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Effectiveness of using Geosynthetic Material for Improvement of Road Construction and Performance - Case Study on Adis Ababa

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***Abstract* - The research is concerned with the Effectiveness of geosynthetic to improve performance of pavement. It has been done on road construction projects under Addis Ababa Road Authority.**

Key words: Geosynthetic material, Geomembrane, CBR test, Asphalt core sample test, and result and discussion.

1. INTRODUCTION

Road sector construction projects in Ethiopia are means through which development strategies are achieved. Development strategies which are fulfilled through successful road projects out end to import accessibility of urban areas, lower costs associated with transport maintenance and open more areas for development activities. Road projects, involving large amount capital, also contribute to the total economy through job creation and in a ripple effect to other business activities. The traffic volume and traffic loads on these roads are getting higher.

Hence there have multi problems which are caused by poor quality subgrade or material used for construction. In large cities, the problem become one of the challenge for the economic activity of the country. Since Addis Ababa is the Capital city of the country, the increase of traffic volume is the other challenge for the roads. According to transport ministry data there have 587,457 vehicles in Ethiopia registered up to July 2015. From these amount 362,664 vehicles are found in Addis Ababa. These number of vehicles increase 2% every year. This shows the traffic volume in the city is increasing through the years, so that increasing roads performance should be considered.

Experimental and analytical investigations were performed to evaluate the comparative performance of pavements with and without geosynthetic stabilization. This was accomplished by the testing of a total of 8 pavement core samples and 11 CBR test sections which could be classified into two different types: one which was constructed without geosynthetics and one with one of two geomembranes or a geogrid.

In evaluating the effectiveness of geosynthetic from this study on permanent paved roads, it is easy to develop that geosynthetic materials can improve the performance of road. Geomembrane, in this study reviewed, tended to perform better for bases, especially where subgrade strengths were below a CBR of 3 (MR of 30 MPa).

By reducing the undercut and thickness of base and subbase material, geomembranes can save initial construction cost of road also the life cycle cost by increasing the design life of the road.

Since Geosynthetic materials, a newly emerging field in the civil engineering and other fields, it offers great potential in varied areas of applications globally. (Dr. Bipin J Agrawal) The addition of materials possessing properties that would enhance the behavior of the soil itself was no doubt done long before our first historical records. It seems reasonable to assume that the first attempts were made to stabilize swamps and marshy soils using tree trunks, small bushes and the like.

1.2 Objectives

- To determine the major effectives of geosynthetic material on paved on road performance based on laboratory test.
- To determine the major cost effectives of geosynthetic materials.
- To provide practical suggestions and recommendations aiming to upgrade the knowledge of applying geosynthetic material on construction of road projects.

1.3 Study Area

This research was conducted in Addis Ababa the capital city of Ethiopia which had founded in 1886, it is the largest city in Ethiopia, with a population of 3,384,569 according to the 2014 population census with annual growth rate of 3.8%. This number has been increased from the originally published 2,738,248 figure and appears to be still largely underestimated.

Addis Ababa which have a large amount of growth in traffic activity. According to transport ministry there have 587,453 total number of vehicles which are registered up to June 2015 in Ethiopia. From this amount 61.73 %(362,664) are found in Addis Ababa. Also the rate of growth increase 3% every year.

Because of these situations, the city administration construct and maintain the roads more highly than ever. While constructing these roads the quality and capacity of the roads

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need to feet with the growth of traffic volume and have to be Cost effective.

For such reason, most of the road lines need maintenance every moment which is not cost effective. So, for application of new technology is needed for preventing the life cycle cost of the road also to improve performance of the road. The place where geosynthetic material application conducted was on National theater center and around Gandhi Hospital which is located in Kirkos sub-city in Addis Ababa city administration as we see on the figure. This research also conduct with laboratory CBR test which is located in Addis Ababa City Road Authority laboratory by comparing samples with geosynthetic material and without geosynthetic material.

2. LABORATORY TEST, RESULT AND COMPARISON OF DEGREE OF COMPACTION

A. core test analysis for existing road.

The data collected by the core drill machine during the course of this project provide the basis for the quantitative and comparative analysis of degree of compaction and estimation of flow and stability of the paved road with geosynthetic material and without geosynthetic material. The analysis of the collected deflection data was undertaken from the same road alignment which contain both road with geogrid material and without this material.

(a)

(b)

Figure 1 (a) Core Drill machine and (b) taken core samples

The core samples of the representative pavements were compared based on their degree of compaction. Table 5-1 lists percent degree compaction of the pavements without geosynthetic and the pavements with geosynthetic for two pavement cases considered in the study.

Sample	Pavement with geogrid reinforcement Degree of Compaction (%)	Pavement without geogrid material Degree of compaction (%)
A-1	99.34	93.46
B-2	97.95	93.06
C-3	95	93.47
cumulative	97.26	93.33

Table 1 Comparison of Degree of compaction for pavement with geogrid and pavement without geogrid

The purpose of this study is to compare the performance among the pavements with and without geosynthetic material instead of comparing different pavement design methods. The above average degree of compaction for pavement with geogrid meet ERA specification for degree of compaction (minimum (97%) but pavement without geogrid does not meet minimum requirement. So that this result shows the geosynthetic material increase bulk density of the pavements.

B. Flow and stability comparison

The core samples of the representative pavements were also compared based on flow and stability. Load Vs flow of the pavements without geosynthetic and the pavements with geosynthetic for two pavement cases considered in the study.

$$Stability = \frac{\text{load}}{flow}$$

For pavement with geosynthetic material

$$\text{Stability} = \frac{103}{7} = 14.7\text{kN/mm}$$

For pavement without geosynthetic material

$$\text{Stability} = \frac{25}{5} = 5\text{kN/mm}$$

For pavement with geosynthetic material have greater stability than pavement without geosynthetic which shows the geosynthetic material increase shear strength of pavement under load.

C. CBR Comparison

Subgrade restraint

Subbase-subgrade with geosynthetic material				Subbase-subgrade without geosynthetic material		
penetration	Load	CBR		penetration	Load	CBR
2.54	290	93.34%		2.54	221	71.73%
5.08	457.5	97.73%		5.08	339	72.42%

Table 2 CBR Comparison of subbase-subgrade with geomembrane and without geomembrane

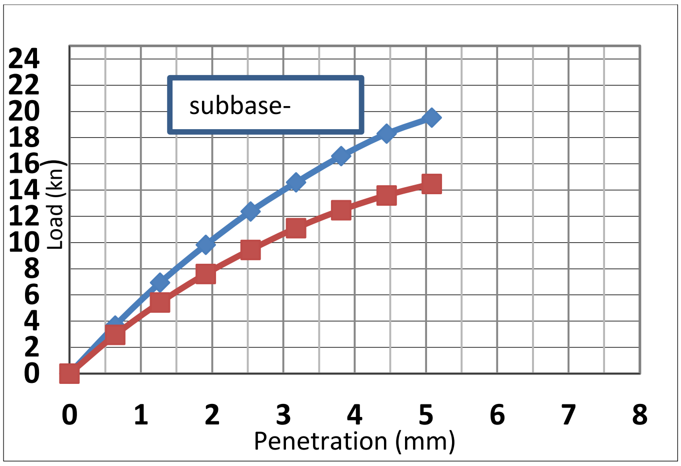

Figure 2 Load penetration curve for subbase-subgrade with and without geomembrane

CBR comparison for Base coarse-subbase reinforcement with and without Geomembrane

Table 3 CBR Comparison of base coarse-subbase with geomembrane and without geomembrane

Base coarse-subbase with geosynthetic material				Base coarse-subbase without geosynthetic material		
penetration	Load	CBR		penetration	load	CBR
2.54	250	70.40%		2.54	245	68.99%
5.08	389	72.70%		5.08	389	72.70%

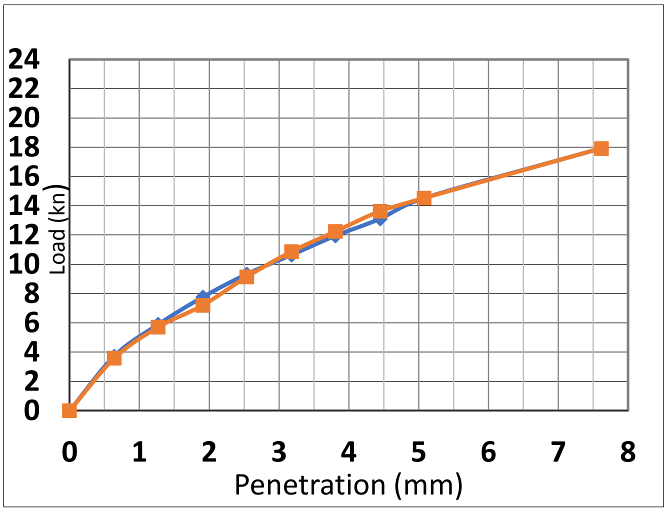

Figure 3 Load penetration curve for base coarse-subbase with and without geomembrane

3. 8Cost Benefit of Geosynthetic Material

It is recommended that an economic evaluation of a proposed reinforced pavement project be performed with life-cycle cost analysis. However, solely examining initial construction costs may demonstrate a cost savings with a geosynthetic reinforcement. In this case, a detailed life-cycle cost analysis may not be required unless total savings over the project life must be quantified (e.g., to compare the savings in thickness reduction as compared to maintaining the thickness and increasing the design life). The initial cost approach oversimplifies the evaluation. Life-cycle cost will invariably show a greater cost savings and is recommended if the initial cost approach does not appear to show a sufficient economic advantage for using reinforcement.

The outlined procedures typically will result in demonstration of a cost savings for construction over low subgrade conditions. Cost savings also may be computed in terms of base thickness reduction for some moderate subgrade conditions. However, maintaining the thickness and extending the design life may provide an even greater cost savings. As previously indicated, lifecycle costs should be examined when the simplistic approach of initial construction costs do not show a savings with use of geosynthetic reinforcement. Other benefits, which cannot be quantified as a cost savings, should be factored into the decision-making process. Based on (GEOSYNTHETIC REINFORCEMENT OF THE AGGREGATE BASE/SUBBASE COURSES OF PAVEMENT STRUCTURES GMA WHITE PAPER II Prepared for: AASHTO Committee 4E Prepared by: Geosynthetic Materials Association June 27, 2000) the initial construction cost benefits of Geosynthetic material has been analyzed.

Initial construction costs

Initial construction cost savings are usually realized when constructing over a low subgrade. The amount of calculated savings may vary with the method and/or geosynthetic used in design. However, the approach to quantifying the cost savings is independent of the design method and geosynthetic. The main problem for Ethiopian road construction industry for not using geosynthetic material is its availability. But one type of geosynthetic material is manufactured in Addis Ababa Ethiopia with a cost of 75 birr per square meter for 1.5mm thickness HDPE geomembrane. So based on the above Table 4.13, the initial cost for road which are constructed using geosynthetic material can save more money and time. Let us see example of sample initial construction cost of road with 1km length, 10m width and have to be excavated upto 1m.

No	Description	Unity	Qty (L*W*H)	Unit Rate	Amount
1	Excavation with thickness of 1m.	M^3	1000*10*1=10000m^3	143.02	1,430,200
2	Capping layer under the subbase	M^3	1000*10*0.75=7500m^3	156.02	112,650
3	Subbase	M^3	1000*10*0.25=2500m^3	279.81	699,525
4	Base coarse	M^3	1000*10*0.15=1500m^3	444.14	666,210
Total					2,908,585

Table 4 Table Sample initial construction Cost for road without geomembrane

No	Description	Unity	Qty (L*W*H)	Unit Rate	Amount
1	Excavation with thickness of 1m.	M^3	1000*10*0.5=5000 m^3	143.02	715,100
2	Capping layer under the subbase	M^3	1000*10*0.40=4000 m^3	156.02	624,080
3	Geomembrane	M^2	1000*10=10000 m^2	75	750,000
4	Subbase	M^3	1000*10*0.175=1750 m^3	279.81	489,667.5
5	Base coarse	M^3	1000*10*0.075=750 m^3	444.14	333,105
Total					2902952.5

Table 5 Sample initial construction Cost for road with geomembrane

Initial construction cost comparison

Description	Road construction without geomembrane	Road construction with geomembrane
Initial construction cost	$ 2,909,585	$ 2,902,952.5

Table 6 Initial construction cost comparison

From the above result the initial construction cost for road with geomembrane have least value than road without geomembrane, which shows geosynthetic materials can save money by improving performance of the road. It also saves materials such as base coarse and subbase materials.

4. CONCLUSION

Based on the testing and analysis of geosynthetic-stabilized pavements constructed in this study, the following findings have been made.

- The performance of bottom pavements structures constructed on poor subgrades with CBR values not greater than of 4 percent were significantly enhanced using geosynthetic material. An increase of bearing capacity for subgrade and can improve the subgrade quality without excavating and filling of select material only by using geomembrane.
- For base/ subbase reinforcement the reinforcement benefits of geomembrane is not significant because the CBR value have no difference but it is significant for separation function from percolation of water into subbase and subgrade.
- By reducing the undercut and thickness of base and subbase material geomembranes can save initial construction cost of road also the life cycle cost by increasing the design life of the road.

Geosynthetic reinforcement in pavement design and construction should be widespread. Geosynthetic reinforcements are incorporated into permanent, paved roads either as base (or subbase) reinforcement — in flexible pavements to aid in the support of vehicular loads over the life of the pavement; or as subgrade restraint for construction of flexible or rigid roadways over weak subgrade conditions to aid in support of equipment loads on the unpaved base, or subbase, course during construction. Clearly, both base reinforcement and subgrade restraint with geosynthetics are proven techniques for use in pavement design and construction. The use of geosynthetics to reinforce the aggregate base course of flexible pavement structures has been researched by many groups, including manufacturers, universities, government agencies, etc. It is well documented that certain reinforcements provide substantial load-carrying benefits, within limits. Limits of applicability are defined by subgrade strength, aggregate characteristics, design requirements, and geosynthetic characteristics.

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