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Effect of Tire Properties on Strength behaviour of Soil Reinforced with Tire Chips: A Review

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Abstract—*Use of tire chips for civil engineering application has several advantages. The manufacturing process for tires combine raw material in a special form that yield unique properties such as flexibility, strength, resiliency and high frictional resistance. Use of tire chips in geotechnical engineering for improving the soil properties has received great attention in the recent times. Approximately 12 million scrap tyres in 1995 and 15 million in 1996 had been used for civil engineering applications including leachate collection systems, landfill cover, artificial reefs, clean fill for road embankment etc. Disposal scrap tires are environmental dilemma. However, they can improve the characteristics of soil which is an essential material of construction. Tire chips is being used as a soil reinforcement not only for strength purpose, it also have some other properties like light weight fill, drainage, deformability, etc. For efficient application of tire chips, proper understanding of effect of different parameters like tire parameters and soil parameters on the behaviour of tire chips reinforced soil is required. In this paper brief review of the findings of different researchers, based upon the experiments is presented which shows the effect of different tire parameters on the strength behaviour of tire chips reinforced soil.*

1. INTRODUCTION

The concept of soil reinforcement with natural fiber materials originated in ancient times. Randomly distributed tire chips reinforced soils have recently attracted increasing attention in geotechnical engineering. The primary purpose of reinforcing soil mass is to improve its stability, increase its bearing capacity, and reduce settlements and lateral deformation. New methods are still being researched to increase the strength properties and to reduce the swell behaviour of expansive soils. Many investigators have experienced on natural, fabricated, and by-product materials to use them as stabilizers for the modification of soils. Recently, there have been many experimental researches on the reinforcement of soils with randomly disturbed tire chips. Properties of tire chips reinforced soil depend upon the properties of tire chips as well as soil properties. In this study effect of tire chips properties like; tire chips content, length of tire chips and type of tire chips on the strength of tire chips reinforced soil is presented.

2. MECHANISM OF TIRE CHIPS REINFORCEMENT

In tire chips reinforcement technique, tire chips is randomly mixed in soil. The reinforcing mechanism of tire chips is similar to the roots of plants. Plant roots bind soil particles and resist its movement. Similar to that when stress applied on tire chips reinforced soil, deformation in the surface of tire chips takes place because of movement of soil particles. This deformation increases the interlock resistance between the soil particles and tire chips. Normal force acting at the soil-tire chips interface, also mobilizes frictional resistance at soil-tire chips interface. So, the interlock force, friction force and bond strength are primarily responsible for resistance of movement of soil particles, which enhances the load carrying capacity of tire chips reinforced soils. Since tire chips is randomly distributed in the soil, so stress isotropy is achieved.

3. PARAMETRIC EFFECT

To understand the behaviour of tire chips reinforced soil different studies based upon model tests, case study, unconfined compression tests and direct shear tests have done. Case studies on slope failure by Eid et al. [4], on road by eldin and senouci [5], on highway embankment by yoon et al. [18] have shown the beneficial utilization of tire chips reinforcement in different applications. Through model test on tire chips reinforced soil sample, improvement in the bearing capacity and stiffness have reported by Akbulut et al. [1], cetin et al. [2], Edincliler et al. [3], Foose et al. [6], Hambirao and Rakaraddi [8], Marto et al. [11], Naval and kumar [12], Naval et al. [13], Yoon et al. [17]] through various tests have shown that performance of tire chips reinforced soil depends upon the properties like length of the tire chips, tire chips content, stiffness of tire chips and soil properties like soil type, size of particles etc. To develop the understanding of behaviour of tire chips, influence on each parameter were considered. In the following section the influence of tire chips parameters on tire chips reinforced soil obtained by different researchers are presented and these are-

3.1. Tire Chips Content

Tire chips content is defined by the amount of tire chips present in unit mass or unit volume of soil-tire chips mixture or solid soil. With increase in tire chips content the strength of soil mass increases. It is observed from the test results of unconfined compression test that peak stress increases with increase in the tire chips content (Fig. 1). Test results of direct shear test also shows that peak stress increases with increase in tire chips content (Fig. 2). This happened because with increase in tire chips content, there will be more tire chips to resist the soil movement. This increase in resistance, enhance the load carrying capacity of soil. But after certain limit the improvement in the load carrying capacity of soil doesn't show significant results. Improvement in the strength due to tire chips inclusion is because of interaction between tire chips and soil, but with further increment of tire chips in the soil-tire chips mixture, tire chips-tire chips interaction increases and soil-tire chips interaction decreases. The tire chips content after which further improvement in the strength of soil is not significant is known as optimum tire chips content. . It is found that with a higher percentage of tire chips it is likely that tire chips will begin to have direct contact, thereby exhibiting a higher compressibility, the maximum being with 100% tire chips.

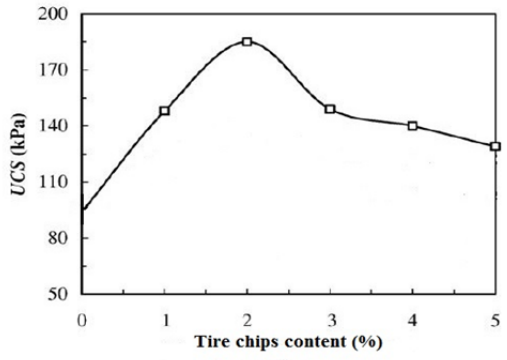

Fig. 1: Effect of tire chips on UCS of Soil Sample [1].

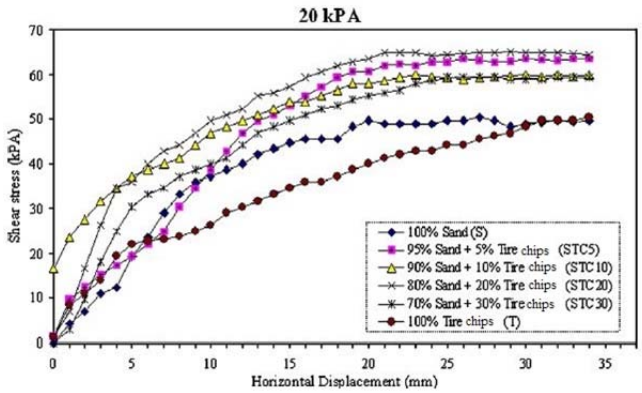

Fig. 2: Sand, Tire Chips, Tire Chips-Sand Mixture Shear Stress-Horizontal Displacement Graph at 20 KPa [3].

3.2. Size of Tire Chips

Through the experimental investigation it is observed that parameters like length and diameter of tire chips play an important role in the development of strength of soil. With increase in length of tire chips the load carrying capacity of soil increases (Fig. 3). Since strength improvement due to tire chips takes place due to interaction between surface of the tire chips and soil particles. So, interaction of tire chips and soil is proportional to the surface area of the tire chips. When length of tire chips increases, surface area of tire chips also increases, so more friction mobilizes. Due to increase in frictional resistance more tensile stress in tire chips mobilizes, because of that confining pressure for soil present in the matrix of the tire chips increases. These increased frictional resistance and increased confinement pressure are major component of strength improvement of tire chips reinforced soil. Increased friction resistance directly resist the movement of soil particles and increased confinement increases the shear resistance of soil. Small tire chips has inadequate friction resistance due to small surface area, so shearing pull out phenomena takes place. For longer tire chips if tensile strength of fiber is not adequate then breakage in the tire chips may take place.

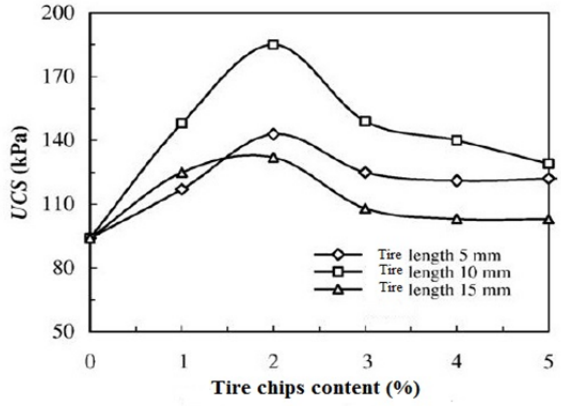

Fig. 3: Effect of Tire Chips on UCS of Soil Sample [1].

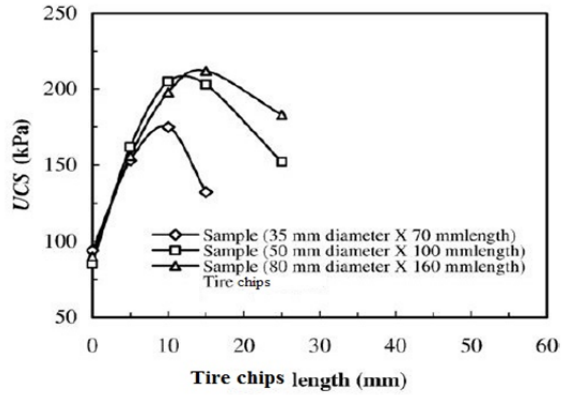

Fig. 4: Effect of Lengths and Dimensions of Tire Chips on UCS of Soil Sample [11].

It is also observed by researchers that after an optimum length of tire chips further improvement in the strength of the soil is marginal. Longer tire chips doesn't remain straight in soil-tire chips matrix, folding of such tire chips takes place. Due to this full length of tire chips doesn't contribute significantly in the strength improvement. Longer tire chips has also tendency of breakage and it is more at higher confinement pressure.

Diameter of tire chips has also impact on the performance of tire chips reinforced soil [17]. Responses obtained from unconfined compression tests have shown that unconfined compressive stress increases with increase in the diameter, due to increased pull out resistance (Fig. 4).

3.3. Type of Tire Chips

Different type of tire chips are available. One can use particular tire chips according to the demand of the work. As the data is presented for following types of tires:-

The chips were

10 mm • 10 mm (Type I)

20 mm • 20 mm (Type II)

20 mm • 10 mm (Type III).

Their average specific gravity was 1.12.

The thickness of these chips varied from 2.25 to 10.8 mm as they are made from scooter tyres (Type I), truck tyres (Type II) as well as car (Type III).

Table 1: Vertical Strain for Sand-Tire Chips Admixture[15].

Tire Chips Content(%)	Vertical Strain (%) for Sand-Tyre Chips Admixture at a Vertical Stress of					
	Type I		Type II		Type III	
	80 KPa	200 KPa	80 KPa	200 KPa	80 KPa	200 KPa
0	0.13	0.33	0.13	0.33	0.13	0.33
5	0.13	0.42	0.22	0.56	0.28	0.56
10	0.19	0.51	0.26	0.66	0.37	0.74
15	0.28	0.67	0.4	0.75	0.5	0.93
20	0.33	0.84	0.49	0.94	0.59	1.1
80	2.06	4	3.39	5.09	3.96	5.84
100	8.53	14.91	10.66	18.86	10.84	19.06

Table 2: Strength Parameters for Sand with Tyre Chips Type I, II and III [15].

Type of Tyre Chips	Parameter	percentage of Tire chips				
		0	5	10	15	20
I	C (KPa)	0	6.6	9.1	11.5	13.3
	ϕ (deg)	38	39.6	39.7	39.9	40
II	C (KPa)	0	9.2	11.6	14.1	15.8
	ϕ (deg)	38	39.5	39.7	39.9	40.1
III	C (KPa)	0	15.2	15.9	17.6	18.4
	ϕ (deg)	38	39.2	39.5	39.7	39.9

From the above tables we can see that compressibility of composite is maximum with chips derived from light motor vehicle tires (Type III) and least with tire derived from two wheeler tires (Type I) and for heavy load vehicles tyres (Type II) it's intermediate. Same in the case of cohesion. In case of angle of internal friction there is no significant improvement with addition of such tyre chips.

4. CONCLUSION

This paper have shown the beneficial contribution of tire chips in the strength improvement of soil. Influence of tire chips properties on behaviour of tire chips reinforced soil are also discussed in the brief. To get the maximum benefit from the performance of tire chips reinforced soil, one must consider all the influencing parameters and their working mechanism. Yet further research is required to understand the behaviour and for proper design of tire chips reinforced soil structure.

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