SHRP (Strategic Highway Research Program) related research in the Nordic countries

Papers presented at an "International Workshop" in Alexandria VA, USA 21st-23rd May 1986
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FOREWORD

Between 1958 and 1960 the AASHO Road Test was conducted in the United States. The main purpose of these full-scale road tests was to learn how different axle loads affect road deterioration. The findings of this project have been substantially incorporated in a number of mechanical-empirical and semi-empirical techniques for dimensioning road pavements, principally through application of the well-known power law and fatigue philosophy.

Not only in the US and Europe, but also in other parts of the world, a great part of the paved road networks have reached an age where extensive maintenance and strengthening activities are required. These circumstances indicate a pressing need for a so-called road maintenance AASHO.

Effective maintenance of pavement requires know-how concerning the expected useful life, the cost and the feasibility of each activity.

To increase competence within this area, a far-reaching R&D program called Strategic Highway Research Program, SHRP, has been set up in the US. The research program spans over six technical areas, one of which is Long Term Pavement Performance, LTPP. The total federal cost of the project is estimated to be around 150 million USD. Extensive support, especially locally but also on a regional basis, will be contributed within the framework of the LTPP plan.

The subprojects have a five-year horizon except for the Long Term Pavement Performance project which is expected to continue for the next twenty years. Within the framework of this latter subproject, 3,000 stretches of road will be selected throughout the geographic US for research surveillance. The sub-project will devote special interest to pavement constructions and the useful life resulting from maintenance activities; the surveillance will cover different types of traffic and climatic conditions.
This long-term subproject has drawn considerable international interest, not least in Europe. A number of European countries will participate in the project in various ways. In the Nordic countries, a LTPP Group has been formed to organize and coordinate participation and to designate road stretches for research surveillance. This work will be carried out in each of the participating Nordic countries and through an observer stationed at the SHRP secretariat, Washington DC.

In May 1986 in Alexandria VA, an International Workshop was held within the framework of the SHRP project. At this workshop, each of the representatives from the Nordic LTPP group held a brief talk. This document contains summaries of these talks.

Linköping, Sweden
August 1987

Hans Sandebring
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THE NATIONAL ROAD LABORATORY

Organization:
The National Road Laboratory (NRL) is a research and service laboratory working for the Danish road sector. NRL is a part of the Road Directorate under the Ministry of Public Works.

Field of Operation:
NRL's principal objective is to develop and apply suitable road materials, methods and measuring equipment in relation to the physical structure and use of roads.

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The present paper was presented by Mr. H.J. Ertman Larsen, Head of Pavement Institute, NRL:

Graduated with M.Sc. in Civil and Structural Engineering from the Technical University of Denmark, 1969.

Member of the OECD Scientific Expert Groups on "Second Generation Investment, Maintenance and Management of Pavements", and "Road Assessment Strategies for Developing Countries", Member of the PIARC Technical Committee on Flexible Roads", Member of the working group "Operations of Roads" under the Nordic Association on Road and Traffic Engineering. Chairman of and participating in different Danish working groups on i.a. operation and maintenance.
INTRODUCTION

Mr. Chairman!

It is a great honour and sincere pleasure to be here. I will go right ahead due to the time limit to give you some ideas of trends and needs in road transport research and development in Denmark and to point out SHRP related activities going on in Denmark. However, in order to appreciate our needs, I will give you a very few basic data concerning our present situation.

Denmark of course, is a very small country of about 17,000 km² i.e. about twice the size of Massachusetts. It has 5 million inhabitants, a car density of about half the one of the United States, but a very dense road network like e.g. the United Kingdom.

<table>
<thead>
<tr>
<th>road admin.</th>
<th>type of road</th>
<th>length km</th>
<th>transport bill.veh.-km</th>
<th>expenditure mill. D.kr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>state</td>
<td>motorways</td>
<td>500</td>
<td>9.7</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>major roads</td>
<td>4,100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 counties</td>
<td>regional roads</td>
<td>6,900</td>
<td>5.7</td>
<td>1.1</td>
</tr>
<tr>
<td>273 boroughs</td>
<td>local roads</td>
<td>58,200</td>
<td>12.4</td>
<td>4.1</td>
</tr>
<tr>
<td>total</td>
<td></td>
<td>69,700</td>
<td>27.8</td>
<td>7.2</td>
</tr>
</tbody>
</table>

Figure 1: Public roads in Denmark.

Figure 1 shows the number of public roads in our country. Altogether some 70,000 kilometers = 43,000 miles, all paved. The yearly value of road transport is about 6 bill. US$. The yearly expenditure by the government into road research is about 4 mill. US$.

Road research was formally commenced in our country 1928, when the National Road Laboratory was established by an Act of Parliament on request from counties and local authorities. They felt a need for a scientific background for their work, yet an assurance of practical applicability of research results. Thus the laboratory has always dealt with R&D and at the same time rendered services and consultancy to highway authorities.

The close link between research and consultancy activities is strongly visible in this simplified organizational chart of the government Road Directorate.
In fact the Road Directorate is responsible for planning, construction and maintenance (incl. rehabilitation) of the national or main road network of about 3000 miles of highways and motorways.

The Road Directorate undertakes or sponsors 80% of R&D related to road transport in Denmark. Basic input to the R&D comes from our technical divisions, practical experiences and needs, and from consultancy work of our research towards local highway authorities and the road industry and of course from research itself. The organizational structure also assures quick implementation of results or testing of ideas in practice. Of course such an organization also has drawbacks, but I feel we have managed to use the strong sides.

One cornerstone in our research work thus is the organizational set-up and interaction between highway administrations and research, both recognizing the need for the other part.

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**Figure 2:** Organizational chart of the Road Directorate in Denmark.

**Figure 3:** Kilometre pole.
The second cornerstone is the Road Data Bank (RDB), initiated 1972 and in use since 1978 on all main and country roads.

Figure 3 showed a pole along a road indicating a specific station or chainage i.e. the physical appearance of our reference system, one of the basic elements of the road data bank.

![Diagram of Road Data Bank](image)

Figure 4: The Road Data Bank.

The four basic elements of the RDB are shown above. I shall not go into any detail, but only stress that the road data bank today forms the basis for our highway administration and for analysis and background for research.

The road data bank today contains five registers, each holding 25-50 parameters. The RDB is currently updated and gives many ways and means of drawing upon its data and a combination of data. The RDB, of course, is also being further developed.

The Road Standards are a third cornerstone of our research. They are based on research and experience, like those of most other countries. Through the use of the standards we gain more experience which again gives rise to new research problems.

Figure 5 shows the significance of the standards compared to most others that very often deal with design of major roads only.

### Design Standards

- **Apply to all** kinds of roads
- **Relate to all** phases of road administration i.e. planning, design, construction and maintenance
- **Suggest range of choices and state the consequences** (economic, environmental, safety aspects)
- **Guide through advice** (can - 90%), recommendation (ought - 8%) and rules (must - 2%)

![Diagram of Design Standards](image)

Figure 5: Design Standards.

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Of course other factors influence our research work; of which not least international cooperation should be mentioned.

TRENDS

Trends we notice these years are shown on Figure 6 all giving rise to R&D activities:

Trends in road administration

<table>
<thead>
<tr>
<th>Present</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Ownership</td>
<td>• User service</td>
</tr>
<tr>
<td>• Company costs/revenues</td>
<td>• Social costs/benefit</td>
</tr>
<tr>
<td>• Traffic registration</td>
<td>• Traffic management</td>
</tr>
<tr>
<td>• Low technology</td>
<td>• High technology</td>
</tr>
</tbody>
</table>

Figure 6: Trends in road administration.

Ownership to service

We have to some extent regarded the roads as "ours". They should be nice and clean and traffic was really a nuisance. Design and construction was our engineering job. Who would not like to say to his grandchildren: "Grandfather designed this motorway!" Those times are gone. Now our aim is to satisfy needs of travellers i.e. to provide a transport system i.e. the road infrastructure, service areas, route maps, 24 hours information service on road conditions through radio and television or free calls from our cafeterias along the road.

Business costs - social costs

Maybe this trend stems from the first, but it is interesting anyway to note this change. For many years highway administrations have taken social economic considerations into account when building new roads. However, maintaining or rehabilitating existing roads almost only took into consideration business economic viewpoints. In other words: how do we get most value for the money we have at the highway department's disposal. Taking a social economic viewpoint will lead to other solutions to problems, but as yet they are difficult to include and hand-
We have come some way, but have many unsolved questions. One major problem is that of convincing politicians of the benefits of a social economic viewpoint which inevitably are going to cost highway administrations more, although society as a whole will benefit from lower total costs.

Traffic registration - traffic management

For many years we have registered through sensors and measuring equipment the number, type and axle weights of vehicles. Classic traffic engineering has been applied. Now with increased traffic and with our service concept, new ideas of traffic management are developing, including not only area traffic control systems, but also guidance at road works and for winter driving. This is a field where we know we can gain a lot through our international cooperation and yet is a field with many unsolved problems.

Low tech - high tech

Highway engineering has traditionally been a low technology business. The introduction of the computer in the late fifties and early sixties did bring about an enormous potential for more rational highway administration and more refined and new methodologies which today have led to the use of data banks and effective management systems. There are signs, however, of new innovations in primarily the electronic field, but also in the use of ultrasonic measurements, in ways of analyzing compounds of bitumen, to mention just a few fields of interest. This might very well within a limited span of years alter many concepts of a modern highway administration to the benefit of society, but also by making a highway administration an attractive working place.

With these trends in mind we have over the past years chosen 5 main subject areas of priority. We call them our 5 "lighthouses". They are shown on the following page.

About 80% of all R&D resources now are bound to these 5 subject areas. Let me briefly through the following key words illustrate our areas of interest:

Pavement Maintenance:

- Deterioration models for pavements (from pavement response to pavement performance)
- Surface distress (from visual inspection to objective measurements)
- User cost as function of pavement condition
- Test roads of modified bitumen.
The key words tell you that we in Denmark since 1975 have put a lot of effort into a systematic approach to pavement management systems. Today we have a system in operation for the state road network and also in operation for the local road network a more simple one operated on personal computers.

The maintenance management system for the state road network consists of 4 elements which are shown in figure 8.
Although the present system operates satisfactorily, it has a number of shortcomings (figure 9).

**SHORTCOMINGS OF PRESENT SYSTEM**

- priorities made for one year only
- yes or no only to one maintenance strategy per road section
- no environmental considerations
- no user costs considered

Figure 9: Shortcomings of present system.

Therefore we have in the next 5 years period decided to carry out fundamental changes so as to

- get from pavement response to pavement performance
- to get from visual inspection to objective measuring methods
- take user and social cost into account.

I would like to mention that we in Denmark have developed a non-destructive test method for overlay design based on measurement with FWD-equipment.

With the FWD, the deflection basin is measured when a falling weight drops down on the road surface. If the thickness of the different layers in the pavement structure is known, it is possible to calculate the stiffness of the different road materials. I also want to point out that we are developing equipment which can give us the thickness of the different layer in a non-destructive way.
Figure 10: FWD deflection measurement

The key words for the second "lighthouse" are

**Bridge Maintenance**

- Bridge maintenance management system
- Vibration measurements
- Shear tests on beams with alkali-silica reaction
- Adhesion failure of water proofing on bridge deck.

Today we have in operation a maintenance system for our bridges on the main road network, and again a simple system for our local network. The vibration measurements are special measurements on our newest bridge - the Farø bridges.

As regards safety/environment the key words are

**Safety/environment**

- Environmental priority method
- Analysis of accidents due to new design standards
- Noise properties of pavements
- Warning systems and user behaviour during ice/snow periods.

Instead of building new roads around our small villages we are trying to arrange special traffic arrangements to slow down the speed.
On winter maintenance we are looking at weather stations which automatically indicate the need to spread deicing salt on specific road stretches.

The lighthouse "Material Technology" has the key words

Material Technology

- Semi-rigid pavements
- Alkali-silica reaction in concrete
- Modified bitumen physical/chemical properties
- Waste materials
- Recycling of asphalt and concrete.

We have only a few semi-rigid pavements, but we feel that this type of pavement can have a future in our country due to lack of oil. As to modified bitumen, every road engineer speaks about the subject today.

Finally the key words for other subjects are

Other subjects

- Traffic management
- Use of modern technology in highway administration.

As to traffic registration I would like to mention that we have a system in operation which gives us the axle load, the speed and the length and the number of axles of the vehicle. As mentioned before we in Denmark feel that traffic management will be a part of our daily life in the future.

As you will see there are many fields that coincide with that of SHRP and therefore I very much welcome the invitation to come here and present what we in Denmark are working with when talking about road transport research.

Thank you for your attention - thank you Mr. Chairman.
NORDIC COOPERATION AND SHRP RELATED INVESTIGATIONS IN FINLAND
by Esko Kankare

I am very happy to be here and to have the opportunity to present not only the SHRP related investigations in Finland but also to have the possibility and permission to express a few words about the co-operation in the field of road and traffic technics between the Nordic Countries.

The Nordic Countries are (in alphabetic order)

Denmark
Finland
Faroe Islands
Iceland
Norway
Sweden

Fig. 1. The Nordic Countries
Long geographical, cultural and historic ties and similarities in social systems and language have created close contacts and co-operation between these countries in almost every field of living and from official to grassroot level.

In the field of road and traffic technics the contacts are various. In this connection I will mention only two of them:

The *Nordic Association of Road and Traffic Engineering* (NVF)

The *Nordic Council of Ministers* with its special committee

*Nordic Senior Officials' Committee for Transport Questions* (NAT) as its active tool in our field.

The NVF was founded in 1935 with some preliminary activities already ten years earlier. Its present organisation is shown in fig. 2.
The aim of the NVF is to encourage the development of road and traffic technics through co-operation and co-ordination among road and traffic technicians from the participating countries. This should be carried out by

- arranging technical meetings and conferences
- appointing committees to deal with ordinary or specific questions which should promote the aim of the association and to publish reports on these questions. There are 14 active committees today.
The NVF has very little money at its disposal and has to run its activities mainly on a voluntary basis. In spite of this, participation in its activities has been enthusiastic and fruitful in all the participating countries. We really do have a forum for discussion of problems with our colleagues in the Nordic Countries.

The NÄT, on the contrary, with its connection to the political organization "Nordic Council of Ministers" has grants at its disposal and has also financed many Nordic joint investigations in the field of road and traffic technics. The most well known of them is probably the STINA, an attempt to adapt the results of the AASHO road test in Nordic conditions. It was carried out during the years 1974 - 1978 the total costs being about 200.000 dollars (ten years ago).

The connections described above are illustrated in Fig. 3.

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THE NORDIC COUNCIL OF MINISTERS

NORDIC SENIOR OFFICIALS' COMMITTEE FOR TRANSPORT QUESTIONS (NÄT)

STINA

AN ATTEMPT TO ADAPT THE RESULTS OF THE AASHO ROAD TEST IN NORDIC CONDITIONS

Fig. 3. The Nordic Council as a promotor of the investigations
### SHRP related activities in Finland

The length of the public roads in Finland is 75,800 km. The share of different surfacing types is:

<table>
<thead>
<tr>
<th>Surfacing Type</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt concrete</td>
<td>15,700 km</td>
</tr>
<tr>
<td>Oil gravel</td>
<td>25,000 km</td>
</tr>
<tr>
<td>Gravel</td>
<td>35,100 km</td>
</tr>
</tbody>
</table>

Total: 75,800 km

All the main roads have asphalt concrete surfacings. Gravel roads are the outermost branches of the road network.

The main SHRP related problems are:

- Too little allowances for road maintenance
- Pavement wear due to the studded tyres on the main roads
- Structural deterioration of roads due to the increase in axle loads, total weights, and number of vehicles
- Ageing of the road network both concerning the design life and design load number.

The following main research activities are going on at the SHRP related area:

1. Systematic monitoring of surface quality (since 1982)
   - Rut depth
   - Evenness
   - Distress

2. Observation roads (since 1979)
   - Failure models
   - Does the road network deteriorate?
3. Pavement management systems (PMS)
   - Condition data
   - Failure models
   - Linear optimization

4. Impact of heavy vehicles on road structure
   - Direct field measurements (Virttaa)
   - Theoretical calculations (Bisar, Chevron)

5. Development of wear and deformation resistant surfacings
   - Mix design
   - Binders
   - Additives
   - Properties of stone aggregates
   - Road tests

6. Use of cement as binder
   - Concrete roads (test roads only)
   - Inventory of roads with cement stabilization

Some comments for the six points above.

1. Systematic monitoring of surface quality

Systematic measurements of the road surface quality were started in 1982 when a new rut depth measuring device was completed. Some 8 000 - 10 000 kms of paved road have been measured each year (a total of some 15 000 kms). In 1984 the systematic measurement of evenness was started on oil gravel pavements (some 25 000 kms), 10 000...12 000 kms per year.

Devices for these measurements have been developed by the Road and Traffic Laboratory at the Technical Research Center of Finland. Rut depth measurements are carried out with a device that measures the cross-profile by means of...
13 measuring wheels (total width 3,1 m)(Fig. 4). Distress can be registered on a keyboard. Evenness measurements are carried out with an inertial profilometer based on laser and acceleration measurements. In connection with rut depth measurements, cross falls are also measured. Both measurements are carried out with a speed of 50...60 km/h.

Fig. 4. The Finnish Rut-Depth Measuring Device

Annual reports are made on the state of the road network and these reports help to plan paving programmes. The measured data are used in PMS.

A new device based on laser technics for measuring the rut-depth, evenness, cross-profile, texture etc. is being designed (and working in 1987). Also a high-speed bearing capacity measuring device, based also on laser, is being planned.

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2. Observation roads

In 1979 58 roads, average length 3 km, were selected for observation of their long-term behavior. The aim of the study was to examine their failure mechanism and to answer the question, whether the Finnish road network is deteriorating or not.

The roads were investigated concerning their structure, pavement history (if known), bearing capacity, traffic, failures, evennes, PSR, maintenance etc. After the first five years a summary of the results was published (Technical Research Center of Finland, Research Notes 429). In it some general failure models for different types of road were presented and the results compared with the OPAC-model. For reliable statistical analyses the number of roads is not large enough. The data collection was, however, done in 100 m sections. This enables us to partition every road in shorter, more uniform sections and thus improve the statistical basis.

Some results are shown in Fig. 5 - 7.

The accuracy of some data concerning e.g. the subgrade, structure and traffic does not yet correspond to the requirements of SHRP-2. Some increase of accuracy will in every case be achieved this summer (1986) and approaching the SHRP-2 requirements is possible in the near future.
Fig. 5. Two failure models obtained from the observation roads. (Good AC-Roads are mainly roads constructed following the valid design guidelines with good bearing capacity and properly build shoulders, poor AC-Roads are mainly old narrow rehabilited roads)
Fig. 6. The decrease of the PSR-value of the observation roads as function of the time.
During the last two years a Pavement Management System (PMS) has been developed by the Road and Traffic Laboratory and tested with the data obtained from the observation roads. Using linear optimization the program allocates maintenance funds to the road network so that either maximum benefits or
minimum costs can be achieved. The program can also investigate how the serviceability of a road network is changing with different budgets or how much funds are needed to keep serviceability at a desired level or alternatively to raise it.

The next step will be to test the system with a large road network. (This has already successfully been done using the AC-roads (1800 km) of one road district as a test network.)

4. Impact of heavy vehicles on road structures

Strain and stress measurement systems have been developed by the Road and Traffic Laboratory in order to study the behavior of asphalt pavement and the effect of different truck combinations (different axle loads, single, tandem and tridem axles, single, twin and supersingle tires, tire pressures, suspensions, etc.).

The special high elongation strain gages are glued on asphalt specimens which are glued with very thin layer of glue to the asphalt pavements so that they act as an integral part of the pavement and the strain gages measure the strains at the bottom of the bituminous layer. The road transport research group 12 (Full Size Pavement Tests) of the OECD arranged a common test at Nardo in Southern Italy in April 1984 (nine participating teams from eight countries of three continents) and our system turned out to be a success.

The stresses in the unbound layers and subgrade are measured with pressure cells made by our laboratory.
The measurement system has been further developed and today a microcomputer (Compag) with 16 measurement channels is used. It stores the signals from all the 16 channels as a truck combination (6 axles) passes the test pit at 50 mph, calculates the peak values of all the gages and axles within 30 seconds. The transversal position of the truck is measured within an accuracy of 10 mm and within a few seconds the temperature corrected values of strains or stresses can be seen on the display of the computer as a function of the transversal position of the passing vehicle. The system is in active use and will be developed further.

The results are compared and made more complete by theoretical calculations using both Bisar and Chevron programs.

The principles of the measuring system are described in figs. 8 and 9.
FIG. 8.

Temperature
Strain corrected to standard
Twin TIRES
Computer display

Temperature (last digit only)
- Transversal position of each pass
- The temperature of the pavement
- The measure of the vehicles
Other input to computer

Twin TIRES
Computer display

Computes peak values
- Stores the values
Microcomputer

An example of strain signal
16 signals from each of cells are measured simultaneously

Pressure cells
Strain gauges
Asphalt concrete

Road and Traffic Laboratory
Technical Research Centre of Finland (VTT)

The measurement system of stresses and strains in road pavement due

24
The Virtta test field is a 3 km long, 40 m wide flat and straight road instrumented at present with 40 strain gauges and 30 pressure cells. Because of the length all heavy freight vehicles can easily attain 80 km/h or more. The circulating time is about 6 min.

The main purpose has been comparisons of the effects of different heavy freight vehicles. In the figure examples of signals at different height levels, on the top strain gauges in the asphalt surfacing and other are from pressure cells (different scales).

**Fig. 9.**
5. Development of wear resistant surfacings

During the last few years in Finland Arabic and Russian based crude oils have been used as binders in asphalt mixes. Bitumen has also been partly modified for improved adhesion. The Finnish Road Administration has started a research project in order to find suitable bitumen grades to pavements and to characterize the most important properties of bitumen.

Research work has also been done in Finland on aggregates used on surfacings in order to find new factors which have an effect on the durability of surfacing.

Different types of additives have also been one of the research topics during the last few years. The purpose is to develop more stable and more weather resistant surfacings with the help of additives like serpentivite and calciumoxide.

In 1987 a large study (5 years, about 600 000 US dollars annually) for designing more wear-resistant has been started in Finland. It is closely related with the SHRP TRA-1 "Asphalt Characteristics".

6. Use of cement as binder

Owing to the price, climate, inhomogeneity and frost susceptibility of most subsoils the use of concrete pavements has been very limited and only experimental in Finland. Owing to the good wearing resistance to studded tyres some research is, however, going on.

The research into concrete pavements concentrates on increasing compression and flexural strengths which can be considered in thickness design. The Westergaard-Eisenmann method is primarily used in design.
Flexural strengths of 7...8 MPa and compression strengths of over 60 MPa have been reached on test roads. These strengths have been achieved with low water-cement ratios (about 0.37) and by using plasticiser. One half of the binder is ordinary Portland cement and the other half is ground blast furnace slag. This concrete also has a very good frost-salt resistance.

Cement is used to some extent as stabilizing agent under asphalt concrete surfacings, especially when reinforcing old roads.

Some years ago an inventory was made of practically all cement stabilized roads.

The results showed quite clearly that less damage was found on roads
 - where the concrete was made with mix-in-plant method and
 - where there was an unstabilized layer between the AC-surfacing and stabilized layer (stabilized sub-base).
The presentation at the workshop is based on slides. This paper gives a brief summary of some of the projects mentioned in the oral presentation.

NORWEGIAN ROAD RESEARCH LABORATORY

Organization:
The Norwegian Road Research Laboratory was established in 1938 and is a sub-division of the Public Road Administration.

The N.R.R.L. is internally organized in five technical sections, Bituminous materials and Chemistry, Concrete, Pavement design, Geology and Soil mechanics, together with a secretariat and a workshop.

Field of Operation:
The main object of the N.R.R.L. is research and development in the area of highway construction and consulting within the technical fields of operation. This work includes offering courses and training programs.

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Telefax: +47 2 46 71 24   Telex: 71238 sreg n
FROST ACTION IN SOILS

The Royal Norwegian Council for Scientific and Industrial Research (NTNF) and the Public Roads Administration have given financial support to the Committee on Frost Action in Soils in order to increase and coordinate the research of frost problems in Norway in the period 1970–76.

The purpose of the frost research was to get know-how about thermal regime, materials and constructions methods for reducing the cost due to frost action damage in soils. In order to build up a technological knowledge about frost action in soils, the research has been carried out for 5—6 years. The total expenses are calculated to about 15 millions Norwegian crowns.

The research work is done in cooperation between several institutions as seen in the Table below.

Institutt for kjøleteknikk, NTH/Division of Refrigeration Engineering
Institutt for husbyggingsteknikk, NTH/Division of Housebuilding Engineering
Institutt for veg- og jernbanebygging, NTH/Division of Road and Railway Engineering
Norges bygdforskningssenter/Norwegian Building Research Institute
Veglaboratoriet/Norwegian Road Research Laboratory
Multiconsult A/S

Some of the running projects in Norway have been:
- Engineering Climate Research
- Measurement of Thermal Regime
- Thermal Properties of Materials
- Thermal Analysis and Design
- Heat Insulation Materials in Road Construction
- Wet Layers (Bark) in Road Construction
- Moisture Movement and Moisture Content in Soils
- The Mechanism of Frost Heave
- Frost Susceptible Criteria
- Frost Protection of Pipe-Lines
- Frost Protection of Small House Foundations

One main thing for the Committee was to publish the results from frost research in Norway and other countries. For this purpose the Committee issues a publication "FROST I JORD" (Frost Action in Soils) which is distributed all over the world.

Subscriptions or request for single or back numbers should be sent to the Committee on Frost Action in Soils, Gaustadalleen 25, Oslo 3, Norway.
MONITORING SECTIONS

During 1985 a system for monitoring of road sections in the existing road network was completed. The main reason for establishing such a system was to standardize the monitoring procedures both regarding what to measure, how to measure and when to measure.

The local road authorities now have a "cookbook" for the monitoring of, for instance, the performance of a new type of base material, the effect of a strengthening work or drainage works in terms of bearing capacity etc. Such monitoring results, which are collected in the same way all over the country, are essential as feedback to the standard specifications, when these are revised.

A monitoring section is normally 100 m but could also be 1000 m in length, depending on the purpose of the monitoring. The required monitoring is described for road pavements built according to specifications, for roads with substandard base or subbase materials, strengthened roads, special types of road constructions or pavement materials, reinforced surfacings etc. etc.

Certain basic information is always required for monitoring sections e.g. pavement construction data, traffic data etc. Bearing capacity, serviceability, rutting, roughness and drainage condition are examples of parameters which are monitored.

The sections are clearly marked with signs where the two numbers indicate the type of monitoring section and the section number in the district.
Evaluation of deflection measurements

Field measurements have been carried out in order to develop a mechanistic model for pavement design and a mechanistic model for evaluation of NDT-data for existing pavements.

Cross-sections on different subgrades (silt, clay, rock) have been instrumented with LVDT-gauges. Each LVDT-core is fixed to the wearing course and the coil is connected to a steel bar which is anchored at a fixed depth in the road structure. On each site there are 3 - 5 steel bars which are anchored at different levels, preferably at the layer boundaries and one deep down in the subgrade soil.

There have been carried out a large number of measurements with the Dynaflect and different FWDs both in 1984, 1985 and so far in 1986. The 1985- and 1986-measuring program also included measurement of deflections under moving wheel loads.

With the described instrumentation we are able to measure the displacement in the different layers. By changing the applied load, the stress level is varied and the recorded displacements can be used to analyze stress dependency of material properties.

Only a few temporary results are available until now. So far the main results are:

- the deformations at depths below 3 meter are almost negligible
- linear material models can be used to describe the elastic properties of both granular and cohesive materials
- the deflections measured with the various devices vary even if the force is equal.
As part of establishing a pavement management system in Norway, an equipment for monitoring pavement condition based on rut depth, surface distress and roughness is developed.

The equipment is built around a commercially available microcomputer. The system diagram is shown below.

The equipment measures the following parameters for assessment of pavement condition:

- rut depth
- surface distress
- roughness (to be included in 1986/87).

Rut depth is measured by ultrasonic transducers mounted in a bar which is mounted on a vehicle. The present configuration uses 8 transducers on a 1.5 meter bar, but the system allows 12 transducers on any length of a bar. Rut depth can be measured 200 times per kilometer road. Maximum rut depth across the measured profile is used as indication of rutting.

Surface distress is manually registered by an operator with the help of a distress-keyboard. The keyboard presently in use, has three pushbuttons for marking the existence of longitudinal cracks, alligator cracking and potholes/patches. The system is capable of using a keyboard with 12 pushbuttons, either as independent pushbuttons or in a matrix of 3 x 4 for registering independent distresses or combinations of severity and extent of distress type. The system stores the location of the distresses and calculate the amount of the total road length of each particular pavement deficiency.

Road roughness is presently not available in the existing system, but will be added during 1986-87. One alternative is to use a commercially available roughness meter, another is to develop a roughness meter based on the same ultrasonic transducers as used for rut depth. This new development will be a kind of automated straight edge; a bar 3-4 meter long equipped with transducers every 20-25 cm. The bar is to be mounted on a vehicle or a trailer. From this roughness measurement it will be possible to perform straight edge simulations, and slope variance or root mean square vertical acceleration of the profile can be calculated.
PAVEMENT PERFORMANCE RELATED RESEARCH AND DEVELOPMENT IN SWEDEN

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PAVEMENT PERFORMANCE RELATED RESEARCH AND DEVELOPMENT IN SWEDEN

Long term planning of maintenance and rehabilitation measures by means of effective tools has become even more necessary in a society where not only costs are of concern but changes from constructing a road network to maintaining it have taken place.

The planning has to be based on a knowledge of how different measures (including materials and procedures) affect the long term performance (performance predictions models) of a roadway. The given conditions may vary from place to place i.e. climate as well as soils may differ.

To make possible building models for the prediction of pavement performance either those are of empirical nature or more analythical data collection programs on existing roads are necessary to perform.

It was decided in Sweden in 1982 to start planning for a data collection program on a sample collection of in service pavements. The Swedish Road and Traffic Research Institute was commissioned by the National Swedish Road Administration to carry out this effort.

The data collection on the 160 road sections that later were selected started in 1984.

IN-SERVICE PAVEMENT VS. SPECIALLY CONSTRUCTED

Specially constructed pavement sections have been frequently used in the long history of Swedish road research and development. Different pavement structures, materials, procedures, etc. have thus, during the
years, been evaluated under real conditions. This will also be the way experiments will be carried out for years to come.

One of the restraints with specially constructed sections that has to be realized is that they, in most cases, are more carefully constructed than routinely constructed roads. Thereby they will not be a representative sample of the population of roads.

When it comes to data collection of in-service pavements the National Swedish Road Administration has since 1973 made routing surveys of their road network. This has helped improving their Pavement Management System, as well as, keeping an eye on the overall condition of the road network. (The Road Administration deals mainly with the rural Swedish road network.) Within the routine surveys a limited number of data has been collected for the entire road network.

For the study described in this paper it was decided to concentrate the efforts on shorter representative sections of the network. This was considered to be the most effective way to get something out of the study within a fairly short period of time. Sections that were in need of a maintenance or rehabilitation measure within a very short period of time could thus be selected. This strategic choice should save time compared to monitoring newly constructed or specially constructed sections. It would also allow to study the effect of maintenance and rehabilitation measures within a short period of time on the same sections. The figure below indicates the adopted strategy.
CHOICE OF ROAD PAVEMENTS AND SECTIONS TO BE MONITORED

It was decided that two types of pavement should be studied:

- bituminous concrete over gravel base and subbase,
- bituminous concrete over crushed stone base and subbase.

A typical design for a daily traffic of 500-1500 heavy vehicles a day is shown in the figure below.
These are the most common pavement structures used in Sweden. Rigid and semirigid pavements are being used to a minimum extent.

When it comes to subgrades it was decided that two subgrade types should be involved - coarse and fine.

Sweden has several "climate regions" partly due to its length partly because it is surrounded by the sea. Thus it was decided to look for candidate sections in areas with repeated freeze/thaw cycles as well as in areas with a more stable winter climate.

Sections were looked for on roads with traffic volumes not less than 500 ADT with a varying percentage of trucks.

The length of sections to be monitored was limited to 100m (300'). This was due to a concern about the variability in subgrade conditions, pavement layers etc. However, on each of the projects to be selected, hopefully, ten 100m sections should be chosen for monitoring.

In the above figure one of the projects on road E3 100 miles west of Stockholm including 14 short sections is shown.
The sections selected should be located either within a fill or a cut. Transition sections were thus to be avoided.

By visiting 5 of the 24 districts within the Road Administration all of which are located in the southern part of Sweden 15 projects were selected. On these projects it was possible to select a total of 160 100m's sections. The distribution of the 15 projects is shown in the map below.
DATA COLLECTION PROGRAM

To the extent possible, data from the time the different projects were constructed (inventory data) has been collected.

For the monitoring it was decided to set up a program to collect data on:

- distress
- roughness (longitudinal unevenness)
- structural performance
- traffic
- weather

Data is generally collected once a year during the summer months although during the first years structural performance data was collected up to four times a year to pick up seasonal variations (during and after thawing period).

Distress data concerns essentially rut formation and cracking. Ruts are measured by means of profiling the cross section. Cracking and other types of distress like patching, ravelling are recorded by means of visual inspection (mapping).

Roughness data has been collected using the response type of device (Laser RST) and Chloe, although it would have been preferred to measure the longitudinal profile.

Structural performance data are collected by means of a falling weight deflectometer (FWD) of the KUAB type. Four sensors are used to measure the deflection basin.

Traffic data collection activities have just started to be planned for. One of the projects already has a WIM device installed. It is planned to use automatic devices for vehicle classification.
Although the intention was to make a strategic selection of projects (see page 35) this was not fully possible. However, since the monitoring started in 1984 9 of the 15 projects were maintained/rehabilitated within the first year.

During 1986 discussions have been underway about increasing the number of test sections from the 160 previously selected to about 300.

ANALYSIS OF DATA, PERFORMANCE MODELS

The analysis of data is planned to start as soon as there is enough of data available. This will be the case after the summer of 1986. The first approach will be to study the relationship between on one hand response to load (FWD measurements) during different times of the year and the traffic load and on the other hand the deterioration of the road pavement (distress, roughness etc.). The model building will be based upon the statistical way of looking at things as many of the factors that affects the deterioration rate are not possible to quantify (describe) at reasonable costs. Examples of such are variation in layer thickness, degree of compaction, binder contents.