Validation of FWD Measurements in Connection with Outsourcing Contract

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ABSTRACT: In the spring of 2000 Ribe County decided to outsource part of the road maintenance work.

A work group was established consisting of representatives from counties and contracting companies in order to work out procedures, terms and conditions for outsourcing of road maintenance and in order to determine, which parameters could be used for quality assurance. In Denmark the bearing capacity was selected as one of the parameters for quality assurance. The bearing capacity was to be measured by means of a falling weight deflectometer (FWD).

In order to find out, how these values could be of benefit, a decision was made to start a test project in order to determine the degree of repeatability of the FWD measuring procedure. The testing results were to form the basis of the procedures, terms and conditions to be set up for the use of bearing capacity measurements performed by means of FWD in connection with outsourcing contracts.

This paper will present the testing part dealing with repeatability and the season variations in the calculated residual life and reinforcement needs.

1 PROJECT DESCRIPTION

A road section of 5 km was selected for the project on a highway in Ribe County, Denmark, as this county had decided to outsource the maintenance of the road.

Bearing capacity measurements with FWD (Phønix/Carl Bro equipment) were carried out on the section in May 2000. The reinforcement needed was calculated with the precondition that the residual life to be obtained should be 15 years. These calculations were enclosed the tendering documents as support documents.

Icopal (now Lemminkäinen A/S) was awarded the outsourcing contract.

In June 2000 Ribe County contacted Carl Bro A/S, Pavement Consultants (CBPC) with a proposal to enter into cooperation about the test project. This proposal was accepted.

Ribe County, the work group and CBPC decided to carry out bearing capacity measurements once a month for a period of minimum 12 months. The measurements started in July 2000. The testing project was extended with two reference sections in continuation with the outsourced section. Sounding pipes were installed to determine the groundwater level at intervals of 500 meters.

Table 1. The originally planned measuring calendar. Measurements in outer wheel track (repeated) were only to be carried out in the first month provided that the obtained repeatability accuracy was acceptable

Year	Month	FWD measurements in outer and inner wheel track	FWD measurements in outer wheel track repeated	Groundwater level soundings	Water in shoulders %
2000	July	x	x	x	x
	August	x	(x)	x	x
	September	x	(x)	x	x
	October	x	(x)	x	x
	November	x	(x)	x	x
	December	x	(x)	x	x
2001	January	x	(x)	x	x
	February	x	(x)	x	x
	March	x	(x)	x	x
	April	x	(x)	x	x
	May	x	(x)	x	x
	June	x	(x)	x	x

FWD measurements were carried out at intervals of 100 m in all wheel tracks so that the measuring points in the outer and inner wheel tracks were made in the same chainaging but with shifting of 50 m between measuring points in both traffic directions. A total of 270 measuring points were registered. The measurements were carried out with a FWD from Phønix/Carl Bro as – PRI2109 equipment. The equipment was calibrated according to the calibration procedures used in Europe and worked out by the Centre for Research and Contract Standardisation in Civil and Traffic Engineering (C.R.O.W.). René Clemen has described the procedures in his paper presented at the BCRA conference in Trondheim in 1998 [1].

According to the measuring calendar (fig. 1 above) measurements should be repeated in the outer wheel tracks every month because some of the persons in the work group did not trust the repeatability of the measuring equipment. The procedure was changed after the work group had seen the results of the measurements made in July 2000 (fig. 3).

All measuring points were marked on the lanes and reference points were set up in the shoulder area. The distance between reference point and measuring point was measured as a control feature.

The measurements in May, July, August and September 2000 were carried out on the old road surface. The paving work was then carried out as appears from figure 1 below.

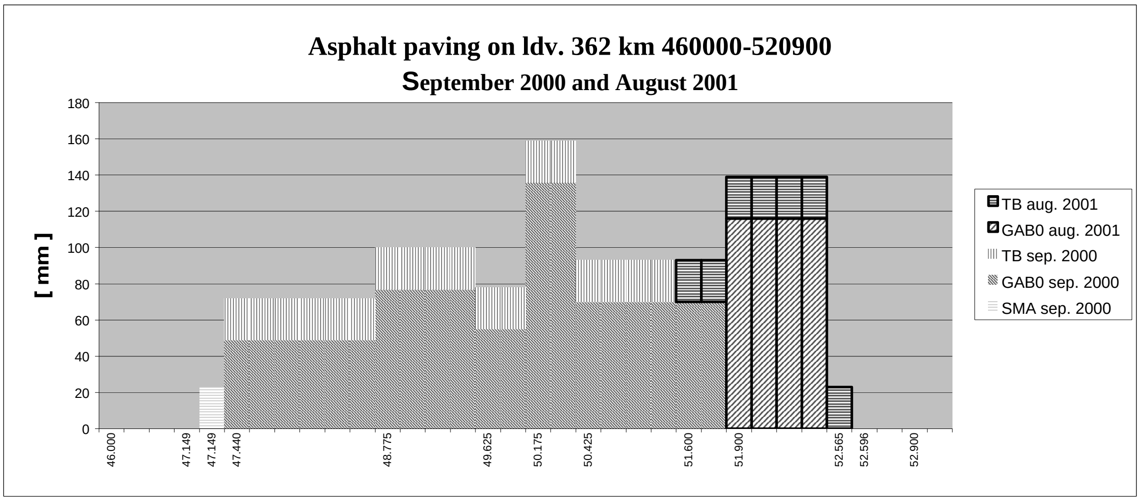

Figure 1. Chart of reinforcement works – new overlay

Lemminkäinen A/S did not carry out reinforcement work on the section between chainage 510900 to 520550 without reinforcement in spite of the fact that it needed a reinforcement of 105 mm. The reason for this was to have a reference section, which had not been reinforced. In this way it would be possible to see the accelerated deterioration at the end of the structural life of the section. A new overlay was paved on the other sections in September 2000 and the monthly bearing capacity measurements were continued.

2 CALCULATION

All deflection bowls measured with the FWD were processed in RoSy Design [2], the backcalculation program for determination of E moduli developed by CBPC.

On the basis of the calculated E moduli, existing layer thickness data and traffic data from 1999 the reinforcement needed to obtain a residual life of 15 years was calculated for all months.

The reinforcement calculations were based on the equivalent thickness method and the criteria appearing from figure 2 below. This complies with the Danish standards for calculation of reinforcement layers and is described in Note 187 “Edp-programs for the Falling Weight Deflectometer by the Hewlett Packard 85 – Computer” [3].

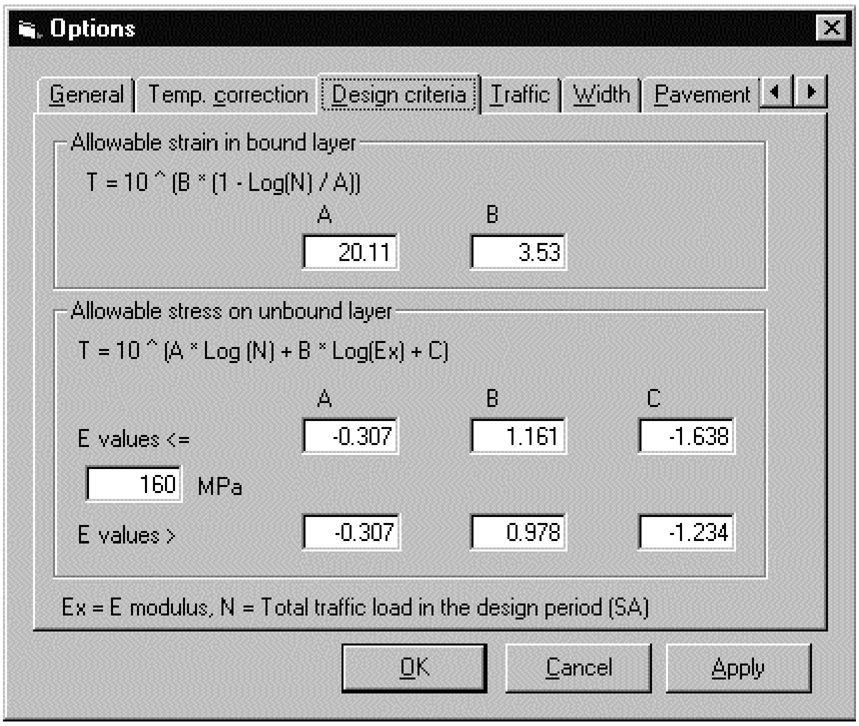

Figure 2. Criteria for calculation of reinforcement need

After calculation of reinforcement need and structural remaining life, the data was imported to a spreadsheet for later statistic analysis.

The first statistic analysis of data was to divide the test section into subsections with uniform bearing capacity. This was done on the basis of the calculated reinforcement that was based on the measurements made in May 2000.

The reinforcement need per section was calculated as the average value for the section plus two thirds of the spreading for the section (the 75 quantile).

The plan for the measurements to be conducted in the month of July included repetition of measurements in the outer wheel track at an interval of two hours. This was done to test the repeatability of the equipment and the calculation programs. The reinforcement need was then calculated on the basis of the two sets of data and the results were compared. The results appear from figure 3 and table 2.

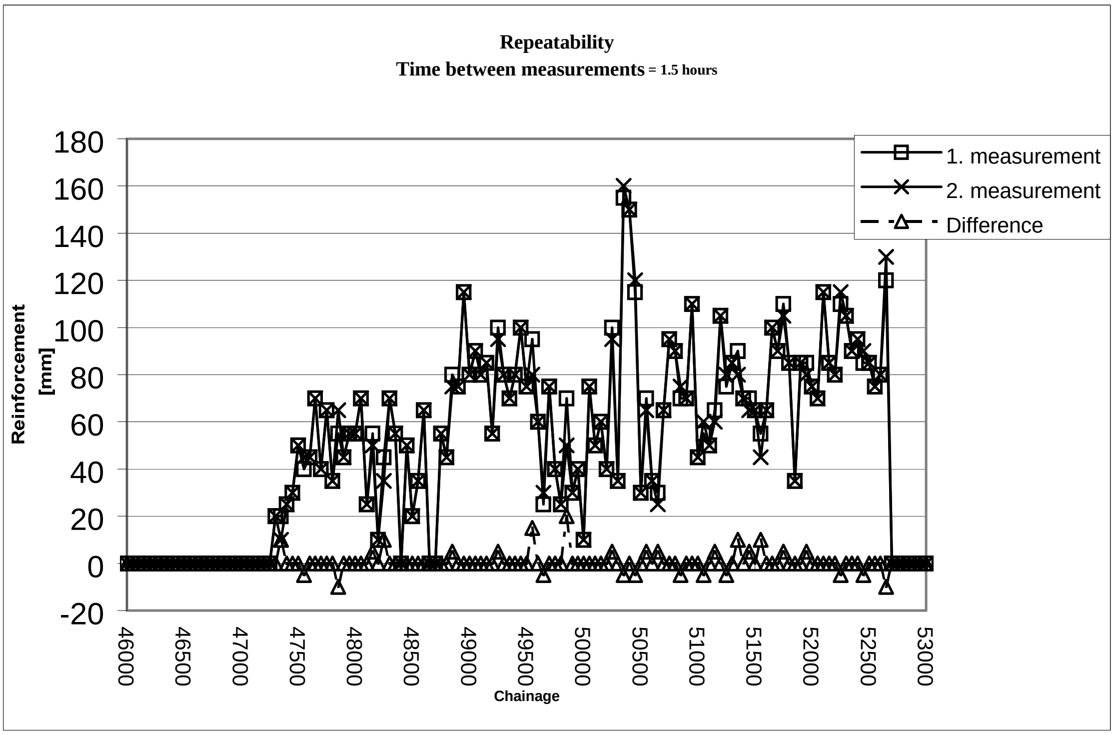

Figure 3. Graphic presentation of calculated reinforcement thickness based on repeated measurements in the same points at intervals of 1.5 hours.

From the chart above appears that from first to second measuring round 8 of the 141 points show variations in reinforcement layer thickness larger or equal to 10 mm. On comparing the average value and spread of the entire section (Table 2) the deviation turned out to be less than 1 mm.

Table 2. Differences between the reinforcement needs calculated on the basis of measurements made at intervals of 1.5 hours.

Repeatability test: Calculated reinforcement for the whole test section							
Lane	0	0	2	2	0+2	0+2	Difference
Test No.	1	2	1	2	1	2	
Average	45	45	55	54	50	50	0.43
STDV	36.9	36.9	39.8	40.1	38.5	38.6	

On the basis of the above results a decision was made to stop the repeatability testing.

3 RESULTS

The reinforcement per section was calculated monthly based on the measurements made month after month. The results were reported to the work group. Figure 4 displays an example of reporting.

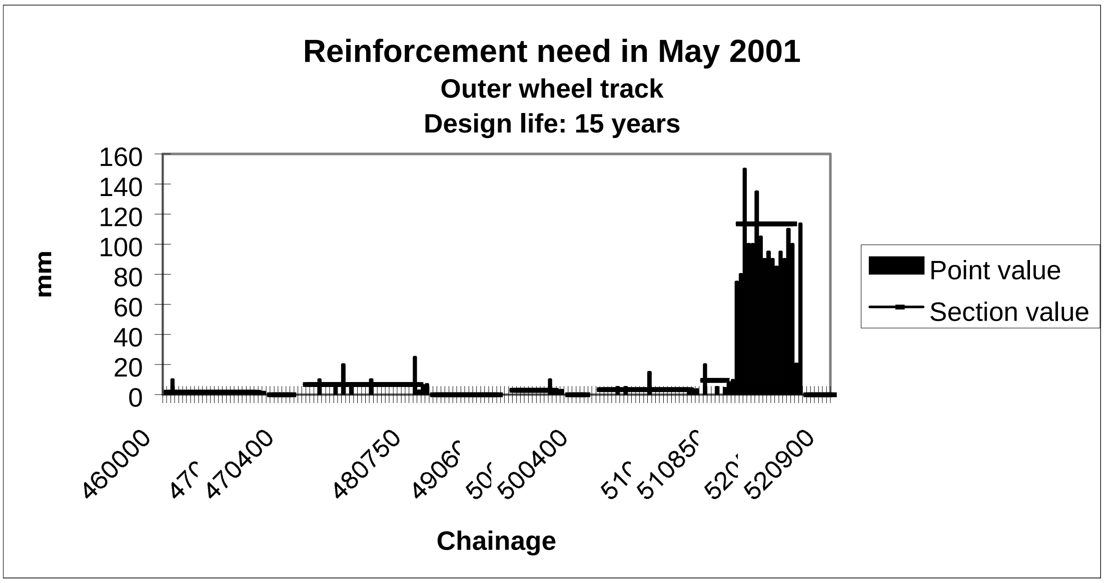

Figure 4. Calculated reinforcement need of the test section in May 2001

The measurements in May show that on the third last subsection 20 mm is lacking. This corresponds to the missing wearing course, which was not paved in year 2000. The results for the second last subsection, on which no paving works were conducted, show that the section has a reinforcement need of 120 mm asphalt.

In August 2001 the last paving works were made and the reinforcement need in September should then in theory be 0 for all sections. The reinforcement need calculated on the basis of measurements made in September 2001 appears from figure 5.

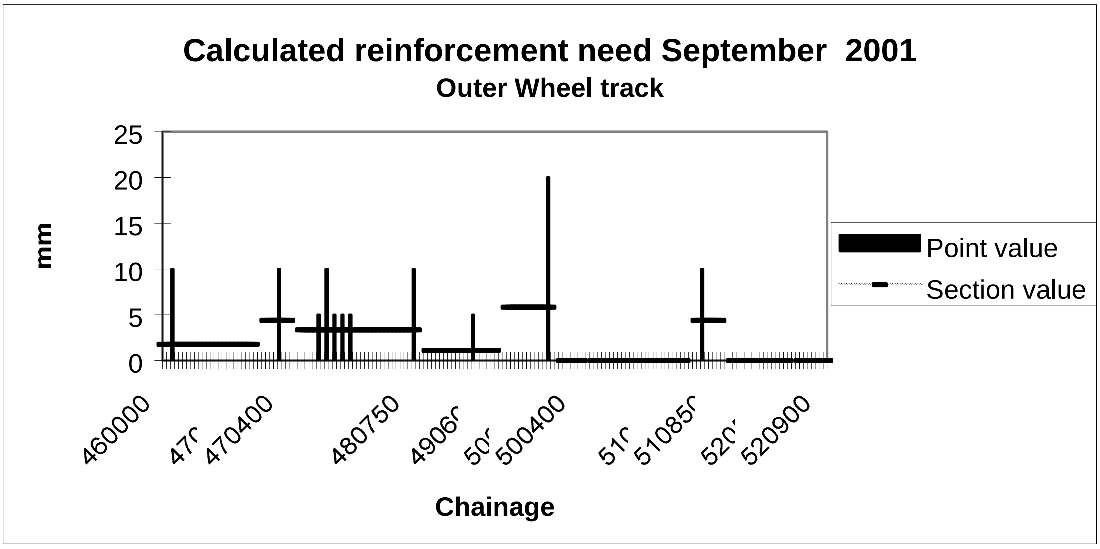

Figure 5. Reinforcement need after paving works in August 2001.

The above chart (fig. 5) illustrates that the reinforcement work carried out fulfills the requirement to obtain a residual life of 15 years. A few of the points seem to need further reinforcement. These points are identical with the points that showed a higher reinforcement need than the average in the initial design calculations.

After the reinforcement layers were laid, many points showed compliance with the requirement for a residual life of 15 years and some could show an even longer residual life. The work group thus wished to see the theoretic remaining life for the months of May and September.

These results appear from figures 6 and 7.

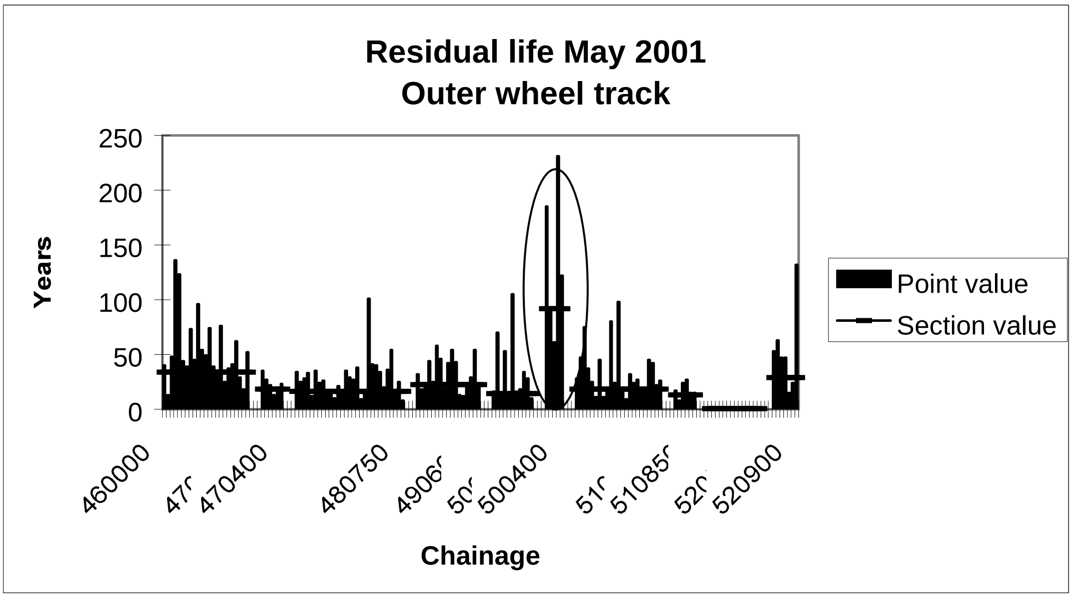

Figure 6. Residual life May 2001 – outer wheel track

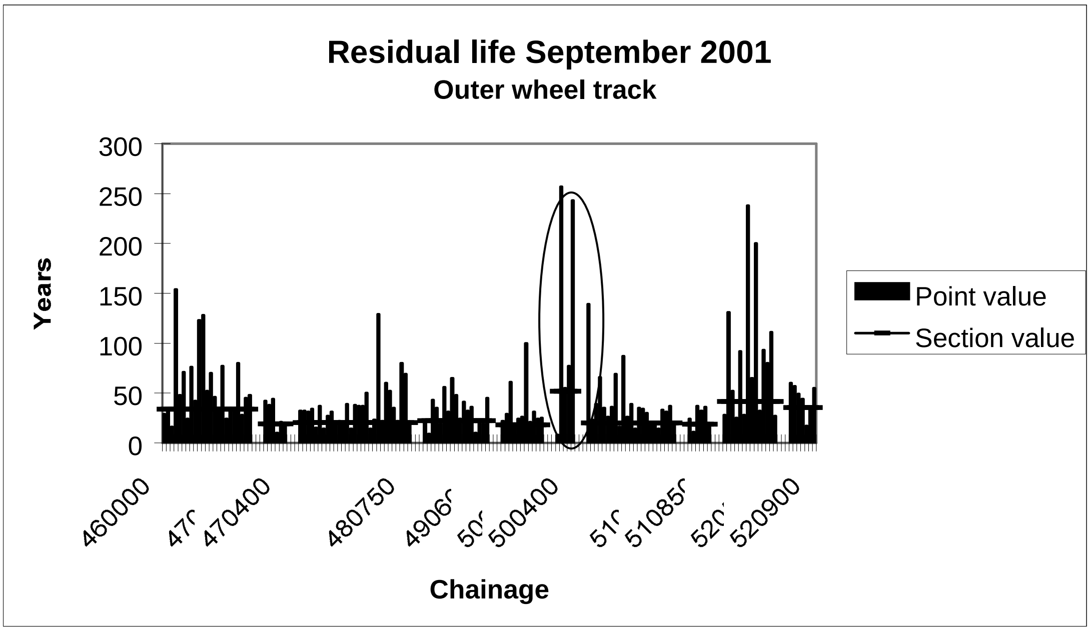

Figure 7. Residual life after paving works in September 2001.

Especially a short subsection, which is marked in the charts 6 and 7 (fig. 6 and 7), has obtained a considerably better bearing capacity than intended. This could be explained by the fact that this section had a measuring point in each end only requiring a reinforcement layer of 40 mm, but the actual laid out layer thickness was 139 mm. The surplus in reinforcement increases the residual life of the section tremendously. This was, however, unintended.

The above indicates that single points deviating seriously from the average values should be avoided when sectioning into sections with uniform reinforcement needs.

The overall result of the measurements carried out so far show that the wished improvement of the bearing capacity is obtained by laying out the calculated reinforcement layer.

The studies of how the water level would influence the road bearing capacity have not shown any variations, which could be related to rain fall or season variations.

The variation in residual life for a representative subsection during the entire measuring period compared to the water level measurements appears from figure 8.

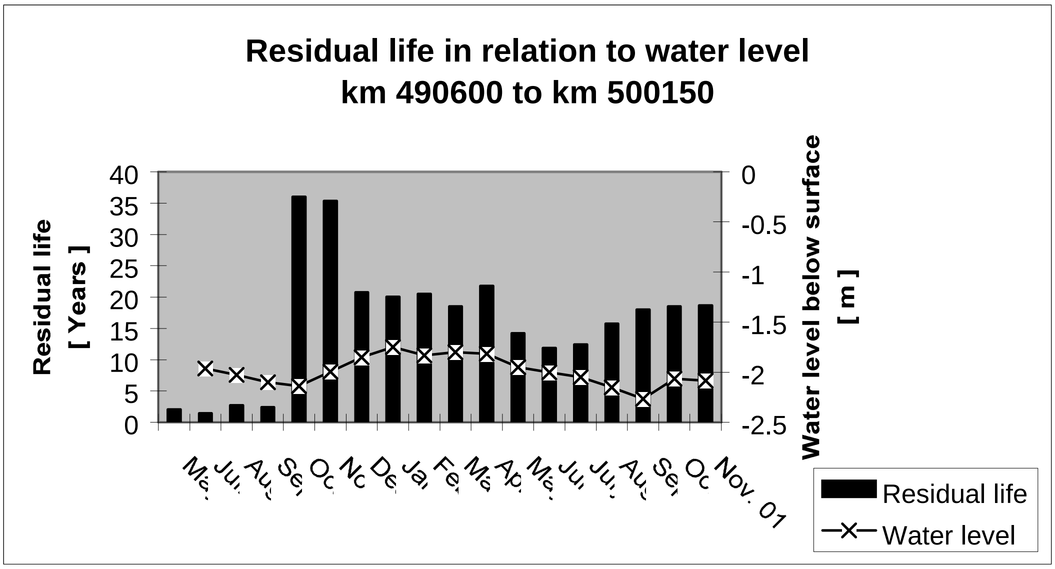

Figure 8. Ground-water level below road surface in mm related to residual life. Road section km 490600 to km 500150.

Figure 8 is representative for the main part of the road. No connection between residual life and measured ground-water levels was found. This is probably due to the fact that the ground-water level has at no time been near to the upper side of planum, which is at the level of –0.8 meters.

A tremendous increase in residual life was found in September 2000, two months after the paving of reinforcement layers. A comparison of the calculated material E moduli shows a general increase in these values. The values decrease again in the remaining months of the measuring period. So far no explanation to this development has been found.

4 CONCLUSION

The results found until 1 November 2001 prove that the use of FWD equipment for collection of data for determination of reinforcement needs is recommendable to the road agencies inviting tenders to obtain a good basis for decision-making as well as for the contractors in connection with outsourcing contracts.

A good conformity was found between the residual life before and after reinforcement paving.

Temperature correction factors for asphalt layers is a parameter in the calculation of material E moduli, and it is unknown, whether these factors are representative / the same for all asphalt layers. Measurements should be carried out as close to the design temperature as possible. Thus a decision was made only to make measurements in the months of May or September.

The measurements show no connection between the measured ground-water levels and the bearing capacity. This should, however, not lead to the exclusion of shoulder – and ditch trimming made with the purpose of leading away the water from the roadbed.

The result displayed in figure 8 shows a difference in residual life from year to year and two measurements are not sufficient to show a trend. A decision has thus been made to continue the testing project for another year.

Steps of 5 mm were applied in the reinforcement layer thickness calculations for the measuring points. This means an average surplus reinforcement of 2.5 for all sections. At the beginning of a contract period this is not a problem, but members of the work group representing contractors have said that this surplus may have very serious financial consequences if the reinforcement need is to form the basis of the decision-making as to whether or not penalties are to be paid.

A new calculation applying steps of 1 mm will thus be made of all data to see the change in calculated reinforcement thickness for individual points.

Until further notice the reinforcement need at the end of the period will not be applied for calculation of penalty amounts.

References

Clemen, René. 1998. *Guidelines for Calibration of Falling Weight Deflectometers*. BCRA '98, Fifth International Conference on Bearing Capacity of Roads and Airfields. Trondheim, Norway 6-8 July 1998 [1]

Pedersen, Jens P. 2000. *User Manual RoSy Design*. Kolding: Carl Bro AS [2]

Leerskov, Vagen; Hansen, Poul; Jensen, B. Roland. 1986. *Edp-programs for the Falling Weight Deflectometer by the Hewlett Packard 85 – Computer*. Copenhagen: The Danish Road Directorate [3]