Stabilization and Durability Analysis of Medium Compressibility Clay using Rubber Fibers

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Abstract. The in-situ soil should bear the load, but at certain instances more adverse conditions may lead to failure of soil and hence can lead to consequence failure of the structures. To avoid these failures, understanding of soil behavior to different loading conditions is essential, thereby arising the need for studying and finding appropriate alternatives. One such alternative is soil stabilization. Tons of rubber waste is produced annually, not only problematic for disposal, but also increase environmental pollution and health risks. The consumption of rubber as an alternative to construction materials can effectively minimize environmental pollution. In this study, rubber fibers in different proportions were added to investigate the effect of rubber fibers on Compaction, UCS, CBR, and durability properties of Intermediate Compressible clay. The tests were conducted on samples with inclusion of rubber fibers in different proportions of 0, 0.5, 1, 1.5, 2 and 2.5%. A comparison was made between light and heavy compaction test. Samples showed decrement in OMC and MDD. Inclusion of rubber fibers with proportion of 1.5% to Intermediate Compressible clay showed maximum increment in UCS and CBR values, and durability was improved due to decrement in weight loss of the specimens in subsequent freeze-thaw cycles.

Keywords: Compaction, Unconfined compressive strength, California bearing ratio, Durability test.

1 Introduction

Soil is a dynamic entity in construction. Soil in the site should be able to bear the load but in adverse conditions soil fails in shear, bearing etc. and hence failure of the structure occurs. To avoid these failures, investigation of the soil is mandatory. It is observed that sometimes the soil doesn't meet the engineering requirements, thereby arises the need for soil stabilization, which improves the soil properties by mechanical and chemical actions.

Considering loads of tons of waste rubber tires produced yearly across the country, which not only poses the problem for disposal but also increases to environmental contamination and health risks, as majority of the waste rubber tires are illegally dumped in landfills. It was observed that if rubber tires are subjected to fire conditions, they burn intensely releasing toxic gases into the atmosphere. Further rubber tires are highly durable and biologically nondegradable and hence can act as effective stabilizing material. Thus, consumption of such refuse and industrial wastes and their secondary products as alternatives to construction materials may effectively subsidize to environmental preservation and minimization of their adversative effects on the environment. The properties of clay including liquid limit, plastic limit, plasticity index, dry density, optimum moisture content, unconfined compressive strength and CBR tests were performed for the different trails. In this paper rubber fibers with different proportions were used to find their effect on stabilization of clay.

Bekhiti et al.,[1] reinforced samples with rubber fibers content of 0, 0.5, 1 and 2% and cement contents of 5, 7.5 and 10% and found maximum UCS and ductility behavior at a rubber fibers content of 2%. Buritatum et al.,[2] incorporated rubber fibers at contents of 0%, 1%, 2.5% and 10% for the reinforcement of the clay and observed when mixed with rubber fibers, the swelling rate decreased to 9.75% at a fiber content of 10%. Kumar et al.,[4] used lime and elastic tire crushed powder and found that by putting 20% of lime and 12% of crushed tire with clay, the compressive strength was enhanced. Signes et al.,[5] found addition of rubber particles to the expansive clay soil exponentially reduced swelling and optimum rubber content to prevent its swelling was 3%. Wang et al.,[6] studied the effects of crumb rubber on the frost resistance of cement-soil for different rubber contents (by weight) of 0, 5%, 10%, 15% and 20% and found higher growth rate of the compressive strength of the rubber cement-soil under a negative temperature. Yadav et al.,[7] focused on inclusion of waste rubber tire fibers on geotechnical properties of cemented clay and found optimum proportion for UCS and CBR was 2.5%. Yadav et al.,[8] used shredded rubber tire passing through 75 micron I.S Sieve and found addition of 4% crumb rubber to the clay soil gave optimum moisture content and shear strength value increased compared to the normal soil.

2 Materials and Methodology

2.1 Materials

Clay. The soil used was collected from a site at NIT, Rourkela. The soil passing through 4.75 mm sieve was collected and stored at room temperature in lab. Geotechnical properties of the soil were analyzed in the laboratory, and it was classified as Medium Compressibility Clay as per IS 1498 (1970). Wet sieve analysis of clay was done as per IS: 2720 (Part 4): 1985. The clay was then tested for Liquid Limit, Plastic Limit and Specific Gravity using density bottle.

The geotechnical properties of the clay obtained is tabulated below:

Table 1. Geotechnical Properties of Clay

Sl. No.	Properties	Value
1	Natural Moisture Content	5% - 7%
2	Specific Gravity	2.67
3	Liquid Limit	40%
4	Plastic Limit	19%
5	Plasticity Index	21%
6	Optimum Moisture Content (OMC)	13%
7	Maximum Dry Density (MDD)	1.9 g/cc
8	Free Swell Index	25%

Rubber Fibers. Rubber has elastic properties and induces ductility to soil. Rubber Fibers extracted from tires were collected for experimental purpose. The size of rubber fibers used in the study was of 3mm x 15mm. These rubber fibers were added to clay in proportions of 0.5%, 1%, 1.5%, 2% and 2.5% by dry weight of clay and the samples were tested.

The properties of Rubber Fibers used is tabulated below:

Table 2. Properties of Rubber Fibers

Sl. No.	Properties	Value
1	Specific Gravity	1.26
2	Water Absorption Capacity	4%

2.2 Methodology Adopted

To evaluate the efficiency of rubber fibers as a stabilizer in clay soil, sequence of tests was conducted by varying the content of rubber fibers that were added to clay soil in proportions by dry weight of the clay taken. The tests performed and Indian Standard codes adhered to are as follows:

- Light Compaction Test – IS: 2720 (Part 7) – 1983
- Heavy Compaction Test – IS: 2720 (Part 8) – 1983
- Unconfined Compressive Strength (UCS) Test – IS: 2720 (Part 10) – 1991
- California Bearing Ratio (CBR) Test – IS: 2720 (Part 16) – 1987
- Dispersion Test
- Durability Test – IS: 4332 (Part 4) – 1968

3 Results and Discussions

3.1 Compaction Test

Light Compaction Test

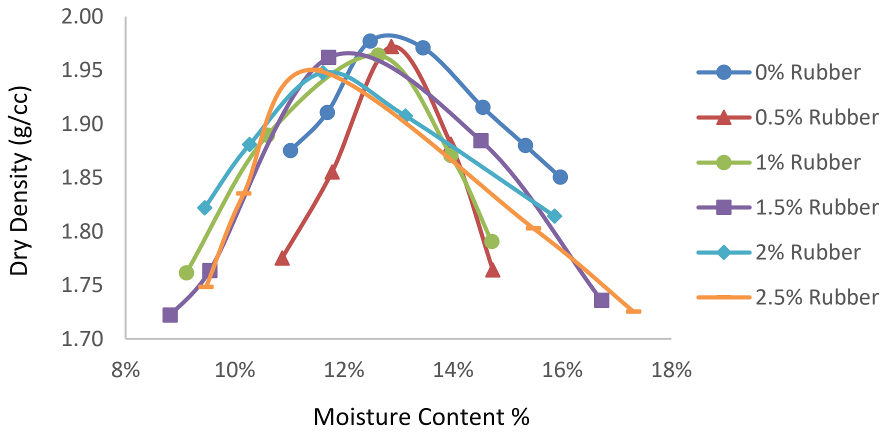

Fig. 1. OMC and MDD of light compaction test for different proportions of rubber fibers.

Heavy Compaction Test

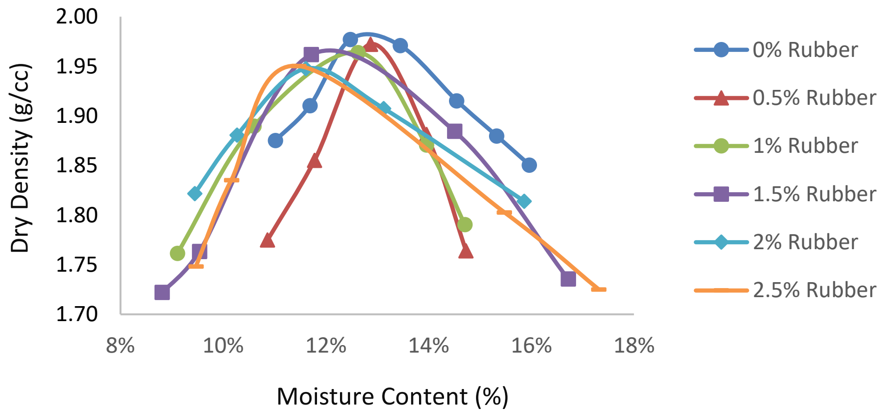

Fig. 2. OMC and MDD of heavy compaction test for different proportions of rubber fibers.

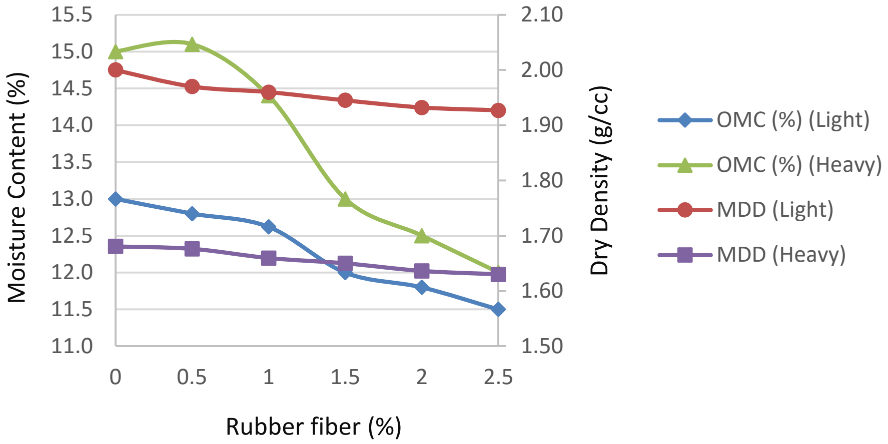

Fig. 3. Comparison of OMC and MDD for light and heavy compaction test.

It was inferred that with the addition of rubber fibers, OMC and MDD for both light and heavy compaction test decreases. This was due to low specific gravity and low water absorption capacity of rubber fibers in comparative to the virgin clay.

3.2 Unconfined Compressive Strength Test

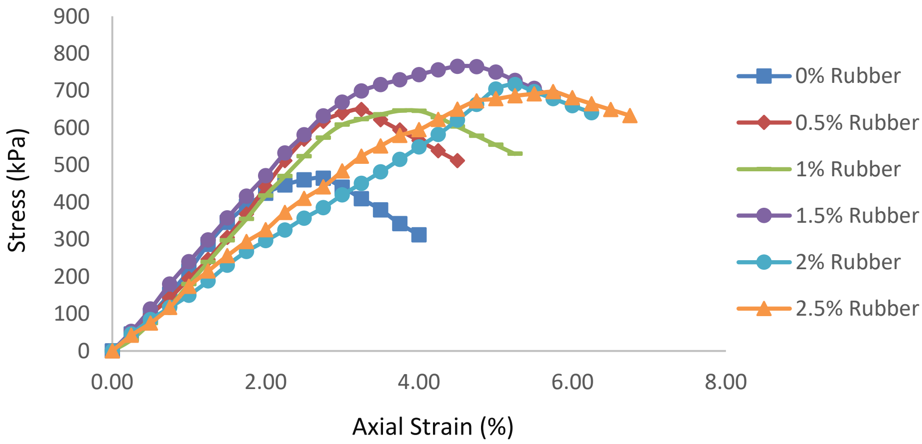

Fig. 4. UCS test for different proportions of rubber fibers.

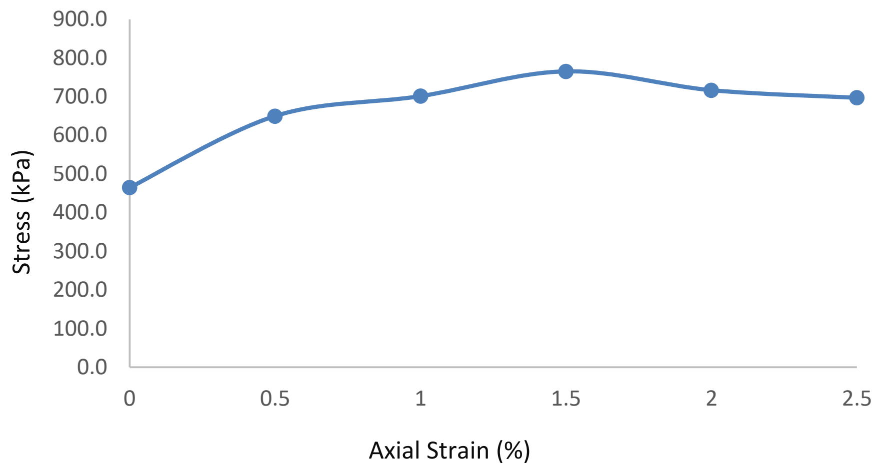

Fig. 5. Variation of UCS with rubber fibers.

It was inferred that with the addition of rubber fibers, UCS increased initially up to 1.5% addition and thereby decreased with further addition of rubber fibers.

3.3 California Bearing Ratio Test

Un-soaked CBR Test

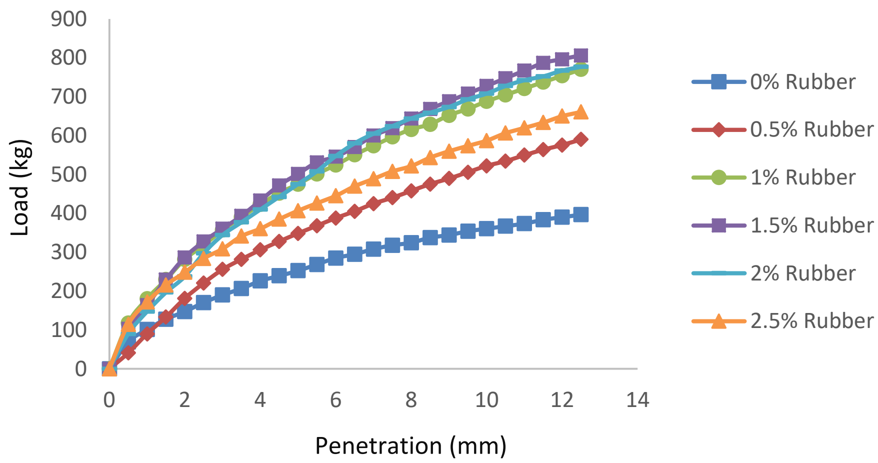

Fig. 6. Un-soaked CBR test for different proportions of rubber fibers.

Soaked CBR Test

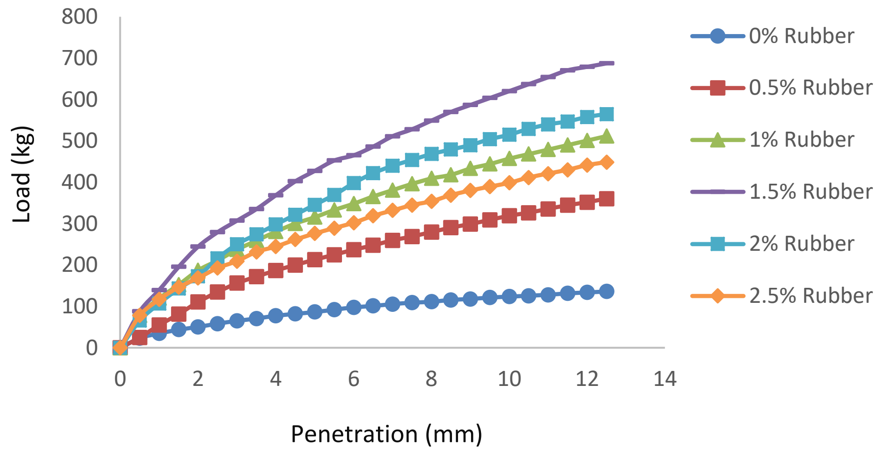

Fig. 7. Soaked CBR test for different proportions of rubber fibers.

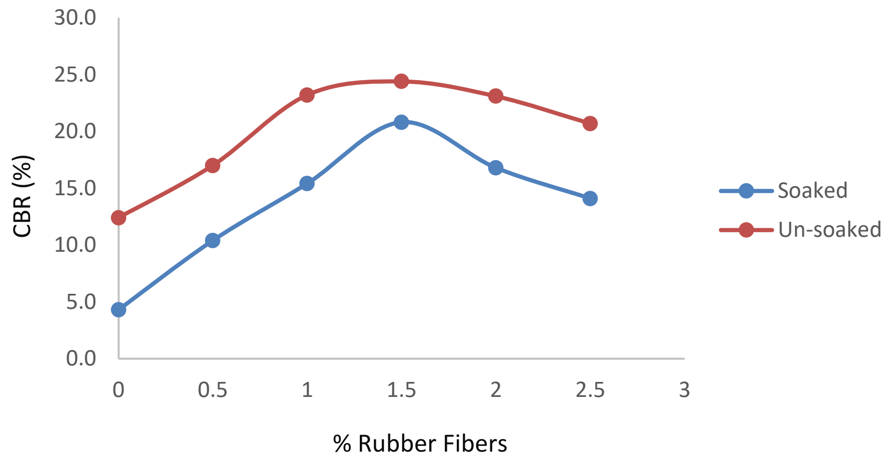

Fig. 8. Comparison of Un-soaked and Soaked CBR values.

It was inferred that with the addition of rubber fibers, CBR value for both Un-soaked and Soaked samples increased initially up to 1.5% addition and thereby decreased with further addition of rubber fibers.

3.4 Dispersion Test

This test is helpful in indicating the potential for dispersion of soils. Dispersive soils are prone for soil erosion easily, hence soils with least dispersion are recommended.

It was inferred from the test that dispersion of clay with addition of rubber fibers reduced compared to that of virgin clay. It is obvious that the rubber fibers act as reinforcement when added to clay, thereby holding the clay particles intact, resulting in reduced dispersion.

3.5 Durability Test

Wetting and Drying Test

The wetting and drying test was performed for the clay samples to check the durability of clay samples subjected to fluctuations in moisture content. After each wetting and drying cycle, the weight loss for the samples was calculated and durability analysis was performed.

The wetting and drying test was performed for the clay samples, and it was inferred that both virgin clay samples and clay samples with rubber fibers failed in the 1st cycle. Hence there was no significant change when rubber fibers were added to the clay

Freezing and Thawing Test

The freezing and thawing test was performed for the clay samples to check the durability of clay samples subjected to fluctuations in temperature. After each freezing and thawing cycle, the weight loss for the samples was calculated and durability analysis was performed.

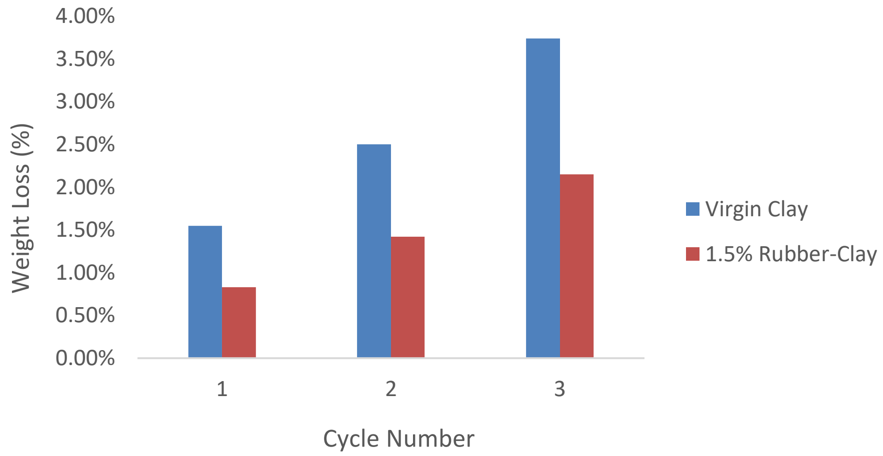

Fig. 9. Weight loss % for freezing and thawing cycles.

The freezing and thawing test was performed for the clay samples, and it was inferred that the weight loss for 1.5% rubber clay was less when compared to virgin clay in each cycle. Thus, addition of 1.5% rubber fibers to clay can increase the durability.

4 Conclusion

- It was inferred that with the addition of rubber fibre, OMC and MDD decreased. This was due to low specific gravity and low water absorption capacity of rubber fibres in comparative to the virgin clay.
- It was inferred that with the addition of rubber fibre, UCS increased initially up to 1.5% addition and thereby decreased with further addition of rubber fibres. Hence the optimum percentage of rubber fibre for maximum UCS was 1.5%.
- It was inferred that with the addition of rubber fibre, CBR value increased initially up to 1.5% addition and thereby decreased with further addition of rubber fibres. Hence the optimum percentage of rubber fibre for maximum CBR was 1.5%.
- It was inferred that with the addition of rubber fibre, there was no notable change in wetting and drying test. However, the weight loss of clay in freezing and thawing test was reduced with addition of rubber fibres which can increase the durability of clay.
- Addition of rubber fibres to the medium plasticity clay improved its strength properties by enhancing the UCS and CBR values at optimal percentage. Hence this method can be used in embankment applications where higher strength (CBR) is a primary requirement.

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