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Research Article

Lime Stabilization of Natural Subgrade Soil along Bishoftu to Koka Road Section, Central Ethiopia

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ABSTRACT

This paper is focused on the treatment of subgrade soil along Bishoftu to the Koka road section by using lime. To achieve the objectives of the research subgrade soils samples were collected along the corridor of the road section and evaluated for its physio-chemical and geotechnical properties. The grain size analysis show the soil contains 13.5% of gravel, 40.3% sand, 25% silt and 21.2% clay and possesses plastic index (PI)>40% and liquid limit (LL)>76% with <5% California bearing ratio (CBR). The soil was classified as A-7-5 in the American Association of State Highway and Transportation Officials (AASHTO) which is considered as a problematic soil for subgrade materials. To determine the effects of lime on geotechnical properties of soil the natural subgrade soil was treated with 3%, 6% and 9% of lime and compacted after a mellowing period of 3 to 4 days and cured for 7, 14 and 28 days. Result shows the soil treated with lime showed lower PI by 33%, OMC by 98% and decrease MDD by 96%, CBR by 24%, with lower swelling potential, higher workability and stabilized soils were feasible to be used as subgrade materials.

Keywords: Subgrade soil; Lime; OMC; MDD; Atterberg limit; CBR

INTRODUCTION

The presence of expansive soil greatly affects the construction activities in many parts of the southwestern United States, South America, Canada, Africa, Australia, Europe, India, China and Middle East [1]. Evaluation and selection of the most suitable improvement techniques are made after the soil consistency is studied in detail [2]. The road is an important infrastructure that provides fundamental functions of delivering national economies over the wide range of distance, so construction of a road with standard quality is very important. Subgrade material (actual foundation) is one of the most important structural components of roads. Ethiopian expansive soils are known to pose severe problems on road construction activity, which leads to an increase in construction and maintenance costs [3]. To overcome these problems understanding of their properties and evaluating suitable stabilization methods are very important. The main objective of the research is to assess the suitability of lime stabilization in improving the engineering performance of expansive subgrade soil along a selected section of Bishoftu-Koka road.

Study area

The study area is located in the central part of Ethiopia within the main Ethiopian rift valley extending toward the west margin of the rift at Bishoftu, along Addis Ababa to Bishoftu asphalt road. Based on rainfall data recorded for 16 years (1997-2014) at Bishoftu and Koka national metrological station the climate condition of the study area categorized into two broad seasons: the dry season (winter) which covers the period from October to May and the wet season extend from June to September, with slight rainfall during autumn and spring (Figure 1). The landscape of the area is characterized with a wide range of topography like lowland, plain, plateaus, valley and rugged mountainous with dendritic drainage patterns at elevation ranges of (1588 -3080)m (Figure 2).

METHODS

Field investigation and sampling of natural subgrade soils are carried form selected road sections (Figure 3). Sampling of natural subgrade soils was done by examination of soil formations using accessible excavations and information was gathered to ensure that the sampling design meets the required objectives. During the field investigation, it was determined that the soils in the study area are similar in their formation and structure. Nine disturbed soils samples were collected along a selected section of the road route at an interval of 300 m distance with test pits of 2.2 m-3 m depth. Seven disturbed soil samples for characterization and additional

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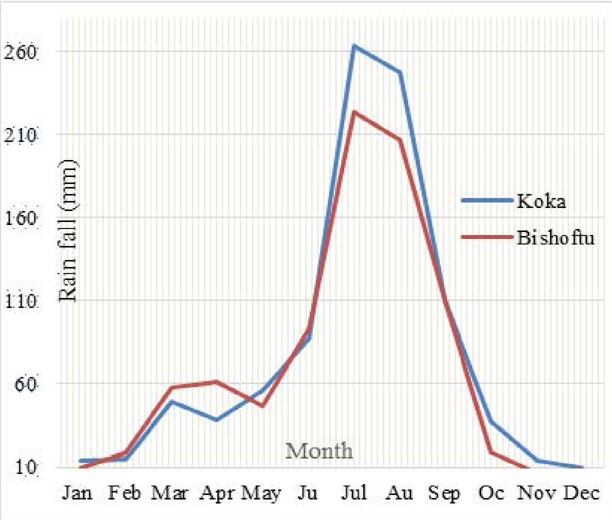

Figure 1: Mean monthly rainfall of the study area (Source: National metrological agency of Ethiopia) volcanic rocks like Nazret group, bofa basalt, pumice, alkaline, rhyolite, alluvial deposit and lacustrine sediments, dominate geology of the study area.

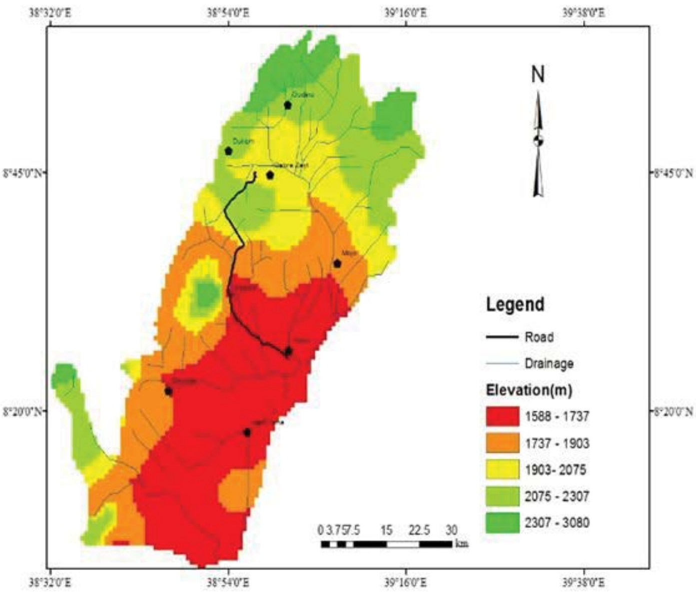

Figure 2: Topographic and drainage map of the study area and its surrounding.

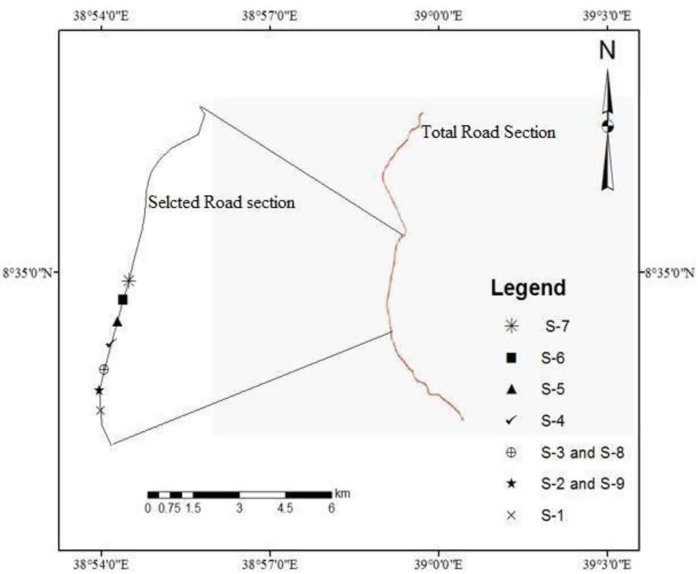

Figure 3: Sampling station along the road section.

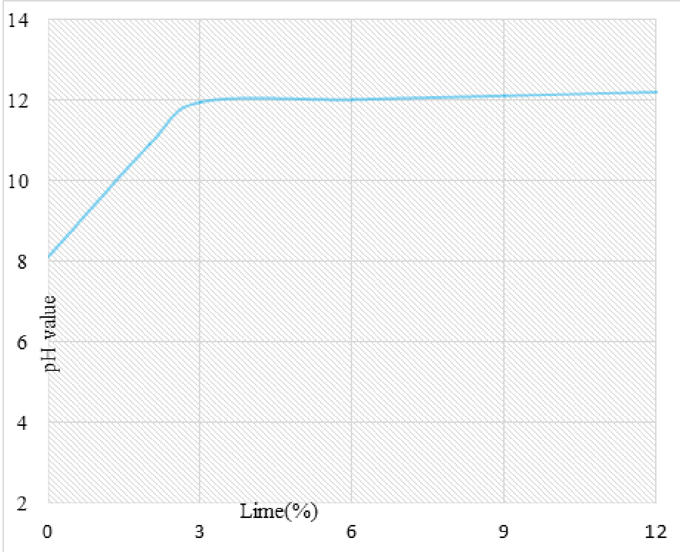

Figure 4: Determining OLC.

two soils samples were collected at most critical sampling locations to determine effects lime on the geotechnical properties of the soils. The geotechnical properties soil samples were analyzed at ASER Plc. construction company mobile laboratory according to different standard shown as follows: Grain size (AASHTO T-88), linear shrinkage, free swell, specific gravity (AASTHO T-00), pH (ASTM D 4972-01), MDD and OMC (AASHTO T-180), Atterberg limit (AASTHO T 89 and T 90), California Bearing Ratio (AASHTO T-193) were analyzed.

Lime mixing procedure

The optimum lime content (OLC) is determined according to test (ASTM D 6276) [4]. In this research 3%, 6% and 9% of lime were used at 7, 14 and 28 days of curing period with 3-4 days mellowing time (Figure 4). The mellowing time ranges from (1-7) days depending on the engineering properties of the soil [5]. Mellowing time (rest time between mixing of chemical with the soil before compacting the mixture into molds) to form a specimen is allowed before compacting [6]. In this study after soil is treated with lime it was sealed in an airtight, moisture proof container and stored at of temperature 25°C for above-mentioned curing period.

RESULTS

In the present study, the suitability of natural subgrade soil for the proposed pavement was assessed in terms of grain size, linear shrinkage, free swell, specific gravity, MDD, OMC Atterberg limit, and CBR. Soil characterization was conducted to determine the geotechnical properties of the natural subgrade soil and choose suitable techniques of stabilization. A detailed investigation is important to determine appropriate techniques for improvement with economic materials. In the next paragraphs laboratory test results obtained for collected samples are presented. The laboratory result of the soil indicates that the soil contains 13.5 % of gravel, 40.3% of sand, 25 % of silt, and 21.2% of clay with 2.2 specific gravity, 166 free swells, 16.6 linear shrinkages, 85 LL, 42 PL, 5 CBR, and 8% swell in CBR. Generally based on the grain size analysis and Atterberg limit data the soil is classified as silty clay soil.

DISCUSSION

Lime stabilization for subgrade soils was used for many years in different parts of the world is and proof as an excellent choice for short-term modification of soil properties [7-9]. Subgrade soil which actual foundation of the road is a very important component for the durability of the pavement. The natural subgrade soils in the present study area are highly plastic as the result; they are highly compressible with poor shear strength and subject to extreme volume change at adverse climate conditions with low bearing capacity.

According to AASTHO, soil classification system the natural subgrade soil is fine-grained soil and classified as A-7-5. These fine-grained soils are also further rated for their suitability for highway based on group index (GI) value determined by the following equation. GI=(F−35) [(0.2+0.005 (LL-40)] +0.01(F-15) (PI-10), Where F-is percentage passing 0.075 mm (No. 200) sieve expressed as the whole number, LL-is the liquid limit PI- plastic index. The group index means rating the values of soil as subgrade materials with its group [5]. The higher the group index the poor the quality of subgrade materials. The representative natural subgrade soils categorized with the same group index of GI=17, indicating the poor quality of these soils as the subgrade.

Subgrade soil is very important for the durability of the pavement. In the present case, the geotechnical properties of natural subgrade materials are not suitable for pavement foundation when compared with Ethiopian road authority specification [3,10] standard. Representative subgrade soil in the study area is categorized under high plasticity soil. The laboratory result of California bearing ratio and swell percent in California bearing reveals that the natural soil is not suitable as subgrade material. The lime-treated subgrade soil shows changes in geotechnical properties as compared to natural subgrade soil.

Change in atterberg limit

The soil in the study area possesses a plasticity index above 43%. According to Bowels (1988), soil with a plasticity index above 35% possesses very high swelling potentials. Therefore, soil in the current study area was classified under the soil with high swelling potentials. Lime treated soil there is a continuous reduction in the plasticity of expansive soil as a higher percent of lime was added to the soil with longer curing periods. These changes in the Atterberg limit values and as result, the treatment enhanced the improvement and workability of the subgrade soil [11,12].

Change of proctor test

Lime with different proportion increases the amount of optimum moisture content (OMC) and decreases the amount of maximum dry density (MDD). By adding 9% of lime in soil, the OMC significantly increased by 7 % and the MDD from decreased by 3.4 % when compared to natural subgrade soil. Generally, the OMC and MDD of the silty clay treated with lime indicate that the MDD decreases and the OMC increase with an increasing percent of lime and curing period. Lime treated soil attains higher densities than natural soil [13-15]. This result reveals that the ability of lime treated subgrade soil to minimize the potential for swelling at a high amount of water content and reduced dry density.

Change in California Bearing Ratio

The California Bearing Ratio (CBR) test is a simple strength test that indicates the bearing capacity of a soil. The value of California bearing ratio for natural subgrade soil below 5% while lime treated soil shows a significantly increased in CBR and decrease in swell in CBR [16,17]. For example, values adding 9% of lime has increased California bearing ratio from 2% to 24% with 28 days curing period. In general, the observed changes of geotechnical properties of lime treated soil directly related to the curing period and percent of lime mixed with soil.

CONCLUSION

In Ethiopia in-situ, stabilization of expansive soils by treating lime, and other additives are not common practice. Removing and replacing non-suitable materials with high quality selected materials like gravel, coarse rocky soil, crushed aggregate, cobbles, and concrete block is a very common. This research determines the influence of lime on engineering properties of natural subgrade soils like optimum moisture content, maximum dry density, liquid limit, plastic limit, and plastic index, California bearing ratio of subgrade soils along Bishoftu-Koka road section.

To evaluate the effect of lime treatment on engineering performance of natural subgrade soil 3, 6 and 9 percent of lime of weight dry soil and treated after 7, 14 and 28 curing days. It was observed that lime treated subgrade soils were significantly changed in their geotechnical properties. The change in geotechnical properties of lime treated expansive subgrade soils are directly proportional to the percent of lime and the curing period, while the percent of lime has a greater effect than curing period.

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