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# Enhancement of Polymer on Road Problematic Soil Stabilization

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**Abstract**

Egypt's desert covers more than two-thirds of the country's entire surface area. As a result, in recent years, the Egyptian government has tended to exploit those spaces by constructing new cities, such as New Sohag. The city of New Sohag was founded in the western desert near the Nile River. Although, these new cities appear to be a cure for a variety of issues, including traffic congestion, population growth, the building of a new road network, and so on. However, most of the soil in these cities is problematic. This type of soils, which may pose engineering challenges when uncovered beneath pavements or foundations, have sparked worldwide interest in recent years. In this study, several ratios of novel polymer additives (Dust Shield) were introduced to the swelling soil of subgrade foundation at New Sohag city, which were employed as supporting pavements, with 1, 2 , 3, and 4 % by dry weight of soil. Increasing additives resulted in an increase in maximum dry density, California bearing ratio, and unconfined compressive strength, as well as a decrease in plasticity index and swelling pressure, according to the results of various tests. This research determined the best dosage amounts for each of the additives studied. Based on the findings, it can be inferred that Dust Shield may effectively improve the expanding soil.

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Keywords: Pavement Distress, Subgrade, Soil stabilization, Expansive soil, Polymers.

## 1. INTRODUCTION

Many highways are being built in Egypt's desert to connect the Nile Valley to other cities in the Red Sea region, as well as new valley cities and other locations. In addition, many highways are being built in new cities in the eastern and western deserts. The city of New Sohag is located in Egypt's western desert. The diverse sediments in this study area are mainly, carbonate sediments that are overlaid by Pleistocene and recent Quaternary sediments, as well as many terraces of varying levels. It is also encircled by a vast carbonate plateau. The geological map, Fig. 1, shows the sediment distribution in considerable detail (1). New Sohag city highways' sub-grade soils are found in expansive soils like shale, clay-stone, mudstone, or Nile deposits like silt and clay. These expansive soils cause a variety of issues, including road uplift, especially when they come into touch with water, which causes a rise in volume, producing pavement uplift. These expansive soils must be improved using different enhancing materials such as lime, fly ash, cement dust, or polymer to avoid these difficulties. Dust shield polymer was employed as a stabilized agent in stabilized sub-grade soil of local roads in New Sohag city to improve the swelling of expansive soils.

## 2. LITERATURE REVIEW

Highways need periodic maintenance against defects that may appear in them to preserve the life of the road as long as possible [2-4]. The treatment or maintenance of these roads needs to know the main cause of this defect. For example: When grooves and block cracks appear in the paving layers, such as, this can be attributed to the effect of different temperatures [5]. Also, the occurrence of highs and lows that appear in the surface of the asphalt as a result of using a weak and unstable asphalt mixture that needs many additions to improve its mechanical properties like waste materials and polymers [6-17]. However, swelling occurs or an enlargement in the levels of part of the paving than the rest of the paving, and it may be accompanied by some cracks, and this is due to the weakness of the foundation layer or the foundation on soil of an expansive nature or soil with problems [1].

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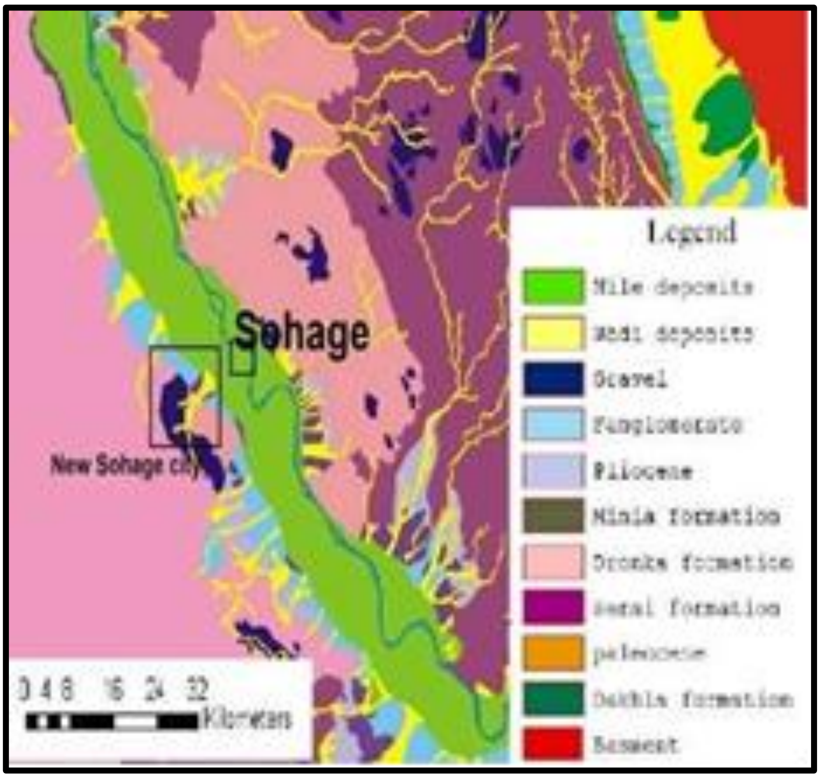


Fig. 1 Geological map of study area (modified after Badry, 2012 [1]).

Heaving and settlement of lightly loaded geotechnical structures such as pavements, railways, roadways, channel and foundations, or reservoir linings are typically expressed as the response of expansive soils in the form of swelling and shrinking due to changes in water content. Bentonitic mudstones, marls and silty mudstones, argillaceous lime stones, and altered conglomerates are examples of expansive materials that have swelling issues. Expansive soils, as a result, cause distress and damage to structures built on them [18].

Egypt's climate is arid, with high evaporation rates, resulting in a constant moisture deficit in soils and rocks. Any sourceof water is likely to create ground heave in any soils or rocks with the ability to swell. The dangers of expanding soils appear to be neglected in some projects' design and construction. The presence of montmorillonite clay minerals in soilscauses most of the problems linked with expansive soils in Egypt. As a result, several structures in New Sohag City havebeen distressed and damaged, and in the worst-case scenarios, others have been demolished [17].

Many studies have found that adding lime to clay soils in the presence of water causes a series of reactions that improvesoil characteristics [20-25]. When clay soils are treated with lime, flocculation is principally responsible for the adjustment of engineering qualities. Lime reduces the soil's swelling potential, liquid limit, plasticity index, and maximum dry density while increasing the soil's optimum water content.

Cement stabilization is similar to lime stabilization in that it yields similar results. The cementitious linkages between the calcium silicate and aluminate hydration products and the soil particles provide cement stability. When cement is added to clay soil, the liquid limit, plasticity index, and swelling potential are reduced, while shrinkage limit and shear strength are increased [26-28].

Fly ash generated by coal combustion has self-cementing properties and can be employed in a variety of stabilization applications. Fly ash treatment reduces the swell potential of highly plastic clays and prevents swell beneath lower foundation pressures. Laboratory tests on these soils show that fly ash improves the texture and plasticity of the treated soils by lowering the amount of clay size particles, the plasticity index, and the swell potential [29-30].

Fiber inclusions significantly alter and improve the engineering behavior of soils. Tri-axial tests, unconfined compression testing, CBR tests, direct shear tests, and tensile and flexural strength tests have all been used in recent research on fiber-reinforced soils. The absence of possible lines of weakness that can develop parallel to oriented reinforcement is one of the key advantages of randomly dispersed fibers [31-32].

## 3. EXPERMENTAL PROGRAM

### *3.1. Materials*

#### *3.1.1. Natural Soil*

Swelling soil was obtained from natural ground found as sub-grade soils on the highways of New Sohag City. This type of soil represents the majority of the soil in the new city of Sohag. The reason for this study is that it was found thatit represents many problems, whether for the roads that have been paved inside or outside the new city of Sohag or for the buildings. This type of soil with problems (expansive or swelling soil) is overcome in building works by making replacement soil at relatively large depths or relying on the dead load of the building itself in cases of buildings with high weights. As for road works, the possibility is being studied. Adding new materials to this type of soil to overcome its expansive properties. The original soil was a greenish grey, laminated silty clay with traces of fine sand and calcareous materials. Table I shows the physical and mechanical properties of natural soil.

#### *3.1.2. Additives*

When diluted in water and put to soil, dust links soil particles together, preventing dust and erosion. When dry, DustShield is colourless and non-toxic to plants and animals. Table II lists the Additive's properties. Shield is a liquid copolymer concentration.

### *3.2. Laboratory Tests*

The geotechnical parameters of the soil were determined after it was treated with the additive at percentages of 1.0 %, 2.0 %, 3.0 %, and 4.0 % of the unit weight of dry soil.

TABLE 1. PROPERTIES OF NATURAL SOIL.

| Characteristics | Values |
|---|---|
| Depth (m) | 2 |
| Natural water content (%) | 3.4 |
| Field dry unit weight (t/m3) | 2.05 |
| Specific gravity “GS” | 2.69 |
| pH | 8.9 |
| Passing No. 200 sieve (%) | 90 |
| Clay content (≤ 2 μm) (%) | 42 |
| Clay activity | 0.945 |
| Unified Soil Classification “U.S.C.” | VHC |
| Montmorillonite | 73.7 |
| Illite | 5.3 |
| Kaolinite | 21 |
| Liquid limit “L.L.” (%) | 70.7 |
| Plastic limit “P.L.” (%) | 31 |
| Shrinkage limits “S.L.” (%) | 9 |
| Plasticity index “P.I.” (%) | 39.7 |
| Optimum moisture content “O.M.C.” (%) | 16 |
| Maximum dry unit weight (KN/m3) | 1.52 |
| Swelling Potential “S” (%) | 40 |
| Swelling Pressure “$S_p$” (kg/cm$^2$) | 3.95 |
| Unconfined Compression strength “UCS” (kg/cm$^2$) “unsoaked” | 6.03 |
| Unconfined Compression strength “UCS” (kg/cm$^2$) “soaked” | 4.21 |
| California bearing ratio “CBR” (%) “unsoaked” | 10.5 |
| California bearing ratio “CBR” (%) “soaked” | 6.2 |

TABLE 2. CHARACTERISTICS OF ADDITIVE.

| Properties | Dust Shield |
|---|---|
| Physical State | Milky liquid |
| Boiling Point | >200 °F |
| Solubility in Water | Dilatable |
| Density | 8.7 lbs/gal |

## 4. RESULTS AND ANALYSIS.

Atterberg Limits, modified Proctor compaction tests, swelling tests, unconfined compression tests, and California bearing ratio at various percentages were used to evaluate the effect of additives on the geotechnical characteristics ofexpansive soil (as shown Table III).

TABLE 3. TEST RESULTS.

| Characteristics | 0.0% N.S* | 1% | 2% | 3% | 4 % | 5% |
|---|---|---|---|---|---|---|
| L.L.% | 70.7 | 63.2 | 58.4 | 51.7 | 50.3 | 48.4 |
| P.L.% | 31 | 34.8 | 36.5 | 38.4 | 40.7 | 39.2 |
| P.I.% | 39.7 | 28.4 | 21.9 | 13.3 | 9.6 | 9.2 |
| U.S.C. | VHC | MH | MH | MH | MH | MH |
| $\gamma_{dmax}$ (t/m$^3$) | 1.52 | 1.58 | 1.62 | 1.63 | 1.64 | 1.65 |
| O.M.C % | 16.0 | 15.0 | 13.5 | 12.8 | 12.7 | 12.7 |
| S% | 40.0 | 25.1 | 18.6 | 12.9 | 11.8 | 11.2 |
| SP (kg/cm$^2$) | 3.95 | 2.92 | 2.08 | 1.67 | 1.50 | 1.46 |
| UCS (unsoaked) | 6.03 | 6.68 | 7.17 | 7.24 | 6.82 | 6.33 |
| UCS (soaked) | 4.21 | 4.3 | 4.45 | 4.21 | 4.2 | 4.2 |
| CBR%(unsoaked) | 10.5 | 13.1 | 14.8 | 14.4 | 11.3 | 11.13 |
| CBR%(soaked) | 6.2 | 7.1 | 8.6 | 8.9 | 9.5 | 10.2 |

### *4.1. Atterberg limits*

This test is considered one of the most important tests that are relied upon in road works according to the Egyptiancode for rural and urban road works. Where the plasticity coefficient should not be more than 8, this test is considered an acceptance or rejection test for the type of soil supplied to the site or used in backfilling. Figure 1 shows the variation in Atterberg limits values with varied percentages of chemical additive added to the expandingsoil. The decrease in the liquid limit is significant up to 3% of chemical added to the expansive clay, but after that,there is only a minor decrease. With stabilized expansive clay, a nominal rise in plastic limit is found.

### *4.2. Compaction Characteristics.*

The addition of Dust Shield resulted in a higher d max and a lower O.M.C. Furthermore, it has been discovered that the increase in density and drop in optimal moisture content have continued up to 3%, after which there is littlechange (as shown in Fig. 3).

Increase the chemical's percentage. Figure 2 shows how the plasticity index changes when chemicals are added to expanding clay. The plasticity index is reduced due to an increase in the plastic limit and a drop in the liquid limit.

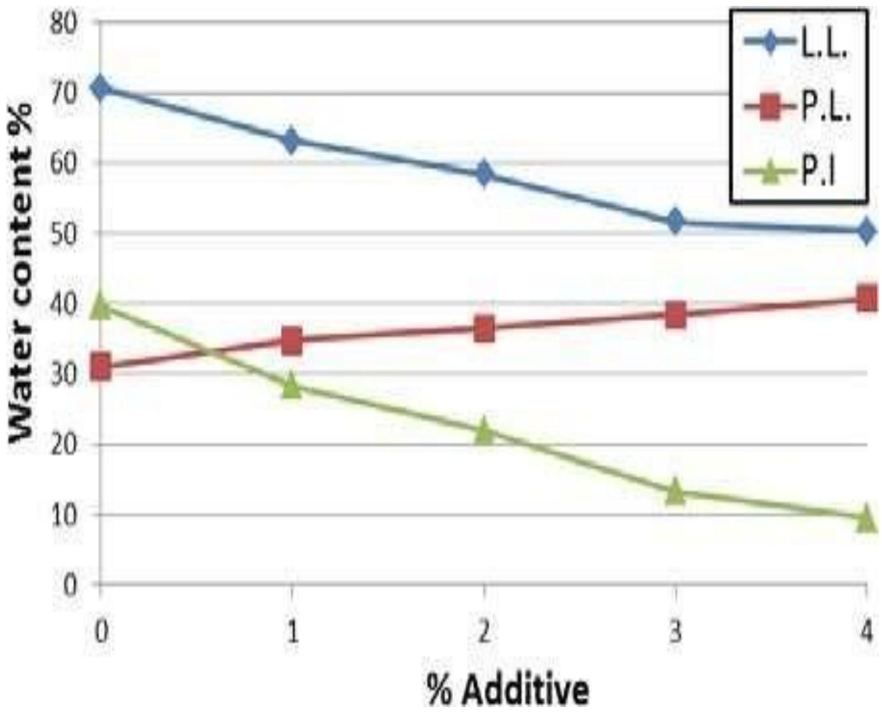


Fig. 2 Effect of additive on Atterberg limits.

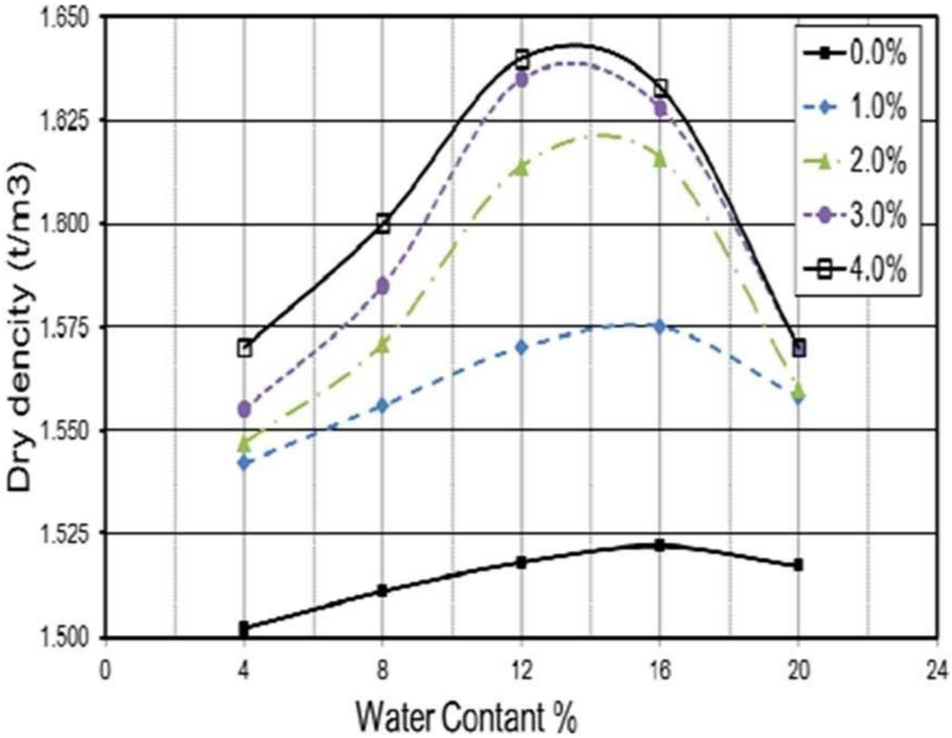


Fig. 3 Effect of Additive on the compaction Proctor test.

*4.3. Swelling Characteristics*

When the Dust Shield ratio is increased, the swelling pressure values of expansive soil decrease. The ideal additive content for reducing soil swelling features appears to be 3.0 percent, as greater additive content ratios did not result in a substantial increase in swelling index (as shown in Fig. 4).

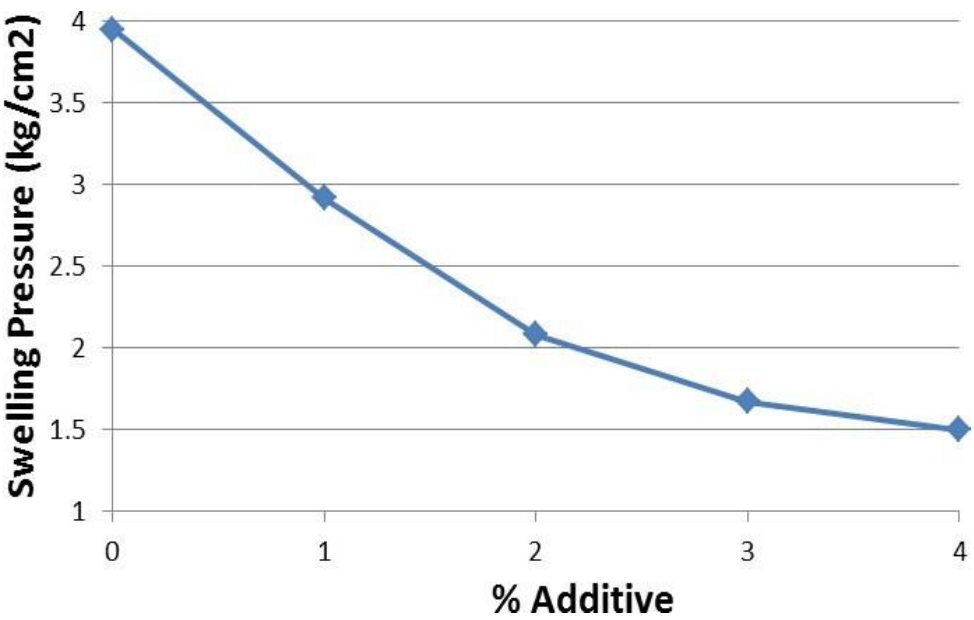


Fig. 4 Effect of additive on swelling pressure.

*4.4. Shear Strength.*

The unconfined compressive strength of expansive soil increases with increasing the additive ratio in unsoaked samples. Furthermore, the rate of rise is high up to 2.0 percent additive, then it is roughly stable up to 3.0 percent additive, and then it starts to decline. Adding Dust Shield, on the other hand, has little effect on the unconfined compressive strength of wet samples (as displayed in Fig.5).

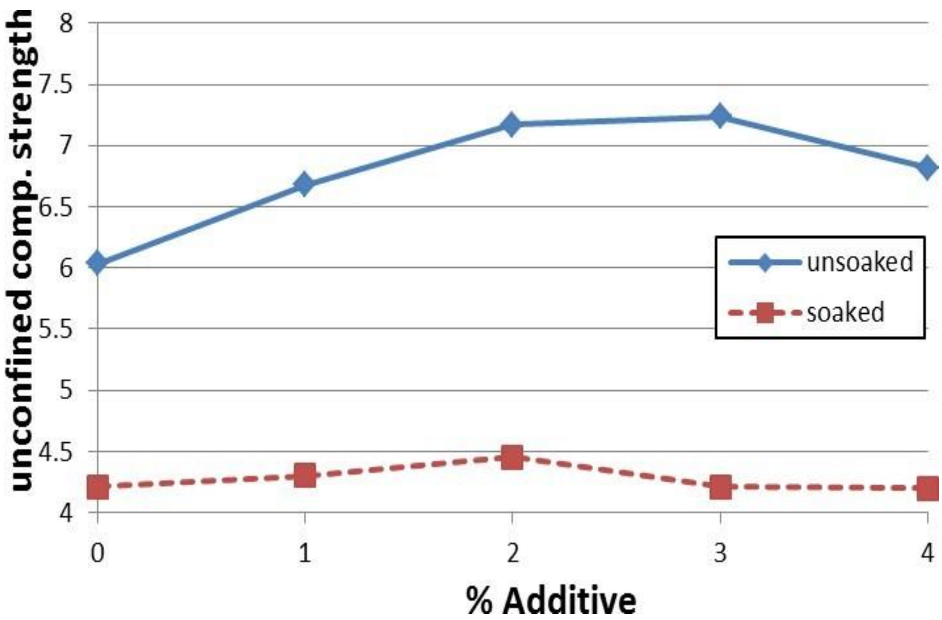


Fig. 5 Effect of additive on unconfined compressive strength.

*4.5. California Bearing Ratio (CBR).*

The California bearing ratio of expansive soil increases with increasing the additive ratio in both un-soaked and soakedsamples. Furthermore, the rate of rise is high up to 2.0 percent additive, then it is roughly stable up to 3.0 percent additive, and then it starts to decline (as shown in Fig.6). For Highway works, it is noticeable that also from the results,with the addition of the dust shield polymer to the swelling soil, the value of the CBR coefficient is increased, both in the case of soaked and un-socked. This can be attributed to the reduction of the exfoliation characteristics of the subgrade soil. It was noted that the value of the CBR coefficient approached the minimum standard specifications for road works (min CBR= 10) for the soil used in the backfilling works, but this was achieved only in the case of socked with an addition of 5%, while with the other ratios the value of the CBR coefficient did not reach the required limit [33].

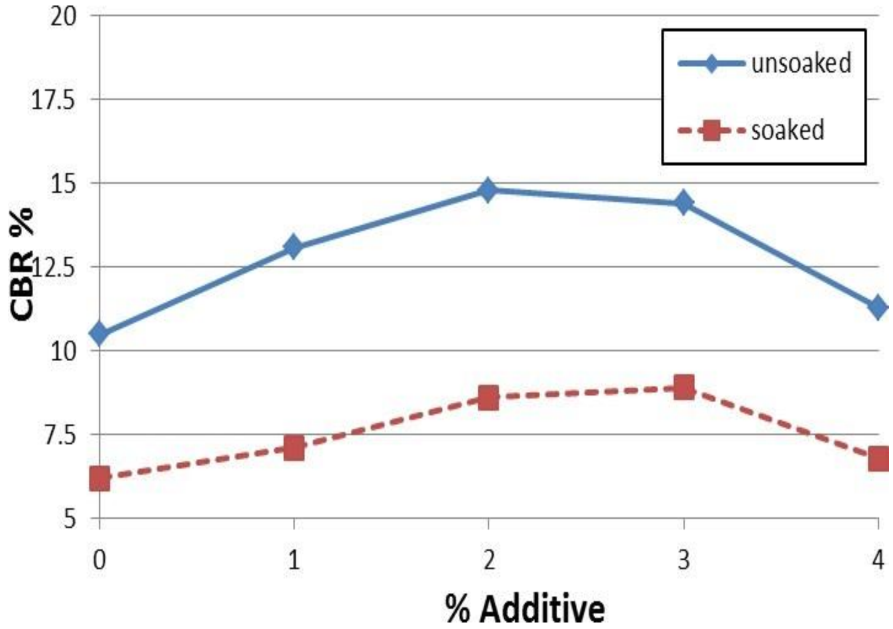


Fig. 6 Effect of additive on CBR%.

## 5. CONCLUSION

The dust shield polymer was utilised in this study to improve the characteristics of sub-grade soils on New Sohag city's internal roads. Increases in Dust Shield rate resulted in increases in maximum dry density (d max), unconfined compressive strength, and California bearing ratio in tests conducted on sub-grade expansive soils. With increasing DustShield rate, the liquid limit, plasticity index swelling values (swelling potential and pressure), and optimum moisture content (O.M.C.) of expansive soil decrease, but the plastic limit increases. Dust Shield can be utilised as an effective stabiliser to improve the qualities of expansive soil under traffic areas, according to the findings of this study.

Although this type of additive has improved the engineering properties of swelling soil, which might be used as a sub-grade layer, it still did not achieve the required specifications mentioned in the Egyptian code for rural and urban road works, especially for the plasticity index coefficient, which did not reach the required limit (Max. PI = 8) [33]. Therefore, we suggest that more laboratory tests be done to reach the standard specifications so that this type of soil can be used in road works by using another type of polymer or adding this type with another type to reach the standard specifications required.

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