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Investigation of different types of fibers for roads by CBR tests

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Investigation of different types of fibers for roads by CBR

Highlights

- *California Bearing Ratio tests and cost alaysis were performed for granular layers reinforced with fibers*
- *Six different fiber types were used in granular road layer by using different adding methods*
- *Generally, each fiber type used in the study have different result values*
- *For small penetration levels in some test results show no improvement for bearing capacity ratio of the road*
- *The cost and layer thickness values were various for different reinforced road layer models*

Graphical Abstract

California Bearing Ratio tests and cost alaysis were performed and the best behavior of the reinforced road was determined

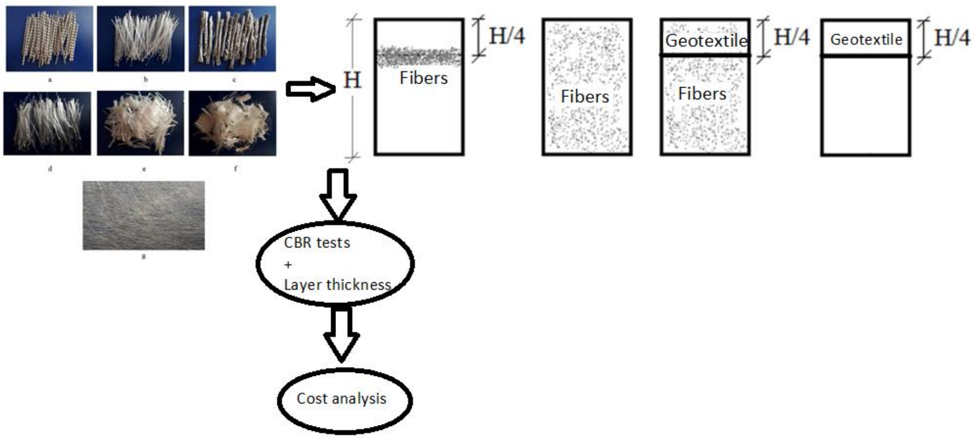

Figure. Flow chart of the study

Aim

Investigate the effetcs of different fiber types on road design and cost analysis.

Design & Methodology

California Bearing Ratio (CBR) tests were conducted, results were determined, road layer design were made and cost analysis were calculated.

Originality

In this study, six different fiber types were used in road layer and different layered methosd were compared and effective cost calculation was conducted as an original effect.

Findings

Stress-penetration curves were compared for different fiber types and layering methods, best configuration types were compared and cost analysis were discussed with unreinforced road.

Conclusion

Different fiber types and laying methods can give various improvement effects.

Declaration of Ethical Standards

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Investigation of Different Types of Fibers for Roads by CBR Tests

Araştırma Makalesi/Research Article

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ABSTRACT

In this study, California Bearing Ratio (CBR) tests in a laboratory were performed to observe the behaviour of granular layer fills reinforced with discrete fibers. Six different fiber types were used in granular road layer by using different methods. Firstly, fibers were added in the road as a layer, then they mixed with soil particles, and as a third method they mixed with soil by laying a geotextile in the road layer, in other words it was used as combine reinforced model. And as the last method only a geotextile was laid and used in the pavement soil. By using these methods, the influence of different type of reinforcements on CBR and bearing capacity ratio values were investigated. Additionally, effects on the pavement layer thickness were calculated and for the best configuration of fiber reinforced sample a cost analysis was conducted. As a result of the study, CBR test values for each fiber type used in the study have different values, and for small penetration levels some test results show no improvement for bearing capacity ratio of the road. It was noticed that when increasing the penetration level, the bearing capacity ratios have larger values. Thus, cost and layer thickness numbers were various for different reinforced road layer models. Therefore, in the real life road projects before using fiber types, cost and performance analysis should be made to determine the more effective one.

Keywords: Pavement, fibers, cost benefit, CBR, bearing capacity ratio.

1. INTRODUCTION

When the literature studies were investigated it can be seen that fibers can be used in transportation engineering structures like other civil engineering construction types [1-8]. However, behaviours of different fiber types in the road layers are not known exactly. Additionally, this can be significant by extending the working life of the road or reducing in subbase or base thickness [9]. Therefore, some studies about fiber reinforcement can be given to illustrate the effects from the literature. For example, Gray and Al-Refeai [10] conducted laboratory tests and they reported the effects of the fibers on soils behaviour. Tingle et al. [5] prepared full-scale test sections to measure the ability of geofiber stabilized sand to sustain military truck traffic and fibers used in the study improved the bearing capacity from 6 to 34%. Jha et al. [11] determined the layer thickness minimizing of reinforced samples according to CBR results. Thickness values significantly can be reduced when fibers were used in the soil and it was found that subbase layer can be minimized up to 50%. Kravchenko et al. [12] tested polypropylene and basalt fibers by 0.25%, 0.5%, 0.75% contents and compared the results with unreinforced condition. It is known that strength and resilient modulus of soil can be decreased. Both before and after freezing thawing, resilient modulus of fiber reinforced samples were obtained higher values than unreinforced samples. Additionally, they found that after fifteen freeze-thaw period, polypropylene fibers and basalt fiber increased compressive strength of soil by %70 and %41.2 when applied by 0.75% content. Moreover, the strength of soil increased by 70% when polypropylene fibers used as 0.75% of content. Cui et al. [13] experimented carbon fibers and nano silica under direct shear tests and conducted microscopy analysis. Results showed that shear strength of reinforced samples can be improved. They reported that carbon fibers effectively improved internal friction angle and cohesion of soil as well. Additionally, combining carbon fibers with nano silica improved the shear stiffness and strength of soil could be increased by 128.3%. As the proportion of the carbon fibers increased, larger values for the shear strength parameters were observed. However, using fibers more than 2% decreased the cohesion increment. The reason of this decreasing was the distribution of high amount of carbon fibers. Another factor could be that optimum carbon fiber content was found as 2% to achieve the highest value of shear strength. Abbaspour et al. [14] studied the effects of the tires on CBR tests. Fibers were applied by 0.5%, 1%, 2%, 3%, and 4% proportions in clayey and sandy soils. It was observed that fibers increased the strength of soil and improved ductility parameters. For clayey soil, fibers decreased CBR values due to low content, however, using fibers in sandy soil increased CBR values up to 270%. Hanafi et al. [15] studied about bottom ash and basalt fiber blends in pure cement paste. The properties of strength and durability of two different percentages of bottom ash (40% and 50%) and three volume fractions of basalt fiber (0.3%, 0.75%, and 1.5%) were used at three curing periods (7, 28, and 56 days). They used compressive strength and flexural strength tests for mechanical properties of composites. They reported that using of basalt fiber can improves the physical, mechanical, and chemical stability properties. As another study Atiyeh and Aydin [16] investigated a pure cement paste by preparing and enriching with carbon fibers. They used four different (0.3%, 0.75%,

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1.5%, and 2.5%) carbon fiber volume fractions in the study. As a conclusion they noticed that the 0.75% carbon fiber addition seems to be an optimum volume percentage, beyond which both physical and mechanical properties were adversely affected.

When engineering characteristics are examined for road design, it is important that maximum amount of fibers could be around 1%. In this study, six different reinforcements were used, different reinforced conditions for road design were compared and best reinforcement placement choice with better material type determined. Firstly, fibers were laid in the pavement layer as a layer, then they mixed with soil particles. Additionally, as can be known not only fibers but also geotextiles can increase the soil behaviour. However, there is no enough information when a geotextile and fibers were used together as a composite material in the soil. Thus, as the third method fibers mixed with soil particles and a geotextile added as a layer. And as a last method, a geotextile was laid in the pavement sample. By using these methods, the effects of different types of reinforcements on CBR and bearing capacity ratio values were investigated. Additionally, effects on the pavement layer thickness were calculated and for the best configuration of fiber reinforced sample a cost analysis was conducted.

2. MATERIAL and METHOD

Particle size distribution and properties of the soil were given in Figure 1 and Table 1, respectively. In (AASHTO T 193-13 [17]) and USCS Classifications (ASTM D2487-06 [18]) the soil property was granular materials as A-1-b and well graded sand (SW). In the study, six different types of polypropylene fiber reinforcements and one geotextile were used. The properties of the reinforcements can be observed from Figure 2. Used reinforcements properties taken from manufacturer firms were listed in the Table 2 and Table 3.

For this study, CBR tests were conducted to see the effect of fiber reinforcements on bearing capacity ratio of road soil and changing thickness of the road layers. In this test method soil in the mold were separated into four equal layers. Each layer had 70 blows with 4.5 kg rammer and compacted samples were soaked in the curing pool for 4 days. Firstly, CBR tests were made for unreinforced soil. Then reinforced models were tested. As for reinforced model, firstly, fibers were prepared for 1% of total mix content but instead of mixing equally with whole soil content, they were all placed on the same layer as H/4 (H is the total height of the sample) as in Figure 3a. For the second method, each fiber type was mixed with soil [17, 18] as can be seen in Figure 3b. As a final method that examined for the purpose of this study was to combine fiber reinforcements with a geotextile in the road aggregate. For this test series, fibers mix mixed with soil and a geotextile was placed at H/4 as can be seen in Figure 3c. Additionally, only a geotextile was laid in the pavement sample as in Figure 3d. Table 4 shows the brief summary of test methods used in this study. CBR values for each scenario were calculated. Then, in order to find the bearing capacity ratio, maximum stress value at specific penetration levels for reinforced pavement was divided by maximum stress obtained from unreinforced model at same penetration level.

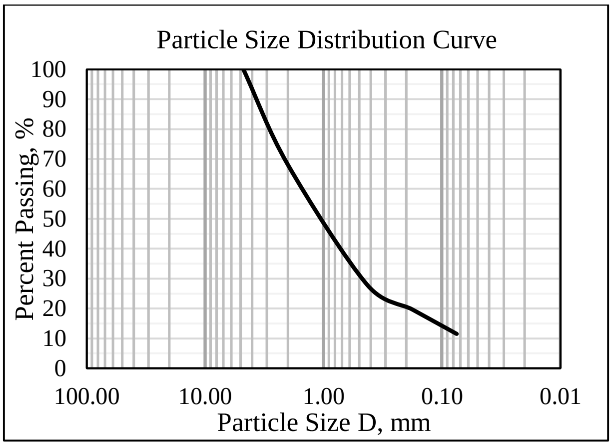

Figure 1. Grain size distribution of soil.

Additionally, in the study, the effects of the fibers on the thickness of the road layers and cost benefit values were analysed. Firstly, a sample of unpaved road was designed, and the total cost of the unreinforced and reinforced pavements were calculated to understand the economical solution. The effect of reinforcements on pavement thickness were examined. Design parameters of the road were assumed and fixed at the beginning by only focusing on the effects of reinforcements for the pavement thickness. Length of the road was assumed as 1 kilometer lane with 3 meters width. Pavement layer thickness values were determined for unreinforced and reinforced scenarios by AASHTO's Guide for Design of Pavement Structures [21] as in Equation 1.

$$\log10(W18) = ZRS0 + 9.36\,\log10(SN+1) - 0.20 + \frac{\log10\left(\frac{\Delta PSI}{(4.2 - 1.5)}\right)}{0.40 + \left(\frac{1094}{(SN+1)^{5.19}}\right)} + 2.32\,\log10(MR) - 8.07 \tag{1}$$

where;

W18 = Number of 18-kip equivalent single axle load (ESALs)

ZR = Standard normal deviate

S0 = Overall standard deviation of traffic

Δ PSI = Serviceability loss at end of design life

MR = Soil resilient modulus

Firstly, a sample flexible road was designed to obtain the layer thickness for unreinforced condition. Structural number (SN) value determines the required pavement thickness in this equation. So, all variables except SN, were fixed to understand the effects of reinforcements on thickness reduction. Variables were chosen in

Table 1. Soil Properties

Property	**Unit**	**Value**
Specific Gravity	-	2.68
Maximum Dry Unit Weight	kN/m^3	21.16
Maximum Void Ratio (e_{max})	-	0.68
Minimum Void Ratio (e_{min})	-	0.41
Relative density	-	70%
AASHTO Classification	-	A-1-b
USCS Classification	-	SW
Cohesion	kPa	0
Angle of Friction	°	35
Coefficient of Curvature	-	2.2
Coefficient of Uniformity	-	24
Optimum Moisture Content	-	6.5%

Table 2. Properties of Fibers.

Reinforcement	Fiber Length, mm	Fiber Amount, per 50 g	Tensile Strength, MPa
Fiber1	50-60	1.850	600
Fiber2	54	3000	600-700
Fiber3	54	>10000	600-750
Fiber4	48-54	>10000	600-800
Fiber5	18	>10000	350-500
Fiber6	18	>4000000	380-450

Table 3. Properties of Geotextile.

Reinforcement	Material	Weight (g/m^2)	Thickness (mm)	Tensile Strength (kN/m)
Geotextile	Polypropylene	110	0.5	7.3

accordance with AASHTO's guide. AASHTO suggested 85-99.9% level of reliability for urban roads so it was taken as 95%. Furthermore, W18, axle load on this pavement was chosen as much as high degree due to create a stronger pavement layer. Another parameter was used as serviceability index (PSI). PSI is a value determining serviceability of a road, which is between 5 (for excellent) and 0 (for poor). Typically, PSI value for a flexible road is 4.2 after construction. If the road with terminal PSI value is under 2.5, rehabilitation can be recommended. Since ΔPSI stands for serviceability loss between terminal and initial conditions, it was taken approximately as 1.9. ZR, S0, W18, ΔPSI were taken as -1.645, 0.350, 14 x 106 and 1.9, respectively.

As can be known resilient module of a road (MR) is related with CBR value of the road. Since AASHTO's MR formula is applicable only for the soils if CBR value is less than 10, equation, which Heukelom and Klomp [21] suggested, can be chosen to create CBR and MR correlation. Besides, this equation gives the least MR result because of the coefficients, which was good for road design to be on the safer side, so CBR and MR relation is given in Equation 2.

$$MR\ (psi) = 2555 \times (CBR)\ 0.64 \tag{2}$$

After finding the resilient modulus for all pavements, SN values were calculated by solving the flexible pavement equation. According to AASHTO, relation between SN and layer thicknesses was defined as the following Equation 3.

$$SN = a1\ D1 + a2\ D2\ m2 + a3\ D3\ m3 \tag{3}$$

where;

SN = Structural Number

D1, D2 and D3 = Structural layer thicknesses wearing surface, base, and subbase

a1, a2 and a3 = Road layer coefficients for wearing surface, base, and subbase

m2, m3 = Drainage coefficients for base and subbase

Layer and drainage coefficients, and thickness values of wearing surface were fixed to focus on the changes on the layer thickness and materials. Therefore, they were assumed as a1 = 0.44, a2 = 0.14, a3 = 0.11, m2,3 = 1, respectively. Unit prices of all reinforcements were obtained from manufacturer firms and total cost of

Table 4. Brief summary of test methods used in this study

Methods	Used reinforcement types	Condition of fibers in pavement
First Method	Fibers were used as separately for each test and six different fiber types were used. Each test was repeated for different reinforcement type.	Fibers were laid as a layer in pavement soil as Figure 3a
Second Method	Fibers were used as separately for each test and six different fiber types were used	Fibers were mixed with soil particles as Figure 3b
Third Method	Fibers were used as separately for each test and six different fiber types were used + a geotextile was added as Figure 3c	Fibers were mixed with soil particles and a geotextile laid in the pavement soil layer as Figure 3c
Fourth Method	Only a geotextile	Geotextile was laid in the pavement sample as Figure 3d

reinforced pavements were determined by adding soil prices. Finally, the cost of unreinforced pavement was compared with the costs of pavements reinforced with different fiber types. Besides their costs, performances, and other advantages of using reinforcements for all models were discussed.

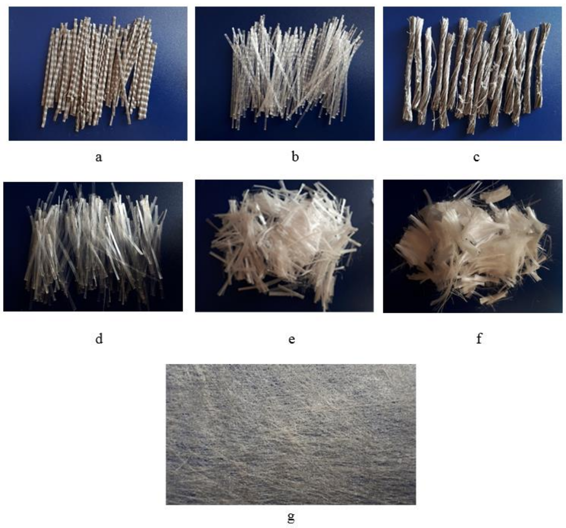

Figure 2. Fiber types used in the study; a. Fiber1, b. Fiber2, c. Fiber3, d. Fiber4, e. Fiber5, f. Fiber6, g. Geotextile.

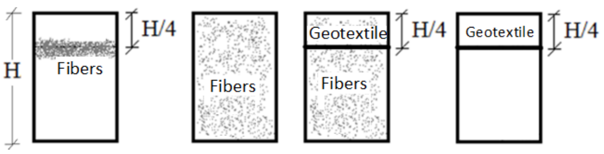

Figure 3. Reinforcement placement models: a. Layered fibers, b. Mixed fibers with soil, c. Mixed Fibers and layered a geotextile, d. Using only geotextile.

3. RESULTS AND DISCUSSION

CBR tests were conducted to understand the effects of fiber reinforced road samples. Stress-penetration curve of unreinforced pavement sample is given in Figure 4 and CBR value of unreinforced soil was found as 38.6. After unreinforced test, reinforced tests were conducted and Table 5 and Table 6 show CBR and bearing capacity ratio values for different reinforced soil conditions. Firstly, in order to see the differences of mixing and using as a layer of fiber reinforcements, 1% amount of each fiber reinforcement were put together and placed as a layer in CBR test mold as can be seen in Figure 3a. Stress-penetration curves of each different fiber reinforced specimen can be observed in Figure 5. Fiber 6 performed best among other fiber types. Since fiber size was smaller and had more flexible than other fibers, it can be adapted better with soil. On the other hand, Fiber 2 showed the lowest value. Reinforcements become more active after taking loads and settlements. Therefore, when penetration values were increased, stress and bearing capacity ratio values can be show better performance and larger values. For this reason, it can be thought that soil can be compacted when taking the loads and fibers are starting to taking the tensile loads more due to the behavior of the general aspect of fibers.

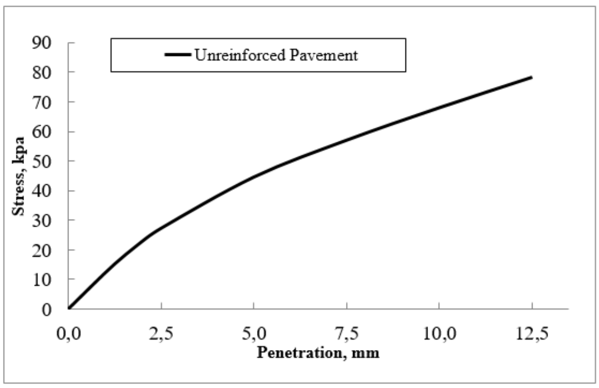

Figure 4. Stress-penetration curve of unreinforced pavement.

Test results of mixed fiber and soil particles can be seen in Figure 6. Although the maximum value of stress for unreinforced sample was only around 80 kPa, fiber reinforced samples showed better performance and larger values. In order to calculate CBR values, loadings at 2.5

Table 5. CBR test results for different reinforced conditions (kPa)

Reinforcement	As a layer	Mixed	Mixed+a Geotextile
Unreinforced	38.6	38.6	38.6
Fiber 1	27.4	31.8	34.9
Fiber 2	8.3	23.1	19.1
Fiber 3	17.1	34.9	17.8
Fiber 4	28	18.2	21.5
Fiber 5	21	28	18.2
Fiber 6	30.7	49	59.9

mm were taken into consideration due to the low CBR results of reinforced models. Results showed that Fiber 6 performed best then other fiber types and Fiber 4 showed lowest bearing capacity. When used the fiber reinforcement having the lowest tensile strength value in the reinforced models showed the highest CBR values. Additionally, it can be said that Fiber 6 was adapted with soil particles better than other fiber types. Furthermore, structure of Fiber 6 was smoother and smaller than the others so its adaptation can be better than others. Fiber 3 had similar softness also, so Fiber 3 could perform as the second-best reinforcement in the results. It was thought that not only tensile strength but also structural properties of fiber types could affect the bearing capacity ratio behavior. Sarbaz et al. [19] reported that in their test settlement values can be effective for behavior of the reinforced soils and this behavior was seen for fiber reinforced soils in this study, also.

For last test series, fibers were mixed with soil and a geotextile was laid at H/4 depth as can be seen in Figure 3c. Results were given in Figure 7. As a result, it can be seen that Geotextile combination with Fiber 6 had the highest stress as other test series. Fiber 1 and Fiber 6 have more effective values than others. At 2.5 mm penetration level, CBR values of Fiber 2, 3, 4, and 5 were nearly same.

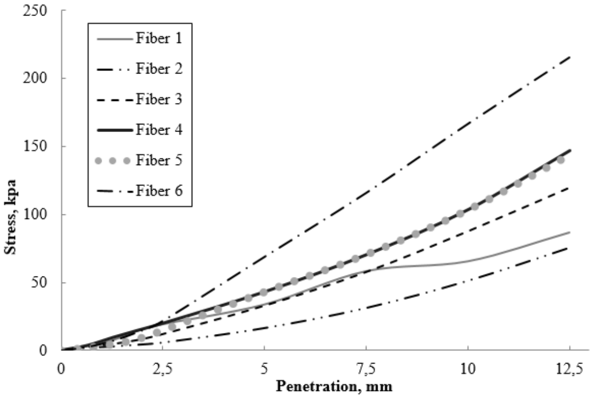

Figure 5. Stress-Penetration curves of layered fiber reinforcement in pavements.

Table 5 and Table 6 show CBR results and bearing capacity ratios for fiber reinforced samples. When fibers were used as reinforcement in the soil, only Fiber 6 improve CBR behavior 2.5 mm and others have smaller values than unreinforced sample. However, it can be seen that as the penetration value was increased larger bearing capacity ratio values could be seen and stress-penetration behaviors were better than unreinforced one. Approximately 3 times larger bearing capacity ratio values for 10 mm penetration can be seen than 2.5 penetration. Especially this behavior can be seen for using Fiber 6 as the reinforcement. Additionally, it can be observed that mixing fibers with soil can give better performance and addition a geotextile can be more

Table 6. Bearing capacities ratios of fiber reinforced over unreinforced samples.

Reinforcement types	Penetration (mm)	Fiber 1	Fiber 2	Fiber 3	Fiber 4	Fiber 5	Fiber 6
As a layer	**2.5**	0.71	0.22	0.44	0.73	0.54	0.8
	5	0.76	0.37	0.74	0.96	0.97	1.54
	10	0.96	0.75	1.29	1.52	1.52	2.44
Mixed	**2.5**	0.82	0.6	0.9	0.47	0.73	1.27
	5	1.6	1.13	1.85	1.01	1.24	2.15
	10	2.8	2.04	3.03	2.08	2.44	3.22
Mixed+a geotextile	**2.5**	0.9	0.5	0.46	0.56	0.47	1.55
	5	1.47	1.06	0.77	1.08	0.78	2.54
	10	2.08	1.96	1.14	2.08	1.25	3.7

results they found the tensile strength can be not effective for CBR test results. Additionally, in this study, Fiber 6 had the least tensile strength but showed the highest performance. In addition to this, Fiber 4 had the largest tensile strength but showed least performance. It can be said that the amount of the fibers can be effective for the behavior of the reinforced model because Fiber 6 has much more number of reinforcements in same amount. Bearing capacity ratio values increased with raising penetration values. Cicek et al. [22] reported that effective. However, this behavior can be changed according to fiber types. Flexible fibers can be more effective to improve the pavement behavior than rigid ones.

Table 7. M_R, SN and D results after computation

Reinforcement	M_R	SN	D(m)
Unreinforced	26478987	3.26	0.21
Fiber 1 (layered)	21244513	3.54	0.27
Fiber 2 (layered)	9915368	4.61	0.52
Fiber 3 (layered)	15753359	3.94	0.36
Fiber 4 (layered)	21570575	3.52	0.27
Fiber 5 (layered)	17943243	3.76	0.32
Fiber 6 (layered)	22878644	3.44	0.25
Fiber 1 (mixed)	23362691	3.42	0.24
Fiber 2 (mixed)	19079530	3.68	0.30
Fiber 3 (mixed)	24815532	3.34	0.23
Fiber 4 (mixed)	16389713	3.88	0.35
Fiber 5 (mixed)	21570575	3.52	0.27
Fiber 6 (mixed)	30860722	3.08	0.17
Geotextile 1 + Fiber 1 (mixed)	24815532	3.34	0.23
Geotextile 1 + Fiber 2 (mixed)	16888947	3.84	0.34
Geotextile 1 + Fiber 3 (mixed)	16136867	3.90	0.36
Geotextile 1 + Fiber 4 (mixed)	18221152	3.74	0.31
Geotextile 1 + Fiber 5 (mixed)	16347725	3.88	0.35
Geotextile 1 + Fiber 6 (mixed)	35053437	2.94	0.13

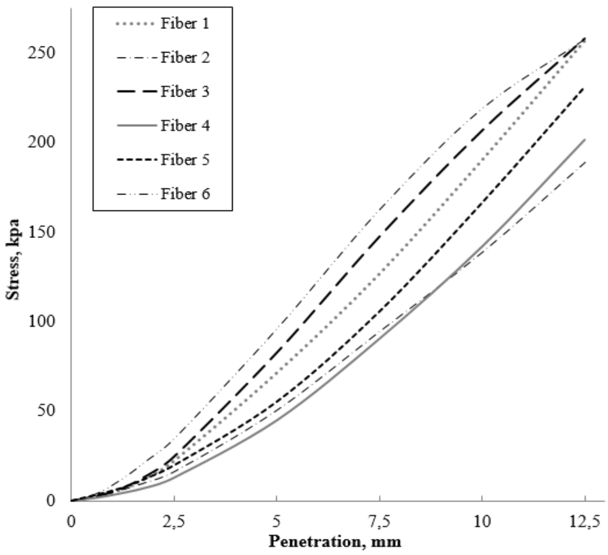

Figure 6. Stress-Penetration curves of mixed fibers with soil

In Figure 8 comparisons of results for samples reinforced with different fiber types and a geotextile reinforcement can be seen. Each fiber type and using fibers with geotextile have different results. Only combination of Fiber 6 and a geotextile has better performance than using the geotextile alone. Generally, each fiber shows different behavior for mixed or layered forms. Therefore, for real field projects fiber used in the pavement should be tested before construction. Additionally, for future studies different soil types and gradations should be used and compared for scale effect of soil particles. Drainage coefficients, structural layer coefficients and thickness values influences SN values. Thicknesses of wearing surface and base course were taken as 3.5 and 6 inches, respectively. As for thickness of the pavement layer reinforced with fibers can be seen as in Table 7. As can be seen from the results, only third method by using geotextile sample with Fiber 6 gave the thinner pavement layers. Therefore, only the reinforced models having better CBR results than unreinforced condition were taken into consideration for cost analysis.

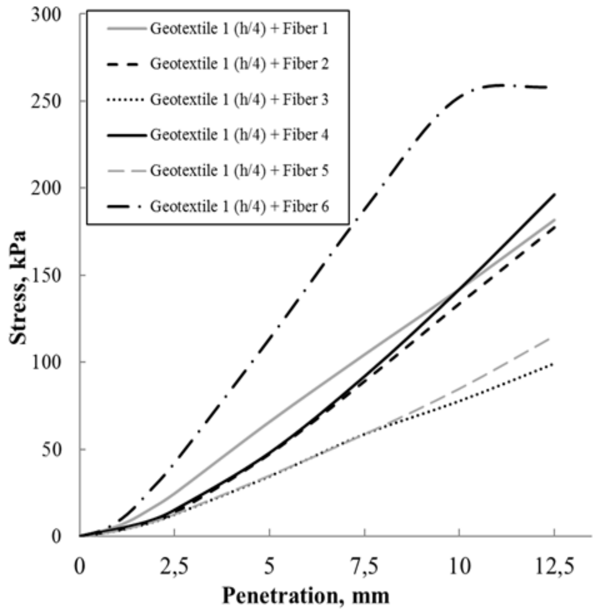

Figure 7. Stress-Penetration curves of mixed fiber and layered geotextile model.

Generally, in the literature geotextile or fibers were used to find the effects of the reinforcements, but this study investigated different models and both geotextile and 6 different fiber types were compared. For example, Yashas & Muralidhar [23] investigated the effect of jute fiber mat on CBR values for flexible pavement design as well. The thickness of pavement layers was calculated by considering CBR values. It is shown that, CBR value of natural soil increased when single layer of reinforcement applied. Therefore, in this study one layer of geotextile was used and the effectiveness was determined by comparing other combination as can be seen in Figure 8. Another illustration for literature is study of Pandit et al. [24]. They investigated the strength improvement of flexible pavement by CBR tests. Soil samples were reinforced with coir and jute fibers. Thickness of soil subgrade was compared for reinforced and unreinforced conditions as well. Since both fiber types increased the CBR values of soil, it is mentioned that the thickness of the flexible pavement can be decreased with fiber reinforcements. Therefore, study highlighted that, using fibers in soil may reduce the pavement layer.

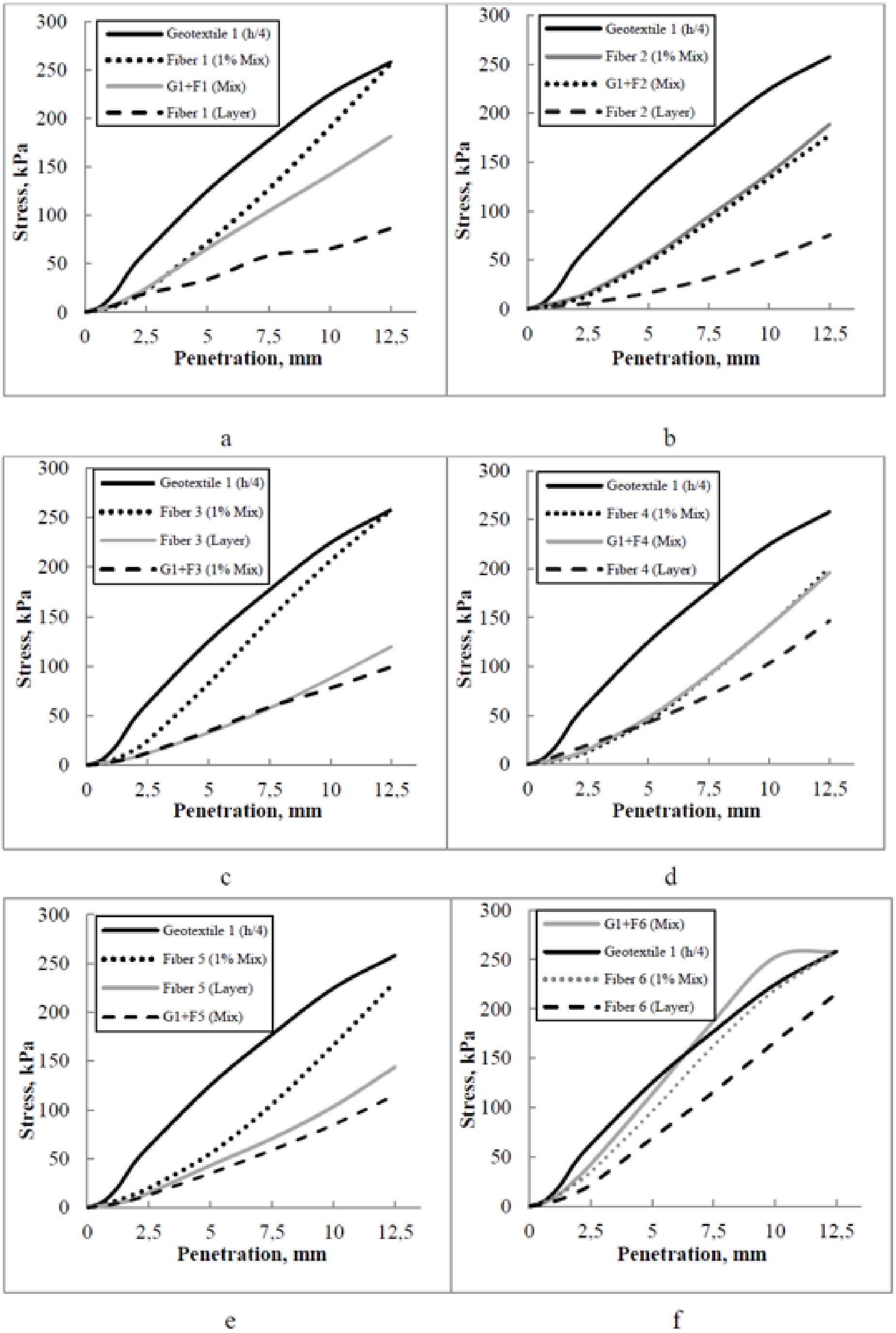

Figure 8. Comparison of the stress-penetration curves of fiber and geotextile reinforcement combinations; a. Fiber1, b. Fiber 2, c. Fiber 3, d., Fiber 4, e. Fiber 5, f. Fiber 6.

In this study, at first cost of soil were calculated for models. Lane width was taken as 3m for 1 km and unit price of soil was 2.36 $/m3. Then cost of reinforcements were added to obtain total cost of the pavement construction. Cost of fibers were calculated in terms of their total mass. Since fibers applied by 1% content of soil mass, which were determined as 510 m3 and 390 m3 in reinforced models, soil mass was calculated by multiplying these results with 1600 kg. Total soil masses were found as 8.16x105 kg and 6.24x106 kg. Thus, required fiber mass was found by taking 1% of these values and costs were found by multiplying results with fibers unit price. Table 8 shows the fiber reinforced pavement cost analyses and as a result, it was observed that when using fiber reinforcements CBR values can be

Table 8. Total cost results.

Reinforcement	Total Soil Volume (m^3)	Total Cost of Soil ($)	Total Cost of Fiber ($)	Total Cost of Geotextile ($)	Total Cost of Reinforced Pavement ($)
Unreinforced	630.00	1486.80	-	-	1486.80
Fiber 6 (1%)	510.00	1203.60	37944.00	-	39147.60
Fiber 6 (1%) + Geotextile	390.00	920.40	29016.00	1800	31736.40

increased and thickness of soil layers can be decreased. However, when the costs of reinforcements are taken into consideration, total cost of reinforced models was found more than unreinforced condition.

Therefore, as a first look it can be seen they are not suitable for construction for economical design, but for long term their bearing capacity ratio values can be increased as can be found from the tests and as a long life span they can be useful for heavier traffic loadings. Therefore, life cycle analysis and aim of the using pavement can be important for designing by using fibers in the pavement layers. As a result, as can be known layered pavement behavior is so critical [25] and there are different improvement methods for road layers [26, 27]. This study shows that not only mechanical design but also cost effect can be significant for road designs.

4. CONCLUSION AND RECOMMENDATION

In this research, effect of fiber reinforcements in the pavement soil were examined by conducting CBR tests. Pavement layer thickness were calculated and cost analysis were conducted for effective models reinforced with fibers. Outcomes of this study can be given as following:

* Different fiber types can give various improvement effects. Each fiber type has a different result. For penetration of 2.5 mm, fiber can decrease CBR values than unreinforced sample and only samples used Fiber 6 have better results.

* Generally, using geotextile has better performance than other mixing types. However, using geosynthetic and fiber mixture for only samples prepared by using Fiber 6 gave better effective values than using only geosynthetic in the sample. It can be thought that adding more reinforcement with geotextile and fibers in the soil can affect the soil friction behaviour and behaviours can be changed according to fiber material properties.

* Tensile strength of fiber is an important parameter in order to choose a fiber reinforcement. However, this study shows that amount and structural properties of fibers can be more effective than tensile strength and in order to have less pavement layer thickness fiber property can be more specific.

* Increasing penetration level can change the performance of a fiber in CBR test results and bearing capacity ratios. As penetration level increases larger improvement values can be seen.

* Bearing capacity ratio is larger for Fiber 6 for all penetration levels. Therefore, it can be said that if fiber can be mixed easily with soil particles and if it is more flexible, more effective bearing capacity ratio values can be observed than laying fibers in the pavement.

* Using reinforcements in road layers can be more effective on pavement thickness and cost analysis values especially for long life spam and for larger penetration values. In another words it can be critical for heavy traffic loads.

* As can be known fiber reinforcements can be used improve the soil, but reinforced pavements need to be more investigation than other soils. Therefore, the results of this study can be important for researchers and factories to be chosen the true one for road design.

* For future studies, new type of the fibers and different road soil types should be tested and results can be compared. Additionally, for large scale test can be conducted for real conditions.

DECLARATION OF ETHICAL STANDARDS

The authors of this article declare that the materials and methods used in their work do not require ethical committee permission and / or legal-specific permission.

AUTHORS' CONTRIBUTIONS

Elif CICEK: Wrote the manuscript**,** determination of the problem, contribute to the application of the methods and tests used in the study and the interpretation of the results

Volkan BUYUKAKIN: Performed the experiments, analyse the results and prepaired the figures and tables.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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