Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 00 (2018) 000–000

Transportation Research Procedia

www.elsevier.com/locate/procedia

World Conference on Transport Research - WCTR 2019 Mumbai 26-31 May 2019

Investigation on Strength Characteristics of Subgrade of Pavement using Waste Material

Dheeraj Sunil Deshmukh[a]*, Dr. Kh. Lakhsman Singh[b]

[a]*Phd Scholar, Civil Engineering Department, NIT Silchar, Assam 788010, India*
[b]*Assistant Professor, Civil Engineering Department, NIT Silchar, Assam 788010, India*

Abstract

This paper is mainly focused on the strength characteristics i.e California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS) of subgrade soil replaced with waste materials such as crumb rubber and stone dust. Hypothesis behind this is to maximize the use of waste material in road construction. Waste is produced in abundant with problem of disposal. Crumb rubber and stone dust is used in 1%, 2%, 3%, 5%, &%, 10%, and 15% replacing soil by dry weight. Changes in un-soaked as well as soaked CBR values are observed on locally available clayey sand. Improvement in CBR was observed for crumb rubber 1.22% in un-soaked and 134% in soaked condition at 3% of replacement with crumb rubber. CBR improvement in case of stone dust was increasing consistently with increasing percentage of stone dust. In case of UCS, at 2% soil replacement of crumb rubber strength increased from 443.69KPa to 617.17KPa. for Soil replaced with stone dust slight increase was observed up to 2% of replacement followed by steady decrease.

Peer-review under responsibility of WORLD CONFERENCE ON TRANSPORT RESEARCH SOCIETY.

Keywords: California Bearing Ratio; Crumb Rubber; Stone Dust; Pavement Subgrade; Soil Stabilisation;

---

1. Introduction

Waste Generation and disposal is one of the problems faced in socio-economic development of any country. Road construction is rapidly growing and much needed infrastructural component for India. Every day there is almost average of 20 km of road is laid all over the country. (NHAI report-2016). India is dependent on road network for inland fright transport. Hence huge number of trucks are moving load or making a return journey on the road. Synthetic rubber tyres are commonly used for motor vehicles in today’s age. Increase in Number of vehicles also increase number of discarded rubber tyres. Proper disposal of these Scrap tyres is a problem. Some of the small

---

* Corresponding author. Tel.: +91-8551822000; fax: +0-000-000-0000 .
E-mail address: dheeraj.deshmukh147@gmail.com

Peer-review under responsibility of WORLD CONFERENCE ON TRANSPORT RESEARCH SOCIETY

industries make use of the waste rubber but it is not sufficient. In this work, scrap tyre rubber is used as stabiliser in subgrade layer of pavement. Approximately 12 million scrap tyres in 1995 and 15 million in 1996 have been used for civil engineering applications including leachate collection systems, landfill cover, artificial reefs, and clean fill for road embankment, road bed support and similar projects (Liu et al. 2000). Crumb rubber for its unique property is widely used in civil engineering application. Crumb rubber has low unit Wight, low bulk density, high drainage capacity, flexibility, strength, resiliency, high frictional resistance and high elastic deformability (Ahmed and Lovell 1993; Bosscher et al 1997). Both stability of embankment and settlement of the road built on soils with low strength can be improved by using lightweight material (Ahmed and lovell 1993). However crumb rubber has not been tried extensively for using it in subgrade layer of the pavement in India. To find substitute to the costly practice of landfill studies to utilize crumb rubber in non-landfill an attempt has been made to investigate its possible use in subgrade layer. Similarly stone dust is by product of the quarries which is not disposed properly creates dusty winds. Both the materials are either by products or wastes of different industries which do not have proper disposal arrangement. Hypothesis of the work is to check whether these materials can be used to increase the Strength Characteristics of the soil.

The shear resistance of sand with addition of shredded tyres was investigated and found to be improved (Foose et al. 1996 and Zornberg et al. 2004). Zornberg et al (2004) used tyre shreds in an embankment of cohesive soil to observe mechanical behavior. The embankment was subjected to heavy truck traffic. Settlement of the embankment was recorded over two years. Results show that the embankment performed satisfactory over two years of extensive traffic exposer. Tatlisoz et al. (1997) used waste tyre chips in fine grained and course grained soils. Mechanical properties of mixes were observed. Mix of soils with tyre chips behaves like soil but to mobilisation of ultimate shear strength requires more deformation and are compressible in nature. Tatlisoz et al. (1998) observed higher shear strength of soil mixes with tyre chips than soil in geo-synthetic reinforced back fill. Hasson et al (2005) based on their tests involving triaxial test and CBR test on shred tyre reinforced soil, concluded that the presence of shredded waste tyres in sand improves the stress-strain properties for all different sizes and contents of shreds waste tyre over that pure sand. CBR values increases with the increase of shreds tyre content up to 3% after which it decreases in both soaked and un-soaked specimens. Prasad, et al. (2008) conducted CBR and direct shear tests on sub base material with waste plastic and shredded rubber. Sub base material, viz gravel, was laid on the expansive soil subgrade. It was observed that load carrying capacity of the model improved significantly compared to unreinforced sub base. The index properties, permeability, compaction test and direct shear tests were conducted on cohesive soil using different percentage (10, 20, 30, 40 and 50%) of pure fine and course rubber tyre chips. It has been shown that 20% of course grained chips and 30 % of pure fine rubber chips can be used above water table for high strength and low settlement for soil (Cetina et al., 2006). R.M. Subramanian et al. (2009) tested crumb tyre mixed with soil in various proportions. Strength characteristics resulted in marginal improvement. CBR observed for tyre pieces was higher than shredded tyre. The main objective of the present study is to find out the strength characteristics (MDD, OMC, CBR, USS) of soil subgrade to be used in pavement construction using different percentage (1% to 15%)of waste materials (Stone dust and Crump Rubber). It was found that soil subgrade mixed with stone dust shows higher strength as compared to soil subgrade using crumb rubber for the pavement construction.

2. Experimental Program

2.1. Material Selection

Soil selected in this study is found in mountains around Silchar and commonly used for embankment for roadways and railways in Silchar (Assam). For improvement of strength characteristics locally available waste materials i.e crumb rubber and stone dust is used. Engineering properties of the soil is found out according to IS 2720 part 2, 3, 5 and 7. Tests such as specific gravity, liquid limit, plastic limit, plasticity index were performed. Soil classification as per Indian standard classification (ISC) (IS 1498-1970) and other index properties are listed in table 1. Soil selected is clayey sand (SC) of low compressibility with fair shear strength.

Crumb rubber obtained from grinded truck tyre. Crumb rubber used was passed through 4.25 mm sieve with no further treatment. As per ASTM D 6270, the particles less than about 12 mm in size, termed granulated or ground rubber, particles from 12 mm to 50 mm in size are grouped as tire chips and articles greater than 50 mm (50 to 305 mm) are grouped with tire shreds obtained by shredding on waste rubber tires. Stone Dust used was obtained from nearby stone quarry. IRC recommends stone dust is crushed rock passed through 600 micron sieve hence dust acquired from quarry was passed through 600 micron sieve. Crumb rubber and stone dust then used to replace by 1%, 2%, 3%, 5%, 7%, 10% and 15% of dry weight of soil. This variation of percentage soil replacement by weight was considered to maximise the utilisation of waste material.

Table 1. Properties of Soil

Property	Value
Specific Gravity	2.15
Plastic Limit (%)	24.16
Liquid Limit (%)	39.92
Plasticity Index	15.76
Maximum Dry Density (gm./cc)	1.83
Optimum Moisture Content (%)	17.69
Soil classification as per ISC	SC (Clayey Sand)

2.2. Tests on Soil Subgrade

2.2.1. Compaction test

Standard Procter test was conducted of only soil and mixture of soil plus different percentages of crumb rubber and stone dust by replacement of dry weight. IS 2720 Part-7 lays down the method for the determination of the relation between the water content and the dry density of soils using light compaction. In this test a 2.6 kg rammer falling through a height of 310 mm is used. Figure 1 shows the effect of maximum dry density (MDD) with different percentages of crumb rubber and stone dust.

2.2.2. California Bearing Ratio (CBR)

CBR tests were conducted on only the soil as well as mix of different percentage replacement with crumb rubber and stone dust. Both soaked and un-soaked CBR tests were accomplished as per IS 2720 part 16. The values of CBR for different Percentage of soil replacement and respective percentage increase are shown in Table 3. Figure 2 and Figure 3 are graphical representation of CBR values observed in Un-soaked and Soaked conditions for proposed mixes. It was noted that CBR values at 5 mm penetration were consistently higher than CBR values at 2 mm penetration for all mixed soil. Values given in parenthesis in Table 3 are percentage change. Pavement design based on CBR value still has significance in low volume roads and state highway building process.

2.2.3. Unconfined Compressive Test (UCS)

Unconfined Compressive Test (IS: 2720 (Part 10) – 1991), It is the load per unit area at which an unconfined cylindrical specimen of soil will fail in the .axial compression test. It is not always possible to conduct the bearing capacity test in the field. Unconfined compressive test is low cost method to evaluate field strength of the soil. In laboratory. Test results help engineers to choose best material from the available resource for embankment. It is easy to perform the unconfined compression test on undisturbed and remoulded soil sample. Specimen size selected was cylinder of 76 mm length and 38 mm diameter. Compacted samples were tested at Optimum Moisture Content derived from Dry density, water content relationships.

3. Results and Discussion

3.1. Compaction Test Result

Maximum dry density and optimum moisture content for unreinforced soil are 1.83 gm./cc and 17.69% respectively(Figure 1). Procter test is conducted with soil replacement by weight, as explained in previous section, by 1%, 2%, 3%, 5%, 7%, 10% and 15% of waste material. Detail of level of compaction achieved is tabulated in Table 2. Figure 1 and Figure 2 represent Dry Density and optimum moisture relations for unreinforced soil, soil reinforced with crumb rubber and stone dust. It can be observed in Figure 1 that MDD goes on decreasing with increase in percentage of crumb rubber. The MDD was found to be 1.82 gm./cc and 1.61 gm./cc at 1% and 15 % of crumb rubber. Percentage decline of MDD for crumb rubber is found to be not that much variation from 1% to 2% of soil replacement but it starts decreases drastically from 3% of soil replacement. In case of stone dust improvement in MDD values were observed from 1.83gm/cc at 0% replacement to 1.91 gm/cc at 15% replacement (Figure 2). Steady increase in MDD was observed in case of stone dust. MDD for crumb rubber is decreasing as crumb rubber is lightweight materials than soil on the contrary MDD for stone dust is found to be Increasing as stone dust is heavy than that of soil. Comparative representation of changes in maximum dry density is shown graphically in Figure 3.

Table 2. Dry Density and Optimum Moisture Content with Varying Percentage of Soil Replacement

Soil Replacement (%)	Crumb Rubber		Stone Dust	
	MDD (gm/cc)	OMC (%)	MDD (gm/cc)	OMC (%)
0	1.83	17.69	1.83	17.69
1	1.82	18.29	1.84	18.16
2	1.78	17.54	1.85	18.15
3	1.79	17.39	1.86	18.20
5	1.78	18.10	1.86	18.10
7	1.72	17.49	1.87	18.11
10	1.66	18.41	1.89	18.24
15	1.61	18.36	1.92	18.17

Optimum moisture content (OMC) does not vary than that of initial value of 17.76% of un-reinforced soil. For crumb rubber and stone dust materials values of OMC deviate maximum of 3% from 17.76%. Insignificant variation in OMC is because fine grained material is replaced by fine grained material, as OMC is a function of surface area.

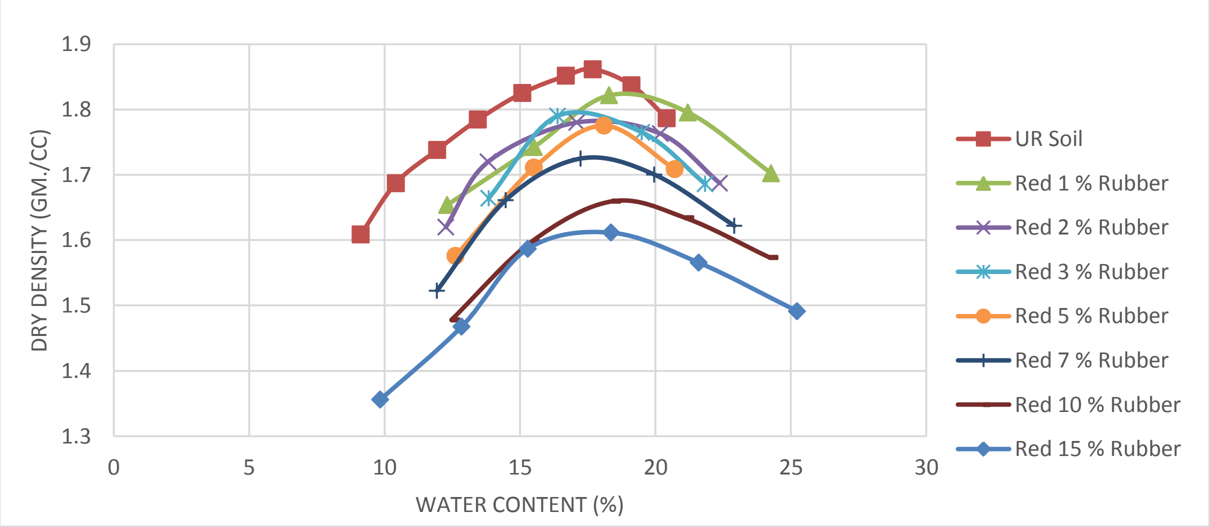

Figure 1: Relationship between Dry Density and Moisture Content for Soil Reinforced with Crumb Rubber

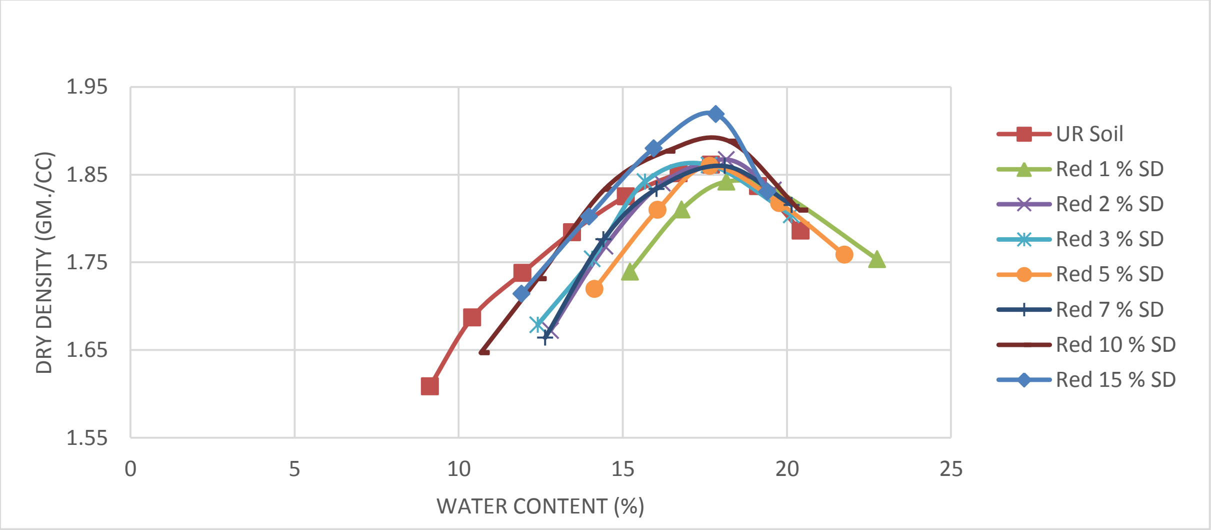

Figure 2: Relationship between Dry Density and Moisture Content for Soil Reinforced with Stone Dust (SD)

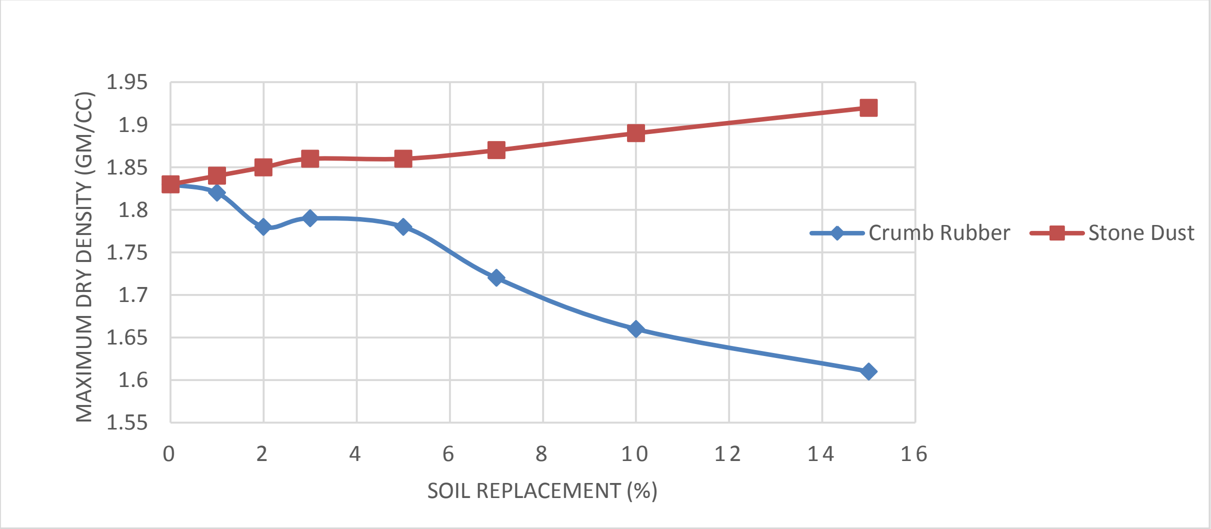

Figure 3. Maximum Dry Density vs. Percentage Soil Replacement

3.2. CBR Test Results

From values shown in Table 3, at 3% of soil replacement with crumb rubber maximum CBR values were found i.e. 16.56 % with an increase of 122% for un-soaked condition and 13.10% with increase of 134 % for soaked condition. From the data and graph it is observed that beyond 7% of soil replacement with crumb rubber CBR value decreases. CBR value increased by 165% from 7.45% at 0% of soil replacement to 19.74% at 15% of soil replacement with stone dust in un-soaked condition and by 218% from 5.61% at 0% of soil replacement to 17.82% at 15% of soil replacement with stone dust in soaked condition. Figure 4 represents trend of un-soaked and soaked CBR value. Optimum value for crumb rubber mix is at 3% of replacement and optimum value for stone dust is inconclusive. Increase in CBR values, in both cases, is due to the additional frictional resistance offered by the rubber particles and stone particles.

Table 3. CBR values for soil mixes different percentage of stone dust and crumb rubber

Soil Replacement (%)	Crumb rubber		Stone dust	
	CBR (Un-soaked)	CBR (Soaked)	CBR (Un-soaked)	CBR (Soaked)
0%	7.45	5.61	7.45	5.61
1%	14.65 (97%)	11.88 (112%)	8.34 (12%)	6.47 (15%)
2%	15.42 (107%)	12.24 (118%)	9.86 (32%)	7.78 (39%)
3%	16.56 (122%)	13.10 (134%)	11.57 (55%)	9.42 (68%)
5%	16.05 (115%)	9.20 (64%)	13.64 (83%)	11.15 (99%)
7%	15.44 (107%)	5.20 (-7%)	15.07 (102%)	11.82 (111%)
10%	12.54 (68%)	4.82 (-14%)	17.59 (136%)	15.64 (179%)
15%	8.84 (19%)	3.56 (-36%)	19.74 (165%)	17.82 (218%)

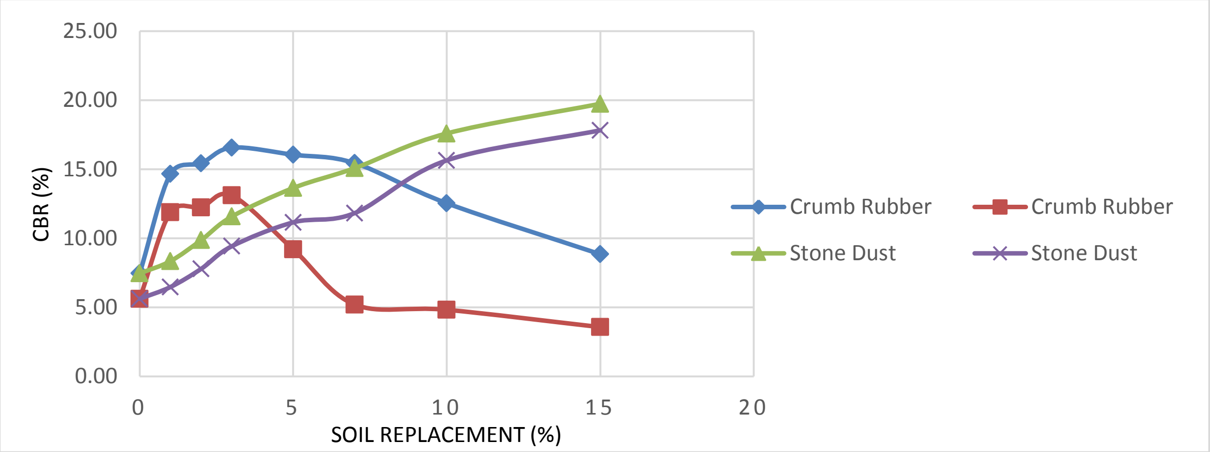

Figure 4. Un-soaked and Soaked CBR values

3.3. UCS Test results

Unconfined test results for varying percentage of soil replacement are tabulated in the Table 4 and graphical representation of same data is shown in Figure 5 and Figure 6. It is clearly observed that Unconfined Strength goes on Decreasing with additional replacement of the selected material. Soil replacement with crumb rubber shows gradual decrease form 478.84 KPa (3% replacement) to 182.90 Kpa (15 % replacement).UCS value for soil replaced with stone dust show slight increase in strength at 1% of soil replacement. From table 4 it can be observed that 2% soil replacement with crumb rubber and 1% of soil replacement with stone dust are optimum values. Mixture of soil and crumb rubber becomes ductile with each increasing percentage of replacement as strain values of failure goes on increasing. When soil is replaced with stone dust and FA ductility of the sample reduces.

TABLE 4: Unconfined Compressive Strength with Varying Percentage of Soil Replacement

Soil Replacment (%)	Crumb Rubber (KPa)	Stone Dust (KPa)
0	443.69	443.69
1	434.25	469.02
2	617.17	454.30
3	478.84	415.34
5	388.57	359.37
7	332.24	319.10
10	281.43	315.17
15	182.90	274.70

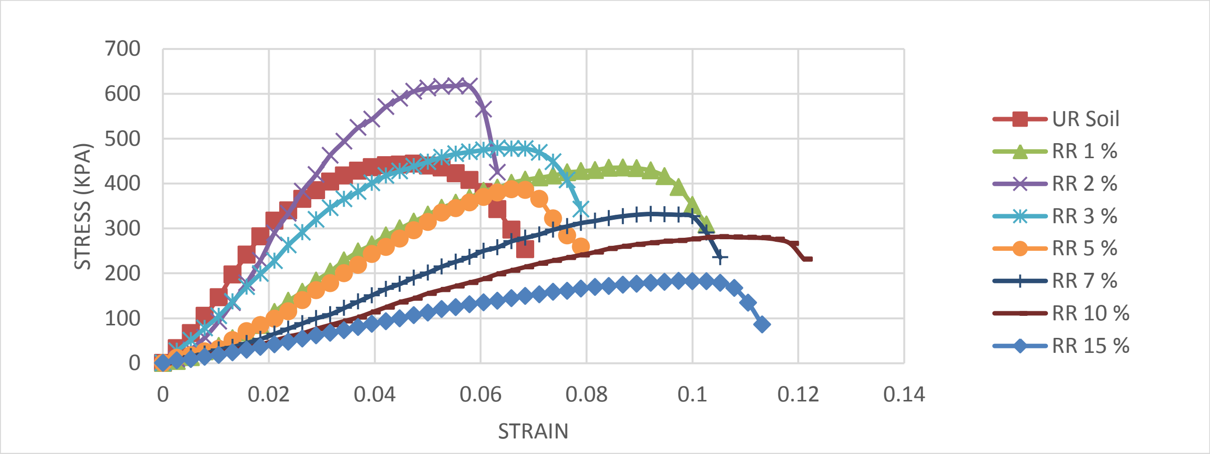

Figure 5. Relationship between Strain and Stress with Varying Rubber Content

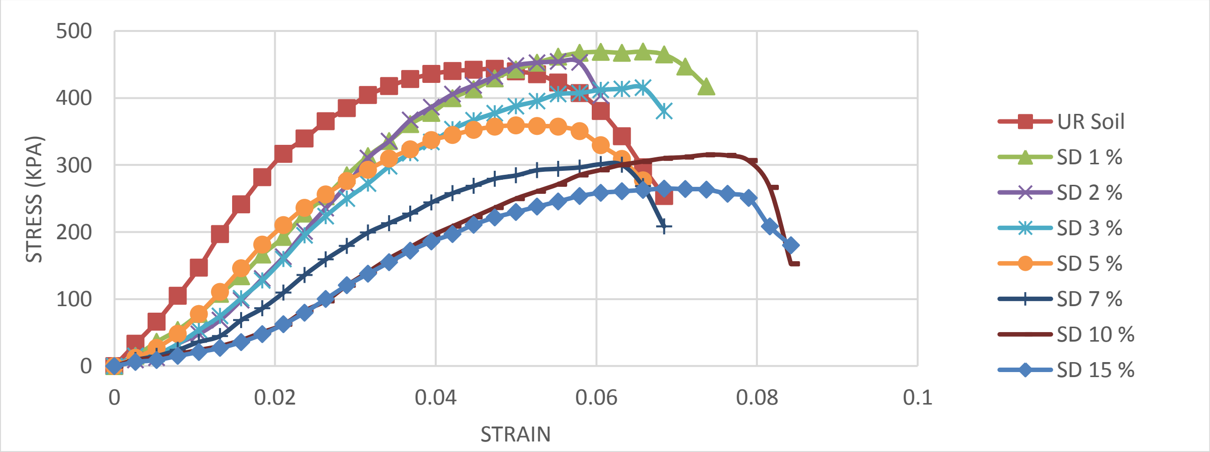

Figure 6. Relationship between Strain and Stress with Varying Stone Dust Content

3.4. Optimum Quantity of Soil Replacement

Optimum soil replacement for present soil study was determined according to CBR value. CBR values observed for all load penetration curves that CBR value at 5mm were consistently higher than that of 2 mm penetration as noted earlier. Optimum value as far as economy of construction is concerned, for crumb rubber will be at 3 % replacement and for stone dust at 15 % replacement, but where utilisation of waste considered it will be at 5 % for crumb rubber and at 15 % for stone dust. CBR value is one of the major index in case of pavement thickness determination. More the CBR value lesser the thickness of pavement required, which in turn saves the cost of construction of roadway. Wastes that are taken as part of this study are produced in abundance as explained earlier. Maximum utilisation of such waste products will solve disposal problem from environmental point of view.

4. Conclusion

Based on test results following conclusion were obtained.

- MDD for crumb rubber is steadily falling with added replacement of soil. MDD falls from 1.83gm./cc to 1.61 gm./cc for 0% replacement to 15 % replacement as material with higher unit weight is replaced by material with low unit weight..
- For soil tested in this study, addition of crumb rubber improvers CBR value two folds ie from 7.45% for soils to 16.56% for Soil + 3% crumb rubber replacement in un-soaked condition. Similar results were obtained in soaked condition CBR value increased two folds from 5.61% to 13.10% for soil and soil + 3% crumb rubber replacement respectively. Hence crumb rubber can be used for subgrade improvement up to 3 % of replacement by weight. Excess addition of crumb rubber beyond 7% replacement resulted in decrease in the CBR value in soaked condition. Percentage of soil replacement by use of crumb rubber must be carefully determined.
- MDD for stone dust is increasing persistently with further replacement of soil. MDD increases from 1.83gm./cc to 1.92 gm./cc for 0% to 15% of replacement as material with low unit weight is replaced by material with high unit weight.
- Subgrade improvement achieved by stone dust is gradually increasing; hence percentage soil to be replaced will depend upon the economics of construction. CBR increased was three times that of the CBR value of 0% replacements with stone dust in un-soaked as well as soaked condition. Breakeven point to maximise economy in construction should be found before deciding optimum percentage of replacement.
- Optimum value for crumb rubber and stone dust was observed at 2% of replacement and 1% of replacement in case of UCS value.
- Reduced thickness of the road structure with Improved CBR value can be achieved which in turn will reduce the strain on the natural resource required for pavement construction directly indirectly. This will prove to be economical in long run for the development of a country. Utilization of the waste material in sustainable way is possible which will help partly to solve disposal problems for such waste materials.

Acknowledgement

The Authors thankfully acknowledge the financial support from TEQIP-III, under the guidance of Prof. Sivaji Bandyopadhyay honourable director of National Institute of Technology Silchar, Assam.

References

Ahmed, I., and Lovell, C. W. 1993. Rubber soils as light weight geomaterials Trans. Res. Rec., 1422, 61–70.

Bosscher, P., Edil, T., and Kuraoka, S. 1997. Design of highway embankments using tire chips. J. Geotech. Geoenviron. Eng., 10.1061/(ASCE)1090-0241(1997)123:4(295), 295–304.

Cetina, H., Fenerb, M. and Gunaydinb, O. 2006. Geotechnical Properties of Tire-cohesive Clayey Soil Mixtures as a Fill Material, Engineering Geology, Vol. 88 (11), pp. 110–120.

Foose, G.J, Benson, C.H. and Bosscher, P.J. 1996. Sand Reinforced with Shredded Waste Tyres, Journal of Geotechnical Engineering, Vol. 122, No. 9, 760–767.

Hassona F A, Hassan M A, Hashem M D, Marei N A, Aly A A 2005. Improvement of soft clay characteristics using sand cushion reinforced with shredded waste tire, Proceedings of the 1st International Conference on Engineering for Waste Treatment, Beneficial Use of Waste and by-Products, Ecole des Mines d'Albi-Carmaux, Albi, France

Hoppe, E.J. 1994. Field Study of Shredded-tyre Embankment, Report No. FHWA/VA-94-IRI, Virginia Department of Transportation, Richmond, VA.

Humphrey, D.N. and Eaton, R.A. 1993. Tyre Chips as Subgrade Insulation—Field Trial, Proceedings of Symposium on Recovery and Effective Reuse of Discarded Materials and By-Products for Construction of Highway Facilities, Denver, CO.

IS 2720 (Part 1) – 1983: Preparation of Dry Soil Samples for Various Tests

IS : 2720 (Part 2) – 1973: Determination of Water Content

IS : 2720 (Part 3/Sec 1) – 1980: Determination of Specific Gravity, Section 1 Fine Grained Soils

IS : 2720 (Part 5) – 1985: Determination of Liquid Limit and Plastic Limit

IS : 2720 (Part 7) – 1980: Determination of Water Content - Dry Density Relation Using Light Compaction

IS: 1498-1970. Classification of Soils for General Engineering Purposes.

IRC 37-2012: Guidelines for Design of Flexible Pavements.

MORTH-2001: Specifications for Roads and Bridge Works, Ministry of Road Transportation and Highways, Govt. of India.

Prasad, Prasada Raju and Murthy, Ramana 2008. Use of Waste Plastic and Tyre in Pavement Systems, IE (I) Journal-CV, Vol. 89, pp. 31–35.

R.M. Subramanian and S.P. Jeyapriya 2009. Study on Effect Of Waste Tyres in Flexible Pavement System, IGC – 2009, Guntur, India

Stalin, V.K. and Jeyapriya, S.P. 2001. A Study on the Performance of Geosynthetics in Expansive Soils, Proc. of Indian Geotechnical Conference, Indore, Vol. 1, pp. 393–395.

Tatlisoz, N., Benson, C., and Edil, T., 1997. Effect of Fines on Mechanical Properties of Soil-Tire Chip Mixtures, Testing Soil Mixed with Waste or Recycled Materials, ASTM STP 1275, Mark A. Wasemiller, Keith B. Hoddinott, Eds., American Society for Testing and Materials,

Tatlisoz N, Edil T B, Benson C H 1998. Interaction Between Reinforcing Geosynthetics And Soil-Tire Cmp Mixtures, Journal of Geotechnical and Geoenvironmental Engineering Vol. 124, Issue 11 https://doi.org/10.1061/(ASCE)1090-0241(1998)124:11(1109)

Zornberg, J.G., Cabral, A.R. and Chardphoom, V. 2004. Behaviour of Tire Shred-sand Mixtures,‖ Can. Geotech. Jl., 41(1), 227–241.