Visakhapatnam Chapter

Proceedings of Indian Geotechnical Conference 2020
December 17-19, 2020, Andhra University, Visakhapatnam

Effect of Addition of Scrap Tire Chips in Stabilization of Clayey Sand

C.N.V. Satyanarayana Reddy [1], G. Tabitha[1], S. Srikanth Reddy[2], K. Chandranna[3]
[1] Andhra University College of Engineering, Visakhapatnam -530003, Andhra Pradesh, India
[2] S.R.K.R. Engineering College, Bhimavaram -534201
[3] Vignan's Institute of Information Technology, Duvvada, Visakhapatnam – 530049
prof.cnvsreddy@andhrauniversity.edu.in

Abstract. As existing highways are continuously upgraded by adding extra lanes to cater to the needs of developing counties, demand on suitable construction materials for highway embankments is increasing day by day. As it is desirable to make construction with locally available soils to minimize construction cost, efforts are required to stabilize such soils if they are inferior for use as construction material. Also, clayey sand with excess fines (more than 30%) possesses low CBR values in soaked condition. Hence, in the present study, locally available clayey sand is stabilized with scrap tire chips of size 10mm and 20mm size in varying proportions of 0 to 20% by weight. The optimum percentage of tire chips by weight for stabilization of clayey sand is determined as 15%, with 10mm size tire chips exhibiting better stabilizing effect than 20mm size tire chips. The permeability and soaked CBR of clay sand increased by about 85% and 65% respectively. Clayey sand under study stabilized with 15 percent of 10mm size scrap tire chips indicated potential for use in construction of high embankments. Further, improved stiffness of stabilized soil with tire chips in terms of coefficient of elastic uniform compression is observed from small scale cyclic load tests.

Keywords: Stabilization; Scrap tire chips, Soaked CBR, Subgrade, Clayey sand, coefficient of elastic uniform compression

1 Introduction

Cohesive soils are invariably used in construction of embankments for canal bunds, earth dams and highway and railway bridge approaches. Impervious non swelling clays are preferred in canal bunds and inner shells of the earth dams whereas clayey sands and clayey gravels are preferred in highway/ railway embankments for strength. In bridge approaches, as required height of embankments is more, the usage of clays is permitted except that top 1-2m portion is filled with soils of higher strength. As the stability of embankment depends on shear strength of material to prevent slope failures, certain countries (TRH 9 – 1982) specify minimum CBR values for use of soils in embankments of varying heights. So, it is essential to ensure adequate shear strength for cohesive soils to avoid slip failures in high embankments. So, in the present study, an attempt is made to improve CBR of clayey sand to make it suitable for use in construction of moderate to high embankments by stabilizing with addition of shredded scrap tire chips of 10mm and 20mm size in proportions of 5%, 10%, 15% and 20% by weight of soil.

Studies of stabilization of soils using scrap tire chips have been conducted by researchers across the world to find useful and effective means of disposal of scrap tires and to improve the properties of soil and aggregate (Edil and Bosscher, 1994; Yoon et al., 2006; Satyanarayana Reddy and Durga Rani, 2014). Granular soils are reported to have significant benefit through stabilization by the addition of tire chips. Tire chips are added to soil in sizes varying from 30mm to 110mm and it is reported that the angle internal friction improved significantly and CBR of granular soils increased by 2 to 3 folds. However, it is reported that clays do not have significant stabilizing action by the addition of tire chips from studies conducted using tire chips of sizes above 30mm (Tatlisoz et al., 1997).

Many researchers have carried out studies on influence of addition of tire shreds/chips in clay soils. It is observed that the addition of different proportions of tire chips (5%-50%) significantly improved the CBR and unconfined compressive strength and reduced compressibility and permeability of clay. (Ahmed and Llovell 1993, Edil 2002, Tabbaa et.al 2010). Partial replacement of black cotton soil/ clay soil with tire chips (4.75mm -2.00mm) have resulted in decrease in weight of fill as well as swell pressure. Hence soil stabilised with tire chips can be used as a light weight fill material for retaining walls and embankments constructed on relatively weak soils resulting in lower earth and bearing pressures (Edil and Bosscher 1994, Edil 2002, Hasan Cetin et.al 2006, Amit Srivastava et.al 2014). Tire shreds can be effectively used for land fill applications subjected to extreme acidic conditions and are highly durable (Reddy and Saicheck, 1998).

2 Details of Study

2.1 Properties of soil

The clayey sand used in the study is procured from P.M. Palem, Visakhapatnam and tested for engineering properties in laboratory by performing tests as per relevant codes of Practice, IS 2720. The engineering properties of soil determined from the tests are presented in Table 1.

The soil is classified as clayey sand based on gradation and plasticity characteristics as per IS 1498-1970. The soil has fines in excess of 40% and poor drainage and low CBR value in soaked condition. The soil has insignificant swelling as free swell index is 20%. The clayey sand is suitable for construction of highway embankments of heights up to3- 9m, but not suitable for embankments of height exceeding 9m based on CBR value (TRH-09).

Table 1. Engineering properties of soil

Property	Value
Specific Gravity	2.68
Grain Size Distribution	
a. Gravel (%)	0
b. Sand (%)	58
c. Fines (%)	42
i) Silt (%)	28
ii) Clay (%)	14
Plasticity Characteristics	
a. Liquid Limit (%)	37
b. Plastic Limit (%)	22
c. Plasticity Index (%)	15
IS Classification Symbol	SC (Clayey Sand)
Compaction Characteristics	
a. Maximum Dry Density (g/cc)	1.85
b. Optimum Moisture Content (%)	13.4
Coefficient of permeability (cm/s)	1.12×10^{-6}
Shear parameters	
a. Angle of internal friction	24^0
b. Cohesion (KN/m^2)	42
California Bearing Ratio (%)	3.2
Free Swell Index (%)	20

2.2 Properties of tire chips

Tire chips of size 10mm x 10mm and 20mm x 20mm are cut from scrap tires for use in the study. The tire chips have specific gravity of 1.05, bulk density of 0.64g/cc and water absorption of 2.2%.

3 Studies on Soil-Tire Chip Mixes

3.1 Compaction characteristics

The clayey sand under study is mixed with shredded tire chips of 10mm and 20mm size in proportions of 5-20% by weight of soil, in increments of 5%. The compaction characteristics of the soil-trye chip mixes are determined from IS Heavy compaction tests and the compaction characteristics obtained from the tests are presented in Table 2.

Table 2. Compaction characteristics of tire chips stabilized soil

Size of tire chips	Details of Mix	Compaction Characteristics	
		OMC (%)	MDD (g/cc)
10 mm	Soil + 0% Tire chips	13.4	1.85
	Soil + 5% Tire chips	12.9	1.83
	Soil +10% Tire chips	11.8	1.80
	Soil +15% Tire chips	11.4	1.74
	Soil +20% Tire chips	10.8	1.72
20 mm	Soil + 0% Tire chips	13.4	1.85
	Soil +5% Tire chips	12.6	1.82
	Soil +10% Tire chips	11.2	1.78
	Soil +15% Tire chips	10.9	1.72
	Soil +20 % Tire chips	10.4	1.70

3.2 Strength characteristics

The shear parameters of soil - tire chip mixes are determined by testing specimens of 50mm diameter and 100mm length prepared by compacting at OMCs and respective MDDs in Triaxial test apparatus. The shear parameters are also determined on saturated specimens in undrained conditions. The shear parameters are determined by plotting Mohr's circles and by plotting the failure envelopes. The shear parameters of soil- tire chip mix specimens determined from the tests are given in Table 3.

Table 3. Shear parameters of tire chips stabilized soil

Size of tire chips	Soil-Tire chips Mix	Shear parameters			
		OMC - MDD compacted state		Saturated State	
		Angle of Internal Friction	Cohesion (KN/m^2)	Angle of Internal Friction	Cohesion (KN/m^2)
10mm	Soil + 0% Tire chips	24^0	42	21^0	35
	Soil + 5% Tire chips	26^0	38	23^0	32
	Soil +10% Tire chips	28^0	34	26^0	30
	Soil +15% Tire chips	30^0	32	28^0	28
	Soil +20% Tire chips	32^0	29	30^0	25
20mm	Soil + 0% Tire chips	24^0	42	21^0	35
	Soil + 5% Tire chips	25^0	40	22^0	33
	Soil +10% Tire chips	26^0	36	24^0	32
	Soil +15% Tire chips	28^0	33	29^0	30
	Soil +20% Tire chips	30^0	30	26^0	27

In addition to shear parameters, the CBR values of soil-tire mixes are important in highway embankment application. Hence, CBR tests are performed on the soil-tire chips mix specimens prepared at OMCs and respective MDDs after soaking for 96 hours. CBR values are determined by plotting load-penetration curves and applying zero correction (wherever it is required) as per IS 2720- part 16. The results of CBR tests are given in Table 4.

Table 4. CBR of tire chips stabilized soil

Size of tire chips	Mix Details	Soaked CBR (%)
10mm	Soil+0% Tire chips	3.2
	Soil+5% Tire chips	4.2
	Soil+10% Tire chips	4.9
	Soil+15% Tire chips	5.3
	Soil+20% Tire chips	4.4
20mm	Soil+0% Tire chips	3.2
	Soil+5% Tire chips	3.6
	Soil+10% Tire chips	4.2
	Soil+15% Tire chips	5.1
	Soil+20% Tire chips	4.2

3.3 Permeability of soil- tire chip mixes

The permeabilities of clayey sand and tire chips mixed clayey sand specimens prepared at OMCs and respective MDDs are tested after saturation in variable head permeability test apparatus. The test is performed as per IS 2720 part 17. The results of Permeability tests are presented in Table 5.

Table 5. Permeability of tire chips stabilized soil

Size of Tire chips	Mix Details	Permeability (cm/s)
10 mm	Soil + 0% Tire chips	1.10×10^{-6}
	Soil + 5% Tire chips	1.12×10^{-5}
	Soil +10% Tire chips	4.30×10^{-5}
	Soil +15% Tire chips	8.40×10^{-5}
	Soil +20% Tire chips	1.12×10^{-4}
20 mm	Soil + 0% Tire chips	1.10×10^{-6}
	Soil + 5% Tire chips	2.92×10^{-5}
	Soil +10% Tire chips	6.34×10^{-5}
	Soil +15% Tire chips	9.34×10^{-5}
	Soil +20% Tire chips	1.32×10^{-4}

3.4 Coefficient of elastic uniform compression of tire chips stabilized soil

The effect of addition of tire chips on coefficient of elastic uniform compression (C_u) is evaluated from small scale cyclic load tests conducted specimens prepared in CBR Mould by compacting in IS heavy compaction condition after soaking for 96 hours. The load tests are conducted in self straining loading frame using the CBR plunger as loading plate. Loading is done up to anticipated safe bearing capacity (150 kPa) in increments of 10 kPa and load at each stage is maintained till settlement reached equilibrium. The load at each stage is released and plate is allowed to rebound and then loaded to next higher load. Based on the dial gauge readings of loading and un-loading stages, elastic settlements are determined and plots are made between applied load intensities and corresponding elastic settlements as shown in Figures 1 and 2. The values of C_u determined as the slopes of liner portions of the plots of different specimens from the tests are presented in Table 6.

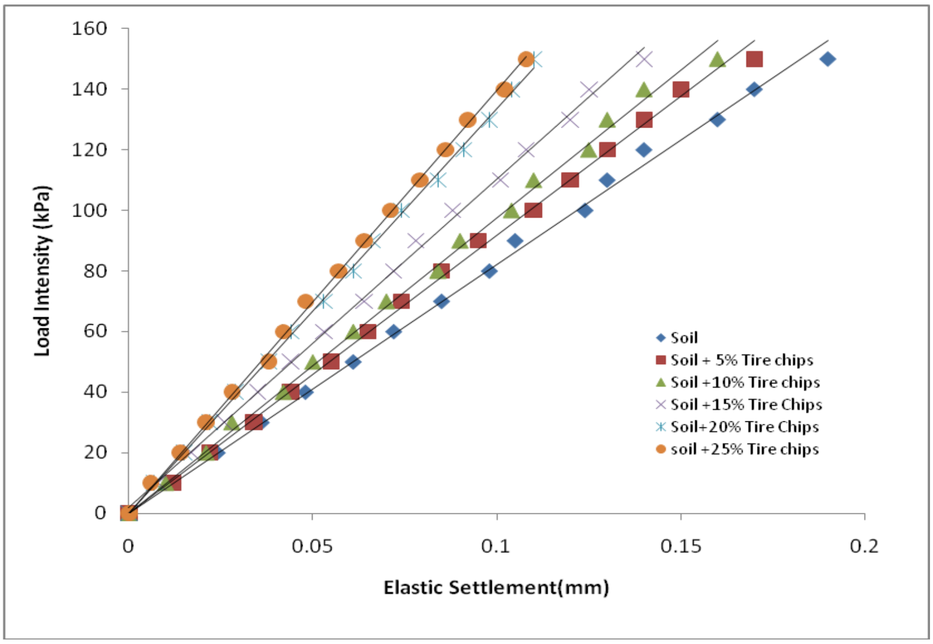

Fig. 1. Load–elastic settlement plots of clayey sand stabilized with scrap tire chips of 10mm size

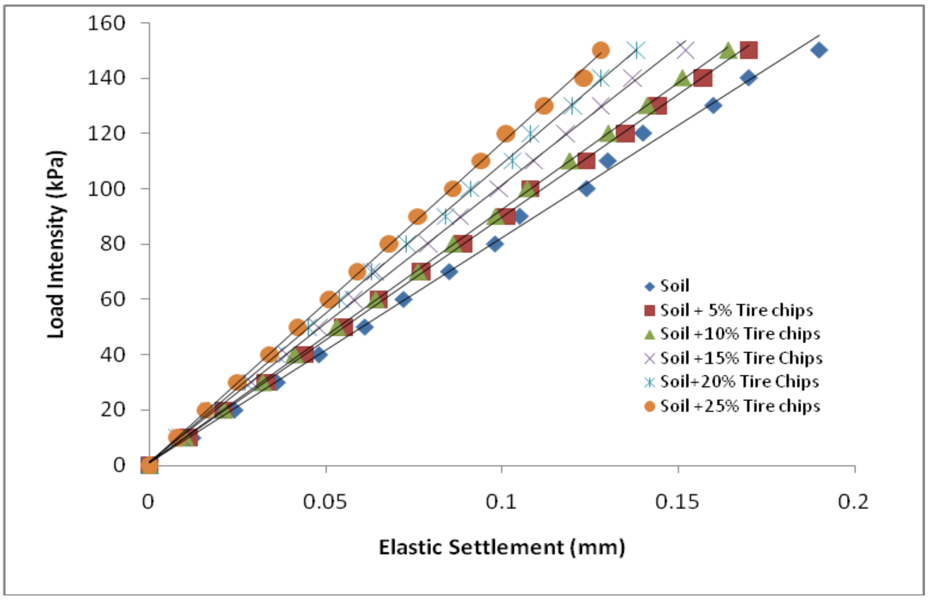

Fig. 2. Load–elastic settlement plots of clayey sand stabilized with scrap tire chips of 20mm size

The values of Cu are determined for foundations of base areas equal to or more than 10 m^2 using Barkan's equation (Barkan, 1962) and are presented in Table 6. The values are applicable for circular vibrating base as circular load plate is used in cyclic load tests.

Table 6. Values of coefficient of elastic uniform compression of clayey sand and scrap tire chips stabilized clayey sand

Tire chips content by weight of soil (%)	Size of tire chips: 10mm		Size of tire chips: 20mm	
	$(Cu)_p$ in kN/m^3	$(Cu)_f$ in kN/m^3	$(Cu)_p$ in kN/m^3	$(Cu)_f$ in kN/m^3
0	8.2 x10^5	1.15 x 10^4	8.2x 10^5	1.15 x 10^4
5	9.1 x 10^5	1.28 x 10^4	9.0 x 10^5	1.26 x 10^4
10	9.5 x 10^5	1.33 x 10^4	9.4 x 10^5	1.32 x 10^4
15	11.3 x 10^5	1.58 x 10^4	10.2 x 10^5	1.43 x 10^4
20	13.5 x 10^5	1.89 x 10^4	11.1 x 10^5	1.55 x 10^4
25	14.2 x 10^5	1.99 x 10^4	11.9 x 10^5	1.67 x 10^4

As the values of Cu influenced by shape of footing (Satyanarayana Reddy and Usha Rani, 2020) in soils, the values are to be modified for shape effect for use with vibrating bases of square shape.

4 Discussion

The compaction characteristics in Table 2 indicate that both OMC and MDD values of soil-tire chips mixes decreased with increase in addition of tire chips. This is attributed to lower water absorption and lower density of tire chips compared to soil. At a given percentage of tire chips addition, 10mm tire chips resulted in relatively higher MDD compared to 10mm tire chips due to better Mixing of tire chips due to smaller size.

The results presented in Table 3 indicate that the angle of internal friction of Tire chips stabilized soil increased and cohesive strength decreased with increase in percentage of tire chips. The increased angles of internal friction are due to inclusion of coarse grained tire chips which are relatively tougher compared to soil. Decrease in cohesion is resulting from increased heterogeneity of tire chips mixed soil with increased tire chips addition. At a given percentage addition of tire chips, 10mm size tire chips resulted in slightly higher values of angle of internal friction over 20mm size, which is attributed to relatively better distribution of tire chips in soil due to smaller size and better mobilization of friction with sand fraction of soil. The permeability of soil is observed to increase with increase in addition of tire chips (Table 4) with relatively higher increase for 20mm size tire chips over 10mm tire chips at a given percentage addition of tire chips. This is due to possible higher void ratio of stabilized soil due to mixing of coarser tire chips. Tire chips of 20mm size in soil makes the compaction less effective and results in higher voids.

From Table 5, it can be seen that the soaked CBR value of soil increased and attained maximum value at 15% addition of tire chips, with relatively higher CBR for 10mm size tire chips addition compared to 20mm size tire chips addition. Hence, the optimum percentage of tire chips for stabilization of clayey sand under study is 15% for both 10mm and 20mm size tire chips. However, 10mm size tire chips are to be preferred to stabilize the soil as 20mm size tire chips will have relatively more chance for punching under the loads and result in lesser shear strength.

The study indicates addition of 15% of tire chips helps in improving the soaked CBR by 65% and with soaked CBR value of 5.3%, it is suitable for constructing embankments with heights of 9- 15m. Further, with increased permeability, its performance will be better as it is transformed to semi-pervious soil from nearly impervious soil.

From Table 6, it can be seen from the results of small-scale cyclic load tests that the values of C_u of clayey sand increased with increase in tire chips content, with 10mm size tire chips resulting in slightly higher values. The results reveal that addition of 15-20% of tire chips of 10mm size in clayey sand increased C_u by 35- 65% whereas addition of 15-20% of tire chips of 20mm size has resulted in increase of Cu by 25-35% only.

5 Conclusions

The following conclusions are drawn from the studies conducted on stabilisation of cohesive soil under study with 10mm and 20m sized scrap tire chips.

1. Optimum percentage of tire chips for stabilizing clayey sand under study is 15%.by weight of soil.
2. 10mm size tire chips exhibited better stabilizing effect in clayey sand under study compared to 20mm size tire chips.
3. The percentage improvement in CBR value of clayey sand under study at optimum percentage addition of 10mm size tire chips is 65 percent.
4. The clay soil under study stabilized by addition of 15% of 10mm size tire chips (by weight of soil) is suitable for use in construction of embankments of 9-15m as CBR value is 5.3%.
5. The permeability of clayey sand stabilized with optimum content (15%) of 10mm size tire chips improved by about 75 times the permeability of untreated soil.
6. The coefficient of elastic uniform compression of clayey sand under study increased by 35-65% by stabilizing with addition of 10mm size scrap tire chips.

Hence, stabilization of clayey sand with 10mm size scrap tire chips may be considered for use as construction material in highway embankments of higher heights and also, as improved foundation bed for supporting machine foundations.

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