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Improvement of Low Compressible Clays Using Crumb Rubber

Vinjamuri Sri Vaishnavi[1][0000-0001-9373-6487], B.N.D Narasinga Rao[2][0000-0001-8257-1904], Venkateswarlu Dumpa[3][0000-0003-0743-3493] and Chandra Shekar Rayi[4][0000-0001-5494-3563]

[1]Student, M. Tech, Department of Civil Engineering, Anil Neerukonda Institute of Technological Sciences (Autonomous),Sanghivalasa, Bheemunipatnam, Visakhapatnam-531162
[2]Professor, Head of the department of Civil Engineering, Anil Neerukonda Institute of Technological Sciences (Autonomous), Sanghivalasa, Bheemunipatnam, Visakhapatnam-531162
[3]Professor, Head of the department of Civil Engineering, Godavari Institute of Engineering and Technology, Rajahmundry-533296
[4]Junior Engineer, Eco. Railway, India
vaishnavivinjamuri1999@gmail.com

Abstract: In India, around 50% of land is prone to earthquakes with huge economic loss annually. In order to reduce impact of earthquake on structures, "Rubber Soil Mixture" method has been developed. Incorporating rubber into soil in various proportions acts as an effective seismic shock absorber and provides strength, firmness to foundation soil. It also reduces settlement of footing. Recycled tyres are shredded into fragments and are added to soil. This method is economical and Eco-friendly. Addition of rubber to soil can reduce linear and lateral shaking of structure significantly. In this paper, various strength parameters of Rubber Soil Mixture like UCS, CBR-soaked and unsoaked, Compaction, Atterberg Limits, etc.; have been studied by conducting laboratory experiments. 1-2 mm sized rubber crumbs in varying proportions 0-5% are used. The main aim of this paper is to study how the addition of rubber crumbs in various proportions to the soil can affect bearing resistance and strength of foundation soil.

Keywords: Bearing Capacity, Recycled Tyres, Rubber-Soil Mixture.

1 Introduction

The practice of soil stabilization aims to enhance the properties of the soil, including its shear strength, compressibility, density, etc. There are many ways to categorize soil stabilizing techniques such as grouting, vertical drains, vibration, admixtures, surcharge load, consolidation, reinforcement, etc. Globally, geotechnical engineers are looking for new alternative materials that can be used for both cost-effective ground improvement solutions and the conservation of finite natural resources. Rubber tyres are produced in enormous quantities in India as a result of urbanization and industrial expansion. These produced waste tyres need to be disposed of carefully since they pose a serious threat to the environment and public health. However, Substantial volumes of rubber tyres require a lot of space to be dumped in a landfill. Therefore, overthe past ten years, numerous scholars have suggested using used tyres in the field of civil engineering. The practice of dumping used tyres in sanitary landfills has already been outlawed in many nations. Due to its negative effects on the environment, the Indian government has officially banned the use of used tyres.

The literature review demonstrates that the inclusion of tyre chips or shreds improves the soil mixture's engineering properties. According to the classification, processed rubber tyres can be shred (50 - 305 mm), or rough shred, chipped (12-50 mm), granulated (425µm - 12 mm) and ground rubber (425µm - 2 mm). However, in order to employ these materials safely in civil engineering applications, it is crucial to understand their engineering behavior.

In light of this, the current research project intends to investigate the impact of rubber crumbs' addition on the geotechnical properties of cohesive soil. In this line, research has been done to explore the usage of crumb rubber with soil for potential use like construction of pavements.

2 Literature Review:

The literature review demonstrates that the inclusion of tyre crumbs improve the soil's Index and Engineering properties. The following are some of the Literature studies regarding inclusion of crumb rubber in clayey soils.

Edil and Bosscher in **1994** have studied the Engineering Properties for recycling discarded tyres into building materials through various experiments like compaction, compressibility, strength and deformability, and hydraulic conductivity for lightweight fill in highway construction, drainage material in highway and landfill construction, and for other related uses **[1]**. **Young et al** in **2003** have studied the Tyre shreds' physical and chemical characteristics and their usage in engineering construction as a backfill material as an alternative to aggregates in embankments. They have conducted several experiments like Specific Gravity, Sieve Analysis, Hydraulic Conductivity, Compaction and UCS. Results revealed that tyre shreds can be used in construction applications. As the size of tyre shred increases, physical properties such as specific gravity remained constant but permeability increased from 0.2 to 0.85 cm/s along with Shear Strength and compressibility of scrap tyre. The angle of friction and cohesion ranged from 15°- 32° and 349-394N/m^2**[2]**. **Subramanian and Jeyapriya** in **2009** have made an effort to make use of waste tyres in subgrade and subbaselayers of flexible pavement by considering clayey soil [CI] with crumb rubber added in 2.5,5,7.5 & 10% percentages respectively. Through experiments like Compaction, UCS and CBR, they have found that with an increase in the percentage of waste tyres in the aggregates, the aggregate crushing value, impact value, and abrasion value dropped **[3]**. **Abhishek et al** in **2014** have extensively worked out over cohesive soils by adding crumb rubber in varying percentages. They have conducted various laboratory experiments like Atterberg Limits, Compaction, UCS, Swell Pressure, Free Swell test, CBR and found that even if the clay's MDD and UCS are reduced with the addition of rubber crumbs, the soil's CBR value is increased. Additionally, it has been noted that when the percentage of rubber crumbs increases, Atterberg limits and swelling pressure of rubber added soil decreases **[4]**.

Sandeep and Rakaraddi in **2014** have chosen Shredded rubber from waste as reinforcing material and cement as binding agent (randomly included) into soil at 5% 10% and 15% by weight of soil. CBR and UCS tests were conducted on Black Cotton soil [MI] and Shedi soil [CI] and the results have shown a significant improvement in shear strength and bearing capacity parameters of soil They have concluded that shredded rubber can be considered as a good earth reinforcement material **[5]**. **Ravichandran et al** in **2016** have stabilized two types of problematic clayey soils [CH] by using crumb rubber in varying percentages of 5, 10, 15 &20% by conducting CBR test and found that the addition of crumb rubber to both soils results in permeability changes that are advantageous. When 10% crumb rubber is added, soil samples CBR values got improved by 161% and 130%, respectively. According to their results, clayey soil can be stabilized more effectively by modifying both strength and permeability **[6]**. **Ravi Kumar** and **Gayatri** in **2018** have collectively worked on red and black soil samples and stabilized them by adding rubber crumbs in the proportions of 5, 10, 15% respectively. They have performed tests like Compaction, Direct Shear and CBR and noted that when the proportion of crumb rubber in soil increases, MDD and OMC decrease. Bearing capacity and shear strength are barely affected by blending **[7]**. **Yadav and Tiwari** in **2018** have conducted several experiments like compaction, UCS, split tensile strength, CBR, consolidation and swelling pressure, along with microstructural studies on crumb rubber added clayey soil of size 0.8-2mm with varying percentages from 0-10% and have found that OMC & MDD are decreased by the addition of crumb rubber to clay. UCS and split tensile strength increase negligibly and improvement in CBR is observed when crumb rubber up to 5% is added to clay. It has also been observed that adding crumb rubber lowers the clayey soil's compression index and swelling pressure **[8]**.

3 Materials

3.1 Soil Sample:

The soil used for this study has been collected from Anil Neerukonda Institute of Technological Sciences (Autonomous), Sanghivalasa, Bheemunipatnam, Visakhapatnam. The inorganic soil collected contains 4.36% Gravel, 36.17% Sand and 59.47% Fines with a Specific Gravity of 2.7. Type of soil is **[CL]**.

3.2 Crumb Rubber:

The crumb rubber has been collected from local markets of Visakhapatnam and has been crushed to required sizes bymeans of mills.

Fig-1: Crumb Rubber (1-2mm & 0.425mm)

4 Experiments Conducted- Results:

Rubber Crumbs are added to soil at proportions 0%, 2.5% and 5% and the following experiments are conducted at laboratory following respective Indian Standard Codal Procedures.

4.1 Index Properties:

Table-1: Index Properties of Rubber-Soil Mixture

Percentage of Rubber Added	Liquid Limit	Plastic Limit	Plasticity Index	Shrinkage Limit
0%	26%	17.2%	8.8	16.6
2.5%	25.4%	18.6%	6.8	24
5%	26.4%	19.9%	6.5	26.7

Fig-2: Plastic Limit

- From **Table-1**, we can observe that the Liquid Limit decreases up to 2.5%. This indicates that soil develops a part of shearing resistance at reduced water content as rubber forms an integrated network with soil skeleton to resist the shear. Then LL increases from 5% as addition of more rubber leads to breakage of mutual soil- grain contact, making the soil difficult to develop resistance against shear.
- Plastic Limit increases with increase in Percentage of Crumb Rubber as ability of soil remoulding reduces since rubber cannot be remoulded due to its rigid structure and absence of plasticity property.
- Shrinkage Limit increases with increase in Percentage of Crumb Rubber as more amount of water is required to bind the rubber soil mass to attain constant volume.
- Increasing the proportion of rubber crumb reduces the clay sample's flow, plastic, and shrinkage properties, according to the experimental results. Highways built over subgrade clay samples will perform better as a result of the beneficial reduction in plasticity properties.

4.2 Engineering Properties:

Table-2: Engineering Properties of Rubber-Soil Mixture:

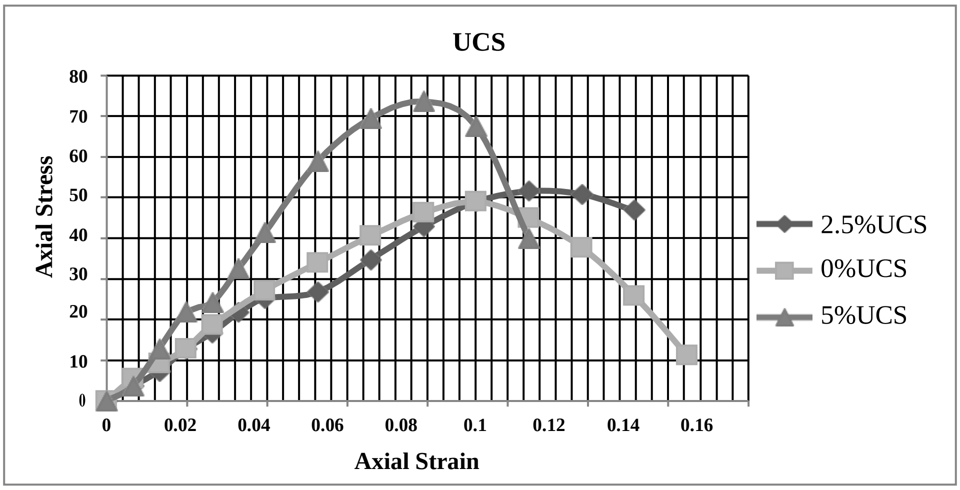
Percentage of Rubber Added	OMC	MDD (kN/m³)	UCS (kPa)	Angle of Shearing Resistance(ϕ)	Cohesion(C) (kPa)	Free Swell Index	CBR (Unsoaked)	CBR (Soaked)
0%	18.3%	19.7	48.9	9°	24.5	1.2	20.5	5.9
2.5%	15.2%	19.0	51.6	13.7°	25.8	0.9	25.6	9.7
5%	14.7%	18.9	73.6	32.4°	36.8	0.5	28.2	10.5

From **Table-2**, we can observe that:

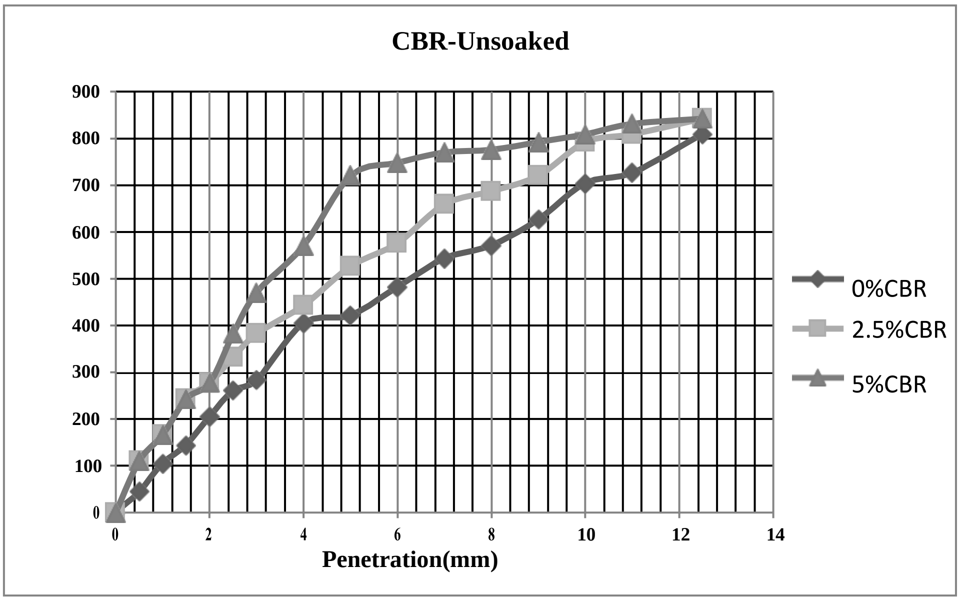
- Both Optimum Moisture Content and Maximum Dry Density decrease with increase in Percentage of Crumb Rubber as a part of soil grain mass is replaced by light weight rubber crumbs. As the density of rubber particle is less than that of density of clay, adding rubber to soil shall reduce the density of soil, thus reducing the soil mass and improving the shear strength of soil. OMC reduces asrubber does not absorb water. As the weight of soil mass decreases, it can reduce lateral pressure and hence can effectively be used as back fill material.
- Unconfined Compressive Strength tends to increase with increase in Percentage of Crumb Rubber as rubber provides resistance against compression by means of its elastic nature. Apart from this, Cohesion also tends to increase along with angle of Shearing Resistance. This indicates an increase in stiffness in stabilized soil when mixed with rubber.
- California Bearing Ratio @5mm Penetration tend to increase for both Unsoaked and Soaked soil specimens with increase in Percentage of Crumb Rubber due to elastic rebounding nature of rubber. This indicates an improvement in bearing capacity of the stabilized soil.
- Free Swell Index has no significant effect(decreases) with increase in Percentage of Crumb Rubber as rubber has no plasticity property to absorb water and its volume remains unchanged after additionof water.



Fig-3: UCS@0% before and after failure **Fig-4: UCS@2.5% before and after failure** **Fig-5: UCS@5% before and after failure**



Graph-1: Unconfined Compression Strength



Graph-2: California Bearing Ratio (Unsoaked)

5 Conclusions:

All the experiments have been done by following respective Indian Standard Codal Procedures at Geo-Technical Laboratory of Anil Neerukonda Institute of Technological Sciences, Visakhapatnam.The following conclusions are made:

1. The **Atterberg Limits** of collected Red Clay soil sample are altered when it is treated with different percentages of Crumb Rubber. The changes are as follows: **Liquid Limit** decreases (Both cone penetration and Casagrande) by **1.5%** when treated with 5%of Crumb Rubber. **Plastic Limit** increases by **15.7%** when treated with 5% of Crumb Rubber. **Shrinkage Limit** increases by **61%** when treated with 5% of Crumb Rubber
2. **Optimum Moisture Content** and **Maximum Dry Density** decrease by **20%** and **4%** respectively when treated with 5% of Crumb Rubber as a part of soil grain mass is replaced byrubber crumbs.
3. **Unconfined Compressive Strength** tends to increase by **50.5%**, **Cohesion** tends to increase by **50.2%** along with increase of **260%** in **Angle of Shearing Resistance** when treated with 5% of Crumb Rubber as rubber provides resistance against compression.
4. **California Bearing Ratio** @5mm penetration tend to increase for Unsoaked specimen by **37.6%** and Soaked specimen by **78%** when treated with 5% of Crumb Rubber.
5. **Free Swell Index** decreases by **58%** when treated with 5% of Crumb Rubber.
6. From the above statements, we can conclude that addition of crumb rubber in various percentages to soil tend to improve bearing strength of soil, which is quite useful in construction of pavements.
7. There is scope to study further about the combination of crumb rubber of various sizes in various types of soils at numerous proportions to evaluate varying strength characteristics of soils.

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