A Study on The Strength Enhancement of Subgrade Soil by Partial Replacement With Waste Aluminium Chops And Wires

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Abstract- *Silt soil cannot satisfy the requirements of highway construction because of its low strength. Increasing the use of waste and recycled materials in earthwork projects has created the necessity a better understanding of the durability and strength performance of these materials against weathering conditions. The reinforcing soil using randomly distributed natural or plastic fibers has been used since ancient times. However, reinforcing of subgrade with discrete metallic fibers is still a relatively new technique in highways construction. In this paper the properties of poorly graded silty soil, waste aluminium wires and aluminium chops are studied and the effect on geotechnical properties of the soil is investigated by adding different amount industrial aluminium wastes into it. The percentages 0.1%, 0.5%, 1% & 2% by weight respectively. Thus, the effectiveness of using aluminium wires and aluminium chops in stabilizing weak soil was investigated in the laboratory. The soil samples in natural state and when mixed with varying percentages of aluminium wires and aluminium chops were used for the laboratory tests that included atterberg limits tests, grain size analysis, standard Proctor compaction tests, unconfined compression tests and California bearing ratio tests.*

Keywords- Aluminium wires and aluminium chops, subgrade, standard Proctor compaction test, California bearing ratio.

I. INTRODUCTION

Weak soft soils are associated with many geotechnical problems. Because of that, some of the pavements located on weak soil have exhibited various types of deterioration in the form of raveling, cracking, rutting and formation of potholes and depressions in recently built highways. The usual approach to soft sub-grade stabilization is to remove the soft soil and replace it with a stronger material of crushed rock. The high cost of replacement has caused highway agencies to evaluate alternative methods of highway construction and one approach is to use stabilized soil for soft sub-grade. The natural durability and strength of the soil can be improved through the process of 'soil stabilization' using different types of stabilizers. The aim of soil stabilizers is to increase the resistance against destructive forces of the weather by increasing strength and cohesion, reducing moisture movement in the soil and imparting water proofing characteristics. Stabilization of soils with low-bearing capacity is an economical way to strengthen the earth for building purposes and to diminish the amount of soil exchanges.

Increasing the use of waste and recycled materials in earthwork projects has created the necessity a better understanding of the durability and strength performance of these materials against weathering conditions. The reinforcing soil using randomly distributed natural or plastic fibers has been used since ancient times. However, reinforcing of subgrade with discrete metallic fibers is still a relatively new technique in highways construction. Thus, as far as the author of this paper know the mechanical and durability properties of soft silt subgrade soil stabilized with waste Aluminium pieces has not been previously studied or reported in literature. Subsequently, this research aims to:

(i) Exploring the possibility of soft subgrade stabilizing with Aluminium fiber depending on the fiber shape, size and amount.
(ii) Evaluating the mechanical properties of the subgrade stabilized with Aluminium chops and wires.
(iii) Exploring the effect of materials on the performance and durability of soil stabilized with this new material.
(iv) Investigating some practical applications for the Aluminium fiber reinforcement especially its effect on the road construction cost savings based on the reduction in base course thickness.

II. LITERATUREREVIEW

Aluminium is the most abundant metal in the earth's crust. It ranks second, next only to steel, in terms of volume used due to its versatility, which stems from its excellent and diverse range of physical, chemical and mechanical properties. Aluminium, which is only one – third the weight of steel is highly resistant to most forms of corrosion, is non magnetic, non combustible, is non toxic and impervious packaging industries) and is also super conductor of electricity. Other valuable properties include high reflectivity and rapid heat dissipation. The metal malleable and easily worked by the common manufacturing and shaping processes. Aluminium was first produced in 1808. There are three main steps in the process of aluminium production First is the mining of aluminium ore, most commonly bauxite, referred to as bauxite mining. Second is the refining of bauxite aluminum oxide trihydrate known as alumina, and the third is the electrolytic reduction of alumina into metallic aluminium.

Soil stabilization is a procedure where we improve engineering properties of soil with the use of natural or synthesized admixtures. In the past many researchers have carried out their research work for improving the strength of weak soil using different types of admixture at different percentages. A brief review of previous studies on clayey soil is presented in this section and past efforts most closely related to the needs of present work.

Steel fiber reinforcements found in concrete structures are also used for the reinforcement of soil-cement composites. In addition, steel fibers can improve the soil strength but this improvement is not compared with the case of using other types of fibers. However, Ghazavi and Roustaie (2010) recommended that in cold climates, where soil is affected by freeze-thaw cycles, polypropylene fibers are preferable to steel fibers. Since, polypropylene fibers possess smaller unit weight than steel fibers. In other words, the former fibers decrease the sample volume increase more than steel fibers. To the knowledge of the author, the use of waste Aluminiumpieces as soft subgrade reinforcement has not been previously studied. Subsequently, this section presents a brief summary of previous investigations dealing with the durability and mechanical properties of soil stabilized with different types of waste and recycled materials.

Few studies have been carried out on effects of fiber inclusion on mechanical behavior of stabilized soil. They conducted some unconfined compressive, direct shear, swelling, and shrinkage tests on polypropylene fiber reinforced lime stabilized clayey soil. While lime stabilized samples showed a brittle failure pattern, fiber-lime specimens showed strain softening ductile failure. Also, inclusion of fiber with cement stabilized soil has shown increase in strength as well as rise in ductility and reduction in brittleness of stabilized material.

Zaimoglu (2010) studied freezing-thawing behavior of reinforced soil by unconfined compressive tests. His experiments disclosed efficacy of fiber reinforcing in increasing of strength and durability of fine grained soils.

Mohammad et al. (2012) investigated the effect of tire cord reinforcement of stabilized and unstabilized soil under freeze-thaw condition by unconfined compression. They obtained that the contribution of fiber in increasing strength is enhanced as the cycles of freeze-thaw increase. Durability index is directly related to the initial strength of the specimens before freeze-thaw. The best durability index belongs to specimens with 4% lime content and it increases by inclusion of fiber.

S. K. Tiwari and J. P. Sharma (2013) have studied 'Influence of Fiber-Reinforcement on CBR-Value of Sand'. The effectiveness of inclusion of randomly distributed fibers in sandy soils for improving the California bearing ratio values is investigated through an experimental investigation. The California Bearing Ratio (CBR) Tests were conducted on fine sand reinforced with randomly distributed discrete polypropylene and coir fibers, under both soaked and unsoaked conditions. The paper describes the load penetration response obtained from CBR tests performed on fine sand. The CBR values of fine sand increase significantly due to inclusion of randomly distributed fibers under soaked and unsoaked conditions. The increase in CBR is as high as 100% due to addition of 1.5% fiber.

Hejazi et al. (2013) reviewed the concept of using discrete randomly distributed fibers in soil, i.e. short fiber soil composites. In this way, both natural (coir, sisal, palm, jute, flax, straw, bamboo; and Cain) and synthetic fibers (Polypropylene PP, Polyethylene PE, Polyester PET, Nylon, Glass, Polyvinyl alcohol PVA.

2.2 STABILIZATION

Soil stabilization is the process of improving engineering properties of the soil and thus making it more stable. Soil stabilization means the improvement of the stability or bearing power of the soil by the controlled compaction; proportioning and/or addition of suitable admixture or stabilizers. Soil stabilization is the alteration of soil to enhance their physical properties.

METHODS OF SOIL STABILIZATION

- Mechanical Stabilization.
- Soil Cement Stabilization.
- Soil Lime Stabilization.
- Soil Bitumen Stabilization.
- Thermal Stabilization.
- Chemical Stabilization.

III. METHODOLOGY

The soil was initially air dried, pulverized and then was sieved through 4.75mm sieve, prior to the testing. The samples were prepared by mixing the pulverized and sieved soil with the needed stabilizing agents in dry condition and then required amount of water is added to make a consistent mix by thorough mixing. The following tests were conducted as per IS Codes of practice to assess the Improving subgrade soils With Aluminium wires and Aluminium chops. In this chapter, a brief description of the experimental procedures adopted in this investigation and the methodology adopted during the course of study are briefly presented.

MATERIALS USED AND THEIR PROPERTIES

3.1 SOIL

The soil sample used for this experimental study was collected locally from a construction site. The collected natural soil is shown in Figure 3.1. The results of the natural water content, liquid limit, plastic limit, plasticity index, specific gravity, modified proctor compaction test, CBR value, cohesion, and angle of internal friction are presented in Table 3.1.

Fig 3.1: Soil sample

TABLE 5.1 Physical properties of the studied subgrade.

Test	Value
Natural Moisture Content (%)	4.11
Liquid Limit (%)	23.2
Plastic Limit (%)	21.1
Plasticity Index (%)	2.1
Specific Gravity	2.31
Maximum Dry Density (gm/cm3)	1.8
Optimum Moisture Content (%)	18
Unified Classification Group	ML
CBR Value (%)	10.56
UCS Value (kg/cm2)	2.64

3.2 ALUMINIUM CHOPS

Aluminium chops used in this research is considered as waste material from the formation process of the Aluminium sections. In this investigation, the Aluminium chops are divided into two categories, first category (AC10) described as the Aluminium chops that pass from sieve No.10 (2 mm) and retained on sieve No.20 (0.85 mm), second category (AC20) described as the Aluminium chops that pass from sieve No.20 (0.85 mm) and retained on sieve No.40 (0.425 mm). The main reason for using Aluminium is that this metal does not rust as steel fibers when exposed to water. Figure 5.2(a) shows the different Aluminium chops used in this research.

3.2 ALUMINIUM WIRES

In this research, Aluminium wires of about 2 mm diameter are carved into small lengths of 0.5 cm (AW0.5), 1.0 cm (AW1.0), and 2.0 cm (AW2.0) and then used as a reinforcing material. Figure 5.2 (b) shows the shape of the used Aluminium wires used. As illustrated before the main reason for using Aluminium is that this metal has a high resistance against corrosion so it can be described as a durable material..

IV. LABORATORY EXPERIMENTATION

The soil was initially air dried prior to the testing. The tests were conducted in the laboratory on the marine clay to find the properties of virgin marineclay.

- Grain sizedistribution
- Specificgravity
- Index properties –liquid limit, plasticlimit
- Compaction tests
- Penetration tests-California bearing ratiotest.
- Unconfined CompressionTest-Triaxial

V. RESULTS AND DISCUSSIONS

5.1GENERAL

In the laboratory, various experiments were conducted by adding different percentages of Aluminiumwires and Aluminiumchops to the Weak silty Soil. Liquid Limit, Plastic Limit and Compaction, CBR and UCS tests were conducted with a view to determine the optimum combination of Aluminiumwires and Aluminiumchops and CBR and UCS are conducted for durability studies.

The influence of the above said materials on the Index, Compaction and Strength properties were discussed in following sections. In the laboratory, all the tests were conducted per IS codes of practice.

5.2 EFFECT OF PERCENTAGE OF ALUMINIUMWIRES AND ALUMINIUMCHOPS ON THE COMPACTION PROPERTIES OF SUBGRADE SAMPLES

Initially, it can be observed that the addition of AC or AW raises MDD and decreases OMC compared with the unreinforced subgrade. Moreover, the samples of subgrade reinforced with AC achieve higher MDD and lower OMC than samples reinforced with AW at all studied reinforcement percentages.

The optimal reinforcement percentages according to MDD and OMC are 1.0% for AC and 1% for AW. For wire stabilization, the length of 1.0 cm (AW1.0) achieves higher MDD and lower OMC. For chops stabilization, AC20 achieves higher MDD and lower OMC. It can be explained that this behavior is the result of the occurrence of flocculation for the tested soil due to the addition Aluminiumpieces.

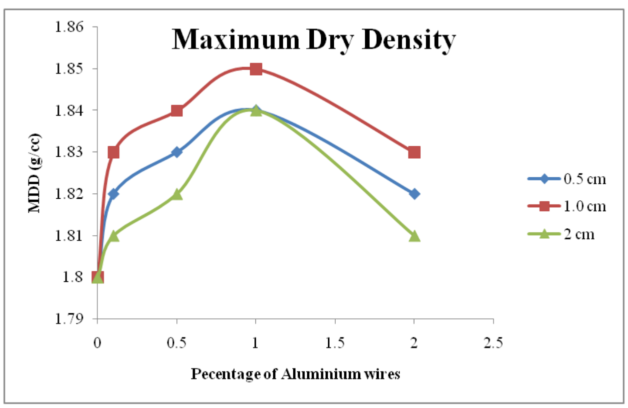

Fig 5.1 Plot showing the Variation in MDD with % of Aluminium wires

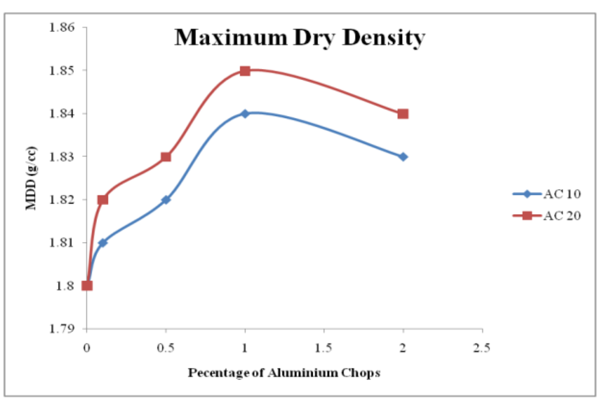

Fig 5.2 Plot showing the Variation in MDD with % of Aluminium chops

5.3 EFFECT OF PERCENTAGE OF ALUMINIUM WIRES AND ALUMINIUM CHOPS ON THE CBR AND UCS PROPERTIES OF SUBGRADE SAMPLES

It is noticed that the CBR and UCS values increases enormously with Aluminium pieces stabilization where the CBR of raw soil is about 10.56% increases to 33.64% by stabilizing with 1% AC20 or AW1.0 and the Aluminium reinforcement has a reasonable effect on increasing the compressive strength especially at using AC20 or AW1.0 with high percentages. AC20 produces higher UCS than AC10 while AW1.0 produces the highest UCS (4.32 kg/cm2) at 1% content. The strength offered by the compacted AC and AW samples is mainly due to the mobilization of frictional strength of the materials. With the increase in Aluminium pieces content in the mixture, the quantity of formation increases, which binds the particles more effectively resulting in higher CBR value. On another hand, the reinforced soil with Aluminium chops has higher CBR values than subgrade stabilized with Aluminium wires at all studied contents. Moreover, AC20 performs better than AC10, while the influence of AW addition becomes more obvious with increasing the ARP where CBR value for AW1.0 and AW0.5 are about 33.64% and 28.5% respectively at ARP of 1%. A sudden drop in CBR value is observed in the case of AW2.0. Thus, it can be concluded that the usage of Aluminium wires of 2.0 cm length provides inferior performance. Therefore, AW2.0 may not be used as a subgrade reinforcement of the remained tests of this study. This indicates that addition of AW or AC ranging from 0% to 2%, to subgrade soil is certainly advantageous in increasing the strength of stabilized mixes.

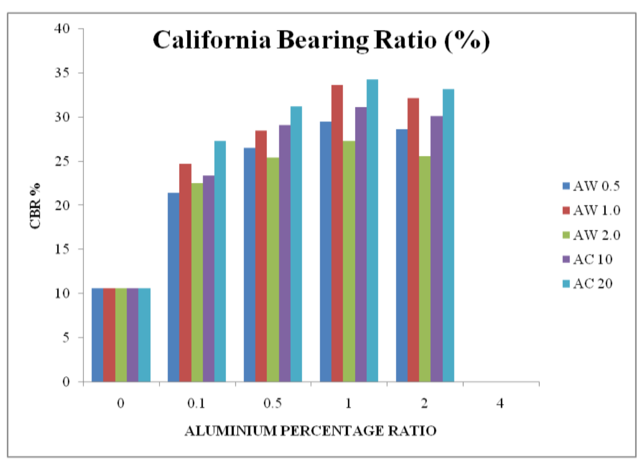

Fig 5.3 shows CBR values of different Aluminium reinforcement mixes

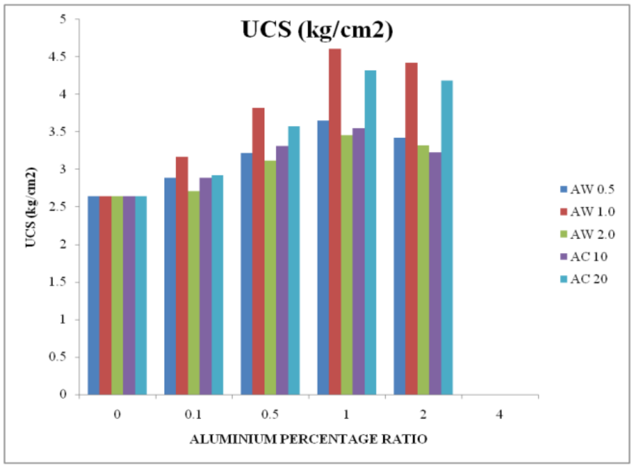

Fig 5.4 shows UCS values of different Aluminium reinforcement mixes

VI. CONCLUSIONS

This study presents the characteristics of fine grained subgrade soils stabilized with randomly distributed Aluminium chops (AC) as well as wires (AW) as a new material in reinforcing soil. The effects of strength of the stabilized soil were investigated in this study. Based on findings and results, the following conclusions can be drawn:

- Subgrade Aluminium reinforcement enhances compaction and strength characteristics. The potential benefit of is found to depend on shape, size and amount of Aluminium fiber. Aluminium chops especially AC20 shows higher dry density, higher CBR and lower moisture content. AW1.0 produces higher strength. The increase in Aluminium chops grade leads to increase the majority of properties. For Aluminium wires, length of 2.0 cm produces reduction in CBR and UCS compared to smaller length.
- The samples of subgrade reinforced with AC achieve higher MDD and lower OMC than samples reinforced with AW at all studied reinforcement percentages. The optimal reinforcement percentages according to MDD and OMC are 1.0% for AC and 1% for AW. For wire stabilization, the length of 1.0 cm (AW1.0) achieves higher MDD and lower OMC. For chops stabilization, AC20 achieves higher MDD and lower OMC.
- It is noticed that the CBR and UCS values increases enormously with Aluminium pieces stabilization where the CBR of raw soil is about 10.56% increases to 33.64% by stabilizing with 1% AC20 or AW1.0 and the Aluminium reinforcement has a reasonable effect on increasing the compressive strength especially at using AC20 or AW1.0 with high percentages. AC20 produces higher UCS than AC10 while AW1.0 produces the highest UCS (4.32 kg/cm2) at 1% content.
- Studying the practical viability proves that the subgrade stabilized with Aluminium pieces has a remarkable influence in reducing the base course thickness (especially at using 1% of AW1.0) and subsequently increasing the construction cost saving (especially at using 1% of AW1.0).Finally it can be summarized that the materials Aluminium chops and Aluminium wires shown promising influence on the properties of soil.

REFERENCES

[1] Hossain, K.M.A., Lachemi, M. and Easa, S. (2007) Stabilized Soils for Construction Applications Incorporating Natural Resources of Papua New Guinea. Resources, Conservation and Recycling, 51, 711-731.

[2] Zaimoglu, A.S. (2010) Freezing-Thawing Behavior of Fine-Grained Soils Reinforced with Polypropylene Fibers. Cold Regions Science and Technology, 60, 63-65. [6] Mahipal, S.C., Satyendra, M. and Bijayananda, M. (2008) Performance Evaluation of Silty sand Subgrade Reinforced with Fly Ash and Fiber. Geotextiles and Geomembranes, 26, 429-435.

[3] Ghazavi, M. and Roustaie, M. (2010) The Influence of Freeze-Thaw Cycles on the Unconfined Compressive Strength of Fiber-Reinforced Clay. Cold Regions Science and Technology, 61, 125-131.

[4] Hossain, K.M.A. and Mol, L. (2011) Some Engineering Properties of Stabilized Clayey Soils Incorporating Natural Pozzolans and Industrial Wastes. Construction and Building Materials, 25, 3495-3501.

[5] Aditya, K.A., Praveen, K. and Ransinchung, R.N. (2013) Use of Various Agricultural and Industrial Waste Materials in Road Construction. Procedia, Social and Behavioral Sciences, 104, 264-273.

[6] Gungat, L., Putri, E.E. and Makinda, J. (2013) Effects of Oil Palm Shell and Curing Time to the Load-Bearing Capacity of Clay Subgrade. Procedia Engineering, 54, 690-697.

[7] Miqueleiz, L., Ramírez, F., Seco, A., Nidzam, R.M., Kinuthia, J.M., Tair, A.A. and Garcia, R. (2012) The Use of Stabilized Spanish Clay Soil for Sustainable Construction Materials. Engineering Geology, 133-134, 9-15.

[8] Fauzi, A., Rahmanb, W. and Jauhari, Z. (2013) Utilization Waste Material as Stabilizer on Kuantan Clayey Soil Stabilization. Procedia Engineering, 53, 42-47.