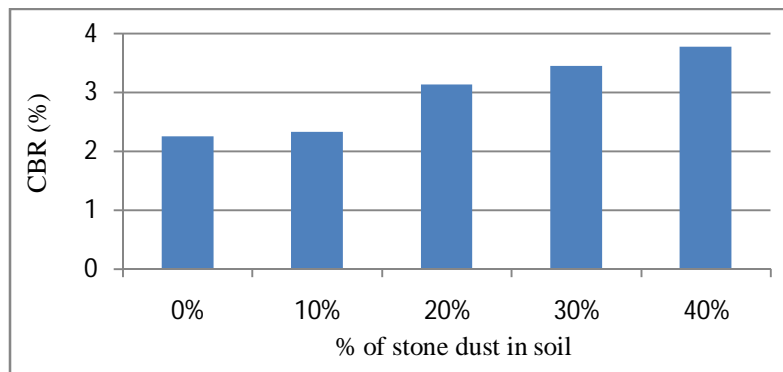


Fig. 6: Variation of CBR in soaked condition of the samples

IV. CONCLUSION

After analysing the test results, it is found that the geotechnical properties of the soil have been considerably enhanced after replacing the soil by stone dust at various percentages by weight of the soil. Stone dust played key role as a soil stabilizer to achieve the objectives of the study.

The detailed analysis of the test results concludes the following:

- As the percentage of stone dust increased in the soil, the maximum dry density also increased and the corresponding moisture content decreased. With the replacement of the soil by 40% of stone dust by weight of the soil, the MDD increased by 14.2% and the corresponding OMC decreased by 26.88% with respect to the natural soil. This enhanced property of the soil helps to achieve high density of the soil at lower moisture content.
- The values of liquid limit, plastic limit and shrinkage limit of the soil with the replacement of the soil by 40% of stone dust by weight of the soil have been decreased by 15.29%, 25.54% and 34.26%, respectively with respect to the natural soil. The decrease in Atterberg's limit decreases the compressibility of the soil which reduces the degree of swelling and shrinkage of the soil due to the variation of moisture content.
- The permeability of the soil increased from 5.308×10^{-6} cm/s to 7.092×10^{-6} cm/s, which is 33.61% more than that of the natural soil after replacing the soil by 40% of stone dust by weight of the soil. It enhanced the drainage property of the soil which is one of the desirable factors in designing the pavements.

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- The CBR value of the natural soil was 3.85% in un-soaked condition and in soaked condition, it was 2.25% while the CBR value of the sample with the replacement of the soil by 40% of stone dust by weight of the soil became 5.78% in un-soaked condition and 3.77% in soaked condition. It implies that CBR value has been increased by 50.12% in un-soaked condition and 67.56% in soaked condition with respect to the natural soil. As the CBR value increases, the thickness of the pavement layers decreases and the design becomes economic.
- The maximum value of the unconfined compressive strength of the modified soil by replacing the soil with 30% of stone dust by weight of the soil has been found to be 4.75 kg/cm², which is 102.12% more than that of the natural soil.
- On the basis of the study of unconfined compressive strength, it may be recommended to replace the soil with 30% of stone dust by weight to the soil for better result.

REFERENCES

1. Naman Agarwal, "Effect of stone dust on some geotechnical properties of soil", IOSR-Journal of Mechanical and Civil Engineering, ISSN: 2278-1684, Volume 12, Issue 1, pp. 61-64, 2015.
2. Nirmali Borthakur, M. Stephen Singh, "Stabilization of peat soil using locally available admixture", Institute of Research Engineers and Doctors, ISBN: 978-1-63248-006-4, pp. 49-53, 2014.
3. Rohit Mahent, Rajesh Joshi, "Improvement of soil index properties by adding stone dust mix", International Journal of Science Technology and Engineering, ISSN: 2349-784X, Volume 2, Issue 2, pp. 61-68, 2015.
4. U. Arun Kumar, Kiran B. Biradar, "Soft subgrade stabilization with Quarry dust-an industrial waste", International Journal of Research in Engineering and Technology, ISSN: 2319-1163, Volume 3, Issue 8, pp. 409-412, 2014.
5. Naman Agarwal, Ajit kumar, "Design of stone dust stabilized road", International Journal of Civil Engineering and Technology, ISSN: 0976-6316, Volume 6, Issue 5, pp. 28-33, 2015.
6. Abeer Sabri Bishara, Y.K. Bind, Prabhat Kumar Sinha, "Effect of stone dust on geotechnical properties of poor soil", International Journal of Civil Engineering and Technology, Volume 5, Issue 4, pp. 37-47, 2014.
7. Arun Patidar, Dr. H. K. Mahiyar, "An experimental study on stabilization of black cotton soil using polyethylene fibre, stone dust and lime", International Journal of Advance Scientific and Technical Research, ISSN: 2249-9954, Volume 6, Issue 4, pp. 90-98, 2014.
8. Vinay Agarwal, mohit Gupta, "Expansive soil stabilization using marble dust", International Journal of Earth Sciences and Engineering, ISSN: 0974-5904, Volume 4, pp. 59-62.
9. Anu Paul, Fatima Moideen, Alka Abraham, "Study on improvement of clayey soil using egg shell powder and stone dust", International Journal of Engineering Research and Application, ISSN: 2248-9622, Volume 4, Issue 4, pp. 55-63, 2014.
10. Mir Sohail Ali, Shubhada Sunil Karanne, "Performance analysis of expansive soil treated with stone dust and fly ash", EJGE, Volume 6, pp. 973-982, 2011.
11. IS: 1498-1970, "Classification and identification of soils for general engineering purposes".
12. IS: 2720 (Part-3-I)-1980, "Determination of specific gravity of fine grained soils".
13. IS: 2720 (Part-4)-1985, "Grain size analysis".
14. IS: 2720 (Part-5)-1985, "Determination of liquid and plastic limit".
15. IS: 9259-1979, "Specification for liquid limits apparatus for soils".
16. IS: 2720 (Part-6)-1972, "Determination of shrinkage factor".
17. IS: 2720 (Part-7)-1980, "Determination of water content-dry density relation using light compaction".
18. IS: 2720 (Part-10)-1991, "Determination of unconfined compressive strength".
19. IS: 2070 (Part-16)-1987, "Laboratory determination of CBR".
20. IS: 2720 (Part-17)-1986, "Laboratory determination of permeability".