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Studying the Structure of the Road Pavement and Specifying the Repair Method

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Abstract.

Studying the structural condition of road pavement is essential for making effective decisions about the type of maintenance or rehabilitation that will be carried out on a pavement section. Reliable quantitative assessment of the volume of necessary repairs will ensure the performance characteristics and durability throughout the entire service life at minimal cost.

This article presents detailed results from Falling Weight Deflectometer (FWD) and Ground Penetrating Radar (GPR) studies. In addition, an analysis of these results and recommendations for strengthening the road pavement for the Sh-176 "Sighnaghi-Saint Nino Monastery" road to develop rehabilitation and maintenance scenarios. FWD results combined with road pavement layer thickness and traffic load information to determine residual service life and necessary treatment type. Thus, using the nonlinear theory of layered half-space elasticity, pavement structure analyzed in the same way as other civil engineering structures.

Keywords: Falling Weight Deflectometer (FWD); Ground Penetrating Radar (GPR); layer thickness; maintenance; rehabilitation; road pavement; service life; structure.

Introduction

Road pavements are a complex engineering building, as they are suitable for operation with temporary traffic loads and permanent effects of climatic and hydrogeological factors. At the same time, the most expensive element of roads is the pavement structure.

Therefore, road pavement structural condition evaluation is quite an important and responsible task.

The Falling Weight Deflectometer (FWD) and Ground Penetrating Radar (GPR) results determine the full dynamic deflection of the bowl under standard wheel load and thicknesses of road pavement structural layers. Using appropriate analysis software, it is possible to determine the structural condition of the road pavement and residual service life quickly and accurately. The corresponding requirements for the rehabilitation or maintenance of road pavement section can be determined based on calculations of the stresses and strains in each layer. More detailed information regarding the application of FWD and GPR testing results is described later.

Design traffic loads on the road section were derived from the average annual daily traffic (AADT) counts combined with estimates of equivalent single axle load (ESAL) factors for each vehicle type.

The field survey was implemented using the Swedish firm KUAB equipment to conduct and analyze the existing condition of the Sh-176 “Sighnaghi-Saint Nino Monastery” road pavement. The measurements were carried out with an FWD KUAB 50 owned by a Georgian state agency. KUAB was selected for this task, since the Department of Roads already possesses a FWD machine manufactured by KUAB.

In addition to the actual FWD survey, a subsidiary survey was also conducted using GPR with 500 MHz and 1600 MHz antennas to provide an estimate of the existing road pavement structure along the entire length. This GPR survey was supplemented by a series of test holes across the road to provide confirmatory data on the thickness of the pavement layer.

Main Part

Investigation of Road Pavement

To assess the structural condition of the pavement, measurements were taken at the Sh-176 “Sighnaghi-Saint Nino Monastery” road. The average annual daily traffic (AADT) estimate was received from the Georgian Road Department with estimates of an equivalent single axle load (ESAL) 450 000 over a 20-year design period.

The Falling Weight Deflectometer (FWD) measurement files show test point position expressed as distance along the road from a reference point, drop number, peak load, peak deflections, air temperature, E Mod, the position measured with an EGNOS GPS, and time. E Mod is the so-called surface modulus, which is the modulus of an assumed linearly elastic, homogenous and isotropic half-space with Poisson's ration 0.5, that would get the same deflection in the center of the load plate as the actual pavement. Picture 1 bellow shows photographs taken on the road during FWD testing.

Pic. 1. Falling Weight Deflectometer FWD KUAB 50 during testing

The measurements were made in the wheel path close to the pavement edge, approximately every 100 m in both directions. The maximum peak load used was about 50 kN, and the rise time about 23 ms. The diameter of the load plate was 300 mm, and deflection sensors were placed 0, 200, 300, 450, 600, 900 and 1200 mm from the load plate center. Fig. 1 bellow show the deflections at 0, 300 mm from load plate center.

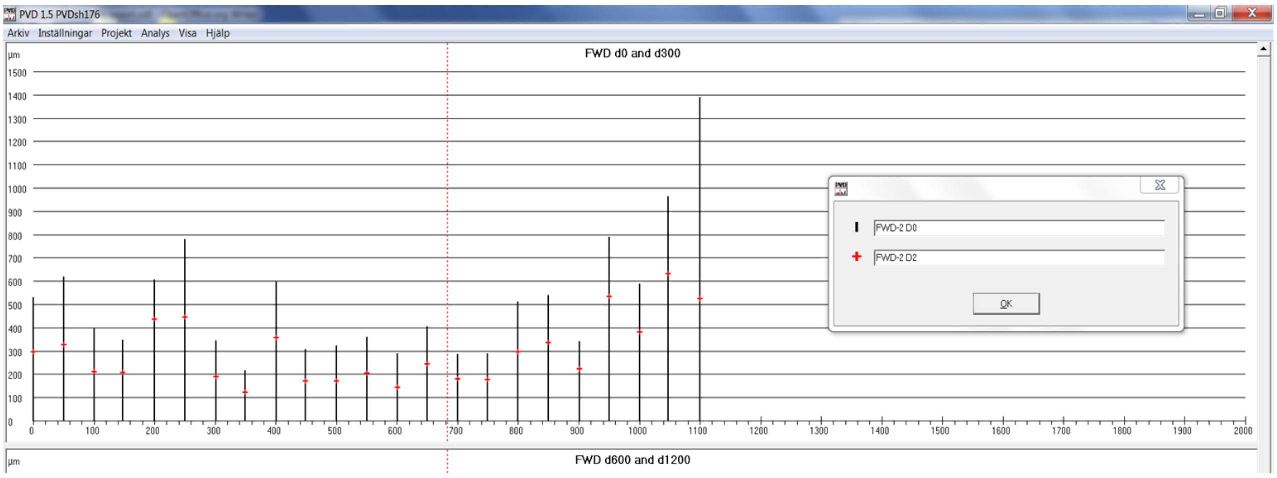

Fig. 1. Deflections at 0 and 300 mm from load center

There is much variation in deflections along the road, mainly due to subgrade modulus variation. The deflection bowls are typical for flexible pavement. Although there is much variation, all bowls are good in relation to the anticipated traffic loading. The higher deflections at the end of the road do not indicate insufficient bearing capacity, but rather, a lack of compaction. Fig 2 shows bowls with high and low deflection.

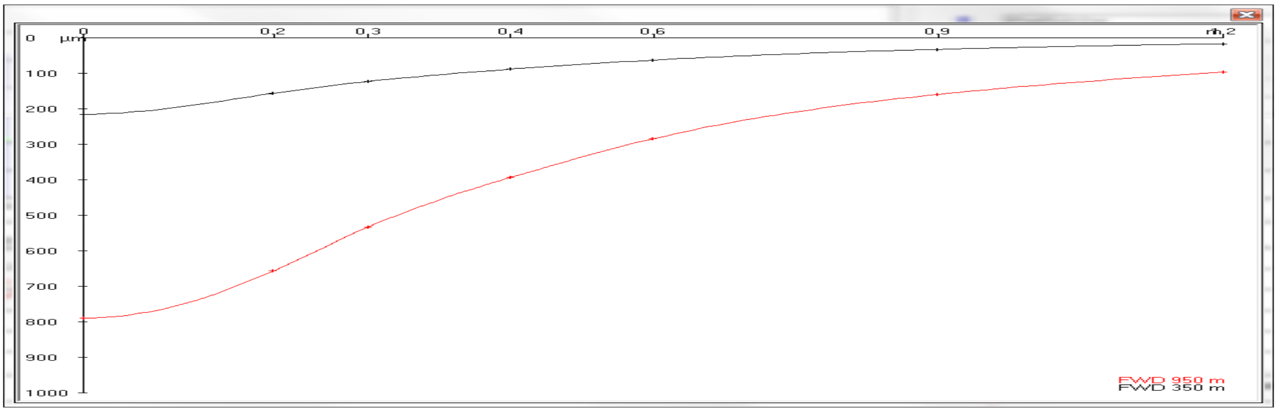

Fig. 2. Examples of deflection bowls

The Ground Penetrating Radar (GPR) layer data was recorded 10 times per meter with the high frequency antenna and 5 times per meter with the low frequency antenna. Fig. 3 shows the layer thicknesses from GPR measurement and from test pit data.

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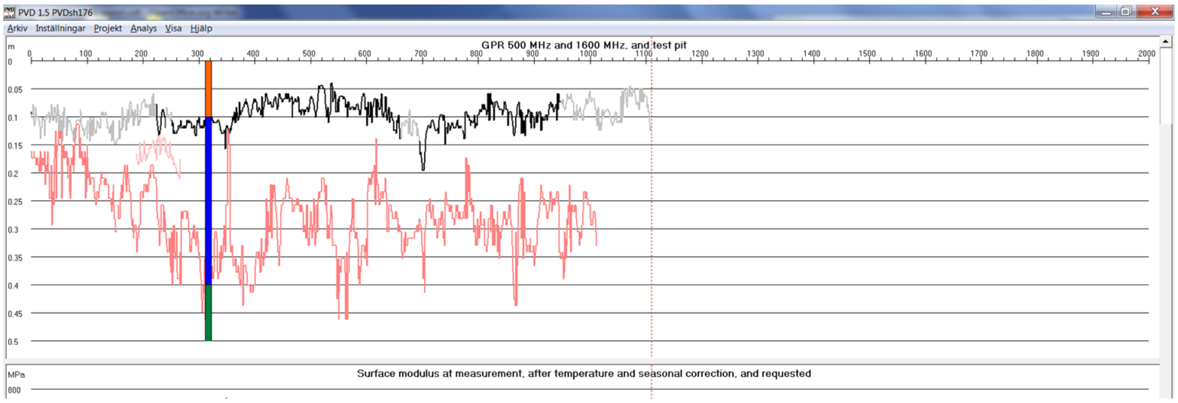

Fig. 3. Layer thicknesses from GPR and test pits

There is perfect agreement between asphalt thickness measured in the test pit and calculated with the typical propagation velocities 0.13 m/ns for asphalt. There is also a clear indication of a base layer. The colors in the diagram have no specific significance, they are just to make the layers visible.

Calculation Principle

The calculations were made with the analysis program PVD.

Two different calculation methods were typically tested on this type of road. One is the so-called MET, Method of Equivalent Thicknesses. A mathematical model of the pavement as a layered elastic structure is created, based on the information from construction records, test pits and GPR. The essential elements of the model are thickness and modulus of elasticity of each layer. In the mathematical model, the FWD load is applied and the deflections calculated. The calculated deflections are compared with the measured values, and the properties of the layers adjusted until there is agreement between the two sets of deflections. The above back-calculation is made at the actual temperature of the measurement. When the final values have been determined, the modulus of the asphalt layer is adjusted to a reference temperature with a temperature adjustment function.

In the mathematical models thus obtained the strains are calculated and compared to the criteria for strain in the different layers. Different institutions suggest different strain criteria. One set of criteria is 195 microstrain horizontal tensile strain for asphalt with 5000 MPa modulus at one million load applications, and 885 microstrain vertical compressive strain for unbound layers at one million load applications. The exponent for adjustment to actual number of load repetitions for asphalt was 5.62 and for unbound materials 4.00. These criteria are taken from the Shell pavement design manual, published by Shell research laboratory in London. Another example is from the Swedish Transport Administration, which uses the more tolerant Kingham's criteria for asphalt layers, and allows only about half the strain for subgrade. When the criteria are not met, additional asphalt layer is added in the model until the strain is small enough.

The other method is also based on equivalent thicknesses. Depending on the design traffic loading a certain surface modulus is required. If the modulus determined for the existing pavement is too small, overlay is added and the new pavement modulus is calculated with the method of equivalent thicknesses. Two calculations are made, one with an asphalt overlay on existing pavement, and one where the current pavement is used as subbase and a base of calculated thickness and an asphalt layer of fixed thickness are added. Fig. 4 shows the pavement modulus under measuring conditions, the modulus after correction for temperature and season and the required modulus 175 MPa.

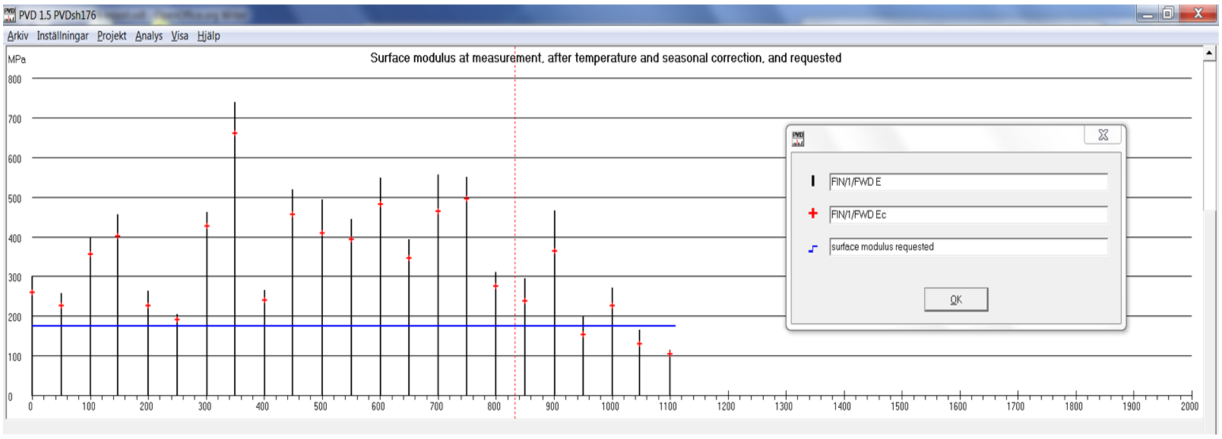

Fig. 4. Surface modulus at measuring conditions, surface modulus after correction for temperature and season and the required surface modulus

The former method is more exact if the materials and thicknesses are well known, while the second is more tolerant to variations and deviations between the real pavement and theoretical assumptions.

Conclusion

Based on the above results, the following conclusions can be made:

- With conventional flexible pavement and typical material properties, this modulus can be sufficient for traffic up to about 600 000 ESAL. The traffic is in this case substantially less, but if the modulus of a road with asphalt pavement is below 175 MPa there is a risk of direct damage by heavy trucks, so 175 MPa is recommended as a minimum even when design traffic is substantially less than 600 000 ESAL.
- This method shows that there are some parts with adequate strength. However, the method is based on average conditions, and tends to overestimate the problems on weak subgrade. Because of this, and because of the risk of reflection cracking it is recommended that the asphalt on the entire length should be ground and mixed with the material below, and that a base of good crushed stone should then be added and surfaced with 5 cm asphalt concrete.
- There may be short sections of road where patching with surface dressing would be sufficient, but there are not enough savings to be made to justify such short variations in the strengthening.

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ანოტაცია. საავტომობილო გზის მონაკვეთის მოვლა-შენახვის ან რეაბილიტაციის ტიპის შერჩევის შესახებ ეფექტური გადაწყვეტილების მისაღებად აუცილებელია საგზაო სამოსის სტრუქტურული მდგომარეობის შესწავლა. ამასთან, საჭირო სარემონტო სამუშაოების მოცულობის განსაზღვრა უზრუნველყოფს საგზაო სამოსის საჭირო საექსპლუატაციო მახასიათებლებსა და გამძლეობას, მინიმალური ღირებულების პირობებში. წარმოდგენილია ვარდნილი ტვირთის დეფლექტომეტრის (FWD) და გრუნტის პენეტრაციის

რადარის (GPR) კვლევების დეტალური შედეგები. ასევე ანალიზი და რეკომენდაციები შ-176 „სიღნაღ - წმინდა ნინოს მონასტრის“ საავტომობილო გზის რეაბილიტაციისა და მოვლა-შენახვის სცენარის შემუშავებისთვის. FWD შედეგები კომბინირებულია საგზაო სამოსის კონსტრუქციული ფენების სისქის მონაცემებსა და სატრანსპორტო დატვირთვის ინფორმაციასთან, რათა დადგინდეს ნარჩენი მომსახურების ვადა და განისაზღვროს საჭირო სარემონტო სამუშაოების ტიპი. ამრიგად, შრეებრივი ნახევარსივრცის ელასტიკურობის არაწრფივი თეორიის გამოყენებით, საგზაო სამოსის სტრუქტურა გაანალიზებულია ისევე, როგორც სხვა სამოქალაქო საინჟინრო ნაგებობების სტრუქტურები.

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