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Comparison of Index and Engineering Properties of Weak Soils Stabilized by Rubber Tyre Chips and Powder

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Abstract

Engineered constructions on weak or soft ground soil carry inherent risks due to the instability of the foundation. Soft ground lacks the necessary strength to support structures adequately, making it prone to settlement, subsidence, or even collapse under the weight of buildings or infrastructure. Various methods of improvements are used to improve the soil's stability to support various loads.one of the solution is can use the waste products incorporated into the soil. The reinforcement material used in this experiment is waste shredded rubber, which comes in the form of chips and powder. The principal aim of this study is to investigate the index and engineering performance of soil reinforced with rubber type powder (RTP) and rubber chips (RTC) randomly incorporated. To find the characteristics of the soil sample, the samples were subjected to various limits in Atterberg's, swelling potential, Standard (Std.) Proctor Compaction test, CBR and uniaxial compression testing. The experimental works were conducted with various percentages namely 0%,4%,6%8% of both additives to virgin soil. By the outcome results, the best additive has been suggested with clayey soil.

Keywords: Weak soil (clayey soil), waste tyre powder, waste tyre chips, MDD, CBR, and UCC.

INTRODUCTION

In light of the escalating population and its consequent surge in waste production, there is a pressing need to address the environmental ramifications and the associated impact on communities. Exploring effective ways to utilize waste products could not only mitigate environmental degradation but also offer cost-effective solutions. This research endeavors to harness the potential of waste products, specifically rubber tyre chips (RTC) and rubber tyre waste powder (RTP), to enhance soil index properties and engineering characteristics. By assessing the efficacy of these waste materials, the study aims to ascertain which holds greater promise in augmenting soil quality and engineering performance.

Swarm Surya Paleru Siddhartha and Teja discussed the use of waste tire chips for stabilizing subgrade soil, ranging from 2.5% to 7.5% incorporation. The results indicate a consistent decrease in Abrasion Value, Crushing Value, and Impact Value as the percentage of waste tires mixed with soil increases. For untreated aggregate, the Abrasion Value, Crushing Value, and Impact Value are recorded as 25%, 25.15%, and 14.76%, respectively. This study aims to explore the efficient utilization of waste tires in subgrade stabilization for highway pavement applications [1].

Edil, Tuncer B. and Bosscher, Peter J conducted a study on the uniaxial compressive strength (UCS) with increasing proportions of various-sized tire scraps, demonstrating soil strength improvement. Overall, soil treated with rubber tire scraps exhibited higher UCS values compared to virgin soil. The tire waste at 18%.While there were no significant variations in strain at failure values,

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there was typically a decrease due to the increased percentage of tire scrap of various sizes. This decrease may be attributed to the granular nature of tire scrap [2]. Jagtar Singh conducted a study utilizing shredded rubber tires to enhance soil properties, employing varying sizes and percentages for experimentation. The utilization of the rubber chips in soil engineering for soil improvement has garnered significant achievement recently. This paper explores the impact of stabilizing pavement subgrade soil with shredded rubber tires on pavement subgrade behavior. Findings reveal that the optimal shredded rubber tire percentage is 1%, with a size of 10mm×20mm, resulting in a 7.83% improvement in uniaxial compressive strength (UCS) compared to virgin soil [3].

A study was carried out to find out how adding crumb rubber—up to 10% of it—improves stabilized soils' strength characteristics as measured by California Bearing Ratio (CBR) tests. In addition to evaluating strength growth, the study looks at how this stabilizer type and different amounts affect drainage properties [4]. Chen and Lin (2009) found that adding tiny amounts of ash from sewage sludge to cement for soil stabilization did not significantly boost its strength at first. But as the curing process went on, strength gradually increased, which was explained by the continuing pozzolanic reactions. These results are supported by the current investigation, which found that although the early strength of soil stabilized with 7% lime and press mud was rather low, it significantly improved with longer curing times [5]. Guleria SP, Dutta RK proved the addition of admixture materials into expansive soil the unconfined compressive strength has been progressively [6].

MATERIALS AND PROPERTIES

This research focuses on weak, clayey soils, which are especially problematic since they can become inaccessible for transportation with even little amounts of rainfall or fine particle present. These soils have a plastic quality that makes them difficult to work with because they stick to tires, snag agricultural equipment, and stick to animal hooves. Further impeding clayey soil's treatment for road construction is its hardness, which makes it difficult to pulverize. As a result, there are eventually serious problems with road performance. Damage manifests itself several years after construction if appropriate stabilization procedures are not used.

The accumulation of non-biodegradable garbage is a major problem, especially as car production continues to rise and result in large amounts of waste tires that need to be disposed of. Nowadays, a large portion of this waste tire rubber is used as fuel in industries, which is not a cost-effective nor environmentally good activity. Investigating options for the utilization of scrap tire rubber is therefore urgently needed. Waste tire rubber's flexibility, light weight, energy-absorbing capacity, and insulation qualities against heat and sound make it a promising material for the building sector. It is a strong choice for a range of construction applications because of these qualities. Therefore, it has been suggested that using scrap tire rubber for soil stabilization is a better way to dispose of these used tires while also protecting the environment. Waste tires have certain qualities that make them potentially combustible and difficult to dispose of. Because of its great versatility and flexibility, this technique is becoming more and more prominent in the field of soil engineering.

The Specific gravity of all soil sample has been analyzed by as per IS methods [7]. The shrinkage limit has been tested by as per IS method [8]. The compaction characteristics with soaked conditions studies referred as per std. methods [9] [10]. The rubber powder and rubber chips are blended with weak soil for required properties of soils sample.

Figure 1. Rubber tyre chips (RTC) & Rubber tyre Powder (RTP)

Table 1. Properties of weak soil

S. N	Properties	Sample CH
1.	Specific Gravity	2.36
2.	Liquid Limit (%)	59%
3.	Plastic Limit (%)	25%
4.	Shrinkage Limit (%)	13.07%
5.	Free Sell Index (%)	65%
6.	Soil Dispersion (%)	68%
7.	Maximum Dry Density (MDD) (g/cc)	1.831
8.	Optimal water Content %	20.29%
9.	Uniaxial Compressive Strength (N/mm^2)	0.138
10	CBR %	4.2%

Table 2. Properties of Rubber Tyre Powder (RTP)

S. N	Properties	Tyre Powder
1	Density %	0.83
2	Size	80 ɥm – 1.6mm
3	Elongation	420
4	Rate of steel fiber	0%

Table 3. Properties of Rubber Tyre Chips (RTC)

S. N	Properties	Rubber Tyre Chips
1	Density %	0.83
2	Size	50mm – 300mm
3	Elongation	420
4	Angle of friction	15 to 30^o
5	Rate of steel fiber	0%

Experimental Investigation

The experimental works was carried out on soil proctor compaction test, swell index and California bearing ratio tests with various percentages of waste rubber tyre chips and rubber powder with virgin weak soil.

Plasticity Characteristics

The clayey soil’s limits of Atterberg’s namely the percentage of liquid limit (LL), the percentage of plastic limit (PL), the percentage of shrinkage limit (SL), and the percentage of plasticity index (%) all denote unique plasticity traits that are important markers of soil behavior for engineering purposes. The variations of moisture level in soil, the soil changes in a phase from liquid, plastic, semi-solid and solid respectively and it’s exposing its fluidity and deformation susceptibility, is known as the liquid limit. On the other hand, the plastic limit, which indicates the moisture level at which the soil becomes too dry to mold, defines the cohesive characteristics of the soil. The shrinkage limit indicates the moisture content at which further drying ceases to induce volume changes. The plasticity index, calculated as the disparity between the LL & PL, gauges the soil's plasticity and its ability to withstand deformation without fracturing. Collectively, these parameters offer valuable insights into the engineering characteristics of clayey soils, aiding in project design and implementation by identifying potential challenges.

Table 4. Variations of Plasticity Characteristics – RTC

S. N	Various Proportions	LL (%)	PL (%)	SL (%)	PI (%)
1	virgin Soil	53	20	15	33
2	Soil+4% RTC	48	20	13	28

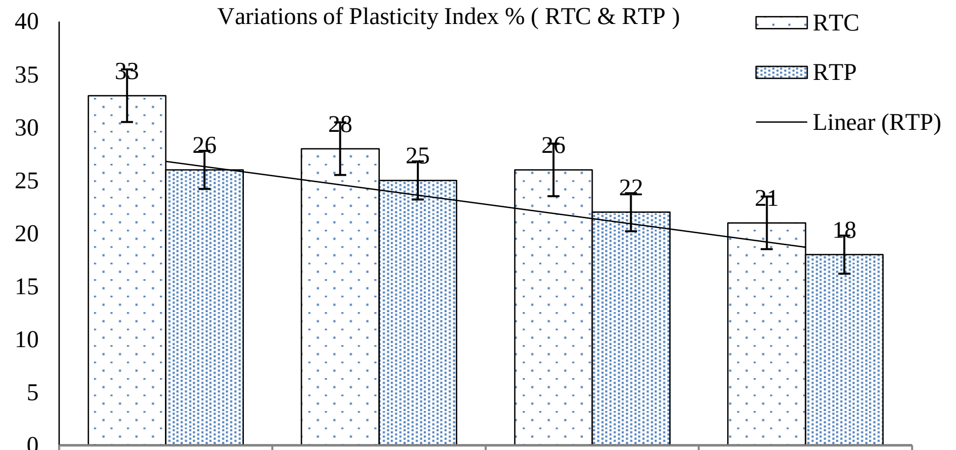
3	Soil+6% RTC	47	21	11	26
4	Soil+8% RTC	40	19	10	21

Table 5. Variations of Plasticity Characteristics – RTP

S. N	Various Proportions	LL (%)	PL (%)	SL (%)	PI (%)
1	Virgin Soil	53	20	15	33
2	Soil+4% RTC	46	20	12	26
3	Soil+6% RTC	41	19	11	22
4	Soil+8% RTC	38	20	10	18

Table 6. Variations of Plasticity index on RTC & RTP

S. N	Various Proportions	Liquid Limit (%)	Plastic Limit (%)
1	virgin Soil	33	26
2	Soil+4%	28	25
3	Soil+6%	26	22
4	Soil+8%	21	18



	Virgin Soil	Virgin Soil + 4 %	Virgin Soil + 6 %	Virgin Soil + 8 %
RTC	33	28	26	21
RTP	26	25	22	18

Figure 2. Variations of PI (%) with (RTC) & (RTP)

Compaction Studies

Soil compaction occurs when a load is applied to soil, leading to the expulsion of air from the voids between soil particles. The soil's ability to rebound from compaction depends on various factors such as climate, mineral composition, and biological activity. Compaction tests has been performed on pristine soil treated with different proportions (namely 4%,6% and 8%) of waste rubber tire chips and rubber powder in accordance with IS 2720 Part VII [8].

Table 7. OMC & MDD values treated with Rubber powder

% of RTP	0	4	6	8
OMC (%)	15.38	16.48	17.25	16.56
Maximum dry density (g/cc)	1.66	1.68	1.72	1.69

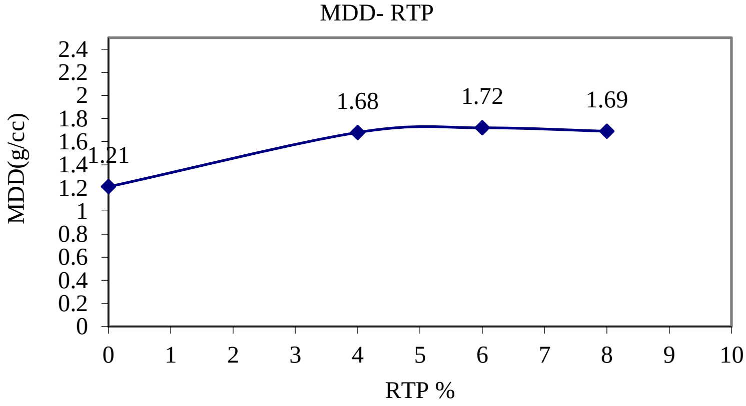


Figure 3. Variations of MDD (g/cc) with RTP (%)

Table 8. OMC & MDD values treated with rubber tyre chips

% of rubber tyre chips	**0**	**4**	**6**	**8**
OMC (%)	15.38	16.04	16.70	17.30
Maximum Dry Density (MDD) (g/cc)	1.66	1.67	1.69	1.71

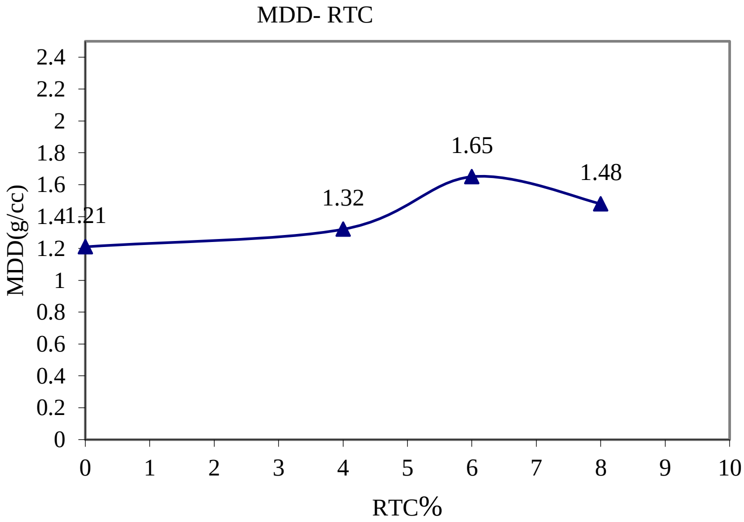


Figure 4. Variations of MDD (g/cc) with RTC (%)

Soil Swelling Characteristics

The swelling properties has been referred by the author Surya I, Sukeksi L, Hayeemasae [11]. The free swell test, pioneered by Holtz and Gibbs, entails placing 10 cm3 of oven-dried soil that passes through 425micro metre sieves into a 100 cm3 required the resulting sediment's equilibrium volume is recorded, and the free swell value is determined as improved percentage of in the soil volume compared to the initial volume. Soil swelling behavior was investigated by incorporating different ratios of rubber powder with distilled water and kerosene, following IS: 2720 (Part XL) – 1977 guidelines.

Table 9. Swelling Index values and Expansiveness Degree.

FSI	**Expansiveness Degree**
<25	Very Low
25-35	Moderately swell
35-55	High Swell
>55	Very high Swell

Table 10. Swelling Index values treated with RTP.

RTP (%)	**0**	**4**	**6**	**8**
Free Swell Index	65	58	45	40

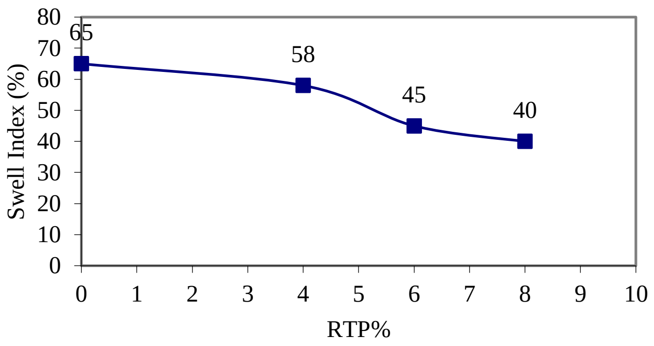


Figure5. Variation of swelling index (RTP)

Table 11. Swelling Index values treated with RTC.

RTP (%)	**0**	**4**	**6**	**8**
Free Swell Index	65	61	50	48

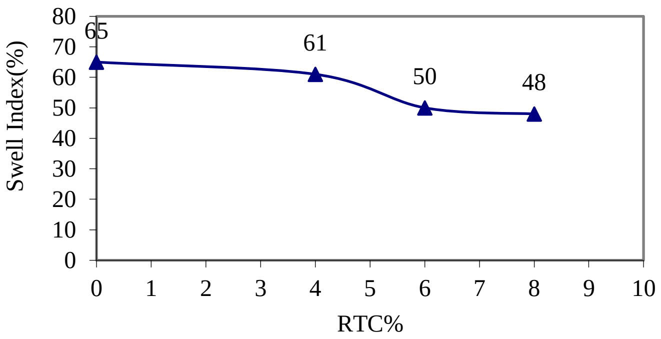


Figure 6. Variation of swelling index (RTC)

California Bearing Ratio (CBR) Test

The standard CBR test, outlined in IS: 2720 (Part XVI, 1979) [12] and is a penetration performance utilized for assessing the soil strength of roads and pavements. The results from these tests, along with associated curves, are crucial for determining pavement thickness and its constituent layers, making it the predominant method for flexible pavement design.

$$C.B.R. = (\text{Actual test load} / \text{Std. load}) * 100$$

The table below outlines the standardized loads applied for various penetrations on the reference material with this value of 100%.

Table 12. Std. load values for penetration.

S. N	**Penetration of plunger (mm)**	**Standard load (kg)**
1	2.50	1370.00
2	5.00	2055.00
3	7.50	2360.00
4	10.00	3180.00
5	12.50	3600.00

The CBR test was conducted under soaking conditions with various percentages of rubber tyre powder and rubber chips and results obtained.

Table 13. CBR values treated with rubber tyre powder (RTP)

RTP (%)	0	4	6	8
CBR	4.2	6.35	8.04	7.65

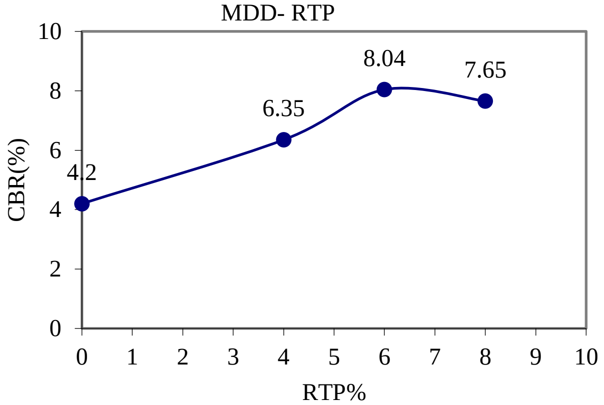


Figure 7. CBR values treated with rubber tyre powder

Table 14. CBR values treated with RTC.

RTC (%)	0	4	6	8
CBR	4.2	2.9	2.36	2.25

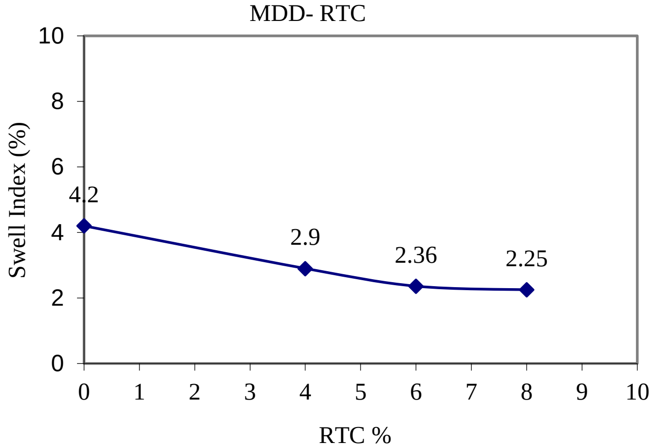


Figure 8. CBR values treated with RTC (%)

Uniaxial Compression Tests

The shear strength of cohesive soils, such as clay, is assessed using the unconfined compression test. It entails applying axial compression to a cylindrical soil specimen without lateral constriction. This test is essential for figuring out the clayey soil's ultimate and peak strength characteristics. The Indian Standard code IS 2720 Part X: 1985 standardizes the process. The authors have been proved the expansive soil shear strength increases using ceramic waste and rice husk ash [13] [14]. The test's results are useful in determining the soil's stability and suitability for engineering endeavors. The test was conducted with the uniaxial compression was conducted with 6% of Rubber tyre chips and rubber tyre powder.

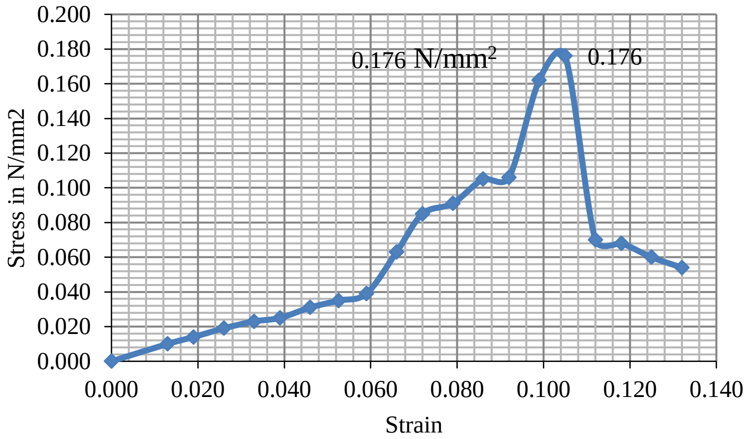


Figure 9. CBR values treated with Rubber tyre chips (RTC)

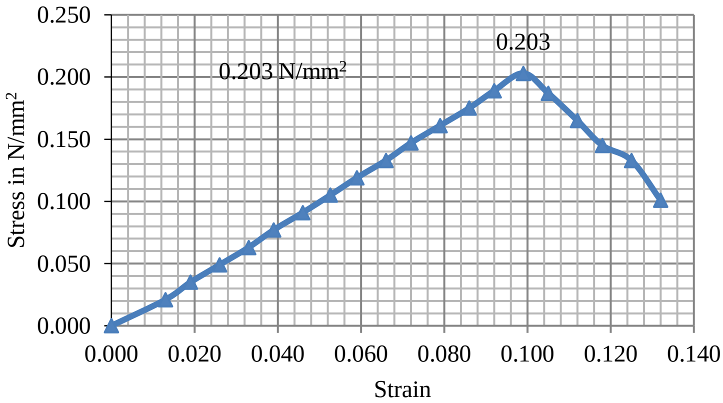


Figure10. CBR values treated with rubber tyre powder (RTP)

RESULTS AND DISCUSSION

Plasticity Characteristics

Observations from Figure 2 reveal changes in the PI of weak soils mixed with rubber tire chips (RTC) and rubber tire powder (RTP). It is evident that rubber tire powder (RTP) consistently yields significantly better results compared to rubber tire chips (RTC). These findings underscore the superior performance of rubber tire powder in enhancing the plasticity characteristics of clayey soils.

Compaction Studies

Tables 7 and 8 depict the obtained results concerning the optimum moisture content (OMC) and maximum dry density (MDD). The data illustrate that as the percentage of rubber powder increased to 6%, both the OMC and MDD values showed an increase. This trend continued with the addition of tyre rubber chips, indicating a consistent rise in both OMC and MDD values.

Soil Swelling Characteristics

Rather than the % of clay size fraction in the soil, the quantity of expansion of clay minerals like montmorillonite is what causes the soil to swell. The table 10 shows that the measured swell percent of the weak soils with various percent of tyre waste powder samples observed to be is goes on decreasing.

California Bearing Ratio (CBR) Test

The test results of the CBR test indicate a notable enhancement in the California Bearing Ratio (CBR) of the weak soil upon the addition of 6% rubber powder compared to 6% rubber chip. Conversely, in

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all other scenarios, there is a reducing in the CBR percentage with the adding of rubber powder. Hence, the adding of 6% rubber powder into the soil can effectively improve the CBR test values, thereby enhancing the soil's bearing capacity. However, the addition of rubber chips in small percentages does not yield improvements in properties due to their variable sizes.

Uniaxial Compression Test

The uniaxial test results demonstrate a substantial enhancement in the uniaxial compressive strength (UCC) of weak soil when 6% rubber powder is added, surpassing the improvement observed with 6% rubber chip inclusion. Conversely, the adding of rubber powder results decreases the value of UCC in all other cases. Consequently, incorporating 6% rubber powder into the soil can enhance UCC test outcomes, thereby boosting soil bearing capacity [15]. However, the inclusion of rubber chips in small percentages fails to enhance soil properties due to their inconsistent size distribution.

CONCLUSION

The following conclusions were arrived on comparing the obtained results from previous explanations, presented tables and diagrams.

- The addition of rubber tire powder (RTP) and rubber tire chips (RTC) to virgin soil leads to a consistent decrease in plasticity index values
- At 6% rubber powder may give effective maximum dry density and will goes on decreasing with more addition of rubber powder. Clay-containing soils have been found to conglomerate more and reach greater maximum dry densities.
- It was observed that by adding weak soil to the chips the maximum dry density (MDD) did not change into optimized value significantly, since the maximum dry density(MDD) value has been reduced.
- With the improvement of the % of rubber powder in soil, its swelling has decreased from 65% to 48%. Hence at 8% of rubber powder the degree of expansiveness is brought into high range from very high range.
- The addition of 6% rubber powder for soil stabilization shows a substantial enhancement in the California Bearing Ratio (CBR) value of weak soil compared to incorporating various percentages of rubber chips.
- It has been observed that 6% rubber powder by its weight is found to be the optimum dosage to weak soil.
- At optimum percentage of rubber powder, the CBR & UCC Values is increases upto 240% and 15% respectively compare to the rubber tyre chips.

REFERENCES

1. Teja SS, Siddhartha P. Stabilization of subgrade soil of highway pavement using waste tyre pieces. International Journal of Innovative Research in Science, Engineering and Technology. 2015(4):3265-72.
2. Edil TB, Bosscher PJ. Engineering properties of tire chips and soil mixtures. Geotechnical testing journal. 1994 Dec 1;17(4):453-64.
3. Singh J, Rattan JS. Soil Stabilization of clayey soil using shredded rubber tyre. International Journal of Engineering Research. 2017 Sep;6(9):246-8.
4. Ravichandran PT, Prasad AS, Krishnan KD, Rajkumar PK. Effect of addition of waste tyre crumb rubber on weak soil stabilisation. Indian Journal of Science and Technology. 2016 Feb 9.
5. Chen L, Lin DF. Stabilization treatment of soft subgrade soil by sewage sludge ash and cement. Journal of Hazardous Materials. 2009 Feb 15;162(1):321-7.
6. Guleria SP, Dutta RK. Unconfined compressive strength of fly ash–lime–gypsum composite mixed with treated tire chips. Journal of Materials in Civil Engineering. 2011 Aug 1;23(8):1255-63.
7. BIS I. 2720 Methods of Test for Soils Part 3: Determination of Specific Gravity/Section 1 Fine Grained Soils.
8. Prakash K, Sridharan A, Baba JA, Thejas HK. Determination of shrinkage limit of fine-grained soils by wax method. Geotechnical Testing Journal. 2009 Jan 1;32(1):86-9.

9. Prasanna HS, Harshitha D, Singh DK, Krishnegowda KH, Suhruth S. Correlation of compaction characteristics of fine-grained soils using atterberg limits. Int. J. Eng. Res. Technol. 2017;6(6):23-30.
10. Bharath A, Manjunatha M, Reshma TV, Preethi S. Influence and correlation of maximum dry density on soaked & unsoaked CBR of soil. Materials Today: Proceedings. 2021 Jan 1;47:3998-4002.
11. Surya I, Sukeksi L, Hayeemasae N. Studies on cure index, swelling behaviour, tensile and thermooxidative properties of natural rubber compounds in the presence of alkanolamide. InIOP Conference Series: Materials Science and Engineering 2018 Feb 1 (Vol. 309, No. 1, p. 012060). IOP Publishing.
12. IS 2720 (Part 16). Laboratory determination of CBR.
13. Sabat AK. Stabilization of expansive soil using waste ceramic dust. Electronic journal of Geotechnical engineering. 2012 Jan;17(Z):3915-26.
14. Basha EA, Hashim R, Mahmud HB, Muntohar AS. Stabilization of residual soil with rice husk ash and cement. Construction and building materials. 2005 Jul 1;19(6):448-53.
15. Bekhiti M, Trouzine H, Asroun A. Properties of waste tire rubber powder. Engineering, Technology & Applied Science Research. 2014 Aug 18;4(4):669-72.

