SOME VISIONS FOR DESIGNING MOZAMBICAN LOW COST ROADS BASED ON NEW ALTERNATIVE CONSTRUCTION TECHNIQUES

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ABSTRACT

Low cost road (LCR) initiatives are often concerned with supporting of the sustainable improvements of roads and creating the basic access to support poverty reduction initiatives in rural communities. In southern Africa low cost roads are those built with thin asphalt surfacings for low volume road traffic and also referred to as improved unpaved roads. LCR can be built or kept maintained cost effectively by using appropriate types of equipment suited to small-scale contractors. The objectives of this essay are to evaluate alternative pavement solutions for low volume roads. In order to evaluate the performance of different LCR, the KENLAYER program was used to evaluate the pavements. The deformation responses of unpaved and surface treated roads before and after surface treatments, at critical locations (bottom of base, top of selected subgrade and top of subgrade) are nearly the same; that means, the use of surface treatment over unpaved roads, does not increase the structural capacity, but it may only improve the riding quality and the drainage of the roads. The comparison of the cost of different LCR different pavement models (untreated, treated with ECOLOPAVI and treated with cement) found that the roads treated with ECOLOPAVI may cost less. Previous research has investigated the use of the ECOLOPAVI road treatment solution for improving roads and suggested, for consistency, further studies may be needed with an aim to investigate its use as an LCR alternative in Mozambican roads.

Keywords: *Low Cost Roads, Road Stabilizer, Structural Capacity.*

1. Introduction

The improvement of road infrastructure is one of the key elements in the development process. LCR are usually located in areas with poor quality materials for construction (Zheng *et al*, 2005, Diogo et al, 2007). Different stabilization techniques are often used to improve the structural capacity of LCR. The objectives of this essay are to evaluate alternative pavement solutions for low volume roads. Many stabilization methods are presented in Yoder and Witczack, 1975, Oglesby and Hicks, 1982, Little, 1999, Little *et al*, 2006, Jirathanathaworn *et al*, 2006, and INDOT, 2002. Diogo 2007 has investigated the use of ECOLOPAVI stabilizer in LCR roads; this stabilizer is a liquid, generally, used in combination with cement or lime at different volume proportion (Roessler, 2006, Diogo 2007). This product is manufactured by the company HICPM (Homi Industria e Comércio de Produtos Químicos, Ltda) based in Sao Paulo, under License of IDESA, located in Manus, Brazil (Roessler, 2006). The ECOLOPAVI technology is detailed in (Roessler, 2006). The authors conducted this research in Geotechnique Laboratory based at CONCRESONDA COMPANY, Brazil. This research took into consideration that in Mozambique, LCR represents the main road system and guarantee connection between rural areas, flow of the agricultural goods and services (David, 2002). LCR are particularly different from other kinds, with a very low traffic volume, usually less than 200 AADT (Annual Average Daily Traffic) (Zheng *et al*, 2005). The effect of ECOLOPAVI in structural capacity is presented herein.

2. Selection of construction strategy based on cost analysis of different unpaved low cost roads (LCR) per km of road and 3.8 m width

2.1. Unitary cost analysis of different pavement types

The unit cost for untreated unpaved roads, unpaved treated roads with ECOLOPAVI, and unpaved treated roads with cement are presented in Tables 1, 2, and 3, respectively. The cost of these three pavements (Diogo, 2007), the gravel untreated roads, the road treated with ECOLOPAVI, and the road treated with cement as shown in these tables are 4.88 USD/m2 (18,544.00 USD/km), 4.00 USD/m2 (15,200.00 USD /km) and 5.95 USD/m2 (22,610.00 USD/km), respectively. It is important to note that in the evaluation models, the Unpaved treated road with ECOLOPAVI indicated in Table 2 used local materials from the construction site with low CBR and after their treatment with stabilizer ECOLOPAVI (Brazilian stabilizer) in different proportions, and as result their CBR increased and reached the CBR values of 45% for the subbase layer and 65% for the base layer. For the gravel road indicated in Table 1, the materials were imported over a long distances with heavy trucks, which increased the costs in comparison with the ECOLOPAVI treated road due to the transportation cost of materials.

Table 1: Unpaved gravel roads, width of road = 3.8m; L=1 km

Description	Unit	Unit cost (USD)
Granular base, t=15 cm, CBR³ 65%	m^2	2.10
Granular subbase, t=12 cm, CBR³ 45%, t=12 cm	m^2	1.70
Selected subgrade, CBR³ 12%, t=15 cm	m^2	1.08
Total	m^2	4.88

Table 2: Unpaved ECOLOPAVI treated roads, width of road = 3.8m; L=1 km

Description	Unit	Unit cost (USD)
ECOLOPAVI treated base with, t=15 cm, CBR³ 65%	m^2	1.46
ECOLOPAVI treated subbase, CBR³ 45%, t=12 cm;	m^2	1.46
Selected subgrade, CBR³ 12%, t=15 cm,	m^2	1.08
Total	m^2	4.00

Table 3: Unpaved cement treated roads, width of road = 3.8m; L=1 km

Description	Unit	Unit cost (USD)
Cement treated base, CBR³ 65%, t=15 cm	m^2	3.42
Cement treated subbase, CBR³ 45%, t=12 cm	m^2	1.45
Selected subgrade, CBR³ 12%, t=15 cm	m^2	1.08
Total	m^2	5.95

2.2. The comparison of costs of three different road types

Table 4 presents the cost comparison of three typical roads (model types: Unpaved, ECOLOPAVI treated road and cement treated roads), each one with a length of 1 km and width of 3.8 m. The computed cost results of 1 km of road presented in the table 4 shows that the costs of Untreated gravel roads is 18,544.00 USD; ECOLOPAVI treated is 15,200.00 USD and cement treated road is 22,610.00 USD.

The cost comparison between these suggested pavement structural types indicates that the costs of road treated with ECOLOPAVI is lower than the cost of gravel roads by about 18% due to high cost for transportation; and lower than the cost of cement treated roads by about 33%. The cost of road treated with ECOLOPAVI is lower than the cost of gravel roads due to high cost for transportation; the cost of road treated with cement also is high due to the high cost of cement. From the results, it can be seen that the alternative of using the ECOLOPAVI treatment technique is cheaper; thus, the construction of LCR treated with ECOLOPAVI can be recommended and consequently its surface treatment for needed improvement, is suggested.

Table 4: Comparison of costs of different road types (width of road = 3.8m; L=1 km)

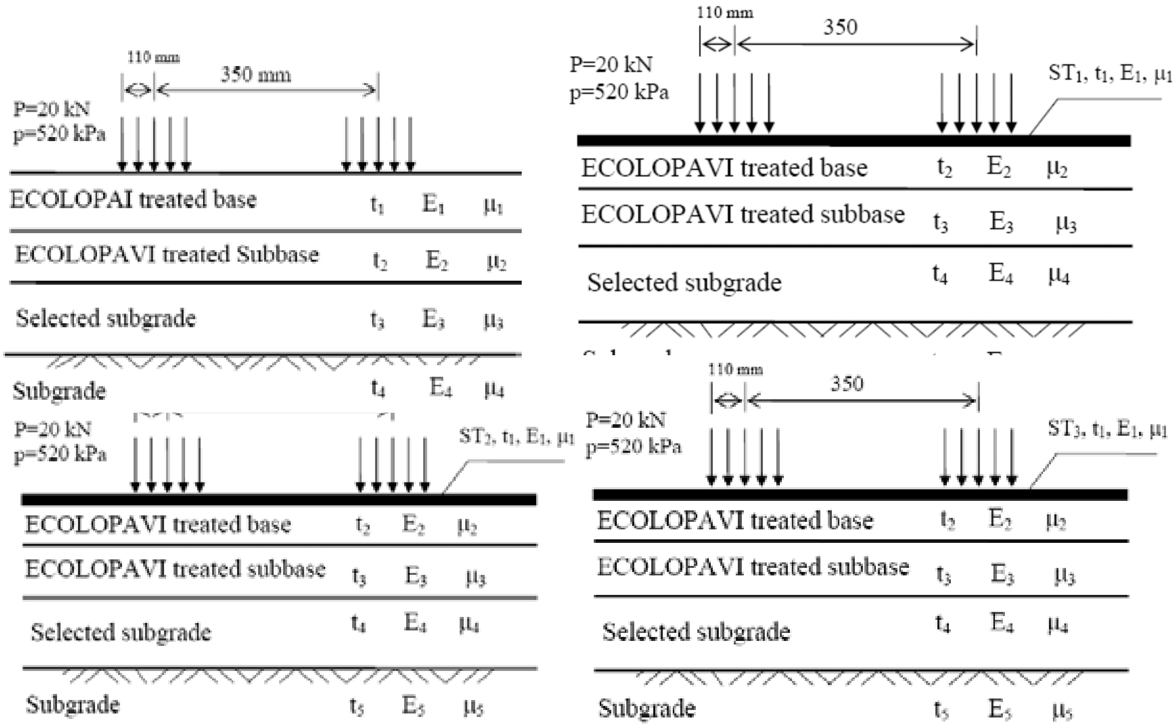
Model base		Model to compare with		Increases C_I (%)
Desciption	Cost (USD)	Description	Cost (USD)	
ECOLOPAVI treated road	15,200.00	Natural gravel	18,544.00	18
ECOLOPAVI treated road	15,200.00	Cement treated roads	22,610.00	33

3. Design of surface treated low cost roads (LCR)

To analyze the pavement response, this study assumed four pavement structures (Figure 1). Figure 1a) presents a 4 layer pavement system, and Figures. 1b), 1c) and 1d), respectively, present 5 layer systems; all systems are assumed to be under a dual circular loaded area. Material sensitivities of the pavements are presented in Tables 5 and 6. The load in each wheel is 20 kN and the contact pressure 520 kPa (Theyse et al., 1996). Layer 1 is linear elastic, and layers 2, 3, 4 are nonlinear elastic. The material properties are given in respective figures and in Tables 5 (for Model 1-UN) and 6 (for Model 2-ST1, Model 3-ST2 and Model 4-ST3). The Elastic modulus or resilient moduli were calculated by Eq. 1 (Yoder and Witczack, 1975).

$$E\ (M_R) = 10.3\ CBR \qquad (1)$$

Where $E(M_R)$ is the elastic modulus or resilient modulus in MPa; CBR = California Bearing Ratio from CBR testing. The simulation was made by the KENLAYER computer program (Huang, 2004).



c) Model 3 - ST2 d) Model 4 - ST3.

Fig. 1: Pavement models of unpaved and surface treated roads;

Table 5: Material sensitivity of the Pavement Model 1 – UN1

Layers	Elastic Modulus (MPa)	Poisson's Ratio (μ)	Thickness (cm)
ECOLOPAVI treated base, CBR^3 65%.	500	0.35	15
ECOLOPAVI treated subbase, CBR^3 30%.	300	0.35	12
Selected subgrade, CBR^3 12%	90	0.35	15
Subgrade CBR ≥ 3%	50	0.35	∞

Table 6: Material sensitivity of the Pavement Model ST1, ST2, and ST3

Layers	Elastic Modulus (MPa)			Poisson's Ratio (μ)			Thickness (cm)		
	ST1	ST2	ST3	ST1	ST2	ST3	ST1	ST2	ST3
Surface treatment	1000	1000	1000	0.44	0.44	0.44	0.5	1.0	1.5
ECOLOPAVI treated base, CBR³ 65%.	500	500	500	0.35	0.35	0.35	15	15	15
ECOLOPAVI treated subbase, CBR³ 30%.	300	300	300	0.35	0.35	0.35	12	12	12
Selected subgrade, CBR³ 12%	90	90	90	0.35	0.35	0.35	15	15	15
Subgrade CBR ≥ 3%	50	50	50	0.35	0.35	0.35	∞	∞	∞

3.1. Pavement response results

The results generated by the KENLAYER computer program (Huang, 2004) are presented in Table 5.21. Pavement deformation responses, indicate that the vertical deformation along the depths are much high at upper layers. The vertical deformations decrease as the depth increases. The deformation responses indicated in Table 7 show that in all models (Model 1=UN, Model 2-ST1, Model 3-ST2 and Model 4-ST3) before and after surface treatments of unpaved LCR, at critical locations (bottom of base, top of selected subgrade and top of subgrade) are nearly the same; this means, the use of surface treatment of roads, does not increase the strength.

Table 7: Pavement deformation responses

	Unpaved surface		Asphalt Surface treatment (mm)					
	Model 1-UN		Model 2-ST1		Model 3-ST2		Model 4-ST3	
Descri-ption	**Depth (h1)**	**Displ (W1)**	**Depth (h2)**	**Displ (W2)**	**Depth (h3)**	**Displ (W3)**	**Depth (h4)**	**Displ. (W4)**
Bottom of AC	-	-	0.5	0.76	1.0	0.75	1.5	0.74
Bottom of base	15	0.70	15.5	0.68	16	0.67	16.5	0.66
Bottom of subbase	27	0.64	27.5	0.62	28	0.61	28.5	0.60
Top of selected subgrade	27.0001	0.64	27.5001	0.62	28.0001	0.61	28.5001	0.60
Top of subgrade	42.0001	0.54	42.5001	0.53	43.0001	0.52	43.5001	0.52

h= thickness (cm);
W = deflection (mm)

3.2. Contribution of surface treatments in cost of ECOLOPAVI treated roads

To study the contribution of the surface treatments in construction costs, 4 models (Figure 1) [Model 1 - UN (Unpaved Ecolopavi treated road); Model 2 – ST1 (surface treatment with a thickness of ST 0.5 cm); Model 3 – ST2 (surface treatment with a thickness of ST is 1 cm), and Model 4 – ST3 (surface treatment with a thickness of ST is 1.5 cm)] were analyzed. The ratios between the costs of pavements according to table 8 (Model 2 – ST1 and the Model 1 – UN, the Model 3 – ST2 and the Model 1 – UN, the Model 4 – ST3 and the Model 1 – UN) are 0.83, that represents an increase at 16%; 0.81, that represents an increase at 19%; and 0.79, represents an increase of 21%, respectively.

Table 8: Different ECOLOPAVI surface treated roads (width of road = 3.8; L=1 km)

Mododel base		Model to compare with		Cost increases	
Description	**Cost base**	**Description**	**Cost base**	**ratio**	**C_I (%)**
Model 1-UN	4.00	Model 2-ST1	4.80	0.83	16
Model 1-UN	4.00	Model 3-ST2	4.94	0.81	19
Model 1-UN	4.00	Model 4-ST3	5.09	0.79	21

4. Findings and conclusions

The main findings and conclusions from this are:

(1) The cost comparison analysis of three typically roads (gravel roads, treated with ECOLOPAVI and treated with cement) were made. It was found that those treated with ECOLOPAVI are cheaper than the gravel roads (by about 18%) or than those treated with cement (by about 33%).

(2) The deformation responses indicated in Table 7 show that in all models (Model 1=UN, Model 2-ST1, Model 3-ST2 and Model 4-ST3) before and after surface treatments of unpaved LCR, at critical locations (bottom of base, top of selected subgrade and top of subgrade) are nearly the same; this means, the use of surface treatment of roads, does not increase the strength.

(3) It is desirable to study the unpaved road with thin coating asphalt where the coating plays a role of improving quality of service rather than that of structural function.

(4) Lastly, the use of stabilizers should be recommended if the existing soil material along the road alignment is of a very low quality and there is need to improve its strength and load bearing capacity.

Note that the evaluation was based on theoretical considerations, and actual field performance under traffic is required to validate the anticipated life.

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