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Economic Analysis of Flexible Pavement by Using Ceramic Waste as a Stabilizer Material for Pavement Subgrade

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ABSTRACT: Poor subgrade soil conditions can lead to inadequate pavement support and reduce pavement life. Soils may be improved by soil stabilization by stabilizing by lime, fly ash, cement, rice husk, ceramic waste etc. which are generally waste products and they create disposal problems. These additives can be used with a variety of soils to help improve their engineering properties. The effectiveness of these additives depends on the soil treated and the amount of additive used. The subgrade strength is mostly expressed in terms of California Bearing Ratio (CBR). Weaker subgrade essentially requires thicker layers whereas stronger subgrade goes well with thinner pavement layers. The pavement and the subgrade mutually must sustain the traffic volume. This work attempts to understand the strength of subgrade in terms of CBR values subjected to different types of stabilizers. Treatment with ceramic waste was found to be an effective option for improvement of soil properties, based on the testing conducted as a part of this work. In this paper, the economic analysis has been done on flexible pavements. The pavements were designed under different traffic conditions and soils treated with ceramic waste. Thickness design of flexible pavement has been conducted as per the IRC:SP:20-2002. Costs are calculated and construction costs have been determined for flexible pavement according to BOQ based on MORTH and compared.

KEYWORDS: Subgrade, Stabilization, Cost, Pavement

I. INTRODUCTION

Roads form the part of the basic infrastructure for a nation and in a developing country like India where distances between two major cities can be a couple of thousand kilometres, roads can be actually termed as lifeline of the nation. Constructing roads for everyone's need and maintaining the vast network, make considerable demand on construction material, India is a vast country where roads serve the purpose of connecting one region to another, one state to another and one metro to another. Road network system of India is important if we want to become an economic superpower. Today there is the need to create more roads, broaden the existing ones and to make them safer so that India is on the road to become a developed nation.

The research aims at assessing the economic viability of using ceramic waste for flexible pavement in road construction. The materials used in the present work are clayey soil, ceramic waste of these materials is as given in the following sections.

1.1 Characteristics of Clayey Soil

The Expansive soil used for experiment was collected from Yavat village at about 55km away from Pune district located in Maharashtra. The properties of clayey soil are detailed below

Table 1. Characteristics of the Subgrade Soil before Stabilization

SR.No	Properties of soil	Values
1.	Specific gravity	2.22
2.	Liquid limit	75.59%
3.	Plastic limit	32.16%
4.	Plasticity index	43.43%
5.	Soil classification	CH Group
6.	Standard proctor test	
	Maximum dry density	1.38
	Optimum moisture content	32%
7.	CBR value (@ 2.5 mm penetration)	3.00%

1.2 Tiles waste

Ceramic Waste is collected from Rak Ceramics, Kalash Ceramics, Global Ceramics. The vitrified tile is a successful waste material in stabilization strategy which enhances the composition qualities, subgrade characteristics, Swelling characteristics, compressibility characteristics. It has a specific gravity of 2.60. The tile waste was crushed into the size range of 4.75mm to 75µm with the help of a hammer for experimental use. The Ceramic waste were crushed first manually and then mechanically to bring them to the required size. The mechanical crushing was done in Los Angeles Abrasion Machine.



Figure 1.1 Ceramic Waste

Table 1.2 Chemical Properties Of Ceramic Waste

Sr. No	Contents	Result (%)
1	Silica	61.38
2	Alumina	17.60
3	Ferric Oxide	3.80
4	Calcium Oxide	7.61
5	Magnesium Oxide	3.91
6	Sodium Oxide	0.63
7	Titanium Dioxide	1.09
8	Potassium Oxide	0.90
9	Sulphur Trioxide	0.75
10	Loss on Ignition @ 1000 ⁰ c	1.00

II. LITERATURE REVIEW

A few reviews of the significance research work under taken by different researchers on this subject is briefed below:

Ranjithahad stabilized black cotton soil mixed with crushed coconut shells. The locally available black cotton soil was mixed with CCS in mix proportions 25gm, 50gm, and 75gm. The effect of CCS on CBR and UCS of black cotton soil were evaluated. From the results of the test it was found that the strength of black cotton soil is improved by the addition of CCS CBR value is increased. This results in increased strength of subgrade soil, reduced base course thickness for same repetitions of traffic load.

Ameta and Wayal had stabilized the dune sand using ceramic tile waste as admixture. From the test results it was found that on increment of particle size of admixture, the C.B.R. value of the mix composition increases. Also as the quantity or percentage of admixture increases, the C.B.R. value of the mix composition increases. Variations in C.B.R. values at different percentages of mix composition at different size also showed that increase in CBR values was more at unsoaked condition than that compared with soaked condition. From the results obtained it was concluded that angle of internal friction varies with increase in size of ceramic tiles wastage in mix composition. On the other hand for the same size of ceramic tiles waste, the angle of internal friction increases with increase in percentage or quantity of ceramic tiles waste.

Raghudeep and Prasad had mixed the available clayey soil with vitrified polish waste (VPW) up to 10% for flexible pavement construction. At 10% mix proportion of VPW, Liquid limit and Plasticity index of the soil decreased by 17.29% and 42.77%. The MDD increased by 13.61% and DFS decreased by 27.93% when 10% VPW added to the soil. Soil classification changes from the CI to CL. CBR value increases from 2.1% to 7.07%. Soaked and Unsoaked CBR values increased 3 to 4 times when 10% of VPW added to the soil compared to original clayey soil.

III. METHODOLOGY

The design procedure adopted and the economic cost calculations are described below:

3.1 Design of Flexible Pavement as per IRC:SP:20-2002

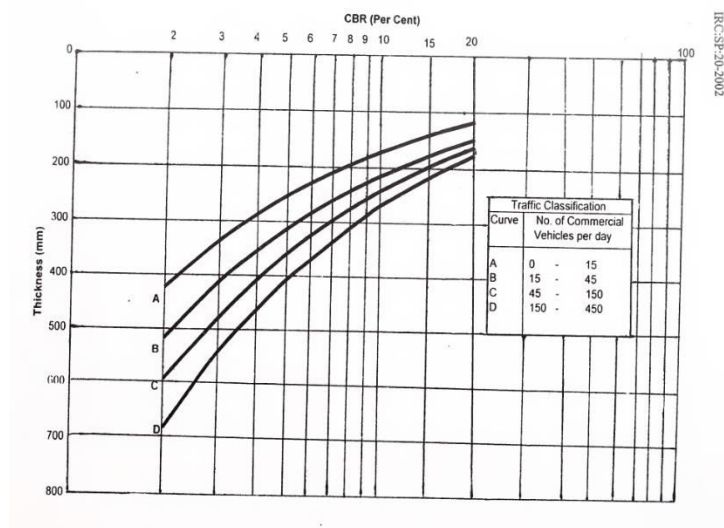


Figure 1.2 CBR curve SP:20-2002

3.1.1 Pavement Thickness and Composition Before Stabilization:

- The commercial vehicles per day = 15 to 45 vehicles/day
- The CBR value of soil as tested = 3.00%
- From the above graph, considering curve B the thickness of pavement = **460mm**.



- Thickness of Sub Base material = 270mm.
- Thickness of Base Coarse material = 150mm.
- Thickness of Surface Coarse material = 40mm.

3.1.2 Pavement Thickness and Composition After Stabilization

- The commercial vehicles per day = 15 to 45 vehicles/day
 - The CBR value of soil as tested = 6.58%
 - From the above graph, considering curve B the thickness of pavement = **300mm.**
- Thickness of Sub Base material = 120mm.
 - Thickness of Base Coarse material = 150mm.
 - Thickness of Surface Coarse material = 30mm

3.2 Cost and Economic Analysis of Flexible Pavement According to BOQ Based on MORTH

Economic analysis of flexible pavement has been conducted for the following two cases by assuming Length of road: 1000 m and width of driving lane as 3.75 m (single lane). Unit rates are derived by using the "Schedule of Rates for Public Works Dept, Pune of the year 2020-2021".

Case-1: Without Stabilization

Cost estimate for the flexible pavement thickness as obtained for without the soil stabilization is as follows:

- Clearing and grubbing road land including uprooting rank vegetation, grass, bushes, shrubs, saplings and trees girth up to 300 mm, removal of stumps of trees cut earlier and disposal of unserviceable materials and stacking of serviceable material to be used or auctioned up to a lead of 1000 meters including removal and disposal of top organic soil not exceeding 150 mm in thickness. = 22.00 per m² (MORTH Spec.201)
 - Quantity = $1000 \times 3.75 \times 1.00 = 3750 \text{ m}^2$
 - Total cost = $3750 \times 22.00 = 82,500.00/-$
- Excavation for roadway in earth, soil of all sorts, sand, gravel or soft murum including dressing section to the required grade, camber and side slopes and conveying the excavated materials with all lifts upto a lead of 50m. and spreading for embankment or stacking as directed. = 90.00 per m³(MORTH Spec.301)
 - Quantity of Excavation = $1000 \times 3.75 \times 0.5 = 1875 \text{ m}^3$
 - Total cost = $1875 \times 90.00 = 1,68,750.00/-$
- Watering and compacting of embankment formed of materials obtained from the road cutting within a lead of 50 m, not less than 97 % of standard Proctor density after laying them in layers of 20 cm. to 30 cm. with vibratory roller.= 77.00 per m³ (MORTH Spec.305)
 - Quantity = $1000 \times 3.75 \times 0.5 = 75 \text{ m}^3$
 - Total cost = $1875 \times 77.00 = 1,44,375.00/-$
- Construction of granular sub-base by providing close graded Material, mixing in a mechanical mix plant at OMC, carriage of mixed Material to work site, spreading in uniform layers with motor grader/ Paver on prepared surface and compacting with vibratory roller to achieve the desired density, complete as per clause 401 - Plant Mix Method and Grading - I Material. = 1771.00 per m³(MORTH Spec.401)
 - Quantity of Granular sub base= $1000 \times 3.75 \times 0.270 = 1012.50 \text{ m}^3$
 - Total cost = $1012.50 \times 1771.00 = 17,93,137.50/-$
- Providing, laying, spreading and compacting stone aggregates of specific sizes to water bound macadam specification including spreading in uniform thickness, hand packing to proper grade and camber, applying and brooming requisite type of screening/ binding Materials to fill up the interstices of coarse aggregate, watering and compacting with Vibratory roller. to the required density. By Mechanical Means - Grading I (Using Screening Type A (13.2) mm Aggregate) = 1910.00 per m³(MORTH Spec.404)
 - Quantity of WBM = $1000 \times 3.75 \times 0.150 = 562.50 \text{ m}^3$
 - Total cost = $562.50 \times 1910.00 = 10,74,375.00/-$

- Prime coat - Providing and applying primer coat with bitumen emulsion on prepared surface of granular Base including cleaning of road surface and spraying, primer at the rate of 0.60 Kilogram/Square Meter using mechanical means. = 22.00 per m²(MORTH Spec.502)
 - Quantity of Prime coat = $1000 \times 3.75 \times 1.00 = 3750 \text{ m}^2$
 - Total cost = $3750 \times 22.00 = 82,500.00/-$
- Providing and applying tack coat on the prepared surface heating by flames in Boiler and spraying bitumen with sprayer on Concrete surface treated with primer @ 3.25 Kilogram/10 Square Meter (VG-30 bulk bitumen rates are considered to arrive at rates) = 14.00 per m²(MORTH Spec.503)
 - Quantity of Tack coat = $1000 \times 3.75 \times 1.00 = 3750 \text{ m}^2$
 - Total cost = $3750 \times 14.00 = 52,500.00/-$
- BITUMINOUS CONCRETE:- Providing and laying bituminous concrete using crushed aggregates of grading 1, premixed with bituminous binder @ 5.20 per cent by weight of total mix and filler, transported to site with VTS, laid over a previously prepared surface, finished to the required grade, level, alignment, and rolling to achieve the desired compaction for 50 mm compacted thickness with specified grade of Bitumen, Excluding prime / tack coat. For Bitumen of specified grade -- USING Batch mix type hot mix plant with SCADA, Sensor Paver, Vibratory roller with Stone Dust filler. (VG-30 bulk bitumen rates are considered to arrive at rates) = 6738 per m³(MORTH Spec.509)
 - Quantity of Bituminous macadam = $1000 \times 3.75 \times 0.04 = 150 \text{ m}^3$
 - Total cost = $150 \times 6738.00 = 10,10,700.00/-$

Overall cost of Flexible pavement for laying 1km length = **44,08,837.50/-**

Case-2: With Soil Stabilization

Cost estimate for the flexible pavement thickness as obtained for with soil stabilization is as follows:

- Clearing and grubbing road land including uprooting rank vegetation, grass, bushes, shrubs, saplings and trees girth up to 300 mm, removal of stumps of trees cut earlier and disposal of unserviceable materials and stacking of serviceable material to be used or auctioned up to a lead of 1000 meters including removal and disposal of top organic soil not exceeding 150 mm in thickness. = 22.00 per m² (MORTH Spec.201)
 - Quantity = $1000 \times 3.75 \times 1.00 = 3750 \text{ m}^2$
 - Total cost = $3750 \times 22.00 = 82,500.00/-$
- Excavation for roadway in earth, soil of all sorts, sand, gravel or soft murum including dressing section to the required grade, camber and side slopes and conveying the excavated materials with all lifts upto a lead of 50m. and spreading for embankment or stacking as directed. = 90.00 per m³(MORTH Spec.301)
 - Quantity of Excavation = $1000 \times 3.75 \times 0.5 = 1875 \text{ m}^3$
 - Total cost = $1875 \times 90.00 = 1,68,750.00/-$
- Watering and compacting of embankment formed of materials obtained from the road cutting within a lead of 50 m, not less than 97 % of standard Proctor density after laying them in layers of 20 cm. to 30 cm. with vibratory roller. = 77.00 per m³ (MORTH Spec.305)
 - Quantity = $1000 \times 3.75 \times 0.5 = 75 \text{ m}^3$
 - Total cost = $1875 \times 77.00 = 1,44,375.00/-$
- Construction of granular sub-base by providing close graded Material, mixing in a mechanical mix plant at OMC, carriage of mixed Material to work site, spreading in uniform layers with motor grader/ Paver on prepared surface and compacting with vibratory roller to achieve the desired density, complete as per clause 401 - Plant Mix Method and Grading - I Material. = 1771.00 per m³(MORTH Spec.401)
 - Quantity of Granular sub base= $1000 \times 3.75 \times 0.270 = 1012.50 \text{ m}^3$
 - Total cost = $1012.50 \times 1771.00 = 17,93,137.50/-$
- Providing, laying, spreading and compacting stone aggregates of specific sizes to water bound macadam specification including spreading in uniform thickness, hand packing to proper grade and camber, applying and brooming requisite type of screening/ binding Materials to fill up the interstices of coarse aggregate, watering and compacting with Vibratory roller. to the required density. By Mechanical Means - Grading I (Using Screening Type A (13.2) mm Aggregate) = 1910.00 per m³(MORTH Spec.404)
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 - Quantity of Tack coat = $1000 \times 3.75 \times 1.00 = 3750 \text{ m}^2$
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- BITUMINOUS CONCRETE:- Providing and laying bituminous concrete using crushed aggregates of grading 1, premixed with bituminous binder @ 5.20 per cent by weight of total mix and filler, transported to site with VTS, laid over a previously prepared surface, finished to the required grade, level, alignment, and rolling to achieve the desired compaction for 50 mm compacted thickness with specified grade of Bitumen, Excluding prime / tack coat. For Bitumen of specified grade -- USING Batch mix type hot mix plant with SCADA, Sensor Paver, Vibratory roller with Stone Dust filler. (VG-30 bulk bitumen rates are considered to arrive at rates) = 6738 per m³(MORTH Spec.509)
 - Quantity of Bituminous macadam = $1000 \times 3.75 \times 0.04 = 150 \text{ m}^3$
 - Total cost = $150 \times 6738.00 = 10,10,700.00/-$
- Ceramic Waste :- It includes the cost of Transportation of ceramic tiles from a distance of 20km, Grinding of ceramic waste.
 - An amount of 20% of ceramic waste is added in Weak subgrade.
 - For 1m³ of volume filled by soil, ceramic waste required = 200 kg
 - For $(1000 \times 3.75 \times 0.5 = 1875 \text{ m}^3)$, ceramic waste required = 375000 kg
 - Rate of ceramic waste per kg = 2 Rupees
 - Total rate of ceramic waste required = $375000 \times 2 = 750000.00/-$

Overall cost of Flexible pavement for laying 1km length = **39,09,975.00/-**

IV. CONCLUSION

The following conclusions can be made based on the present laboratory investigations and the economic analysis:

- (a) The use of Ceramic waste as stabilizer material with subgrade soil is found to be a definite improvement in the engineering properties and California Bearing Ratio (CBR) value.
- (b) The pavement design as per IRC:SP:20-2002 reveals that there will be definite decrease in thickness of the flexible pavement
- (c) The savings in construction cost of the flexible pavement is found to be Rs.4,98,863/- per km length and it is worked out to be about 11.31% of overall cost of the construction.

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