ASSESSMENT OF THE EFFECTS OF GEOSYNTHETICS ON STRENGTH PROPERTIES OF ROAD PAVEMENT LAYERS

Juma Sospeter
Civil and Building Engineering Department, Dar es Salaam Institute of Technology (DIT), Dar es Salaam, Tanzania

sosie.jumahamka@gmail.com

ABSTRACT

A non-woven geotextile sample was used as a common specie of Geosynthetics together with soil materials borrowed from two different pit sources of Kambodia, Bunju in Dar es Salam and Lumecha, Ifakara Morogoro region. Further, experimental tests were done in Central Materials Laboratory of Tanzania (CML) to assess effects of their applications in roads construction technology and viable strength properties that would serve the pavements. The research team has simulated this in two sets of lab tests to identify the difference in strength property of product materials during its construction. One of the set of tests involved only plain soil samples that was termed as control test and another set of tests was termed as experimental test as it conformed to the virgin soil samples impregnated with non-woven geotextile specimen prepared in a round form.

The research objective is to assess the effects of geosynthetic on strength properties of road pavement layers, specifically the soil samples and geotextile specimens were collected for conduction of lab tests in order to characterize soil properties and evaluate geosynthetics properties.

Since roads are subjected to distresses of traffic loading, it has been observed that the sets of experimental tests have shown great performance compared to the sets of control tests. However the strength property values were increasing as the number of non-woven geotextile specimens increased in the sampled sets, also other related indicative parameters of the strength of pavement such as bearing capacity, ultimate stresses, unconfined strained area, strains, and compressibility were part of recorded results with remarkable improved property values.

These Geo-findings have viable implications in roads construction and that Geosynthetics are significantly important in both unpaved and paved roads as well as other related infrastructures.

Furthermore, our country's industrialization drive and building the middle income economy will be supported by sound construction of reliable highways.

Keywords: *Geosynthetics, impregnated soil, non-woven geotextile, ultimate stress, unconfined strained area, polyethylene, virgin soil.*

1.0 INTRODUCTION

Low volume roads especially in rural, unpaved and paved roads in urban are important transportation medium that influence economic growth of a particular place. In the history of many societies engaging in agriculture activities all over the world, land transportation through unpaved roads normally served as auxiliary access to highways for transporting raw materials from farms between neighbor villages and linking them to market places.
The roads have been playing very important roles by influencing rural economy, industrial resources and transportation of agricultural goods, large scale products from the estates, plantations and remote areas of productions to the marketing centres especially in urban areas as platform of selling, stocking and processing industries.

The subgrades as the foundation of these road pavements, when it is weak with low bearing capacity to carry designed traffic loads, the base course materials intrude the subgrade and intermixing of materials occur between the layers.

This alteration of ultimate strength properties of road layers under action of applied traffic loading with excessive stresses cause pre-mature road failures to emerge on finished surface of road pavement including cracks, rutting, potholes, shoving and upheaval. Normally, the results of these early deformations when reported for post rectifications, are likely to inflate the project budgets also cause discomfort to traffic movements, bypass roads to be built, unplanned high maintenances costs, affect time for serviceability before designed period of pavement and defect period liability.

However, the results of this research would provide useful preliminary conclusion and guidance for interim use in practice as an improvement over the normal techniques or accustomed in construction practices. It was believed also that this assessment would serve as a logical precursor for more detailed research that would include physical geotechnical modeling as well as instrumented observation of actual roadwork. Thus it's hoped that the results of this research will serve as both catalyst and resource for improving the current state of construction practices as well as the future research.

The main objective of this research is to assess the effects of geosynthetic on strength properties of road pavement layers. Specifically soil samples and geotextile specimens is to be collected for laboratory tests in order to characterize soil properties and evaluating geosynthetics properties.

In general, there is need to address researches and resurvey on the associated causative of problems and a careful look of ways of how to reach to a reliable engineering solution for improvements of constructed pavements that serve in less than expected design life time.

1.1 Scope of the research

This research is practical experiment and not limited to theoretical investigation of one relative effect and hypothetical problem that included what are the key components of typical Geosynthetics' strength effects on road works with respect to the objectives of the research. Because of restriction caused by available resources, the research is not intended to be comprehensive design guideline for all road works.

1.2 General background

Geosynthetics has been defined by American Society for Testing and Materials (ASTM), Committee D3, the scientific world journal Volume (2014), Review article ID 76421 as "planar product manufactured from polymeric material that are specifically fabricated to be used in geotechnical, geo environmental, hydraulic, and transportation engineering related materials as an integral part of a man-made projects, structures, or systems. These synthetic polymers are such that polypropylene, polyester, polyethylene, polyamides, polyvinyl chloride".

According to Korner (1999), deterioration of paved and unpaved roads is much faster than replacement of new road when aggregates intrude the subgrades. When the subgrade consists of soft clays, silts and organic soils, this type of subgrade is often unable to adequately support traffic loads and must be improved. Excavation and replacement of unsuitable materials is costly and time consuming. Geosynthetics have been found to be cost effective alternative to improve poor sub-soils in adverse locations especially in situations where the soil is with low bearing capacity and places where the desired soil types which are demanded in geotechnical engineering projects such as highway pavements, Parking lots, ports and others related infrastructures reported in Geosynthetics Materials Association GMA, (2002) (pp. 12) need improvement. An increment of materials and construction costs, make it important to explore

alternative construction methods with longer service life but at the same time cost efficient, by Perkin, et. al., (2009).

The practice of using Geosynthetics for subgrade stabilization saves money, time, and resources. In areas where excavation and replacement of inferior sub soils is not cost effective, soil stabilization using Geosynthetics may provide a working platform so that the base course gravel layer can be properly constructed and overall rutting reduced by 30%. Historically, geotextiles were first used in these applications; however, geogrids have also been commonly used in more recent years reported by Perkins and Cuelho (2014).

Soil confinement creates beneficial effects for stress-strain response to Geosynthetic materials particularly for non-woven geotextiles in which its stiffness and therefore modulus are significantly enhanced as a results of confinement. Thus, the use of unconfined stress-strain properties in designs with non-woven geotextiles appears to be overly conservative. Increases of 50 to 40 percent of modulus have been measured, this is stated in report no. FHWA-RD-97-143 (1997).

Geosynthetics are used in all fields of civil engineering to increase the safety and life span of structures in addition to satisfying necessary functions including separation, reinforcement, filtration, drainage, sealing and acting as a liquid barrier, but in the asphalt layer if properly installed they mainly function as fluid barrier, and reinforcement. All these key functions have been applied in paved and unpaved roads as well as in parking areas by increasing the load-carrying capacity of the system and maintaining separation between the soft Subgrade and sub base materials, stated in NAUE Geosynthetics (2013). According to Hatterji et al., (2013), Geosynthetics provides better performance and longevity of infrastructure projects such as increasing the life of roads by 10-15 years,

The roles of Geosynthetics as integral planar products for engineering works are significantly important in both unpaved and paved road pavements as well as in other related infrastructures. Therefore, their applications is recommended as a viable technique to improve the performance of infrastructures especially in places where there are scarcity of construction materials, weak subgrades and dampness regions all over the country.

2.0 MATERIALS AND METHODOLOGY

2.1 Materials

Soil materials were borrowed from two different pits of Lumecha, Ifakara Morogoro and Kambodia, Bunju in Dar es Salam region. Whereby geotextile fabric was obtained from Nabaki Afrika the most leading supplier of Geosynthetics materials in Tanzania.

2.2 Methodology

Two elementary sets of laboratory tests were objectively designed and analysed, that is, a set of control test that involved only virgin soil compacted in layers ***"without geotextile"*** and another set of test ***"with geotextile"*** impregnated beneath each subgrade layer.

2.2.1 Test without Geotextile specimen

In this test, virgin soil was prepared with no embedded geotextile specimens. Then, all plain samples were crushed and penetrated to obtain unconfined compressive strength and California Bearing Ratio (CBR) values as a control test (M_1).

2.2.2 Test with Geotextile specimen

A circular cut of geotextile fabric about 150mm diameter for trial specimen and 120mm diameter were cut and impregnated beneath the soil layers, forming separation between the two compacted layers. This set of laboratory test with application of Geosynthetics layers was termed as experimental test (M_2).



Figure 1. Samples preparation in the lab with CBR moulds and rammer of 4.5kg.



Figure 2. Show two soil samples prepared before crushing on Automatic UCS Machine

3.0 DATA COLLECTION

In order to accomplish objectives of this research, research team used collected materials to prepare and conduct indicator tests according to guiding methodology of CML laboratory that located in Dar es Salaam Tanzania. Further soil tests were conducted without alteration of guiding standards and specifications as shown in Figures 1 and 2. These tests included Proctor tests, Sieve analysis, Atterberg's limit tests, unconfined compressive strength (UCS) and California Bearing Ratio, CBR in which their results were carefully recorded accordingly to specific soils labels [i.e. Soil sample I–SS_1 and Soil sample II–SS_2 and Geotextile specimens], (shown in Tables 1, 2, 3, 4 and 5).

Table 1: Summary results of M_1-SS_1, M_2-SS_2 Atterberg's A_1, A_2, Compaction P_1, P_2

	(PROCTOR) - COMPACTION TESTS					ATTERBAG LIMIT TESTS				
S_{soil}	Wet Density (Bulk) kg/m³	Dry Density (MDD) kg/m³	OMC (%)	Water added cm³	Field Degree of Compaction (%)	LL (%)	PL (%)	PI (%)	SL (%)	S_{soil}
C-SS_1	2235	2093	6.8	357	98-102	35	15	20	15	A-SS_1
C-SS_2	1877	1671	11.4	611.3		56.2	27.2	29	21	A-SS_2

Table 2: Summary results of UCS, CBR, Ultimate Stress, Strain and Unconfined Strained Area (A_ε),

		M_1-SS_1 & M_2-SS_1						M_1-SS_2 & M_2-SS_2					
Geotextile		UCS in kPa		Strain	Stress	A_ε	CBR	UCS in kPa		Strain	Stress	A_ε	CBR
nr.	%	UCS	Av. UCS	(%)	MPa	x10^{-2} m^2	%	UCS	Av. UCS	(%)	MPa	x10^{-2} m^2	%
0’		818					3	324					3
0	0	781	800	7.6	0.9	2.03	6	296	310	11.7	0.4	1.95	5
1’		1000						560					
1	0.04	998	999	9.9	1.1	2.02	12	348	454	11.1	0.5	1.99	8
2’		1078						684					
2	0.08	1027	1053	9.5	1.2	2.01	8	662	673	10.8	0.8	1.98	10
3’		1167						1301					
3	0.13	1147	1157	9.4	1.3	1.93	41	1212	1257	7.2	1.4	1.98	15
Trial 4	0.28	1403	1403	5.5	1.5	1.91						1.91	

Table 3: Summary results of M_1-SS_1, M_2-SS_2 for Sieve Analysis

		S – SS1 (%)	S – SS2 (%)
Soil Constituents	Gravel (G)	30	7
	Sand (S)	32	34
	Silt (M)	38	59
Soil type		Sandy SILT	Sandy SILT
Soil group symbol		MS	MS
Soil Texture/Color		Reddish - brown soil	Reddish - brown soil
Grading Modulus		1.38	0.74
Grading		Poor graded soil	Poor graded soil

4.0 TECHNICAL ANALYSIS OF DATA.

This analysis has adopted standards, specifications and guides especially Unified Soil Classification System (USCS), American Society for Testing and Materials (ASTM), Federal Highway Administration (FHWA), American Association of State Highway and Transportation Officials (AASHTO), Southern Africa Transport and Communications Commission (SATCC), Tanzania Road Works Standards Specification (MoW), Pavement and Material design manual and Central Material Laboratory Testing Specifications Manuals (CML).

4.1 Selection of synthetics-specimen

The specimen were cut in a circular form of 120mm diameter true specimens and 150mm diameter for trial specimens, the average weights were S^a = 2.3gm, S^1 = 3.6gm respectively;

Specimen, S^a

Cross section area of cut S^a = πR^2

= 3.14 x 0.06 x 0.06

= 0.0113 m^2 ……..…….……..…..… (A-S^a)

Weight of geotextile per squire meter = $\frac{\text{Weight of Specimen}}{\text{Cross section area}}$ (g/m^2)

$= \frac{2.3 \text{ g}}{1.13 \times 10^{-2} \text{ m}^2}$

= 204 g/m^2 ……..…….…….

Table 4: Summary results of Dimensional length of failure (L_f), Densities, Geo weight (%), Strain, OPC (%), UCS (kPa), Stress (MPa) and CBR (%) for soil sample M_1-SS_1 and M_2–SS_1.

TANZANIA NATIONAL ROADS AGENCY — SUMMARY SHEET — Unconfined Compressive Strength — CML Central Materials Laboratory

Project:	ASSESMENT OF THE EFFECTS OF GEOSYNTHETICS IN STRENGTH PROPERTIES OF ROAD LAYERS				
Project type	Research	Sample No.	T/Pit	Date	Approved
Responsible Technician		(I)	Kambodia	17, Jan, 2017	
SOSPETER Jumna					
TEST METHOD		CML TEST 1.21, ref. TMH1-1986-A14			
Geosynthetics type:		Geotextile Non – woven	Class:		II – A

COMPACTION				SPECIMEN DATA			
						Compressive Strength	
Spec. Length at failure L_1	Geotextile Layers (Nos.)	Max. Dry Density Kg/m³	Optimum Moisture Content (%)	Dry Density kg/m³	Moisture Content (%)	Individual Specimen (kPa)	Av. UCS (kPa)
118.00	0'	2093	6.8	2013	8.0	818	
116.80	0			2008	16.4	781	800
114.00	1'			2128	6.9	1000	
114.80	1			2114	7.1	998	999
112.00	2'			2100	17.9	1078	
118.00	2			2108	18.1	1027	1053
115.20	3'			2119	7.0	1167	
115.00	3			2109	7.1	1147	1157
120.00	4 Trial			2014	21.7	1403	1403

SUMMARY						
	Test type	M_1-SS_1	M_2-SS_1			
	Geo (Sr.)	0	1	2	3	4
	Geo (%)	0%	0.04%	0.08%	0.13%	0.28%
	UCS (kPa)	800	999	1053	1257	1403
	Strain (%)	7.09 | 8.03	10.24 | 9.61	11.81 | 7.09	9.29 | 9.45	5.5
		7.6	9.9	9.5	9.4	5.5
	Stress (MPa)	886 | 846	1106 | 1103	1186 | 1129	1283 | 1261	1488
		0.9	1.1	1.2	1.3	1.5

Table 5: Summary results of Dimensional length of failure (L_f), Densities, Geo weight (%), Strain, OPC (%), UCS (kPa), Stress (MPa) and CBR (%) for soil sample M_1-SS_2 and M_2-SS_2

TANZANIA NATIONAL ROADS AGENCY — S Y SHEET — Unconfined Compressive Strength — CML Central Materials Laboratory

Project:	ASSESMENT OF THE EFFECTS OF GEOSYNTHETICS IN STRENGTH PROPERTIES OF ROAD LAYERS				
Project type	Research	Sample No.	T/Pit	Date	Approved
Responsible Technician		(II)	Lumecha	17, Jan, 2017	
SOSPETER Jama					
TEST METHOD		CML TEST 1.21, ref. TMH1-1986-A14			
Geosynthetics type:		Geotextile Non – woven	Class:		II – A

COMPACTION				SPECIMEN DATA			
						Compressive Strength	
Specimen Length at failure L_1	Geotextile Layers (Nos.)	Max. Dry Density Kg/m³	Opt. Moisture Content (%)	Dry Density kg/m³	Moisture Content (%)	Individual Specimen (kPa)	Av. UCS (kPa)
113.00	0'	1671	11.4	1597	20.1	324	
111.40	0			1621	21.2	296	310
113.40	1'			1471	21.6	560	
112.30	1			1587	21.4	348	454
115.00	2'			1479	21.6	684	
111.60	2			1593	20.5	662	673
120.30	3'			1669	21.2	1301	
115.50	3			1558	20.9	1212	1257

SUMMARY						
	Test type	M_1-SS_2	M_2-SS_2			
	Geo (Sr.)	0	1	2	3	
	Geo (%)	0%	0.04%	0.08%	0.13%	
	UCS(kPa)	310	454	673	1257	
	Strain (%)	11.1 | 12.3	10.70 | 11.58	9.45 | 12.1	5.28 | 9.06	
		11.7	11.1	10.8	7.2	
	Stress (MPa)	0.37 | 0.33	0.63 | 0.39	0.76 | 0.74	1.4 | 1.3	
		0.4	0.5	0.8	1.4	

(W/m^2)

Therefore:

Weight of geotextile specimen was 204g/m², which normally is classified as medium weight non-woven geotextile with an area ranging 203g/m² - 271g/m² stated in American Standard and Testing Materials ASTM D5261.

The same specimen is classified as class II - A by Federal Highway Administration (FHWA, section 714) and in AASHTO M 288 – 06

4.2 The density of the Geotextile specimen

This specimen has a thickness of 1.5mm as per manufacturers guides, therefore its density can be calculated as follow;

$$\text{Density} = \frac{\text{Mass of geotextile}}{[\text{Area of specimen x thickness of material in 1 m}^2]\ \text{m}^3}\ \text{g}$$

$$= 0.204\ \text{Kg/ 1m}^2 \times 1.5 \times 10\text{-}3\text{m}$$

$$= 136\ \text{Kg/m}^3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(Density)}$$

4.3 Ultimate stress

Table 6: Analytical calculations for ultimate stress of soil sample M_1-SS_1, M_2-SS_1, M_1-SS_2 and M_2-SS_2

Soil sample (I) - SS_1:	**Soil sample (II) - SS_2:**
Ultimate Stress = $\frac{\text{Compressive loading}}{\text{Av. cross section area}}$ $\partial_c = \frac{P}{A}$ But, **1 kN/m² = 0.001 MPa** M_1-Stress$_1$ at 0 = $\frac{15.59\ \text{kN}}{0.018\ \text{m}^2}$ = 866.1 kN/ m² x 10-3 = 0.9 MPa M_2-Stress$_1$ at 1 = $\frac{19.88\ \text{kN}}{0.018\text{m}^2}$ = 1104.44 kN/ m² x 10-3 = 1.1 MPa M_2-Stress$_1$ at 2 = $\frac{20.83\ \text{kN}}{0.018\ \text{m}^2}$ = 1157.2 kN/ m² x 10-3 = 1.2 MPa M_2-Stress$_1$ at 3 = $\frac{22.9\ \text{kN}}{0.018\ \text{m}^2}$ = 1272.2 kN/ m² x 10-3 = 1.3 MPa M_2-Stress$_1$ at 3 = $\frac{26.78\ \text{kN}}{0.018\ \text{m}^2}$ = 1487.78 kN/ m² x 10-3 = 1.5 MPa	Ultimate Stress = $\frac{\text{Compressive loading}}{\text{Av. cross section area}}$ $\partial_c = \frac{P}{A}$ But, **1 kN/m² = 0.001 MPa** M_1-Stress$_2$ at 0 = $\frac{6.28\ \text{kN}}{0.018\ \text{m}^2}$ = 348.89 kN/ m² x 10-3 = 0.4 MPa M_2-Stress$_2$ at 1 = $\frac{9.17\ \text{kN}}{0.018\text{m2}}$ = 509.44 kN/ m² x 10-3 = 0.5 MPa M_2-Stress$_2$ at 2 = $\frac{13.53\ \text{kN}}{0.018\ \text{m}^2}$ = 751.67 kN/ m² x 10-3 = 0.8 MPa M_2-Stress$_2$ at 3 = $\frac{24.26\ \text{kN}}{0.018\ \text{m}^2}$ = 1347.78 kN/ m² x 10-3 = 1.4 MPa

4.4 Strain

Table 7: Analytical calculations for Strains of soil sample M_1-SS_1, M_2-SS_1, M_1-SS_2 and M_2-SS_2

Soil sample (I) - SS_1:	**Soil sample (II) - SS_2:**
Strain = Change in length / Original length $\varepsilon = \frac{\Delta L}{L_0}$ $\varepsilon = \frac{L_0 - L_1}{L_0}$ **Note:** Original length of specimens, L_0 = 127mm before crushing on Automatic UCS Test Machine. M_1-$Strain_1$ at 0 = (127-117.4) mm x 100% / 127 = 7.6% M_2-$Strain_1$ at 1 = (127-114.4) mm x 100% / 127mm = 9.9% M_2-$Strain_1$ at 2 = (127-115) mm x 100% / 127mm = 9.5% M_2-$Strain_1$ at 3 = (127-117.4) mm x 100% / 127mm = 9.4% M_2-$Strain_1$ at 4 = (127-120) mm x 100% / 127mm = 5.5%	Strain = Change in length / Original length $\varepsilon = \frac{\Delta L}{L_0}$ $\varepsilon = \frac{L_0 - L_1}{L_0}$ **Note:** Original length of specimens, L_0 = 127mm before crushing on Automatic UCS Test Machine. M_1-$Strain_2$ at 0 = (127-112.2) mm x 100% / 127mm = 11.7% M_2-$Strain_2$ at 1 = (127-112.9) mm x 100% / 127mm = 11.1% M_2-$Strain_2$ at 2 = (127-113.3) mm x 100% / 127mm = 10.8% M_2-$Strain_2$ at 3 = (127-117.9) mm x 100% / 127mm = 7.2%

4.5 Strained cross sectional area (Aε)

Table 8: Show analytical calculations for Cross section area and Strained cross sectional area of soil sample M_1-SS_1, M_2-SS_1, M_1-SS_2 and M_2-SS_2

Soil Sample (I) - SS_1:	**Soil Sample (II) - SS_2**
Compressive strength, UCS = Ultimate stress x Deviation value = Applied Loading / Cross section Area x Calibration value = $\frac{F}{A}$ x 0.9994kN => $\frac{(F/A \times 0.9994)}{1000}$	

Original area of specimen SS_1: Cross section Area, $A\upsilon = \pi R^2$ $= 3.14 \times 0.075 \times 0.075$ $= 0.0176\ m^2$ **Area of strained soil specimen – SS_1** $A\varepsilon = \frac{A\upsilon.}{[1 - \varepsilon]}$ $A\varepsilon$ at 0 $= \frac{0.018}{[1 - 0.076]}\ m^2$ $= 0.0195\ m^2$ $A\varepsilon$ at 1 $= \frac{0.018}{[1 - 0.099]}\ m^2$ $= 0.0199\ m^2$ $A\varepsilon$ at 2 $= \frac{0.018}{[1 - 0.095]}\ m^2$ $= 0.0198\ m^2$ $A\varepsilon$ at 3 $= \frac{0.018}{[1 - 0.094]}\ m^2$ $= 0.0198\ m^2$ $A\varepsilon$ at 4 Trial $= \frac{0.018}{[1 - 0.055]}\ m^2$ $= 0.0191\ m^2$	: **Original area of specimen SS_2:** Cross section Area, $A\upsilon = \pi R^2$ $= 3.14 \times 0.075 \times 0.075$ $= 0.0176\ m^2$ **Area of strained soil specimen – SS_2** $A\varepsilon = \frac{A\upsilon.}{[1 - \varepsilon]}$ $A\varepsilon$ at 0 $= \frac{0.018}{[1 - 0.117]}\ m^2$ $= 0.0203\ m^2$ $A\varepsilon$ at 1 $= \frac{0.018}{[1 - 0.111]}\ m^2$ $= 0.0202\ m^2$ $A\varepsilon$ at 2 $= \frac{0.018}{[1 - 0.108]}\ m^2$ $= 0.0201\ m^2$ $A\varepsilon$ at 3 $= \frac{0.018}{[1 - 0.072]}\ m^2$ $= 0.0193\ m^2$

4.6 Unconfined Compressive Stress (UCS)

Table 9: Show analytical calculations for unconfined compressive strength of soil sample M_1-SS_1, M_2-SS_1, M_1-SS_2 and M_2-SS_2

Soil Sample (I) - SS_1:	Soil Sample (II) - SS_2
CONTROL TEST I (UCS SS_1): M_1-UCS_1 at 0' $= \frac{15.95\ kN}{0.0195\ m^2}$ $= 817.95\ kN/m^2$ $= 818\ kPa$ M_1-UCS_1 at 0 $= \frac{15.22\ kN}{0.0195\ m^2}$ $= 780.51\ kN/m2$ $= 781\ kPa$	**CONTROL TEST II (UCS SS_2):** M_1-UCS_1 at 0' $= \frac{6.566\ kN}{0.0203\ m^2}$ $= 323.45\ kN/m^2$ $= 324\ kPa$ M_1-UCS_1 at 0 $= \frac{5.996\ kN}{0.0203\ m^2}$ $= 295.36\ kN/m^2$ $= 296\ kPa$
EXPERIMENTAL TEST (I) -UCS SS_1: M_1-UCS_1 at 1' $= \frac{19.9\ kN}{0.0199\ m^2}$ $= 1000\ kN/m^2$ M_1-UCS_1 at 1 $= \frac{19.86\ kN}{0.0199\ m^2}$ $= 997.99\ kN/m^2$ $= 998\ kPa$	**EXPERIMENTAL TEST (II) -UCS SS_1:** M_2-UCS_1 at 1' $= \frac{11.32\ kN}{0.0202\ m^2}$ $= 560.39\ kN/m^2$ $= 560\ kPa$ M1-UCS1 at 1 $= \frac{7.02\ kN}{0.0202\ m^2}$ $= 347.53\ kN/m^2$ $= 348\ kPa$

M1-UCS1 at 2 = 21.35 kN / 0.0198 m^2 = 1078.28 kN/ m^2 = 1078 kPa	M_1-UCS_1 at 2' = 13.75 kN / 0.0201 m^2 = 684.07 kN/ m^2 = 684 kPa
M_1-UCS_1 at 2 = 20.33 kN / 0.0198m2 = 1026.77 kN/ m^2 = 1027 kPa	M_1-UCS_1 at 2 = 13.31 kN / 0.0201 m^2 = 662.19 kN/ m^2 = 662 kPa
M_1-UCS_1 at 3 = 23.10 kN / 0.0198 m^2 = 1166.67 kN/ m^2 = 1167 kPa	M_1-UCS_1 at 3 = 25.11kN / 0.0193 m^2 = 1301.04 kN/ m^2 = 1301 kPa
M_1-UCS_1 at 3 = 22.70 kN / 0.0198 m^2 = 1146.46 kN/ m^2 = 1147 kPa	M_1-UCS_1 at 3 = 23.39 kN / 0.0193 m^2 = 1211.92 kN/ m^2 = 1212 kPa
M_1-UCS_1 at 4 (Trial) = 26.8 kN / 0.0191 m^2 = 1403.14 kN/ m^2 = 1403 kPa	

5.0: RESULTS AND DISCUSSION

Results of the experiment were observed, recorded, analyzed, and presented in graphical plots, in which a methodology referred in Figure 3 was adopted to measure dimensional alterations in thickness of road pavement layers into two (2) set of samples as stated in 2.2, sub item 2.2.1 and 2.2.2. Cuelho et al. (2014) State that, the base course tends to penetrate into the subgrade soil, in which its intrusion affects the strength of base course layer.

A separation layer of non-woven geotextiles was used to prevent adjacent soil layers, fill materials from directly intermixing and pressing out of the primary formed layer into the soft subgrade. Synthetic such as non-woven geotextiles that exhibit an elongation capacity are the materials of choice in most applications.

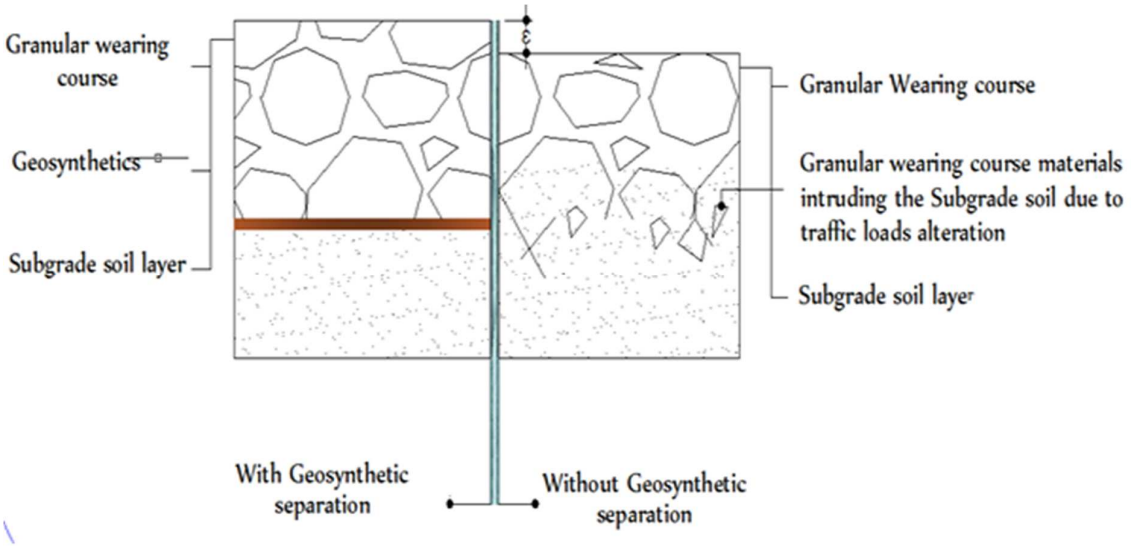


Figure 3. Show an exemplary road section with Geotextile layer and other without Geotextile

Application of Geosynthetics have clear positive effects on strength of the pavements and

durability to sustain the traffic impacts over all time of its application. In accordance to the experimental tests that were done in the CML, the results show that much improvement is notable. Sieve analysis and Atterberg's Limit test played important role of characterizing the soil properties.

5.1 Critical swelling effects

On consideration of critical conditions like rainfall season to soil sample, all CBR specimens were soaked into water tanks for four (4) days, then they were observed daily and gauge readings were recorded for swelling effects, the results showed that swelling values for control specimen were greater than those of the experimental specimen which contained Geotextile. This implied that, the vertical infiltration and water flow in specimens of experimental tests was much less compared to set of control tests.

5.2 Unconfined compressive strength, (UCS)

Results of unconfined compressive strength tests in Figures 4 and 5, show that as the number of Geotextile increased in the prepared soil specimens, UCS in kPa increased likewise.

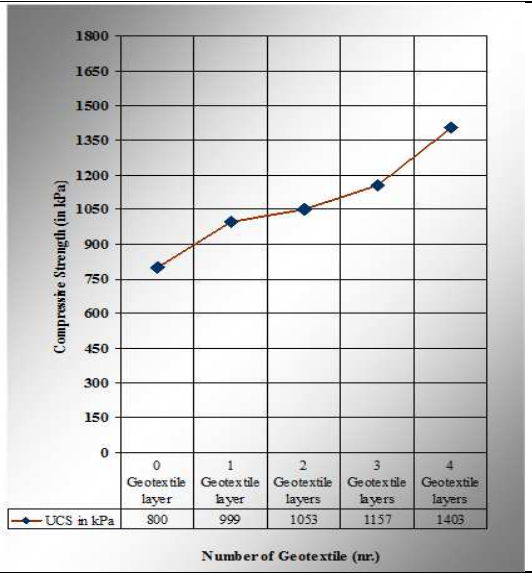


Figure 4. Plot of UCS_1 versus Number of Geotextile for soil sample SS_1

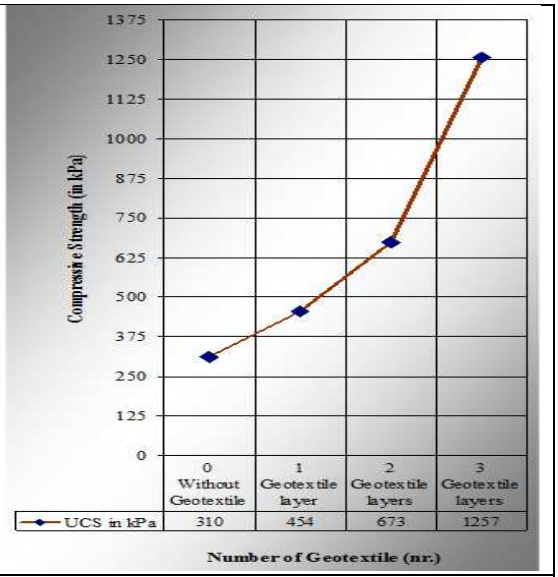


Figure 5. Plot of UCS_2 versus Number of Geotextile for soil sample SS_2

5.3 California Bearing Ratio, (CBR)

From Figures 6 and 7, the results have show that the CBR value increased with increase in number of Geotextile applied to the soil specimens. Also it observed and recorded that the swelling value of samples that were exposed and immersed into water soaking for four (4) days for all sets of control test specimens their swells was greater than those of specimens separated with Geotextile. This implies that, the vertical infiltration and water flow in the set of experimental test parameters was less compared to that of the control tests.

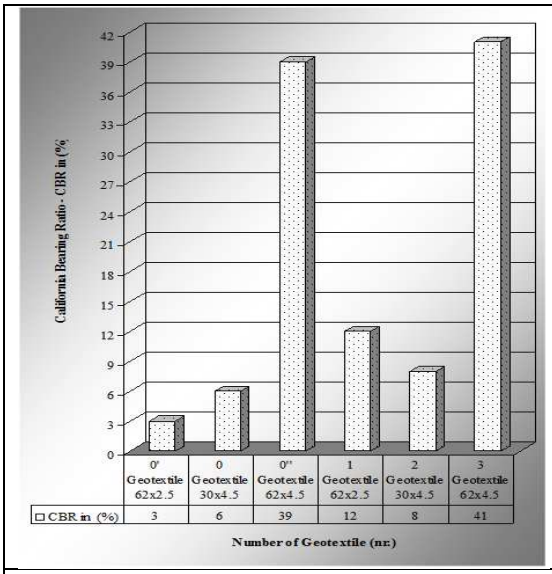


Figure 6. Plot of CBR_1 versus Number of Geotextile for soil sample SS_1

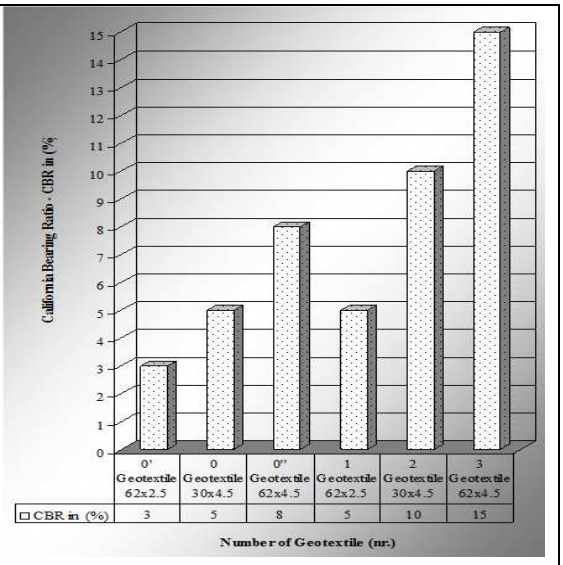


Figure 7. Plot of CBR_1 versus Number of Geotextile for soil sample SS_2

5.4 Ultimate Stresses effects

The ultimate stresses values for specimens with application of Geotextile increased in comparison to control tests specimen. Also, when the number of Geotextiles between separation of the layers was increased the ultimate stresses increased, (see Figures 8 and 9).

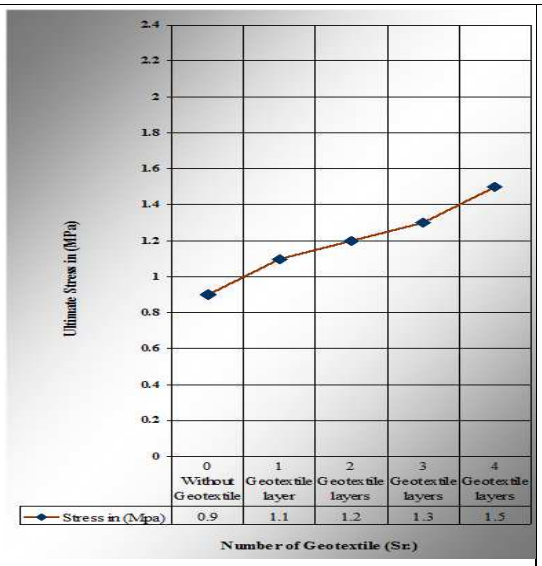


Figure 8. Plot of Unconfined Ultimate Stresses-strain versus Nr. of Geotextile of Soil SS_1

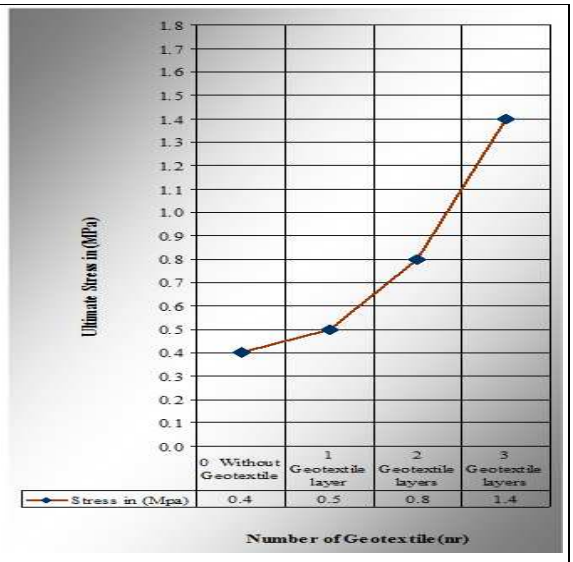


Figure 9. Plot of Unconfined Ultimate Stresses - strain versus Nr. of Geotextile of soil SS_2

5.5 Strained Cross sectional Area (Aε)

The effects of an increment of the number of Geotextile in soil specimens prepared in the laboratory, showed a trend of an increased value to original area of specimens pre-crushed on UCS test machine. while, in Figures 10 and 11, the area of strained specimens (Aε) was

decreasing under the condition that the maximum load applied during UCS test caused deformation and critical changes of the original dimensions of specimens due to failures.

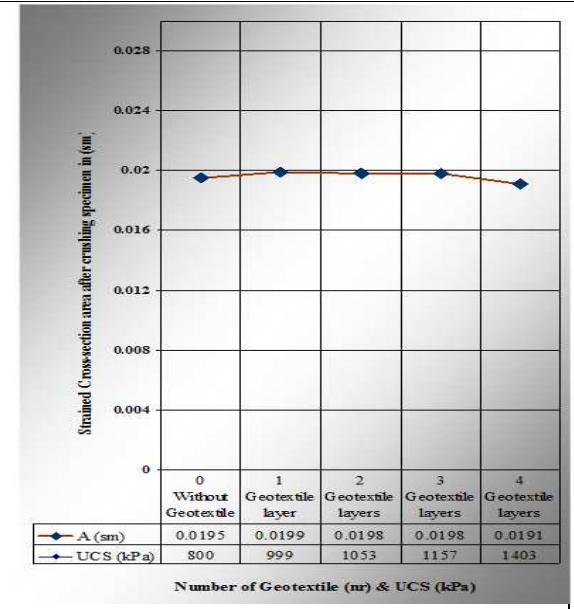


Figure 10. Plot of strained cross sectional area versus Nr. of geotextile of soil sample SS_1

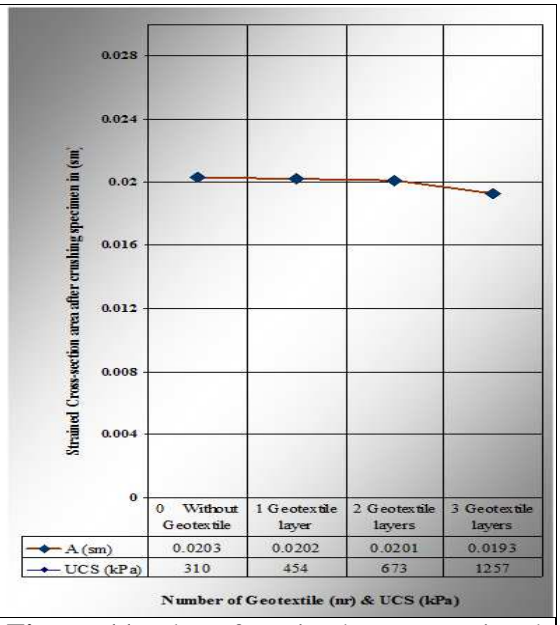


Figure 11. Plot of strained cross sectional area versus Nr. of geotextile of soil sample SS_2

These deformations are termed as collapse and bulging failures. The failures occurred as referred to Figure 12, 13(a), 13(b) and 13(c), which are described according to their mode of raptures. The soil specimens for control test bulged and collapsed when were subjected to maximum impact loading while experimental tests, bulged vertically from loading plate of UCS test machine.



Figure 12. CML Engineer, crushing prepared samples on UCS machine and recording the results



Figure 13(a). Control specimen initially was cracked



Figure 13(b). Control specimen finally was collapsed



Figure 13(c). Experimental specimen bulged without collapse

5.6 Percentage by Weight effects

It have shown in Figures 14 and 15, that an increase of Geo-percentage (%) in the specific separated layers tend to increase the values of unconfined compressive strength and Ultimate stresses of the soils.

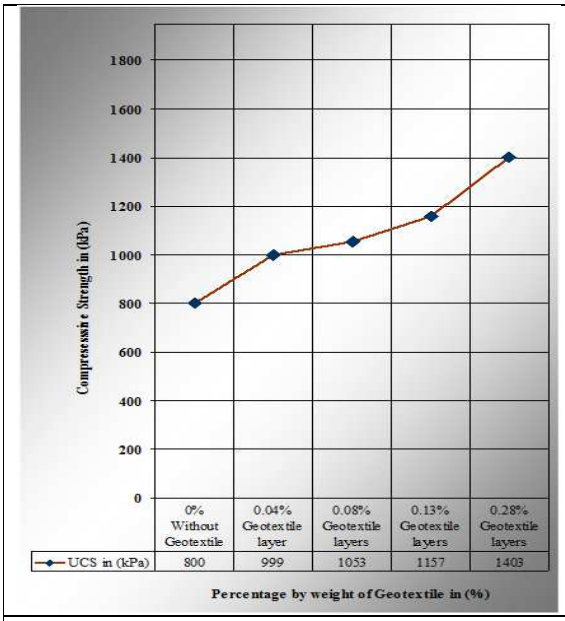


Figure 14. Plot of Compressive strength$_1$ versus % by weight of Geotextile sample SS_1

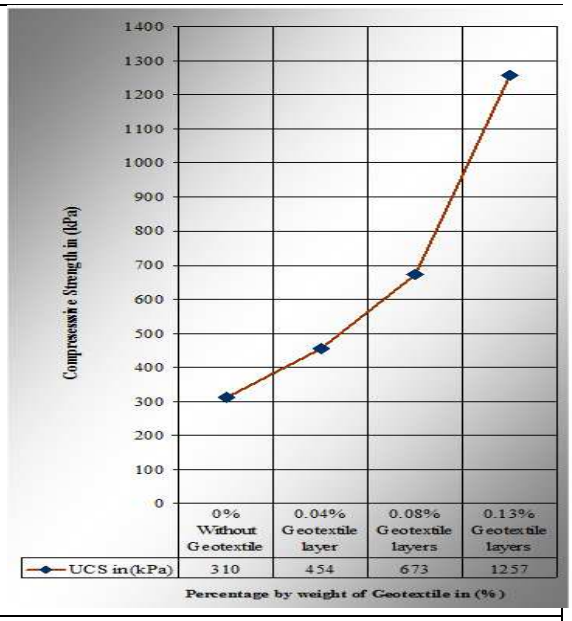


Figure 15. Plot of Compressive strength$_1$ versus % by weight of Geotextile sample SS_2

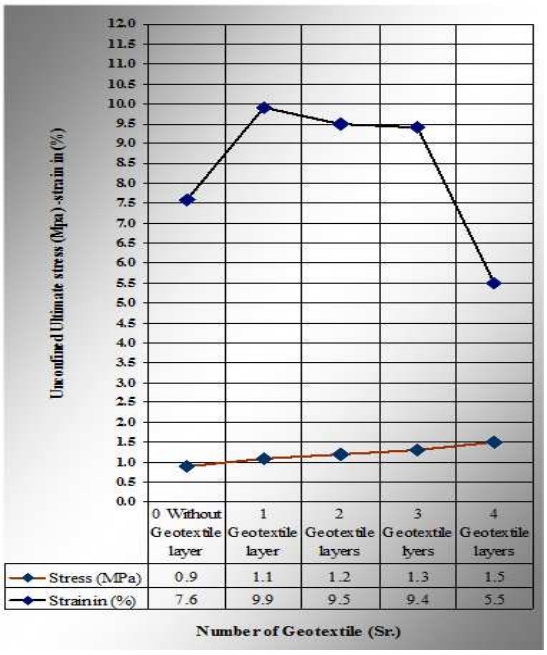


Figure 16. Plot of Unconfined Ultimate Stresses - strain versus Nr. Geotextile SS_1

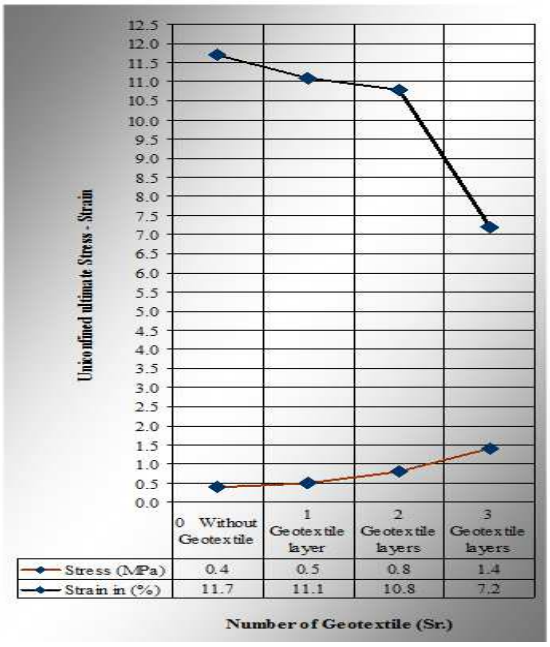


Figure 17. Plot of Unconfined Ultimate Stresses - strain versus Nr. Geotextile SS_2

5.7 Unconfined Ultimate Stress- strain

Figures 16 and 17, show that the ultimate stress of soil containing geotextile highrrbthan that of the control specimens also the ultimate stress of soil increased with the increase of geosynthetics layer. In addition, strains decreased as the number of geotextile incressed as the stresses increased.

6.0. GEO-FINDINGS OF THE RESEARCH

The performance of roads when Geosynthetics technology with variety of manufactured synthetic species is applied in the construction industry will improve, provided that the geotextiles are used not only as a partially applied technique as a filter material in damp regions, but also broadly be recommended for reinforcement, stabilization, drainage, and separation.

From technical analysis, graphical presentation, and further observations made on the lab tests the following were significant practical geo-findings of the assessment of the effects of soil impregnated with non-woven geotextiles;

(1) The ultimate stresses on the road pavement layers increases when the number of Geotextile layer (s) increases, and the strain decreases. In all cases, the initial cracks were initiated at the edge/corner of the square specimens.
(2) The unconfined compressive strength results shows that as the number of geotextile is increased in the soil specimen, the unconfined compressive strength increases.
(3) The California Bearing Ratio, CBR value increases with the increase in number of Geotextile applied in the soil specimen.
(4) The ultimate stress for specimen with Geotextile show higher values than those of control specimen.

(5) The swelling value of samples which were exposed and immersed in water by soaking for four (4) days, was greater for control test specimens compared to those of specimens separated with Geotextile. This implied that, the vertical infiltration and water flow in specimens separated with Geotextile was less compared to that control specimens.
(6) The ultimate stresses property of the soil was increasing with decrement of strain property.
(7) The increment for the number of Geotextile in the soil specimens prepared in the laboratory, shows an increase area of specimens pre-crushed on UCS test machine relative to its original area.
(8) Whereby, the increases of Geo-percentage (%) in the specific separated layers tend to increase the unconfined compressive strength of the soils.

7.1 CONCLUSION

The experimental results and geo-findings of this research when provide a chance to advance techniques and accustomed methods in engineering designs and construction practices in Tanzania. Application of Geotextiles would have great significance not only in cost savings but also ascertaining project effective budgets, timely construction completion, materials quality control, and environmental sensitivity. Also, Geotextiles will play a role of minimizing unplanned road maintenance costs by providing solutions to both physical and mechanical defects of pavements especially pre-mature road failures such as cracks, rutting, shoving, potholes, and upheavals. In addition, geotextiles improve the life span of highways due to improved stability of pavement layers, which are always under traffic distresses effects.

7.2 RECOMMENDATION

It is recommended that a set of tests should be conducted on a trial section of road pavement segment of at least 200-300m. The road section is to be designed with application of geotextile beneath the sub-base layers and the subgrade. Then, the trial sections should involve a single lane adopting geosynthetics technology while the other set of lane shall not consist of geosynthetics (i.e. Geotextile).

It is expected that, installation of Geotextiles will create a separation between two road layers elsewhere, practically about 95% of base course materials shall not be intermixed and only 5% of fines will pass through the punched holes of the synthetics. Then, observation of different parameters based on durability, workability and survival life span of the trial sections will be taken effectively under condition that heavy equipment and tools are to be deployed during road formation and pavement to be opened and exposed to the traffic.

Further research is recommended to establish and address the significance of introduction of Geosynthetics in Tanzania for highway networks which is expected to be rational example with survival of infrastructures as per design period, cost effectiveness set-up, better quality properties such as durability and workability of pavements that influence minimization of costs from unplanned road maintenances and rehabilitations.

Normally, it has been experienced that our national roads agency controllers TANROADS has been tracing pavements sustainability with sets of axle loading standards and various legislated regulations that are intended to safe-guard survival of constructed roads all over the country. This is to minimize costs of unplanned maintenances which seemed to inflate project budgets for most pre-designed and projects to be commenced.

Moreover, because of the positive effects which have been observed from the results of experimental sets of tests with Geotextile application in road works, it is advisable that,

governmental and professional institutions especially ERB, IET, TANROADS, Ministry of Education Science and Technology, Ministry of Transportation Communication and Infrastructures, Tanzania Bureau of Standards, consulting firms and others stakeholders to look on how the Geotextiles and other related Geosynthetics materials like geogrids, geonets, geocomposite, geosynthetic clay liners GCLs, geofoams and geopipes for hydrology, geotechnical and environmental engineering can be adopted and promoted in our national higher learning education curriculum and taught because of their proven stability and function for improved infrastructure performance.

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