Improvement of Road Pavement Sustainability. Case Study Application

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Abstract: - Road infrastructure has an important role in the transportation system by connecting communities, ensuring a crucial contribution to economic development and important social benefits. They have vital importance in sustainable cities and bring the most important economic and social benefits to all public assets. This paper describes the design process of pavement improvement of old Albanian roads by using geogrid or geotextile material and presents the data information gathered findings, and conclusions that can be drawn. The case of study is the rehabilitation design of Fier-Seman old road. The American Association of State Highway and Transportation AASHTO standards methods have been used to design pavement system rehabilitation depending upon the existing condition and improving the bearing capacity performance. This method includes consideration of the following items: pavement performance, traffic volume and composition, roadbed soil, properties of materials for construction, drainage, environment, reliability, and life-cycle costs.

Key-Words: - Flexible pavement; Aashto Standard; Geotextile; Geogrides Pavement; Paivement Maintenance; California Bearing Ratio.

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1 Introduction

For the road to serve its functions, it needs a layer package that is appropriate, affordable, and well-maintained. Every infrastructure project undergoes a phased evaluation, contingent on the type of project and the proposed pavement, [1], [2]. We are able to work on the following types of projects:

The building of new roads construction; their expansion and rehabilitation; and large-scale projects for maintenance and reconstruction.

The "Reconstruction of the Fier-Seman Highway Road" project consists of the reconstruction of the 18-kilometer road segment that begins at the train tracks in Fier City and continues to the police station in Seman Beach. The Seman Beach and Fier City's urban center are connected by this section. The road is set in flat terrain with pore geological formations.

Both locals and visitors use the road rather frequently. It will provide services to 17,000 people living in 20 nearby communities that generate a substantial amount of agricultural goods annually. Given that it is anticipated to greatly enhance access to Seman Beach, this project is also a key pillar for the growth of tourism in Fier and the neighboring districts. Investing in this route is crucial because it makes it easier for farmers to reach markets, promotes agritourism, and allows people to utilize the coast. The field surveys provided precise and comprehensive information about the road, including its existing condition, its pavement layer, its width, its secure element, its traffic, and more.

Based on the information gathered, a number of options were presented to improve road pavement sustainability. The sub-grade can be efficiently strengthened by using geotextile or geogrid. It significantly increases the pavement's service life and successfully lowers maintenance costs.

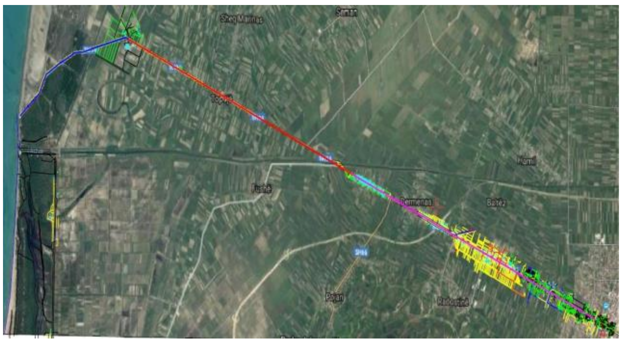

Fig. 1: Fier - Seman Road track route position

Fig. 2: Road existing view

Because of its high resistance to deformation, it provides structural strength and effectively separates subbase from subsoil, [3], [4], [5], [6], [7]. The Fier-Seman track route position and the current road view are displayed in Figure 1 and Figure 2, respectively.

2 AASHTO Flexible Pavement Design Method

The Road Test is the foundation of the 1993 AASHTO guide for the flexible pavement design approach, which establishes the relationship between the performance of flexible pavement and the number of repetitions of specified axle loads, [8], [9], [10].

The following input parameters are necessary for pavement design, [10]:

Vehicle classification, load traffic, reliability, material properties, drainage features, the environment, and existing subgrade conditions are all factors.

Superstructure performance measurement: User ratings are used to gauge the effectiveness of the AASHTO technique. The following issues make these estimates highly erratic:
(a) Subjective difficulty, (b) significant variable changes and (c) the PSI, or Current Serviceability

Assessment Specialized equipment or direct group observations are used for the assessment, which culminates in an evaluation based on the following index:

0-1 very poor
1-2 poor
2-3 medium
3-4 good
4-5 very good

The number of cumulative equivalent traffic axles ($ESAL^{Predicted}$) is given in formula 1:

$$W = 365*TGM * p*p_l*p_d*d*C_{eq}*n_a*\frac{(1+r)^n-1}{r} \quad (1)$$

where;
TGM = average daily load traffic
p = % percentage of traffic distribution according to the movement direction
p_l = % percentage of traffic in the loaded lane
C_{eq} = equivalent coefficient
r = % percentage of traffic growth rate
n = road serviceable life

The following performance indicators serve as the basis for these evaluations: a. Visible damage (cracks); b. Friction surface; and c. Severity

The following empirical design equations for flexible pavement specify design traffic of equivalent single axle load $ESAL^{Design}$:

$$\mathrm{Log}W_{18} = Z_R*S_0 + 9.36*\log(SN-1) - 0.2 + \log\frac{\frac{\Delta PSI}{4.2-1.5}}{0.4+\frac{1094}{(SN+1)^{5.19}}} + 2.32*\log M_R - 8.07 \quad (2)$$

In which;
W_{18} = accumulated 80 Kn equivalent single axle load for the design period
Z_R =reliability factor
S_0 = standard deviation
SN= structural number
ΔPSI = initial PSI – terminal PSI
MR= subgrade resilient modulus (psi)
The assessment of log W_{18} = f (Z_R* S_0; SN; ΔPSI; N_R) $ESAL^{Design}$ is compared of $ESAL^{Predicted}$= f(TDM; P; P_d; P_l; d; r; n; c_{ek}), when $ESAL^{design}$ > $ESAL^{predicted}$ [8], [9], [10].

Different combinations of materials and layer thicknesses must result in the same SN structural number.

The task of the designer is to choose the most economical combination, use available materials, and consider these guidelines:
1. Geometric requirements (filling/excavation)
2. Drainage requirements
3. Frost requirements

AASHTO suggests that the structure of road layers should not be overloaded. It must be checked that each layer itself complies with the structural requirements.

3 Road Pavement Rehabilitation Analysis

Due to varying mechanical and physical soil characteristics, the Fier-Seman road territorial is separated into five sections, as illustrated in Figure 3.

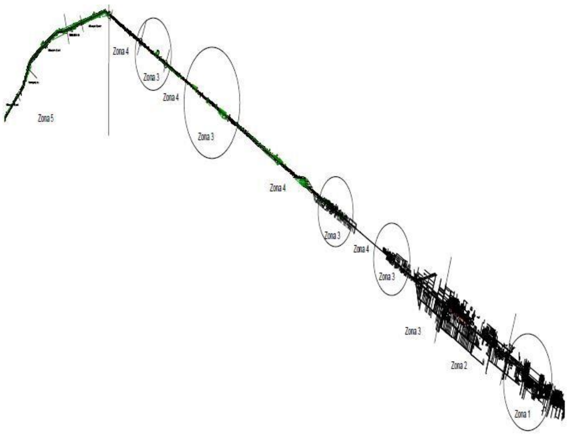

Fig. 3: Project road territorial division

Table 1 presents the subgrade design California bearing ratio (CBR) and resilient modulus value taken from in situ test results of existing roads.

Table 1. CBR and Resilient modulus value of Fier – Seman road

Road	Name	Subgrade design CBR (%)	Resilient modulus (psi)
Zone 1	Fier	6	9000
Zone 2	Bypass Fier	1.5	2250
Zone 3, 4	Topoje	1.5	2250
Zone 5	Beach	3.5	5250

A subgrade strength foundation is considered weak when the California Bearing Ratio (CBR) test yields a value of about 1-2 percent.

Zones 2, 3, and 4 have CBR design values of 1.5%, which is less than the 2% limit. To increase the strength of the road foundation, subgrade upgrading is required. Geotextiles and geogrids are regarded as viable solutions to enhance the characteristics of soil foundations. Geotextiles or geogrids are used in the design to increase soil stability and load-bearing capacity in order to improve the performance of the road foundation, [3], [4], [5], [6] and [11]. According to the ASTM D6992 (SIM) test, using road geosynthetics can extend their useful life by up to 75 years.

3.1 Annual Average Daily Road Traffic

The annual average daily traffic (AADT) volume for a route can be determined from the available traffic numbers. No factor for seasonal variation was available and this was taken into account based on literature recommendations. Based on these daily count results, the annual average daily traffic was calculated, and the results are shown in Table 2.

Table 2. Traffic in the area where the Fier bypass connects with the Fier city

Vehicle Description	Daily Traffic	Average Annual Daily Traffic (AADT)	Design (AADT)
Motorcycle	93,8	117,2	141
Car Small	104,2	130,2	156
Car Medium	1875,0	2343,8	5063
Agriculture Vehicle	197,9	197,9	238
Four-Wheel Drive	41,7	52,1	63
Truck Light	41,7	41,7	50
Truck Medium	104,2	104,2	825
Truck Heavy	0,0	2,5	53
Truck Articulated	0,0	2,5	13
Bus Light	10,4	13,0	16
Bus Medium	20,8	26,0	31
Bus Heavy	0,0	1,3	2
Total	2489,6	3112,0	6649

The predicted growth rates from 2025 to 2045 year of passenger and goods vehicles are 2.5% and 2 % respectively.

The traffic load is determined based on future traffic forecasts, vehicle damage factors, and cumulative standard axles for a period of 20 years. Traffic studies have been carried out, which are used as basic figures for determining the traffic load. Traffic growth rates are made relative to existing traffic volumes on the project route.

The total volume of traffic forecasts during the design life is two-way traffic. Assume that 50% of the total traffic goes in each direction. According to Albanian standards during design, 55% of the total traffic is considered in one direction and 85% reliability. The equivalent standard cumulative load (ESAL) is used for the road section for a 20-year design life.

The summary of equivalent standard axes ESAL for different vehicles of all project roads is presented in Table 3.

Table 3. Determination of design ESAL

Road Section	ESAL load total	ESAL load in the esign lane
Bypass Fieri	8.2	4.1
Zone 2, 3, 4	1.38	0.69
Zone 5	0.2	0.2

Using the results obtained from traffic counts and axle load factors by vehicle class it was possible to obtain the number of vehicles that will use the road and the loads incurred during the design life of 20 years.

Based on traffic data, the total value of $ESAL^{Design}$ assessment for zone 3, 4, and bypass Fier taken from equation 2 is **683,401.5** and **4,125,553.8**, respectively. The results show that $ESAL^{design} < ESAL^{predicted}$, which means the improvement necessary to improve subgrade soil properties.

3.2 Structural Number Equations

The structural number (SN) is given as the sum of each layer thickness by its structural layer coefficient as shown in Equation 3 and Figure 4:

$$SN= a_1D1+a_2D2+a_3D3 \quad (3)$$

In which:

a_1, a_2, a_3 = structural layer coefficients for surface, base, subbase

D1, D2, D3 = thickness for surface, base, subbase

Structural coefficient values a_i for different layers are:

Plant mix asphalt, wearing course = 0.44
Plant mix asphalt, base course = 0.35
Bituminous treated crushed stone = 0.3
Crushed stone base = 0.14
Sand-gravel sub base = 0.11

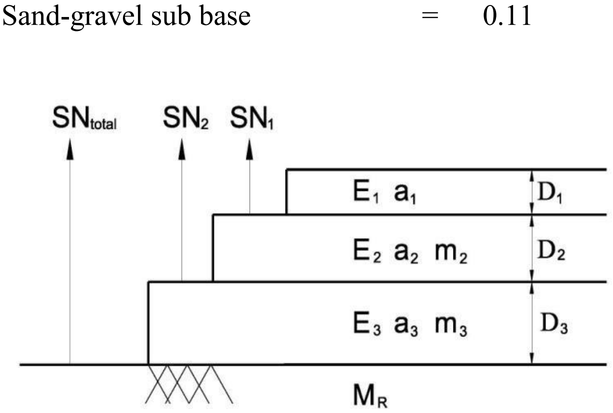

Fig. 4: Structural number determination

The minimum and maximum of the existing thickness layer from the in situ test are given in Table 4.

Table 4. Minimum and maximum existing pavement layer thickness

Road	Asphalt mm		Crushed stone base mm	
	min	max	min	max
Bypass Fier	70	110	250	320
Zone 2, 3, 4	50	100	250	350
Zone 5	40	70	210	270

Road payment layers are illustrated in Figure 5.

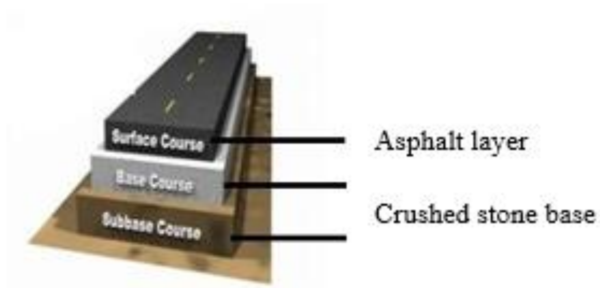

Fig. 5: Road payment layers illustration

Table 5 shows the existing structural number versus the minimum required structural number.

Table 5. Existing structural number (SN) versus minimum required structural number

Section ID	Existing structural number	Required structural number
Zone Fier city	2	3.77
Zone bypass Fieri	2	5.92
Zone 3,4	2.2	4.61
Zone 5	1.4	2.87

Table 5's comparable structural number values demonstrate the need for soil improvement. Studies on the test qualities of geotextiles show that they are very valuable for applications involving weak foundations, especially where there is under-road vehicle action. The following characteristics are present in the geotextile or geogrid foundation layer:

The deformation modulus, Md, is 100 Kpa. The foundation's modulus of elasticity is equal to Eel = 60KPa, as shown by the CBR indicator of 6%, after using geotextile or geogrid.

Layer thickness options and structural number values with geotextile or geogrid soil improvement are summarized in Table 6.

Table 6. Layer thickness and structural number values with soil improvement

Pavement type number	**Asphalt thickness mm**	**Granular thickness, mm**	**Structural number SN**
Fier city	120	350	6
Bypass Fier	100	350	3.8
Zone 2,3,4	100	350	4.8
Zone 5	100	250	3

4 Conclusions

The development of agritourism and beach tourism in the nearby villages is significantly impacted socially and economically by the Fier Seman road rehabilitation.

Because it connects to Seman Beach, promotes agrotourism, and makes it easier for farmers to reach markets, investment in this road project is crucial.

The layer payment improvement for road reconstruction with an index of California bearing ratio (CBR) value below 2% is examined in this study. CBR value increased to 6.0% from 1.5% after using geotextile or geogrid.

The necessary structural number is obtained by examining the computation of the current road superstructure and the improvement payment layer using geotextile or geogrid.

The geotextile or geogrid increases the modulus of elasticity and provides very good support for the asphalt, distributing the stresses throughout the lower layers and reducing subsidence.

According to the findings of preliminary research, the improved superstructure is effective in resolving the majority of geotechnical issues on roads and ensures a lifespan of up to 75 years when using geosynthetic or geogrid, as opposed to the 20 years anticipated without its use.

The method used to produce geotextile material is simple to use and doesn't require any specialized knowledge for deployment or transportation.

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