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Influence of Copper Coated Micro Steel Fibers on Soil Stabilization for Road Subgrade

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Abstract

A common bad characteristic expansive soil which is randomly located in hot terrorism areas located in the middle of Iraq. This is required to improve the soil , then implement a flexible roads for reaching to those areas quickly. A copper coated micro steel fiber (CCMSF) is chosen to stabilize the sub grade soil of flexible roads. An experimental study focused on the physical properties of the resulting stabilized soil has been achieved.

Various percentages fiber/soil of (1, 2, 3, 4 &5%) are tested for CBR, Indirect Tensile Strength & Linear Shrinkage percent to investigate the improvements and due to the suggested addition and the physical manipulations obtained by comparing with a control samples (zero fiber content).

It is found that a 3% fiber/soil offers the best fit with engineering specification and economic feasibility coast. Accordingly, 3% of CCMSF increases the *CBR* and *Indirect Tensile Strength* values with 114% and 122% respectively, whereas *Linear Shrinkage* value reduces with 70%. However, the increment in CBR reduces the design thickness of the flexible pavement constructed above such stabilized sub grade soil with 39% comparing with non-stabilization soil of similar circumstances. Thus in turn leads to shorten the implementation time of flexible pavement by the same percentage and saving the implementation road cost by about 24%.

Keywords: Copper Coated Micro Steel Fibers (CCMSF) , Soil Stabilization, Flexible Road, Physical Properties.

1. Introduction

In the recent years, discrete fibers has been used in geotechnical engineering serving as a new reinforced materials (C. Yi et al, 2006) . (J. Prabakar ,R,S. Sridhar, 2002) presents that ,the strength of the soil can improve when using the discrete sisal fiber .While (G.X. Li et al ,1995) and (X.J. Zhang et al,1998) conducted that the soils reinforced with discrete polypropylene fibers have increases in tensile strength and fracture toughness ,which can prevent the further development of cracks and enhance the self-seaming ability of the soil. Fiber reinforcement consists of mixing discrete, randomly oriented fibers has been used in soil to assist the soil in tension (I.D. Hussin, 2006) .

(M.Y. Fattah et al, 2010) treated the expensive soil for the hamamuk earth dam, north of Iraq using different additives .They conducted that, the treatment of expensive soil with 5% of cement or steel fibers or the injection with cement grout revealed a better improvement. Also they found that the angle of internal friction is not affected by these additives while the cohesion is slightly affected due to a change in the adhesion between the additives and soil particles. The study of (C. Yi et al, 2006) showed that, the treatment of soil by steel fibers can greatly improve CBR values ,indirect shear strength and reduce the capacity of shrinkage .

(J.K. Mitchell, 1977) indicates that cement is well fit for well graded granular soils of (A-2 & A-3) whereas in the case of asphaltic stabilization for granular soils he presents it is good for soil with less than 20% passing sieve No. 200 and plasticity index less than 6, he is also reveals that with lime stabilization is need enough curing time to allow pozzolanic reaction to occur due to the existence of high percentage of Silica and Alumina (see Table 2) of the considered soil. Since the available physical local soil properties (soil type A-7-6, 47% passing sieve No. 200, and P.I = 21%) are not fit the required specifications, then the CCMSF is chosen as a better alternative stabilizer of sub-grade soils to improve its specifications especially the soil stability.

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2. Research Significance and Terrorism War Consequences

As a result of the current war terrorism in Iraq**,** and corresponding to the impact of its collapse, many social and environmental variables are issued especially in the middle and south of Iraq; among them the establishment of temporary and permanent roads that have to be built and passing through an expansive (bad engineering characteristics) and collapsible soils to attain the regions of a terrorism sources.

The general circumstances in Iraq are that the rise of temperature in summer, uncontrolled allowable truck loads particularly during the treatments of the terrorism process. Accordingly it is required to design and establish a well-designed roads.

The above variables are usually causing road failures which in turn many traffic problems consequentially occurred such accident and late in transportation traffics and high expenditures for road maintenance and rehabilitation of the economical constructions. For defeating and solving such problems, the *Copper Coated Micro Steel Fiber* is employed for expansive soil stabilization purposes rather that the looking for economic cost.

Consequently, the following purposes are considered in the current laboratorial study:-

1- Examining the effects of CCMSF on soil characteristic; California Bearing Ratio, Indirect Tensile Strength and Linear Shrinkage Ratio.
2- Evaluating the resulting designed flexible road thickness depending on the issued CBR percentages of the stabilized subgrade layer.
3- A feasibility studying is carried on.

3. Materials and Method

3.1. Soil: the selected soil was taken from Technical Institute of Babylon. The index properties of the soil were determined and the soil was classified according to the Unified and AASHTO Classification Systems as shown in Table.1, and the chemical composition was listed in Table.2. Fig.1 shows the grain size distribution of the soil.

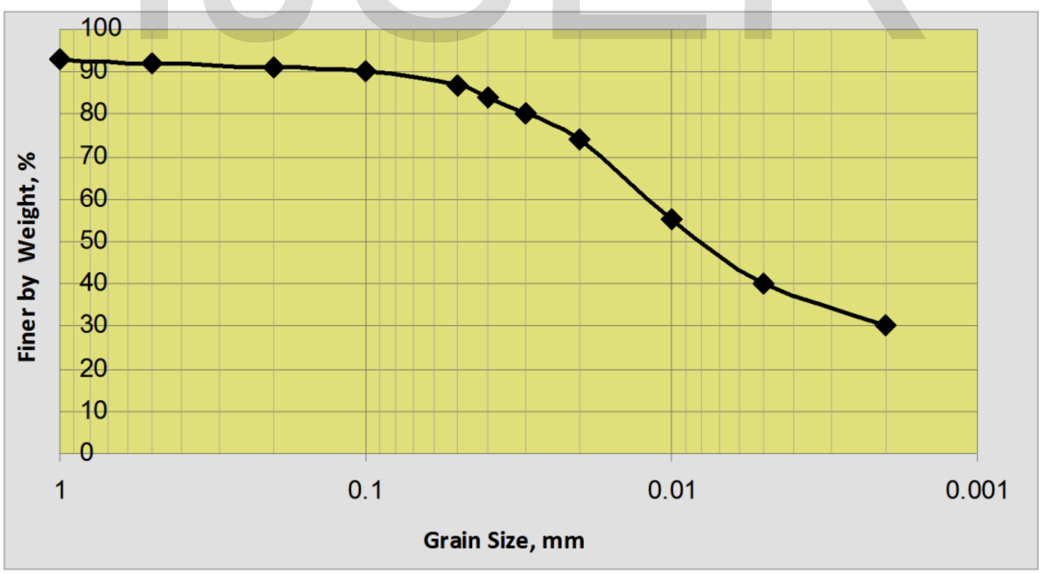

Fig.(1) Grain Size Distribution of the Considered Soil

3. 2. Fiber : the steel fiber available from Jingjiang Huayuan , Int'l Trade Company , Ltd , Jiangsu ,China which was used in this study and is called Copper Coated Micro Steel Fiber (CCMSF) with 0.2mm diameter and (12-14)mm length. It manufactured from low carbon steel wire and coated with copper. The aspect ratio of the CCMSF is about 65 and the tensile strength 2850 Mpa (see Fig.2).

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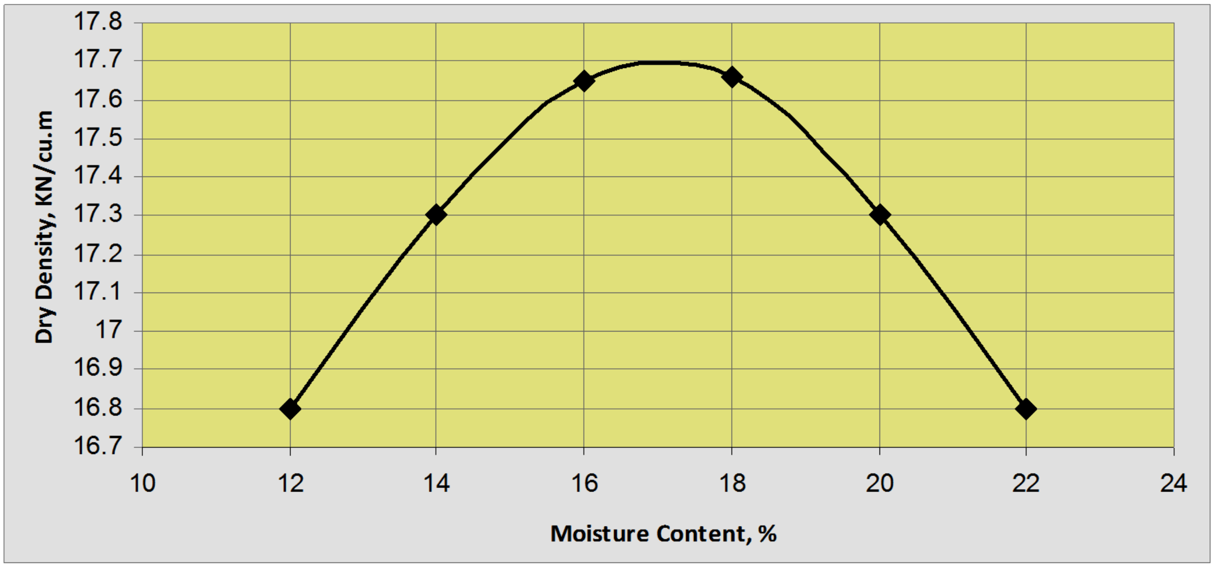

Fig.(6) Modified AASHTO Compaction Test for Control Section (Without Fiber)

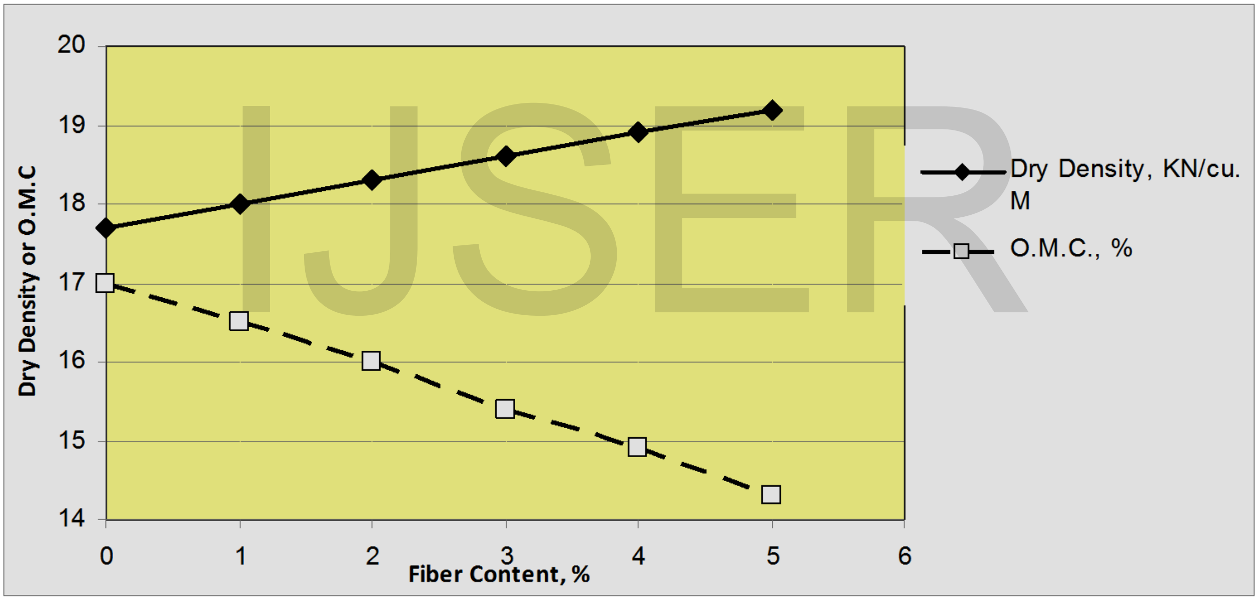

Fig.(7) Fiber Content Versus Max. Dry Density and Optimum Moisture Content Relations

Fig(8) shows the improvement of CBR for the used soil with addition of CCMSF. This increment in CBR values is attributed to the steel fibers which restrict the swell of soil and act as a reinforcement material, thus consequently increase the CBR values. The addition of 3% CCMSF causes an increment of CBR value by 114%. Also the figure shows that the sharp increase in CBR values tell 3 percent ,then less rate of increasing for CBR values were found with increasing CCMSF percent. This is due to a large quantity of steel fibers used and causes a sliding motion between some of fiber pieces which resulted in a less resistance to the applied loads during testing the samples.

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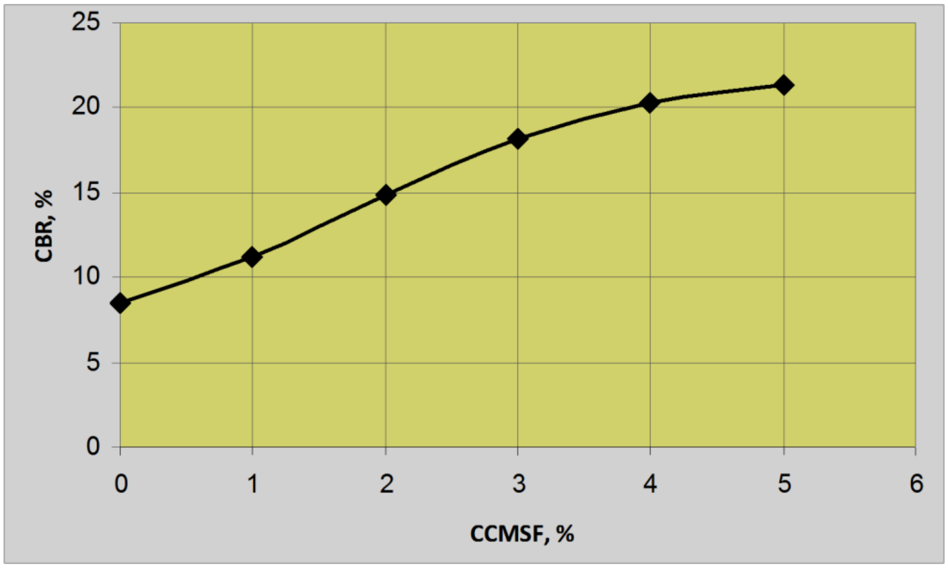

Fig.(8) CCMSF % Versus CBR % Relation

Fig.9 shows the results of split tensile strength test due to using different percentages of CCMSF. The addition of steel fibers increases the tensile strength and the rate of increasing the strength decreases after using 3 percent of CCMSF. These results confirm the California bearing ratio test results. Also the figure shows that an addition of 3% CCMSF causes an increase in the value of indirect tensile strength by 122% relative to control section.

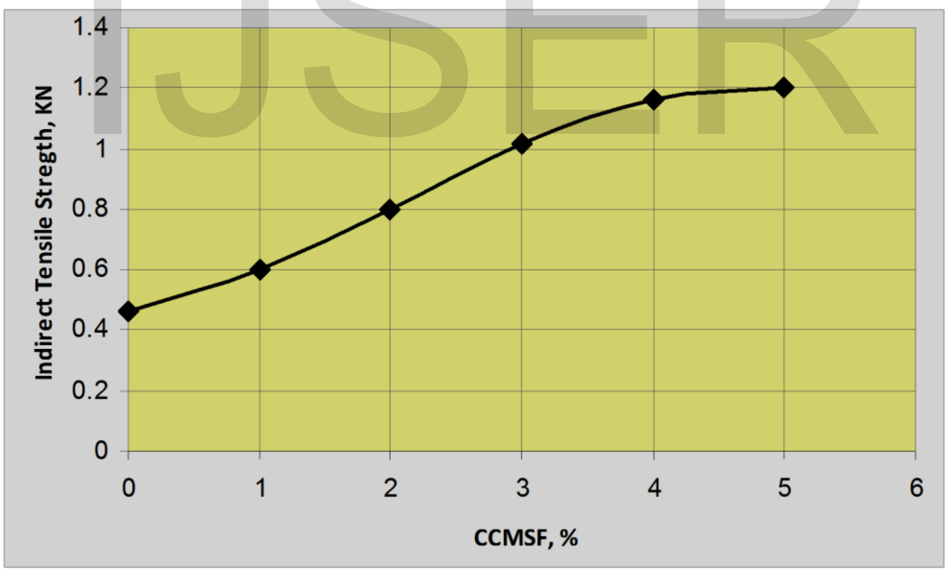

Fig.(9) CCMSF% Versus Indirect Tensile Strength Relation

Linear shrinkage determined by measuring the change linear dimension upon losses of water. Fig.10 shows the results of linear shrinkage of soil when using different percentages of steel fibers in addition to control sample. The figure shows that, the linear shrinkage decreases directly (decrease 69.7% when using 3% CCMSF) with increasing fiber percent and the rate of reduction is less when using more than 3% CCMSF. This is due to the action of a fiber as a reinforcement, and it holds the soil mass causing a restrict to the soil particles against the free movement due to water content variation.

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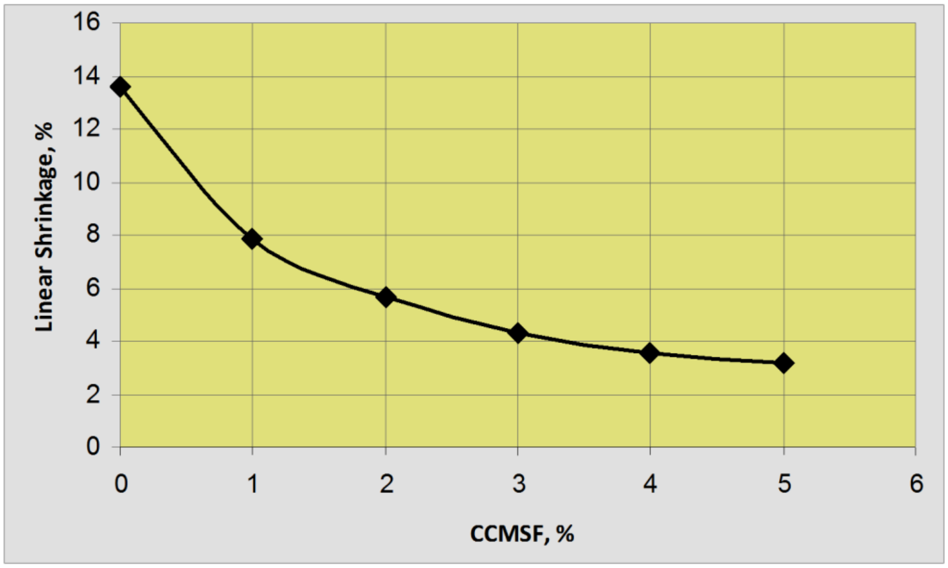

Fig.(10) CCMSF% Versus Linear Shrinkage Relation

Then, using 3% of CCMSF can be considered the optimum percentage which gives the best results for improvement the subgrade soil to increase the stability and reduce the shrinkage properties of the fixable roads.

6. Result Analysis & Discussion

6.1. Technical Result Analysis

Fig.(11) presents the designing thickness of the flexible road according to the obtained CBR values of each fiber additives.

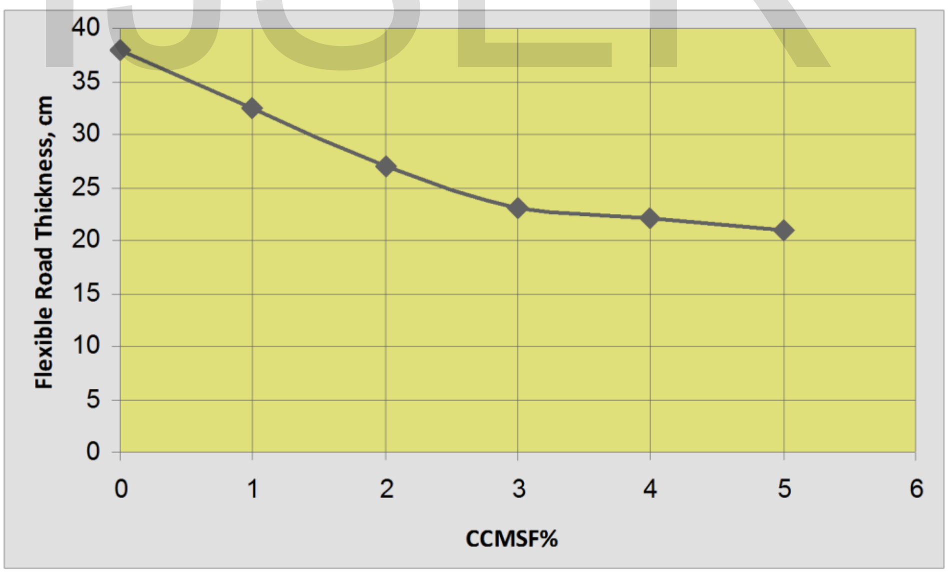

Fig.(11) CCMSF% Versus Flexible Thickness Relation

The figure shows that road thickness considerably and steeply reduces with fiber addition increase till 3%, after that the rate of change with respect to CCMSF% increase is largely reduced. Accordingly, in order to present the percent reduction in flexible road thickness versus the increment of CCMSF% increase, the results redrawn graphically in Fig.(12).

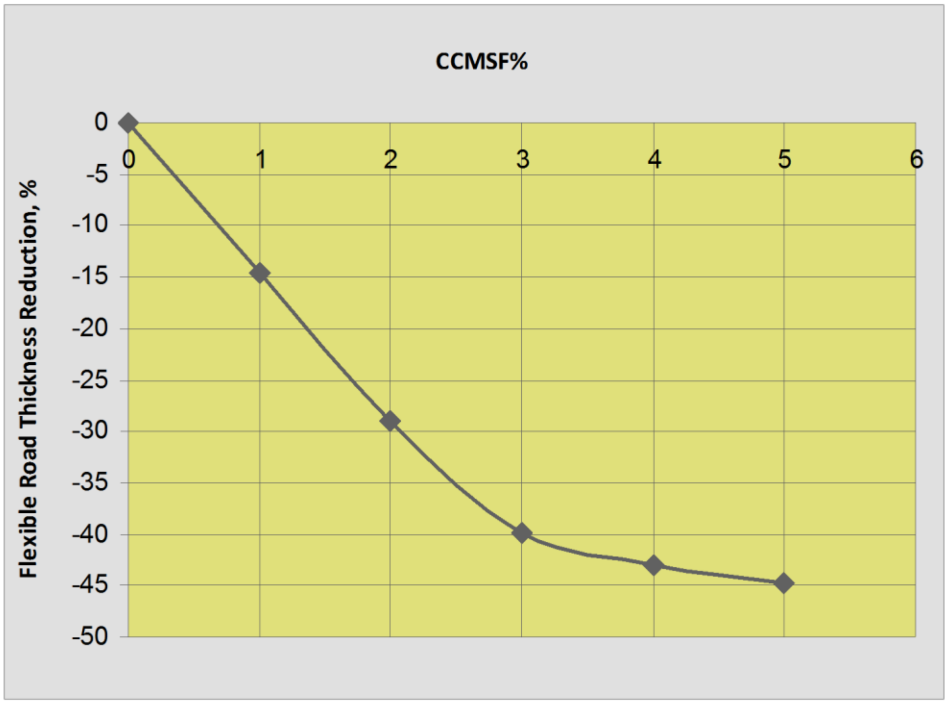

Fig.(12) CCMSF% Versus Road Thickness Reduction %

Fig.(12) indicates that for CCMSF additive of 3%, the thickness reduction % is found to be 39% by using a *Standard CBR Design Method*. This result means reducing the time required for the implementation of the flexible road by about 39%.

6.2.Feasibility Analysis

Table (3)
Cost Benefit Analysis

CCMSF% Col.1	Reduction in Road Thickness % Col.2	Reduction in Road Cost ($/m^2) Col.3	Road Cost after CCMSF Addition ($/m^2) Col.4	Cost of Additives ($/m2) Col.5	Final Cost of the Road $/m^2 Col.6	Benefit in Road Cost due to CCMSF Additives $/m^2 Col.7	Benefit % Col.8
0	0	0	114	0	114	0	0
1	15	17	97	6	103	11	9.7
2	28	32	82	12	94	20	17.5
3	39	45	69	18	87	27	23.7
4	43	49	65	24	89	25	21.9
5	46	52	62	30	92	22	19.3

Col.3 = Col.2*114 $/m^2 (initial cost of non-reinforced total road thickness)
Col.4 =114$/m^2 - Col.3
Col.6 = Col.4+ Col.5
Col.7 = 114$/m2 – Col.6
Col.8 = Col.7/114 %

Table (3) and Fig.(13) are included with the cost reduction horizon and its economical dimensions to the using of CCMSF additives in the stability of subgrade layer. This table shows that the use of 3% CCMSF give the best economic result, it reduces the road cost by about 24%. The analytical results are based on a thickness of 20cm sub-grade layer.

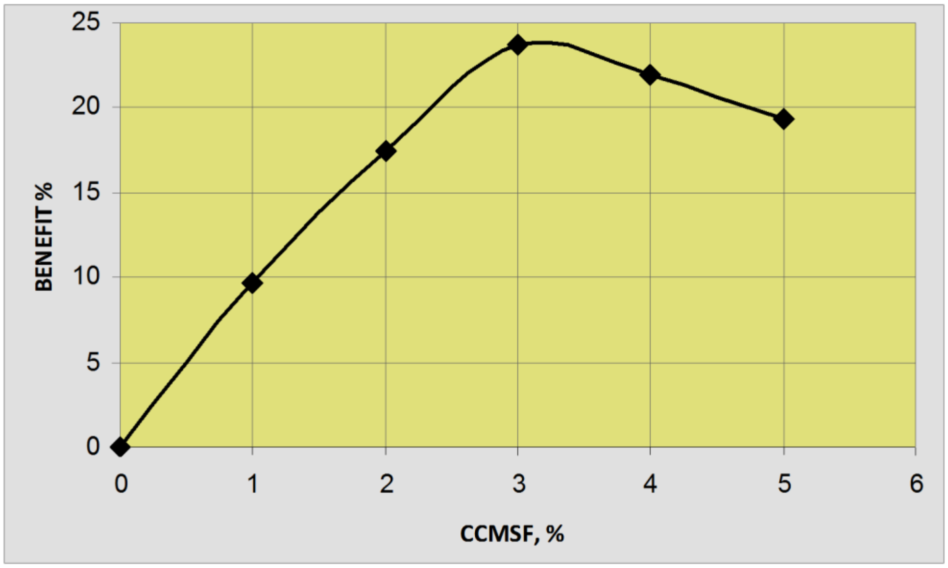

Fig. (13) Benefit Gained Percent Versus CCMSF% Increment

Analytical Preference Key

It is observed from Table (3) - Col.8 and Fig.13 that the maximum benefit is fulfilled in the CCMSF addition of 3% which is matched with previous technical analysis of Figs. (8, 9, 10, 11, and 12).

Conclusions

The followings may be concluded in this research:

1. The maximum dry density for flexible road sub-grade soil changes directly whereas the optimum moisture content changes inversely with CCMSF% increase
2. CBR values increases rapidly till 3% of CCMSF, whereas the changes rate reduces considerably for more values.
3. Accordingly, the addition 3% of CCMSF offers an increment of CBR and indirect tensile strength by 114% and 122% respectively relative to the control section.
4. *Linear Shrinkage* decreases rapidly till 3% of CCMSF and latterly it reduces for more values; it is equal 69.7% at 3% of CCMSF
5. The flexible designed thickness of road decreases rapidly with CCMSF increase till 3%, then it is reduces for excess values of CCMSF%. It is also found that at 3% of CCMSF, the road thickness reduction is found to be about 39% which in-turn saving the road constructing time by about 39%.
6. The feasibility analysis results coincide with the engineering tests results that the best profit is fulfilled when using 3% of CCMSF with the flexible road sub-grade layer which saving the implementation road cost by about 24%.

Recommendations

The followings are recommended:

1- Using different types of steel fiber to stabilized the flexible road sub-grade layer.

2- Using CCMSF to reinforcing a cohesion-less sub-grade layer.
3- Using CCMSF to reinforcing asphaltic layers for flexible roads.
4- Using CCMSF to reinforcing concrete layer for rigid roads.
5- Using different types of steel fiber to reinforcing the flexible and rigid roads pavement.

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