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RESEARCH OF INFLUENCE OF MEASUREMENT SPOTS DISTANCEON VALUE OF REPRESENTATIVE PAVEMENT DEFLECTION

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ABSTRACT

Efficient roadway management requires knowledge of the structural capacity of the roadway or the load-bearing capacity of the pavement structure. In order to determine the existing conditions of the pavement structure and define appropriate intervention measures, it is necessary to determine relevant impact on surface of the pavement structure on homogeneous road section. The aim of study is to investigate influence of distance between measurement spots of deflection to the value of relevant deflection. Based on calculation of representative deflections, error values were obtained depending on range of deflection measurements spots and subsections length considered.The key question is whether it is possible to obtain qualitative and quantitative data on the basis of which the structural state of the overall network with acceptable error can be estimated by increasing distance between measurements spots.

Key words: *road pavement, structure, deflection, measurement, homogenous section,*

INTRODUCTION

The load capacity of pavement construction is the ability of the construction to take over the load from vehicle regardless of its climatic conditions and transfer it to the subgrade. Over time, under the influence of traffic load and the climatic - metrological conditions, pavement structure loses the bearing capacity. In this respect, it is necessary to increase carrying capacity of the pavement, i.e. structural reinforcement is required.

According to "AASHTO 1990 Guidelines for Pavement Management Systems’’ there are three basic methodologies for roadway management [1]:

- Pavement condition analysis (project-level approach) . This method, considered the simplest of the three, aggregates pavement condition information at the project level and then selects the most appropriate MR&R strategy.
- Priority assessment models (project-level approach) . This method improves upon pavement condition analysis by incorporating predicted future pavement condition information.

- Network optimization models (network-level approach) . This method, considered the most sophisticated, simultaneously evaluates an entire pavement network to determine the optimum network management strategy.

Efficient pavement management requires not only knowledge of pavement conditions indicators which are visible (e.g. cracks or routings) or which can be felt (e.g. roughness), but also knowing the structural capacity of pavement i.e. the bearing conditions of pavement structure.

One of the most reliable ways to determine the bearing capacity of a pavement is the measurement and analysis of vertical deformation or deflection of the pavement surface caused by a controlled static or dynamic load.

DETERMINATION OF ROAD PAVEMENT PERFORMANCE MEASURING DEFLECTION

In order to determine existing conditions of pavement structure and to define appropriate intervention measures, it is necessary to determine relevant defection on the surface of pavement within homogeneous road section. Given that estimation of pavement structural capacity on deflection database, for the purposes of management maintenance of pavement at the network level, implies the collection and processing of a large number of data, this method is very rarely applied. Figure 1. shows typical deflection basin based in road pavement deflection measurement.

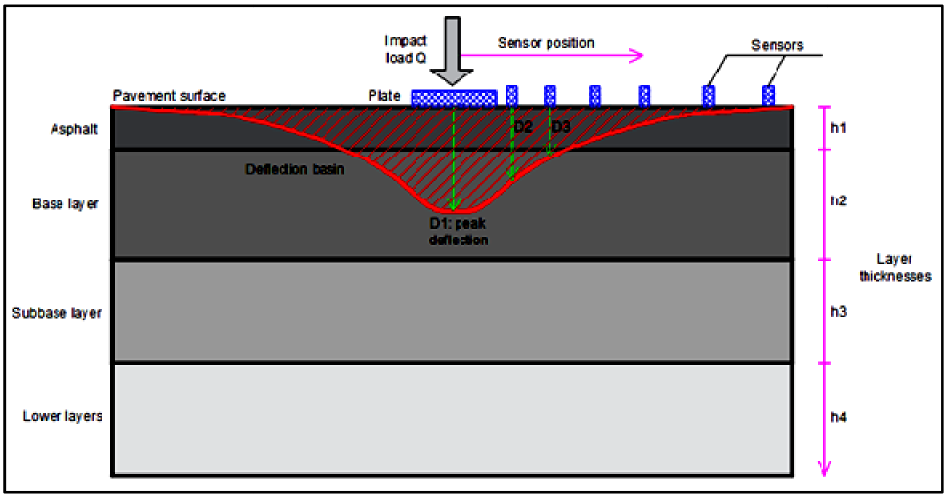

Figure. 1. Typical deflection basin [2]

The aim of this paper is to investigate the influence of deflection measurements spots range at the value of relevant deflection on homogeneous road section. For the purposes of analyzing condition of pavement construction at the network level, sections length are much larger than the investigations for the needs of project level analysis. The key question is whether it is possible to obtain qualitative and quantitative data on the basis of which the structural state of the overall network with acceptable error can be estimated by increasing distance between measurements spots.

Many researchers have conducted surveys to analyze the impact of measuring spots distance on data quality.

For the purposes of the Transport Department of the Federal State of Indiana, Noureldin S. et al. carried out research aimed at analyzing relationship of data volume and simplification of method for assessing condition of pavement. This study found that is enough to collect data at three locations at one mile once a year to estimate the status of a road construction at the network level. This approach allows the data collected to provide the equivalent of the entire network coverage over 5 years. The authors used data on deflections for calculating surface and total thickness of the pavement, with the analysis of layer module, coefficient of the surface and bearing layer and the structural number [3].

Zhang Z et al. used a structural condition index as a variable of response in their research. Statistical analysis has shown that high quality data can be obtained by capturing deflection at 4 locations per mile (at least 2 measuring locations per 800 meters) [4].

Link RE et al. analyzed three variables of response during their research:

- normalized and corrected deflection recorded with the first sensor (d1)
- Elastic surface layer module after backcalculation (Mr)
- Effective pavement module (Ep)

Statistical analysis has shown that three-year deflection analysis at the network level gives statistically similar response of pavement and layer properties. It is also noted that deflection analysis on 20% of the road network provides a fairly satisfactory pattern for the entire road network, while the minimum test frequency is three tests at three locations per mile [5].

Javed A et al. have explored the possibility of reducing the number of test points per share length as well as the number of load application levels applied. This would increase the recording speed and reduce the cost. The substrate module, effective structural number and layer module are calculated using AASHTO and ELMOD methods. Results of the study have shown that a 10 points per mile can be reduced to 3 points per mile without reducing the quality of deflection data or the need for subsequent analysis, at the network level. The study has shown that previous practice of recording "four levels" (6,000, 9,000, 12,000 and 16,000 lbf) can be reduced to 1-level recording without disturbing data quality. However, it is recommended to rewind the recording at least twice the same load level [6].

Yongjoo K et al. for the needs of the Transport Division of the Iowa State Department (DOT) carried out deflection measurements at the level of the road network with the aim of establishing deflection databases for the needs of assessing condition of road construction, life expectancy estimates and possible interventions. The impact of reducing number of load applications and number of test sites on deflection data quality was analyzed with the aim of reducing costs.

Statistical analysis has determined that the number of test points for deflection measurement can be reduced by 30% or 50% without decreasing data quality. Also reducing the number of discharge levels dramatically increases the rate of deflection recording up to 1.5 times for network-wide recording [7].

According to AASHTO Designition T 256-01 (2011) (Standard Method of Test for Pavement Deflection Measurements) [8], locations and number of tests depend on whether the data will be used for network or project level analysis. When analyzing at the network level, deflection measurement is usually performed at intervals of 100 to 500 m, depending on the specific conditions of pavement. A minimum of 7 tests per uniform / homogeneous part of pavement is recommended to provide a statistically significant sample.

Project level analysis provides a more detailed analysis of pavement construction. Test should be carried out at intervals of 50 to 200 m, depending on the specific conditions of pavement. A minimum of 15 tests per uniform / homogeneous part of pavement is recommended. Detailed project-level testing allows for a specific pavement analysis for the purpose of identifying localized areas with large deflections or detection of underground ‘’holes’’ in rigid (concrete) pavement constructions. For flexible asphalt pavement structures or continuous reinforced concrete slabs, testing is usually performed at intervals of 10 to 100 m, according to the designer's recommendation. On roads, city streets and motorways, testing is often carried out on both routings.

RESEARCH METHODOLOGY

Research methodology includes following steps:

- measurement of deflection on the road network

- division of considered section into: subsections of 1 km, 2 km, 3 km, 4 km and 5 km
- determination of homogeneous subsections based on structure of the pavement
- determination of homogeneous subsections based on structure of the pavement and the method of cumulative differences
- calculation of representative values (response variables) for subsections based on deflection recorded at a distance of 100 meters. Representative values are considered to be characterized by a deflection and the required thickness of overlapping as a function of reinforcement of the pavement
- defining a subgroup by skipping the measurement points or dividing the deflection data depending on the distance between the deflection measurement points. A total of 10 subgroups are defined, with a distance of 100 m, 200 m, 300 m, 400 m, 500 m, 600 m, 700 m, 800 m, 900 m and 1000 m
- generating all possible combinations of deflection measurement points for each subgroup.
- calculation of characteristic deflectionvalues and the required thickness of overlay in the function of reinforcement of pavement that characterizes the subsection on the deflection database according to the selected sampling strategy (for spacing between 200 m, 300 m, 400 m, 500 m, 600 m , 700 m, 800 m, 900 m and 1000 m)
- calculation of the average values of the subsections characteristics
- defining a representative sample based on statistical analysis
- error calculation depending on the range of measurement which is interpreted as the accuracy (degree of deviation) of the average value of the subsection characteristics associated with the chosen sampling strategy in relation to the real value of the subsection characteristics obtained by a deflection analysis recorded at a distance of 100 meters
- calculation of reinforcement thickness using revised AASHTO method and in ELMOD software

Measurement of deflection was performed for the purpose of drafting the project documentation for carrying out the rehabilitation work of main and regional roads in the Republic of Srpska, Bosnia and Herzegovina (Table 1). The measurements were carried out at the project level. The data on the thicknesses of pavement layers, which were necessary for analysis of recorded deflections, are taken from project and contract documentation.

Table 1. Sections of the road network where field measurements were performed

No.	Road section	Road name	Length (km)
1.	M-4	Banja Luka - Čelinac	10,9
2.	M-4	Čelinac - Ukrina	30,0
3.	M-4	Prijedor - Lamovita	19,9
4.	M-4	Lamovita - Šargovac	20,0
5.	M-4	Šargovac - Rebrovac	6,7
6.	M-16.1	Klašnice - Prnjavor	40,0
7.	M-1.8	Lepnica – Lončari - Blaževac	17,5
8.	M-14.1	Nova Topola – Srbac - Derventa	60,0
9.	M-15	Prijedor (Tukovi) - Koprivna	20,0
10.	M-18	Rača – Gojsovac – Bijeljina	20,4
11.	R-480	Derviši - Klašnice	9,2
12.	R-462a/R-463/R-464	Šamac – Grebnica – Obudovac - Lončari	25,3
		Total	**279,9**

Measurement of deflection of pavement surface was carried out using the Dynatest 8000 FWD deflectometer.

Results of deflection pavement surface measuring with deflectometer enable determination ofmeasuring site characteristics (actual condition, durability) as well as actual condition of materials in pavement structure

The Dynatest 8000 FWD deflectometer (figure 2.) base is a single-axle trailer with:

- weights of 150 kg for roads and 400 + 250 kg for airports with vertically falling and creating a dynamic load (the height varies from 0.04 to 0.4 m)
- sensors
- rubber springs system
- a circular plate with a cell for a load of diameter 300 to 450 mm
- deflectiongauge - geophones
- a computer support system for monitoring and transferring data to a computer
- computer programs to control the entire measurement procedure and equipment for recording and processing of all necessary data about derived deflection measuring and results obtained

Figure 2. Dynatest 8000 FWD deflekcometer [9]

Data processing was performed using ELMOD 5.0 software package. Developed by Dynatest International A / S and uses an approximate method based on Boussinesq's Equations and Odemark's Equivalent Thickness Method for Estimating Layer Modules on the Deflection Database. Data processing, or "backcalculation", is based on the iterative procedure of calculating the modulus of pavement layers elasticity (figure 3).

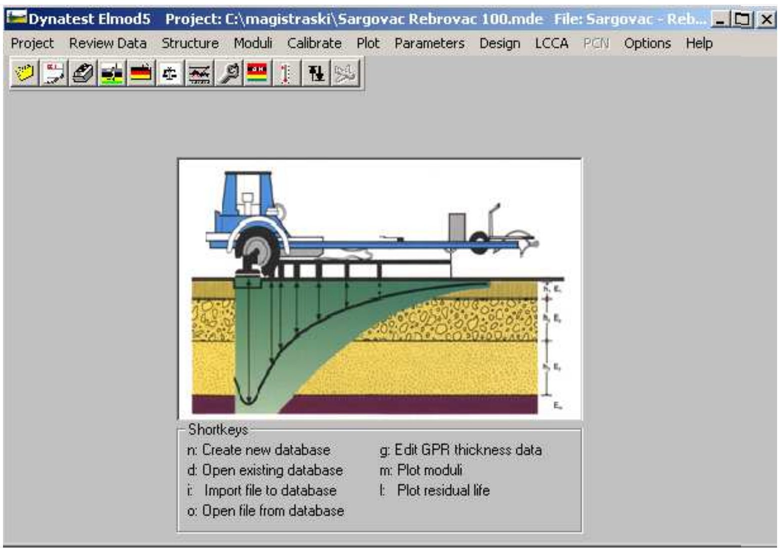

Figure 3. Software ELMOD 5.0 [10]

RESULTS

Based on calculation of representative deflections, error values were obtained depending on range of deflection measurements spots and subsections length considered [11].

Table 2. The error value for subsection lengths of 1 and 2 km [11]

Increment of deflection measurement for 1km	Expected error value - AASHTO method	Expected error value - software ELMOD	Increment of deflection measurement for 2km	Expected error value - AASHTO method	Expected error value - software ELMOD
200	1.64%	1.44%	200	1.53%	1.45%
300	2.38%	3.00%	300	2.45%	2.58%
400	3.98%	3.38%	400	3.54%	3.03%
500	4.28%	4.33%	500	3.49%	4.59%
600	7.09%	4.32%	600	4.59%	5.49%
700	8.11%	5.88%	700	5.17%	5.06%
800	10.74%	5.95%	800	5.76%	5.81%
900	12.12%	7.15%	900	5.93%	6.81%
1000	15.16%	7.08%	1000	6.56%	6.66%

Table 3. The error value for subsection lengths of 3 and 4 km [11]

Increment of deflection measurement for 3km	Expected error value - AASHTO method	Expected error value - software ELMOD	Increment of deflection measurement for 4km	Expected error value - AASHTO method	Expected error value - software ELMOD
200	1.30%	1.67%	200	1.60%	1.45%
300	2.28%	2.71%	300	2.42%	2.69%
400	3.61%	2.93%	400	3.78%	3.47%
500	3.96%	4.69%	500	3.57%	4.82%
600	4.25%	5.36%	600	4.21%	5.26%
700	5.41%	5.33%	700	5.30%	5.18%
800	5.93%	6.52%	800	5.60%	6.95%
900	6.52%	7.06%	900	6.04%	7.00%
1000	6.46%	6.52%	1000	5.93%	7.08%

Table 4. The error value for subsection lengths of 5 km [11]

Increment of deflection measurement	Expected error value - AASHTO method	Expected error value - software ELMOD
200	1.53%	1.22%
300	2.59%	2.76%
400	3.68%	2.59%
500	3.78%	5.36%
600	4.83%	5.73%
700	5.72%	6.08%
800	6.47%	7.66%
900	7.20%	7.93%
1000	6.41%	8.15%

Table 5. Expected error value of required thickness of reinforcement depending on applied methodology [11]

Increment of deflection measurement	Revised AASHTO method		Software ELMOD	
	Defined by pavement structure	Defined by pavement structure and cumulative differences of deflections	Defined by pavement structure	Defined by pavement structure and cumulative differences of deflections
200	4.47%	5.54%	2.18%	2.36%
300	10.18%	4.87%	3.14%	3.19%
400	10.86%	6.97%	3.78%	4.44%
500	9.69%	8.52%	5.51%	5.72%
600	11.12%	10.63%	5.47%	6.08%
700	12.80%	12.96%	5.45%	5.97%
800	15.55%	13.11%	7.13%	7.83%
900	16.39%	14.60%	6.97%	10.14%
1000	14.93%	15.57%	8.59%	10.22%

CONCLUSION

When calculating representative deflections, taking into account the different subsections lengths, depending on measurement spots distance, the error values are in the range of 1.3% to 15.16%.
It can be noted that when calculating values of representative deflections depending on measurement range, and for subsections lengths of 2 km, 3 km, 4 km and 5 km, the expected errors are almost identical and ranging from 1.30 % for measurement range of 200 m, up to 8,15% for measurement range of 1000 m.

Only for subsection lengths of 1 km, the expected errors are different in relation to errors occurring for larger subsection lengths, especially if the distance between measurement points is greater than 500 m. When analyzing the sample, it was found that in 70% of sampling intervals of 700 m, 800 m, 900 m and 1000 m there is a statistically significant difference, and as such they must be discarded. In this case, the expected values for the 1 km long subsection and measurement range of more than 500 meters should be taken with caution because they were not obtained on a sufficiently large representative sample basis.

Since deflection databases use mostly representative deflection data for 1 km long subsections, deflection recording can be performed for this purpose at a distance of 500 meters, whereby a 4.28% error can be expected.

Comparing expected error rates depending on measurement range obtained on basis of analysis of the required reinfrcement thickness calculated by revised AASHTO method and in ELMOD program, and for homogeneous subsections defined by the pavement structure and cumulative deflection differences, it can be concluded that errors in the revised AASHTO method were twice as big in relation to the errors that occur during the calculation in the ELMOD program.

The main reason for such large differences is a different approach to data processing, which is reflected in the fact that the ELMOD program takes into account all deflections individually at all recorded locations, while the Revised AASHTO method performes calculation with representative deflections obtained for homogeneous subsections.

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