Streamlining Information Transfer between Construction and Structural Engineering
Edited by Shiau, J., Vimonsatit, V., Yazdani, S., and Singh, A.

ISBN: 978-0-9960437-7-9

DESIGN OF FLEXIBLE PAVEMENT USING MARBLE DUST IN SUBGRADE SOIL

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Harnessing of industrial waste for improvement of soils is economical and efficient. It helps in enhancing the soil properties and overcoming the disposal problem. Therefore, it is essential to understand the properties of these wastes in order to understand their performance level. In this study, waste marble dust was added to stabilize the soil which was collected from Rajpura Punjab. The various index properties liquid limit, plastic limit was studied by adding Marble dust 10%,15%,20% and 25% by weight of soil. Similarly, California Bearing Ratio (CBR), Unconfined Compressive Strength (UCS) was calculated at maximum dry density obtained from compaction test. It was observed that based on tests that 20% of waste marble dust was optimum for strengthening of the parent soil. Resilient Modulus was calculated afterwards for the subgrade using models specified by Heukelom and Klomp, Thompson and Robnett, Transport and Road Research Laboratory, Erdem Coleri. Based on the results obtained, pavement thickness was determined for designing flexible pavement section as per IRC 37-2012 using IITPAVE. Design was done considering the horizontal tensile strain and vertical compressive strain at the bottom of bituminous base and at top of subgrade, responsible for fatigue and rutting of pavements.

Keywords: CBR, UCS, Resilient modulus, IITPAVE, Crust thickness.

1. INTRODUCTION

Road network is expanding at a reasonable rate worldwide. Construction cost can be substantially decreased by using locally available materials which comprise of construction of granular layers or subgrade/embankment of pavement. Utilization of waste products which are generated by industries is a major issue. Application of these waste materials for engineering purposes can cut down the disposal problems and environmental issues caused by their disposal. Clay is a fine-grained soil with high moisture content generally shows low CBR values as compared to another type of soils. This low CBR value of clayey soil results into high pavement thickness and subsequently into higher construction cost. Marble reserves in India are estimated to be approximately 1200 million tons (Indian Bureau of Mines 2016). Around 70% of marble is wasted in the process of mining, polishing etc. Also, marble slurry generated after cutting gives rise to disposal problems. Therefore, this large amount of waste generated can be used for various engineering purposes, depending upon its properties.

A pavement section mainly consists of bituminous layers resting over the base and/or sub-base which are together compacted over subgrade. There can be rutting in the granular base and subbase layers if the soil subgrade does not have appropriate strength. This rutting in the bottom layers can cause fatigue cracking in the bituminous layers of the pavement section.

Resilient Modulus is the estimation or measurement of the elasticity of the material at a particular stress and temperature. Dione *et al.* (2014) concluded that California Bearing Ratio (CBR) is the most widely used parameter for determining resilient modulus (M_R) of subgrade soil. Over the past few years, various empirical relations have been developed by researchers showing that resilient modulus is not solely dependent on the CBR value. These empirical relations showed that index properties of soil can be used for the prediction of resilient modulus.

2. EXPERIMENTAL PROGRAMME

2.1 Materials

Soil used for the experimental study was obtained from Shmabu Kalan, Punjab (India). Waste marble dust was procured from local a marble cutting store. The various engineering properties of clay (IS: 2720-Part IV:1985) and waste marble dust are shown in Table 1 and 2 respectively.

Table 1. Geotechnical properties of the collected soil sample.

S.No.	Properties	Values
1	Particle Size < 75 µ, %	88.3
2	Liquid Limit (w_L), %	28.7
3	Plastic Limit (w_P), %	16.67
4	Plasticity Index (I_p), %	12.03
5	Flow Index (I_f)	23.7
6	Toughness Index (I_T)	0.507
7	Optimum Moisture Content, %	15.29
8	Maximum Dry Density ($\Upsilon_{d\ max}$), kN/m^3	18.76
9	Unconfined Compressive Strength, kPa	62.34
10	California Bearing Ratio (CBR), %	2.96
11	Soil Classification	CL

Table 2. Physical properties of waste marble dust.

S.No.	Properties	Value
1	Particle Size < 75 µ, %	25.75
2	Specific Gravity	2.62
3	Colour	Grey

2.2 Laboratory Investigation

Marble dust was added at 0%, 10%, 15%, 20% and 25% by weight of soil and are designated as CM0, CM10, CM15, CM20, CM25. Liquid limit and plastic limit values calculated from Atterberg's test are important in determining the plasticity index which determines the range at which soil exhibits plastic properties. The value of liquid limit for each sample was calculated using Casagrande tool as per procedure specified in IS:2720 (Part V):1985.

Light compaction test was performed for each of the samples for determining optimum moisture content and maximum dry density, as per procedure specified in IS:2720 (Part VII):1980. The optimum water content obtained was used to prepare samples of California Bearing Ratio (CBR) test and Unconfined Compressive Strength (UCS) test. The CBR tests for clay and marble dust mixtures were conducted in soaked conditions and the values were determined in accordance with IS:2720 (Part XVI):1987and UCS values were determined for all mixes as per IS:2720 (Part X):1991.

3 RESULTS AND DISCUSSION

There was a decrease in the liquid limit and increase in the plastic limit values upon addition of marble dust. Consequently, the value of the plasticity index also decreased upon addition of marble dust to the parent soil. Values obtained at various percentages of soil and marble dust mixtures are shown in Figure 1.

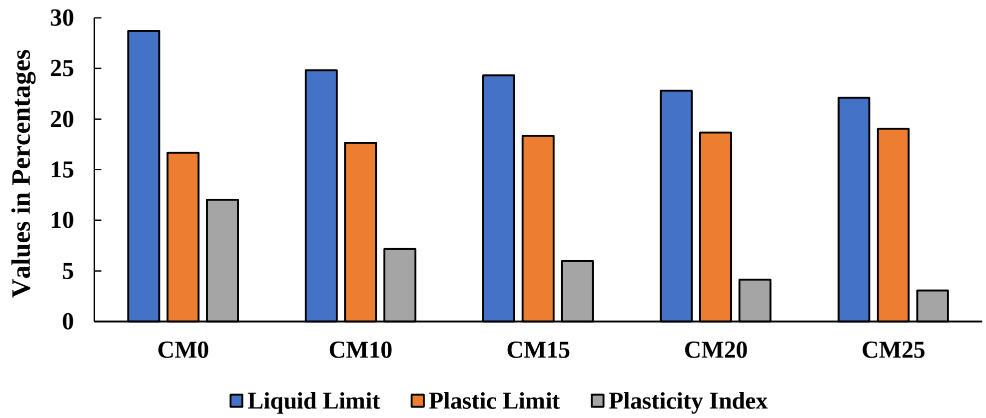

Figure 1. Variation of liquid limit, plastic limit, plasticity index with the addition of marble dust.

Optimum moisture content (OMC) values decreased and maximum dry density (MDD) values increased, up to 20% addition of marble dust in the parent soil. At 25%, the value of OMC increases and MDD decreases. The variation of optimum moisture content (OMC) and maximum dry density (MDD) for different mixes are shown in Table 3.

Table 3. Effect of marble dust on compaction characteristics.

Soil ID	Optimum Moisture Content, %	Maximum Dry Density, kN/m^3
CM0	15.29	18.76
CM10	13.72	18.9
CM15	13.48	19.16
CM20	13.1	19.46
CM25	13.98	19.05

California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS) values were determined at OMC (from Table 3) at various mixes. Both CBR and UCS values increase up to marble dust content of 20% and then a slight reduction in the value when marble dust was present 25% as shown in Table 4.

Table 4. Effect of Marble dust on CBR and UCS values.

Soil ID	California Bearing Ratio (CBR), %	Unconfined Compressive Strength (UCS), kPa
CM0	2.96	62.34
CM10	3.89	105.25
CM15	4.67	111.34
CM20	6.08	136.75
CM25	6.03	131.77

4 DESIGN OF FLEXIBLE PAVEMENT

4.1 Design Considerations

Pavement design was done for a traffic of 50 msa. The values of Poisson's ratio were considered as 0.35 for all of the layers i.e. bituminous layers, granular layers and subgrade. Tyre pressure and single wheel load were taken as 0.56 MPa and 20,000 N respectively. Dual wheel configuration was used for analysis of fatigue and rutting values.

4.2 Determination of Resilient Modulus (M_R)

For bituminous layers, i.e. DBM and BC, the temperature was assumed to be 35ºC and grade of bitumen was taken as VG40. Based on this, resilient modulus value for bituminous layers was taken as 3000 MPa (from Table 7.1, IRC 37:2012). Determination of resilient modulus for subgrade was done as per correlations suggested by Heukelom and Klomp (1962), Thompson and Robnett (1979), Transport and Road Research Laboratory (TRRL), Coleri (2007). Resilient modulus values calculated using these empirical equations are mentioned in Table 5.

Table 5. Subgrade resilient modulus (M_R) values.

Soil ID	Resilient Modulus, MPa			
	Heukelom and Klomp	Thompson and Robnett	TRRL	Erdem Coleri
CM0	29.6	25.06	35.24	65.74
CM10	38.9	38.23	41.98	76.52
CM15	46.7	40.099	47.19	78.82
CM20	60.8	47.87	55.87	82.30
CM25	60.3	46.36	55.58	73.98

Depending on the resilient modulus (M_R) of subgrade, the resilient modulus values of granular layers were computed as per the equation 7.1 of IRC37:2012.

4.3 Determination of Limiting Strains

The value of maximum tensile strain at the bottom of the bituminous layer (ε_t) was computed using equation 6.1 of IRC37:2012. The calculated value of the maximum permissible tensile strain was 155.27 $\mu\varepsilon$. Also, the value of permissible vertical strain in the subgrade was determined using equation 6.4 of IRC37:2012 and the value came out to be 371.7 $\mu\varepsilon$.

4.4 Determination of Actual Strains and Pavement Thickness

Actual strain values were calculated using IITPAVE. Data was inputted as specified in the above sections and pavement thickness was determined using the methods mentioned above. The values of actual strain calculated for various M_R values determined using Coleri (2007), Heukelom and Klomp (1962), Transport and Road Research Laboratory (TRRL), Thompson and Robnett (1979) are tabulated from Table 6 where (εt), $\mu\varepsilon$ is horizontal tensile strain and (εz), $\mu\varepsilon$ is vertical compressive strain.

Total crust thickness calculated using all of the methods is shown in Figure 2 and granular layer thickness is shown in Figure 3. The thickness of bituminous layers was 160 mm for Coleri Method. For Heukelom Klomp method, the bituminous layer thickness was 205 mm for CM0 and 190mm for rest of the cases. Also, for TRRL method, the bituminous layer thickness was

195 mm for CM0 and 190mm for rest of the cases. Thompson and Robnett method had bituminous layer thickness as 215mm for CM0 and 190mm for the remaining cases.

Table 6. Actual strain values by various models.

Soil ID	Erdem Coleri Model		Heukelom and Klomp Model		TRRL Model		Thompson and Robnett Model	
	(ε_t), με	(ε_z), με	(ε_t), με	(ε_t), με	(ε_t), με	(ε_z), με	(ε_t), με	(ε_z), με
CM0	153.4	170.7	153.9	153.7	181.3	198.2	153.8	220.8
CM10	153.2	213.8	153.7	153.6	199.1	178.7	153.7	174.0
CM15	152.7	218.8	153.1	153.0	226.8	228.3	153.6	186.4
CM20	152.1	227.2	152.4	152.5	263.7	281.6	153.4	232.9
CM25	152.6	200.5	152.5	152.8	264.7	294.8	153.5	225.6

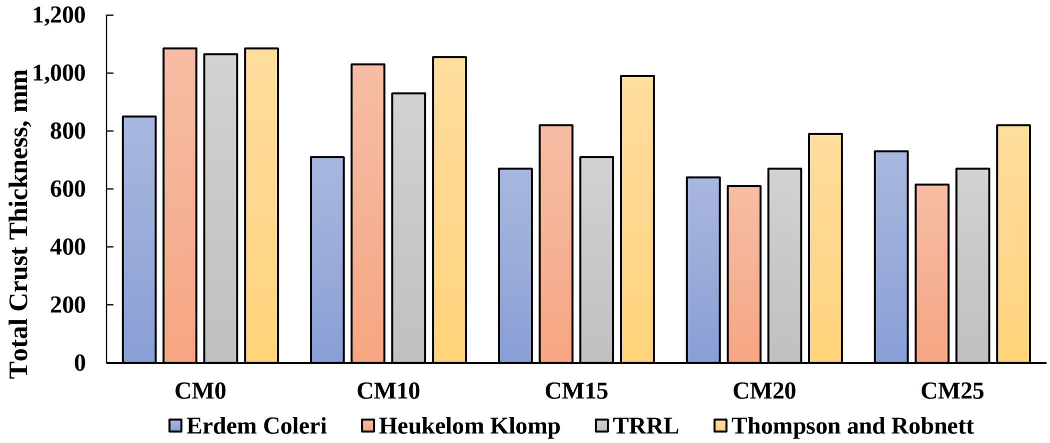

Figure 2. Total crust thickness calculated for clay and marble dust mix calculated using various models.

Figure 3 shows variation of granular layer thickness obtained for different clay and marble dust mixtures using resilient modulus (M_R) values calculated by methods specified above.

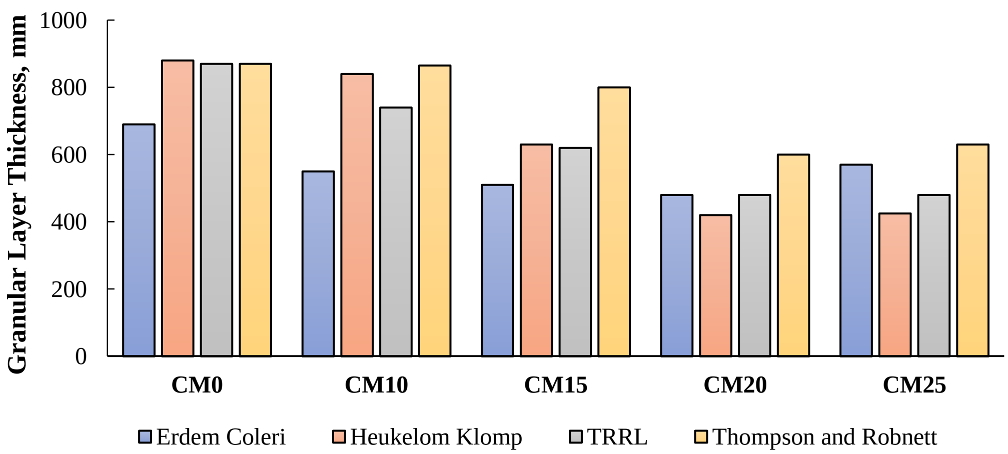

Figure 3. The thickness of granular layers calculated for clay and marble dust mix using various models.

5 CONCLUSION

Addition of 20% waste marble dust showed a maximum increase in CBR and unconfined compressive strength of stabilized soil. Pavement designs also showed 50% decrease in the pavement thickness on the addition of marble dust. So, waste marble dust can be used effectively along with parent soil for subgrade or embankment construction. Also, among various methods, the resilient modulus (M_R) calculated using Coleri (2007) Model yielded the highest value.

References

Coleri, E., *Relation Between Resilient Modulus and Soil Index Properties of Unbound Materials* (master's thesis), CiteSeerX. (10.1.1.632.9765), 2007.

Dione, A., Fall, M., Berthaud, Y., Benboudjama, F., and Michou, A., Implementation of Resilient Modulus–CBR Relationship in Mechanistic Pavement Design, *Sciences Appliquées et de l'Ingénieur*, 1(2), 65-71, 2014.

Heukelom, W., and Klomp, A. J. G., *Dynamic Testing as a Means of Controlling Pavement During and After Construction*, Proceedings of the 1st International Conference on the Structural Design of Asphalt Pavement, University of Michigan: Ann Arbor, Mich, 1962.

Indian Bureau of Mines, Indian Minerals Yearbook (Part- III: Mineral Reviews), 54^{th} Edition, *Marble*. Retrieved from www.ibm.gov.in, on November 2016.

IS: 2720 (Part IV)-1985, *Method of Test of Soils: Grain Size Analysis*, New Delhi, India: Bureau of Indian Standards, 1985.

IS: 2720 (Part V)-1985, *Method of Test of Soils: Determination of Liquid Limit and Plastic Limit*, New Delhi, India: BIS, 1985.

IS: 2720 (Part VII)-1980, *Method of Test of Soils: Determination of Water Content-Dry Density Relation Using Light Compaction*, New Delhi, India: BIS, 1980.

IS: 2720 (Part XVI)-1987, *Method of Test of Soils: Laboratory Determination of CBR*, New Delhi, India: BIS, 1987.

IS: 2720 (Part X)-1991, *Method of Test of Soils: Determination of Unconfined Compressive Strength*, New Delhi, India: BIS, 1991.

IRC: 37-2012, *Guidelines for the Design of Flexible Pavements*, New Delhi, India: Indian Road Congress, 2012.

Thompson, M.R. and Robnett, Q.L., Resilient Properties of Subgrade Soils, *Journal of Transportation Engineering*, 105(1), 71-89, 1979.