Volume: 10 Issue: VI Month of publication: June 2022

DOI: https://doi.org/10.22214/ijraset.2022.44405

Effect of Tire Buffings Addition on Compaction Properties of Bentonite-Sand, Bentonite-Rock Dust, and Bentonite-Sand-Rock Dust Mixes

Tinku Kalita[1], Nazrul Islam[2], Malaya Chetia[3]
[1, 2 ,3]*Department of Civil Engineering, Assam Engineering College*

Abstract: In landfills, the compacted bentonite-sand (B:S) combination is widely employed as a liner. Since sand is a scarce and expensive material, other waste materials such as rock dust which possess similar properties are used instead of sand, or in other cases, both sand and rock dust are mixed in varying proportions along with bentonite. Urbanization and population explosion have triggered the continuous increase in industrial waste output, particularly waste tires, which posed several challenges to mankind. Incorporating wastes tire as raw resources have been suggested in various industries. Waste tires as stabilizers and investigation of geotechnical properties of the composite can help to minimize pollution while also providing economic and scientific benefits. Past research indicates short fibre has been shown to improve the ductility, toughness, and resistance to tensile cracking of clays. Fibre-shaped tire buffings or tire dust (T) from the retreading process can be used as a fibre reinforcing element in a liner. The objective of this study is to examine the effect of fibre-shaped tire dust (T) addition on the compaction characteristics of bentonite-sand (B:S),bentonite-rock dust (B:R), and bentonite-sand-rock dust(B:S:R) mixes. Locally available sand and rock dust, and commercially available bentonite have been used in this research. The gradation of the (T) used is equivalent to poorly graded sand. Here, all the mixes were prepared with different (T) contents (2 to 16%), and the standard compaction tests were performed. The results reveal that when the tire dust increases, the variation in the optimum moisture content and maximum dry density follow a consistent and predictable pattern. To put it another way, with the increase in the percentage of tire dust in the combination, the optimum moisture content increases while the maximum dry density decreases. Additionally, relationships were offered to predict the maximum dry density and the optimum moisture content with various tire dust content of the composite to be functional in the field.
Keywords: Maximum dry density, Sand, Tire dust, Optimum moisture content, Compaction.

I. INTRODUCTION

With the rise of urbanization and automation around the world, waste disposal has become a major concern for humans. Many waste management facilities have been constructed in response to increased environmental contamination and its disposal. At the municipal solid waste disposal site, sand-bentonite mixtures with a sufficient degree of compaction can be utilized as a liner/barrier material. Soil compaction is an ancient and fundamental procedure that uses mechanical force to increase the density and other properties of the soil. Due to this, the air voids between the particles get reduced and the particles are arranged more compactly during the compaction process. This increases the frictional resistance or intermolecular frictions between them, which increases the shear strength and reduces the compressibility and permeability.

Bentonite-sand composites have been applied as a liner material in an extensive range of engineering applications such as waste containments which include landfills, cores of earth dams, cutoff walls, etc. These compacted bentonite-sand mixes are commonly used because of their fewer susceptibility to frost action and desiccation cracks (Dixon et al. 1985). Bentonite is a type of clay that is largely composed of montmorillonite and has low permeability. In a bentonite-sand mixture due to bentonite’s high swelling capacity, it fills up the pores between the sand particles which results in low permeability and high compaction. However, the sands are scarce due to their wide applications hence, it’s important to opt for an alternative. Rock dust is such an alternative, it is a fine residue generated during the rock crushing process and unlike sand, it is abundant though mostly as a waste. This can be utilized as an alternative to sand to enhance its geotechnical properties (Sridharan et al. 2006). According to Sridharan et al. (1986), 20% bentonite is sufficient to fill the pores created by the sand skeleton. So, different proportions of these mixtures can be experimented with to achieve desired results.

The number of motor vehicles on the road has increased dramatically over the last two decades all over the world. Tire scraps are predicted to be produced at a rate of 0.6 million tonnes per year in India. Around 70% of these wasted tires end up in landfills or are illegally dumped (Pasalkar 2015) leading to waste disposal problems all over the world. Stockpiling scrap tires is forbidden because it pollutes the environment and puts people at risk of fire and illness. As a result, there is a demand for eco-friendly methods of recycling and reusing discarded tires. Scrap tire research has increased in recent years, with applications including soil stabilization in roadwork, ground erosion control, resonance isolation, non structural acoustic containment fills, composite materials for backfilling of retaining walls, slope stabilization, bitumen stabilizer materials, and low-strength but durable concrete. Tires can be used alone or in combination with soil in geotechnical works. Tires, in the form of shreds, fibre, and dust, forms composite with lightweight soil that offers better engineering properties, such as strength that with soil alone. Shredded tires have excellent frictional qualities whether used alone or in combination with soils because they enhance the strength of soil internally, provide stability, and cause minimal differential settlement. It is suggested by (Edil 2004) that the tire chips may be employed in a zone of high contamination levels when they can perform as a sorbent media. Standard or modified Proctor tests is done to determine the OMC at which the densities of soils or dry unit weights are maximum. It was observed from the test experiment that the dry densities of B:S:(T), B:R:(T), B:S:R:(T) mixes decrease as the amount of tire dust increases. Very few works have been done on bentonite sand mixes liner in landfill by addition of rock dust and tire buffing's. This research examines the effect of tire buffing's addition on compaction properties of bentonite-sand, bentonite-rock dust, and bentonite-sand-rock dust mixes, and relationships are developed for determining the MDD and OMC of clay mixtures comprising tire dust that can be employed in engineering activities.

II. MATERIAL AND PROPERTIES

Locally accessible sand (S), rock dust (R), tire dust (T), and bentonite clay (B) of high compressibility were chosen for this research. Sand samples were taken from the Kulsi River, while rock dust samples were taken from the Patharkuchi rock crusher site unit in Kamrup. Various tests were carried out according to the Indian standard (IS) code of recommendations, including the liquid limit, a plastic limit test of bentonite, gradation test of sand, and rock dust. The specific gravity of rock dust, sand, and bentonite was found to be 2.72 2.67, and 2.65 respectively. The particle size distribution curves of rock dust, sand, and tire dust are shown in Fig. 1, which shows that rock dust has a higher percentage of finer particles than sand. Both rock dust and sand are found to be are poorly graded. Tire dust is categorized as tire crumbs/granulated rubber based on its size and range (ASTM D6270). The physical characteristics and classification of rock dust, sand, and bentonite are shown in Table 1.

Table 1: Physical attributes and classification of rock dust, sand, and bentonite

Sl. No.	Property	Rock dust	Sand	Bentonite
1	Effective diameter (D_{10}) (mm)	0.12	0.21	-
2	D_{30} (mm)	0.24	0.37	-
3	D_{60} (mm)	0.8	0.6	-
4	Coefficient of uniformity, C_u	6.66	2.85	-
5	Coefficient of curvature, C_c	0.6	1.08	-
6	Classification as per IS: 1498 - 1970	SP	SP	-
7	Liquid limit (%)	-	-	207
8	Plastic limit (%)	-	-	62.5
9	Plasticity index (%)	-	-	144.5
10	IS classification	-	-	CH
11	Swelling index	-	-	883.3

III. TESTING METHODOLOGY

The experimental investigation was carried out in three phases. From the literature, it is evident that bentonite content of 20% to 40% can effectively fill the pores created by the sand matrix. The B:S mix was defined as B30:S70 in this research, with the bentonite percentage kept at 30% and the sand content kept at 70%. Likewise, in the B30:R70 combination, the bentonite and rock dust concentrations were kept at 30% and 70% respectively.

In the initial phase, compaction tests were conducted on bentonite-sand mixes combinations i.e., B10:S90, B20:S80, B30:S70, B40:S60, and bentonite-rock dust combinations i.e., B10:R90, B20:R80, B30:R70 and B40:R60. In the second phase, bentonite, sand, and rock dust were combined, where the proportion of bentonite is kept constant at 30% whereas sand and rock dust proportions vary. The following are the combinations: B30:S70:R0, B30:S49:R21, B30:S35:R35, B30:S21:R49, and B30:S0:R70. Here the sand proportion is decreased with the increase in rock dust proportion since the sand is scarce and expensive material whereas the rock dust is a waste material thereby decreasing the cost of the combinations. In the third phase, the tire dust was added gradually in an increasing proportion of the overall weight of the mix. Samples were prepared by integrating air-dried bentonite with air-dried rock dust or sand. After adding sand or rock dust to the bentonite, 2 to 16 percent tire dust was added as a fraction of the total weight. Before the test, each sample was thoroughly mixed with water and placed in an airtight polyethylene bag, and maintained in a desiccator for 24 hours to ensure consistent moisture distribution. The mixes were compacted using the standard Proctor test, as per IS: 2720-7 (1974). Three mixed samples were prepared; they are designated as per Table 1.

Table 1: Physical attributes and classification of rock dust, sand, and bentonite

Samples	Proportion	Remarks
B30-S70	30:70	Bentonite, sand mixed in the ratio of 30:70
B30-R70	30:70	Bentonite, rock dust mixed in the ratio of 30:70
B30-S49-R21	30:49:21	Bentonite, sand & rock dust mixed in the ratio of 30:49:21

IV. RESULT AND DISCUSSION

Table 2(a), 2(b), 2(c) show the OMC and MDD values for B30:S70:(T), B30:Q70:(T) and B30:S49:Q21:(T) mixes respectively. The dry density vs. water content curve of B10:S90, B20:S80, B30:S70, B40:S60, and B100:S0 are shown in Figure 1(a). Similarly, the dry density vs. water content curve of B10:R90, B20:R80, B30:R70, B40:R60, B100:R0, and B30:S70:R0, B30:S49:R21, B30:S35:R35, B30:S21:R49, B30:S0:R70 are shown in Figure 1(b) and Figure 1(c) respectively. The compaction curve of B30:S70, B30:S70:T(2%), B30:S70:T(4%), B30:S70:T(6%), B30:S70:T(8%), B30:S70:T(10%), B30:S70:T(12%), B30:S70:T(14%), B30:S70:T(15%) and B30:S70:(T)(16%) are shown in Figure 2(a). Similarly, the compaction curve of B30:R70, B30:R70:T(2%), B30:R70:T(4%), B30:R70:T(6%), B30:R70:T(8%), B30:R70:T(10%), B30:R70:T(12%), B30:R70:T(14%), B30:R70:T(15%), B30:R70:T(16%) and B30:S49:R21, B30:S49:R21:T(2%), B30:S49:R21:T(4%), B30:S49:R21:T(6%), B30:S49:R21:T(8%), B30:S49:R21:T(10%), B30:S49:R21:T(12%), B30:S49:R21:T(14%), B30:S49:R21:T(15%), B30:S49:R21:T(16%) are shown in Figure 2(b) and Figure 2(c) respectively. The variation of OMC and MDD with tire dust content for B30:S70, B30:R70, B30:S49:R21 are shown in Figure 3(a) and Figure 3(b) respectively.

Table 2(a): OMC and MDD values of B:S:(T)

Composites	OMC (%)	MDD (gm/cc)
B30: S70	15.10	1.82
B30: S70:T(2%)	16.20	1.79
B30: S70:T(4%)	17.00	1.75
B30: S70:T(6%)	17.30	1.71
B30: S70:T(8%)	17.50	1.68
B30: S70:T(10%)	17.61	1.67
B30: S70:T(12%)	17.72	1.65
B30: S70:T(14%)	18.01	1.64
B30: S70:T(15%)	18.05	1.63
B30: S70:T(16%)	18.10	1.63

Table 2(b): OMC and MDD values of B:R:(T)

Composites	OMC (%)	MDD (gm/cc)
B30: R70	12.60	2.02
B30: R70:T(2%)	15.80	1.98
B30: R70:T(4%)	16.01	1.87
B30: R70:T(6%)	16.40	1.80
B30: R70 :T(8%)	16.82	1.76
B30:R70 :T(10%)	17.03	1.70
B30:R70 :T(12%)	17.40	1.68
B30:R70 :T(14%)	17.90	1.65
B30:R70 :T(15%)	18.00	1.64
B30:R70 :T(16%)	18.20	1.643

Table 2(c): OMC and MDD values of B:S:R:(T)

Composites	OMC (%)	MDD (gm/cc)
B30: S49: R21	13.00	2.025
B30: S49:R21 :T(2%)	13.35	1.87
B30: S49: R21:T(4%)	16.00	1.73
B30: S49: R21:T(6%)	16.90	1.72
B30: S49: R21:T(8%)	17.00	1.68
B30: S49: R21:T(10%)	17.30	1.65
B30: S49: R21:T(12%)	17.80	1.63
B30: S49: R21:T(14%)	17.91	1.62
B30: S49: R21:T(15%)	18.00	1.612
B30: S49: R21:T(16%)	18.10	1.61

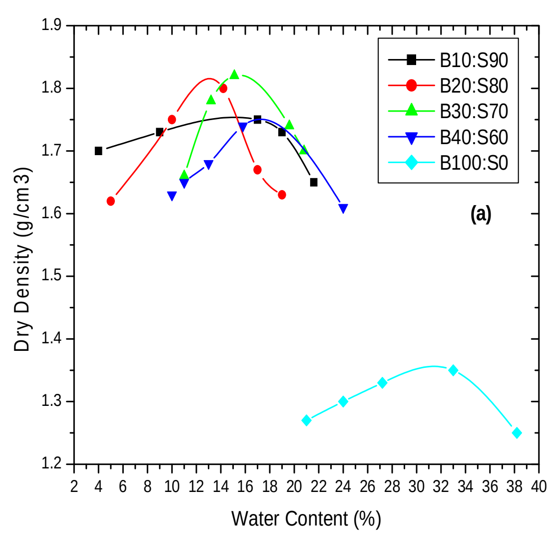


Figure 1(a): Dry density vs. water content curve of B:S mixes

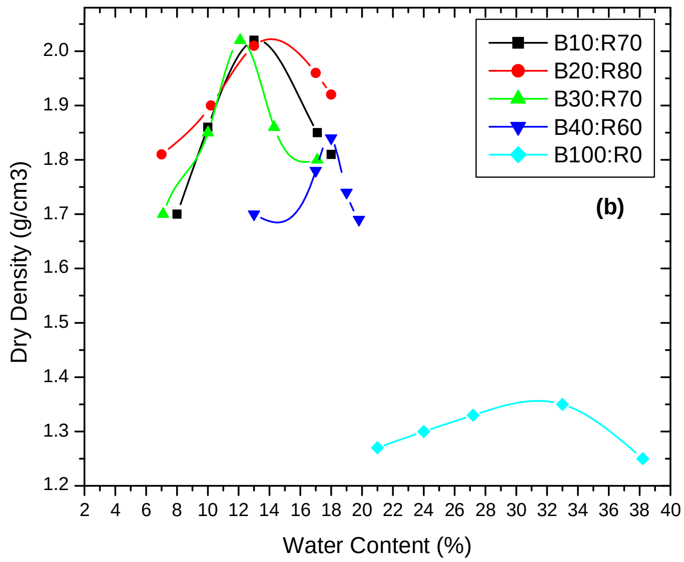


Figure 1(b): Dry density vs. water content curve of B:R mixes

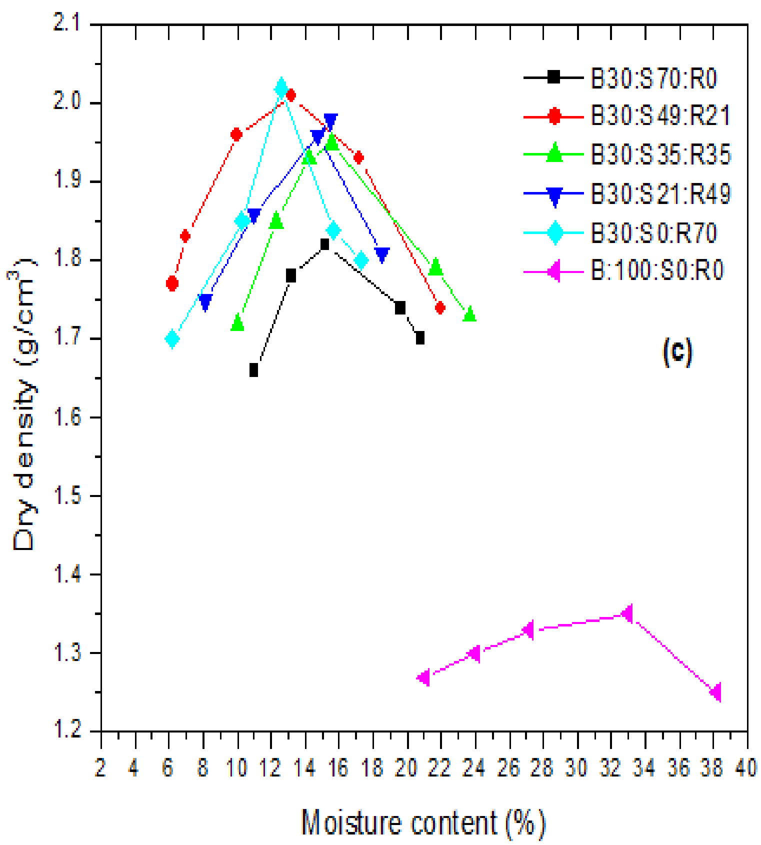


Figure 1(c): Dry density vs. water content curve of B:S:R mixes

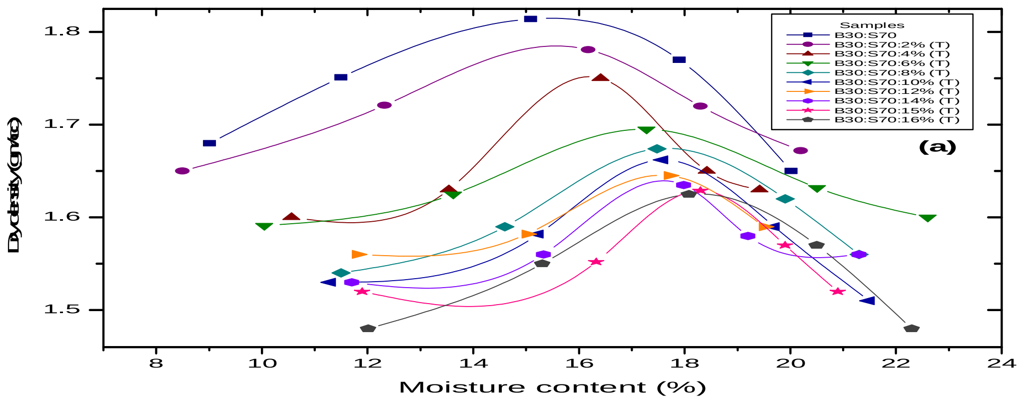


Figure 2(a): Dry density vs. water content curve of B:S:(T) mixes

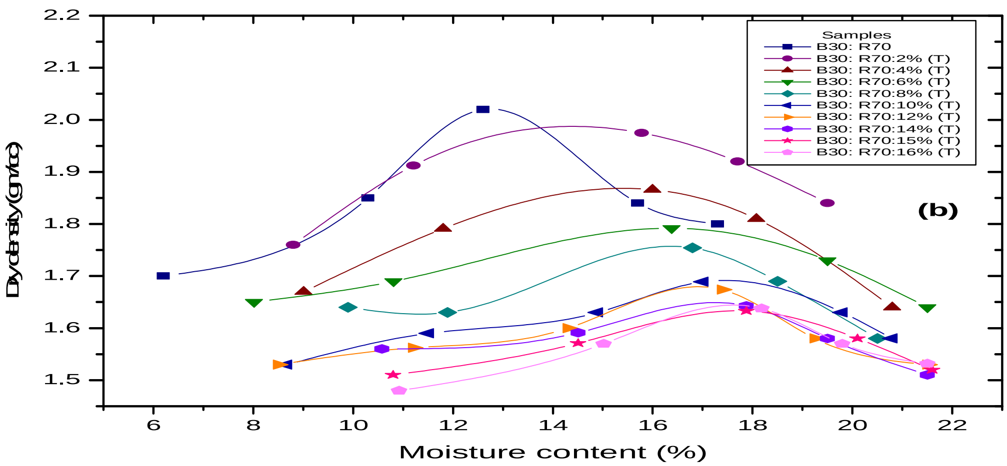


Figure 2(b): Dry density vs. water content curve of B:Q:(T) mixes

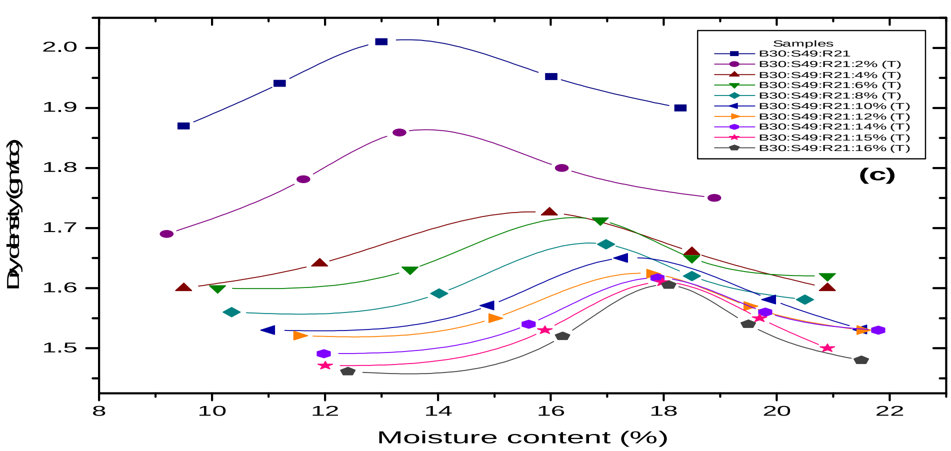


Figure 2(c): Dry density vs. water content curve of B:S:Q:(T) mixes

Figure 3 (a) illustrates the variations of optimum moisture content and tire dust mix. It is noticeable that when the tire dust content rises, the soil's optimum moisture content rises as well. The water content of the soil is equal to the weight of water in the soil to the weight of dry soil. The reason for enhancing the optimum moisture content by increasing tire dust % is that as the amount of tire grows, the proportion of dry soil reduces, resulting in an increase in the optimum moisture content. The observed trend is polynomial in shape. The following relationship is suggested between the OMC and the tire dust so that the OMC can be evaluated at any amount of tire dust content:

y(B30:S70:TD)= $(-0.0139x^2+0.3833x+15.368)$ $R^2 = 0.9584$ (1)
y(B30:Q70:TD)= $(-0.0196x^2+0.5832x+13.581)$ $R^2 = 0.882$ (2)
y(B30:S49:Q21:TD)= $(-0.0276x^2+0.759x+12.803)$ $R^2 = 0.9489$ (3)

Figure 3(b) shows that as the amount of tire dust in the soil increases, the MDD of the soil decreases. The reason for decreasing MDD with rising tire dust content is that the density of tire dust is smaller than the dry density of the bentonite-sand, bentonite-rock dust, and bentonite-sand-rock dust mixes. As a result, enhancing the amount of tire dust in the combination reduces the specific weight of the mixture. The variations are polynomial for B30:R70:T and B30:S49:R21:T mixes and linear for B30:S70:TD mixes. The following relationship is suggested between the MDD and the tire dust content so that the MDD can be evaluated at any amount of tire dust content:

y(B30:S70:TD)= $(-0.0119x+1.8002)$ $R^2 = 0.9465$ (4)
y(B30:Q70:TD)= $(0.0013x^2-0.0458x+2.0368)$ $R^2 = 0.9919$ (5)
y(B30:S49:Q21:TD)= $(0.0023x^2-0.0586x+1.9897)$ $R^2 = 0.9594$ (6)

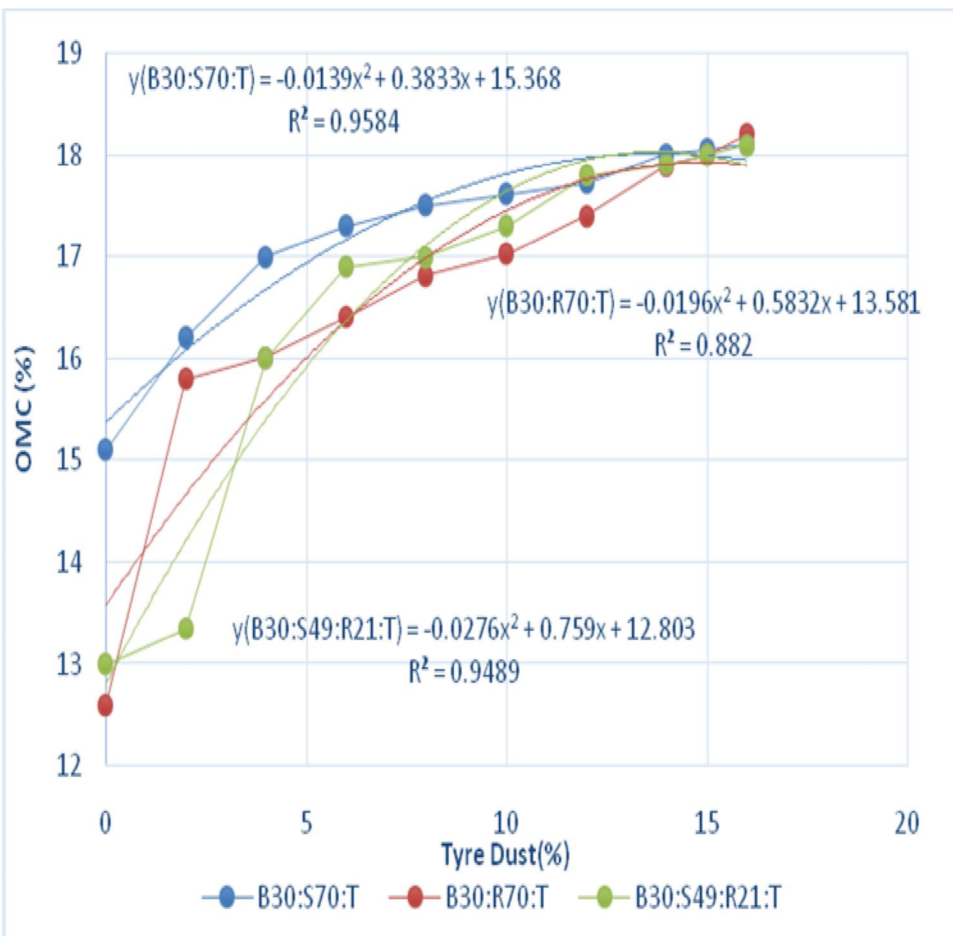


Figure 3(a): Variation of OMC with tire dust content for various mixes.

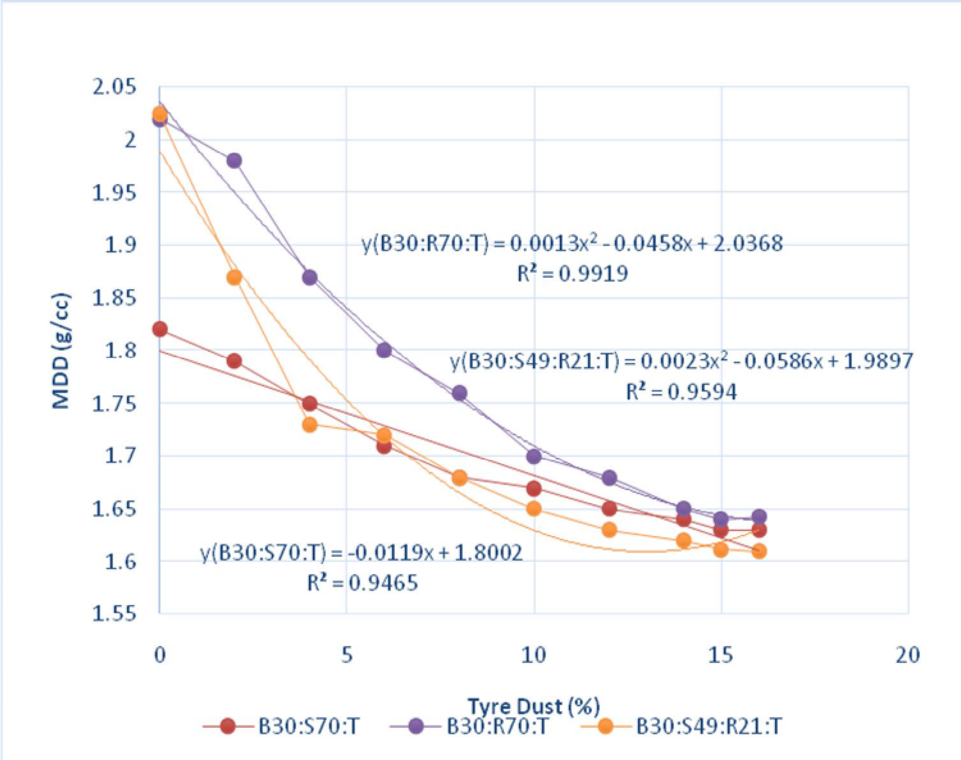


Figure 3(b): Variation of MDD with tire dust content for various mixes.

According to the test results, the MDD of all the mixes reduces as the tire dust content increases; however, the OMC increased as the tire dust proportions increase. As revealed in Table 2(a), (b), (c), before adding tire dust, the MDD of the B30:S70, B30:R70, and B30:S49:R21 mixes was 1.82, 2.02, and 2.025 gm/cc, respectively, which drops to 1.63, 1.643, and 1.61 gm/cc after adding T = 16%. This is due to the average unit weight of the B30:S70, B30:R70, or B30:S49:R21 mix per unit volume being reduced. The OMC of the mixes, on the other hand, increased from 15.10 to 18.10 % for B30:S70 mixes, 12.60 to 18.20 % for B30:Q70 mixes, and 13.00 to 18.10 % for B30:S49:R21 mixes after adding T=16%. This is mostly due to the fiber's increased surface area, which increases the required amount of moisture for the composite materials to become workable under load. However, Kalkan (2013) found, that both MDD and OMC get reduced when tire rubber fibre was added. Tire rubber fibres have a low density and a high specific surface area, resulting in these reductions.

For the same tire dust content, the MDD of the B30:R70:T mixes was found to be higher than the B30:S70:T and B30:S49:R21:T mixes. This could be due to the good interlocking bonding between the angular shape of rock dust particle and round shape particle of bentonite which in turn makes good compaction. The variation of MDD values of B30:S70:T, B30:R70:T, and B30:S49:R21:T mixes is significantly more for less tire buffing content, however, it gets reduced as the tire dust content increases gradually. And become almost comparable at 16% tire dust content. Similarly, the variation of OMC values of B30:S70:T, B30:R70:T, and B30:S49:R21:T mixes is significantly high for less tire dust content, however, this range gets reduced as the tire dust content increases gradually. And the difference becomes negligible at higher tire dust content.

V. CONCLUSIONS

From this research, the following findings can be drawn:

1) The MDD of B30:S70:T, B30:R70:T, B30:S49:R21:T mixes reduces as the tire dust content increases, whereas the OMC increases. When comparing the B30:S49:R21:T mixes with B30:S70:T and B30:R70:T mixes, the reduction in MDD is significantly more pronounced. The rise in OMC is significantly more pronounced in B30:R70:T mixes than in B30:S70:T and B30:S49:R21:T mixes.
2) The MDD is reduced by 10.43% when the B30:S70 mix is replaced with a B30:S70:T(16%) mix. Similarly, the MDD is reduced by 18.66% and 20.49% when the B30:R70 and B30:S49:R21 mix is replaced with B30:R70:T(16%) and B30:S49:R21:T(16%)mix respectively.

3) The OMC is increased by 19.86% when the B30:S70 mix is replaced with a B30:S70:T(16%) mix. Similarly, the OMC is increased by 44.44% and 39.23% when the B30:R70 and B30:S49:R21 mix is replaced with B30:R70:T(16%) and B30:S49:R21:T(16%) mix respectively. This is due to the fibre's increased surface area, which increases the quantity of moisture required to make the composite materials workable under load.
4) The value of MDD for B30:R70:T shows a higher value as compared to B30:S70:T and B30:S49:R21:T at the same tire dust content. This could be due to the good interlocking bonding between the angular shape of rock dust particle and round shape particle of bentonite which in turn makes good compaction.

The shape of tire dust is a crucial component that influences MDD and OMC. Understanding the variation of such factors can help engineers to make more accurate engineering judgments in the field. When it comes to soil improvement, it's always important to employ the optimum amount of additives. The MDD and OMC of B:S, B:R, and B:S:R mixes with various percentages of tire dust concentration were studied in this study. Taking into consideration that using these mixes in practice demands more knowledge and understanding of their geotechnical characteristics, it may be beneficial to combine the result of this research with other test findings in order to determine the optimum mixes that meet the requisite geotechnical standards.

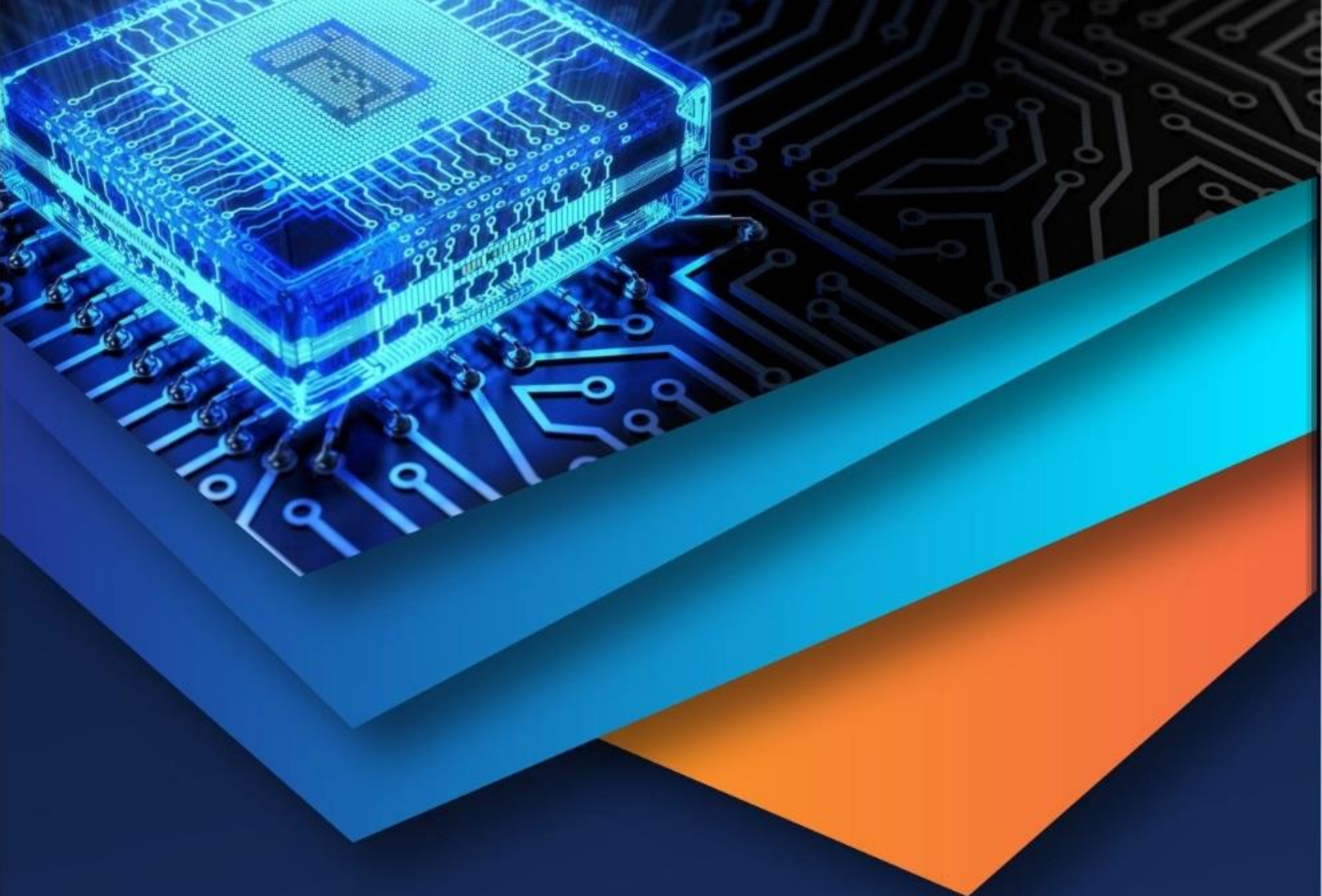
The findings imply that increasing tire dust content enhances OMC and reduces MDD of various mixes. The decreased MDD of the composites does not always indicate lower strength; the cause for the drop in the parameter is lower density of the tire as compared to mixes, and the composite's strength may be examined and analyzed. Furthermore, because tire dust behaves consistently in soil, it's fair to believe that they yield a uniform mixture that can be accurately predicted in practice. In this research work, relationships for determining the MDD and OMC of various composites comprising tire dust that can be employed in engineering activities were also provided.

VI. ACKNOWLEDGMENT

The authors would like to acknowledge the department of civil engineering, Assam Engineering College, Jalukbari, Assam for providing all the necessary lab facilities for carrying out all the experiments.

REFERENCES

[1] ASTM D6270, "Standard practice for use of scrap tires in civil engineering applications", ASTM International, West Conshohocken, United States, 2008
[2] Dixon DA, Gray MN, Thomas AW, "A study of the compaction properties of potential clay-sand buffer mixtures for use in nuclear fuel waste disposal". Engng Geol. 21: pp. 247-255, 1985
[3] Edil TB, "A review of mechanical and chemical properties of shredded tires and soil mixtures", in Geotechnical Special Publication No. 127, Eds A.H. Aydilek and J. Wartman, Recycled Materials in Geotechnics, pp. 1–21, ASCE, Reston, VA, USA, 2004
[4] IS: 1498 (1970) Indian standard classification and identification of soils for general engineering purposes. Bureau of Indian Standards, New Delhi, India
[5] IS: 2720 (Part 3/section 2) (1980) Methods of test for soils: determination of specific gravity, fine, medium and coarse grained soils. Bureau of Indian Standards, New Delhi, India
[6] IS: 2720 (Part 4) (1985) Method for grain size analysis of soil. Bureau of Indian Standards, New Delhi, India
[7] IS: 2720 (Part 5) (1985) Methods of test for soils: determination of liquid and plastic limit. Bureau of Indian Standards, New Delhi, India
[8] IS: 2720 (Part 7) (1980) Determination of water content-dry density relation using light compaction, Indian standard methods of tests for soils. Bureau of Indian Standards, New Delhi
[9] IS 2720 (part 10) (1991) Methods of test for soils: determination of unconfined compressive strength. Bureau of Indian Standards, New Delhi, India
[10] IS: 2720 (Part 40) (1977) Methods of test for soils: determination of free swell index of soils. Bureau of Indian Standards, New Delhi, India
[11] Kalkan E, "Preparation of scrap tire rubber fiber–silica fume mixtures for modification of clayey soils", Applied Clay Science, 80 (2013): pp. 117-125, 2013
[12] Pasalkar A, Bajaj Y, Wagh A, Dalvi J, "Comprehensive literature review on use of waste tyres rubber in flexible road pavement". International Journal of Engineering Research & Technology: pp. 685-689, 2015
[13] Sridharan A, Rao A, Sivapullaiah PV, "Swelling pressure of clays". Geotech Test J., 9(1): pp. 24–33, 1986
[14] Sridharan A, Soosan TG, Jose BT, Abraham BM, "Shear strength studies on soil-quarry dust mixtures". Geotechnical and Geological Engineering, Springer, 24(5): pp. 1163-1179, 2006



10.22214/IJRASET

INDEX COPERNICUS

45.98

IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY