International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.10 No.7, pp 428-439, 2017

Stabilization of Weak Subgrade using Pumice Stone, a Waste Material

Palanikumar M

Department of Civil Engineering, PSG College of Technology, Coimbatore, India

Abstract : A pavement designed for a particular set of conditions and resting on a weak subgrade is very thick and hence is expensive. The cost of such a pavement could be reduced by strengthening the subgrade by a suitable stabilization process. In the present work, the suitability of waste pumice stone as a mechanical stabilizer in pavements has been studied. Pumice stone, a by-product of steel and garment industries, is a locally available, porous, light and non-plastic material. This has been mixed with the weak soil in different proportions and CBR tests have been performed on them. The experimental results show that there is a considerable increase in the CBR value of the stabilized subgrade leading to the reduction of overall cost of pavements. Use of pumice stone not only reduces the overall cost of the pavements but also solves the disposal problem faced by industries producing pumice stone as a by-product.
Key words : pavement, subgrade, stabilization, waste pumice stone, CBR.

Introduction

One of the problems faced by civil engineers all over the world is designing infrastructures on weak soils. Design of flexible pavement on a weak subgrade poses a great challenge as it requires a thicker and hence expensive pavement. When the weak subgrade is stabilized mechanically, the strength increases, the required thickness of the pavement decreases. But, if the mechanical stabilizer is costly, the reduction in cost due to the reduced thickness of the pavement may be offset by the increase in the cost of the stabilizer itself. This, in turn, may result in increase in overall cost of the pavement. If the selected mechanical stabilizer is a waste material obtained as a by-product from an industry, it serves the twin purposes of reducing the overall cost of the pavement and solving the disposal problem of the waste material. Moreover, if these waste materials are used for making internal roads for the industries from where they are collected, the transport cost is also nullified.

In the present work, two weak subgrades are considered namely Clay with Medium Compressibility and Clayey Sand. The samples of these soils are collected from Coimbatore, Tamil Nadu, India. Classification tests and CBR tests conducted on these soils confirm their weakness. The waste material considered is pumice stone (Fig. 1) which is obtained as a by-product from a garment industry, Tirupur, Coimbatore, India. It is porous, light in weight and non-plastic and is composed of alumina and silica. Its silica content brings abrasive properties to the aggregates and the alumina content brings durability to fire and heat.

Fig.1 Photographs of pumice stone used in the present work

Many research works carried out in the recent years on the use of pumice stone indicate an increase in strength and Resilient modulus and an improvement over plasticity characteristics of subgrade. [1, 2, 3]

The objective of the present study is to determine the physical properties and soaked CBR of the selected virgin soils as well as soils stabilized by pumice stone in different proportions, designing flexible pavement for a particular set of conditions for each case and carrying out cost analysis.

Experimental Results And Discussion

Classification tests on the virgin soils

The results of classification tests performed on the selected virgin soils and the classification as per Indian Standards [4] are given in Table 1.

Table 1 Results of classification tests on the virgin soils

Test results	**Clay with Medium compressibility**	**Clayey Sand**
Colour	Brown	Red
Fraction finer than 75 microns	69%	36%
Fraction finer than 4.75 mm	99%	100%
Liquid limit	36%	23%
Plastic limit	18%	13%
IS Classification	CI	SC

Light compaction test on virgin soils

Light compaction test [5] is conducted in each of the soil samples to obtain the Optimum Moisture Content (OMC) and the Maximum Dry Density (MDD). The results of the tests are presented in Fig. 2 and Fig. 3 respectively.

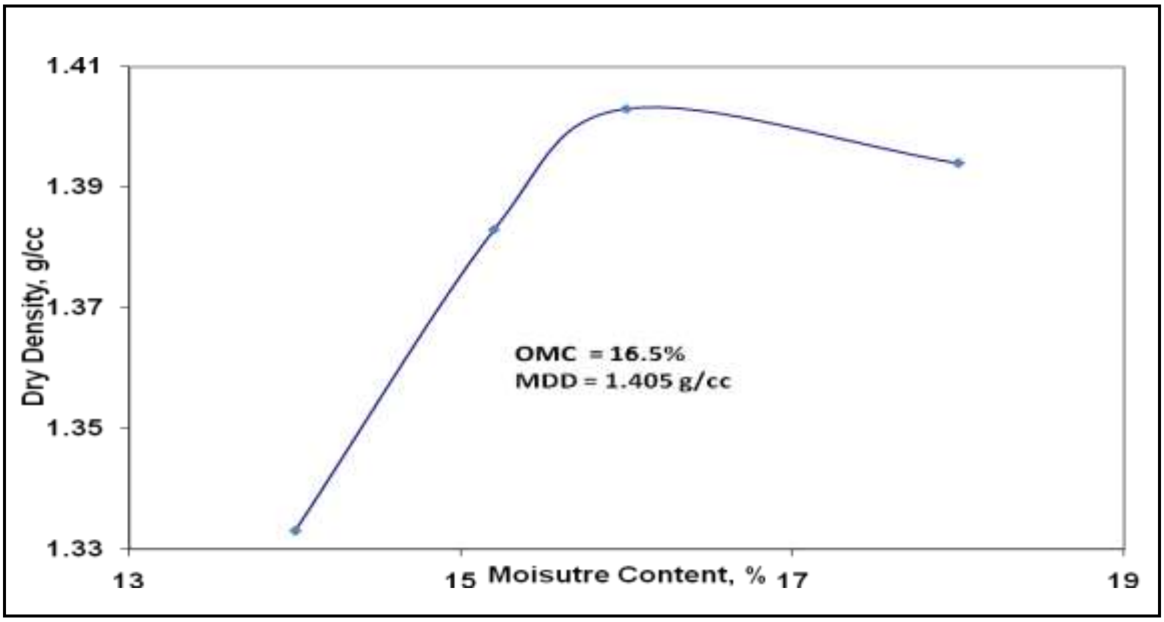

Fig. 2 Results of light compaction test on Clay with Medium Compressibility

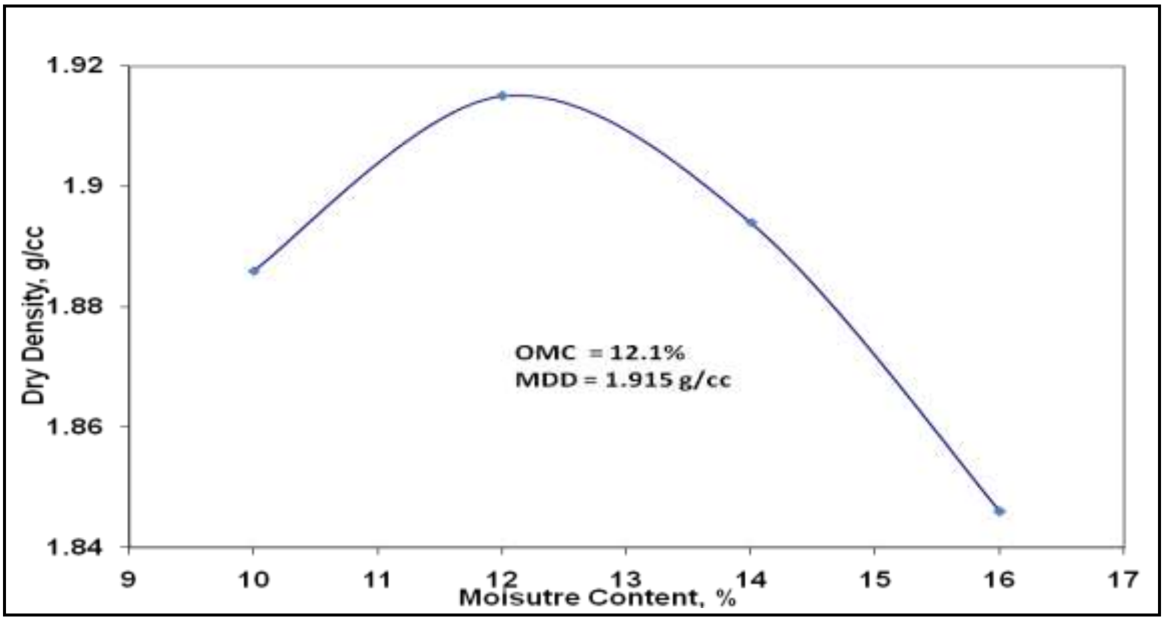

Fig. 3 Results of light compaction test on Clayey Sand

Soaked CBR tests on the virgin soils

Soaked CBR test [6] is conducted in each of the soil samples to obtain the design CBR values. The results of the tests are presented in Fig. 4 and Fig. 5 respectively.

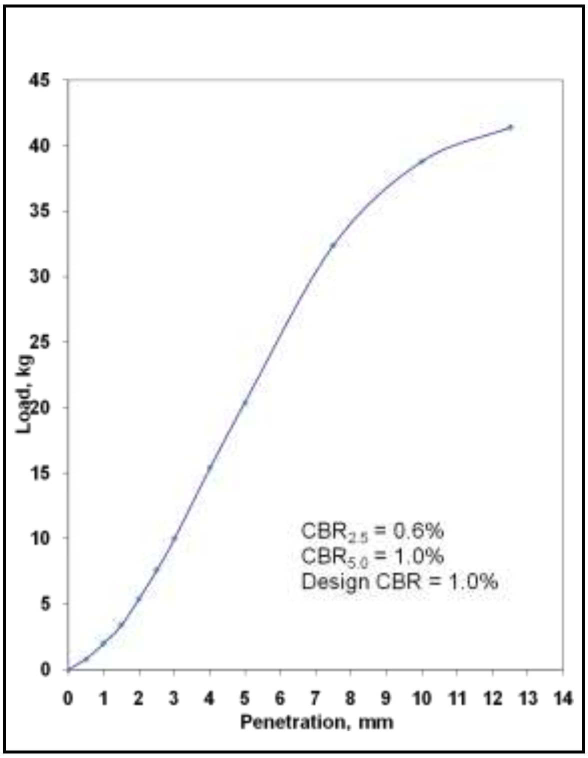

Fig. 4 Results of soaked CBR test on Clay with Medium Compressibility

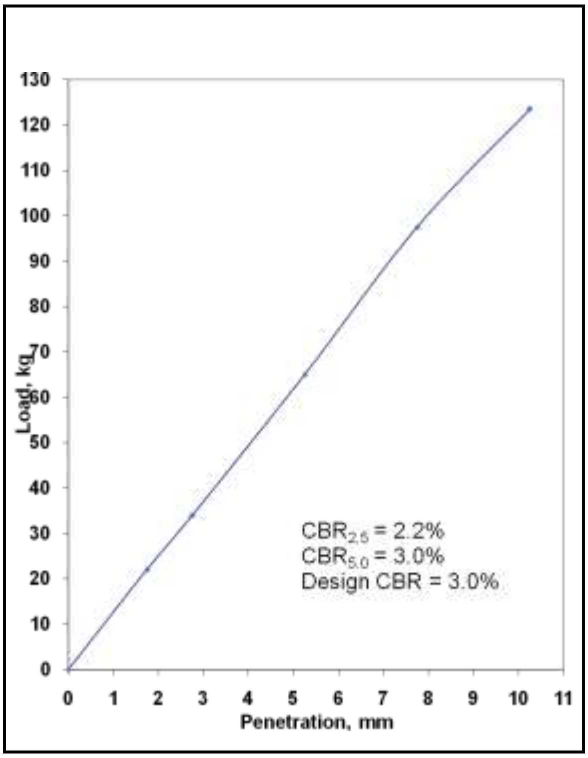

Fig. 5 Results of soaked CBR test on Clayey Sand

Stabilization of Clay with pumice stone

The pumice stone is mixed with clayey soil in various proportions i.e., 10:90, 30:70 and 50:50 (Pumice stone: clay in mass), light compaction test is conducted in each of the mixes to obtain OMC and soaked CBR test on the sample compacted in the respective OMC is carried out. The results are shown in Fig. 6 to Fig. 8 respectively. The OMC is indicated in the corresponding graph in each case.

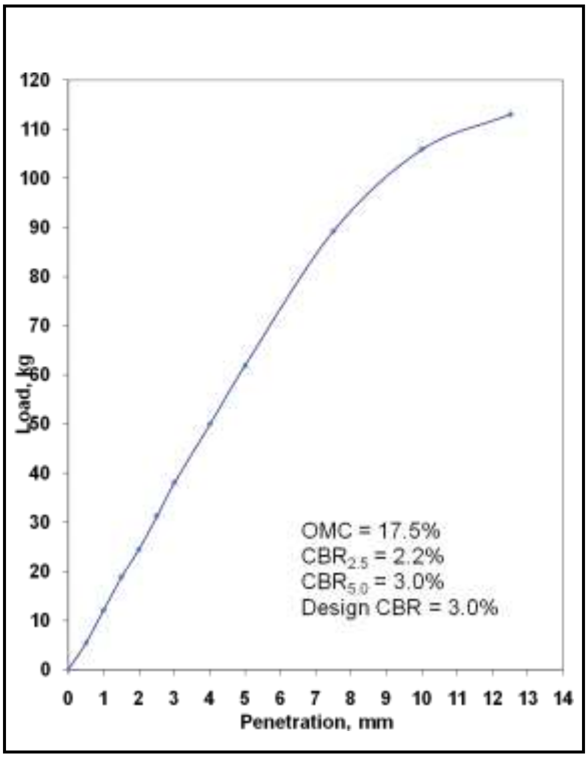

Fig. 6 Results of soaked CBR test on pumice stone – clay mix (10:90)

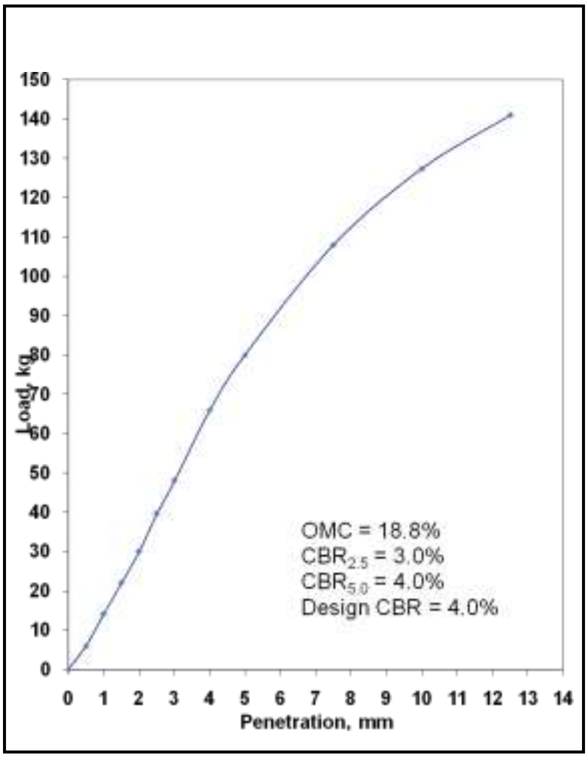

Fig. 7 Results of soaked CBR test on pumice stone – clay mix (30:70)

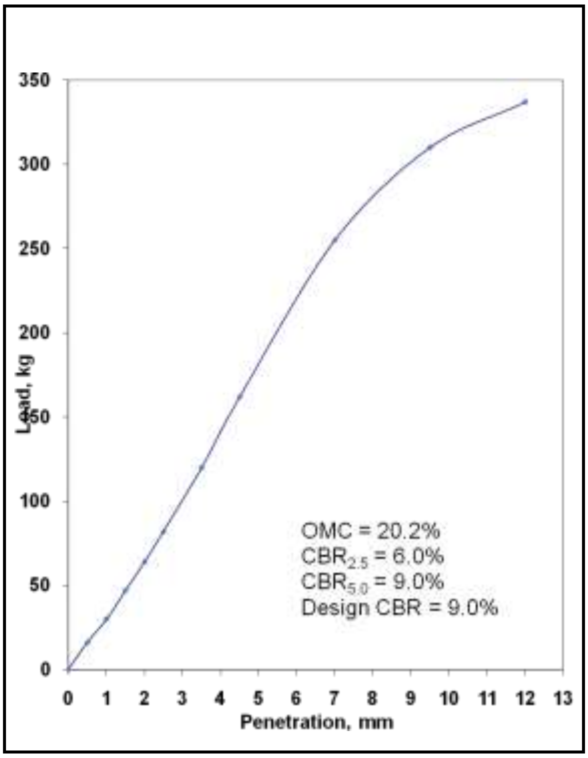

Fig. 8 Results of soaked CBR test on pumice stone – clay mix (50:50)

Stabilization of Clayey Sand with pumice stone

The pumice stone is mixed with clayey sand in various proportions i.e., 10:90, 20:80 and 30:70 (Pumice stone: clay in mass), light compaction test is conducted in each of the mixes to obtain OMC and soaked CBR test on the sample compacted in the respective OMC is carried out. The results are shown in Fig. 9 to Fig. 11 respectively. The OMC is indicated in the corresponding graph in each case.

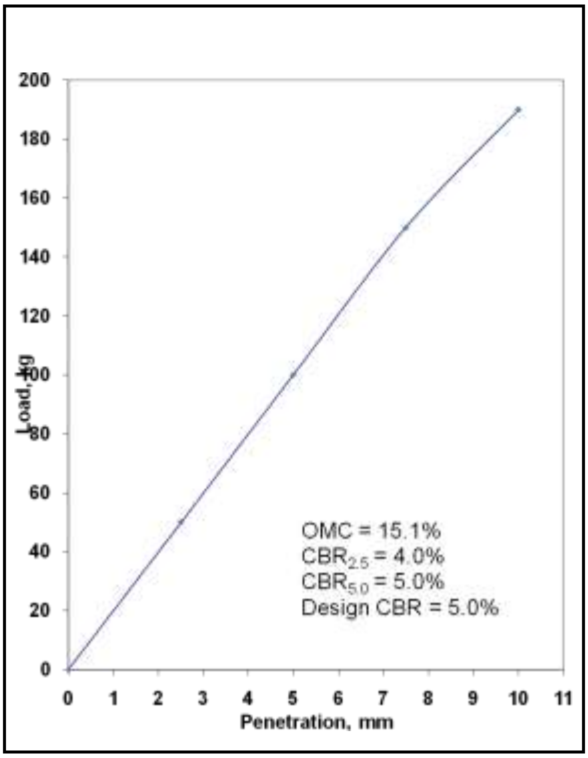

Fig. 9 Results of soaked CBR test on pumice stone – clayey sand mix (10:90)

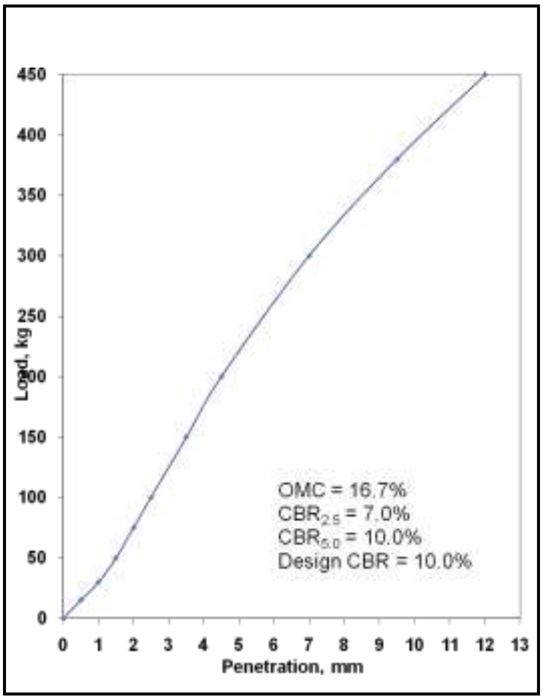

Fig. 10 Results of soaked CBR test on pumice stone – clayey sand mix (20:80)

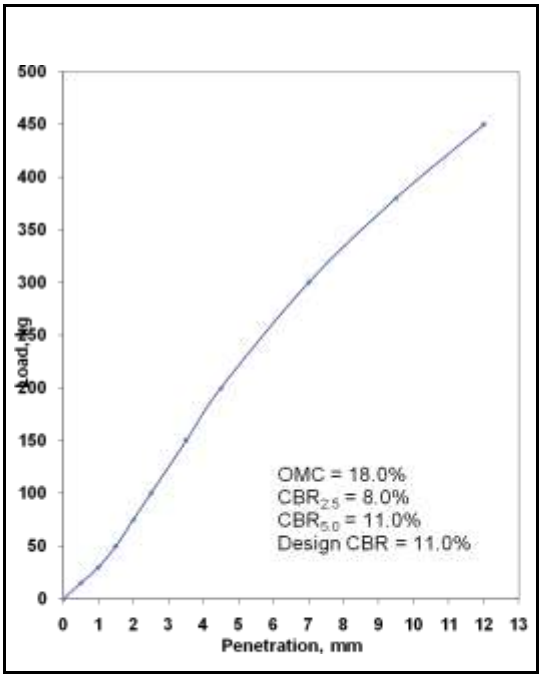

Fig. 11 Results of soaked CBR test on pumice stone – clayey sand mix (30:70)

Discussion on the test results

The results of light compaction test on both the soils indicate that the OMC increases with the increase in the proportion of pumice stone. This is because of the fact that pumice stone absorbs more water owing to its high porosity. This is in spite of the fact that it has lower surface area as the particle size of pumice stone is more than that of the virgin soil. The increase in CBR value with the increase in content of pumice stone is on the expected lines because addition of the coarser particles increases the resistance to penetration.

Pavement Design and Cost Analysis

The summary of test results on Clay (CI) and the Clayey Sand (SC) are given in Tables 2 and 3 respectively.

Table 2 Summary of test results on Clay (CI)

Mix Proportion (Pumice stone: Clay)	OMC	Design CBR
0:100	16.5%	1%
10:90	17.5%	3%
30:70	18.8%	4%
50:50	20.2%	9%

Table 3 Summary of test results on Clayey Sand (SC)

Mix Proportion (Pumice stone: Clayey Sand)	OMC	Design CBR
0:100	12.1%	3%
10:90	15.1%	5%
20:80	16.7%	10%
30:70	18.0%	11%

Table 2 shows that when pumice stone and Clay (CI) are mixed in 50:50 proportion, the CBR is increased to 9% from 1%. Since the flexible pavement structure is the same for subgrades with CBR more than 9%, no attempt is made to increase the CBR beyond 9%. Using IRC: 37 - 2001 [7] specifications, flexible pavement is designed for a low traffic intensity of 2 msa for virgin soil as well as virgin clay and pumice stone-clay mix (50:50) respectively and the cost estimation is carried out for each case.

Similarly, Table 3 shows that when pumice stone and Clayey Sand (SC) are mixed in 20:80 proportion, the CBR is increased to 10% from 3%. Using IRC: 37 - 2001 specifications, flexible pavement is designed for a low traffic intensity of 2 msa for virgin soil as well as virgin clayey sand and pumice stone-clayey sand mix (20:80) respectively and the cost estimation is carried out for each case.

Pavement structure for virgin clay (CI)

The pavement structure suggested by IRC: 37 – 2001 for a traffic intensity of 2 msa and a subgrade CBR of 1% is given in Fig. 12. The IRC stipulates that when the CBR of subgrade is less than 2%, the pavement structure corresponding to a CBR of 2% shall be provided but a capping layer whose CBR is not less than 10% shall be introduced between the subgrade and subbase.

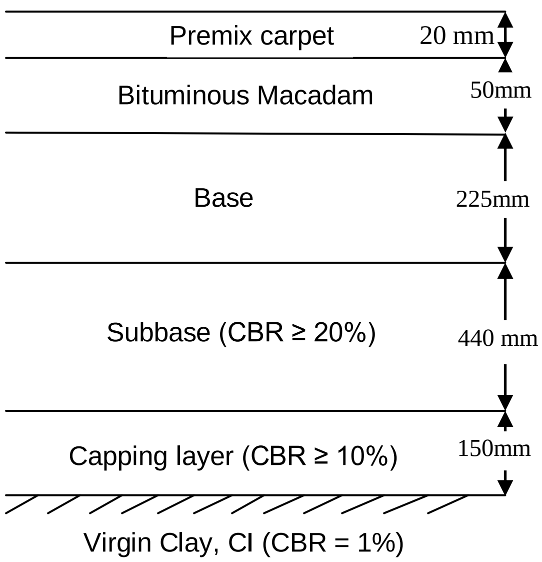

Fig. 12 Pavement Structure for virgin Clay (CI) for 2 msa

Pavement Structure for stabilized Clay

Similarly, the recommended pavement structure for the stabilized clay (pumice stone: clay = 50:50) is given in Fig. 13. The increase in CBR of the subgrade leads not only to the elimination of the capping layer but also to the considerable reduction in the thickness of subbase.

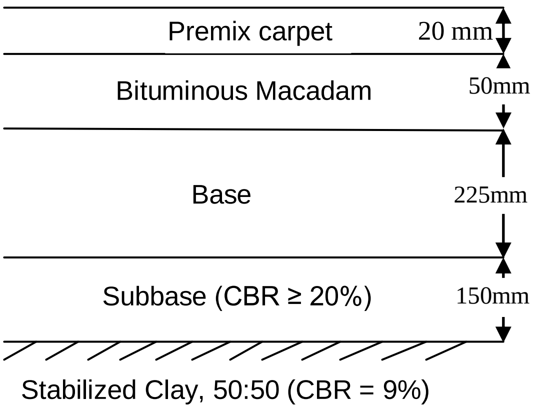

Fig. 13 Pavement Structure for stabilized clay for 2 msa

Pavement structure for virgin clayey sand (SC)

The CBR of subgrade for this case is 3% and hence capping layer is not necessary. The recommended pavement structure for the same traffic intensity of 2 msa is given in Fig. 14.

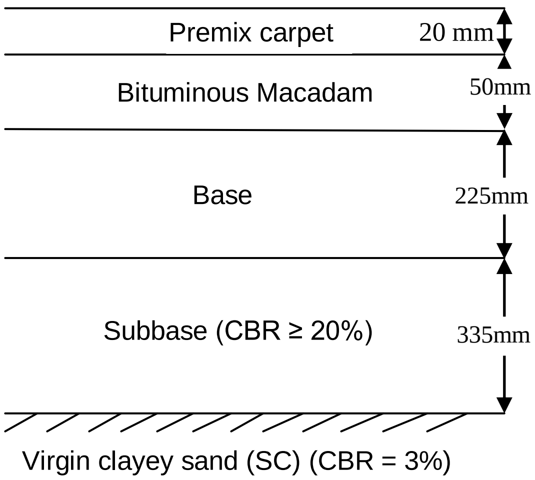

Fig. 14 Pavement Structure for virgin clayey sand (SC) for 2 msa

The recommended pavement structure for the stabilized clayey sand (pumice stone: clayey sand) with a CBR of 10% is the same as that given in Fig. 13.

Cost Analysis

The quantity estimation for various materials and hence the cost of pavement per unit area for pavement structure on the virgin clay and the stabilized clay are presented in Tables 4 to 5 respectively.

Table 4 Estimation of quantity for various materials for pavement structure resting on virgin clay (CI) (Reference: Fig. 12)

Items of works	Thickness (m)	Quantity	Unit rate, Rs.	Total amount, Rs.
Compaction of sub grade	0.5	0.5 m^3	200	100
Capping layer	0.15	0.15 m^3	500	75
Sub base	0.44	0.44 m^3	1000	440
Base	0.225	0.225 m^3	2000	450
BM	0.05	0.05 m^3	10000	500
PC	0.02	1 m^2	50	50
Total cost per m^2 area				1615

Table 5 Estimation of quantity for various materials for pavement structure resting on stabilized clay (Pumice stone: clay = 50:50) (Reference: Fig. 13)

Items of works	Thickness (m)	Quantity	Unit rate, Rs.	Total amount, Rs.
Compaction of the mix	0.5	0.5 m^3	250	125
Sub base	0.15	0.15 m^3	1000	150
Base	0.225	0.225 m^3	2000	450
BM	0.05	0.05 m^3	10000	500
PC	0.02	1 m^2	50	50
Total cost per m^2 area				1275

Comparing Table 4 and Table 5, the reduction in cost is estimated to be 21%.

Similarly, the quantity estimation for various materials and hence the cost of pavement per unit area for pavement structure on the virgin clayey sand is presented in Table 6

Table 6 Estimation of quantity for various materials for pavement structure resting on virgin clayey sand (SC) (Reference: Fig. 14)

Items of works	Thickness (m)	Quantity	Unit rate, Rs.	Total amount, Rs.
Compaction of sub grade	0.5	0.5 m^3	200	100
Sub base	0.335	0.335 m^3	1000	335
Base	0.225	0.225 m^3	2000	450
BM	0.05	0.05 m^3	10000	500
PC	0.02	1 m^2	50	50
Total cost per m^2 area				1435

Since the pavement structure on stabilized clay and stabilized clayey sand is the same, the total cost per m^2 area of pavement structure resting on stabilized clayey sand is also equal to Rs. 1275 (Table 5)

Comparing Table 6 and Table 5, the reduction in cost is estimated to be 11%.

The reduction in cost of pavement structure resting on stabilized subgrade with original CBR of 1% is more than that on stabilized subgrade with original CBR of 3%. This indicates that the weaker the original subgrade, the greater is the reduction in the overall cost. In the cost analysis, the transport cost for the pumice stone is not considered and hence the reduction in cost is applicable only for the internal roads of the industries producing the waste pumice stone or for village roads nearer to the industries.

Conclusion

Based on the present study, the following conclusions are arrived at.

1. The mechanical stabilization of weak subgrade using pumice stone, a waste material in industries, is very effective.
2. The mix consisting of 50% pumice stone and 50% virgin Clay with Medium Compressibility (CI) produces optimum result. For this case, the CBR value increases from 1% to 9%
3. Similarly, the mix consisting of 20% pumice stone and 80% virgin Clayey Sand (SC) produces optimum result. For this case, the CBR value increases from 3% to 10%
4. The increase in CBR leads to reduction in thickness of the pavement and hence overall cost. The reduction in the overall cost of the pavement resting on the clay is 21% whereas it is 11% in the case of clayey sand
5. It is also observed that the weaker the original subgrade, the greater is the reduction in the overall cost.
6. Since the transport cost for pumice stone is not considered in the cost analysis, it is applicable only for internal roads of the industries producing the waste pumice.

Acknowledgement

The author thanks the Institution of Engineers (India) for providing the financial support and Department of Civil Engineering, PSG College of Technology for providing the facilities for carrying out the experimental works.

References

1. Mehmet Saltan, F. and Selcan Ertem, Stabilization of subgrade layer with waste pumice in flexible pavement, Journal of Building and Environment, 2008, 43, 415–421.
2. Yucel Kavlak and Selcan Fındık, Utilization of Pumice Waste for Clayey Subgrade of Pavements, Journal of Materials in Civil Engineering, 2010, 30.
3. Wael Alkasawneth and Ernian, Evaluation selection and assessment of guidelines for flexible pavement of tropical residual soils, American journal of Environmental Sciences, 2007, 4, 303 -309.
4. IS : 1498-1970, Classification and Identification of Soils for General Engineering Purposes, Bureau of Indian Standards, 1970.
5. IS : 2720 (Part 7)-1980, Methods of test for soils: Part 7 Determination of water content-dry density relation using light compaction, Bureau of Indian Standards, 1980.
6. IS : 2720 (Part 16)-1979, Methods of test for soils: Part 16 Laboratory Determination of CBR, Bureau of Indian Standards, 1979.
7. IS : 2720 (Part 16)-1979, Methods of test for soils: Part 16 Laboratory Determination of CBR, Bureau of Indian Standards, 1979.
8. IRC : 37 – 2001, Guidelines for the design of flexible pavements, The Indian Roads Congress, New Delhi, 2001.

*****

*****