Pavement Strengthening and Rehabilitation in Norway - Assessing the needs

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ABSTRACT: The Norwegian Pavement and Materials Design Guidelines were revised in 2005. A new system for road strengthening and pavement rehabilitation, based on an evaluation of the surfacing service life, was then introduced. In this new system the strengthening need is based on the Surfacing Life Factor (SLF). The SLF describes the relation between the functional (observed) surfacing service life and the expected surfacing service life. Depending on this factor the need for strengthening is given:
SLF above 0,7
- the required strength improvement is considered to be taken care of by the ordinary resurfacings.
SLF 0.7 - 0.5
- the required strength improvement is expressed in term of structural number values and depends on the SLF and traffic volume.
SLF below 0.5
- indicates a pavement structure with serious deficiencies and a full investigation is required.
The change has been made possible by the introduction of the Norwegian pavement management system in 1990.

KEY WORDS: Rehabilitation, road strengthening, surfacing service life, PMS, Norway

1 INTRODUCTION

In 1994 the BUAB report ("Better Utilization of the Bearing Capacity of the Roads") (Senstad, 1994) (Senstad, 1995), presenting four years of research in the field of road bearing capacity, recommended the following major changes:

- a lifting of all seasonal axle load restrictions (affecting approx 50 % of the road network)
- a change in the strengthening procedure, with focus on the obtained surfacing service life as an alternative to an analytical approach to this problem

The lifting of the seasonal axle load restrictions was politically sanctioned only weeks after the publication of the BUAB report and the results are described in (Refsdal et al. 2004). The proposed change in the system for road strengthening and pavement rehabilitation required a longer period of performance data than what was available through the PMS in 1994. However, when the Norwegian pavement design standards were revised in 2005, a new system for pavement strengthening and rehabilitation was introduced. This system was based on information from 14 years of extensive monitoring of pavement performance on road network level.

1.1 Traditional Road Strengthening Indicators

The need for road strengthening or pavement rehabilitation is commonly related to inadequate service levels for the road users in combination with excessive costs in maintaining the existing pavement structure.

The need for road strengthening was for many years based on “engineering judgement”. It was later followed by the introduction of deflection measurements (with or without backcalculated moduli), and today there is a move towards an analytical approach, taking into use the best possible knowledge of

- material characterization of the pavement layers
- existing traffic loads and predicted traffic growth
- the climatic regime

The analytical approach has been greatly improved over the last 10-20 years, and many pavement strengthening design methods are today based on field measurements with FWD’s combined with the backcalculation of layer moduli.

2 THE BACKGROUND FOR THE CHANGE

The Norwegian procedure for pavement strengthening design, as described in the new Norwegian Pavement and Materials Design Guidelines, has for a long period been based on both an investigation of the pavements structural number as well as the determination of bearing capacity or layer moduli based on deflection measurements.

During the 70’ies and 80’ies the Dynaflect equipment was in extensive use in Norway - with 18 units in use. While the use of the Dynaflects has been fading out, the falling weight deflectometer (FWD) was introduced in Norway during the late 80’ies and 90’ies, but only in a limited number, and the equipment has mainly been used for research purposes.

The use of the deflection equipment has been very useful in evaluating strengthening needs, but Norway has never adopted the analytical approach in full. This is partly based on scepticism letting material parameters represent the service life of a surfacing/pavement and partly limited funding to develop such a system.

2.1 Analytical Design Methods and its Shortcomings

Among the existing design methods for evaluation of existing road pavement conditions are:

- the structural number (index method)
- deflection measurements
- DCP investigations
- analytical methods with backcalculation of deflection measurements

The different methods often give significantly diverging answers. Analytical methods may work well, but a calibration against in situ performance is necessary.

The analytical methods require information regarding the pavement structure, as:

- layer thicknesses
- strength properties (back-calculated E-moduli or even tri-axial testing)
- particle size distribution and moisture condition
- frost susceptibility

etc.

In a country like Norway, where subgrade conditions and roadside topography is frequently changing, the frequency of sampling and testing will have to be limited due to practical reasons. But analytical methods may contribute in explaining short surfacing service lives.

2.2 Surfacing Service Life versus Pavement Design Life

In pavement design systems, emphasis has generally been placed on pavement design life. However, the surfacing service life may in many cases be used as an indicator of success in the structural pavement design process.

The pavement design life might typically be 20 or even 30 years for a flexible pavement, but at the end of the design life cycle, there will be no one around to tell whether the pavement design engineer did a good job or not. And if there was, the pavement design engineer could easily explain the discrepancies on several factors not taken into account in the original assumptions.

The surfacing service life is a parameter closely linked to costs. With the new possibilities to obtain the surfacing service life, as provided by the pavement management system at project level, it is tempting to utilize this more extensively, also as a bearing capacity parameter. However, this will require a link between the expected and the observed surfacing service life. The observed surfacing service life is derived from the PMS registrations. The expected surfacing service lives is found from accumulated data in the Norwegian Road Data Bank (RDB) over years with PMS registration on the road network, see Table 1.

All analytical/mechanistic design systems have to be calibrated against in situ performance. Such systems therefore represent an indirect way of providing an answer. On the other hand, the PMS gives us an answer directly from the in situ conditions in the form of a real surfacing service life.

The advantage of using the surfacing service life as a parameter for pavement strength is that

- it reflects performance, which is the main demand for the road user
- it provides a direct link to economy

3 THE BASIS FOR CHANGE: THE NORWEGIAN PAVEMENT MANAGEMENT SYSTEM

3.1 The Norwegian Road Network

The Norwegian main national road network comprises approximately 26000 kilometers, of which 7000 kilometers are trunk road and 100 kilometres are multilane motorways. In addition there are about 27000 kilometers of county roads and 37000 kilometers of municipal roads.

All national roads are now paved, while 20 % of the county roads still have gravel surfacings. The current average pavement surfacing age is 8.2 years for national roads and 9.9 years for county roads.

Approximately 30 % of the annual maintenance budget of 3800 million NOK (about US$ 550 million) of the national roads is spent on pavement strengthening and rehabilitation.

3.2 Philosophy of the Project Level Pavement Management System

A brief presentation of the Norwegian Pavement Management System (Gryteselv et al. 2001) is given here:

The Windows-based system utilizes all available data from the Road Data Bank and presents the data for the users in a format that makes it easy to make correct decisions when producing plans at project level. The PMS is used primarily by the regional pavement engineers to plan resurfacing works at the project level and also at project selection levels for a 6-year period. The main focus is on making and adjusting plans for the next 1-2 years so that budgetary constraints are met. This helps the engineers make the right decisions concerning location, timing and extent of future resurfacing works within their region.

3.4 Data Collection

Performance data for the road network is collected with the ALFRED measuring system, see Figure 1. There are 13 ALFRED vehicles in operation, one for every 4000 kilometers of roads. The vehicle is equipped with:

- a dual beam of 17+1 ultrasonic transducers, spaced at 125 mm
- a sensor unit carrying gyros, accelerometers, inclinometers and a laser distance sensor
- a high precision tachometer, an instrument computer and an operators computer

Figure 1: The ALFRED measuring vehicle.

The measuring system produces

- detailed rut depth data
- detailed International Roughness Index (IRI) data, as well as
- cross profile, cross fall, horizontal radius and longitudinal profile

Data are collected for every meter.

In addition, a digital camera system (VidKon) is utilized to capture photos every 20 meters of road. An example of a screenshot from this system is shown in Figure 2. Any site can be seen from both directions if desired. The photos are extensively used to check damages like potholes, cracking etc.

The collected performance data is transferred from the computer to the central Road Data Bank (RDB). These data are further on imported into the PMS database. A simple

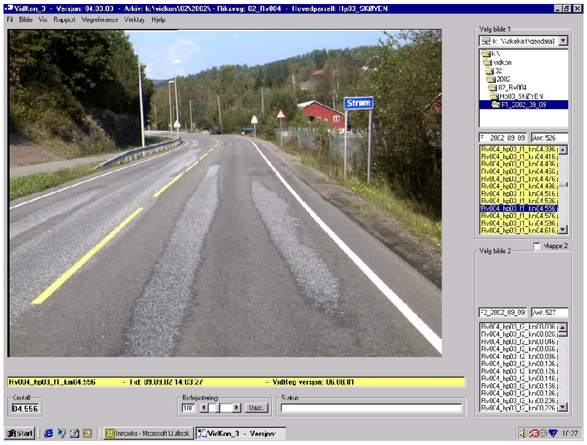

Figure 2: Example of screenshot from the digital road photo system, VidKon.

screen gives the users an overview of the PMS sections, which varies from a few hundred meters to several kilometers. Specific sections may be studied in detail, either as the historical development of rutting and roughness, as shown in Figure 3, or the detailed condition (rutting, roughness and cross-fall) along every 20 meters of the section (not shown here).

Performance data for each section as in Figure 3 are presented as the "90/10-percentage" value, i.e. 10 % of the section is of a substandard condition. These graphically presented data are used together with photos and other information of the specific road section to produce plans for resurfacing within a region.

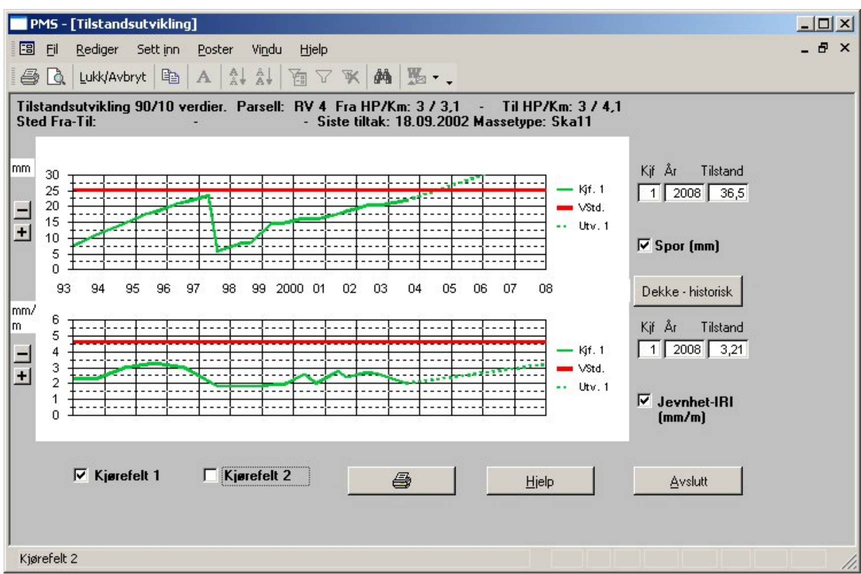

FIGURE 3: The historical and predicted development of rutting (top) and roughness (bottom) for a specific road section over the period 1993 - 2008. The red lines are target values.

This Pavement Management System has been implemented in all the five regions of the Norwegian Public Roads Administration. The utilization of road performance data is considered to be a considerable improvement for the regional pavement engineers, assisting them in the planning of resurfacing works.

Surfacing Service Life

The presentation of performance development for rutting and roughness in Figure 3 allows the determination of the surfacing service life of the existing surfacing, i.e. the period from the laying of the surfacing until the target values for rutting or roughness have been reached.

On the national road network rutting is in most cases the determining parameter for resurfacing. On the county road network roughness is more likely to be critical.

4 THE NEW NORWEGIAN SYSTEM FOR PAVEMENT STRENGTHENING AND REHABILITATION

4.1 The Need for Pavement Strengthening or Rehabilitation

Pavement strengthening or rehabilitation is considered when

- the surfacing service life is unreasonably low, or
- the allowable axle load shall be increased

The aim of a strengthening is normally to upgrade a new road in order to achieve a surfacing service lives as expected from a new road. Another case is upgrading of an existing road in order to increase the allowable axle loads..

The system gives an answer to whether there is a need for strengthening or not, as well as the additional pavement strength required. The type of strengthening method has to be addressed separately, and evaluated using traditional field measurements and sound engineering judgement.

4.2 Assessing the Need for Strengthening

On road sections where the surfacing service life is unacceptable short, the strengthening need is established based on the Surfacing Life Factor (SLF).

Definitions
SLF = the relation between the *functional (observed) surfacing service life* and the *expected surfacing service life*.
Functional surfacing service life = the service life that can be observed/estimated until target performance parameters are reached
Expected surfacing service life = the service life that should be expected on a correctly designed road, depending on surfacing type and traffic volume

This procedure requires that the expected surfacing service life can be derived. Table 1 shows the present expected surfacing service lives for new roads in Norway according to accumulated data in the RDB. Local experience can call for the use of other an alternative estimate of "acceptable" surfacing lives, but this will be a modification according to sound engineering judgement.

A low surfacing service life indicates a defect in the pavement construction. This could be due to a generally substandard design, or caused by deficiencies in the pavement calling for other remedies than just a new surfacing, even if the SLF only calls for this. For SLF's below 0.7 an evaluation of the pavement structure is therefore required to identify the deficiencies in the structure and the strengthening needs in order to achieve a reasonable surfacing service life.

Table 1: Expected surfacing service lives (years) for typical flexible surfacings in Norway.

	Expected Surfacing Service Lives for flexible surfacings in Norway (years)						
	AADT						
Surfacing type	< 300	300 - 1500	1500 - 3000	3000 - 5000	5000 - 10000	10000 - 15000	> 15000
Stone mastic asphalt	-	-	-	-	9	7	6
Asphalt concrete (type I)	-	-	13	11	8	6	5
Asphalt concrete (type II)	-	13	12	-	-	-	-
Asphalt concrete with soft binder	14	12	10	-	-	-	-

Surfacings with Surfacing Life Factors above 0.7
The required strengthening is based on Table 2. When SLF > 0.7, the required strength improvement is expected to be taken care of by the ordinary resurfacing.

Surfacings with Surfacing Life Factors 0.7 -0,5
The required strengthening is based on Table 2. However, the required strengthening should be verified by material sampling and an evaluation of pavement deficiencies.

Surfacings with Surfacing Life Factors below 0.5
A Surfacing Life Factor below 0.5 indicates a pavement structure with serious deficiencies. Such a pavement is generally substandard in many aspects, or the materials in one or more of the pavement layers may be of substandard quality. The root of the problem will normally be identified through sampling and testing of pavement materials and an evaluation of pavement structure deficiencies. In addition both deflection measurements and DCP/CBR testing may contribute to a correct evaluation of the pavement structure and the need for strengthening.

Table 2: Strengthening needs related to Surfacing Life Factor (SLF).

	Strengthening needs related to Substandard Surfacing Service Lives (additional pavement structural index required) 1)			
	Traffic group (million 10 tons ESAL's)			
Surfacing Life Factor 2)	**< 0,5 million**	**0,5 - 1 million**	**1 - 2 million**	**2 - 3,5 million**
f = 0,8	6	6	7	8
f = 0,7	9	9	10	11
f = 0,6	12	13	14	15
f = 0,5	15	17	18	19

1) a structural index of 3 is equivalent to 1 cm of asphalt concrete - 1 is equivalent to 1 cm of sub-base material
2) the relation between the functional surfacing service life and the expected surfacing service life.

4.3 Other Effects than Bearing Capacity

A short surfacing service life may be caused by factors affected by other conditions than poor bearing capacity, and such conditions will have to be excluded in the evaluation process. These factors may include

- problems related to the surfacing itself
- frost heave problems

Deficiencies related to the asphaltic surfacing itself, should be detected during the construction quality control or the warranty period (3- 5 years). Also earlier history of surfacing performance, which can be obtained from performance history (Figure 3), can contribute to a clarification of this.

Premature resurfacing can also be caused by frost heave problems. Such problems will normally be possible to identify, and should be handled separately. Frost problems related to the base layer and the presence of water susceptible materials, should still be handled as a strengthening task.

4.4 Other Considerations

Due to gradual improvements in material technology and construction techniques, change in policy, for instance regarding the use of studded tires, change in target values for performance parameters (rutting and roughness) etc, the expected service lives, as presented in Table 1, may be revised.

The present Norwegian design catalogue for new roads does not consider climatic differences, but a differentiation of expected surfacing service lives due to climatic conditions may be taken into consideration in a later revision.

4.5 The Need of Strengthening is One Thing - What To Do is Another

The system described here, based on the evaluation of the surfacing service life, is used to evaluate the need for strengthening, i.e.

- whether there is a need for strengthening or not , and
- the extent of the required strengthening

While the need for and the extent of the required strengthening can be established through the Surfacing Life Factor (SLF), there are many options in the selection of strengthening method. If the pavement structure is just too thin, adding strength at the top of the pavement may be a reasonable solution. When there is a material quality problem is in the base layer, or even deeper in the construction, the most cost-effective solution may be to improve these substandard parts of the pavement, for instance by milling and stabilisation.

The correct type of strengthening is obtained by an investigation of the reason for the short surfacing service life. This includes the following methods:

- sampling and testing of materials in the pavement layers
- DCP measurements
- deflection measurements
- georadar

and other types of investigations.

5 CONCLUSIONS

A new approach has been introduced in the revised Norwegian Pavement Design Guidelines from 2005. This approach involves the functional (observed) surfacing service life as an input parameter for the need for and design of strengthening and rehabilitation. Observed surfacing service lives has been used by practitioners for years, but is now adopted in the design system expressed by the parameter Service Life Factor, SLF.

Norway will in the future definitely also pursue an analytical design method, but such a system could be looked at more as a supplement to this performance based system to explain pavement behaviour or short surfacing service lives for particular road sections.

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