Laboratory Evaluation of Recycled Pavement Materials Stabilized with Nano Polymer

[a]Mhlongo, S.M., [a]Ndambuki, J.M., [a]Kupolati, W.K., [a]Abiola, O.S*
[a]Department of Civil Engineering, Tshwane University of Technology, Pretoria, South Africa
*corresponding author: E-mail: AbiolaOS@tut.ac.za Tel. +27844483004

Abstract—The paper dealt with the laboratory evaluation of the recycled pavement materials stabilized with SoilTech Mk lll Nano polymer, which uses water as a carrier to lubricate the fine particles at molecular level that gets interlocked under mechanical compaction. Sampling was carried out in line with specifications. The samples cored shown a three layer pavement. Sub-base and base materials were collected from the rehabilitated pavement in Mpumalanga Province, South Africa. Laboratory tests were conducted to determine the mechanical properties, optimum moisture content (OMC), maximum dry density (MDD) and California bearing ratio (CBR) of the pavement materials in accordance with the South African road specifications and American Society for Testing Materials (ASTM). The plasticity index (PI), OMC and CBR of the sub base and base are: 15, 10; 7.04%, 5.3%; and 52%, 34% respectively. The specification states that if PI > 6 such materials should be stabilized. Sub-base and base materials were mixed with 0, 0.5, 0.8 and 1.0% SoilTech polymer at OMC and MDD. The stabilized materials were examined for Unconfined Compressive Strength (UCS) test in line with specification at 14-day of curing. The results showed an increase in strength at 0.5% polymer of 76%, 86% for sub base and base respectively of their original strength. Addition of the polymer results in further increase in strength. For optimum and cost effectiveness in terms of the polymer, 0.5% polymer met the requirement for design. It can be concluded that the polymer improved the UCS values of the pavement materials.

Keywords- SoilTech polymer; improvement; pavement materials; unconfined compressive strength; stabilized

I. INTRODUCTION

Road construction projects require soils with sufficiently good engineering properties. However, geotechnical problems arise in construction works, when unsuitable materials with engineering properties are frequently encountered and hence it is necessary to improve their properties to make them acceptable for construction. The use of soil stabilization has shown a major increase in geotechnical engineering applications such as construction of buildings, roads, railways, embankments, stabilization of slopes and improvement of soft ground. Improvement of soil properties or soil stabilization is a collective term for any mechanical, chemical or biological method, or any combination of such methods which is employed to improve certain properties of a natural soil to make it adequately serve an intended engineering purpose over the service life of an engineering facility [1-3]. Improvement of certain desired properties such as bearing capacity, shear strength and permeability characteristics of soil can be undertaken by a variety of improvement techniques.

Conventional road construction depends on quarrying non-renewable resources; the process of stabilization has developed primary in areas where these resources are difficult to obtain. It is important to preserve these resources, the engineers and designers involved in all forms of construction and specifically in road construction to give consideration to the preservation of these valuable non-renewable resources for future generations. Two major challenges facing road authorities are the need to rehabilitate existing pavements composed of marginal materials being subjected to higher loads than originally anticipated, and the increasing shortage of quality quarried materials available for new construction. One option being considered that can be considered is the use of the marginal materials which are upgraded to acceptable quality through the use of in-situ stabilization. One of the major benefits of the method is that it enables the road pavement to be strengthened without the need to import expensive material. Other benefits include a short construction period, significantly reduced road closures, user's delays and improvements relating to safety. These advantages contribute to significantly lower unit costs for road rehabilitation, in comparison with other rehabilitation methods [4].

The reconstruction of failed roadways and highways has become a priority of public works agencies. Scarifying or milling and resurfacing using overlays are the techniques most often used to rehabilitate failed pavements. However, these techniques are not always the most cost-effective and have not proven successful in preventing the recurrence of pavement failures. Full-depth reclamation (FDR) is more suitable alternative for addressing recurring problems caused by marginal pavement materials. FDR is a method of rehabilitating deteriorated roadways in America [5, 6]. In the FDR process, the asphalt layer and some of the native granular base material are recycled to create a new base material [5, 6, 7]. Cement stabilization is often used in conjunction with FDR when the base material does not exhibit adequate strength or durability [7]. The use of FDR offers specific advantages over the use of other asphalt pavement rehabilitation techniques.

Lime, cement and fly are the conventional soil stabilizing agents recognized as conventional soil stabilizing agents but there are few research works in the field of non-traditional stabilization additives. Several researchers [8–11] have

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discussed aqueous polymer applications while others [12 – 15] have provided useful data on polymer-soil interactions that determine the effectiveness of polymer solution in various applications. This study present laboratory evaluation of recycled pavement materials i.e. sub base and base stabilized with SoilTech MK lll Nano polymer.

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II. MATERIAL AND METHODS

A. Materials

The soil used for this study was obtained from Jabulani Selepe Road, Bethal, Mpumalanga Province, South Africa. Sampling was done in line with TMH 5 specifications. Samples were taken to cover the study area. Test holes of 1m by 2m to a depth of 1m were opened to check for depth and variability in the layers, three layers were found and sampled. Samples for the base and sub-base course were collected from various locations from the site, pulverized and then air-dried. Tests were conducted to determine mechanical properties, soil classification, optimum moisture content, maximum dry density, compaction and California bearing ratio (CBR) in accordance with TMH 1 (Test Methods of Highways), of Committee on Land Transportation Official (COLTO) [16] specification. The results of tests for sub-base and base material are presented in Table I; the sub-base and base materials according to COLTO (Table 3402/1) specification can be classified as G 5 and G 6 material respectively. According to specification, material having plasticity index (PI) greater than 6, has to be stabilized to reduce the PI value. SoilTech MK III a Nano polymers stabilizer was used for both the sub-base and base material. The product is a mixture of water based copolymers and bitumen emulsion and its properties are presented in Table II. It is an environmentally and green product, reduces construction time substantially and its good strength gain it had with the material at a small quantity when compared with cement or lime.

B. Methodology

Sub-base and base materials were mixed with 0, 0.5, 0.8 and 1.0% SoilTech Mk lll (dry weight of the soil) prepared at optimum moisture content and maximum dry density. Unconfined compression tests were conducted on the sub-base and the base specimens following ASTM D5102. Test specimens were prepared by adding the SoilTech Mk lll polymer to the amount of water required, subsequently spread on the soil for mixing. Standard proctor compaction effort was applied, the specimens were extruded and air cured for 14 days according to COLTO specification. The material was not covered with plastic like normal UCS test because the bond between soil and SoilTech was mechanical not chemical [17]. Unconfined compressive strength (UCS) tests were conducted in order to access the improvement in strength.

Table I Property of the Pavement Materials

	Sub-base	Base
Liquid limit	22.0	23.0
Plasticity index	15.0	10.0
Linear shrinkage	3.7	4.0
Gravel (%)	49.0	52.0
Sand (%)	24.0	40.0
Silt & clay (%)	27.0	8.0
Classification	G 5	G 6
OMC	7.04 %	5.30 %
MDD	2376 kg/m^3	2266 kg/m^3
CBR (%) @ 95 % mod. AASHTO	52.0	34.0

Table II SoilTech Mk lll Polymer Characteristics [17] (IPPL, 2013).

Properties	Specification
Appearance	Dark brown
Odour	Slight
pH	8.0 – 9.0
Density	1.05 g/cm^3 at 23^0 C
Boiling point	100^0 C
Specific gravity	>1.0
Vapour pressure	As per water
Water solubility	Fully miscible
Environment	Environmental friendly

III. RESULTS AND DISCUSSION

Figures 1 and 2 show the compaction curves for sub-base and base material. Both materials were of dolerite type. The optimum moisture content, maximum dry density and CBR are 7.04%, 5.3%; 2376 kg/m^3, 2266 kg/m^3; and 52%, 34% respectively. The variations of unconfined strength against percentage of SoilTech Mk lll polymer for both the sub-base and base mixes are presented in Table III and figure 3. It can be seen that the polymer has an influence on the UCS. The improvement in the UCS is due to the mechanical compaction of the specimens. Typically, the polymer chain orientations are random and give the plastic an amorphous structure. The amorphous plastic has a good impact strength and toughness, but do not mix with water however, with other polymer additives, the SoilTech polymer uses water as a transport means to lubricate the sand particles at molecular level. Under mechanical compaction, the chains of SoilTech polymers are interlocked. The more the compaction the stronger these bonds become and the stronger the soil stabilization become. As the water between the soils particles evaporate, a film layer forms to prevent water ingress. Initially for both base and sub-base specimen with 0.5% of SoilTech polymer, there was an 86.2% and 76.6% increase in UCS value; further addition of 0.8% of the polymer induces the stiffness and result in 100% and 93.1% increase respectively. The results of UCS on recycled sub-base and base materials stabilized with 0.5% SoilTech Mk lll polymer met the specification.

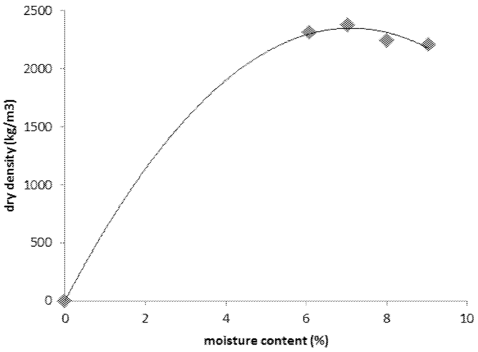

FIGURE 1. OMC & MDD for Sub-base material

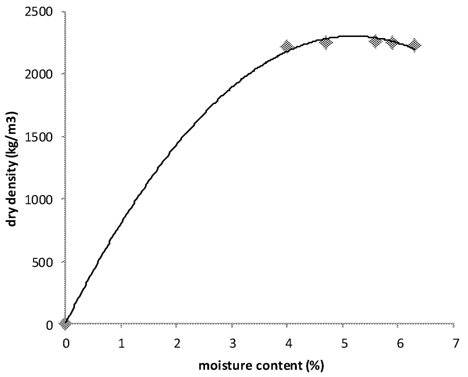

FIGURE 2. OMC & MDD for Base material

Table III Average UCS of SoilTech Mk lll polymer stabilized Pavement Materials

Soiltech (%)	0	0.5	0.8	1.0
$UCS_{sub-base}$ (MPa)	2.89	5.12	5.62	6.25
% increase	0	76.6	93.1	113.8
UCS_{base} (MPa)	2.75	5.12	5.50	6.00
% increase	0	86.2	100	118.2

IV. CONCLUSION

In the present study, sub-base and base material from rehabilitated road were evaluated in terms; Atterberg limit, California bearing ratio, Unconfined compressive strength and compaction. The sub-base and base materials were classified as G5 and G6 respectively according to COLTO specification and needs to be stabilized to C3 to meet structural design. SoilTech Mk lll Nano polymer was used as a stabilizing agent at the rate of 0, 0.5, 0.8 and 1.0 % dry weight at optimum moisture content and maximum dry density. The product is a mixture of water based copolymers and bitumen emulsion. The result showed that the addition of SoilTech Mk lll increases the unconfined compressive strength of the mixes and the 0.5% dry weight met the requirement for design.

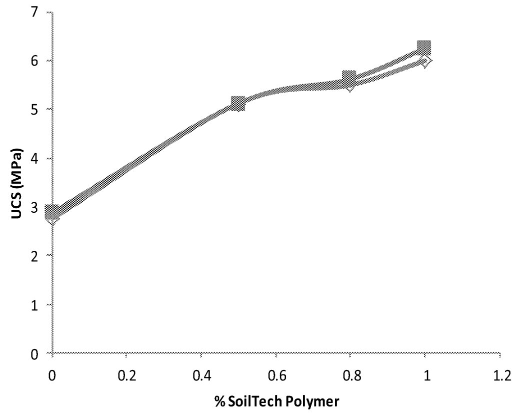

FIGURE 3.UCS of SoilTech Mk III Nano Polymer Stabilized Pavement material

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