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EFFECT OF COIR GEOTEXTILE AS REINFORCEMENT ON THE LOAD SETTLEMENT CHARACHTERISTICS OF WEAK SUBGRADE

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Abstract: Geotextiles are permeable fabrics which, when used in association with soil, have the ability to separate, filter, reinforce and drain. It is not only allows reduction in the thickness of the pavement on a soft subgrade by the reinforcement action of geotextiles but gives less maintenance problems for long-term use. Coir geotextiles are made from coconut fibre which is a natural material composed of ligno cellulose cell obtained from the husk of coconut.

This paper presents the strength aspects of woven coir geotextiles on weak subgrade. In this paper, the results of laboratory investigation on the load-deformation behavior of the road sections are summarized. Two different varieties of coir geotextiles H2M5 and H2M6 were used as reinforcement in pavement section. The static plate load test results provide evidence that the inclusion of H2M5 coir geotextile gives higher strength at lower deformation compared to unreinforced section. Also, horizontal tensile strain and vertical compressive strain values were determined using KENPAVE software. The result of KENPAVE analysis shown that the section reinforced with H2M5 coir geotextile has lower strains as compared to unreinforced and H2M6 coir geotextile reinforced sections.

Keywords: Coir geotextiles, Pavement, Reinforcement, Soft subgrade.

1. Introduction

Over the last six decades, the State and Central Governments had drawn up several policies, programmes and implemented various schemes for the development of rural roads in India. Still there is need for further planned intervention for providing rural connectivity in an optimal way to achieve the objective of 100 percent connectivity, ensuring sustainable development. The Rural Roads Vision - 2025 aims at achieving all weather road access to all habitations by the year 2025 [1].

Road engineers are often faced with the problem of constructing roadbeds on or with soils which do not possess sufficient strength to support wheel loads imposed upon them either in construction or during the service life of the pavement. Road construction and maintenance along difficult soils have been problematic due to their inherent potential for volume change in the presence of water, which adversely impacts the performance of roads. Unless the subgrade is appropriately treated at the construction stage, the total transportation cost will increase substantially due to deteriorated pavement performance and associated road user costs.

Geosynthetics have proven to be the most versatile and cost effective ground modification material. Most of the geosynthetics are made of polymeric material. Natural geotextiles made of coir, jute, etc. are preferable to synthetic fibres on account of the fact that the material is environment friendly and ecologically compatible as it gets degraded with time. Moreover, natural fibres are less costly which make it a better choice compared to synthetic fibres. Reinforcing the sub grade using coir fabrics helps to distribute the load over a wider area and results in enhanced bearing capacity and reduced settlement. In the case of a pavement, this would result in reduced thickness of road structure and less earth work when it is used as a membrane between the subgrade and the overlying thin granular sub base layer. For unstable and wet subgrade, a coir fabric appears to provide satisfactory solution to stability and drainage problems.

2. Coir geotextile for Strengthening Subgrade

Coir is a 100% organic naturally occurring fibre, from a renewable source obtained from coconut husk. Naturally resistant to rot, moulds and moisture, it needs no chemical treatment. Hard and strong, it can be spun and woven into matting. Geotextiles made of coir are ideally suited for low cost applications because coir is available in India in abundance at very low price compared to other synthetic geotextiles. These geotextiles can be applied in the construction of unpaved roads where they can be effectively serving the purposes of reinforcement, separation, filtration and drainage.

induced by the traffic loads. At this stage, the subgrade may be strong enough to support the loads on its own without the necessity for reinforcement. For such applications, where the strength of subgrade increases with elapsed time, the natural reinforcement products are extremely suitable. After the degradation of the coir geotextiles, the organic skeleton remains in place in compressed form which will act as a filter cake keeping the moisture content of the subgrade soil constant.

3. Literature Review

Subaida et al. [2] conducted experiments to investigate the beneficial use of coir geotextiles as reinforcing material in a two layer pavement section. The effects of placement position and thickness of geotextiles on the performance of reinforced sections were investigated using two base course thickness and two types of woven coir geotextiles. The test results indicate an enhancement in the bearing capacity of thin sections.

Baruah et al. [3] studied the variation in the resistance of soil in terms of CBR value with respect to placement of coir mat in CBR mould from top surface of soil. The test results revealed that, in soaked condition the inclusion of coir mat has improved the CBR by nearly two times.

Raji et al. [4] carried out field simulation on subgrade soil with different combination of fly ash, cement and coir geotextile using a wheel tracking apparatus. It was reported that the subgrade obtained with the application of fly ash, cement and coir geotextile gives significant improvements in performance of subgrade in terms of rutting. The investigators also suggested that the rut depth and wheel repetitions obtained can be utilized for predicting the design life of unpaved roads in terms of number of load repetitions.

Nithin et al. [5] conducted model studies to investigate the beneficial use of coir geotextiles as reinforcing material on weak lateritic soil with Wet Mix Macadam (WMM) representing unpaved roads on soft subgrade. The coir geotextiles are kept at

Coir geotextiles are found to last for four to six years within the soil environment depending on the physical and chemical properties of the soil. When it is used as reinforcement, the coir layers can share the load with soil until its degradation thus increasing the load bearing capacity of the subgrade. When coir geotextiles are used, they also serve as good separators and drainage filters. In many instances, the strength of subgrade soil increases in course of time as the soil undergoes consolidation different levels in the subgrade model sections for studying the effect of position of geotextiles in upgrading the bearing capacity of soil under the monotonic loading system. It was reported that there

is a considerable amount of increment of the bearing capacity of reinforced subgrade with respect to the unreinforced subgrade at a specified settlement. The placement of coir geotextiles at base and subgrade interface shows a significant increase in the load at higher settlements due to the membrane action. Whereas, placing the coir geotextile within the base course resulted in a considerable increase in load at small as well as at large settlements.

4. Objectives of the Study

The major objectives of the study are as follows:

i. To study the feasibility of coir geotextile as a soil stabilizing material for application in road pavements.

ii. To compare the performance of H2M5 and H2M6 coir geotextile as a soil stabilizing material.

iii. To study the variation in vertical displacement and vertical stress under the static loading for coir geotextiles reinforced and unreinforced sections.

iv. To carry out the stress analysis of coir geotextiles reinforced section under loading by KENPAVE software.

5. Experimental Studies and Results

The study was conducted on the soil sample using two different coir geotextiles (H2M5 and H2M6). California Bearing Ratio (CBR) and Plate Load tests were conducted to evaluate the strength properties of the soil and to compare the influence of the different types of coir geotextile on them. The details of the testing programs are explained below:

5.1 Materials Used for Investigation

5.1.1 Subgrade Soil

The coastal area soil subgrades are predominantly composed of silt and clays. Coastal zone with poor soil subgrade was considered in this investigation. problematic soil classes. Material characterization has been made as per Indian standard specifications [6]. The values are summarized in Table 1.

Table 1: Properties of soil used

Sl No.	Properties	Value
1	Specific gravity	2.67
2	Coefficient of uniformity (Cu)	10
3	Coefficient of curvature (Cc)	0.32
4	Liquid limit (%)	27
5	Plasticity index (%)	12
6	IS Soil classification	SC
7	Optimum moisture content (%)	12
8	Maximum dry density (g/cm^3)	1.94

5.1.2 Coir Geotextiles

Two types of coir geotextiles designated as H2M5 and H2M6 were used in the experimental work. The physical properties of these coir geotextiles are reported in Table 2 [7]. Figures 1 and 2 show photographs of H2M5 and H2M6 coir geotextiles.

Table 2: Physical properties of H2M5 and H2M6 Coir geotextile

Sl.No	Parameter	H2M5	H2M6
1	Material	100% Natural coir fibre	
2	Mass/unit area (g/m^2)	740	365
3	Mesh size (mm x mm)	9 x 9	20 x 20
4	Thickness at 2kPa (mm)	9.0	7.57
5	No. of warp thread	11.0 per dm	4.6 per dm
6	No. of weft thread	7.0	4.0
7	Minimum breaking load (kN/m)		
	Warp Way	20	10.30
	Weft Way	18	9.70
8	Tensile strength (kN/m)	10.4	7.8
9	Puncture resistance (N)	920	440

Soil samples were obtained from Keelaiyur-Mattankarai Road in Kuththalam Block, Nagappattinam district, Tamil Nadu, India. The investigation conducted on the soil sample collected show that these silt and clays belong to the

Figure 1: H2M5 Coir geotextile

Figure 2: H2M6 Coir geotextile

5.2 California Bearing Ratio (CBR) test

The CBR value of the virgin soil sample was found to be 2%. Hence the soil was inferred to be weak in strength. CBR test was conducted for soil sample stabilized with two different varieties of coir geotextiles H2M5 and H2M6 placed at heights of h/2, h/3 and h/4 from the top of the mould, h is the height of the mould.

5.2.1 Results from CBR test

Load-penetration curves were plotted for the observations obtained from the tests. The curves for each type of coir placed at different positions were compared as shown in Figures 3 and 4. The CBR values obtained for different specimens are given in Table 3. It can be observed from the results that there is a considerable increase in the CBR value due to the presence of coir geotextile. Coir geotextile is more effective when placed near the top of the soil sub-grade due to the coir's presence come in the loading plane of the plunger.

Table 3: CBR test results

Type of Coir Geotextile	Placement of Coir Geotextile from top		
	h/4	h/3	h/2
H2M5	9.0%	7.5%	6.0%
H2M6	7 .5%	7.0%	5.0%
Unstabilized		2%	

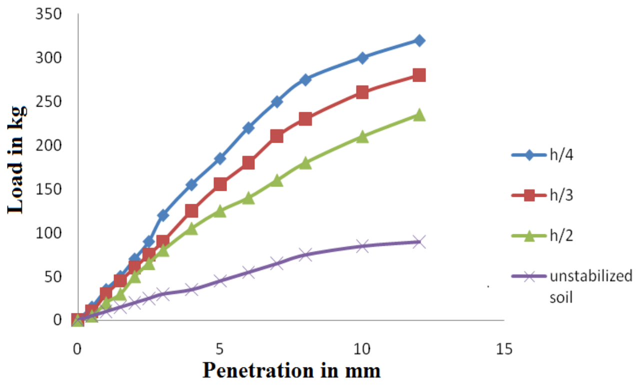

Figure 3: Load-Penetration curve for H2M5 at various positions

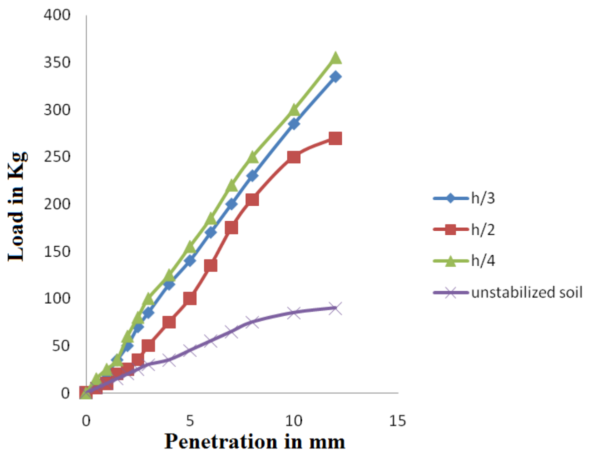

Figure 4: Load-Penetration curve for H2M6 at various positions

5.3. Plate Load Test

5.3.1 Experiment setup

Plate load tests were carried out to investigate the behaviour of soil reinforced with coir geotextile. The tests were performed in a mild steel rectangular tank of size 1.2 m x 1.2 m in section and 0.75 m deep. The loading was done with the help of 200 KN capacity hydraulic jack and reaction frame through a proving ring of capacity 50 KN.

5.3.2. Experimental procedure

The dry soil sample was thoroughly mixed with water to attain the maximum dry density and compacted in layers at required height. The water content and dry density of soil was kept constant in all the layers and equal to 12% and 1.94 g/cm^3 respectively. To achieve this, the water content of soil was determined before each layer and the water content was adjusted accordingly. Reinforced section was prepared by laying coir geotextiles at the middepth of subbase. The load was applied through a circular plate of 150 mm in diameter and 25 mm thick. The vertical deformation of the steel plate were recorded using dial gauge of the least count 0.1 mm. Load was applied at regular intervals and corresponding settlement were noted. The soil was loaded till failure. Different test sections used for testing are given in Table 4. The load setup and test process are shown in Figures 5 and 6.

Table 4: Test sections used for testing

Test Sections	Subbase thickness (mm)	Type of Coir Geotextile	Location of Coir Geotextile
Soil + Subbase	280	-	-
Soil + Subbase + Coir geotextile	280	H2M5	Mid- depth of Subbase

Figure 5: Coir geotextile at mid-depth of subbase

Figure 6: Loading arrangement for Plate load test

5.3.3 Results from Plate Load Test

The plate load test was carried on all the test sections. Figures 7 and 8 represent the relation between load and settlement for with and without coir geotextile respectively.

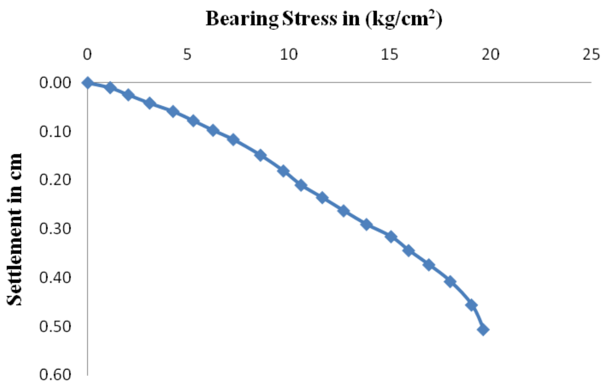

Figure 7: Load-Settlement curve for soil without Coir geotextile

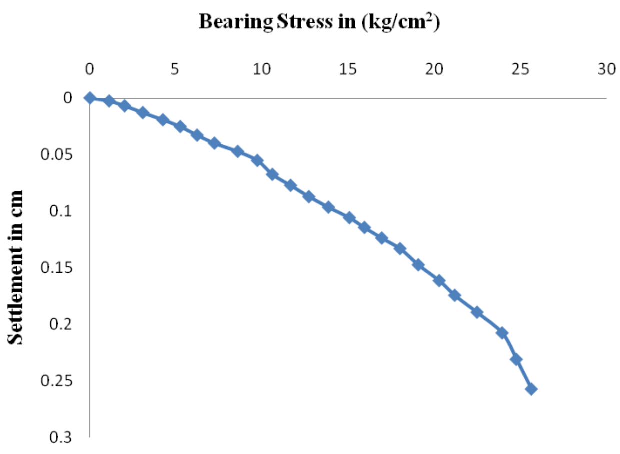

Figure 8: Load-Settlement curve for H2M5 Coir geotextile reinforced section

It is observed that the load sustained by the soil sample was 10.5 kN at a 20 mm settlement and the section reinforced with H2M5 coir geotextile can sustain a load of 23.85 kN for the same settlement. The percentage increase in load is 127% and at greater settlement the percentage increase was still higher.

6. KENPAVE Analysis

The analysis was done using the computer software KENPAVE for pavement design and analysis. The backbone of KENLAYER is the solution for an elastic multilayer system under a circular loaded area. The software does linear elastic multi-layer analysis to obtain the results including stresses, strains and deflections.
KENPAVE software was used to analyze the reinforced and unreinforced pavement sections with subgrade, sub-base, base and surface course. The sections were analyzed by using input parameters given in Table 5.

Table 5: Input parameters used for KENPAVE analysis

Sl.No	Parameter		Values
1	Material		Linear elastic layered system
2	Axle load		10.2 tonne
3	Tyre pressure		7 kg/cm^2
4	Commercial vehicle per day		200
5	Rate of growth of traffic		7.5%
6	Vehicle damage factor		0.75
7	Carraige way		Single lane
8	Subgrade thickness (mm)		500
9	Subbase thickness (mm)		450
10	Base thickness (mm)		500
11	Dense Bituminous Macadam thickness (mm)		80
12	Semi Dense Bituminous Concrete thickness (mm)		30
13	Elastic Modulus (MPa)	Subgrade	20 *
		Subbase	62.52 *
		Base	76.27 *
		DBM	1500 **
		SDBC	1700 **

*Elastic Modulus computed by using empirical formula given in IRC 37: 2012 [8].
** Assumed values of Elastic Modulus

6.1 Section Considered for KENPAVE Analysis

The pavement section designed by using above parameters was used as the primary section and various models of pavement sections were developed by varying thickness of the base and sub base course. Figures 9 and 10 show the primary section used for analysis

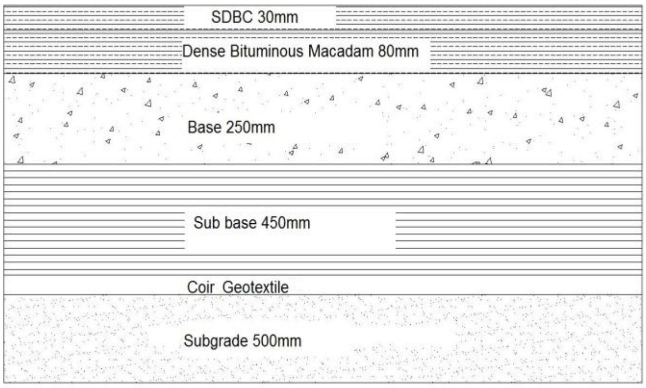

Figure 9: Pavement section with coir geotextile at interface of subgrade and subbase

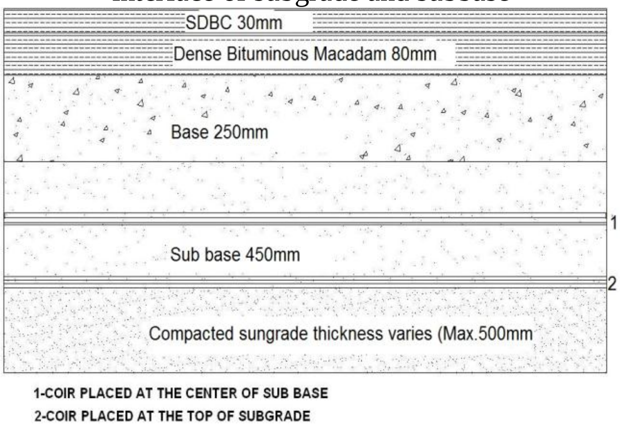

Figure10: Pavement section with coir geotextiles at interface and mid-depth of subbase

6.2 Output

The outputs of the analysis were settlement, tensile and compressive strains and shear stress. The behaviour of the pavement sections considered for analysis were studied by using coir geotextile as an intermediate layer between subbase and subgrade and by placing the coir at the top of subgrade and at the centre of subbase. Comparisons of settlement, stresses and strains at different positions of coir geotextile is shown in Figure 11 to 14.

6.3 Results and Discussion

The variation in settlement, tensile and compressive strain and shear stress for different types of coir placed at various positions, having different base and subbase course thickness are shown in Figures 11 to 14.

It is observed from Figures 11 and 12 that there is significant reduction in the settlement and the compressive strains in the pavement, as the soil is reinforced with the coir geotextile. This is due to the coir acts like a membrane, tension member which provides the necessary reaction to the applied load.

It is also observed that stiffness of coir geotextile significantly influenced the settlement and compressive strain in pavement. H2M5 coir geotextile is more effective in reducing settlement and strains than H2M6 coir geotextile, because of more stiffness. The additional layer of coir geotextile at mid-depth of sub-base further reduces the settlement and strain, but overall effect is marginal.

It has been observed from Figure 13 that reinforced pavement section with coir geotextile reduces the tensile strain in pavement. Coir geotextile has good frictional capabilities and provide tensile resistance to lateral soil movement. It is also observed that the additional layer of coir geotextile in mid-depth of sub-base significantly decreased the tensile strain over loaded area of the pavement by providing an additional lateral confinement. The reduction in tensile strain in pavement section is more for thicker sub-base course.

Figure 14 shows the variation of shear stress in pavement section for reinforced and unreinforced section. The result indicated that the shear stress increase a by minimum 2% for coir geotextile reinforced section. Also it is observed that the additional layer of coir geotextile at mid-depth of sub-base significantly increase the shear resistance of pavement section due to the hardening of lower layers. The improvement in shear stress for H2M6 two layer reinforced section is almost equal to H2M5 single layer section for thicker subbase.

7. Conclusions:

Based on the experimental results and KENPAVE analyses following conclusions were drawn:

1. Coir in the form of geotextile is advantageous for strengthening of weak soil since it reduce the settlement of soil subgrade.
2. Reinforcing the soil with coir geotextile can improve the strength characteristics of the soil.
3. The section reinforced with H2M5 coir geotextile shows significant improvement in the load carrying capacity.
4. Inclusion of a coir geotextile layer, at the interface of subgrade and subbase improves the load settlement characteristics and an additional layer of coir geotextile at mid-depth of subbase produces marginal improvement in the system.
5. Provision of a layer of geotextile at the interface between subgrade and sub base reduces the

deformation by 40%, which in turn results in the reduction of sub-base thickness required.

6. KENPAVE analysis shown that the section reinforced with coir geotextile can carry more traffic load and can be used for low volume rural roads with reduced pavement thickness in subbase course than the conventional section.

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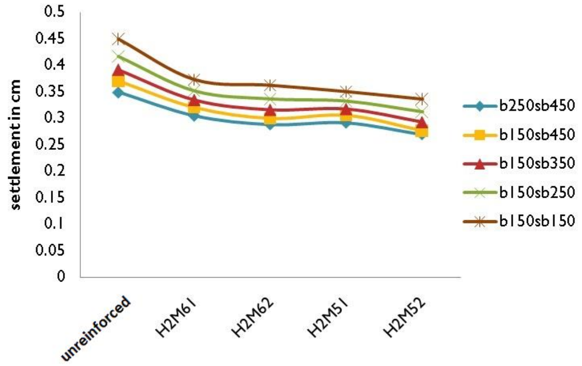

Figure 11: Settlement variation for different sections

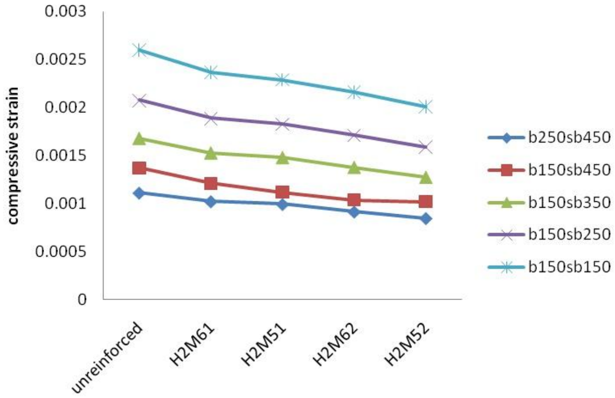

Figure 12: Compressive strain variation for different sections

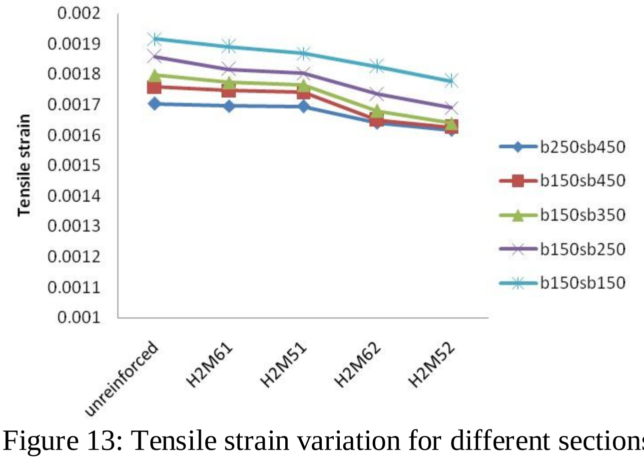

Figure 13: Tensile strain variation for different sections

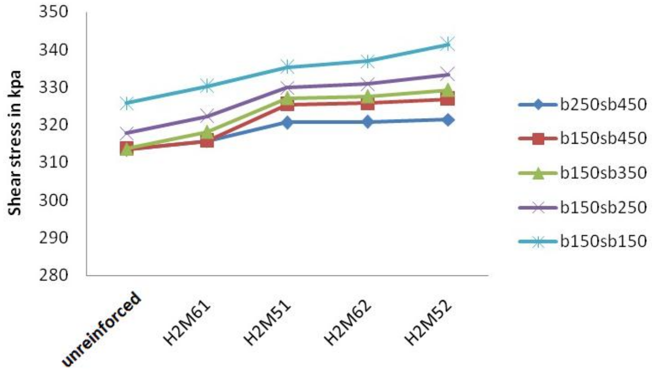

Figure 14: Shear stress variation for different sections

Note: 1) b250sb450 denotes a pavement with base thickness 250 mm and subbase thickness 450mm.
2) H2M51 and H2M61 – Coir geotextiles placed at interface of subgrade and subbase.
3) H2M52 and H2M62 – Additional coir geotextiles layer at mid-depth of subbase

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