Effect of Percentage of Silicon Manganese Slag on Maximum Dry Density and CBR Values in Black Cotton Soils

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Abstract:

As the population grows and the amount of available land decreases, weak or soft soil is being used more and more often for the construction of buildings and other civil engineering constructions. Due to the poor shear strength, significant swelling, and shrinkage of this type of soil, a wide range of ground improvement procedures, such as soil stabilisation and reinforcing are used to improve the mechanical behaviour of the soil, which also increases the construction reliability. In the current research, the black cotton soil is treated with various percentages of Silicon Manganese Slag (i.e., 10%, 20%, 25%, 30%) in order to improve the strength of the black cotton soil. Atterberg's Limit, Compaction Test, California Bearing Ratio Test were performed to determine the soil characteristics. It is observed that results were satisfactory up to the addition of 20% of Silicon Manganese Slag. however, results obtained with additions of more than 20% of Silicon Manganese Slag were ineffective.

Keywords: *Black Cotton Soil, Silicon Manganese Slag, Optimum moisture content, maximum dry density, California Bearing Ratio.*

1. Introduction

Black cotton soil is called expansive soil, these soils are made of clayey soil. In black cotton soils, wide cracks develop during the dry season as these soils are having high clay content. These soils fall under the montmorillonite group having more swelling and shrinkage characteristics. These characteristics are changed due to moisture content and temperature conditions. Swelling and shrinkage of expansive soil cause differential settlements resulting in severe damage to the foundations, buildings, roads retaining structures etc. Black Cotton soils are having a low bearing capacity, low permeability, high compressibility nature. These soils are threatened as problematic soils because many engineering problems were observed in structures, pavements due to the expansive behaviour of these soils. The expansive soils have been improved using a variety of techniques by stabilising the soil with additives. There are numerous techniques for stabilisation, such as:

Mechanical Stabilization: It is the process of improving the soil properties by rearrangement of particles and densification by compaction, or by changing the gradation through addition or removal of soil particles.

Chemical stabilization: This method involves mixing or injecting the soil with chemically compounds such as Portland cement, lime, fly ash, calcium, or sodium chloride or with viscoelastic materials such as bitumen. Numerous waste products, including Jute, nylon fibre, aluminium residue, iron residue, fly ash, and coal, can be utilised to stabilise expansive clayey soils. Recycled waste materials are used to stabilize expansive soils, and it is the most important way to save cost and reduce environmental pollution, which has been attracting more and more attention. These waste materials increase the strength and durability of the soils. In this study the Silicon Manganese Slag by dry weight of soil was taken as 10%, 20%, 25%, 30% were taken and mixed with the soil and examine its effect on MDD, CBR properties of soil.

2. Materials used in this study

2.1. The soil used in this study

The soil used in this study is black cotton soil collected at a depth of 1.0 m to 2.0 m from ground level in Mandapeta near Kakinada, Andhra Pradesh, India. The properties of Black cotton soil were determined, the classification of the soil according to IS 2720 are presented in Table 1.

Table 1: Properties of Black Cotton Soil

S.No.	Parameters	Value
1	Specific Gravity	2.67
2	Liquid Limit (L.L)	91.5%
3	Plastic Limit (P.L)	25%
4	Soil Classification	CH
5	Maximum Dry Density (g/cc)	1.59
6	Optimum Moisture Content	11%
7	CBR (soaked)	1.277
8	Free Swell Index	81.37%

2.2. Silicon Manganese Slag

The main oxide components in raw materials for silicomanganese production are MnO, SiO2, CaO, MgO and Al2O3. MnO and SiO2 are partially reduced whereas the more stable

oxides CaO, MgO and Al2O3 are regarded as unreducable and will go entirely to the slag phase. Even though these oxides do not take part in the reduction process, they are of great importance for the thermodynamic and physical properties of the slag phase.

Silicon Manganese Slag is brought from sardha energy & sardha metals & Alloys Ltd Visakhapatnam. It is a granular base sample. The particle size is between 4.75 mm to 75 microns.

Table 2: General Characteristics of Silicon Manganese Slag

S.No	Tests Conducted	Result Obtained
1	Ph	8.80
2	Particle Density	2.91
3	Crushing	%Mass 26
4	Water Resistance	%Mass 12.00
5	Water Absorption	Mass<0.90
6	Particle Shape	Angular
7	Surface Texture	Medium Rough
8	Freeze Thaw Durability	Mass 11.0
9	Radio Activity Value	0.82635-0.25022

3. Experimental program

In order to determine maximum dry density (MDD) and optimum moisture content (OMC) of unstabilized and stabilized soils, the compaction test is performed as per IS 2720 (Part 7)-1980. The CBR test was performed according to specifications IS 2720 (Part 16)-1987 to determine the CBR values of soil treated with various percentage of silicon manganese slag.

3.1. Compaction Test:

From the compaction test, the maximum dry density (MDD) and optimum moisture Content (OMC) of the soils are found for the selected type and amount of compaction. The light weight compaction test is performed as per Indian standard codes of practice I.S: 2720 (Part VII -1983) at different proportion of silicon manganese slag and corresponding MDD and OMC is figured out from the graph. The OMC of the soil indicated the moisture content at which the soil should be compacted to achieve maximum dry density. If the compacting effort applied is less, the OMC increases and the value can again be found experimentally or estimated.

In field compaction, the compacting moisture content is first controlled by checking the dry density achieved and comparing with maximum dry density. Thus, compaction test results are used in the field control test in the compaction projects. Compaction in general is considered most useful in the preparation of sub grade and other pavement layers and in construction of embankments in order to increase the stability and to decrease settlement.

Figure 1. Proctor Mould

Figure 2. Black Cotton Soil Mixed with Silicon Manganese Slag

Figure 3. Proctor Mould with BC soil Mixed with Slag

3.2. CBR Test

The CBR is a measure of shearing resistance of the material under controlled density and moisture conditions. The load-penetration curve for each specimen is plotted on natural

scale. The load values at 2.5 mm and 5mm are obtained from the load penetration curve to compute CBR values using the following.

$$\text{CBR (\%)} = (\text{Test load} / \text{Standard load}) \times 100$$

Based on extensive CBR test data collected, empirical design charts were developed by the California State Highway Department, correlating the CBR value and flexible pavement thickness requirement. For various traffic volumes different design thickness curves are available. The California bearing ratio tests (as per IS: 2720 (part-16)-1979) were conducted on all the combinations listed in table, at the end of the curing period. Samples were prepared by compacting different mixes to the maximum dry density of the soil. The initial moisture content for these samples was maintained at optimum moisture content of the Soil. The amount of sea sand to be added to the amount of water was arrived at based on the optimum moisture content of the natural soil and the sea sand. This sea sand was added to the air-dry soil and mixture was thoroughly mixed.

Figure 4. CBR Test Apparatus

Figure 5. CBR Mould Preparation

4. Test results and discussions

4.1. Standard Proctor Test results of Untreated Black cotton soil and treated black cotton soil with various percentage of Silicon Manganese Slag:

Standard proctor tests have been conducted to obtain the OMC and MDD values of Black cotton soil and black cotton soil treated with various percentage of Silicon Manganese Slag.

4.1.1. Optimum Moisture Content and Maximum Dry Density of Untreated Black Cotton Soil:

Table 3: Compaction Results for Untreated Soil

S.No.	Water Content (w)%	Dry Density(g/cc)
1	7.69	1.298
2	11.5	1.395
3	15.3	1.455
4	18.18	1.483
5	21.95	1.439
6	26.4	1.394
7	34.48	1.237

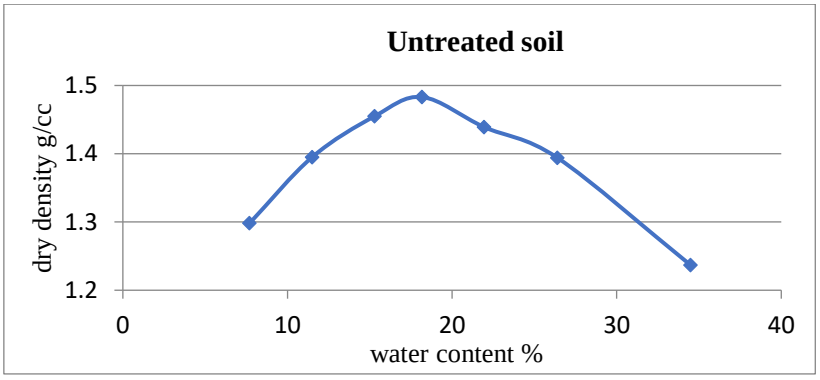

Figure 6. Compaction Curve for Untreated Soil

From figure 6, it has been observed that the optimum Moisture Content (OMC), Maximum Dry Density (MDD) values are 18.18% and 1.483 gm/cc respectively.

4.1.2. Optimum Moisture Content and Maximum Dry Density of Black Cotton Soil treated with 10% of Silicon Manganese slag:

Table 4: Compaction Results for Soil With 10% Silicon Manganese Slag

S.No.	Water Content (w)%	Dry Density (g/cc)
1	8.33	1.444
2	10.5	1.514
3	12.5	1.528
5	22.22	1.410
6	25	1.360

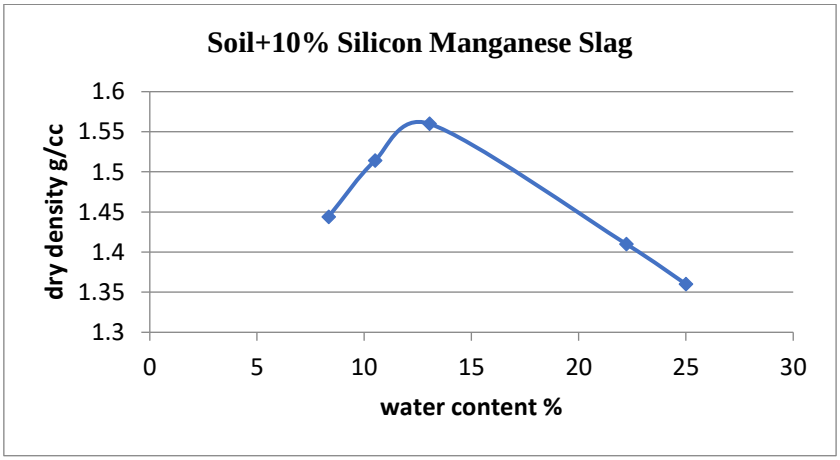

Figure 7. Compaction Curve for Soil with 10% Silicon Manganese Slag

From figure 6, it has been observed that the optimum Moisture Content (OMC), Maximum Dry Density (MDD) values are 13.04% and 1.56 gm/cc respectively.

4.1.3. Optimum Moisture Content and Maximum Dry Density of BC Soil treated with 20% of Silicon Manganese slag:

Table 5: Compaction Results for Soil With 20% Silicon Manganese Slag

S.No.	Water Content (w)%	Dry Density (g/cc)
1	8.69	1.314
2	9.09	1.501
3	9.89	1.577
4	11.11	1.527
5	14.7	1.172

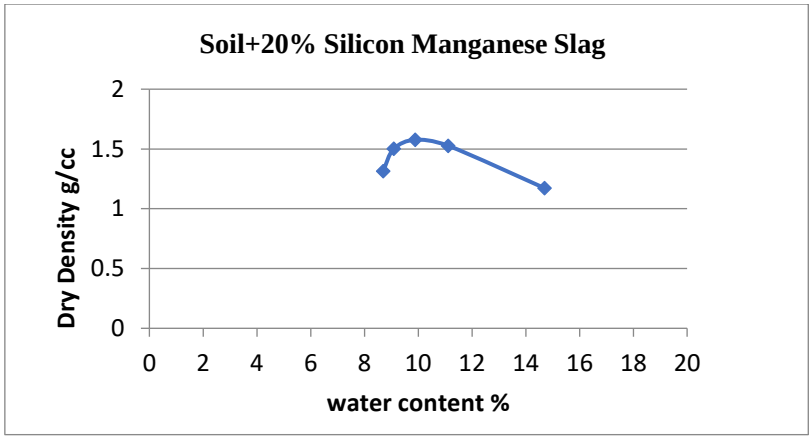

Figure 8. Compaction Curve for Soil with 20% Silicon Manganese Slag

From figure 6, it has been observed that the optimum Moisture Content (OMC), Maximum Dry Density (MDD) values are 11 % and 1.59 gm/cc respectively.

4.1.4. Optimum Moisture Content and Maximum Dry Density of treated BC Soil with 25% Slag

Table 6: Compaction Results for Soil With 25% Silicon Manganese Slag

S.No.	Water Content (w)%	Dry Density (g/cc)
1	8.33	1.299
2	11.76	1.419
3	16.12	1.497
4	19.71	1.261

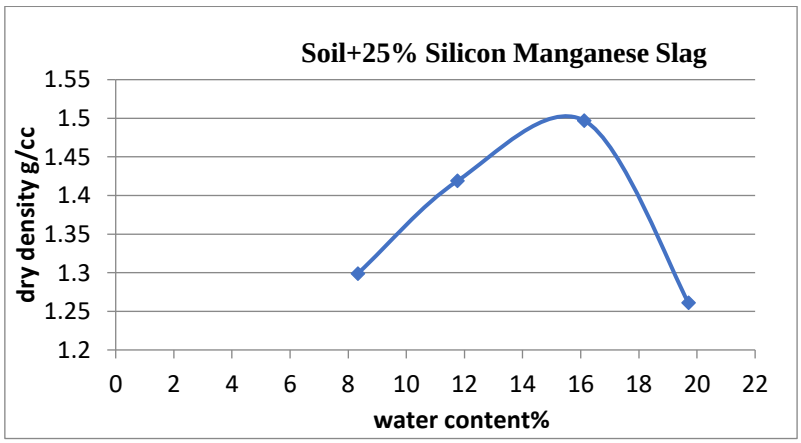

Figure 9. Compaction Curve for Soil with 25% Silicon Manganese Slag

From figure 6, it has been observed that the optimum Moisture Content (OMC), Maximum Dry Density (MDD) values are 16 % and 1.51 gm/cc respectively.

4.1.5. Optimum Moisture Content and Maximum Dry Density of treated BC Soil with 30% Slag

Table 7: Compaction Results for Soil With 30% Silicon Manganese Slag

S.No.	Water Content (w)%	Dry Density (g/cc)
1	11.11	1.287
2	16.78	1.482
3	23.07	1.37
4	25	1.332

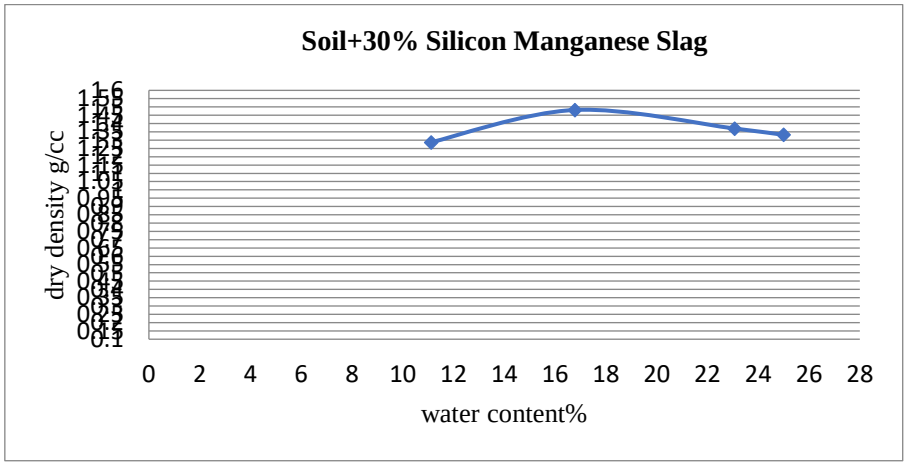

Figure 10. Compaction Curve for Soil with 30% Silicon Manganese Slag

From figure 6, it has been observed that the optimum Moisture Content (OMC), Maximum Dry Density (MDD) values are 16.7 % and 1.47 gm/cc respectively.

4.2. Effect of Silicon Manganese Slag in soils on maximum dry density

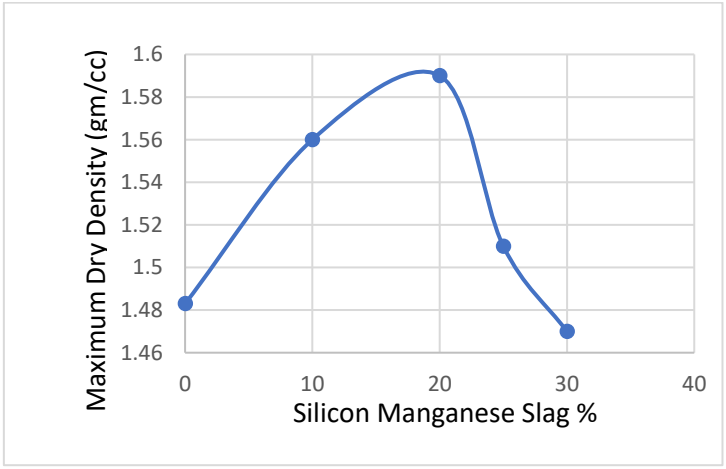

Figure 11. Maximum Dry Density Versus Silicon Manganese Slag

Lightweight proctor tests were conducted as per IS 2720 (Part 7)-1980 to obtain OMC and MDD values of Black Cotton soil and soil treated with different proportions like 10%, 20%, 25% 30% of Silicon Manganese Slag. Fig 1 shows the MDD value of untreated Black Cotton

soil was 1.483 gm/cc, the optimum MDD value has been observed to be 1.59 gm/cc when 20% of Silicon Manganese Slag has added.

4.3. Effect of Silicon Manganese Slag on CBR

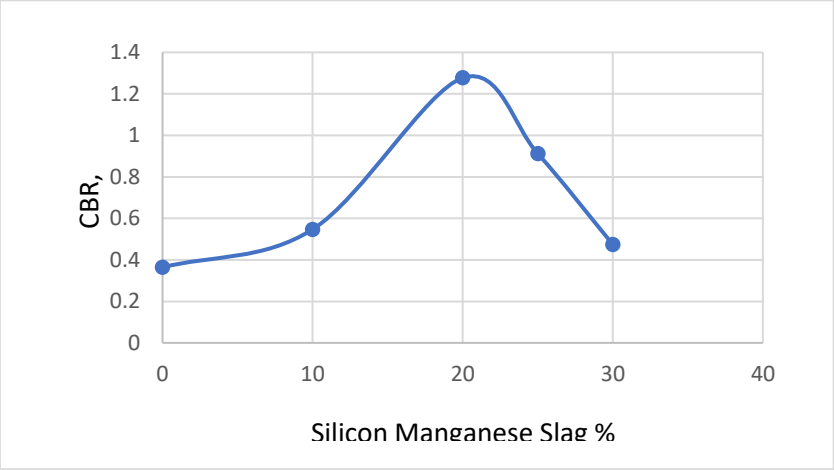

Figure 12. CBR Value % Versus Silicon Manganese Slag

CBR tests were conducted as per IS 2720 (Part 16)-1987. Fig 2 shows CBR values of black cotton soil treated with various proportions like 10%, 20%, 25% 30% of Silicon Manganese Slag. CBR value of untreated Black Cotton soil has been observed to be 0.364%, the optimum CBR value has been observed to be 1.277% when 20% of Silicon Manganese Slag has added.

5. Conclusions

The current research is based on the soil stabilization of black cotton soil with the combination of various percentages of silicon manganese slag. Based on the results obtained the following conclusions were made:

- It is observed from the laboratory test results of compaction that the density of the untreated clay soil is 1.483 g/cc.
- The density of the clay soil treated with 10% silicon manganese slag is increased by 5.1%.
- The density of the clay soil treated with 20% silicon manganese slag is increased by 7.21%
- The density of the clay soil treated with 25% silicon manganese slag is increased by 1.82%
- The density of the clay soil treated with 30% silicon manganese slag is decreased by 0.539%.
- It is observed that the CBR value of the untreated clay soil is 1.364 in soaked condition.
- It is observed that the CBR value of the clay soil treated with 10% silicon manganese slag has been decreased 0.675 in soaked condition.
- It is observed that the CBR value of the clay soil treated with 10% sea sand has been decreased by 59.89% in soaked condition.
- It is observed that the CBR value of the clay soil treated with 20% silicon manganese slag has been decreased by 6.37% soaked condition.
- It is observed that the CBR value of the clay soil treated with 25% silicon manganese slag has been decreased by 29.32% in soaked condition
- It is observed that the CBR value of the clay soil treated with 30% silicon manganese slag has been decreased by 65.2% in soaked condition.

- Optimum values of MDD and CBR values have been obtained for 20% addition of silicon manganese slag with the black cotton soil and further increase in the slag percentage diminishes the strength of the soil.

References:

[1] Kumar, C. R., Gadekari, R. S., Vani, G., & Mini, K. M. (2020). Stabilization of black cotton soil and loam soil using reclaimed asphalt pavement and waste crushed glass. Materials Today: Proceedings, 24, 379-387.

[2] Andavan, S., & Pagadala, V. K. (2020). A study on soil stabilization by addition of fly ash and lime. Materials Today: Proceedings, 22, 1125-1129.

[3] Adeyanju, E., Okeke, C. A., Akinwumi, I., & Busari, A. (2020). Subgrade stabilization using rice husk ash-based geopolymer (GRHA) and cement kiln dust (CKD). Case Studies in Construction Materials, 13, e00388.

[4] Mozejko, C. A., & Francisca, F. M. (2020). Enhanced mechanical behavior of compacted clayey silts stabilized by reusing steel slag. Construction and Building Materials, 239, 117901.

[5] He, J., Shi, X. K., Li, Z. X., Zhang, L., Feng, X. Y., & Zhou, L. R. (2020). Strength properties of dredged soil at high water content treated with soda residue, carbide slag, and ground granulated blast furnace slag. Construction and Building Materials, 242, 118126.

[6] Tiwari, N., Satyam, N., & Shukla, S. K. (2020). An experimental study on micro-structural and geotechnical characteristics of expansive clay mixed with EPS granules. Soils and Foundations, 60(3), 705-713.

[7] Phanikumar, B. R., & Raju, E. R. (2020). Compaction and strength characteristics of an expansive clay stabilised with lime sludge and cement. Soils and Foundations, 60(1), 129-138.

[8] Cikmit, A. A., Tsuchida, T., Hashimoto, R., Honda, H., Kang, G., & Sogawa, K. (2019). Expansion characteristic of steel slag mixed with soft clay. Construction and Building Materials, 227, 116799.

[9] Etim, R. K., Eberemu, A. O., & Osinubi, K. J. (2017). Stabilization of black cotton soil with lime and iron ore tailings admixture. Transportation Geotechnics, 10, 85-95.

[10] Dalal, S. P., Patel, R., & Dalal, P. D. (2017). Effect on engineering properties of black cotton soil treated with agricultural and industrial waste. Materials Today: Proceedings, 4(9), 9640-9644.

[11] Mohanta, Nihar Ranjan, Paresh Biswal, Senapati Suman Kumari, Sandeep Samantaray, and Abinash Sahoo. "Estimation of sediment load using adaptive neuro-fuzzy inference system at Indus River Basin, India." In Intelligent Data Engineering and Analytics: Frontiers in Intelligent Computing: Theory and Applications (FICTA 2020), Volume 2, pp. 427-434. Springer Singapore, 2021.

[12] Mahvash, S., López-Querol, S., & Bahadori-Jahromi, A. (2017). Effect of class F fly ash on fine sand compaction through soil stabilization. Heliyon, 3(3), e00274.

[13] Goodarzi, A. R., & Salimi, M. (2015). Stabilization treatment of a dispersive clayey soil using granulated blast furnace slag and basic oxygen furnace slag. Applied Clay Science, 108, 61-69.

[14] Mallick, Maitri, Bhabanisankar Sahani, Mohini Priya Padhi, Jyoti Prasad Ganthia, Nihar Ranjan Mohanta, and Dhanada Kanta Mishra. "Quality Enhancement of Bituminous Concrete Using Cenosphere Fillers." In Smart Technologies for Energy, Environment and Sustainable Development, Vol 2: Select Proceedings of ICSTEESD 2020, pp. 1-7. Singapore: Springer Nature Singapore, 2022.

[15] Jha, A. K., & Sivapullaiah, P. V. (2015). Mechanism of improvement in the strength and volume change behavior of lime stabilized soil. Engineering Geology, 198, 53-64.
[16] Yilmaz, Y. Ü. K. S. E. L. (2015). Compaction and strength characteristics of fly ash and fiber amended clayey soil. Engineering Geology, 188, 168-177.
[17] Bhavsar, S. N., & Patel, A. J. (2014). Analysis of swelling & shrinkage properties of expansive soil using brick dust as a stabilizer. Int J Emerg Technol Adv Eng, 4, 303-8.
[18] Mohanta, Nihar Ranjan, and Meena Murmu. "Alternative coarse aggregate for sustainable and eco-friendly concrete-A review." Journal of Building Engineering (2022): 105079.
[19] Yadu, L., & Tripathi, R. K. (2013). Stabilization of soft soil with granulated blast furnace slag and fly ash. International Journal of Research in Engineering and Technology, 2(2), 115-119.
[20] Mohanta, Nihar Ranjan, and Sandeep Samantaray. "Study of Combined Effect of Metakaolin and Steel Fiber on Mechanical Properties of Concrete." Pertanika Journal of Science & Technology 27, no. 3 (2019).
[21] Rao, A. S., & Sridevi, G. (2011). Utilization of industrial wastes in pavements laid over expansive clay sub-grades. In Geo-Frontiers 2011: Advances in Geotechnical Engineering (pp. 4418-4427).
[22] Venkateswarlu, H., Prasad, D. S. V., & Raju, G. P. Study on Geotechnical Properties of Stabilized Expansive Soil-Quarry Dust Mixes.
[23] Bairagi, H., Yadav, R. K., & Jain, R. (2014). Effect of jute fibres on engineering properties of lime treated black cotton soil. Int. J. Eng. Res. Technol, 3(2), 1550-1552.
[24] Murmu, Meena, Nihar Ranjan Mohanta, and Nikhil Bapure. "Study on the fresh and hardened properties of concrete with steel slag as partial replacement for natural aggregates." Materials Today: Proceedings (2023).
[25] Agarwal, N. (2015). Effect of stone dust on some geotechnical properties of soil. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), 12(1), 61-64.
[26] Shalabi, F. I., Asi, I. M., & Qasrawi, H. Y. (2017). Effect of by-product steel slag on the engineering properties of clay soils. Journal of King Saud University-Engineering Sciences, 29(4), 394-399.
[27] IS:2720, Part 3 Sect. 1-1980: Determination of Specific Gravity- Fine Grained Soils.
[28] IS:2720, Part 5-1970: Determination of liquid and plastic limits.
[29] IS:2720, Part 7-1983: Determination of water content dry density relation using light compaction.
[30] IS:2720, Part 40- 1977: Determination of free swell index of soils.