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The Influence of Waste Carpet on the Structural Soil Characteristics in Pavement Granular Layer

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Abstract

Solid waste materials can be left out of environment in different ways or can be used again. As an example of waste fiber materials is the fibers reselling from producing carpet which are made in Iran in largest quantity. These materials are added to soil and granular materials and improve their various properties as compressive and tensile strengths. In present study, the result of previous researches are collected and presented, then, they are used to analyses the effect of using from waste materials in subgrade on highway pavement performance. By using analytical software and results of testing, tensile strain under asphalt layer and compressive strain on subgrade of pavement containing these materials are calculated and after that they are compared together. Next the allowable frequencies of loading for different pavement models are calculated by using existing formula. The results indicate that adding 1.5% of waste fiber to pavement subgrade increases the allowable frequency of loading to 15%.

Keywords: environment problem; waste carpet; pavement layer; unconfined compressive strength; soil property

1. Introduction

Waste materials resulting from different industries especially from agricultural compartments are an important environmental problem (Rahman *et al*., 2010). There are several ways to leave out solid waste materials safely from environment. Some of them are offshore, land filling, incineration or using them in underground (Abessi *et al*., 2010). In performed studies; use of solid waste materials on pavement base layers has been tested. The results have indicated using from these materials in subbase layer increases the strength against rutting failure about 50 to 60 percent (Khabiri, 2010). In recent years, researchers have paid attention to use of waste materials for reinforcement of soil (lin *et al*., 2005), which one of these methods is to use from waste fibers.

Carpet becomes a problem to the environment later than usage. Controlling of a variety of waste carpet in an eco-friendly technique is the thrust area of current day study. Iran, as the oldest carpet producer, produces more than two million square meter of carpet yearly, and it is the biggest carpet producer in the world. Iran exports more than 70% of its productions to all over the world. Saltan et al have presented that it is possible to use from pumice materials as a light aggregate in stabilized subbase layer. His conclusions indicated this operation increase the strength of mixed materials (Saltan *et al*., 2007).

The research by parsad et al was been about use of industrial waste materials in operation of flexible pavement. Geosynthetic materials, by operating like synthetic fibers, can create a reinforced soil which increases the strength of soil. The results of abovementioned researches represent the development of fiber quantity increase maximum dry density and decrease the optimum moisture content (Prasad *et al*., 2009; Ramesh *et al*., 2010). Also by increasing 2% of these materials the CBR and soil strength increases to 12.4, by adding 2.5% of hair fiber to soil its CBR decreases to 9.4 (Akhtar *et al*., 2008; Sobhan, 2004; Wang, 2006).

Examined bearing capacity of reinforced sand-silt soils with palm leaves is the heading of porebrahimi and his coworker's research. Palm leaf as a reinforcer of earth develops mechanical properties and bearing capacity of sand-silt soil. This leaf is low-cost and consistent with environment. Also, it increases the flexibility of foundations behavior in comparison with unreinforced forms (porebrahimi *et al*., 2008). Attom and his colleague present a paper about the influence of two kinds of polypropylene fibers on shear strength factors of sandy soil. Results of this above paper showed that the crimpled shape fiber improved the shear strength of the sand under strong normal force (Attom *et al*., 2010).

Nowadays, using from materials and waste ones results in reduction of storage quantity and economic costs and in avoiding from environmental negative effects. On the other hand, the vehicle traffic intensity is increasing; so the pavement layer strengths should be increased too. The previous researches were about the effect of using from solid waste materials and fibers on soil performance, but they weren't examined the operation of all pavement layers together. The current study concentrated on mechanical characteristics and attempted to recognize the recycling ability of waste carpet fibers in the creation of soil improvement. In present study, not only using form waste fiber in soil layer is examined; but also the increase in strengths of granular layer according to previous published researches is tested. Then the effect of these materials in reduction of pavement failure is examined.

2. Materials and Methods

2.1. Study sample soil and the waste fiber Properties

To obtain the goals of this study, a sample soil was obtained from a depth of 20 cm from the granular road surface around Vali-e-Asr University of Rafsanjan campus. Fig.1 shows the subgrade material grading before mixing. Waste carpet fibers are used in this research shown in the Fig. 2.

Major physical behavior of the used fibers in carpets, that is to say, nylon and polypropylene are summarized in Table 1.

Table 1. Waste carpet fibers properties (Vilkner *et al.*, 2010)

Property	Nylon	Polypropylene
Unit weight [gr/cm^3]	1.13 -1.15	0.9 -0.91
Reaction with water	Suck up water	Hydrophobic
Tensile strength [kg/cm^2]	83 - 100	35 - 46
Extension at break [%]	15 - 300	100 – 600
Fusing point [oC]	265	175
Thermal conductivity [W/m/K]	0.24	0.12

2.2. The effect of fiber materials on soil compaction behavior

The different percents of fiber materials have affect on soil compaction behavior. The optimum moisture content of soil is the result of having 1.0% of fiber in soil and maximum dry density indicates the least in this percent. Table 2 shows the effect of various contents of fiber on maximum dry density of soil. Also, the effect of different content of exiting fiber of soil on optimum moisture content is represented (Ramesh *et al.*, 2010).

2.3. The effect of fiber characteristic on Soil strength

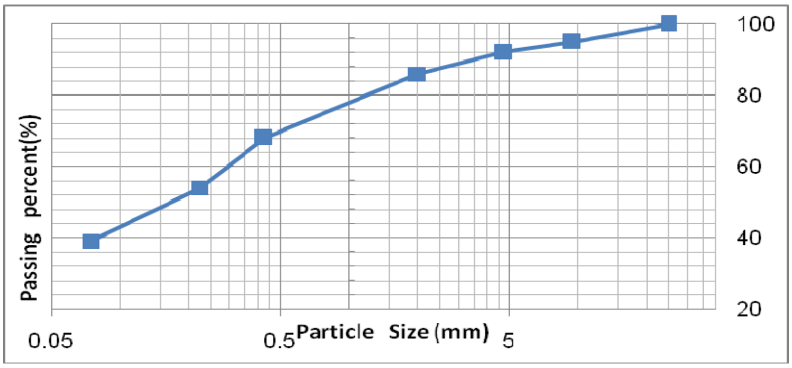

Figure 1. Particle size distributions of soils curve

Figure 2. Samples of used waste carpet fiber in this research

Table 2. The effect of fiber content on MDD and OMC (Ramesh *et al*., 2010)

Fibre Content (%)	Fibre length (mm)	**Optimum moister Content (%)**	**Maximum Dry Density (Kg/m^3)**
1.0	4 0	32	1430
	60	30.5	1425
	80	32	1360
	100	35.5	1360
1.5	40	31.5	1360
	60	36.5	1425
	80	36.5	1440
	100	37	1370
2.0	40	34	1420
	60	32	1380
	80	32.5	1360
	100	37	1360
2.5	40	35	1330
	60	31.5	1340
	80	35	1340
	100	36	1340

Increasing of fiber has some effect on increasing the Unconfined Compressive Strength (UCS) of Soil. Some quantities of fibers with 1.0, 1.5, 2.0 and 2.5 percents are mixed with soil, and then their UCS has been tested. These materials are been used in embankments along the road and reliability .The UCS of soil without adding fiber is equal to 90 kg, but by adding 1% of fiber to soil, its UCS grows up to 120 kg.

To determine what length of fiber is suitable, diagram of strength of soil containing fiber against fiber length is drawn and shown in Fig. 3. It's noted that by having 1.5% of fiber, its best lengths is 40 mm.

Fig. 3 shows the effect of performed tests on different contain of fiber on soil. When the content of fiber in soil increase, the soil strength increases too, and when the content of waste carpet fiber of soil is 2.0%, the soil strength increases up to 200%.

2.4. The effect of fiber content on pavement performance

Figure 2. The mixed soil with fibers samples and testing method in this research

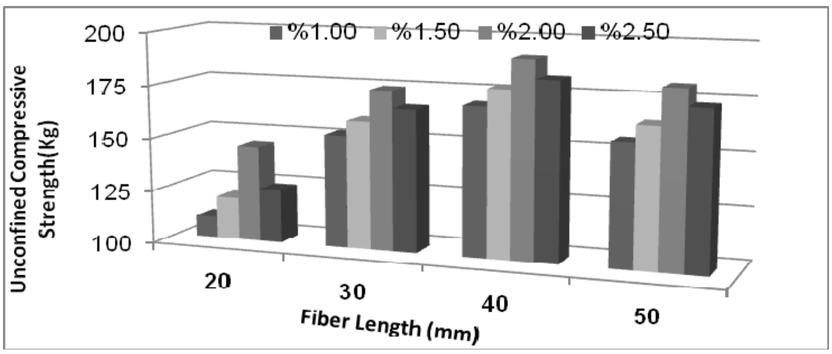

Figure 3. The effect of fiber length and fiber content on soil strength

The use of fiber in subgrade materials leads to increase in soil Unconfined Compressive Strength and consequently its modulus of elasticity increase, so, the pavement performance will improve. By considering the previous studies, everyone can account resilient modulus based on soil Unconfined Compressive Strength. For calculation modulus of elasticity of subgrade layer by considering the measurement of its compressive strength is used from Equation 1 (SPO, 2007; Khabiri, 2010):

$$E_{eq} = 550 \times f_{me} \tag{1}$$

Where,
E_{eq} = Elasticity modulus of materials (kg/cm^2)
f_{me} = Compressive strength of materials(kg/cm^2)

The Kenlayer software has been used for calculation of strains and deformations in many researches (Huang, 2004). It is used from mentioned software to calculate compressive strains on subgrade and tensile strain under asphalt layers. A sample of these studies is related to Rana's thesis in which pavement performance, which its subgrade was stabilized by waste materials, was examined (Rana, 2004). In flowing parts, the results of analyzing the strains of pavement model are presented in Fig. 4. loading is done by the 8.2 tons standard axle and by the content pressure about 5.6 kg/cm^2. Then strains are calculated in two pointed places of pavement.

3. Results and Discussion

By increasing the content of existing fiber of soil, the quantity of strains changes too. It's noted by increasing1% of fiber to soil, the tensile strain under asphalt layer decreases about 15% and the compressive strain on subgrade decrease 20% too. In present study different thickness of base layer are tested. Therefore when the thickness of base layer increases 25%, the compressive strain and tensile strain are in order 10% and 5% and in this time the fiber contents of soil is 2%. The outputs of Kenlayer software are showing 9 separate parameters involving different types of strains, stresses and deformations. Based on calculated strains, it's possible to calculate the allowable frequency of loading for each pavement by using equation 2.

$$N = f_1(\varepsilon)^{f_2} \tag{2}$$

All F_i are factors for calculation of loading frequency and ε is strain in critical points (Huang, 2004; Rana, 2004).The result of loading frequency (N) and their comparisons are represented in Fig. 5.

4. Conclusion

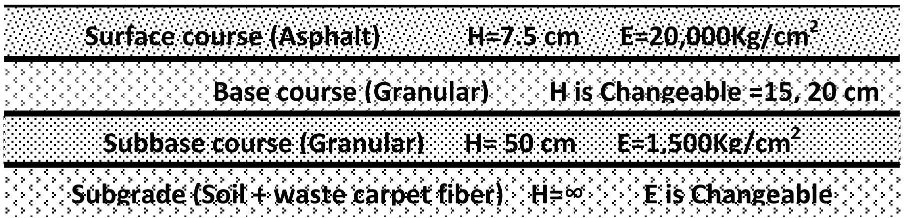

Figure 4. Geometric model of used pavement layers in this research

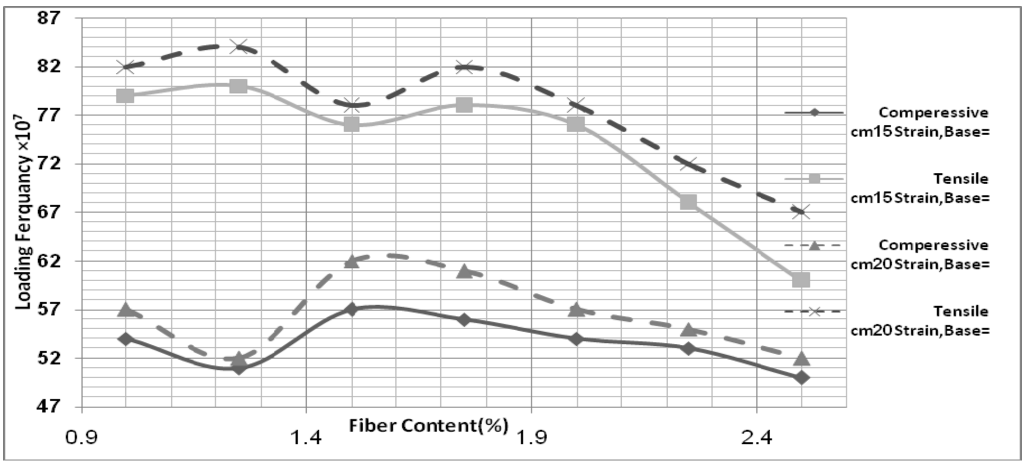

Figure 5. The loading frequency for different content of existing fiber on subgrade

Dependent upon the test consequences of this study, the subsequent conclusions may be drawn out:

• Increasing the waste fiber of soil leads to increase in soil UCS. So that, by increasing 1% of fiber to soil, its UCS increase on average 10%.

• The most suitable length of waste fiber, in which the most quantity of strength for mixed soil is possible, is 40 mm.

• Adding waste carpet fiber to soil decreases its maximum dry density and increases its optimum moisture content. But if someone will make use of excessive quantity of these materials, it will lead to decrease in maximum dry density and increase in optimum moisture content.

• By adding waste fiber to subgrade, the strength of all pavement layer against loads increase. As, by adding 1% of these fibers to soil, tensile strain under asphalt layer and compressive strain on subgrade will decrease in order 15% and 20%.

• The effect of adding 10% to thickness of base layer is fewer than the effect of adding 1% of waste fiber to subgrade.

It's suggested to do these actives about the heading of present study in next researches:

A) To test the effect of waste carpet fiber on different performances of soil such as permeability, freezing depth and soil plastic characterizes.

B) If a part of road will be made by these materials experimentally and its operation will be tested in length of time; they can confirm the laboratories result of present research.

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