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Studies on the Effect of Waste Tires on the Stabilization of Lateritic and Lithomargic Soil Subgrades of Rural Pavements

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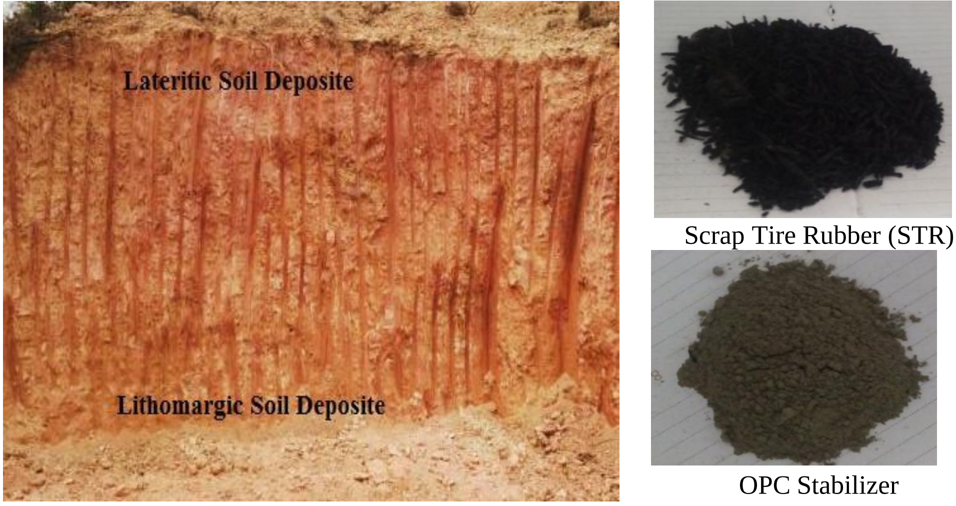
Abstract. In the coastal regions of Karnataka, the lateritic and lithomargic soils are available abundantly. In this study, a successful attempt has been made to use scrap tire rubber as stabilizing additive along with Ordinary Portland Cement (OPC) for the rural lithomargic and lateritic soil subgrade applications. The investigation was intended to determine the engineering soil properties, when lateritic and lithomargic soils were blended with scrap tire rubber (STR) at various dosages along with the fixed dosage of OPC. The results reveal that 12% of STR for lithomargic soil and 8% of STR for lateritic soil can be effectively used to stabilize the subgrade along with 2% of OPC. The stabilization is attributed to the combination of mechanical stabilization in the gradation (STR) along with the chemical stabilization (OPC) of the soil. The pavement composition design (as per Indian standards) with the comparison of performances pertaining to the stabilized and un-stabilized pavement subgrade has been proposed in the paper.

Keywords: Scrap Tyre Rubber (STR), Stabilization, CBR value, Unconfined Compressive Strength, Pavement Design.

1 Introduction

Due to increased heavy traffic volume and extreme environmental conditions, there is increased distress in the conventional bituminous pavements. These increased distresses will lead to the reduced design life of the pavements. Hence, there is a continuous search for better construction techniques that would encounter the existing problems and ensures the satisfactory performance of the resulting pavements. Soil subgrade course will always be considered the most important layer which is responsible for the overall stability of the pavements [14]. Subgrade stabilization is the most used method employed for modifying the properties of weak soil subgrades to improve civil engineering performances. Literature reveals the use of many stabilizing agents, most of them constitute cementing agents, mechanical stabilizers, industrial by-product materials, chemicals etc.; use of locally available waste materials in stabilization works could reduce the burden on solid waste disposal problems of local governments. The management of industrial wastes is considered to be a major concern for town planners due to the increasing quantum of demolition rubble, shortage of dumping sites, increase in transportation and disposal costs and above all growing concern about pollution and environmental deterioration. The Central Pollution Control Board (CPCB) of India estimated that the amount of solid waste generation in India is about 48 million tons per annum of which waste from the construction industry accounts for 25% [16, 21]. Amongst these solid wastes, rubber waste has historically represented a significant solid waste management and disposal problem, as evidenced by large stockpiles that have become public health hazards and liabilities. This problem is largely due to the fact that recycling of rubber waste is very less. Large amounts of rubbers are used in the manufacture of vehicle tires (the largest consumption of rubber, greater than 65% in the automobile industry alone). But after a long run, these tires are either discarded or the reuse is very minimal. As a result, huge quantities of rubber waste are being generated every year. Due to the special properties of certain types of synthetic rubber, there are now more than a hundred thousand types of articles in which rubber is used as a raw material. This poses two major problems: wastage of valuable rubber and disposal of waste tires leading to environmental pollution. Every year millions of new vehicles were added to the roads, and the production of scrap tires from the old aged (scrap) vehicles is also of higher order, which creates a burden on the disposal-related problems with the local government [1]. For this reason, the emphasis is more on the reuse of rubber waste products (eg. scrap tires). As a result today, many of the applications are in civil engineering-related fields. Scrap rubber tires can be used in several ways either as a whole or shredded. Shredded tires obtained from scrap tires have been used as an alternative fill material for road, embankment and backfill construction- specifically to embankment fill, retaining wall and bridge abutment backfill, insulation layer to limit frost penetration, vibration damping layer and drainage layer etc. Whole waste tires have found demand, suitability and economic advantages in fields such as erosion control, highway crash barriers, breakwaters, dams, artificial reefs, playground equipment, etc [17]. Hence, in the present study, an attempt was made to utilize the locally available Scrap Tire Rubber (STR) in the stabilization process of the locally available soils at the coastal region of the undivided Dakshina Kannada district of Karnataka state. Figure 1 illustrates the ground profile, showcasing lateritic and lithomargic soil stratum respectively at the top and bottom regions in the locality where the soil is collected for the investigation. Figure 1 also indicates the Scrap Tire Rubber (STR) and Ordinary Portland Cement (OPC) Stabilizer used for this investigation. Many studies revealed the utilization of OPC as a fundamental additive to stabilize the locally available lithomargic, lateritic soils and successfully could able to implement the application to the desired levels [13, 18, 19]. The presence of OPC mainly leads to the binding of individual soil grains and thereby the attainment of chemical stabilization of the soil [15], whereas the use of waste rubber tires in (shredded form) would help the soil to achieve improved gradation properties and thereby achieve the mechanical stabilization of the latter soil [13]. Hence, the main objective of this study is to investigate the effect of STR in cement stabilized lithomargic and lateritic soils through geotechnical investigations.



Scrap Tire Rubber (STR)

OPC Stabilizer

Fig. 1. Cutting Showing a typical Profile of Lateritic and Lithomargic Soil. Scrap Tire Rubber (STR) and OPC used for the investigation.

2 Materials and Methodology

The lateritic soil and lithomargic soils for this investigation were collected from the local area. The basic geotechnical properties of the soil are indicated in table 1. The scrap shredded rubber tire waste chips were obtained from tire rethreading centres and prepared to pass 19 mm down size, retained on a 4.75 mm sieve and had an approximate thickness of about 2 mm. The specific gravity of these STR is found to be 1.18. These STR were free from steel wires or any form of impurities. Grade 43 OPC was also used as a binding chemical stabilizing additive with STR, whose specific gravity was found to be 3.15, initial and final setting time was found to be 96 minutes and 275 minutes respectively, and Le-Chatelier’s soundness was about 0.90 mm. The tests to learn the effect of the stabilizer on the geotechnical features were done as per the appropriate Indian standard codes of practice.

Initially, the preliminary tests on the lithomargic and lateritic soils, OPC and STR were performed. From the preliminary studies, the optimum dosage of OPC was fixed at 2% by weight of soil and was maintained the same throughout the investigation for both types of soil. Further, the dosages of STR were increased from 0% to 16% at a regular interval of 4% and the compaction properties were studied. Nomenclature M indicates the mix and the suffix number indicates the percentage of STR with respect to the weight of the soil; for an instant, M-4 indicates the soil mixed with 4% of STR. For the selected mixes the California Bearing Ratio (CBR) Tests and Un-confined Compressive Strength (UCS) tests were performed and the results were reported as an average of three consecutive sample test results. The sequence of the compaction, CBR and UCS Testing of soil samples are typically presented in figure 2. The pavement design suggestions were proposed based on the IRC recommendations for the low volume road applications using the IRC: SP:62 guidelines for low volume concrete (rigid) pavements [3] and IRC: SP-72 for the bituminous (flexible) pavement applications [2].

Table 1. Properties of Soil.

Soil Property	**Soil Type**		**Test Method**
	Lateritic Soil	**Lithomargic Soil**	**(BIS code)**
Specific Gravity (G)	2.57	2.32	IS 2720-3: 1980 [12]
Shrinkage Limit (%)	24.3	27.1	IS 2720-5: 1985 [8] ;
Plastic Limit (%)	27.2	29.7	IS:2720-6: 1972 [9]
Liquid Limit (%)	49.2	59.3	
Standard Proctor Test			
(i) OMC	14.70 %	20.68 %	IS 2720-7: 1980 [11]
(ii) MDD	1.84 g/cc	1.51 g/cc	
Modified Proctor Test			IS 2720-8: 1983[10]
(i) OMC	13.90 %	19.62 %	
(ii) MDD	1.92 g/cc	1.63 g/cc	
IS Classification	SP-SM	MH	IS 1498: 1970 [4]
UCS value (kPa)	163	93	IS 2720-10: 1991 [5]
Permeability (k) cm/s	2.87×10^{-7}	9.21×10^{-9}	IS:2720-17:1987 [7]
Soaked CBR value (%)	9.0	2.4	IS: 2720–16 1987 [6]

Fig. 2. Sequence of Compaction, CBR and UCS Testing of Soil Samples.

3 Results and Discussions

Table 2 indicates the results from the standard proctor compaction tests which is reported as a mean from three tests for the OPC-STR stabilized lateritic and lithomargic soil mixes. From the results, it can be noticed that as the dosage of STR increases there is an increase in the "maximum dry density" (MDD) of the mix up to a certain limit and then further increment of STR lead to the decrement of the MDD value; whereas, the Optimum Moisture value (OMC) of the mix did not show any studied trend. The increment of the STR dosage made the soil relatively drier and the soil particles tend to separate as single grained structure, because of which there was an irregular water requirement for the highest compactness observed during the compaction tests. From the compaction test results, the lateritic soil attained the highest MDD at 8% dosage of STR in the presence of 2% OPC, whereas the lithomargic soil attained its peak value of MDD at 12% dosage of STR in the presence of 2% OPC. For lateritic soil mixes, there was an increment of 14% and for lithomargic soil mixes, there was an increment of 24% of MDD compared with the mixes without stabilizer dosages. Hence, these respective mixes were considered for the UCS and CBR tests.

Table 2. Compaction Properties of STR-OPC Modified Soil.

Mix ID	% STR	% OPC	Lateritic Soil		Lithomargic Soil	
			OMC (%)	MDD (g/cc)	OMC (%)	MDD (g/cc)
-	0	0	14.70	1.84	20.68	1.51
M-0	0	2	14.29	1.93	20.12	1.62
M-4	4	2	15.72	1.96	22.70	1.68
M-8	8	2	17.00	2.10	22.93	1.77
M-12	12	2	16.62	2.00	22.69	1.88
M-16	16	2	17.05	1.88	23.45	1.65

Table 3.CBR and UCS results of selected STR-OPC Modified Soil.

Mix ID	% STR	% OPC	Lateritic Soil		Lithomargic Soil	
			CBR value	UCS value	CBR value	UCS value
-	0	0	9.0 %	163 kPa	2.4 %	93 kPa
M-0	0	2	10.2 %	219 kPa	4.72 %	112 kPa
M-8	8	2	18.2 %	293 kPa	-	-
M-12	12	2	-	-	8.51 %	156 kPa

Further, the CBR and UCS tests were conducted for the selected three mixes only. Reference mixes with 0% STR (with 0% OPC and 2% OPC) and optimum mixes i.e., 8% STR (with 2% OPC) for lateritic soils and 12% STR (with 2% OPC) for lithomargic soil. Table 3 shows the results of UCS and CBR tests. The test results reveal that the CBR value could be increased to 102% and UCS value to about 80% with the incorporation of 8% STR with 2% OPC for the lateritic soil; whereas for the lithomargc soil the CBR value could be increased up to 250% and the UCS value to higher than 65% with the incorporation of 12% STR with 2% OPC. Further, it was also observed a reduction in the cohesion value and increment in the angle of internal friction value for both the soils upon the STR-OPC modifications. These observations of enhanced geotechnical performances may be attributed to the enhancement of the "post-peak strength" of the material upon reduction in the stiffness value as reported by the previous studies on a type of soil; where they also reported a decrease in the strength performance upon the increment in the dosage of rubber which is attributed towards the decrease in the "elastic energy capacities" of the resulting soil composite after a permissible dosage level of the rubber particles [20]. Hence the dosage of STR cannot be increased beyond certain limits for the given soil under consideration.

For the rigid pavement design applications, as per IRC:SP:62, the modulus of subgrade reaction (k) could be determined from the soaked CBR value of the soil. Since there is an increase in the soaked CBR value of the STR-OPC modified lithomargic and lateritic soil subgrades, it could be able to develop economical design composition for rigid pavements of low-volume rural roads. There will be about 30% improvement in the k-value of the STR-OPC modified lateritic soil and about 72% improvement in the k-value for the STR-OPC modified lithomargic soil subgrades. Similarly, for the flexible pavement case as per the guidelines provided in IRC:SP-72, a typical pavement composition for the unmodified and STR-OPC modified lithomargic and lateritic soil subgrades has been proposed in Table 4 for the design traffic of 0.9 million standard axles, which is classified under traffic category of T-7 as per IRC-SP 72 [2]. The open graded premix carpet (OGPC) surface course of 20 mm thickness is considered common for all the compositions. Also, WBM of grade III with 75 mm thickness is also warranted to be used in low-volume roads. From the approximate pavement design composition table 4, with the usage of STR-OPC modifier, a reduction of 4% of the total thickness in the case of lateritic soil and around 15% reduction in the case of lithomargic soil could be achieved. However, the exact design of the flexible and rigid pavements could be achieved by studying the actual field conditions and accordingly the composition design could be developed. The results were encouraging and this would further lead to the savings in the huge amount of natural or virgin materials used for the construction of pavements along with the reduction in the cost of construction which lead to the achievement of sustainability with the economy in construction. The outcome of this study also gives a sustainable alternative to the disposal problems associated with the disposal of rubber wastes which otherwise could go as a non-degradable landfill.

Table 4. Typical design composition of flexible pavement as per IRC:SP-72.

Mix ID	**Soil Subgrade**	**Total Thickness (mm)**	**Design Composition (mm)**				
			SG	**GSB**	**GB**	**WBM**	**OGPC**
-	Lateritic soil	695	300	150	150	75	20
M-8	Modified Lateritic soil	670	300	125	150	75	20
-	Lithomargic Soil	820	300	225	200	75	20
M-12	Modified Lithomargic soil	695	300	150	150	75	20

Note: GB: Granular Base; WBM: Water Bound Macadam Base;
OGPC: Open Graded Premix Carpe; GSB: Granular Treated Sub-Base; SG: Soil Subgrade

4 Conclusions and Future Scope

Under the present scope of the study, limited experimental investigations on geotechnical properties are studied to understand the stabilization of locally available lithomargic and lateritic soil subgrades in the region of the un-divided Dakshina Kannada district. After the preliminary investigations on both the soil, and the compaction tests were performed by the incorporation of the various dosages of STR contents at regular intervals up to 16% with a constant 2% OPC content. Based on the compaction outcomes, the optimum dosage of STR for lateritic and lithomargic soils was obtained respectively as 8% and 12% with 2% OPC content. The UCS and CBR tests were carried-out only on a few selected samples with the optimum dosage of stabilizer and on the reference mixes. The test results reveal that the CBR value could be increased to 102% and UCS value to about 80% with the incorporation of 8% STR with 2% OPC for the lateritic soil; whereas for the lithomargc soil, the CBR value could be increased up to 250% and the UCS value to higher than 65% with the incorporation of 12% STR with 2% OPC. Further, it was also observed a reduction in the cohesion value and increment in the angle of internal friction value for both soils upon the STR-OPC modifications. The results were extended to understand the effect of STR-OPC stabilization on pavement design applications with a considerable and successful reduction of total pavement thickness that could be achieved for the design and construction of rural pavements. The overall results were encouraging and would further lead to the achievement of sustainability with the economy in the construction of low-volume pavements. The outcome from this study also mainly gives a sustainable alternative to the disposal problems associated with the dumping of rubber wastes which otherwise could go as a non-biodegradable land filler.

However, the investigations could be extended to study further the performance characteristics such as long-term or prolonged strength developments, tri-axial properties, permeability, compressibility characteristics, rutting studies on the pavement models, repeated loading studies, split tensile strength tests, retained strength, etc., so as to gain more confidence in adopting STR-OPC stabilizing combinations in the lithomargic and lateritic soil subgrades. Also, the pavement design for the actual traffic data and field conditions could be studied with the implementations for pavement design applications for both low volume and high volume pavements.

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