International Journal of Mechanical Engineering

MECHANICAL STABILIZATION OF SUB-GRADE SOIL USING TEXTILE WASTE SALT

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Abstract:

This study aims to solve the problems faced due to expansive soil in road constructions and find a way to use the textile waste salt which is dumped in landfills. Mechanical stabilization is adopted in this study to counteract the expansive nature of the virgin soil. The waste material used in this study is obtained from the effluent treatment of the dying industry after recovery of 85% of the salt. In this study the virgin soil (Liquid limit = 42%, Plasticity Index = 22%, hence Classified as CI) is mixed with the waste salt (Non-plastic) in the proportions of 90:10, 80:20, 70:30, 60:40 (Soil: Waste Salt). Optimum Moisture Content (OMC) of Virgin soil as well as all the mixes has been found and California Bearing Ratio test has been carried out to find the optimum mix. As per the CBR results the optimum mixes are the ones which increase the CBR value from 1.4% (Virgin Soil) to 2.49% (70:30 Mix) and to 3.46% (60:40 Mix). Flexible Pavements have been designed as per IRC37:2001 for all the mixes for both 2 msa and 10 msa and cost analysis for all the designed pavements has been carried out.

Keywords: Flexible Pavement, Mechanical stabilization, Optimum Moisture Content, California Bearing Ratio

1. Introduction

Sub-grade soil is a crucial element in the design of both flexible and rigid pavements. The influence of expansive soil on flexible pavement is much more than that on a rigid pavement. A flexible pavement resting on expansive soil requires more thickness to counteract the swell-shrink characteristics. This problem can be overcome using soil stabilization methods. The commonly used methods for soil stabilization are physical, mechanical and chemical stabilization. Physical stabilization is done by making changes to the texture of the soil, mechanical stabilization is done by adding locally available materials mixed together in certain proportions to the soil which satisfies the requirement and chemical stabilization is done by adding chemicals to modify the properties of soil to achieve the desired properties.

In this study mechanical stabilization is adopted in order to modify the properties of the soil sample taken. This is carried out by mixing of a waste material which is more effective than the materials that are readily available in the market. It helps in the usage of the waste material which would otherwise be dumped in the landfills leading to contamination of the land as well as ground water.

Certain districts in Tamil Nadu are mass producers of textile which export to various parts of the world. The wastes generated from textile industries contribute to pollution of water bodies and land alike. Due to strict rules that require the industries to treat the wastes, the effluent treatment plants are used to treat the waste water generated from the textile industry. These treatment plants comprise of primary, secondary and tertiary treatment units which are used to treat the waste water and then release them into the water bodies. But some industries carry out an additional process known as Reverse Osmosis (RO).

In the process of dying, inorganic salts, acids, water are added. This process leads to the presence of Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD). The primary, secondary and tertiary treatments remove TDS, COD, and BOD. Salt recovery is done to recover back 85% of the salts used and to reuse them. The remaining 15% of the salt which is dried in the sludge drying tanks is disposed in landfill.

In this study, the textile waste salt is used to stabilize the problematic soil. The components of this waste salt are Sodium Sulphate, Sodium Hydroxide, and Sodium Bi-Carbonate in certain proportions. Experimental study was carried out by Roberts M. Brook (2009) for the strength comparison of upgraded expansive clayey soil mixed with Rice Husk Ash (RHA) and fly ash. In this study, it was concluded that addition of 12% RHA and 25% fly ash with expansive subgrade produces the maximum strength whereas addition of 15% fly ash produces the best result as far as the reduction of swelling is concerned. The unconfined compressive strength of the subgrade was also found to be increased by the addition of RHA. Yi Cai et al (2006) suggested the use of polypropylene fibre mixed with lime, for improving the strength of a weak clay. They also proved that the greater the curing period, the greater is the strength of the mix. An experimental analysis of stabilization of expansive soil by reducing the swelling property and improving its mechanical capacity was done by Seco et al (2011). The swelling capacity of the soil shows a positive effect when added with monovalent cations that help in the dispersion of clay for this type of soil.

Using lime and sand as stabilizing agents in order to decrease the plasticity index and increase CBR of the expansive sub-grade was carried out by Gati Sri Utami et al (2017). They have concluded that the swelling potential, liquid limit and plasticity index of the clay are reduced with the increase in percentage of sand and lime and the CBR value increases. A combination of 15% of lime and 30% sand is found to be optimum based on the reduction of swelling characteristics and improvement in the CBR. Moses et al (2012) found that the CBR value of the black cotton soil treated with 16% Cement Kiln Dust (CKD) increased from 2% to 3%. They also found a reduction in the swelling characteristics of black cotton soil. Amaia Lisbona et al (2012) in their study on the stabilization of clay with calcined paper sludge and cement found the unconfined compressive strength of the mix after 90 days of curing to be maximum for a ratio of 25:75 (calcined paper sludge: cement).

2. Methodology

The flow chart indicating the methodology adopted for the present study is given in Figure 1.

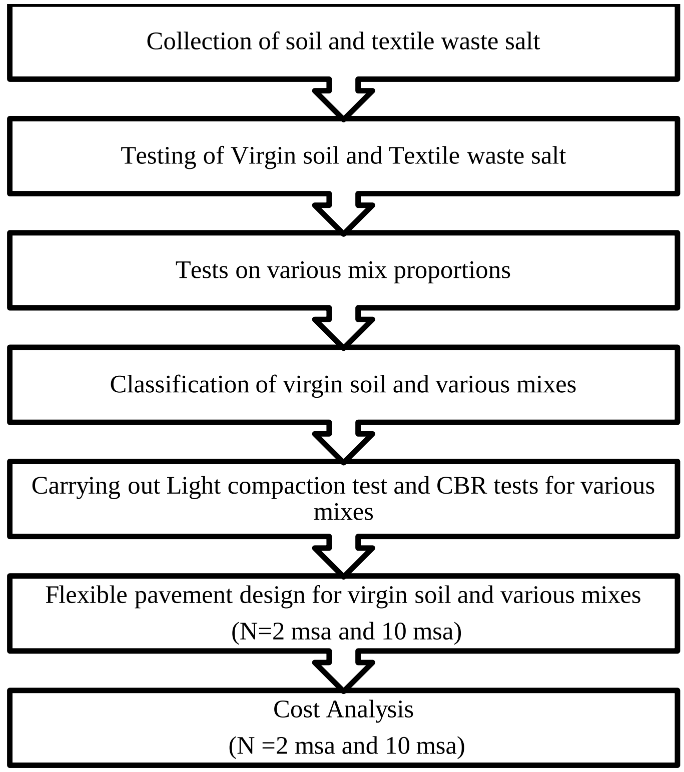

Figure 1 Methodology

3. Collection of soil and textile waste salt

The soil sample was collected from Kalapatti, Coimbatore and the textile waste sample was collected from a dying industry in Tirupur. The physical appearance of the soil is brown in colour and the salt is also brown in colour with pungent smell. The salt was obtained after the effluent treatment in which 85% of $NaSO_4$ was recovered and the rest of the salt is generally disposed in landfills. The waste salt contains 15% of $NaSO_4$ (Sodium Sulphate), NaOH (Sodium Hydroxide), and Na_2HCO_3 (Sodium Bi-Carbonate).

4. Results of tests on virgin soil and mixes

Laboratory tests pertaining to classification, swelling characteristics, compaction and CBR were conducted on the virgin soil as well as the soil and waste salt mixes in various proportions.

4.1 Results of tests on virgin soil and the textile waste salt

The results of classification tests, differential free swell and swell pressure tests carried out on virgin soil are given in Table 1. Based on the classification tests, the virgin soil is classified as CI as per IS: 1498 – 1970. The results of light compaction test performed as per IS: 2720 (Part 7) – 1980 are presented in Figure 2.

Table 1 Test Results of Virgin soil

Tests	Results
Percentage of Fines	65%
Liquid Limit (w_L)	42%
Plastic Limit (w_P)	20%
Plasticity Index(I_p)	22%
Differential Free Swell (DFS)	35%
Swell pressure	42 kPa
IS Classification	CI

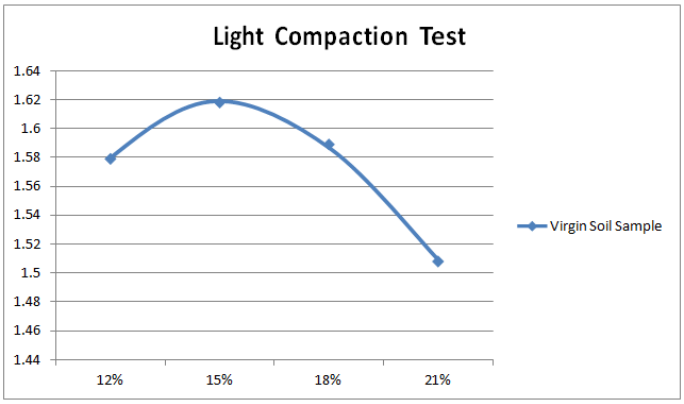

Figure 2 The results of light Compaction test on virgin Soil

The test results show that the virgin soil is moderately expansive. The optimum moisture content and maximum dry density are 15% and 1.620 g/cc respectively.

The wet sieve analysis carried out on the waste salt indicates the presence of nil fine grained fraction. It is also found that it is non-plastic. From the results, it is concluded that the material can be used along with a more plastic sub-grade or sub-base material in order to reduce its plasticity and make it less plastic and less expansive.

4.2 Results of tests on various mix proportions

The various mixes considered are given in Table 2

Table 2 Mixes used in this study

Soil, % by mass	Textile waste salt, % by mass
90	10
80	20
70	30
60	40

The results of liquid limit, plastic limit, DFS and swell pressure tests conducted on the various mixes are given in Table 3.

Table 3 The test results on various mixes

Mix Proportions	Liquid Limit	Plastic Limit	Plasticity Index	DFS	Swell pressure
90:10	31%	16%	15%	25%	30 kPa
80:20	26%	14%	12%	20%	24 kPa
70:30	22%	13%	9%	14%	18 kPa
60:40	16%	11%	5%	Nil	10 kPa

The tests results on the various mixes show that as the proportion of the waste salt increases, the mix becomes less and less plastic and expansive.

4.3 Classification of virgin soil and various mixes

Based on the liquid limit and plasticity index values, the various mixes are classified as per IS and presented in the Table 4. It shows that addition of the waste salt makes the clay from the one with medium plasticity (CI) to the one with low plasticity (CL or CL-ML)

Table 4 Classification of virgin soil and various mixes

Mix Proportion	Classification
Virgin soil	CI
90:10	CL
80:20	CL
70:30	CL
60:40	CL-ML

4.4 Results of light compaction test and CBR tests

The results of the light compaction tests and CBR tests (as per IS: 2720 (Part 16) - 1987) are tabulated in Table 5 and Table 6 respectively

Table 5 Light compaction test results

Mix Proportion	Maximum dry density (g/cc)	Optimum Moisture Content (OMC)
90:10	1.66	14%
80:20	1.672	13.5%
70:30	1.683	13%
60:40	1.678	13%

Table 6 The results of CBR tests

Mix Proportion	$CBR_{2.5}$	CBR_5	Design CBR
100:0	1.4%	1.4%	1.4%
90:10	0.61%	0.61%	0.61%
80:20	1.16%	1.26%	1.26%
70:30	1.89%	2.49%	2.49%
60:40	2.03%	3.46%	3.46%

The compaction test results show that the addition of the salt decreases the OMC. This is because of the higher specific surface area of the salt compared to the virgin soil. The maximum dry density and CBR also increase with the increase in the proportion of the salt. The CBR almost remains the same and is less than 2%

upto 20% salt. When the proportion of the salt is more than 20%, the CBR becomes more than 2%.

5. Flexible pavement design for virgin soil and various mixes (N=2 msa and 10 msa)

Flexible pavement is designed for 2 msa (million standard axles) and 10 msa respectively as per IRC: 37 – 2001 considering the virgin soil and the various mixes as subgrade. IRC: 37 recommends a buffer layer of thickness ranging from 600 mm to 1000 mm for flexible pavements on expansive soil. Since the virgin soil is moderately expansive, the thickness of the buffer layer is taken as 600 mm. Since all the mixes have become less expansive, the buffer layer is eliminated for the pavement structures designed on the mixes. However, for the mixes 90:10 and 80:20, as the CBR is less than 2%, a 150 mm-thick capping layer whose CBR is not less than 10% is introduced between subgrade and subbase. For the remaining two mixes (70:30 and 60:40), even this capping layer is eliminated as the CBR value is more than 2%. The pavement structures are presented from Figure 3 to 7.

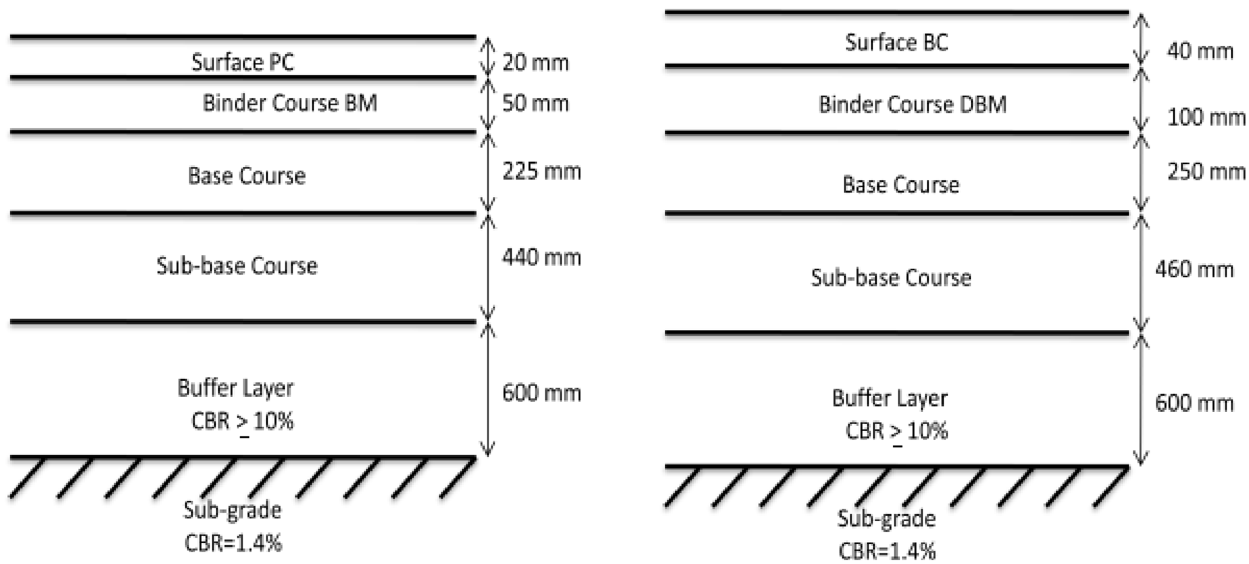

Figure 3 Flexible Pavement for Virgin soil
(N= 2 msa & N= 10 msa)

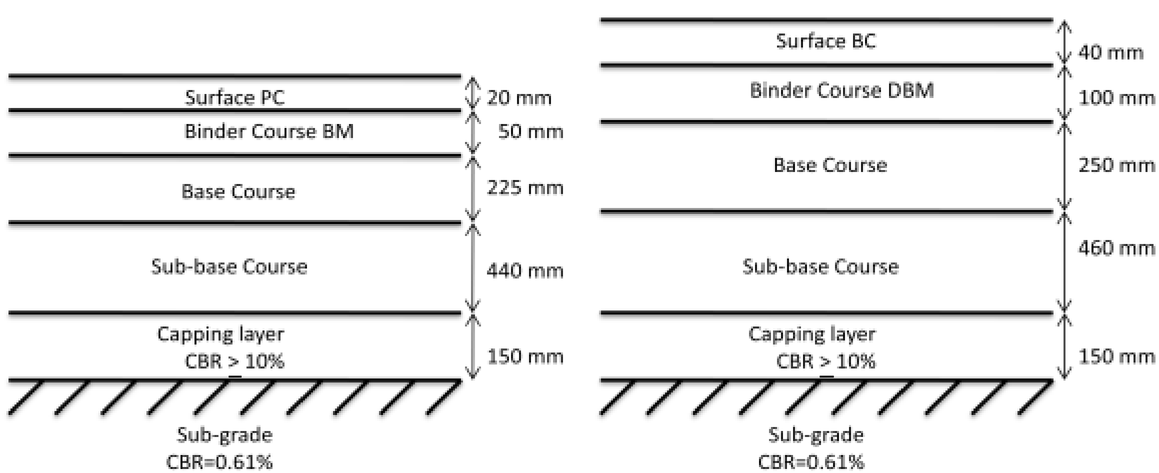

Figure 4 Flexible Pavement for 90:10 mix

(N= 2 msa & N= 10 msa)

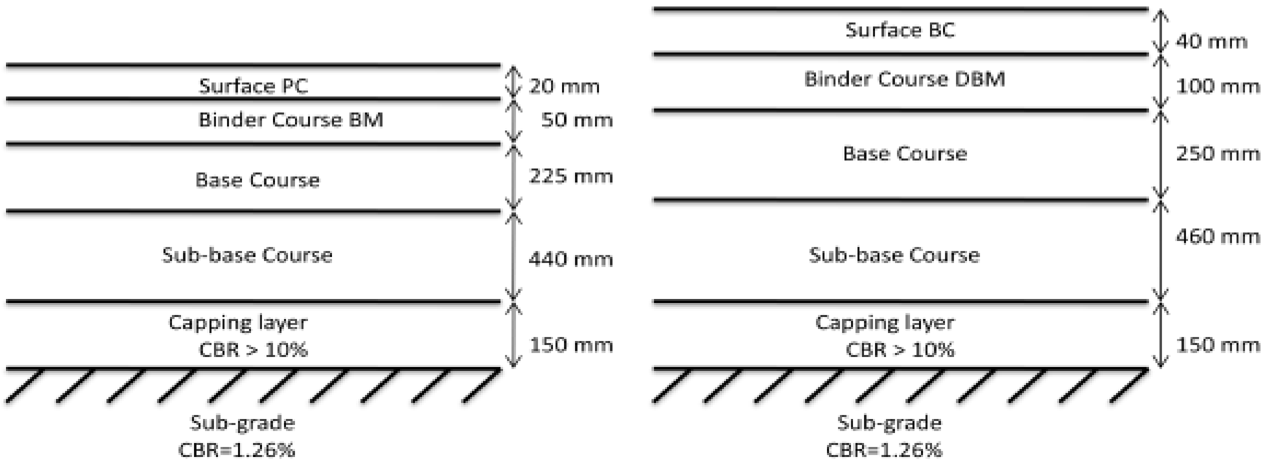

Figure 5 Flexible Pavement for 80:20 mix
(N= 2 msa & N= 10 msa)

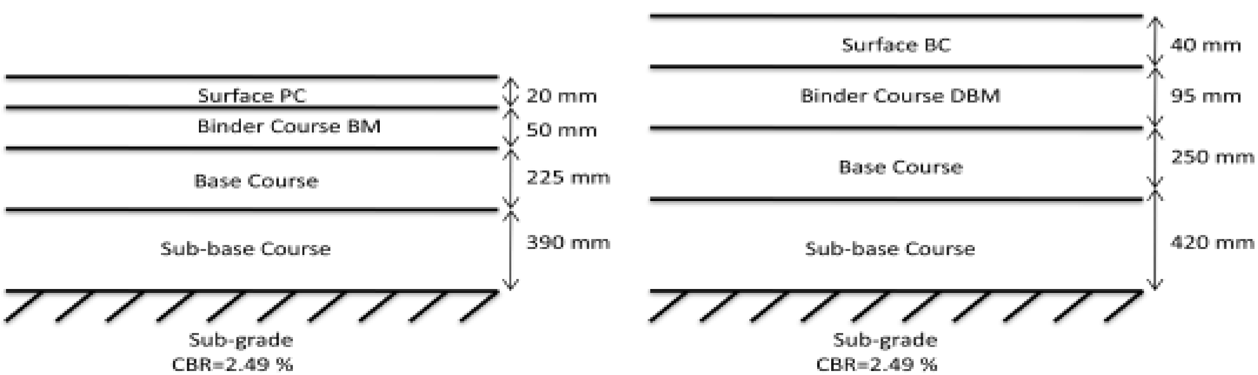

Figure 6 Flexible Pavement for 70:30 mix
(N= 2 msa & N= 10 msa)

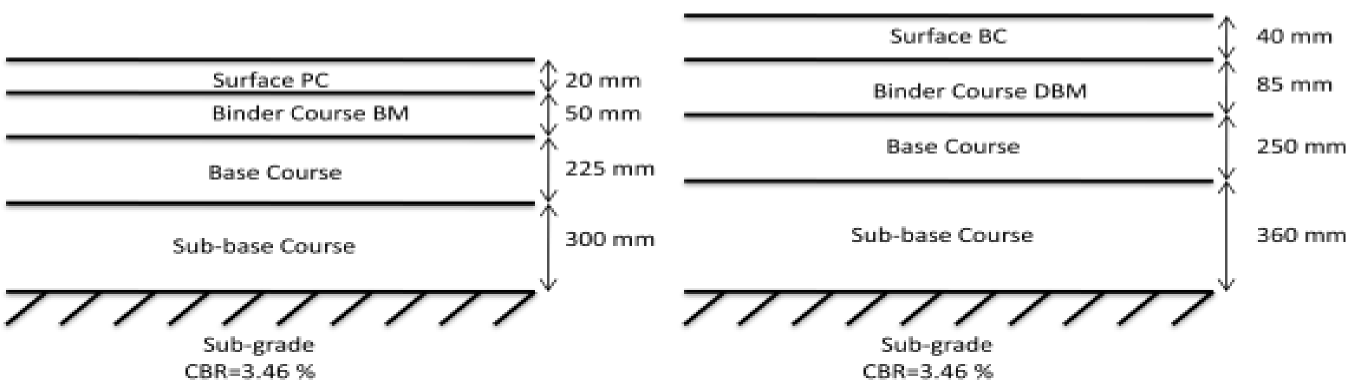

Figure 7 Flexible Pavement for 60:40 mix
(N= 2 msa & N= 10 msa)

6. Cost Analysis (N =2 msa and 10 msa)

The cost of the flexible pavement designed for the virgin soil and the various mixes is arrived at per m^2 area. The results of the cost analysis are presented in Table 7.

Table 7 Cost Analysis

Mix Proportion (Soil: Salt)	Total Cost (Rs.)	
	N= 2msa	N= 10 msa
100:0	1959.5	2515
90:10	1509.5	2065
80:20	1509.5	2065
70:30	1294.5	1830.5
60:40	1177.5	1687.5

The table 7 shows that the greater the proportion of the salt, the less is the total cost. This is because of the fact that as the proportion of salt increases, the soil not only becomes less plastic but also stronger resulting in the elimination of both the buffer layer and capping layer.

7. Conclusions

Based on various test results, design of pavements and the cost analysis, the following conclusions have been made:

- Addition of textile waste salt to the expansive subgrade not only makes it less expansive and stronger but also solves the disposal problem of the waste
- Addition of waste salt to the virgin soil reduces its liquid limit and the plasticity index values so much that the soil changes from CI to CL or CL-ML (in the case of 60:40 mix).
- Design CBR value increases from 1.4% (for virgin soil) to 3.46% (60:40 mix) and to 2.49% (70:30 mix). As the addition of waste salt not only reduces the plasticity of the soil but also increases the strength, both the buffer layer and capping layer which would have otherwise been introduced between the subgrade and subbase are eliminated resulting in the huge saving in the cost for the pavements designed to rest on these mixes.
- But, in the case of 80:20 mix and 90:10 mix the buffer layer is eliminated because the mix is made less plastic by the addition of the salt whereas the capping layer could not be eliminated as the mix is still weak with a CBR value less than 2%.
- A cost reduction of 34% and 40% is observed in 70:30 and 60:40 mix respectively, when compared to flexible pavement designed for 2 msa on virgin soil. Similarly, the corresponding reductions in these mixes for 10 msa are 27% and 33% respectively. This shows that the saving in cost is more for pavements designed for low traffic intensity than that for higher traffic intensity

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