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# Stabilization of Expansive Soil Subgrade Using Recycled Carpet Waste and Fly Ash

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**Abstract —** *The structure of asphalt pavements subjected to problems and collapse for many reasons one of them, when pavement section built on swelling soil, which has volumetric change due to variation of water content, which results the appearance of cracks collapse. For this reason, additives are used for treating expansive soil and increase its efficiency. Polymers are one of many types of additives; there are two types of polymers natural and synthetic. Using carpet disposal waste in soil stabilization is one of solutions for obtaining safer and harder pavements. In addition to using carpet waste will benefit the community environmentally and economically. For achieve this purpose a series of laboratory investigation were carried out to evaluate the effect of treating the subgrade with carpet waste. CBR tests were conducted on treated and untreated soil at different carpet waste contents ranged from 0.5% to 2% at an increase rat of 0.5%. The results of CBR tests showed that the CBR value for treated soil with 0.5% carpet waste increased about 14 times their untreated soil.*

***Keywords***- *swelling; soil; stabilization; carpet waste; CBR*

## I. INTRODUCTION

Use of local materials, including local soils, can considerably lower down the construction cost. If the stability of local soil is not proper for supporting wheel loads, their properties are improved by soil stabilization techniques. The stabilization of soil for utilize in subgrade for pavement is an economic substitute of costly paving materials. Randomly distributed fiber, when utilized as stabilizer in highway subgrade, can generate a high performance in the stabilization of weak roads. Many researchers have used several types of fibers under various test conditions. The most substantial findings of the previous research are that the utilize of specific fiber, in road construction can significantly improve pavement resistant to rutting as compared to non-stabilized pavement resistance over a weak subgrade.

## II. STABILIZATION OF SOIL USING FIBER

Polypropylene fiber reinforcement enhanced the unconfined compressive strength (UCS) of the soil and reduced both volumetric shrinkage and swell pressures of the expansive clays [1]. By mixing nylon fibers and jute fibers, the CBR value of soil is enhanced by about 50% of that of unreinforced soil, whereas coconut fiber increases the by as high as 96%. The optimum quantity of fiber to be mixed with soil is found to be 0.75% and any addition of fiber beyond this quantity does not have any significant increase in the CBR value [2]. Highly compressible clay was tested in UCS test with 0%, 0.5%, 1.0%, 1.5% and 2.0% flat and crimped polyester fibers. Three lengths of 3 mm, 6 mm and 12 mm were chosen for flat fibers, while crimped fibers were cut to 3 mm long. The results indicate that as the fiber length and/or fiber content increases, the UCS value will improve [3]. The effect of fiber inclusion was investigated on CBR ratio. A series of laboratory investigation were carried out to evaluate effects of reinforcing the sub grade soil in pavement system with randomly distributed plastic fibers and natural fibers. CBR test were conducted on unreinforced samples as well as reinforced ones at different fiber contents (i.e. 0.1%, 0.3%) and different fiber length (i.e. 10mm, 25 mm and 50mm). The results of CBR test showed that the CBR ratio for reinforced clay increased even more than two times in some cases as fiber content and fiber length increased [4]. The soil bearing capacity and the safe bearing pressure (SBP) both increase with increase in fiber content up to 0.50% and then it decreases with further insertion of fibers. Japanese scientists have been found that short polyester fiber (PET) fiber (64 mm) reinforced soil had high piping resistance, and that the short fiber reinforced soil layer increased the stability of levee against seepage of rainfall and flood [5].
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. Increasing the waste fiber of soil leads to increase in soil UCS. 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 [6]. The effect of natural and synthetic fibers was investigated on the swelling properties of clayey soils. The swelling pressure and swell potential of the clayey soils can be significantly reduced with the increase in fiber content [7]. Results of a comprehensive investigation into utilization of carpet waste fibers were presented in order to improve the swelling characteristics of compacted cohesive soils. The results indicated that the behavior of the fiber reinforced soils seems highly dependent on the initial compaction state and secondary on the moisture content. It was found that the swelling

 

pressure drops rapidly as the percentage of fiber increases in samples prepared at the maximum dry unit weight and optimum moisture content. Reducing the dry unit weight, while maintaining constant moisture content or increasing the moisture content at constant dry unit weight was found to reduce the swelling pressure [8]. A serious of laboratory experiments were carried out to investigate the use of the waste fibers of the polypropylene for the improvement of the various properties of the Clayey (CL) type of soil obtained from Ambala City, Haryana (India). They indicated that unconfined compressive strength (UCS) of the soil reinforced with waste fibers of polypropylene used for the improvement of the engineering properties of the soil with 20mm length and 0.25% weight of polypropylene by weight of dry soil sample is found as 52.80% increase in UCS.[9].

## III. PROGRAM OF EXPERIMENTAL WORK

To investigate the effect of using carpet waste and fly ash on strength, CBR tests were executed to evaluate the effect of carpet waste, fly ash and carpet waste/fly ash on strength of the soil mixture. In the first step, material characterization tests have been performed on expansive soil, carpet waste and fly ash. Recycled carpet waste was considered as stabilizer material that may be randomly added to the soil in the first series of the testing program. Carpet wastes were added to the expansive soil at rates of 0.5%, 1%, 1.5% and 2% by dry weight of the soil. Soaked condition of CBR tests was performed on soil carpet waste mixtures with given percentage of carpet waste. Fly ash was considered as a stabilizer material that may be added to the soil randomly in the second series of the testing program. Fly ash was added to the expansive soil at rates of 5%, 10%, 15% and 20% by dry weight of the soil. Soaked condition of CBR tests was executed on soil fly-ash mixtures with given percentage of fly ash. In the third series of the test program on soil-carpet waste/fly ash mixtures CBR tests were executed on soil-carpet waste/fly ash mixtures with given percentage in soaked condition. Recycled carpet waste and fly ash were randomly oriented during soil compaction process. Modified proctor compaction was used in sample preparation for CBR.

## IV. MATERIALS

Expansive soil samples are brought from Fayoum governorate, Egypt. Undisturbed soil samples are extracted from 3.00m depth below ground surface. The index and mechanical properties of that soil were determined. All tests on expansive soil samples are conducted according to ASTM. Results of tests are presented in Table 1.
Carpet is manufactured in several various ways, thus there are different types of fibers used in carpet manufacture such as polypropylene, polyethylene, polyester, nylon and etc. Many factories in Egypt specialize in carpet manufacture. Carpet waste was brought form certain carpet factory. Carpet waste is prepared by cutting it into small parts range from 5 mm to 15 mm length. Carpet waste properties are summarized in Table 2. Where, Fly ash is the mineral remainder that is left after the burning of coal. Fly ash is micro-sized particle consists of silica, alumina and iron. Particles of fly ash are commonly spherical in size, and this particularity makes it to flow and blend also its size allow it to fill the void that's existed between soil particles. Fly ash has been used successfully in many projects to improve the strength characteristics of soils. Fly ash can be used to stabilize base, sub-base and subgrade soil. The primary reason for using fly ash in soil stabilization applications is to improve the compressive and shear strength of soils. Properties of fly ash are measured and summarized in Table 3.

**Table 1 Properties of natural expansive soil**

| Engineering property | Value |
|---|---|
| Liquid limit (%) | 113.2 |
| Plastic limit (%) | 30.58 |
| Plasticity index (%) | 82.62 |
| Specific gravity | 2.59 |
| Maximum dry density (g/cm$^3$) | 1.62 |
| Optimum moisture content (%) | 20 |
| Bulk density (g/cm$^3$) | 1.94 |
| Free swell % | 200 |
| Passing #200% | 92.1 |
| USCS classification | CH |
| ASTM classification | A-7-5 |
| California bearing ratio (%) | 1.08 |

 

**Table 2: Carpet waste properties**

| Property of Fiber | Value |
|---|---|
| Color | Blue |
| Material type | Pure polypropylene |
| Elongation (%) | 34 |
| Tensile strength ($kg/cm^2$) | 3500 |

**Table 3.5: Fly Ash properties**

| Properties of Fly ash | Value |
|---|---|
| Color | Gray |
| Specific gravity ($g/cm^3$) | 2.28 |
| Plastic limit | Non plastic |

## V. RESULTS

### A. Soil reinforced with carpet waste

CBR values for randomly reinforced soil with carpet waste contents ranged from 0.5% to 2% at 0.50% interval are shown in Figure 1. It can be observed from figures 1 and 2 that mixing of randomly distributed carpet waste in expansive soil increased the penetration load considerably until 0.50% and then it decreases. The figure further reveal that the initial slope of the load penetration curve is significantly improved due to the incorporation of carpet waste in expansive soil. From these figures, it is also evident that inclusion of carpet waste increased the CBR value significantly. The CBR value increased from 1.08% to 15.11% at 0.5% carpet waste content as presented in Figure 1. This increase in CBR value because of the interaction between the soil and carpet waste reinforcement bound the particles and enhanced the strength of the soil.

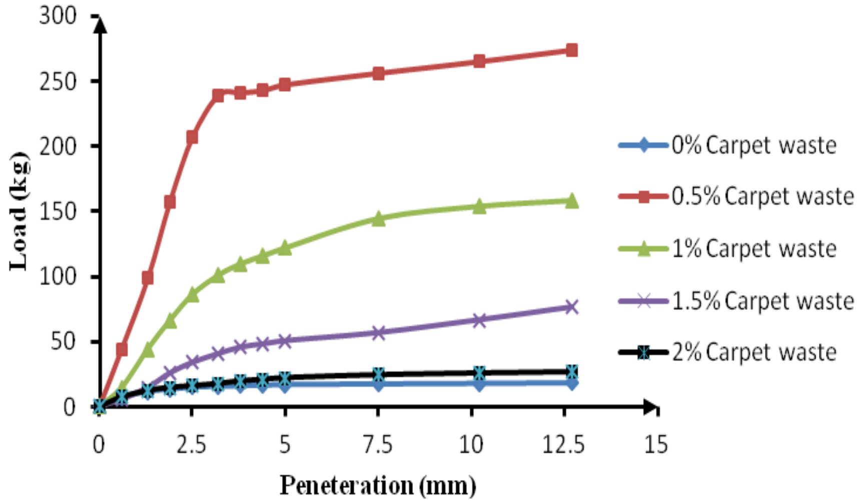


**Figure 1: Load penetration curves for soil with different percentage of carpet waste**

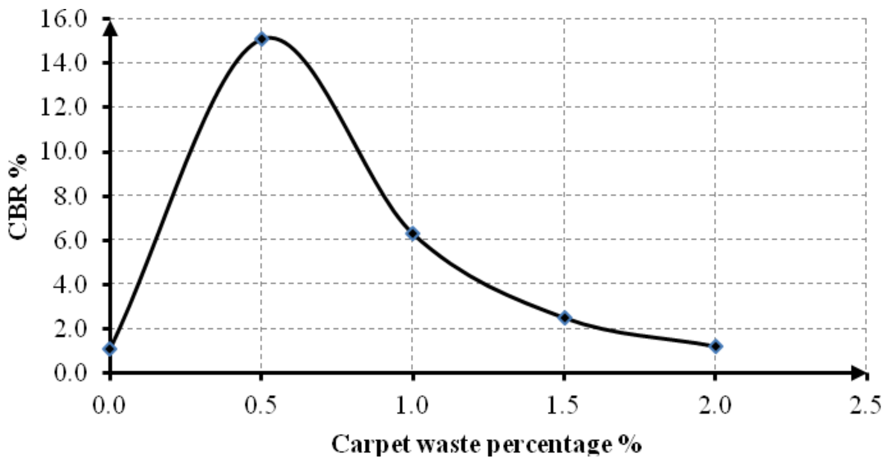


**Figure 2: CBR value for soil at different carpet waste content**

**B. Soil stabilized with fly ash**

Soil-fly ash mixtures were prepared with 5%, 10%, 15% and 20% fly ash by dry weight of expansive soil. The CBR values of these mixtures are indicated in Figure 3. Figure 4, shows the relation between CBR and fly ash percentage which was used to reinforce expansive soil. It is noted that, a increase in fly ash content in soil- fly ash mixture generally resulted a considerable increase in CBR value. As expected, the increase in CBR value is noticeably attributed to fly ash inclusion in soil. For example, the CBR of untreated soil of 1.08% can be increased to 7.79% and 10.08% when 5% and 10% fly ash is added. When the fly ash content was increased to 15%, the CBR value decreased to 2. Similar trend was observed when fly ash further increased to 20%.

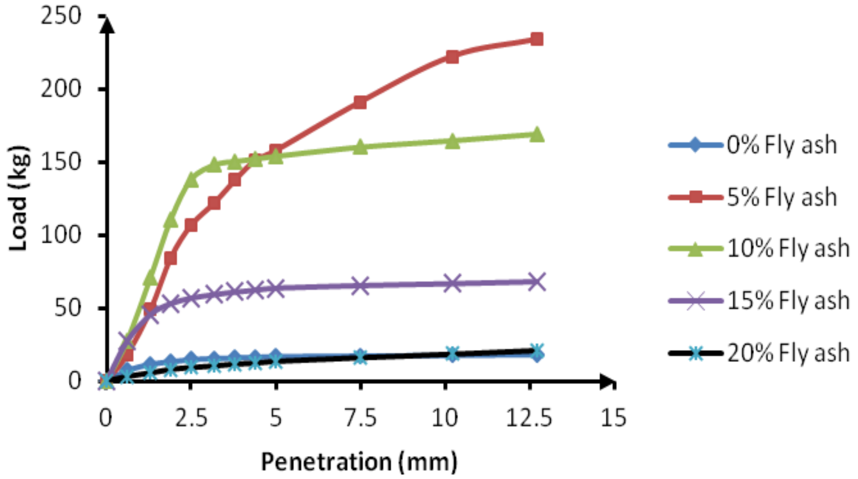


**Figure 3: Load penetration curves for soil with different percentages of fly ash**

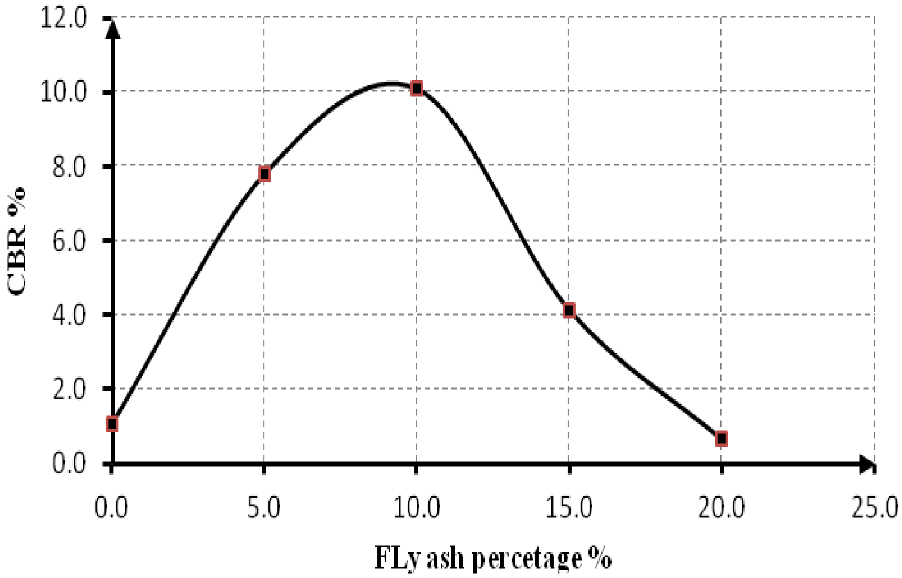


**Figure 4: CBR value for different fly ash content**

**C. Soil stabilized with carpet waste and fly ash mixture**

Carpet waste content prepared with different fly ash percentage to evaluate the effect of utilizing fly ash on soil-carpet waste mixture. Figure 3 reveals that CBR value for 0.5% carpet waste content having 5% fly ash is 2.66% but this value increased to 3.87% when fly ash content was increased from 5% to 10% without changing the carpet waste content. When fly ash was further increased to 15% or 20% again without changing the carpet waste content, the values of CBR are decreased to 3.06% and 1.84% respectively. Soil-carpet waste reinforced with fly ash showed improvement in CBR value with its addition up to 10% and there onwards decreased with further increase in fly ash content in soaked condition. A similar trend was also observed for other carpet waste contents.

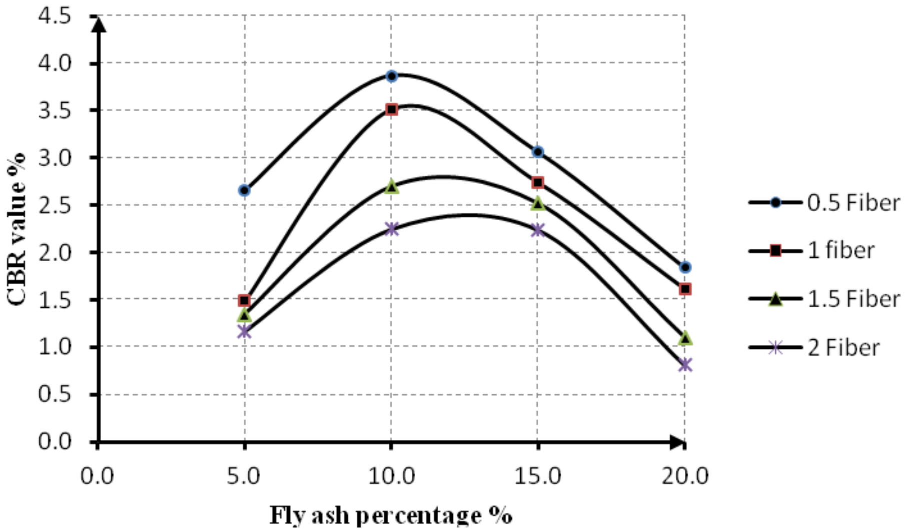


**Figure 5: CBR value for different fly ash content with different carpet waste content**

With respect to the results of CBR tests which presented in Figure 1, 2 and 3, it seems that by addition of 0.5% carpet waste only the CBR value reach its maximum value and increased by 14 times of unreinforced soil, also by addition of 10% fly ash only, the CBR value increased by 9.33 times their unreinforced expansive soil. While in the case of soil-carpet waste/fly ash mixture the maximum CBR value achieved when the mix contain 0.5% carpet waste and 10% fly ash whose CBR value increased by about 3.58 their unreinforced expansive soil.

## VI. CONCLUSION

Based on the results, the following conclusions can be drawn:

- Addition of carpet waste to expansive soil increases the CBR value up to a certain level, afterwards, the CBR value decreases after continuous addition of carpet waste.
- The maximum improvement in CBR value was obtained when carpet waste content was 0.5%.
- The results of CBR test shows that the soaked CBR value of expansive soil reinforced by 0.5% carpet waste is approximately 14 times that of unreinforced soil.
- The inclusion of fly ash in expansive soil increases the CBR value to a certain fly ash content, further increasing in that content the CBR value decreases.
- The CBR value of expansive soil blended with 10% fly ash increases from 1.08% to 10.08%.
- The results of CBR test shows that, after stabilization of soil with 0.5 % carpet waste and 10% fly ash, CBR value of expansive soil increases from 1.08% to 3.87%.

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