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Influence of Tire Chips on the behaviour of Soil: A Review

Preetpal Singh[1], Shailja Bawa[2], Akash Priyadarshee[3] and Gurjeet Kumar[4]

[1,2,3,4]NIT Jalandhar
E-mail: [1]preetpals91@gmail.com, [2]bawas@nitj.ac.in,
[3]i.akashpriyadarshee1@gmail.com, [4]paras.ptk2@gmail.com

Abstract—*The primary objective of the paper is to review the application of the tire reinforced soil as a construction material for light-weight fill material in highway construction, for drainage material in highway and landfill construction, and for other similar applications. Reuse of scrap tires would not only provide a means of disposing of them but would also help solve difficult economical and technical problems. Approximately 12 million scrap tires 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. Growing piles of discarded tires create fire and health hazards. Current disposal methods are wasteful and costly. Use of shredded tires in geotechnical engineering for improving the soil properties has received great attention in the recent times. This paper presents the characteristics of shredded scrap tires and their engineering properties and behaviour alone or when mixed with soils.*

Keywords*: tire chips, reuse, engineering properties*

1. INTRODUCTION

The centuries-old problem of land scarcity in the vicinity of existing urban areas often necessitates the use of sites with soils of marginal quality. In many cases these sites can be utilized for the proposed project by using some kind of soil improvement. The soil must be capable of carrying overcoming load without a shear failure and with settlement in the limit. Most structural distress attributed to poor foundation design in form excessive settlements. The soil often poses design, construction and maintenance hazards to civil engineering structures founded on them. Problems may arise during construction stage due to inability of the soil to provide adequate support to the construction work. Excessive settlement, insufficient bearing capacity of the subgrade etc. may lead to loss of stability of the overlying structures. If such soil cannot be removed then its engineering behaviour can often be enhanced by some method of ground improvement techniques also called soil reinforcement techniques. An extremely large number of methods have been used and/or reported in the literature to achieve the desired results. Soil reinforcement is one of the popular technique for ground improvement. It is used from very ancient time. But systematic study and development of the concept and principle of soil reinforcement was first developed by [1].He demonstrated that the introduction of reinforcement elements in a soil mass increases the shear resistance of the medium. The primary purpose of reinforcing soil mass is to improve its stability, increase its bearing capacity, and reduce settlements and lateral deformation [2,3,4].Several reinforcement methods are available for stabilizing expansive soils. All these methods may have the disadvantages of being ineffective and expensive. Therefore, new methods are still being researched to increase the strength properties and to reduce the swell behaviours of expansive soils [8]. Disposal of worn-out tires has become a national problem. It is estimated that more than 200,000,000 automobile tires and 40,000,000 truck tires are discarded in the United States each year [5]. The growing stockpiles of discarded tires create potential fire and health hazards. Because of their chemical composition, stockpiles of tires, once ignited, burn at high temperatures and produce excessive volumes of thick black smoke due to incomplete combustion. The melting tires also generate large quantities of oil that not only add to the fire itself but also, through the runoff, contaminate soil and ground water. Large stockpile fires cause environmental damage and create unnecessary expenses for taxpayers. The Hagersville fire, for example, took 200 fire fighters 17 days to extinguish and cost approximately $1,000,000 for only essential site cleanup and limited environmental testing. In addition to the fire hazard, improper storage of used tires poses a direct threat to public health. Discarded tires, when allowed to collect water and organic debris, become an optimal breeding habitat for four of the most important disease-carrying mosquitoes in the United States. Epidemiological studies have correlated fatal epidemics to the existence of scrap-tire stockpiles. It has been concluded that epidemics in certain localities were a result of the artificially enlarged population of these disease-carrying mosquitoes due to the optimum environment created by tire stockpiles .If tires are reused as a construction material instead of being burned (burning is currently the leading method of reuse accounting for 17% of scrap tires), the unique properties of tires can once again be exploited in a beneficial manner. In

recent years, civil engineering applications of tire shreds, which are pieces of whole tires cut into 50-305 mm pieces, have increased. These uses include: lightweight fill [9, 10], insulation beneath roads [11], and lightweight backfill for retaining walls [12,13, 14]. The effects on water quality have been found to be negligible [15], although three thick tire shred fills have experienced serious heating reactions [16]. Tire shreds have also been used as an alternative to crushed stones (gravel) as drainage media in landfill leachate collection systems [17, 18].

1.1. Tire Chips as Soil Reinforcement

Several researchers have been undertaken in order to study possibilities of using tire-chips in civil engineering applications such as highway embankments and backfills behind retaining structures over weak or compressible soils. According to Humphrey [17], using tire-chips in civil engineering applications are advantageous because of their low density, high durability, and high thermal insulation and in many cases least cost compared to other fill materials. Previous studies have mainly concentrated on determining engineering properties of pure tire-chips and/or various mixtures of tire-chips with sand as a lightweight fill material [5, 34, 41]. They concluded that tire-chips and sand mixtures can be used as a lightweight fill material behind retaining structures and highway embankments over weak or high compressibility soils .Usage of tire-chips especially in highway embankments will have a positive impact on the environment since large quantities can be consumed in these voluminous structures. Reinforcement by tire scrap is similar to the fiber reinforcement. It binds particles of soil through surface interaction between soil particles and tire scraps. Surface resistance due to interaction between soil particles and tire scrap resist the movement of the soil particles. Due to this resistance load carrying capacity increases. Fig. 1 shows the typical shapes of different types of processed Tires. Figure2 shows the SEM image of a single tire-rubber particle. Composition of tire is shown in Table No. 1, which make it clear that silica is present in the tire chips which is the major component for the strength.

Fig. 1: Typical shapes of different processed used Tires [29].

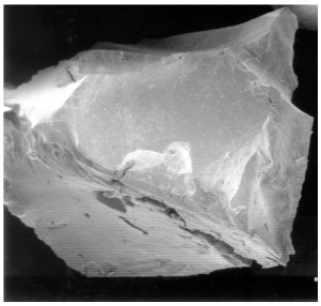

Fig. 2: SEM image of a single tire-rubber particle (size -1.2 mm) [30]

Table 1: Composition of Tire

Material	Automobile (%)	Trucks (%)
Rubber/Elastomers	48	45
Carbon Black and Silica	22	22
Metal	15	25
Textile	5	-
Zinc Oxide	1	2
Sulphur	1	1
Additives	8	-

2. EFFECT OF TIRE CHIPS ON THE SOIL PROPERTIES

Different laboratory tests were conducted by different researchers to evaluate the properties of the soil mixed with tire chips. A review on the effect of tire chips on the index and engineering properties of the soil is presented in the following section.

2.1. Plasticity behaviour and hydraulic conductivity of soil

Plasticity of soil depends upon the minerals and the properties of the soil. By mixing of tire chips, plasticity behaviour of soil changes with amount of tire chips. So when it is mixed with the clay liquid limit (LL), plastic limit (PL), shrinkage limit of clay changes [33]. Clay content decreases with increase of the percentage of tire chips while plastic limit and liquid doesn't show much variation. It also increases the consistency of soil. Change in the liquid limit or plastic limit depends upon the type of soil. Fig. shows the variation of the liquid limit and plastic limit of the soil mixed with the tire chips content. Hydraulic conductivity or permeability property of soil is an important criterion for the structures like liners. Hydraulic conductivity of soil depends upon the types of soil and particle size distribution of soil. For clay or fine grained soil hydraulic conductivity is less, while for coarse grained soil it is greater. Well graded soil or the soils with different sizes of particles have less permeability and for poorly graded soil permeability is greater. When tire chips are mixed with the soil it changes the distribution of particle sizes of soil, so hydraulic conductivity changes [34].

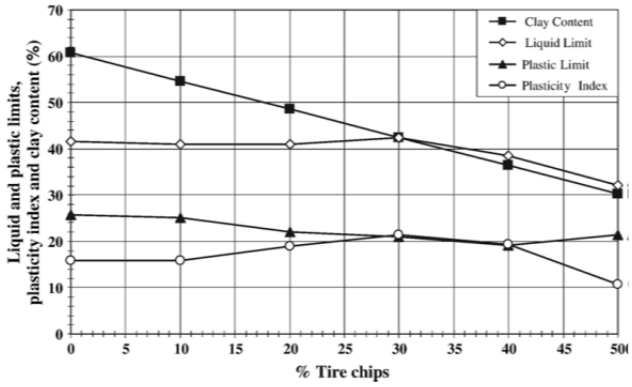

Fig. 3: Changes of liquid limit, plastic limit, plasticity index and clay content as the % tire-chips increases [33]

2.2. Compaction behaviour of soil

Compaction behaviour of soil depends upon the type of soil. For coarse grained soil maximum dry density is greater than fine grained soil. While optimum moisture content (OMC) of coarse grained soil is less than OMC of fine grained soil. . Gradation of the soil has also major impact on the compaction behaviour of soil. Well graded soil have greater maximum dry density than poorly graded soil. Due to the addition of the tire chips maximum dry density decreases for both types of soil. This could be due to light weight nature of tire waste [43]. Fig. 4 and 5 shows the variation of MDD and OMC with content of tire chips. Since specific gravity of tire chips is less, so when it is mixed with the soil, soil changes into lighter material because of which MDD of soil decreases with increase in the content of tire chips. When tire chips is mixed with the fine soil, it decreases the MDD of soil and doesn't affect much the OMC [35-38]

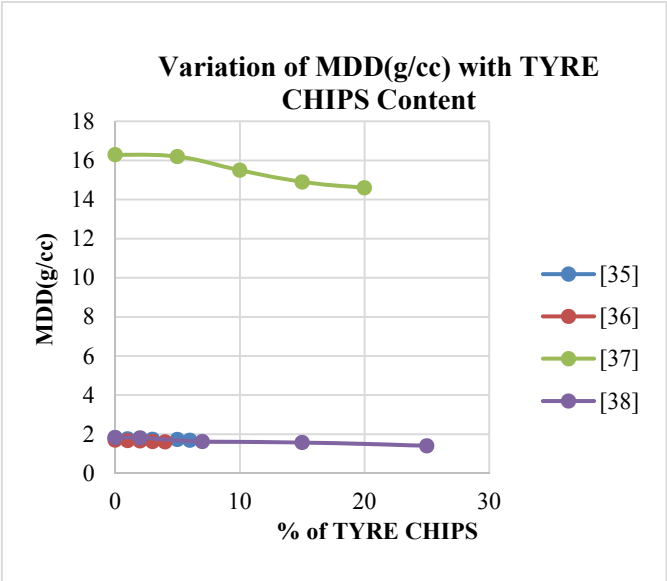

Fig. 4: Variation of MDD with Tire chips content

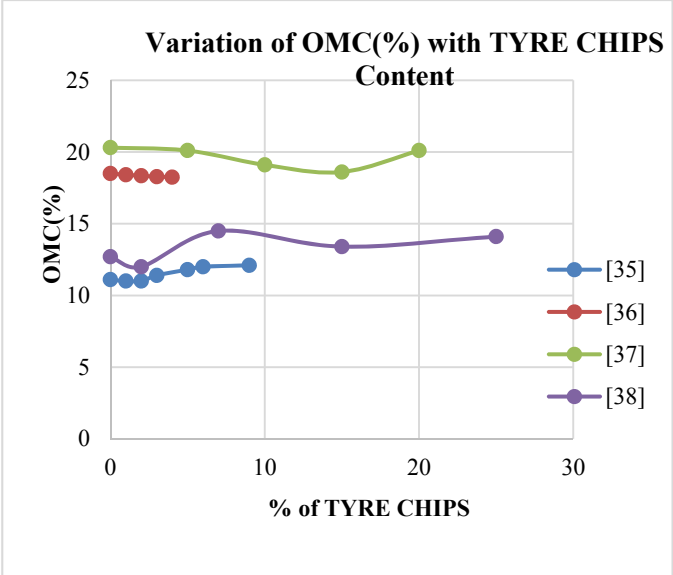

Fig. 5: Variation of OMC with Tire chips content

2.3 Effect on Strength of Soil

Strength of soil increases with increases in the amount of cementious material. Tire Chips have shown the cementaneous properties. Tire Chips has silica contents, which shows the pozzolonic reaction. The pozzolonic reaction increases the cementenious quality in the soil. It has shown by study that with increase in the quantity of tire chips, strength of soil increases [37,39,40].The addition of tire chips to sand increases the shear resistance at higher displacement although the magnitude and nature of this increase are affected by normal stress, chips content and aspect ratio[37].Shear strength parameters of soil are affected by the addition of the tire chips upto a extent [41]. The tire chips behave more like gravel in the mixture rather than reinforcing elements [42]. The sand reinforced by waste tires had more than twice the bearing capacity of loose sand. The improvement in bearing capacity due to the tires decreased with increase of the density and the settlement reduction due to tire reinforcement with combination of treads and sidewalls was as much as about 70% for loose sand and 34% for dense sand [32]. Many researchers have reported that the after a certain amount of tire chips content further increment of tire chips content doesn't improve the strength of soil significantly. Such amount of the tire is known as optimum content of tire. Further improvement in the tire content is responsible for the reduction in the strength. The compressibility of tire waste is much higher than the soil. Due to this at higher content of the tire waste much more deformation takes place.

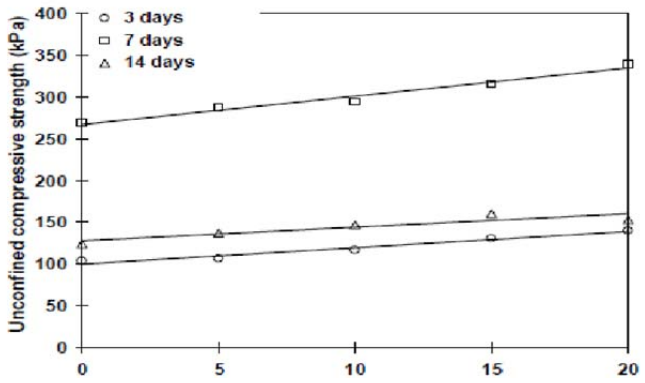

Fig. 6: Variation of unconfined compressive strength of cohesive soil-tire chip mixtures with curing period [37]

Table 2: Variation of Angle of Friction and Cohesion with Tire

	[37]		[39]		[40]	
% of Tyres chips	**Φ(°)**	**c'(kPa)**	**Φ(°)**	**c'(kPa)**	**Φ(°)**	**c'(kPa)**
0			38	0	36.8	7.8
5			39.6	6.6	36.1	7
10	36.2	7.9	39.7	9.1	35.7	21.7
15			39.9	11.5		
20	36.5	8.6	40.0	13.3	37.2	22
30	38.6	14.8			36.4	30.7
40	35.4	21.3				
50	21.6	22.5				
60					34.4	18.2

2.4 Swelling behaviour of soil

Expansive soils or swelling soils are one of the problematic soils. They have tendency to increase in the volume when water is made available and to decrease in the volume if water is removed due to which cracking takes place. Non expansive soil undergoes large compaction at high water content. There are different techniques like replacement of expansive soil, modification of soil and use of foundation like belled piers, under reamed piles are generally adopted by Geotechnical engineers. Use of admixtures of the modification of the property of swelling soil is one of the ground improvement techniques. Tire chips have also potential to suppress the swelling behaviour of soil [31].

3. CONCLUSIONS

This paper briefly discussed the impact of the tire chips on the behaviour of soil mixed with the tire chips. For the utilization of the waste material for geotechnical purposes it is important to understand its impact on the behaviour of soil. It is found that mainly the shape and size of the tire chips, particle size distribution, chemical constituents etc. are mainly affecting the geotechnical properties of mixed. Yet further study is required to understand the mechanism and potential of tire chips with different type of soil for the improvement of properties of soil.

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