Stabilization of Lithomargic Soil Using Cement and Randomly Distributed Waste Shredded Rubber Tyre Chips

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***Abstract*— Lithomargic soil is locally known as Shedi soil, which is found in shallow depth usually under the lateritic soil. These soils tend to destabilize the pavements that are constructed on the embankment or the subgrade made up of lithomargic soil, as they do not have the required shear strength. Thus it is required to improve the engineering properties of this soil before it can be used as a highway material. This soil can be stabilized by various chemical and mechanical means. This paper focuses on the stabilization of the soil using normal 53 grade cement and randomly distributed shredded tyre chips obtained from waste rubber tyres. The rubber when introduced into the lithomargic soil acts as a reinforcing agent and the cement provides the binding aid which fortifies the soil and improves the shear strength by improving the friction component of the latter soil. The modified proctor results have shown the highest value of maximum dry density (MDD) and lowest optimum moisture content (OMC) for the trial mixes, when compacted with 4% shredded rubber pieces and 2% cement, which can be taken as the optimum dosage. The strength is evaluated based on unconfined shear strength and the penetration resistance in terms of California Bearing Ratio (CBR) test for the samples compacted at maximum proctor density for optimum dosage of cement and shredded rubber pieces in the lithomargic soil. The results showed that the lithomargic soil can be effectively stabilized to be used as a highway material to a great extent by making use of waste shredded rubber pieces that would otherwise degrade the environment. This ground modification method is an eco-friendly and cheaper method when compared to other stabilization techniques, using which sustainability with economy can be achieved.**

***Keywords*— Stabilization, Lithomargic soil, Shredded Rubber tyre chips.**

Introduction

In present times, the road conditions of India are deteriorating due to failure in the soil subgrades and embankments. Highway and Geotechnical engineers across the country are searching the alternative to the standard method of soil modification of foundation soil, which is cheap, eco-friendly and give improved performance of the road. Present study aims to provide such an alternative, which is eco-friendly method for the stabilization of road basement. Rubber wastes are generated in large quantities throughout the country from the scrap tyres. Rubber waste is chemically inert with all types of soils and are also a cheap alternative to expensive chemical stabilizers to manufacture and difficult for the application as stabilizer. The investigation is carried out for stabilizing weak lithomargic silty soil (locally known as Shedi soil) which is one of the major type of soil available in Dakshina Kannada and Udupi district of Karnataka. In this context, an attempt is made to overcome the weak nature of lithomargic soil by making use of waste rubber tyre pieces as stabilizing material in addition to the conventional cement, to achieve sustainability and economy in stabilization. By utilizing these rubber wastes, the adverse impact on environment can also be reduced. These are the waste materials, which are abundantly available in nearby tyre repair workshops for free of cost. It is required to mechanically obtain the pieces of these waste tyres to get the required shredded rubber fibers.

I. Objectives of the Present Investigation

1. To study the engineering properties of locally available lithomargic soil.
2. To obtain the optimum dosage of cement and rubber pieces to lithomargic soil from strength criteria.
3. To evaluate the engineering properties of lithomargic soil on addition of obtained optimum percentage of randomly distributed shredded rubber pieces and cement.
4. To check the suitability of randomly distributed shredded rubber to be used as effective soil reinforcing material.

II. Literature Review:

Many researchers made attempt to study the effect of strength behavior of weak subgrade soil on addition of rubber tyre chips, out of which, some of the key research work is briefly outlined here.

Seda et al. (2007) have shown from their research that, one can effectively use waste tyre chips as a potential solution to improve the strength and stiffness properties of expansive soils. Dunham and Friel (2009) observed that the shear strength of rubber chip modified expansive soil may be slightly higher than that of the same normal soil. These major research using rubber chips lead to the development of new field in engineering soil modification named as expansive soil-rubber (ESR) mixture technique referred to as ESR stabilization.

Stabilization of soil using cement has been carried out from early 20th century. Any weak soil is treated with low dosages of cement to achieve required strength (Zhang and Tao 2008). Oyediran and Kalejaiye (2011) have been stated in research that as the dosage of cement is increased, properties like Maximum Dry Density (MDD), California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS) increased while there was reduction in Optimum Moisture Content (OMC).

According to Gomez and Anderson (2012), the normal soil to cement mix design can be gained by using traditional laboratory methods of mixing and Proctor compaction of the soil, which is a reliable procedure to establish the optimum percentage for mix. Jaritngam et al. (2012) have also shown that, cement can be effectively used to stabilize sandy and silty soil to be used as road base course for the pavement.

George Rowland Otoko and Pere Preye Pedro (2014) found that an increase in Unconfined Compressive Strength (UCS value) and California Bearing Ratio (CBR value) of the soil with the increase in cement content at an optimum fiber content of 5% of dry soil. They made the study on Chikoko and on soft lateritic soil and observed an increase in the CBR and UCS values after the modification by making use of randomly distributed rubber chips and cement. Hence concluded that these soils can be effectively stabilized.

Based on the wide literature survey research results, one can effectively make attempt to choose cement and rubber chips as the stabilizing materials for modifying any type of soil. In the present study, an attempt was made to investigate the effect of waste shredded rubber pieces with cement in stabilizing the locally available weak, fine grained lithomargic soil having little swelling nature due to the presence of Kaolinite.

III. Study Area, Materials Used, Methodology, and Essential Properties of the Normal and Modified Soil:

The present study was conducted on pure silty lithomargic soil which is one of the major soil type found to occur most commonly in the coastal regions of the District of Dakshina Kannada, and also in the major parts of peninsular areas of Southern India. The soils which is encountered by Highway Engineers for the construction of embankments and subgrade comprises mainly of pure and blended lateritic and lithomargic soil (Anil Kumar et al. 2015).

In this study the shredded rubber chips used are of length between 6.7 mm and 19 mm. These shredded rubber tyre chips have been obtained from various tyre rethreading centres in Kanhangad, Kerala state. These chips have a thickness of at least 2mm, having specific gravity of 1.18. These rubber chips are sieved through 4.75 mm IS sieve, as to eliminate the smaller shredded pieces. These chips do not possess steel wires or any form of reinforcement.

A 53 grade ordinary Portland cement (OPC) is also used as a binding material in addition to shredded rubber chips for the investigation, and this a fresh cement has been taken from cement bags not less than 3 months old as specified by IS 2269:2009.

TABLE 1.1
Geotechnical Properties of Lithomargic soil used

Specific gravity	2.30
Atterberg's limits:	
Liquid limit (%)	51.1
Plastic limit (%)	27.8
Plasticity Index (%)	23.3
Shrinkage limit (%)	22.1
Gravel (%)	0.0
Sand (%)	13.2
Fines (%)	86.8
Soil classification as per BIS	MH

Laboratory investigations were carried out on lithomargic soil, which was having fines more than 50%. The preliminary geotechnical properties of soil shown in Table 1.1. The specific gravity test, Atterberg's limits and Indices test, combined sieve analysis are carried out as per the relevant parts of Indian standard code IS:2386. The soil classification as per IS: 1498-1899 shown that the given lithomargic soil sample is highly compressible silt.

Further modified proctor test was carried out to study the compaction characteristics of lithomargic soil as per BIS. Then, based on the compaction test results, the California bearing ratio (CBR), and unconfined compression strength (UCS) tests are carried out to understand the strength and stiffness characteristics. The results are tabulated in Table 1.2, which indicates the numerical average results of six tests.

TABLE 1.2
Strength and Stiffness Properties of Lithomargic soil samples

IS heavy compaction:	
MDD	12.2 kN/m^3
OMC	21.9 %
CBR Test:	
Un-Soaked	19.04%
Soaked	06.58%
UCS Test:	
UCS value	37.02 kPa
C-Value	29.1 kPa
Φ-Value	02.26°

In the present work initially an attempt was made by using the results of Modified Proctor (IS heavy compaction) test as per the prescribed procedure in conjunction with the IS 2720-Part VIII-1983, to obtain an optimum dosages of cement and rubber to give maximum proctor density, and this optimum dosage is made use for further strength investigations for the modified lithomargic soil. For achieving it, firstly, the weight of the lithomargic soil passing through 4.75mm IS sieve essential for conducting modified Proctor test is taken and the soil is mixed with rubber at 2%, 3%, 4% and 5% by weight and cement correspondingly added at 2%, 4% and 6% by weight of soil. Then, this soil-cement-rubber mix is mixed well and properly handled so as to make sure the mix is uniform. Then the experiment is continued as per the specifications given in IS code.

The dosage of cement and rubber corresponding to the highest value of maximum dry density was selected as the optimum dosage for the determination of strength using UCS and the penetration resistance in terms of CBR. The details of the test blend and the test results of compaction test are tabulated in Table 1.3.

From the compaction test results it can be observed that an optimum dosage of cement is 2% and dosage of rubber is 4% by weight of the lithomargic soil respectively, for which maximum dry density is achieved (highlighted in the Table 1.3). The variation of MDD with various percentage of rubber pieces for the given dosage of cement is graphically represented in the Fig 1. It's also viewed from the table 1.3 that, the Maximum dry density (MDD) values for test blends, initially increases with increase in percentage of rubber, reaches the maximum value and then decreases.

TABLE 1.3
IS Heavy Compaction Results for trial blends

Sl No	% of Rubber	% of Cement	MDD (kN/m^3)	OMC (%)
1	2	2	17.15	17.35
	2	4	16.325	15.1
	2	6	16.71	15.25
2	3	2	17.675	13
	3	4	17.23	13.5
	3	6	17.6	13.6
3	4	2	18.125	12.65
	4	4	17.6	12.8
	4	6	17.85	14.75
4	5	2	17.64	12.6
	5	4	17.33	12.8
	5	6	17.53	13.1

The shear strength of the modified lithomargic soil is found in terms of unconfined compressive strength (UCS) by conducting Unconfined Compression (UCS) test for the dry lithomargic soil upon the addition of obtained dosage of 2% cement and 4% shredded rubber pieces, compacted at its Proctor density maintaining the optimum Proctor moisture content. The UCS test is carried out in accordance with IS: 2720-1991 (Part 10). The standard UCS test specimens of 38 mm diameter and 76 mm height were prepared and cured in a desiccator maintained at laboratory molding temperature before testing. The tests have been done after 0, 7, 14 and 28 days of curing. The table 1.4 shows the UCS test results for various curing periods for the modified lithomargic soil using optimum blend. The test results tabulated are the average UCS strength of 5 samples tested at various curing periods.

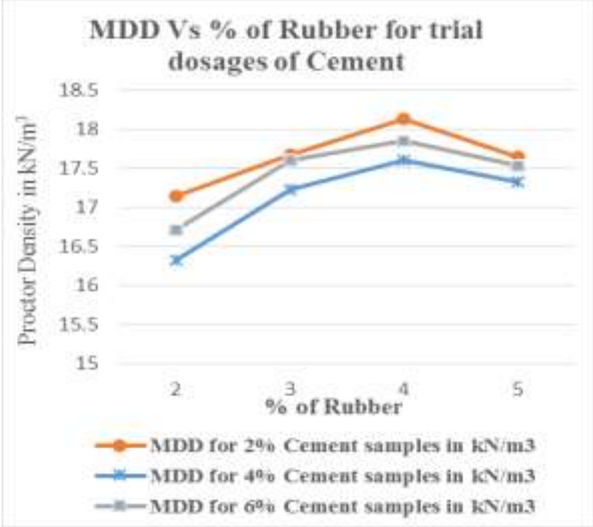

Fig. 1 Proctor density Vs % of rubber

The samples tested for 7, 14 and 28 days showed a barrel shape failure and did not give a good failure plane as shown in Fig 2. This may be attributed to the additives in the mixture, which may have caused the ductile failure. Fig 3 indicates the variation of unconfined compressive strength with the curing time.

TABLE 1.4
Results of UCS test for Modified Lithomargic Soil

Curing Period (Days)	Unconfined Compressive Value (kPa)	C-Value (kPa)	Φ -Value (Deg)
0	64.01	19.04	20.1
7	113.39	18.68	24.8
14	139.63	18.23	25.7
28	193.21	18.00	26.46

Fig. 2 Failed specimen after UCS test

To analyze the effective utilization of this modified lithomargic soil as a highway subgrade material, the California Bearing Ratio (CBR) test is carried as per the guidelines given in IS: 2720 (part 16)-1987.

Fig. 3 UCS strength Vs Curing Period

Fig. 4 CBR Testing

The CBR test is carried out by maintaining the modified proctor conditions for both the lithomargic soil as well as for its rubberized counterpart. The lithomargic soil modified using mixture of 2% cement and 4% rubber worked well in comparison to the unmodified soil. The CBR test has been done for both un-soaked and 4 days soaked conditions. Each of the time its observed that the penetration resistance at 5 mm penetration is higher than that in the case of 2.5 mm penetration. Thus in the result, the reported CBR value is for 5mm penetration. The CBR values indicated in Table 1.5 are the numerical average of 4 CBR tests. Fig 4 shows the CBR Testing machine mounted with CBR test molded soil specimen during testing.

TABLE 1.5
Results of CBR test

Soil	Un-soaked CBR (%)	4 day soaked CBR (%)
Lithomargic Soil	19.04%	6.58%
Stabilized Lithomargic Soil	37.57%	17.27%

IV. Results and Discussions:

Based on the results of the various tests, mainly for the determination of the results of the Modified Proctor compaction test, and strength determination in terms of UCS and CBR performed, the following major outcomes may be observed.

From the Table 1.3, it can be seen from a typical variation that, the Maximum dry density (MDD) values for test blends, initially increases from 17.15 kN/m^3 for 2% rubber, with an increase in percentage of rubber, it increases, reaches the maximum value at 18.125 kN/m^3 for 4% rubber and then decreases. Also, the plot for the variation of MDD with percentage of rubber pieces represented in the Fig 1 indicates that as the cement content increases from 2% to 4%, there is a decrease in MDD and when it is further increased to 6%, MDD value increases. However, this increase is not more than that corresponds to 2% cement. Thus, from the Modified Proctor test results on various trial blends, the optimum dosage of 2% cement and 4% rubber is obtained to check the strength.

The variation of unconfined compressive strength against the curing time shown in Fig 3 indicates that UCS strength is increased from 61.01 kPa for 0 day curing to 193.21 kPa for 28 day curing. This shows that an increase up to 300% can be obtained for the modified lithomargic soil sample tested after 28 days of curing when compared with the sample tested just after preparing, indicating increase in the strength value with the curing time. It can also be seen from the Table 1.2 and Table 1.4 that, while compared with the unmodified lithomargic soil, the modified soil is showing very high UCS value. The modification tend to reduce the value of cohesion and an increase in the value of friction. The curing period also have a minor variation in C and Φ values as indicated in the table. The overall results indicate that the shear strength property of pure lithomargic soil can be effectively modified using optimum dosage of rubber and cement.

The CBR test results indicated from Table 1.5 indicates that by the modification, the both soaked and un-soaked CBR value can be increased. The soaked CBR can be increased from 6.58% to17.27%, and the un-soaked CBR from 19.04% to37.57%. From the observed increase in CBR value, the modified soil can be effectively used as a highway Subgrade material. Thus, the thickness of flexible pavement designed for the given traffic condition in this region will be lesser on the modified soil than that on the natural lithomargic soil on the basis of IRC-37-2012.

V. Conclusions:

1. The optimum dosage of randomly distributed waste tyre chips and cement from the modified proctor test is 4% and 2% respectively.
2. The engineering properties of the weak lithomargic soil can be effectively and econolically increased by the addition of 2% cement and 4% waste shredded rubber pieces.
3. The unconfined compressive strength value of the modified soil increases with the curing time.
4. The randomly distributed tyre chips induce friction to the lithomargic soil, indicated by the increase in the value of ϕ value.
5. The CBR value of the lithomargic soil can be effectively increased when modified with optimum dosage of Cement and randomly distributed tyre rubber pieces.

6. The stabilized soil can be used to reduce the overall thickness of pavement layer, which may reduce the cost of road construction.
7. This modification can be successfully used in areas where the lithomargic soils to improve the bearing capacity while designing the foundation.

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