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IMPROVEMENT OF COHESIVE SOIL SUBGRADE BY USING TIRE SCRAP

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Abstract — *The disposal of tire scrap has become a nightmare in contemporary times. With the global increase in number of vehicles the production of tires has also increased manifold which in turn has resulted in accumulation of tones of tire scrap being generated each year. Traditionally, tire scrap is either burnt or being dumped off having severe environmental consequences. The cohesive soils are not preferred by highway engineers due to its low shearing strength and poor water draining capabilities thereby making it an undesirable choice for construction of a highway project. In this study an A-6 soil was taken and various proportions (05%,10%,15%) of tire chips (0.5",1",1.5') were added to form samples which were then tested against Modified Proctor, Falling Head Permeability and Large-scale Direct Shear Tests. It was concluded that addition of tire chips to cohesive soil mass had far reaching impact on the strength and hydraulic conductivity parameters of the mixtures and hence the waste could be utilized in an environmental friendly manner.*

Keywords-*Cohesive soil; tire chips; modified proctor test; falling head permeability test; large scale direct shear test*

I. INTRODUCTION

A typical flexible pavement consists of a bituminous wearing course over base course and sub-base course. The surface course may consist of one or more bituminous or Hot Mix Asphalt (HMA) layers. These pavements have negligible flexure strength and hence undergo deformation under the action of loads. The structural stability of flexible pavements is attained by the combined action of the different layers of the pavement. The vehicular load is directly applied on the wearing course, and it gets dispersed (in the form of a truncated cone) with depth in the base, sub base, and subgrade courses, and then ultimately to the naturally occurring strata.

The failure of flexible pavements occurs due to many reasons one of the reason is the failure of sub grade soils. Cohesive soils as subgrades poses serious threat to the integrity of a flexible pavement built over them as they retain moisture for a longer period besides possessing low shearing strength. Excessive settlements along the wheel tracks on pavement surface and bearing capacity failures in the subgrade soil are often observed in the flexible pavements constructed over such subgrades [1].

The disposal of tire waste has become a serious problem for the state agencies these days as the hike in production of automobiles has greatly flourished the tires industry. Tire scrap serves as a perpetual source of environmental hazard being non-biodegradable, highly inflammable with emitting hazardous non-criteria pollutants when burnt and proves as breeding ground for mosquitoes and rodents when dumped in open.. Utilizing waste tires in geotechnical applications is one of the ideal options [2]. This tire scrap could be utilized in improving certain engineering properties of a cohesive soil having some of the very promising utilities such as lightweight fill, insulation beneath roads, and lightweight backfill for retaining walls [3]. It has been concluded that soil-tire mixture has some of the very promising properties like lightweight, low earth pressure, high elasticity, less compressible, good shear strength, good drainage than pure tire shreds [4] [5]. The effects on water quality are negligible [6]

Using tire scrap for improvement of subgrade soil has great potential. In areas where traversing of road alignment through cohesive soils is unavoidable, adding tire scrap to the soil mix can potentially enhance the shear strength and hydraulic conductivity of the cohesive soil mass. The insulation qualities of tire shreds would reduce frost penetration [7] Moreover, their high permeability would provide good drainage. Since shreds are free draining and thus do not induce excessive pore pressure, that can potentially cause stability problems during loading, makes tire scrap a very good option for soil stabilization. In this study an attempt to improve the geotechnical properties of a cohesive soil subgrade is being carried out by preparing clay soil-tire chip samples. Soil sample from National Highway N-5 (Peshawar-Nowshera section) was taken and tested for Atterberg's Limits to identify its class. Plasticity Index of the soil came out to be 12 while the grain size distribution curve highlighted that 92% of the particles had passed through sieve no 200 thus qualifying the sample to be an "A-6 soil" as per AASHTO soil classification system. Various sizes of tire chips have been used (0.5",1",1.5") and samples have been prepared after adding tire chips in three different percentages (05%,10%,15%). The samples thereof were tested against Modified Proctor Tests, Falling Head Permeability Tests and Large-scale Direct Shear Tests.

A. Modified Proctor Tests

Modified Proctor Test is a laboratory test used for calculating the moisture content known as "Optimum Moisture Content" at which maximum dry density of a soil is achieved. The Modified Proctor Test was conducted on virgin clayey soil sample as well as on the samples prepared with tire chips added in different percentages (5%,10%,15% to dry weight of soil). The modified proctor test conducted on virgin soil revealed that the Maximum Dry Density of the sample was 118.66 lb/ft^3 with OMC of 14.87%. Later tests carried out on sample prepared with various percentages of tire chip content unveiled that the Maximum Dry Density of the mixture decreased with increase in the percentage of tire rubber and the minimum value was recorded as 99.7lb/ft^3 with OMC of 13.7% when mixed derived from 15% of tire chips (0.5") was tested. This may be attributed to the reason that tire rubber has specific gravity value lesser than that of soil and thus overall density of the mixture decreases with the addition of tire mass. However no significant change in the value of Optimum Moisture Content was observed.

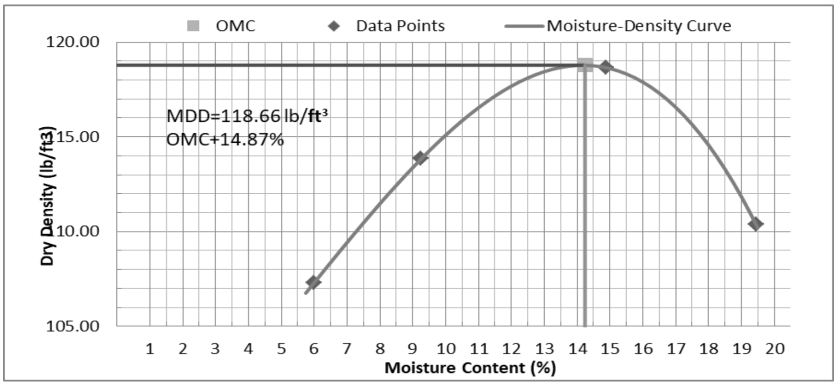

Fig 1: Modified Proctor Test Graph for virgin soil sample

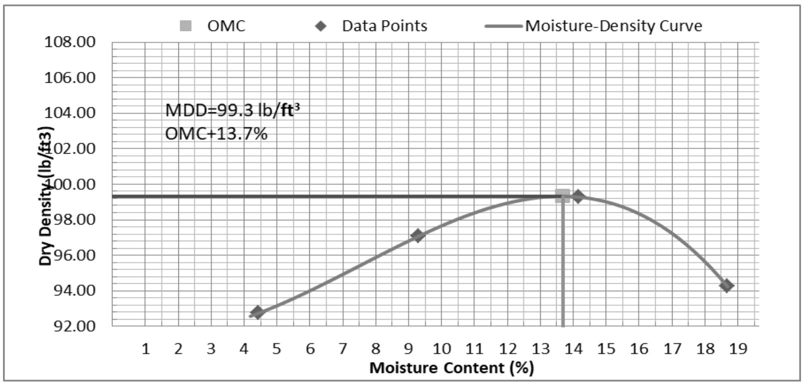

Fig 2: Modified Proctor Test Graph for Soil Sample with 05% Tire Chips (1.5')

B. Falling Head Permeability Tests

The falling head permeability test is a laboratory testing method used to determine the permeability of fine grained soils with intermediate and low permeability such as silts and clays. The falling head permeability test was conducted on virgin clayey soil sample as well as on the samples prepared with shredded tire scrap added in different percentages (5%,10%,15% to dry weight of soil). The virgin soil possessed the permeability 2.205E-07cm/s. The test results revealed that with addition of tire chip content to clayey soil mixture the hydraulic conductivity of the sample increased exponentially. Optimum value was achieved by when 15% of 1.5" sized tire waste was added to soil resulted in k value of 1.957E-06cm/s which is 7.82 times greater than the value obtained from virgin soil. This may be due to the reason that introduction of tire chips to cohesive soil mass acts as gravel (coarser material) and results in incremental drainage value Furthermore the addition of shredded tire scrap to the soil also causes creation of voids due poor adhesive properties of tire rubber which results in creation of water pathways within the mixture and hence the enhanced permeability. It's evident from the test results that by enhancing the quantum of tire chip content as well as increasing the size of it greatly contribute towards the improvement of permeability of cohesive soil mass.

Percentage by weight (dry) of soil	Permeability k (cm/s)
Virgin Soil Sample	2.502E-07
Sample with 15% of tire chips (1.5")	1.957E-06

C. Large Scale Direct Shear Tests

Direct Shear Test is a test used to measure shear strength parameters of soils by deforming a sample at a controlled rate on or near a single shear plane. Since the conventional direct shear test has got some limitations due to smaller size (6cmx6cm) of its shear box and hence testing larger size material (tire scrap) was not possible. To overcome this deficiency a large scale direct shear apparatus has been developed for testing various samples prepared with mixing shredded tire waste in different proportions. Large scale direct shear tests were conducted on virgin cohesive soil samples and thereafter to the mix containing tire chips having size of 1.5" and blended with the soil in three percentages (05%,10%,15%) to the dry weight of soil. The size 1.5" was only selected for testing against shear strength because the mix prepared from said sized tire chips yielded maximum value of hydraulic conductivity at thrice the percentages (05%,10% and 15%) respectively. The test results revealed that by increasing the normal load to a sample the shear strength increases. As shear strength is a sum of angle of internal friction and cohesion of expansive soils. With introduction of tire rubber the angle of internal friction increases substantially while the cohesion decreases. The increase in angle of internal friction may be attributed to large surface area of the tire chip which comes in to contact with the soil and thus acts as a course aggregate and hence the enhanced strength due to internal friction between the soil and tire. The presence of tire content across the shear plane acts as a reinforcing material and hence provides sufficient resistance to shearing. The cohesion on the other end decreased with the application of tire content which may be due to that the shredded tire waste having larger area as compared to that of soil possesses poor adhesive properties when mixed with soil it does not make a good bond with the clay particles and therefore the strength due to cohesion between the particle decreases with the increase in quantum of waste tire. With the increment in tire chip content the quantity of clay decreases resultantly the cohesion of the sample decreases accordingly. The optimum value of Angle of Internal Friction (Φ) was achieved when 15% of tire chips were added to the soil enhanced the Angle of Internal Friction (Φ) from 21.18° to 34.95°. However the cohesion value decreased from 26.04kPa to 16.46kPa. The dilation of the samples being negligible was neglected.

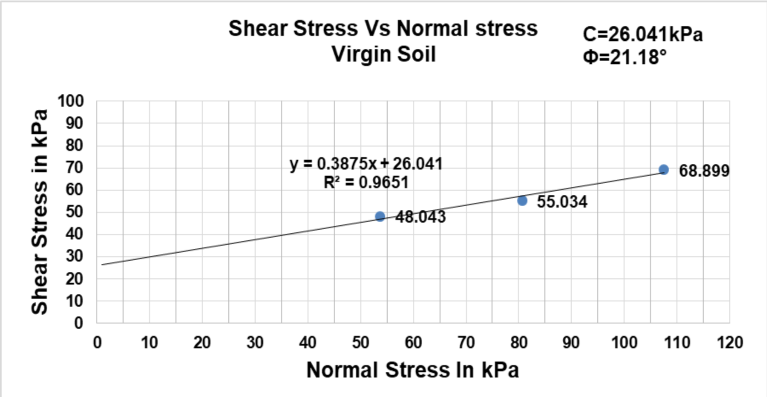

Fig 3: Normal Stress Vs Shear Stress Graph for Virgin Soil

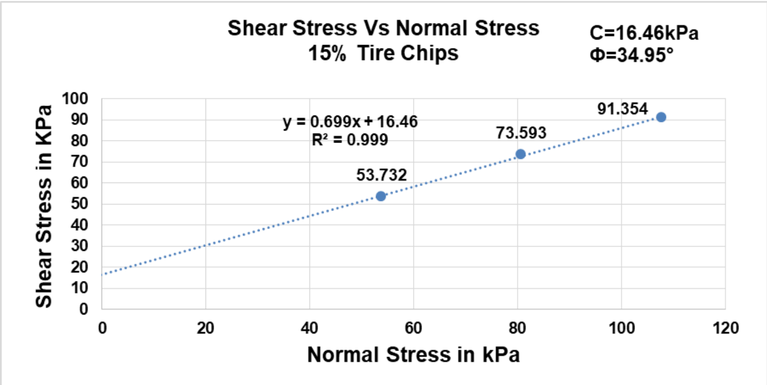

Fig:4 Normal Stress Vs Shear Stress Graph for Soil containing 15% Tire Chips (1.5')

Parameter	Without adding tire chips	Sample Prepare by adding 15% of tire chips (1.5")
Angle of Internal Friction (Φ)	21.18°	34.95°
Cohesion (c) (kPa)	26.04	16.46

D. Conclusions

Decrement in density of the soil-tire chip mixture was observed with the addition of tire content this property could be beneficial in constructing light weight embankment in marshy areas. The vehicular load inflicts severe tremors to nearby structures across the highway the soil-tire mixture could be used in those areas for having excellent vibration absorbing qualities. The lightweight of the mixture could also be significant in usage as backfill material in embankments as the same would exert minimum lateral force on the retaining structure and hence could result in a stable structure. From the results of falling head permeability tests results it was deduced that introduction of tire chip to cohesive soil significantly enhances the hydraulic conductivity of soil-tire chip mixture. With increase in size and percentage of tire chip the permeability value goes up. This property could be utilized in construction of road embankments where drainage is of prime importance. The test result from large scale direct shear test revealed that with the addition of tire chip content the shear strength of the mixture increases this property could be utilized in overcoming the settlement issues associated with foundations constructed over cohesive soils. The tire waste other could be used in environment friendly manner which otherwise is either used as a fuel in brick kilns or just simply dumped thereby providing breeding ground for mosquitoes and rats. The increase in strength and permeability of clayey soil with the addition of tire chips can significantly reduce the cost of highway project where the clayey soils are usually replaced with material of better qualities. It is recommended that various other sizes of shredded rubber tire waste may also be got tested with different percentages and its performance thereof be analyzed to assess optimum size and percentage to be used in highway engineering. Combination of different additives may also be used along with shredded rubber tire waste to evaluate whether shear strength and other parameters are enhanced or otherwise.

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