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Establishment of Relationships between Compaction Parameters and Oxides Composition of Industrial Waste Materials

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Abstract. Research regarding the effectiveness of using industrial wastes as a stabilizer is rapidly increasing. Industrial wastes, generally, constitute with chemical and mineralogical compositions in disproportional quantity that varies from minor to remarkable. At this juncture, it is essential to have a better understanding on the suitability of waste materials to be used as local construction material in a way to minimize the amount of waste to be disposed off and thereby, reduce environmental pollution. This paper attempts to establish correlations of the compaction parameters of waste materials with their oxides composition. Oxides contents such as SiO_2, Al_2O_3, CaO, and Fe_2O_3 are considered in the study. In general, it was observed that maximum dry density increases with an increase in calcium and ferric oxides, and decreases with an increase in silica and aluminum oxides. With regard to optimum moisture content, it is noticed an increase of it with an increase in aluminum and silica oxides, and decrease with an increase in calcium oxide. Out of these four main oxide compositions, the impact of calcium oxide on both maximum dry density and optimum water content is found predominant.

Keywords: Expansive Soils, Waste Materials, Oxide Composition, Compaction Characteristics.

1 Introduction

Waste generation from different sources became the big issue due to rapid growth of industries all over the world. Among them India also one of it, that rounds to 1.50 lakh MT/day solid waste generation. Out of it only 1,35,000 lakh MT can be collected, which accounts to 90%. In that only, 20% of the waste was utilizing or processing in different aspects and the remaining is dumped into the landfills. The disposal of solid waste is a perennial problem in India, creating huge environmental pollution due to employment of open disposal [1]. Land is a very valuable commodity. Filling it with such waste by-products will obviously lead to loss of the precious commodity. Reuse of solid wastes in various fields, specifically in civil engineering applications, seems to be one of the promising options [2].

Locally available soils, though, are used extensively for geotechnical purposes, they may not always comply with the suitability requirement of the construction activity due to poor bearing capacity and higher compressibility or even sometimes excessive swelling in case of expansive soils [3,4]. As such, if the soil fails to meet the requirement, it will be treated with appropriate additive or stabilizer [5]. Furthermore, improvement of ground at a site also becomes indispensable due to ever rising in the cost of land and huge demand for high-rise buildings. To conserve the natural resources, intense emphasis is made on improving properties of soils using cost-effective practices like use of industrial wastes. Nevertheless, chemical compatibility may become an issue in the selection of a suitable waste material, in a sense that the chemical composition [5], especially oxides content of waste materials can influence the compaction characteristics of soils [6].

Compaction characteristics play a crucial role in all practical scenarios for achieving the desired strength, permeability and compressibility properties. The obvious effect of compaction is the removal of air from void spaces, which in turn increases the strength and stability of a material [7]. Studies appraise that several parameters such as percent fines, specific gravity of soil solids, grain size distribution and shape of grains in the case of granular soils, compaction effort, and chemical composition of soils greatly influence the maximum dry density and optimum water content values[3, 5, 8]. For wastes and by-products, in particular, chemical compositions and their contents dominate the geotechnical behaviour. The major oxides present in soils or wastes are calcium, silica, aluminium and ferric oxides. Large-scale variance of these oxides is inevitably can be expected in waste by-products, especially due to the diversity of the process by which they are generated, though such variability is marginal for natural soils. The increase or decrease in any of the oxides of aforementioned might exhibit direct or indirect impact on geotechnical behaviour [5]. However, a very few studies are available in the literature addressing the impact of oxides composition on geotechnical properties.

Based on the studies reported by research fraternity, it is apparent to expect the chemical compositions effect on compaction characteristics. In this paper, an attempt is made to correlate oxides contents with compaction parameters such as maximum dry density and optimum water content. The study, in its present state, primarily focuses on wastes and by-products due to their ever increasing concern on their disposal in an environmentally safe way. The findings outlined in the present study will immensely be helpful for accurate determination of waste material that can effectively modify the natural soil and further reduction of waste materials.

2 Data Collection

In the present study, compaction parameters include maximum dry density, MDD, and optimum water content, OMC, are considered as the prime parameters to be investigated for the impact of oxides contents. Accordingly, substantial data pertinent to these parameters belonging to many varieties of wastes and by-products were collected. Different types of wastes and by-products against them significant data were reported by research fraternity is listed in Table 1. Typical range of compaction parameters reflecting that of different wastes and by-products is also listed in Table 1.

Using the collected data as input, several correlations were plotted for compaction parameters against oxides compositions, as depicted in Figs. 1 and 2. From the assimilation of data, it is found that four oxides SiO_2, Al_2O_3, CaO and Fe_2O_3 dominantly vary across different wastes and by-products. For the sake of better understanding, individual figures with respect to different oxide contents are plotted.

Table 1. Typical range of compaction parameters of different waste materials assimilated from the literature

S. No.	Material	MDD (kN/m^3)	OMC (%)	References
1	Fly ash	11.4-13.33	19.8-37.3	[8,9]
2	Bottom ash	7.6-15.3	17-45	[9]
3	Pond ash	8.4-13.8	26.5-42.14	[10]
4	Copper Slag	16.9-29.1	6.3-11.96	[11]
5	RHA	7.1-19	17.5-75	[12]
6	Quarry dust	15.8-22.7	7.9-21	[13]
7	Steel furnace slag	15.4-24.5	4-24.6	[14]
8	Red mud	14.41-20.1	18-34.5	[15]
9	Jarosite	11.3-13.5	35-48.3	[16]
10	GGBS	13-17.9	18-26.4	[8]
11	Bagasse ash	11.9-13.29	17.1-48	[17]
12	Ladle furnace slag	14.2-26.4	9.2-30	[18]
13	Mine tailing	16-17.5	14.92-21.54	[19]
14	Ceramic dust	21.4-23.03	16.11-16.5	[20]
15	Cassava peel ash	16.3	27.5	[13]
16	Cement kiln dust	15.2	22.5	[21]
17	Coal Wash	15	10.8	[22]

3 Results and Discussion

Fig. 1 shows the variation of MDD as a function of different oxides content. From the figure, it is clear that MDD decreases with an increase in SiO_2 and Al_2O_3 contents, and increases with an increase in CaO content. Similarly, it can be observed from Fig. 2 that OMC increases with an increase in SiO_2 and Al_2O_3 contents, and decreases with CaO contents. Clearly, from Figs. 1 and 2, reversal effect between MDD and OMC with Fe_2O_3 can be seen. MDD initially increased with an increase in Fe_2O_3 content up to 40%, reached a peak, and thereafter receded with further increase in oxide content. Conversely, OMC decreased initially up to Fe_2O_3 of 40%, reached a minimum, and then raised with the further increase in Fe_2O_3 content. MDD attained a peak and OMC reached a minimum when Fe_2O_3 is in between 40-50%. The trends in Figs. 1 and 2 demonstrably convey that individual oxide contents have the distinctive influence on compaction parameters of waste materials. An appreciable scatter in the results of Figs. 1 and 2 can be observed, which is basically attributed to dissimilarities in the waste materials. In order to depict the variability in trends linear lines were fit as displayed on the graphs.

The decrease in MDD with aluminium and silica oxide may be due to the pozzolanic reaction with the addition of water and also due to their high porosity. Similarly, the decrease in OMC due to calcium oxide can be attributed to the fact that calcium oxide due to its hydration effect (heat generation) causes drying in the mixture to achieve its maximum dry density and thereby, reducing the optimum moisture content. Among the four oxide compositions, it seems the effect of CaO is more prevalent on MDD and OMC, as evidently the slope values are highest displayed on the graphs. As the oxide contents vary with the waste materials, it is little difficult to propose the different optimum oxide composition at which MDD and OMC attained a peak.

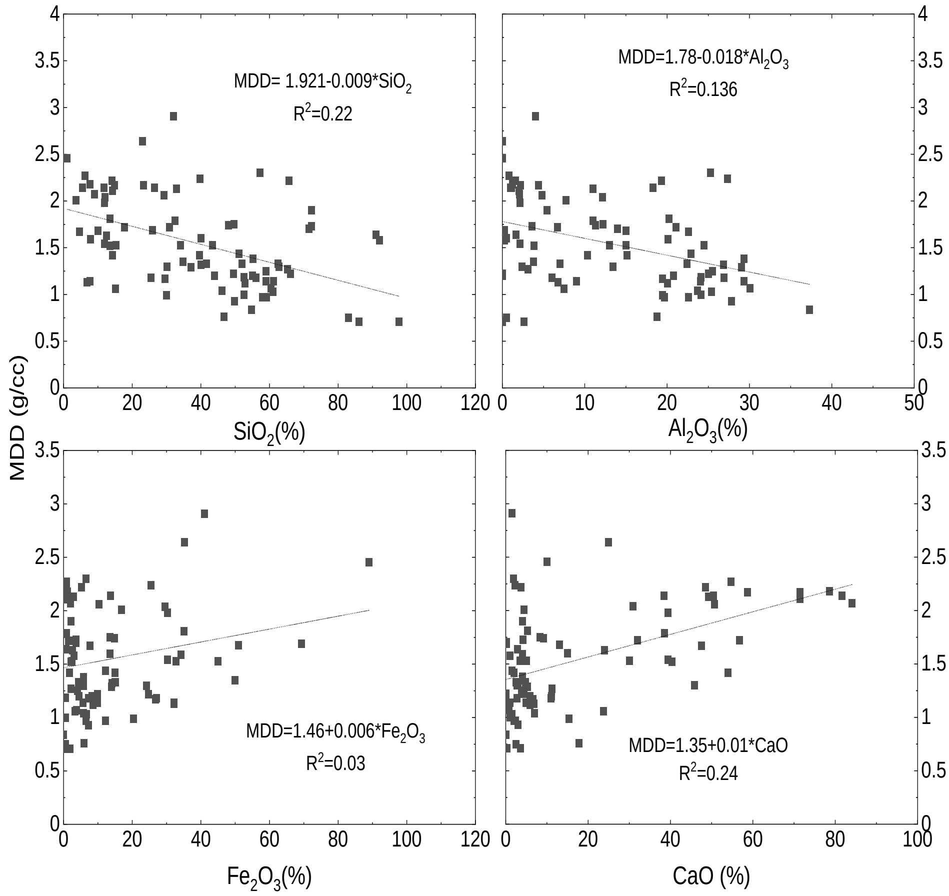

Fig. 1. Variation of MDD with oxides content of different waste materials

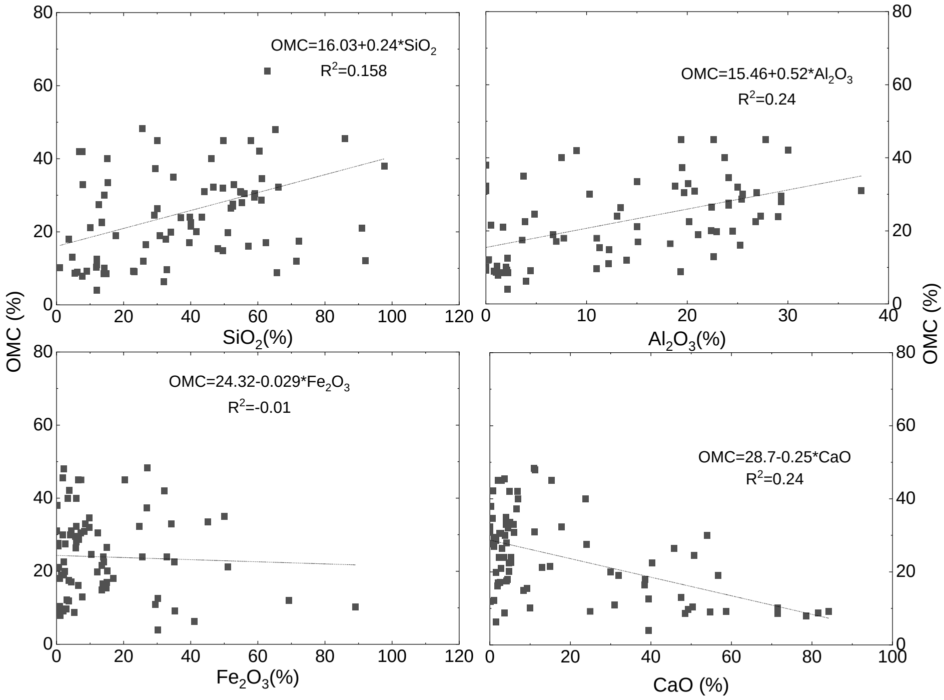

Fig. 2. Variation of OMC with oxides content of different waste materials

In order to conduct such data driven analysis better in the future, such anomaly data point should be removed. Moreover, further works need to be carried out in order to find better correlations by including physical properties of the particle such as coefficient of uniformity, coefficient of curvature, D_{10}, D_{60}, mean particle size and various other parameters.

4 Conclusions

In the current study, oxides contents and compaction characteristics of different wastes and by-products were collected from the literature and correlations were established between them to draw an understanding of the effect of former parameters on latter ones. From the various relationships, the following major salient observations have been made:

1. A significant variability in the oxide compositions among waste materials has been noticed from the study.
2. The correlations revealed that maximum dry density generally tends to increase with an increase in CaO, and decrease with Al_2O_3 and SiO_2 contents.

3. Demonstrably, the impact of calcium and silica oxide on MDD and OMC is found prevalent.
4. With regard to optimum moisture content, it has been noticed that it generally tends to increase with an increase in Al_2O_3 and SiO_2, and decrease with CaO contents.
5. It has been found that the effect of Fe_2O_3 on both MDD and OMC is distinctive.

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