Indian Journal of Science and Technology, *Vol 9(5), DOI: 10.17485/ijst/2016/v9i5/87259, February 2016*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Effect of Addition of Waste Tyre Crumb Rubber on Weak Soil Stabilisation

P. T. Ravichandran*, A. Shiva Prasad, K. Divya Krishnan and P. R. Kannan Rajkumar

Department of Civil Engineering, SRM University, Kattankulathur - 603203, Tamil Nadu, India; ptrsrm@gmail.com, ashivaprasad9@gmail.com, er.divyakrishnan@gmail.com

Abstract

Objectives: In this work, the possibility of using crumb rubber powder was an additive to improve the strength of soft soil was investigated. **Methods:** Two types of problematic clay soils are stabilised with the various percentages of crumb rubber (5, 10, 15 and 20%). The strength properties of stabilized soils were improved by increasing percentages of crumb rubber up to 10% is studied by the CBR tests. In addition to strength development, the influences of this stabilizer type and different quantities on drainage characteristics are also studied. **Findings:** Addition of crumb rubber in both the soils shows desirable changes in permeability. With the addition of crumb rubber of 10% shows the improvement in CBR value of soil is 161% and 130% in soil A1 and A2. The results obtained shows that both strength and permeability modification results in the better stabilization for clayey soil. **Applications:** Increase in CBR value of stabilized soil can significantly reduce the overall thickness of the pavement and hence the total cost involved in the construction of road.

Keywords: California Bearing Ratio, Crumb Rubber, Permeability, Stabilisation

1. Introduction

Soil stabilization is a technique to improve the soil parameters such as shear strength, compressibility, density, hydraulic conductivity etc. The techniques of soil stabilization can be categorized into a number of ways such as consolidation, vertical drains, vibration, surcharge load, admixtures, grouting and reinforcement and other methods[1]. Geotechnical engineers around the world are in search of new alternate materials which are required both for cost effective solutions for ground improvement and for conservation of scarce natural resources. With globalisation of Indian economy and emphasis on development of infrastructure, the number of vehicles on road is increasing day by day. This increase in growth apart from causing noise and air pollution has begun to cause pollution in terms of stock piles of discarded tyres. Many countries already banned the disposal of the waste tires in sanitary landfills. The use of waste tyres as fuel is now prohibited by the Indian Government due to its environmental impact. In this regard, to develop newer applications a study has been conducted to use crumb rubber with soil for possible use in highway construction.

2. Literature Review

In the present economic and environmental ambiance, high pressures are laid on engineers to identify suitable methods wherever possible to re-use any locally available waste materials in order to minimize the costs of a project and its impacts on the environment. In ground improvement methods, waste materials are also used to improve geotechnical properties of soil. Waste materials such as scrap tires, ETP sludge and fly ash offers a viable alternative from economical, technical and environmental stand points. They showed good

**Author for correspondence*

potential for stabilizing soils by blending[2]. The benefits of reusing scrap tyres are particularly enhanced if they can be used to replace (fully or partially) scarce and valuable virgin construction materials which are non-renewable. Keeping this in view many attempts are being made for their use in highway applications. Researchers have shown that tyre shreds are highly compressible at low normal pressure. However, most of the compression that occurs is permanent, that is, the compressibility decreases substantially once the tyre shreds have experienced one load application. Thus, preloading can be used to eliminate permanent compression once the fill has been constructed. Confinement has also been shown to reduce compressibility[3,4]. Studies on compressibility performance[5] of sand with and without tire derived mixture and observed that the tyre derived aggregate was more compressible than sand, and the addition of sand of 15% to 35% reduces the compressibility of rubber derived aggregate by around 50%.

Shear strength properties of sand-tire mixtures using direct shear tests and it was reported that sand reinforced with crumb rubber mixture exhibits higher shear strength than sand[6]. The stress-strain and volume change response in triaxial compression tests on sand-tyre chip mixtures was assessed. The tyre chips used in the study was having effective size (D_{10} = 5 mm, with maximum shred size of 16 mm). The study indicated that with an increasing proportion of sand in the mixture, the density, unit weight and shear strength of the mixture increased but the compressibility decreased[7]. In assessing the stress-strain-volume change response in triaxial tests on sand; tyre chips (with a 30 mm minus size) and sand-tyre chip mixtures, indicated that the response of sand-chip mixtures is intermediate between those of sand and pure tyre chips[8]. The present study focus on the improvement of CBR value and permeability characteristics of clayey soils mixed with crumb rubber of various percentages.

3. Materials and Properties

The two soil samples A1 and A2 used in this study collected at a depth of about 0.7m below the ground level from the site as disturbed but representative soils[9]. The soil collected from the site was air-dried and then pulverized. The soils were characterized by means of laboratory tests as per BIS[10–12]. From the gradation analysis it was found that the sample A1 and A2 contained 97% and 94% of fine grained soils. The respective specific gravity values of the two soils were 2.1 and 2.3. UCS tests were conducted in accordance with (IS:2720, Part-X)[13]. Both the soils were classified as Clay of High compressibility (CH) based on the gradation and consistency limits of soil as per IS:1498-1970[14]. The characteristics of soils are given in Table 1. For improving the properties of both the clay samples, crumb rubber powder was chosen as an additive. The crumb rubber powder was obtained from recycled rubber from automotive and truck scrap tires. The crumb rubber used in the study ranged from 425 micron to 600 micron in size. Specific gravity of crumb rubber determined in the laboratory ranges from 0.8 to 0.9.

Table 1. Properties of soils

Properties	Value	
	Sample A1	Sample A2
Liquid Limit , %	74	56
Plastic Limit, %	36	20
Shrinkage Limit, %	4.8	5.9
Maximum Dry Density (MDD), kN/m^3	15.3	15.2
Optimum Moisture Content (OMC), %	25	26
Unconfined compressive strength, kPa	142	100

4. Experimental Investigation

The compaction tests on virgin soils and soils with crumb rubber powder were conducted to determine its compaction characteristics (OMC and MDD in accordance with IS:2720 (Part-VII)[15]. Compaction tests were done on both the soil samples by replacing a portion of soil with varied percentages of crumb rubber powder of 5%, 10%, 15% and 20% by weight of soil. Results obtained from Proctor compaction tests were used to prepare California Bearing Ratio (IS: 2720, Part - XVI)[16] and Permeability (IS: 2720, Part - XVII)[17] test samples. The test samples were carefully prepared by maintaining uniformity in density and moisture content in order to ensure a fair assessment of the effects of the admixture on improvement in soil characteristics. The variation of OMC and MDD values obtained for both the soils mixed with crumb rubber are shown in Figure 1. From the results it can be observed that the increase in percentage of crumb rubber decreases the OMC and MDD. The reduction in MDD is due to the lower specific gravity of crumb rubber powder.

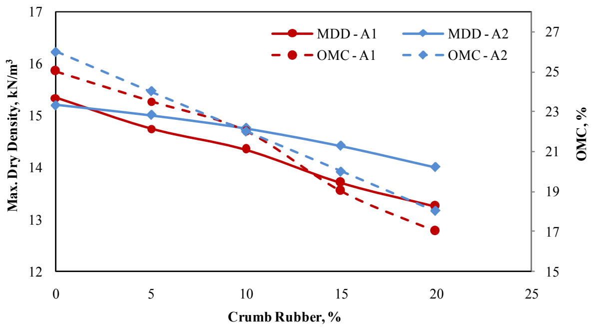

Figure 1. Variation of MDD and OMC with the addition of crumb rubber on soils.

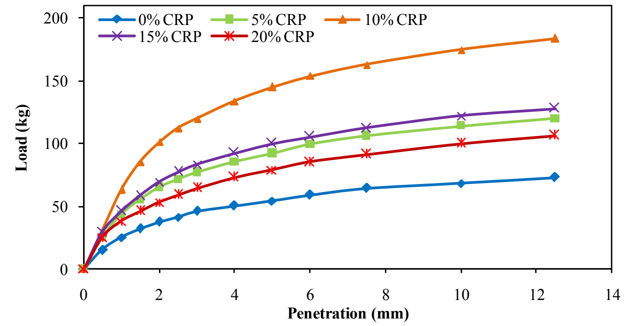

Figure 2. Load – penetration curve for the soil A1 and soil with varied % of crumb rubber.

CBR tests conducted on the soil measure the strength of a sub-grade material as compared to a standard dense graded aggregate. CBR is one of the important parameter in pavement design to decide the thickness of the pavement. Hence CBR tests were conducted on both the untreated soils and soil - crumb rubber powder mixtures as per the procedure described in IS:2720 (Part- XVI). The CBR apparatus consisted of a mould 150 mm in internal diameter with a base plate and a collar, a loading frame with a cylindrical plunger of 50 mm diameter, a LVDT for measuring the penetration value and a load cell to measure the load. The samples were first compacted in the CBR moulds to the corresponding MDD of the mix. Thereafter, placing the CBR mould in position under a surcharge pressure of 2.5 kPa, load was applied to the penetration plunger such that the penetration rate was 1.25 mm/min. The load values that cause 2.5 mm and 5 mm penetration were recorded. These loads are expressed as percentages of standard load values at respective deformation levels to obtain the CBR value. The load – penetration curve for the untreated soil A1 and soil A1 mixed with varied percentages (5%, 10%, 15% and 20%) of crumb rubber are shown in Figure 2. The CBR values of both the treated and untreated soils are given Table 2. From the Figure 2 it is observed that the addition of crumb rubber on soil A1 shows the constant penetration of plunger on application of load. A similar trend was observed in soil sample A2 also. The CBR value for both the soils increased upto the addition of 10% crumb rubber powder after which it started decreasing. It may be due to the presence of more crumb rubber powder causing high compressibility. However upto the addition of 20%, the CBR value of the soil is higher than that of the untreated soil A1 and A2.

Table 2. CBR values of untreated soil and soil mixed with CRP

Soil	CBR Value				
	Crumb rubber powder %				
	0	5	10	15	20
A1	3.1	5.2	8.1	5.6	4.3
A2	2.7	3.4	6.2	5.6	4.3

From the CBR test results the Admixture Influence Factor (AIF) on both the soils were calculated using the following relationship.

AIF = Treated CBR value of the soil/Untreated CBR value of the soil

The AIF calculated using the above relationship for both the soils are given in Table 3 and the variation is shown in Figure 3. The minimum and maximum increase in AIF for both the soils were found to be in the range of 1.25-1.6 and 2.3-2.6. For both the soils, AIF increases with the increase in admixture upto 10% , but the increase is more in soil A1 when compared to soil A2, it may be due to the availability of more clay which can

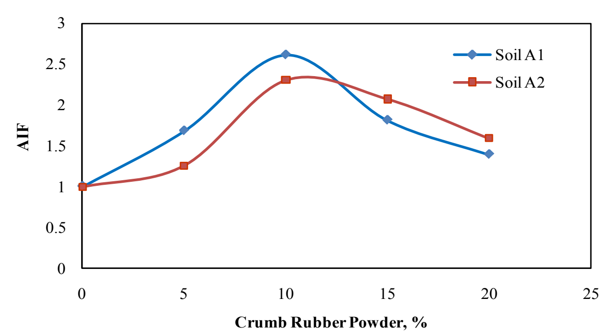

Figure 3. Variation of admixture influence factor on CBR values with the addition of CRP.

act as a binder, after 10% addition of admixture the AIF decreased rapidly in soil A1 when compared to soil A2. It may be due to separation of binder content contacts with the crumb rubber powder.

Table 3. Admixture influence factor on CBR values with the addition of CRP

Crumb rubber%	AIF	
	A1	A2
0	1	1
5	1.68	1.26
10	2.61	2.30
15	1.81	2.07
20	1.39	1.59

Permeability is usually measured in term of water flow through the soil in a given time. The size of pore space and interconnectivity of the spaces is a measure to determine permeability, so shape and arrangement of grains play a vital role. In this study constant head permeability tests as per IS:2720 (Part - XVII) were conducted on both the untreated samples and samples mixed with the various percentages of crumb rubber. The samples were prepared in permeameter with the OMC and MDD obtained from the Proctor test results. Test was conducted using three replicate samples of untreated and treated samples after the steady-state flow was attained. The average values of co-efficient of permeability determined for both the samples given in Table 4 shows the variation in co-efficient of permeability of soil with crumb rubber addition. From the test results it was observed that the co-efficient of permeability of soil increase 3 to 75 folds in soil A1 and 4 to 100 folds in soil A2. In the untreated soil, particle sizes are smaller; smaller the particle size smaller the size of the individual flow channels, hence the soil is highly impermeable, whereas in treated soil the permeability value increases with the addition of larger particle sizes of crumb rubber in lieu of smaller particle sizes of soils. The rate of increase in permeability value increases with increase in percentage of crumb rubber for both the soils. From the test results it was observed that the co-efficient of permeability of soil increase 3 to 75 folds in soil A1 and 4 to 100 folds in soil A2.

Table 4. Permeability value of untreated and soil mixed with crumb rubber powder

Crumb rubber %	Co-efficient of permeability, x 10^{-9} cm/sec	
	Soil A1	Soil A2
0	6.22	8.3
5	20.1	34.6
10	86.3	140.7
15	185.5	323.5
20	479.3	840.5

5. Conclusions

Based on the analysis of results on the crumb rubber stabilized soils the following observations and conclusions are drawn:

- Crumb rubber powder mixed with both the soil showed improvement in CBR value with its addition up to 10% and there onwards decreased with further increase in crumb rubber powder.
- Percentage improvement in CBR value of soil is 161% and 130% in soil A1 and A2. Increase in CBR value of stabilized soil can significantly reduces the overall thickness of the pavement and hence the total cost involved in the construction of road.
- The permeability value shows a rapid increases with the increase in crumb rubber content for the both the soils. From the test results it was observed that the co-efficient of permeability of soil increase 3 to 75 folds in soil A1 and 4 to 100 folds in soil A2.
- The use of crumb rubber as a stabilizer introduces a low cost method for stabilization and it significantly reduces the waste tyre disposal problem that currently exists.

6. References

1. Kazemian S, Huat BB K. Assessment and comparison of grouting and injection methods in geotechnical engineering, European Journal of Scientific Research, 2009; 27(2):234–47.
2. Ashmawy A, McDonald R, Carreon D, Atalay F. Stabilization of marginal soils using recycled materials. The National Academics Science and Engineering; 2006. p. 169.
3. Edil TB, Bosscher PJ. Engineering properties of tyre chips and soil mixtures. Geotechincal Testing Journal. 1994; 17(4):453–64.
4. Humphrey D, Manion W. Properties of tyre chips for light weight fill. Proceedings Conference on Grouting, Soil Improvement and Geosynthetics, ASCE; New York. 1992. p. 1344–55.

5. Wattman JM, Natale MF, Strenk PA. Immediate and time-dependent compression of tire derived aggregate. Journal of Geotechnical and Geo environmental Engineering. 2007; 133(3):245–56.
6. Ghazavi M. Shear strength characteristics of sand-mixed with granular rubber. Geotechnical and Geological Engineering. 2004; 22(3):401–16.
7. Youwai S, Bergado DT. Strength and deformation characteristics rubber shredded tire-sand mixtures. Candian Gotechical Journal. 2003; 40(2):254–64.
8. Lee JH, Salgado R, Bernal A, Lovell CW. Shredded tyres and rubber - sand as light weight backfill. Journal of Geotechnical and Geoenvironmental Engineering. 1999; 125(2):132–41.
9. IS:2720 (Part I). Methods of test for soil: Preparation of dry soil sample for various tests. New Delhi: Bureau of Indian Standards; 1983.
10. IS:2720 (Part III). Methods of tests for soil: Determination of specific gravity. New Delhi; Bureau of Indian Standards; 1987.
11. IS:2720 (Part V). Methods of tests for soil: Determination of liquid limit and plastic limit, New Delhi: Bureau of Indian Standards; 1985.
12. IS:2720 (Part VI). Methods of tests for soil: Determination of shrinkage factors. New Delhi; Bureau of Indian Standards; 1972.
13. IS:2720 (Part X). Methods of tests for soil: Determination of unconfined compressive strength. New Delhi: Bureau of Indian Standards; 1973.
14. IS:1498. Classification and identification of soils for general engineering purposes. New Delhi: Bureau of Indian Standards; 1970.
15. IS:2720 (Part VII). Methods of tests for soil: Determination of water content-dry density relation using light compaction. New Delhi: Bureau of Indian Standards; 1987.
16. IS:2720 (Part XVI). Methods of tests for soil: Laboratory determination of CBR. New Delhi: Bureau of Indian Standards; 1987.
17. IS:2720 (Part XVII). Methods of tests for soil: Laboratory determination of permeability. New Delhi: Bureau of Indian Standards; 1986.