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THE INFLUENCE OF MARBLE DUST ON THE RUTTING AND FATIGUE CHARACTERISTICS OF FLEXIBLE PAVEMENT IN SUBGRADE SOILS

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Abstract— **Binding manufacturing waste for improving the soil is a cost-effective and resourceful solution. It contributes to enhancing soil qualities and eradicating the dumping problem. As a result, understanding the routine level requires knowledge of the qualities of these wastes. In the present study, the soil from Banur, Punjab, was calmed using leftover marble dust. The Indian Standard Classification System was used to classify this soil based on its CL mode. 10%, 15%, 20%, and 25% of the soil's weight was added to marble dust. The plastic limit was established at various fractions of marble dust, as previously mentioned, but the index properties were the same as the liquid limit. In a similar vein, the Proctor test for the improved soil showed that the California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS) remained at the Optimum Moisture Content. According to the testing described above, 20% leftover marble dust was quite effective at solidifying the parent soil. The robust modulus of the subgrade was calculated by Heukelom and Klomp, Thompson and Robnett, Transport and Road Research Laboratory, Erdem Çöleri. Pavement thickness for flexible pavement divide planning in compliance with IRC 37-2012 was computed using IITPAVE based on the grades acquired. The plan was finished with the vertical compressive strain and horizontal tensile strain along the upper subgrade and lowermost bituminous base, which are vulnerable to rutting and pavement fatigue.**

Keywords— **Pavement, Modulus, IITPAVE, CBR, Marble Dust**

I. INTRODUCTION

Globally, the road infrastructure is expanding at a respectable rate. However, there is an urgent need for more practical and economical methods to meet the growing needs of trafficking. The cost of building can be greatly decreased by employing locally accessible resources, such as the creation of granular layers or subbase/embankments. One of the most serious issues facing our companies is the disposal of the garbage they generate. The usage of these wastes in engineering can help to reduce disposal concerns as well as environmental issues. Fine-grained clay expands as it comes into contact with water and contracts when the water concentration decreases. In addition, compared to other soil types, clayey soils with significant moisture content usually have low CBR values. Clay-like soil has a low CBR value, which leads to a thicker pavement and an increased cost of construction because pavement design is based on the soil's CBR value. India's marble reserves are estimated at 1200 million tons. [1] Approximately 70% of marble gets wasted during extraction, polishing, and other processes. Furthermore, marble sludge formed during the cutting process causes disposal issues. As a result, a huge amount of trash produced can be used for a variety of engineering uses, depending on its qualities.

The majority of a pavement section is composed of bituminous layers that are pressed together on an appropriate foundation layer and rest on a base and/or sub-base. The foundation dirt is the most crucial part of a road. The base layer and granular sublayers may develop ruts if the foundation soil is not sufficiently bearing. The bituminous layers of the road section may regularly experience fatigue cracking due to rutting in the lower layers. [2]

A material's elasticity at a certain temperature and stress is estimated or measured by the resilience modulus. Both a

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constant pressure in the cell for detecting an elastic axial stress and a repeated deviation stress were applied to the lab test for calculating the elastic modulus. Due to the complexity and high expense of the testing, numerous correlations have been developed to predict the resilience module. The most often utilized metric for determining the strength modulus (MR) of foundation soil is the California Bearing Ratio CBR. Researchers have developed in recent years various empirical relationships showing that the resiliency module does not depend solely on the value of CBR. These empirical relationships have shown that soil index properties can influence the prediction of the resilience modulus. [3]

II. EXPERIMENTAL STUDY

A. Materials

The experiment's dirt was purchased from Banur, Punjab, India. A 0.075 mm sieve was used to filter 88.3% of the soil, yielding fluid and plasticity limit values of 28.7 and 16.67, respectively. Consequently, the soil was categorized using the Unified Soil Classification System (USC) as CL (inorganic clays with low to medium plasticity). A marble cutting shop provided the leftover marble dust. While 25.75% of the marble dust made it through the 0.075mm sieve, 97.65% of it made it through the 4.75mm filter. [4] The specific gravity of marble dust is 2.62. The particle size distribution curve for marble dust and clay is displayed in Figure 1. [5]

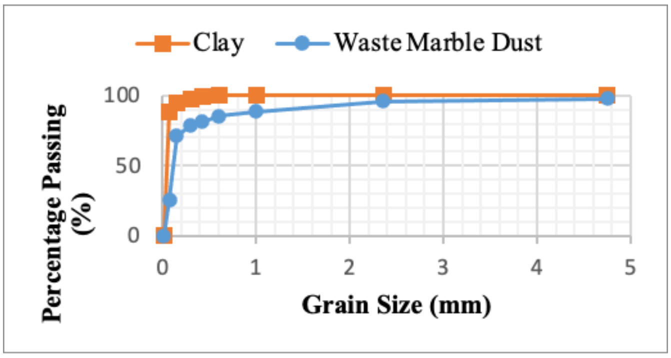

Figure 1: Particle size distribution of clay and marble dust.

B. Tests conducted

The following tests were used to determine the California bearing ratio (CBR), the unconfined soil compressive strength at various marble dust percentages, the Atterberg limit test, the Proctor compaction test, the limit of plasticity and the limit of liquidity, the ideal moisture content, and the maximum dry density. 10%, 15%, 20%, and 25% of the soil's weight was added to marble dust. [11] The plasticity index, which establishes the range of plastic qualities of the soil, is mostly determined by the liquidity and plasticity limits derived from the Atterberg limit test. Following the steps outlined in IS2720 (Part V): 1985, the Casagrande tool was used to determine the value of the liquidity limit for every sample. [6]

Using the method described in IS2720 (Part VII): 1980, each sample was subjected to a light compaction test to determine the ideal maximum moisture content and dry density. Test samples for the California Bearing Ratio (CBR) and Unlimited Compression Resistance (UCS) were prepared using the ideal water content that this process produced. Under impregnation conditions, the CBR tests were conducted for clay dust and marble dust mixtures, and the results were computed in compliance with IS2720 (Part XVI): 1987. [7] At comparable percentages of marble and clay dust, unconfined compression strength values (UCS) were also calculated. IS2720 (Part X): 1991 was followed in the preparation and testing of the samples. [8]

C. Results and Discussions

When marble dust was added, the fluidity limit and plastic limit values increased and decreased, respectively. As a result, the plasticity index value dropped when marble dust was added to the base soil. Table 1 shows the results for various amounts of soil dust and marble combinations. [9]

TABLE 1: INFLUENCE OF MARBLE DUST'S ON ATTERBERG'S LIMITS.

Soil ID	Liquid Limit, %	Plastic Limit, %	Plasticity Index, %
CM0	29.7	15.67	13.03
CM1	25.8	16.64	7.26
CM1.5	23.3	17.34	6.06
CM2	21.8	18.55	4.25
CM2.5	21.1	19.14	3.16

The following percentages of clay contain marble dust by weight: CM0 has no marble dust, CM1 contains 10%, CM1.5 contains 15%, CM2 contains 20%, and CM2.5 contains 25%. The base soil's MDD and OMC increased when up to 20% marble dust was added. The OMC rose by 25% while the MDD decreased in relation to the prior value. The change in MDD and OMC for different mixtures of clay and marble dust is shown in Figure 2. [10]

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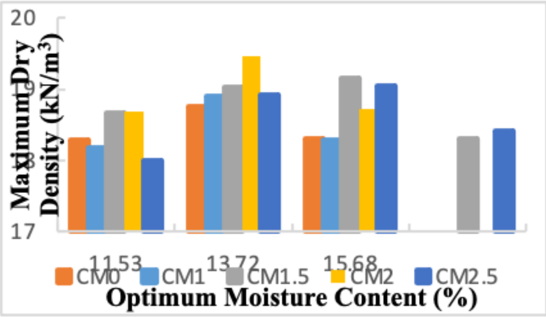

Figure 2: Compaction curves at different clay and marble dust percentages

At 5%, 10%, 15%, and 20% by weight of the soil, marble dust enhanced the unconfined compressive strength (UCS) and California bearing ratio (CBR). When marble dust was added at a rate of 25% by soil weight, CBR and UCS values slightly decreased. Table 2 displays the computed values. [12]

TABLE 2: UNCONFINED COMPRESSIVE STRENGTH VALUES AND THE CALIFORNIA BEARING RATIO WITH VARYING AMOUNTS OF CLAY AND MARBLE DUST

Soil ID	California Bearing Ratio, %	Unconfined Compressive Strength, kPa
CM0	2.96	62.34
CM1	3.89	105.25
CM1.5	4.67	111.34
CM2	6.08	136.75
CM2.5	6.03	131.77

III. DESIGN OF FLEXIBLE PAVEMENT SECTION USING IITPAVE

a. . Considerations in Design

The pavement was designed to handle 50 msa of traffic. For all strata, including the bituminous, granular, and subgrade layers, the Poisson's ratio values were taken to be 0.35. Single-wheel load and tire pressure were measured at 20,000 N and 0.56 MPa. Fatigue and rut values were analyzed using the two-wheeled setup. [13]

b. Determination of the resilience module (MR)

It was expected that the bitumen quality was VG40 and the temperature was 35°C for the bituminous layers, specifically DBM and BC. Accordingly, 3,000 MPa was determined to be the bituminous layers' resilience module value (see Table 7.1, IRC 37: 2012). [14]

The correlations proposed by Heukelom and Klomp (1962), Thompson and Robnett (1979), the Transport and Road Research Laboratory (TRRL), and Erdem Çöleri (2007) were followed in determining the foundation soil's Resilient Modulus. Table 3 displays the Resilient Modulus values determined by applying these empirical equations. [15]

TABLE 3 SUBGRADE RESILIENT MODULUS (MR) VALUES

Soil ID	Resilient Modulus, MPa			
	Heukelom and Klomp	Thompson and Robnett	TRRL	Erdem Çöleri
CM0	29.6	25.06	35.24	65.74
CM1	38.9	38.23	41.98	76.52
CM1.5	46.7	40.099	47.19	78.82
CM2	60.8	47.87	55.87	82.30
CM2.5	60.3	46.36	55.58	73.98

Equation 7.1 of IRC37: 2012 was used to determine the Resilient Modulus values of the granular layers based on the resilient modulus (MR) of the support. [16]

c. The limiting strains' identification

Equation 6.1 of IRC37: 2012 was used to estimate the maximum tensile strain (εt) at the bottom of the bituminous layer. 155.27 $\mu\varepsilon$ was the calculated maximum permitted tensile strain. Equation 6.4 of IRC37: 2012 was used to calculate the allowable vertical distortion in foundation soil, which came out to be 371.7 $\mu\varepsilon$. [17]

d. Determination of actual deformations and pavement thickness

IITPAVE was used to calculate the actual strain values. After the data was entered as directed in the aforementioned sections, the pavement thickness was computed using the aforementioned methods. Table 4 to 7 display the actual strain values computed for different MR values based on Thompson and Robnett (1979), Heukelom and Klomp (1962), Erdem Çöleri (2007), and the Transport and Road Research Laboratory (TRRL). [18]

TABLE 4: ERDEM ÇÖLERI METHOD ACTUAL STRAIN VALUES

Soil ID	Actual Tensile Strain (ε_t), με	Actual Compressive Strain (ε_z), με
CM0	153.4	170.7
CM1	153.2	213.8
CM1.5	152.7	218.8
CM2	152.1	227.2
CM2.5	152.6	200.5

TABLE 4: ACTUAL STRAIN VALUES FOR HEUKELOM AND KLOMP METHOD

Soil ID	Actual Tensile Strain (ε_t), με	Actual Compressive Strain (ε_z), με
CM0	153.9	198.2
CM1	153.7	178.7
CM1.5	153.1	228.3
CM2	152.4	281.6
CM2.5	152.5	294.8

TABLE 5: ACTUAL STRAIN VALUES FOR TRRL METHOD

Soil ID	Actual Tensile Strain (ε_t), με	Actual Compressive Strain (ε_z), με
CM0	153.7	181.3
CM1	153.6	199.1
CM1.5	153.0	226.8
CM2	152.5	263.7
CM2.5	152.8	264.7

TABLE 6: ACTUAL STRAIN VALUES FOR THOMPSON AND ROBNETT METHOD

Soil ID	Actual Tensile Strain (ε_t), με	Actual Compressive Strain (ε_z), με
CM0	153.8	220.8
CM1	153.7	174.0
CM1.5	153.6	186.4
CM2	153.4	232.9
CM2.5	153.5	225.6

Figure 3 shows the crust's overall thickness as determined by all methods, whereas Figure 4 shows the thickness of the granular layers. For the Erdem technique Çöleri, the bituminous layers had a thickness of 160 mm. [19] The bituminous layer's thickness for the Heukelom Klomp technique was 205 mm for the CM0 and 190 mm for the remaining cases. [20-21] Furthermore, the bituminous layer's thickness for the TRRL technique was 190 mm for the other cases and 195 mm for the CM0. For CM0, the bituminous layer thickness using the Thompson and Robnett approach was 215 mm, while for the other cases, it was 190 mm. [22]

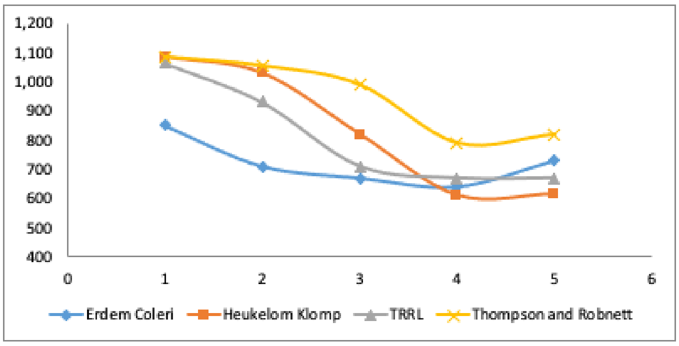

Figure 3: Each clay and marble dust mix's total crust thickness is determined using a variety of techniques.

Using resilient modulus (MR) values determined using the previously mentioned procedures, Figure 4 displays the variation in granular layer thickness achieved for various clay and marble dust combinations. [23]

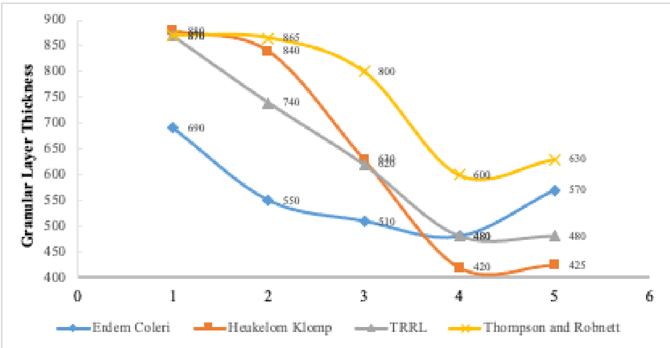

Figure 4: Granular layer thickness is determined for each clay and marble dust mixture using a variety of techniques.

IV. CONCLUSION

The base soil's bearing ability has risen with the addition of marble dust. When marble dust was added, the pavement design also revealed a following drop in pavement thickness. Therefore, utilized marble dust can be mixed with base dirt to make embankments or foundations. Furthermore, even a bituminous layer thickness of 160 mm allowed for reliable pavement design, and the Resilient Modulus (MR), calculated using the formula provided by Erdem Çöleri (2007), produced the highest value out of all the other ways. [24]

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