INFORMATION GATHERING REPORT
Task Group 2 - FWD at Network Level

Version: Final draft report

Date: March 18, 1998
In 1996 COST Action 336 ‘Falling Weight Deflectometer’ officially started and was a continuation of the FEHRL-FWD group.

COST deals with European co-operation in the field of scientific and technical research and is a framework for scientific and technical co-operation, allowing the co-ordination of national research on a European level. COST Actions consist of basic and precompetitive research as well as activities of public utility. COST Co-operation was set up in 1971. The organisation is based upon a flexible set of arrangements enabling different national organisations, institutes, universities and industry to join forces and make concerted efforts in a broad range of scientific and technical areas (e.g. Transport).

The goal of this COST-336 Action is develop a European common code of good practice for the use of Falling Weight Deflectometers in pavement evaluation.

This involves:

- the development of a harmonisation proposal for the evaluation of flexible pavements at project level using FWD-tests. (This is an update and an expansion of the existing FEHRL document [1]).
- the assessing of the potential for using of FWD's in evaluation at network level
- the establishing of common requirements for calibration of measurements and machines
- the establishing of a preparatory basis for possible European standardisation in the field of the use of Falling Weight Deflectometers in pavement evaluation.

The COST 336 project comprises four tasks:
- Task 1: Post-Processing of FWD Data
- Task 2: Applicability of FWDs at Network Level
- Task 3: FWD Calibration
- Task 4: Finalisation of Project Deliverables and Reporting

The result of the information gathering work of Task Group 2 is described in this report.

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Dr. M. L. Antunes organised the workshop at LNEC in Portugal
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APPENDIX NO. 3 -
   FWD DISTRIBUTION ON COUNTRIES AND TYPE OF OWNER
1 Introduction

This report is one of the four TG 2 deliverables as described in the technical annex to COST 336 MoU. To include the newest literature this report will be updated until the end of the COST 336 action in June 1999.

Other deliverables are the Workshop in Lisbon June 1997 and the Workshop Management Report distributed in August 1997.

The ultimate deliverable will be the combination of the three above in the Guidelines on the applicability of the Falling Weight Deflectometer at Network Level.

Since in April 1996 information gathering has been done parallel to the organisation and completion of the workshop.

The information gathering include five main items:

- Literature survey
- Selected relevant information from other COST actions
- Detailed summaries from the Lisbon Workshop
- Supplementary COST 336 information
- FWD owners.

The literature survey was started by questioning the IRRD-OECD and TRB-TRIS data bases. The 27 titles found was analysed at the TG 2 meetings in 1996 and it is noticed that only 5 different papers are dealing with a method, which is actually specific to network level. Up to now only papers with abstracts in English language was found.

From the COST 324 (Long Term Performance of Road Pavements) final report valuable information are achieved regarding inter calibration of deflection measurements. Deflections are compared from FWD, Benkelman Beam, Curviameter and Lacroix Deflectograph.

From the COST 325 (Road Monitoring Equipment) final report, chapter 5.2 presents the results from a questionnaire. Some answers regarding the use of FWD at network level are found in 5.2.1 (Aim of Bearing Capacity Data Collection), in 5.2.2. (Methods for Evaluating the Bearing Capacity of Roads) and in 5.2.3 (Measurement with Benkelman or FWD).

The Workshop in Lisbon June 1997 was a major part of the information gathering exercise. The four session secretaries reports summarise the workshop presentations.

Supplementary COST 336 information include, the Task Group 1 questionnaire, the Short Workshop report, the COST 336 home pages and the Network Level guide as the final deliverable of this Task Group.

Distribution of FWD owners are listed by, countries and type of owner in Appendix no. 3.
2 Literature survey

2.1 Introduction

As a part of the COST 336 project, the Task Group 2 has to produce, as far as possible, a "draft of guidelines for FWD use at the network level". This document should mainly answer the following question: "Can the FWD be used, and how, to bring structural information useable in a Pavement study at the network level?"

From the beginning, it was clear that, to reach this objective, it was necessary first to successively enlighten the following points:

1. What is a "study at the network level"?
2. Which structural information is excessive, necessary, recommended, simply interesting and without interest in the context of such a study at the network level?
3. Under which technical and economical conditions the FWD is able to bring some of this information?

The first question was discussed during a meeting of the Task Group 2, and as a conclusion, a classification of the studies "at network level" was proposed. This proposal is summarised in the next section of this document.

To complete this approach, and to answer the other questions, it was decided that two approaches would be followed in parallel: a literature survey, and a workshop.

2.2 What is a study at the network level?

The "network level" considers the road system as a set of roads arranged in different classes depending on the function, traffic, climate, etc., rarely as a route. The minimum size of a network can be of the order of 100 km. The "network level" of management deals with the following issues:

- top level (later called "owner level") decision, mainly in the economical and financial fields related to the principal options of maintenance and rehabilitation; they should be based on results easy to understand by the executive officers and the economists;

- intermediate level (latter called "central agency level") decisions of strategic order for localisation, priority and scheduling of maintenance and rehabilitation; this level is also in charge of the preparation of executive budget.

In comparison, the "project level" is dealing with diagnosis of the problems with the pavements and design of the solutions, on the sections where some maintenance works were programmed in study at the network level. The decision level for these studies are the local agency.
Network level studies aim at providing the proper decision level with information needed for:

- budgeting, which means defining the global budget required to reach maintenance objectives; this budget is depending on both the actual condition of the roads (from a global in situ evaluation) and the condition required by the owner (maintenance objective).

- planning, which means allocating the budget per area, agency or class of roads.

- programming, e.g. selecting all the sections of road which actually require maintenance work.

- prioritisation, which means organising the program in a list of priority from the more to the less urgent.

This classification is summarised below, in table no. 1.

**Table no. 1: Network versus project level**

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>ACTIVITY</th>
<th>OBJECT</th>
<th>CONCERN</th>
</tr>
</thead>
<tbody>
<tr>
<td>NETWORK</td>
<td>Global economic analysis</td>
<td>Global budget to reach objective</td>
<td>Owner</td>
</tr>
<tr>
<td></td>
<td>Planning</td>
<td>Allocation of budget per area</td>
<td>Owner</td>
</tr>
<tr>
<td></td>
<td>Programming</td>
<td>Selection of maintenance sections</td>
<td>Central agency</td>
</tr>
<tr>
<td></td>
<td>Prioritisation</td>
<td>Ranking of maintenance sections</td>
<td>Central agency</td>
</tr>
<tr>
<td>PROJECT</td>
<td>Diagnosis</td>
<td>Identification of the problem</td>
<td>Local agency</td>
</tr>
<tr>
<td></td>
<td>Design</td>
<td>Maintenance solution</td>
<td>Local agency</td>
</tr>
</tbody>
</table>

As far as structural maintenance is addressed, evaluation of bearing capacity may be necessary or at least useful, but it is not sufficient. It should be associated with other indicators (visual distresses, rutting, roughness, etc.).

There is different way to assess the bearing capacity. At first sight, it was stated that Global Economic Analysis and Planning could be based on a statistical monitoring of
the bearing capacity, whereas Programming and Prioritisation require a systematic deflection monitoring.

2.3 Literature Surveys

2.3.1 Sources

The literature survey was started by questioning the IRRD-OECD and TRB-TRIS data bases. The key words which were used were:

Deflection, Deflectograph, Bearing Capacity

and

Network

As a consequence, only English papers or, at least, papers with an English abstract were selected. Some French papers or reports were added to this list.

Twenty-seven papers of various interest were pointed out by this procedure. The list of this papers is provided in 2.3.4 (short references), and they are number from [1] to [27]. Their abstracts are available in Appendix no. 1.

2.3.2 Short analysis of the papers

The tables no. 2 (2.3.4.1) to no. 5 (2.3.4.4) give some information about the content of the different papers. This information is issued from the abstracts, and in some cases ([1], [2], [3], [4], [8], [11], [14], [16], [17], [18], [19], [20], [21], [23], and [24]), from the entire papers. As the information from the abstracts is often insufficient, and as the entire papers, when available, were only overviewed, these tables cannot be considered as a synthesis of the papers. They may display some lacks or misinterpretations. They only aim at providing some entries to the literature, by answering to the question: what is the paper speaking about, as far as deflexion is concerned. The terms and acronyms printed in italic letters, in tables no. 2 to 6, are explained below.

Interpretation: What is the method of interpretation?

network: it tends to be a method specific to network level

gen. project: the measurements are interpreted with a project level procedure systematically applied on all the sections of the network (1) or no explanation are provided about the interpretation of the measurements (2).

lane/track: one measurement par lane or one measurement per track, at each location

BC: Bearing Capacity
2.3.3 A few comments

The following comments must be considered with care, as the literature survey which is reported in this document is not completed. It should be supplied with new references all along the COST 336 action. Furthermore, some of the papers are dealing with monitoring procedures or testing equipment and provide no specific information on the use of deflexion at the network level, although this is mentioned in the abstract.

First, one can notice that, on the 27 references, only 10 different papers ([2], [7], [13], [14], [15], [23], [24], [25], [26], and [27]) are dealing with a method, which is actually specific to the network level. In the other ones, no information is provided on the interpretation of data, or the described procedure is nothing but a generalisation of a procedure which is currently used at the project level. This is consistent with the fact that, in most of the papers, the measurement procedure is systematic and the interpretation is deterministic.

Amongst these 10 papers, four ([2], [7], [15], [23]) are reporting measurements performed with a Deflectograph, five others ([13], [24], [25], [26], [27]) are reporting FWD measurements, and the last one [14] does not specify anything about the measurement equipment, but has later been clarified to be a FWD.

As a last observation, it is often difficult to classify the actual objectives of the papers in the four categories proposed by the Task Group no. 2 of COST 336 (see section 2.2). This is not surprising since the proposed classification is still not usual.
2.3.4 Short references of surveyed literature

Long references in Appendix no. 1, one page each reference.

[1] Oliver J.E., "Use of deflections to manage the structural maintenance requirements at network level in England", 1995


[13] Scullion T., "Incorporating a structural strength index into the Texas pavement evaluation system. Final report", 1988


### Table no. 2: Key information to the 27 papers.

<table>
<thead>
<tr>
<th>Ref.</th>
<th>Country</th>
<th>Network</th>
<th>National</th>
<th>Local</th>
<th>~length</th>
<th>Deflect.</th>
<th>FWD</th>
</tr>
</thead>
<tbody>
<tr>
<td>[1]</td>
<td>England</td>
<td>X</td>
<td>11 000 km</td>
<td>PDDLM</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>[6]</td>
<td>Jordania</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[8]</td>
<td>Finland</td>
<td>on finish &amp;</td>
<td>1340 km</td>
<td>FWD &amp; BB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[10]</td>
<td>US-Oregon</td>
<td>X</td>
<td>-</td>
<td>(Dynaflect)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[11]</td>
<td>Denmark</td>
<td>X</td>
<td>15 000 km</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[12]</td>
<td>Hungary</td>
<td>X</td>
<td>30 000 km</td>
<td>Benkelm. B</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[14]</td>
<td>Hungary</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[15]</td>
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<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>[16]</td>
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<td>X</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>[17]</td>
<td>Hong-Kong</td>
<td>Urban net</td>
<td>160 km</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[18]</td>
<td>England</td>
<td>X and X</td>
<td>45 000 km</td>
<td>PDDLM</td>
<td></td>
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</tr>
<tr>
<td>[22]</td>
<td>Singapore</td>
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<td>2 780 km</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[23]</td>
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<td>-</td>
<td>-</td>
<td>PDDLM</td>
<td></td>
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</tr>
<tr>
<td>[24]</td>
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<td>FWD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[25]</td>
<td>Netherlands</td>
<td>Gelderland</td>
<td>-</td>
<td>X</td>
<td></td>
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</tr>
<tr>
<td>[26]</td>
<td>Netherlands</td>
<td>Utrecht</td>
<td>100 km</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[27]</td>
<td>Netherlands</td>
<td>Zeeland</td>
<td>-</td>
<td>X</td>
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</table>
### 2.3.4.2 Table no. 3 : Key information to the 27 papers.

<table>
<thead>
<tr>
<th>Ref.</th>
<th>Measurement procedure on sample</th>
<th>Systematic</th>
<th>Measurement parameters step length</th>
<th>Lane/track</th>
<th>Interpretation network</th>
<th>gen. project</th>
</tr>
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<td>[1]</td>
<td>X</td>
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<td>3.8 m</td>
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</tr>
<tr>
<td>[2]</td>
<td>X (20%)</td>
<td></td>
<td>3 m</td>
<td>track</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>[3]</td>
<td>X (13%)</td>
<td></td>
<td>1 / section</td>
<td>lane</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>[4]</td>
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<td>[9]</td>
<td>X</td>
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<td>X</td>
<td></td>
<td>300 m</td>
<td>lane</td>
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<tr>
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<td>[15]</td>
<td></td>
<td>4 years</td>
<td>3 m</td>
<td>track</td>
<td>X</td>
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<td>[17]</td>
<td>X</td>
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<td>50 m</td>
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</tr>
<tr>
<td>[18]</td>
<td>3, 5 years</td>
<td></td>
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<td>2</td>
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<td>[19]</td>
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<td></td>
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<td></td>
<td>2</td>
</tr>
<tr>
<td>[21]</td>
<td>X</td>
<td>depending</td>
<td>on equip.</td>
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<tr>
<td>[22]</td>
<td>X</td>
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<td>3.8 m</td>
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### Table no. 4 : Key information to the 27 papers

<table>
<thead>
<tr>
<th>Ref.</th>
<th>Type of interpretation</th>
<th>Measurement are processed to calculate</th>
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<td>[1]</td>
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<td>X</td>
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<td>X</td>
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<td>[3]</td>
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### Table no. 5: Key information to the 27 papers.

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3 Information extracted from other COST actions.

Considerations related to bearing capacity at network level have been formulated in the ongoing COST 333 action and two former COST actions COST 324 and 325.

3.1 Introduction

The ongoing COST 333 action on Development of New Bituminous Pavement Design Methods, review the current pavement design methods in a pan-European questionnaire. An interim version (English, French, German), Glossary of terms used in pavement design including references to other road glossaries is available from the COST 333 homepage.

The former COST 324 action on Long Term Performance of Road Pavements, acknowledges the importance of structural adequacy as one of the major factors affecting pavement performance. The analysis of distress data of test sections used to build prediction models incorporates information on structural condition derived from deflection measurements.
This action was completed in February 1997.

The former COST 325 action on Road Monitoring Equipment, has gathered information on current road condition monitoring practices in Europe and has identified further needs for improvements particularly in the field of measuring bearing capacity. It analyses among other sources of information the results of an inquiry (by ways of a questionnaire) providing the statistics of answers to questions related to bearing capacity data collection. It is to be noted that the measuring methods covered are the Benkelman beam, the FWD, the Lacroix deflectograph or similar and the Curviameter.
This action was completed in November 1996.

Both actions are targeting the issue of network level monitoring although several of the practices recommended (COST 324) or reported (COST325) are associated to project level procedures.

The information’s gathered from the two COST actions are presented in the following manner. They are grouped into two categories in the form of logically structured quotations. One category is related to the general aims and requirements to be met in order to conduct measurements at network level. The other is concerned with the reported measurement performance linked to present days current procedures.

Further information on these and other COST actions can be found at this internet page http://www.cordis.lu/cost-transport/src/
3.2 **Aims as formulated in the COST 324 and 325 actions.**

Methods to evaluate the bearing capacity of roads at network level are applied in a majority of cases to the whole network and more scarcely only to heavy loaded roads.

The purpose for collecting bearing capacity data can be ranked in order of importance as follows:
- to determine rehabilitation measures on section of roads;
- to determine a long term maintenance plan for roads;
- to predict network evolution;
- to determine a long term budget for road maintenance;
- for research;
- to follow-up the efficiency of a maintenance policy.

It is considered that the most important applications of information on bearing capacity are to determine rehabilitation measures on sections of roads (first rank) and to determine long term maintenance plans for roads (second rank).

The evaluation of bearing capacity is performed either on a continuous or discontinuous basis. In the latter case, it can be selective, regular or random. The deflection measurements are mainly carried out in the wheel tracks, and a relative few between the wheel tracks or both.

The bearing capacity is expressed in order of importance as:
1. the reinforcement thickness;
2. the residual lifetime of the pavement;
3. the residual ESAL capacity for the pavement;
4. the cost of the maintenance solution of the pavement.

Combining the results of the priorities set on the purpose and expression of bearing capacity data it appears that the latter is mainly used for the programming of structural maintenance on sections of roads (project level) or for maintenance plans (network level) with the calculation of thickness (quantity of maintenance) and of the residual lifetime of the pavement (priority of maintenance).

To achieve this it is to be reminded that additional information is also needed on:
1. pavement structure;
2. pavement temperature;
3. surface distress;
4. traffic.

In the case of treatment of data, a majority of practices use deflection measurement data in combination with surface distress data and determine also homogeneous (uniform) sections based on pavement construction or deflection measurement and to a less extent on traffic volume or pavement distress.
3.3 Measurement performance from COST 324 and 325

Interchangeability of deflection data
Deflection data depends substantially on the type of equipment that is used and to a lesser extent on the brand or make of the equipment. For FWD, the duration of the load pulse can vary in ranges from 50 to 60 ms and from 20 to 35 ms.

Because of the visco-elastic behaviour of bituminous materials, the loading time can have a significant effect on the measured deflections. To make the data totally interchangeable, a comprehensive inter-calibration of the equipment should be established. It is recommended that for comparisons of deflection measurements equipment, these should be traceable to a reference device such as for example a FWD type used in a majority of cases.

Measurement procedures
When measuring with FWD the most frequent load is 50 kN but in some cases other loads, ranging from 10 to 150 kN, are used. The shape of the surface deflections produced by the impulse load is measured by four to nine sensors.

To measure the deflection bowl, the FWD is stationary for about 2 minutes at one location. To obtain a realistic value of the structural condition of a pavement section, measurements should be carried out at a minimum of 10 locations.

Regarding network level information, the maximum deflection is sufficient (at project level it is necessary to know the shape of the deflection bowl).

The average distance between measurements is close to 130 m with values ranging from 20 to 500 m, more often from 50 to 200 m.

Measurement capacity and cost
The capacity per day is from 10 to 20 km (mean value: 14 km per day). Measurement costs are in the range of 50 to 140 ECU / km (1995) depending, in part, on the number of points where measurements were made.

The main difference between FWD and rolling deflection measuring equipment comes from the fact that, to have the same daily capacity, the distance between measurement spots for the FWD has to be from 50 to 200m which is too long to make it suitable to define homogeneous sections (as it is the case for the rolling deflection measuring equipment with a sampling distance typically 3-5m).

Unfortunately the answers to the questionnaire do not give any indication concerning the maximum acceptable sampling distance.
3.4 Requirements for the future

The outcome of the COST 325 questionnaire stresses the need that development of new equipment should address technical and economic issues as well as traffic safety.

Target performance at network level monitoring was summarised as follows:
1. maximum sampling distance 5 - 20 m.;
2. maximum accuracy <=0.05 mm
3. load range 30 - 130 kN.
4. operating speed up to 60 km/h (for rolling deflection measuring equipment).

For the network level measurements it is sufficient to measure the air and pavement surface temperatures.

Use of Ground Penetrating Radar to complement information on pavement structure (layer thickness).
4 The Lisbon workshop

To collect the widest possible experience in the use of deflection data at Network level, a workshop named 'COST 336 Workshop on Falling Weight Deflectometer at Network Level’ was held in Lisbon, 4-5 June 1997. The workshop is a major contribution for this document.

The workshop was divided into four sessions according to the network levels defined in section 2.2 of this report. Copies of the complete presentations were distributed to all participants at the workshop. For each session two secretaries summarised the presentations for the purpose of this report.

- Session 1: Global economic analysis - Presentation Spain by Mr. G. Albrecht, secretaries Mr. Ales Hocevar, Slovenia and Mr. Leif G. Wiman, Sweden.
- Session 2: Planning - Presentations Finland by Mr. V. Mannisto and Denmark, Mr. J. M. Jansen, secretaries Mr. Brian W. Ferne, United Kingdom and Mr. Arthur van Dommelen, the Netherlands.
- Session 3: Programming - Presentation Australia by Mr. G. W. Jameson, France by Mr. Simonin and United Kingdom by Mr. B. Ferne, secretaries Mr. Frank Clancy, Ireland and Mr. Francisco Sinis, Spain.
- Session 4: Prioritisation - Presentations FHWA USA by Mr. F. Botelho, the Netherlands by Mr. Thewessen, Croatia by Mr. M. Srsen, Ireland, Mr. F. Clancy and Switzerland, Mr. G. Cuennet, secretaries Dr. Michel Gorski, Belgium and Dr. Laszlo Gaspar, Hungary.

4.1 Session 1: Global Analysis

4.1.1 General observations

In addition to the reported results of recent studies, some general observations can be made with regards to the importance of pavement parameters (condition indicators).

Surface distress is a parameter the road user (i.e. general public) is most aware of, and since the taxpayer’s money is used for maintenance and rehabilitation, it is certainly important for road authorities to consider, in addition to the valuable information it provides the engineer on the extent of deterioration and condition of a road. It is often used by local governments and others as a political tool for questioning the amount of funds approved or their allocation (distribution).

Unevenness is another sign of deterioration or even poor construction, but in terms of a PMS, it is generally related to increased road-user costs.
Skid resistance on the other hand is very important and synonymous with road safety. Therefore actions to improve skid resistance, along with transverse unevenness (rutting), usually have a high priority and are often considered before any other measure, especially if there is a risk for accidents.

Determining the structural adequacy of pavements, however, has been traditionally linked to project level analysis. The fact that COST 336 had been initiated to deal with, among other things, the use of FWD’s at network level, and that an international workshop had been organised on this topic, is a sign, that this is evidently changing. This conclusion is also supported by the results of studies mentioned previously.

The costs of laying new overlays are very high. Therefore, including information on bearing capacity at network level - along with other parameters - certainly improves the results of a PMS in determining optimum solutions. It provides road agencies with better estimates for the timing of maintenance and strengthening requirements.

In countries, where inadequate funding in the past did not enable the appropriate (timely) development of the network (not to mention maintenance), in terms of strengthening needs, necessary widening, construction of bypasses and motorways, the increase in traffic volume and loading that followed, caused a rapid deterioration of the road infrastructure. In certain areas, where load limitations during the thaw period were not respected due to the fact that a route may have provided the only accessibility, overall damages to the pavement were even greater. In all such cases, where parts of a network are structurally in poor condition, funds can be used economically and effectively simply by approving programmes on the basis of prioritisation, following an evaluation of bearing capacity based on deflection measurements.

On the other end of the scale, where the development of the network had progressed with the needs, and the construction of motorways and other major roads carrying the greatest and heaviest traffic is almost complete (while the remaining road network had been maintained reasonably well), the strategy is more complex and more “fine tuning” is possible due to the availability of comprehensive road data bases and well established road management systems. Life-cycle costs, environmental concerns, possibilities to optimise cost/benefit effects, by applying appropriate new overlays very close to the end of the structural lifetime of a road section, are but a few among many possible considerations.

### 4.1.2 Considerations for executing FWD measurements at network level

Whether or not FWD measurements are carried out at network level and what type of methodology is adopted depends on the overall needs and strategy formulated by the central (and/or local) road authority/agency. In this respect, the presentations and discussions during the workshop, had shown that there are several important points that need to be considered. These include:

- the size of a road network
The size of the overall network or the length of any one if its categories of roads may be the reason not to perform any FWD network monitoring until such equipment is developed, that can operate at higher speeds, allowing greater coverage (i.e. USA). In other cases, the network in itself is small enough that it is reasonable to use existing equipment for network level purposes (i.e. Denmark, Slovenia). In situations in between, selecting portions of the network or adopting a statistical sampling methodology is perhaps a more adequate approach (i.e. Finland) that provides sufficient information for global economic analysis.

- the status of the road data base regarding the availability of information on bearing capacity

In some countries information on bearing capacity of pavements has been available for a long period of time (i.e. France, UK, NL, etc.). It was obtained either on the basis of past evaluations of deflection measurements at project level and/or network level, using Curviameters, the Lacroix deflectograph or even FWD’s, or determined by other means and using site specific information on pavement design and especially accumulated traffic loadings. By means of aggregating such data obtained in the past, the data base may provide sufficient information on the network that only measurements at project level may be necessary, especially considering all other implications regarding network monitoring.

- the overall importance given to particular parameters (and therefore measurements) within a PMS and the requirements of such a system

In countries, where PMS do not contain information on structural adequacy and have no respective pavement models, the optimisations are based on other parameters, so there obviously is no benefit assumed in executing FWD measurements at network level. In countries, where data obtained by evaluating deflection measurements (i.e. E moduli in Denmark and remaining life in Slovenia, for instance) is available, the fact that the PMS is based on a deterministic or probabilistic model, may even necessitate a certain sampling methodology (i.e. a statistical sampling methodology in the case of the Finnish probabilistic model).

- overall costs for executing measurements and the time needed for fulfilling the task

In some cases, costs associated with the mere quantity of measurements determines whether a statistical or systematic sampling method is adopted, or whether FWD measurements at network level are executed at all. In other cases, due to safety precautions, circumstances necessitate road or lane closure, which again has significant cost implications. Traffic disruptions, time delays and safety implications thus also need to be considered. On the other hand, availability of government employed staff for executing various monitoring activities may in itself, together with needs for increased equipment utilisation, favour network
monitoring, to utilise the time available between project level studies, for a useful purpose.

- the requirements of the customer

The fact that a customer may award a contract for executing FWD measurements over the length of a longer road (i.e. an example was presented at the workshop regarding a case in Switzerland), which due to the extent, is effectively comparable to network level monitoring, necessitates from the organisation carrying out the task, to consider minimum necessary requirements and an appropriate methodology. The same is true for another example given on evaluating the bearing capacity of pavements anew in Bosnia and Herzegovina, after the war, due to the transport of tanks and other military equipment on those roads.

- "historic reasons" - which includes a combination of design standards, an adequate budget over a longer period of time and sound information on traffic levels and trends

In the UK and Germany, the motorways were designed based on standards that were less conservative, due to the fact that the budget available enabled this and existing traffic at the time was already high enough to merit a somewhat different approach. Moreover, the roads received timely maintenance treatments that kept prolonging the structural lifetime of the roads. In these cases, executing deflection measurements to obtain information on the bearing capacity of such roads is unnecessary. This however, is not true for the remaining road network (i.e. secondary roads, etc.), nor roads in many other countries.

Whatever strategy the road authority/agency adopts when considering (directly or indirectly) the above points, it remains a fact, that every country needs to obtain in some way information on the bearing capacity of its pavements at network level at least once. In some cases the network approach using deflection measuring devices has been accomplished over 20 years ago (i.e. France), in other cases, such actions are underway. In doing so and making use of other available information, the short, medium and long term global budget needs can be assessed, and the distribution of funds between new construction, maintenance and rehabilitation (strengthening) can be determined.

4.1.3 Comments on the presentation in Session 1

The only presentation on global economic analysis at the workshop came from Spain. The presentation was comprehensive and in many ways seemed to reflect the situation that can be found in other European countries. A detailed description was given of the pavement management system, which provides the basis for most of the decision making. Various monitoring equipment is available for executing systematic survey's at network level, that include unevenness measurements with a laser profilometer, skid resistance measurements with SCRM and deflection measurements using a curviameter. Visual inspections of the road network are primarily oriented towards
recording the type and extent of cracking (within and outside the wheelpaths), in addition to rutting. Ground penetrating radar’s are used to determine the pavement composition. GPR data supplements existing historical data that is available in the road data base and information obtained by taking cores. At project level, deflection measurements are carried out using the Lacroix deflectograph (for flexible pavements) and the FWD (for rigid pavements). For prognosis purposes, the evolution of parameters is obtained on the basis of different prediction models that have been developed elsewhere (abroad) and implemented locally. Although the benefits of a PMS are well understood and it is recognised that the tool allows global maintenance investment planning, budget distribution and optimisation based on available resources, there is still some opposition and full implementation is hindered due to traditional decision making, costs of survey’s, limited yearly budgets and decisions based on political interventions. The PMS was used for the first time primarily to determine the condition of roads, the effects changes in threshold values or road categories have, and to quantify the budget needs and compare them to existing limits. The PMS generated the need for initiating/continuing periodic survey’s at various (time) frequencies. The sampling method used is either statistical or systematic, and is influenced by considerations such as road safety, costs and time. When deflection measurements are carried out at network level using a FWD, they are executed every 200 meters.

4.2 Session 2: Planning

According to the definitions adopted by Task group 2 of COST 336, planning is “the allocation of maintenance budgets per area, agency or class of roads within the total road network and is the concern of the owner of this network”. It would require statistical monitoring of deflections. The planning activity can be discerned from the global determination of the maintenance budget for the entire network, the further programming (selection of sections that need maintenance) and the further prioritisation (determining order and schedule of maintenance works).

This report tries to contribute to a description of how FWD can be used for this planning activity and which requirements follow from this, on the basis of the presentations given and the material distributed at the COST 336 TG 2 workshop held in Lisbon on 4 and 5 of June 1997. Each presentation is shortly described, with comments on the relevance for the planning level and with attempts to highlight practical basic elements such as measuring distances and evaluation periods. Also the main features of the presented methods are summarised in the tables in Appendix no. 2.
• Spain has a Pavement Management System that is used for State Road Network and for a number of Regional Road Networks. It gives maintenance actions and budgets, both global and by road stretches (defined by pavement age, traffic volume and pavement type). No reference was given in the presentation or in the copies about a distribution of a central budget over regions or subnetworks. On the state network it uses Curviameter for systematic survey’s. On project level it uses Lacroix (flexible) or FWD (rigid). If FWD is used for input, measurements are required at every 200 m. This can be per lane or direction, probably depending upon road width and such. Survey period for deflections is 4 years. It uses empirical deterioration models and threshold values. For cracks it uses HDM.

• Finland has a separate Highway Investment Programming System for planning purposes. For structural assessment it uses KUAB FWD data, measured at 10 to 20 points per section of 1 to 10 km, but not further apart than 500 m. The measuring points are chosen systematically. The measuring cycle is 3 to 5 year, depending on the variability of the former measurement. It should be noted that the same data are also intended for the District Level Pavement Management System and even for project level. Main derived structural parameter is the spring Bearing Capacity Ratio, determined as 160/D0 and a target value depending on design standards and cumulative axle loads. It is only good at network level. A problem with it is that the measurement is done in summer; this requires a correction factor (0.4, 0.6 or 0.8) depending on observed frost behaviour. A statistical Markov process gives, per type of pavement per traffic volume class, an optimal long time funding level and an optimal short term funding level, of course observing other kinds of distress (rut depth, IRI, surface defects) and considering budgetary constrains and economic indicators. No prediction model for the deterioration of the BCR is used in this, but the probability of a change in condition class represents the deterioration. It is planned to change to SCI instead of 160/D0.

• Denmark has PMS since 1988. Deflections are from FWD measurements. For the minor road network it uses only the centre deflection for pre-evaluation of the possible need for more detailed pavement evaluation. The combination of deflection and ADT determines whether the bearing capacity is rated good, fair or poor. The rather small major network is measured and investigated in detail, one could say on project level. Construction details are obtained from trial pits at every 300 m and are updated with contract overlay thickness. Asphalt thickness is considered as not so important. It was argued that some kind of "structural thickness" would solve a lot of problems. It was asked whether GPR would give this. Deflections are measured at 200 m distance in both directions, staggered 100 m. Moduli are backcalculated in a simplified way (by using equivalent thickness approach). These data and other strength data go into the road database. Residual life and overlay need (from chosen design period) are calculated from this straight away for each measuring point. As representative residual life for a section the 25% value of individual point values is taken; for overlay thickness the 75% is taken. Future development of residual life and overlay need are calculated from a (verified) theoretical degradation model. Tests are carried out on sections with expected residual life of 5 years or less and on sections overlaid last year. The network level information (necessary budgets; consequences of restricted budgets and such) for the major road network comes from an aggregation of project level information.
• System applied by ARRB Traffic Research from Australia uses FWD D000, D900 and D1500 deflections to estimate SNC from deflections for use in HDM 3 system. Temperature correction requires asphalt thickness information. Surveys are done every 3 years with a spacing of 50 m (Hong Kong) to 500 m (Philippines). Actual network level application (global analysis, planning, programming, prioritisation) is unclear.

• France has done a systematic sample (2 km per 10 km) Lacroix measurement of the highways network in the mid sixties. Distance between two measurements was 4 metres. From this, and traffic data, followed a global analysis of the reinforcement needs (by classification into 4 maintenance needs) and a works prioritisation for a period of 5 years. Recently, a new Highways PMS has been introduced which is used both for network and section level. Again, no subnetworks are discerned. The system uses central deflection and radius of curvature, if available, to confirm visual condition in the network analysis. Characteristic value are taken, being $\sigma + 2 \mu$. Threshold values are given for $D_0$ and SCI depending on traffic class and maintenance. When a pavement is confirmed to be structurally weak, it can be subjected to complementary studies, but the decision of reinforcement can also be taken directly.

• England does a full coverage of the network with the UK Deflectograph at 3.5 m intervals in a 3 year cycle. Using normalised peak deflection (85 % per 100 m length), temperature, pavement type and traffic, a residual life and overlay thickness is determined for each section. This is based upon empirical deterioration models. Global analyses and planning are again an aggregation of these data, which can also be used for programming, prioritisation and detection of further investigation needs.

• In the United States, 4 out of 50 states do rough evaluation of bearing capacity from 2 FWD measurements per mile. Most assessment is based upon visual observation of cracking. The presentation however underlined the importance of deflection for the future.

• The common system in the Netherlands does not use deflections. It uses visually observed distress which can be entered in dimensionless deterioration models to give residual life and prioritisation. Some provinces use deflection based systems. An elaborate system has been proposed by SHRP-NL. It gives a panel rating based classification of the structural condition (10 classes from very poor to excellent) from tables where the traffic intensity, the IDK (comparable to SCI) from between the wheel paths, the ratio (IDK in wheel path) : (IDK between wheel paths) and the visually observed degree of cracking is entered. It can be considered applicable for programming and prioritisation.

• The project described by representative from Croatia, used SNC calculated from $D_0$ from Lacroix in HDM model. This model predicts damage development. It is again an section analysis that can be aggregated to network. For each section the optimum maintenance measure and strategy / timing is determined. User costs were included. Net present value of savings (compared to “do nothing”) was optimised.
• Ireland is developing some criteria for classification of pavement bearing capacity (D_1 and D_1 - D_2 -> 5 classes: strong to poor), subgrade bearing capacity (D_0 -> 6 classes; very stiff to very weak) and overlay thickness for cost estimation (D_1 and Traffic -> thickness). They use 200 m sections with measuring distances of 25 to 50-m. There is a National Road Needs Database under development that will also use ARAN and SCRIM data, as a basis for future maintenance strategy decisions.

• The Swiss study was a detailed (project level) assessment (including backcalculation of moduli) of the residual life of 140 km of road in one canton, as a first step to creating a road database. FWD measurements were taken at 25 m intervals in each direction. Thickness’ were radar measured in 0.5 m intervals at 40 kph -> mean thickness per 25 m.

From the above workshop presentations it can be concluded that it is hard to derive information about FWD requirements for Planning purposes from the present practice as reported by the participants.

There are several reasons for this.

Those countries that do network level analyses, often do not explicitly discern the four levels of network analysis proposed by COST 336, and / or do not perform these analyses separately but more or less integrally.

A number of countries do systematic measurements of the complete road network, often with other deflection measuring devices than FWD, obtaining such deflection data that these can also be used for programming and prioritisation (and in some cases even for project level decisions). Even when the systems that interpret these data for global analysis/planning are separate from those used for programming/prioritisation, it is not easy to determine which data would have been sufficient for planning only. Often however there is only one system, that makes the global analysis and planning on the basis of an aggregation of programming and prioritisation results, making it virtually impossible to see a difference in requirements.

This sensitivity of the requirements to the context of the assessment strategy, also means that one should be very careful with comparing the tabular data given in Appendix no. 2 of this report and even more so with a further tabular compression of these data, as in Appendix 4 of the Short Report of the seminar.
Overview of Session C - Programming

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<th>Mr. Brian W Ferne</th>
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<td>Min. Section Length</td>
<td>1 kM app.</td>
<td>&quot;</td>
<td>2kM per 10kM</td>
</tr>
<tr>
<td>Maintenance Section Selection</td>
<td>Based on Roughness Data</td>
<td>&quot;</td>
<td>Systematic</td>
</tr>
<tr>
<td># Lanes Tested</td>
<td>ALL</td>
<td>ALL</td>
<td></td>
</tr>
<tr>
<td>Threshold Levels</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Return Period</td>
<td>3Y</td>
<td>3Y</td>
<td>4Y up to 1993</td>
</tr>
<tr>
<td>Methodology</td>
<td>HDM III</td>
<td>HDM III</td>
<td>Bearing Capacity</td>
</tr>
<tr>
<td>Strength Parameters</td>
<td>Modified Structural Number (SNC)</td>
<td>&quot;</td>
<td>Deflection, Layer Thickness</td>
</tr>
<tr>
<td>Relevant Equations</td>
<td>SNC = SN + SNsg</td>
<td>&quot;</td>
<td>Overlay based on Deflection &amp; Traffic</td>
</tr>
<tr>
<td>Limitations</td>
<td>Not Used on Concrete Roads</td>
<td>Reservations about Thin Layer Roads</td>
<td>Used on Flexible Only</td>
</tr>
<tr>
<td>Deflections Used</td>
<td>D0, D900, D1500</td>
<td>&quot;</td>
<td>Peak Deflection</td>
</tr>
</tbody>
</table>

Presentation by:

4.3.1 Mr. Geoffrey Jameson, ARRB Transport Research, AUSTRALIA

Summary:
The paper presented was based on the use of HDM III for flexible roads in Hong Kong and the Philippines. The strength index used was the modified structural number which was developed from the ASSHO road trials.

\[
SNC = SN + SNsg
\]

Where, \( SN = 0.04 \cdot a_i \cdot h_i \)

and \( SNsg = 3.51 \log(CBR) - 0.85 (\log CBR)^2 - 1.43 \)

The influence of structural number on other pavement parameters such as roughness and crack initiation was also discussed. Structural number has much more influence on heavily trafficked roads(1 MSA/y) than on lightly trafficked roads. A modelling relationship was set up to estimate SN and CBR(hence SNC) from FWD deflections. The derived modelling relationships were:
SN = 13.5 - 6.5 \log D_0 + 3.7 \log D_{900}

\log (CBR) = 3.26 - 1.02 \log D_{900}

Thickness and layer moduli had been obtained for over 400 sites in Hong Kong. Structural number was calculated for these sites and then compared with modelling relationships which had been developed using FWD deflections (D_0, D_{900}). Regression analysis was then carried out in order to check the validity at the modelling relationship. The regression relationship which resulted was:

\[ SN = 1.7 + \frac{813}{D_0 - D_{1500}} - \frac{39}{D_{900}} \]

Central deflections were corrected for temperature based on air temperature.

The relationship between structural coefficients and layer moduli was also investigated. One interesting point from this was that for the same layer modulus value asphaltic material can have a structural coefficient at three to four times that of a cemented material.

The FWD estimated CBR values were compared to values from DCP for a number of sites. The results indicated that more work needs to be done in this area. The speaker suggested that the deflections used to predict CBR may need to be reviewed.

Summary at Question/Answer session:

Q. Could this approach be used for more complicated structures?
A. This exercise should really be carried out for a number of different types of structures. The speaker also expressed reservations about the use of this system for thin bituminous layers on granular roads.

Q. How are homogeneous sections picked?
A. They are based on roughness data. Sections are typically 1km in length. Mean values of structural number are used in the deterioration model and characteristic values for overlay thickness design.

Q. Why not use asphalt thickness to try and improve the regression equations?
A. Could be a good idea but not done in this case.

Q. Was stress dependency investigated?
A. Not in this case.

Q. Is this system used in Australia?
A. No. FWD is not used at Network level in Australia.
Q. Would it be possible to use a simple back analysis model to estimate structural coefficients?
A. This is a possibility but not done in this case.

4.3.2 Mr. J. Simonin, LCPC, FRANCE

Summary:

The use of deflection measurement in network analysis in France was outlined in this talk. Network analysis using the Deflectograph began in the early sixties. The network was rated on the basis of deflection and traffic scales. Overlay thickness tables were constructed for both hydraulic (water) and bituminous bound materials.

Deflectograph deflections are carried out every four meters during testing. Two kilometres per ten were tested systematically every four years up to 1993.

Since 1993 systematic deflection testing has ceased as a new PMS has been introduced. The PMS is based on visual condition of the road using high speed road monitor. Deflection testing is now used at project level for detailed overlay design.

Summary of Question session:

Q. What deflection value is used for dividing into homogeneous sections?
A. The mean plus two standard deviations was used initially. The 97.5 percentile is now more often used as the distribution is thought to be normal.

Q. On what basis was the 2 km per 10 km picked?
A. A continuous 2 km per 10 km was chosen arbitrarily.

Q. Is overlay thickness estimated on the basis of high speed monitor readings in the new PMS?
A. Yes, but this is used for network analyses only. Detailed overlay design is carried out project level.

4.3.3 Brian Ferne, TRL, UK

Summary:

The speaker first acknowledged the input made by Mr. L.G. Hawker of the Highways Agency and C.K. Kennedy at WDM Ltd. into the presentation preparation.
There are approximately 10,000 km of motorway and trunk road in England. This has been tested on a network basis using the UK Deflectograph since 1984. The procedure for trunk road assessment was described as a combination of High Speed Road Monitoring (HRM) and deflection testing.

The TRL have developed methods of predicting residual life and strengthening requirements based on Deflectograph measurements. This has been done by monitoring in service pavements using deflection and other measurements. The road network is then colour coded on the basis of remaining residual life. This information is presented in both piechart and map form in order to make administration easier. The section lengths are based on minimum maintenance lengths which, for example, would be approximately 4 km for motorway. A similar exercise has also been carried out for overlay design thickness values.

The Deflectograph is a more economic instrument for use in network evaluation than is the FWD. The approach used is therefore to identify priority sections using the Deflectograph which can then be further investigated at project level using FWD.

Study of deflection values versus time have shown that deflection does not increase with time on all roads. In some cases the deflection values have fallen as the pavement materials stiffen with time.

Summary of Question/Answer Session:
Q. Are there defined steps involved in going from using deflection at network to project level?
A. Yes. A flow chart was produced which outlined the steps involved.

Q. In the UK both HRM and Deflectograph are used at network level. Why not use roughness information from HRM to identify deflection locations?
A. There are still some problems in matching deflection data with roughness data on the road. The cost of Deflectograph makes it economical and worthwhile to continue to use it systematically at network level.

Q. What changes do you foresee with the implementation of a Pavement Management System (PMS)?
A. The PMS will look at the whole life costs of design strategies.
4.4 Session 4: Prioritisation

PRIORITISATION, means organising the program\(^1\) in a list of priority from the more to the less urgent (according to a criteria based on a predefined indicator).

The report is based on two parts:

1. Response to a series of topics related specifically to prioritisation (PRIORITISATION SPECIFICS).
2. Summary of the information that should be collected together with the data processing and reductions to be performed (INFORMATION SUMMARY, retrieved from Workshop Reports).

4.4.1 Prioritisation specifics

4.4.1.1 Basis of prioritisation

The basis of prioritisation is to rank in order of importance or urgency, maintenance sections selected in the programming phase. These sections are the ones which already need structural reinforcement or are those who are still in an acceptable time schedule before reaching the strengthening trigger threshold. The ranking scale is function of the structural adequacy or inadequacy of the maintenance sections which is described by an appropriate indicator. This indicator is compatible with the criteria adopted for priority decision making.

This indicator can be time dependant or not. The nature of the indicator is a result of the type of analysis, technical and/or economical, which is conducted in the PMS process for optimising maintenance strategies (**Life Cycle Cost Analysis, Remaining Service Life Analysis, Multicriteria Analysis**).

Deflection measurements contribute with other road condition factors (functional, structural and environmental) to the calculation of such indicators. But in some cases statistical expressions of deflection are used directly for the classification of priorities. More details are given on indicators in 4.4.1.4 Structural data used.

4.4.1.2 Accuracy

Accuracy of prioritisation is dependent on two factors. The first is how well the section selected for maintenance is identified and located. In particular, how are the homogeneous zones determined and what are the minimum lengths accepted for

\(^{1}\) eg. Selecting all the sections of road which actually require maintenance work.
overlays. The second is linked to the sensitivity of the indicator used and its ability to discriminate between structural conditions. This necessarily implies that deflection data provided for the network level are obtained from systematic monitoring. Systematic monitoring means continuous or regular measurements with a maximum equal sampling spacing of 20 to 50m. The latter can be produced if consecutive values remain relatively constant, that is if variations of the measurements are kept within limits, for example remain within a given class of deflections. If it is not the case, then spacing should be reduced to a maximum of 20m in order to detect rates of changes and allow thus sections to be determined with an accuracy of ±20m. This is important to apply if minimum allowable lengths for sections to be reinforced are reduced typically to 100 or 200m sections which is not so uncommon.

4.4.1.3 Apportionment of structural maintenance versus total maintenance

In order to establish what is the share of structural maintenance versus the entire maintenance to be prioritised it is important to make a rational partition between sections to be reinforced and sections to be maintained (without additional strengthening). “Fortunately” where there are structural problems, there are inevitably some associated surface distresses. The opposite is of course not necessarily true. The partition will depend on the ability to make a diagnose of the probable causes of the surface distresses, in other words, do the latter originate in the structure or not. This is particularly important if monitoring the network is organised in such a way that deflection measurements are carried only on roads which exhibit surface distresses and this for the purpose of reducing the burden of systematic structural monitoring of the whole network.

4.4.1.4 Structural data used

The following list of data related to structural evaluation outlines the parameters that are needed to formulate the indicator(s) used at prioritisation level (in italic, optional parameters):

- deflection (peak, *bowl*), (in wheel track, *between wheel tracks*),
- pavement structure (age, layers, *thickness, soil type*),
- pavement temperature (air, surface, *inside layers*),
- surface distress (fatigue cracks, *deformations, rutting, evenness*),
- climatic conditions (seasonal temperature, *moisture*),
- traffic (ADT, ESALs and annual progression).

These parameters will have to be translated into indicators that express best the concept of bearing capacity. Indicators currently practised are in the order of importance:

- technical:
  - the reinforcement thickness,
time dependant:
• the residual life time of pavements,
• the residual ESAL capacity for the pavement,

economical:
• the cost of maintenance solution (amortisation, present net benefit, rate of return).

Remark: some management systems have an objective function to optimise, which targets the functional aspect of pavement (road user implication) and where evenness is of major importance (for example the HDM3 of the World Bank). In such systems deflection plays a restricted role and is being considered only as an explanatory variable among those used to predict the progression of evenness.

Details are given in the next paragraph: INFORMATION SUMMARY.

4.4.1.5 Strategy at low budget.

Two cases can be considered:

1. Low budgets for the Network Level Study (implying limited affordability for data collection and monitoring).

In the context of financial constraints, there will be no alternative other than to cut down on the quality (accuracy) and amount of information collected. But this in turn should not be detrimental to the evaluation and sensitivity of determining the chosen priority indicator. One could switch from continuous measurements to a statistical sampling approach applied to homogeneous sections predetermined by an assessment other than deflection measurement for instance, evenness or visual inspection of cracking. If statistical sampling is used, then it is necessary to determine the minimum number of randomly located samples to be measured in each predetermined homogeneous road section.

The risk will nevertheless always remain as to an over or under evaluation of structural adequacy following this procedure.

2. Low budget allocation from decision makers (Global Economic Analysis) for maintenance and reinforcement.

If the PMS priority is based on the “worst first” approach, the indicator to use is either the residual life time of pavements, or the residual ESAL capacity for the pavement. If the PMS is driven by the “life cycle costing” approach, then the indicator, cost of maintenance solution (expressed in terms of economic performance) will necessarily be used.

Both options will display in their priorities, residual road sections whose maintenance will have to be postponed. In general, both options will generate priority lists in different orders.
4.4.2 Information summary

This information is structured according to items used identically within the chapter on “Minimum Needs for Network Use”. The responses summarise the contributions of the authors that have taken part in the presentations of the session “Prioritisation” of the Workshop on FWD use at Network Level. Only items that are documented are listed with author’s names.

4.4.2.1 Assessment strategy
- Swiss Guidelines (CUENNET),
- HDM3 (SRSEN),
- Priority based on classes of residual lives (THEWESSEN),
- Road Information System associated with Intervention Levels (CLANCY).

4.4.2.2 Required measurements
- Deflection parameters used:
  - full bowl (CUENNET, THEWESSEN), partial bowl (discrete, THEWESSEN),
  - curvature indexes (THEWESSEN),
  - visual distress (SRSEN, THEWESSEN),
  - thickness: GPR (radar), (CUENNET),
  - traffic (SRSEN, THEWESSEN, SRSEN).

4.4.2.3 Measurement procedures
- transducer spacing (300mm) (CLANCY),
- test spacing (regular 20-50 m) (CUENNET, CLANCY),
- transverse spacing (lanes, wheel path), (THEWESSEN).

4.4.2.4 Data processing
- normalisation: temperature, climatic/soil condition (SALT, discussion),
- output used: engineering units (deflections data), (CUENNET, THEWESSEN), SNC (HDM, SRSEN), residual service life (CUENNET, THEWESSEN), new indicators (BOTELHO).
5 Supplementary COST 336 information

5.1 Task Group 1 questionnaire

This questionnaire was answered by 28 participants in 13 COST member countries representing to day's FWD practice. The answers give a detailed picture of the practical post processing both for project and for network level.

Combined with one ore more systems presented at the workshop they will serve as a useful guide for Road Administrations when they implement or expand the use of FWD at Network level.

The questionnaire deals with all aspects of FWD post processing from backcalculation programs over traffic to evaluation report and quality assurance.

5.2 Short Workshop management report

The COST 336 workshop on the use of FWD at network was held in Lisbon in June 1997. Systems from nine member countries and two non member countries was presented and discussed. The Short Workshop Report summarise the workshop with the programme, list of participants and a table showing the major parameters in the systems presented during the workshop.

5.3 Network level guide

This guide will, as the final deliverable summarise all the achieved information during this literature survey and during the workshop, to a useful guide for Road Administrations in the use of FWD at network level.

5.4 Internet home pages

The official home page of this COST 336 action can be found at this URL http://www.cordis.lu/cost-transport/src/cost-336.htm

In addition the progress of the action can be followed at the COST 336 "day to day" home page at this URL http://www.crow.nl/cost-336.htm
Appendix no. 1

Abstracts of reviewed papers
as printed in the IRRD-OECD and TRB-TRIS data bases

COST 336 Falling Weight Deflectometer
INFORMATION GATHERING REPORT
Task Group 2 - FWD at Network Level
Short references, full abstracts on the following pages, one page each reference.

[1] Oliver J.E., "Use of deflections to manage the structural maintenance requirements at network level in England", 1995


[13] Scullion T., "Incorporating a structural strength index into the Texas pavement evaluation system. Final report", 1988


A major task for the manager of a maintenance program is to collate and present a robust case for funds to ensure that the network is maintained at an appropriate level. In England a project was conducted to collate and analyze deflection data collected, principally for project-level design, for the benefit of network-level planning. The total national highway network in Great Britain is some 11,000 km long, representing only 4% of total road length but carrying 30% of all traffic and 60% of heavy traffic. Deflection data usually are collected under contracts let by some 90 maintenance agents. Between 1985 and 1991 some 80% of the length of flexible roads was surveyed, some of it more than once, and the results analyzed. On the basis that the most cost-effective strategy for strengthening is to overlay the surface at the critical point, the network has been shown to be in suboptimal condition. The project collated deflection data and presented them in a consistent and easily understood format to illustrate requirements for restoring the network to its optimal condition. Condition data were also analyzed through a network model to investigate alternative strengthening strategies over the medium and longer terms. Collection and analysis of data in this way offers the opportunity to carry out valuable audits of the range of projects put forward—and not put forward—by agents. It therefore improves the management of maintenance at both network and project levels.
SB: IRRD-OECD
TI: GUIDE TO THE SOUNDING OF FLEXIBLE PAVEMENTS. (GUIDE D’AUSCULTATION DES CHAUSSEES SOUPLES.)
AU: AUTRET-P (LCPC); SAUTEREY-R (LCPC)
SO: COLLECTION DU LCPC. 1977. XVI+180P
PB: EYROLLES, BOULEVARD SAINT GERMAIN 61, PARIS, F-75005, FRANCE
PY: 1977
LA: FRENCH
AB: THIS BOOK DEALS WITH A METHODOLOGY FOR THE STRENGTHENING OF FLEXIBLE PAVEMENTS. SPECIAL ATTENTION IS PAID TO THE IN SITU COLLECTION OF DATA, THE COMPOSITION OF THE WORK TEAMS, EQUIPMENT FOR SOUNDING AND LABORATORY TESTS, AND THE INTERPRETATION OF RESULTS AS THESE AFFECT DESIGN METHODS.
DE: FLEXIBLE-PAVEMENT; 2944-; SURVEILLANCE-; 9101-; SPECIFICATIONS-; 0147-; APPARATUS-MEASURING; 6155-; DEFLECTION-; 5586-; DETERIORATION-; 5255-; SURFACE-; 6438-; PHOTOGRAPHY-; 6751-; METHOD-; 9102-; STRENGTHENING-PAVEMENT; 3096-; PAVEMENT-DESIGN; 3055-; PROFILOMETER-; 6103-; SOUNDING-; 5720- SC: PAVEMENT-DESIGN (22)
AN: 106063
UD: 199511
CN: LCPC16488E
Francais[2]

SB: IRRD-OECD
TI: GUIDE D'AUSCULTATION DES CHAUSSEES SOUPLES.
AU: AUTRET-P (LCPC); SAUTEREY-R (LCPC)
SO: COLLECTION DU LCPC. 1977. XVI+180P
PB: EYROLLES, BOULEVARD SAINT GERMAIN 61, PARIS, F-75005, FRANCE
PY: 1977
LA: FRANCAIS
AB: L'OUVRAGE, REDIGE PAR UNE EQUIPE D'INGENIEURS DU LCPC ET DES PAR (POINT D' APPUI RENFORCEMENT) DES LABORATOIRES REGIONAUX, AIDE A FAIRE CONNAITRE LA METHODOLOGIE MISE AU POINT POUR LES ETUDES DE RENFORCEMENTS COORDONNES EN DECRIVANT EN PARTICULIER LE RECUEIL DES DONNEES EN PLACE, LA COMPOSITION DES EQUIPES, LE MATERIEL D'AUSCULTATION ET LES ESSAIS DE LABORATOIRE, L'INTERPRETATION DES RESULTATS ET EN DONNANT DES INDICATIONS SUR LA METHODE DE DIMENSIONNEMENT. (12592 - GEOTECH : M LAGABRIELLE ; 12591 - CHAUSSEES : M LEFLAIVE ; 12589 - BIBL ; 12590 - BIBL).
DE: CHAUSSEE-SOUPLE; 2944-; AUSCULTATION-; 9101-; GUIDE-RECOMM; 0147-; APPAREIL-DE-MESURE; 6155-; DEFLExION-; 5586-; DEGRAdATION-; 5255-; SURFACE-; 6438-; PHOTOGRAPHIE-; 6751-; METHODOLOGIE-; 9102-; RENFORCEMENT-CHAUSSEE; 3096-; DIMENSIONNEMENT-DES-CHAUSSEES; 3055-; APPAREIL-DE-MESURE-DE-PROFIL; 6103-; SONDAGE-; 5720-
SC: DIMENSIONNEMENT-DES-CHAUSSEES (22)
AN: 106063
UD: 199511
CN: LCPC16488F
SB: TRB-TRIS
TI: NETWORK-LEVEL DEFLECTION DATA COLLECTION FOR RIGID PAVEMENTS. INTERIM REPORT.
AU: Perrone-E; Dossey-T; Hudson-WR
CA: Texas University, Austin, Center for Transportation Research, 3208 Red River, Suite 200, Austin, TX, 78705-2650, USA; Texas Department of Transportation, Office of Research and Technology Transfer, P.O. Box 5051, Austin, TX, 78763-, USA
SO: 1994/07. pp57 (Figs., Tabs., 17 Ref., 1 App.)
NT: Research study title: Texas Pavement Management System.
PY: 1994
RN: Report Number: TX-94-1908-3; Report Number: Res Rept 1908-3; Report Number: CTR 7-1908; Contract/Grant Number: Study 7-1908
LA: English
AB: The existing rigid pavement deflection data contained in the Texas Pavement Evaluation System (PES) database are evaluated and found to be inadequate for any network-level study of the structural behavior of rigid pavements. The PES data were evaluated by comparing them with existing data contained in the University of Texas’ Center for Transportation Research (CTR) rigid pavement database. Having found the data to be questionable, no further analysis was performed. For the network evaluation of the structural behavior of rigid pavements, recommendations are provided for future falling weight deflectometer (FWD) data collection for rigid pavements at the network level. The optimum sample size, the testing procedures, and a cost estimate for the data collection plan are given.
DE: RIGID-PAVEMENTS; PAVEMENT-DEFLECTION; DATA-COLLECTION; FALLING-WEIGHT-DEFLECTOMETERS; SAMPLE-SIZE; TEST-METHODS; RECOMMENDATIONS; COST-ESTIMATES; PAVEMENT-MANAGEMENT-SYSTEMS
SC: PAVEMENT-DESIGN-AND-PERFORMANCE (H24); PAVEMENT-DESIGN (I22); PROPERTIES-OF-ROAD-SURFACES (I23)
PA: National Technical Information Service
AN: 00677785
UD: 199602
In this paper a method is presented to translate the results of a falling weight deflection measurement into a straightforward matrix in such a way that a practical implementation in a pavement management system (PMS), on network-level, will be possible. In this way, a practical combination and translation from data collected during a visual inspection and data collected from a falling weight deflection measurement into a PMS has been made. The presented method takes into account the effect of the category of road (traffic load). This paper ends with some conclusions concerning the use and benefit of a falling weight deflection measurement in a PMS.
The Texas State Department of Highways and Public Transportation has 13 falling weight deflectometers to obtain deflection information for the Pavement Management System, determine optimum rehabilitation and reconstruction strategies for highway segments, design new pavements and overlays, establish load restrictions on light pavements, and to determine wheel load capacity of pavements for superheavy permit moves. SDHPT has developed procedures to utilize FWD in the determination of elastic moduli of paving materials for design and evaluation on both rigid and flexible pavements. Special equipment is used with each FWD to perform load transfer surveys across joints and cracks on rigid pavements. A microcomputer program called MODULUS was developed to backcalculate pavement layer moduli using FWD or dynaflect deflections. Pavement design and overlay thickness determination is also accomplished with a microcomputer program. The network level deflection test surveys of its highway system performed by SDHPT is described.
The objective of this paper is to investigate current methods of pavement evaluation in Jordan. The results of five methods are presented and discussed. These methods are: (i) present serviceability rating (PSR), (ii) laboratory testing, (iii) visual inspection, (iv) pavement condition index (PCI) and (v) non-destructive deflection testing (NDT). The results indicated that most of the pavement damage results from heavy loading and the high percentage of trucks using the roads. Also, the degree of patching and cracking as a measure of pavement serviceability was found to be more effective than the use of patching alone. It was recommended finally to separate these methods depending on the objective of the evaluation, i.e., if it is at the network level or the project level. These methods can be successfully used in the existing Highway Maintenance Management System (HMMS) in Jordan to set maintenance priorities and allocate maintenance funds under a situation of limited budget and resources.
In the past few years, the Roads Administration of the Belgian Ministry of Public Works has developed, in co-operation with the Belgian Road Research Centre, a management system for the maintenance of the Belgian road network (the 'SOGER' system). This system utilizes several files of the Road Data Bank (RDB), of which it is a satellite. It is based, among other things, on a catalogue of maintenance techniques, which contains an inventory of items relating to pavement maintenance. For each item, a description is given of the operations involved, the influence on the characteristic road parameters, and the service life resulting from the maintenance techniques in relation to traffic. The characteristic parameters are skid resistance, longitudinal evenness, transverse evenness, deflection and visual condition (cracking, stripping, deformation and miscellaneous). On the other hand, the system makes use of a catalogue of standardized road work items, which contains an inventory of all items involved in road construction, maintenance and repairs. Each item has been given a code number, so that it can be retrieved in the various files of the data bank (A). For the covering entry of the Conference, see IRRD number 823206.
This paper presents a statistical study to use road condition variables and other technical variables from the Road Data Bank to estimate road bearing capacity. This study was motivated by the need to evaluate the bearing capacity distribution without using slow and expensive deflection measurements. Three data sets were analysed, two of which were from roads in the Lappi district of Finland and the third of which was from Shandong Province, China. A stepwise discriminant analysis was used to select the best set of quantitative variables for a discriminant model; the set of exploratory observations classified about 40% to 50% of the observations into the right classes. For further usage of the results, posterior classification probabilities can be calculated from the discriminant function. The results of this study are encouraging, despite the rather high misclassification rate of the observations. In many cases, it seems that the required number of bearing capacity measurements can be reduced and the measuring effort can be concentrated on the most important sections of the road network. Several problems need further research; especially the evaluation of the number of variables needed in the dataset for convenient use of the results. For the covering abstract of the conference see IRRD 833507.
AB: In this paper, the authors are concerned with the Pavement Maintenance Management Unit and in particular with Road Assessment Survey Systems within the full Highway Management System. Road Assessment Survey Systems include the collection, storage and processing of measurements and their comparison with threshold or intervention levels. Detailed descriptions are given of the tools available to produce these measurements required for routine network monitoring, including the High Speed Road Monitor (HRM), the Sideway Force Coefficient Routine Investigation Machine (SCRIM), the High Speed Texture Meter (a single function version of the HRM) and the Pavement Deflection Data Logging Machine (PDDLM) or "Deflectograph".

DE: MAINTENANCE-; 3847-; HIGHWAY-; 2755-; CONTINUOUS-; 9006-; SURVEILLANCE-; 9101-; DATA-ACQUISITION; 8623-; EVALUATION-ASSESSMENT; 9020-; DEFLECTION-; 5586-; MEASUREMENT-; 6136-; SURFACE-TEXTURE; 3053-; SKIDDING-RESISTANCE; 3031-; DATA-BANK; 8614-

SC: ECONOMICS-AND-ADMINISTRATION (10); MAINTENANCE (60)

AN: 827410

UD: 199511

CN: 9003TR323E
SB: TRB-TRIS
TI: A PAVEMENT MANAGEMENT RESEARCH PROGRAM FOR OREGON HIGHWAYS. FINAL REPORT.
AU: Parker-D
CA: Oregon Department of Transportation, 140 Transportation Building, Salem, OR, 97310, USA; Federal Highway Administration, 400 7th Street, SW, Washington, DC, 20590, USA
SO: 1989/12. pp43 (Figs., Tabs., 20 Ref., 1 App.)
PY: 1989
RN: Report Number: FHWA-OR-RD-90-08; Contract/Grant Number: 5253
AB: An extensive program was developed to measure pavement deflection, skid resistance, and rideability throughout Oregon. The data from those "objective" measures were then evaluated for correlations with observed pavement distress and traffic factors. It is concluded that "Dynaflect" deflections and other "objective" measures of pavement performance can best be used on the project level. The mechanized data gathering methods evaluated here have not proven valuable in network level pavement management.
DE: PAVEMENT-MANAGEMENT; OREGON-; PAVEMENT-DEFLECTION; DYNAFLECT-DEFLECTIONS; SKID-RESISTANCE; RIDEABILITY-; CORRELATION-; PAVEMENT-DISTRESS; TRAFFIC-LOADS
SC: PAVEMENT-DESIGN-AND-PERFORMANCE (H24); PAVEMENT-DESIGN (I22); PROPERTIES-OF-ROAD-SURFACES (I23)
PA: National Technical Information Service (PB90-253238/AS)
AN: 00493602
UD: 199602
SB: IRRD-OECD
TI: EXPERIENCES IN USING FALLING WEIGHT DEFLECTOMERS AS ROUTINE
AU: SCHMIDT-B (ROAD DIRECTORATE, DANISH ROAD INSTITUTE)
SO: STATENS VEJLABORATORIUM NOTAT. 1989. (220) 19P
PB: ROAD DIRECTORATE, DANISH ROAD INSTITUTE, ELISAGAARDSVÆJ
5, POSTBOX 235, ROSKILDE, 4000, DENMARK
PY: 1989
IS: 0109-5315
LA: ENGLISH
AB: This report describes the Use of the Dynamic Loading Facility and the Falling Weight Deflectometer in the Danish Pavement Management (PM) System. Within the last decade, a great deal of work has been undertaken in Denmark to develop a Pavement Management System suitable for the Danish state road network. In the period from 1984 to 1987 the present PM system has been tested in three different counties and improvements and further developments of the system have been based on the results from these tests. In late 1987 the revised PM system was considered to be reliable enough to be implemented in all counties in Denmark. The present paper describes the experiences obtained during 1988. This involved the determination of the structural conditions and hence the remaining lifetime and overlay design of a particular road based on measurements from the dynamic loading facility. Falling Weight Deflectometer measurements, and the incorporated mechanistic approach used for pavement analysis are described as is the method of Equivalent Layer Thicknesses. Although the Falling Weight Deflectometer is regarded as non-destructive equipment to determine the bearing capacity of a road, it is necessary when using a back-calculation procedure such as the Method of Equivalent Layer Thicknesses to be in possession of exact information about the pavement layer thicknesses.
DE: PAVEMENT-DESIGN; 3055-; EVALUATION-ASSESSMENT; 9020-;
DYNAMICS-; 5473-; LOAD-; 5567-; BEARING-CAPACITY; 3085-; FLEXIBLE-
PAVEMENT; 2944-; MODULUS-OF-ELASTICITY; 5919-; NON-DESTRUCTIVE;
6216-; STRENGTHENING-PAVEMENT; 3096-; DEFLECTION-; 5586-
SC: MAINTENANCE (60); EQUIPMENT-AND-MAINTENANCE-METHODS
(61); PAVEMENT-DESIGN (22)
AN: 859211
UD: 199511
CN: 9309SL032E
SB: IRRD-OECD
TI: DESIGN OF PAVEMENT CONDITION PRESERVATION IN THE HUNGARIAN PAVEMENT MANAGEMENT SYSTEM.
AU: BOROMISZA-T (INSTITUTE FOR TRANSPORT SCIENCES, BUDAPEST, HUNGARY)
SO: ACADEMIC CONFERENCE PROCEEDINGS OF INTERNATIONAL CONFERENCE AND EXHIBITION ON ROAD TRANSPORT, BEIJING, CHINA, 7-12 MAY 1989. 1989/05. pp205-9 (4 Refs.)
PB: TECHNOLOGY EXCHANGE CENTER OF THE MINISTRY OF COMMUNICATIONS, 22 DALIUSHUBEICUN, BEIJING, 100081, CHINA (30$)
PY: 1989
LA: ENGLISH; CHINESE
LS: CHINESE
DE: PAVEMENT-; 2955-; ROAD-NETWORK; 2743-; MAINTENANCE-; 3847-; DATA-BANK; 8614-; ADMINISTRATION-; 0145-; OPTIMUM-; 9056-; PRIORITY-GEN; 0131-; BEARING-CAPACITY; 3085-; EVENNESS-; 3071-; DEFLECTION-; 5586-; PAVEMENT-DESIGN; 3055-; CONFERENCE-; 8525-; SC: ECONOMICS-AND-ADMINISTRATION (10); PAVEMENT-DESIGN (22); EQUIPMENT-AND-MAINTENANCE-METHODS (61)
AN: 824570
UD: 199511
CN: 8910CD008E
The current Pavement Evaluation System used in Texas rates the condition of pavements in terms of visual distress and present serviceability index. This report discusses the addition of another dimension to the rating system; that of a Structural Strength Index. The Falling Weight Deflectometer is to be used for this purpose. In this report, an overview is given of the FWD and data analysis techniques, a discussion on sample size is presented and two possible structural strength schemes are proposed. The first is a simple statistically based scheme which ranks pavement strength in terms of key deflection bowl parameters, and includes weighting factors for traffic level and rainfall. The second is a mechanistic approach in which a remaining service life is calculated. These two approaches were pilot tested on data collected in several Texas districts. It was recommended that the statistically based scheme be implemented. Although the mechanistic scheme shows promise at the project level, several factors including incomplete layer information and insufficient traffic data, currently limit its applicability at the network level.
The first Hungarian network-level pavement management system relies on Markov transition probability matrices. A combined condition parameter is applied taking into consideration the bearing capacity, the unevenness, and the surface quality scores. The matrix variables are pavement type, traffic volume, and intervention variants. The system can be used to calculate the funds needed for highways at various condition levels, for the regional distribution of given amounts of money at a minimum cost to the national economy, and for the determination of the economic and technical consequences of subsequent modifications in funds distribution. Several trial runs have proved the practicability of the system.
SB: IRRD-OECD
TI: LES ETUDES D’AUSCULTATION DES CHAUSSEES POUR LA PROGRAMMATION DES TRAVAUX D’ENTRETIEN ET DE RENFORCEMENT DU RESEAU ROUTIER FRANCAIS.
AU: BOULET-M (LCPC)
SO: RAPPORTS DES LABORATOIRES - SERIE CONSTRUCTION ROUTIERE.
1983/07. (CR-1) 59P (17 Figs.; 111 Refs.)
PB: LABORATOIRE CENTRAL DES PONTS ET CHAUSSEES, BOULEVARD LEFEBVRE,58, PARIS CEDEX 15, F-75732, FRANCE
PY: 1983
RN: 2-7208-3502-1
LA: FRANCAIS
AB: LE LCPC ET LES 16 LABORATOIRES REGIONAUX CONTRIBUERENT A L’APPLICATION DE LA POLITIQUE DE RENFORCEMENT DU RESEAU ROUTIER NATIONAL MIS EN PLACE APRES LES DEGATS DE L’HIVER 1963 ET DE LA POLITIQUE D’ENTRETIEN PREVENTIF DES CHAUSSEES NEUVES ET RENFORCEES MISE EN PLACE EN 1972 EN APPORTANT DES ELEMENTS DE RATIONALISATION DES AFFECTATIONS BUDGETAIRES :
This paper describes the implementation of the Danish Pavement Management System (PMS) from a pilot project to a nationwide system. This was only possible through extensive collaboration between the Road Directorate, National Road Laboratory and the Technical Administrations of the countries. As foreseen, the introduction of strengthening overlay design as a routine procedure became a crucial part of the implementation. 15000 falling weight deflectometer (FWD) tests were performed, to collect the required bearing capacity data. 4000 trial pits were excavated, to measure accurately the layer thicknesses at the analysis test points. 4000 FWD test results were backcalculated for assessment of pavement E-moduli and needs for strengthening. The successful acquisition of the bearing capacity data was ensured by stepwise implementation of the PMS, starting with those parts of the Danish road network that most urgently needed attention. Available resources did not allow implementation of the whole road network in one step. Close reference lines, extensive information for all participants, and follow-up meetings during the implementation gave good motivation and high quality of work. 10 rules for successful implementation are given. For the covering abstract of the conference see IRRD 833507.
AB: This article reviews the Pilot Pavement Management System (PMS), which was implemented by the Hong Kong Highways Department in mid-1993 with the objective of studying the practicality of the PMS's full-scale introduction. The Pilot PMS generates life-cycle cost analyses of pavements, using the World Bank's Highways Design and Maintenance Standard and prediction model HDM-3, and optimises maintenance investment decision making. The network for the Pilot PMS is in Shatin new town, which has 147 roads of total length 160km, including 40km of high-speed roads, and 20km of cycle tracks. 90% of its roads have bituminous surfaced pavements, and 10% concrete pavements. The Australian NAASRA roughness meter, rather than a laser profilometer, was selected, mainly because of its lower cost. The network was tested using a Dynatest Series 8000 falling weight deflectometer (FWD) with a test spacing of 50m. The paper also describes the use of low-cost data collection systems, to facilitate the automatic processing of data collected by the PMS. It discusses: (1) the analysis and presentation of the data; (2) the updating of summary results to the pilot PMS database; and (3) graphical presentation on a network basis.
This report presents the results of the 17th visual condition survey of roads in England and Wales. It also presents the results of a deflectograph survey measuring the structural condition of local authority roads. This survey began in 1992. The trends in road condition over the last ten years are illustrated. A comparison is made between road condition in 1993 and the condition in both in 1992 and ten years ago.
This paper considers the measurements available from routine surveys, and the intervention criteria by which they can be interpreted to identify potential road maintenance schemes. Mechanically-based surveys are undertaken using: (1) the High-speed Road Monitor (HRM); (2) the Sideway-force Coefficient Routine Investigation Machine (SCRIM); and (3) the deflectograph. To target maintenance works to areas of most need, it is necessary to define minimum standards of condition at which road operation is considered acceptable. Such standards are defined for: (1) functional condition; (2) rate of change of functional condition; (3) safety; and (4) structural condition. They have been developed from long-term pavement studies, supported by analytical and economic studies at the Transport Research Laboratory (TRL). The purposes of network level evaluation are to: (1) identify what proportion of the network needs maintenance in a given year, so that budgets can be adjusted; (2) define the general location of maintenance schemes at the network level; (3) predict the future condition of the network; and (4) prioritise network maintenance schemes, so that detailed design can be undertaken. Project level detailed design is used to select the most appropriate engineering solution, in terms of whole life cost or pavement condition. For the covering abstract see IRRD 867382.
This paper discusses how rural roads are routinely assessed in the county of Somerset, which currently spends less per km on road maintenance than almost any other English county. Thus the best possible value must be obtained from available funds, and there is no incentive to experiment with systems and data-bases, that are unlikely to provide a quick return on investment. Assessment techniques and instruments include: (1) the deflectograph; (2) road monitors, which are vehicles all able to assimilate quickly large quantities of road condition data; (3) visual condition assessment surveys; (4) road construction surveys; and (5) skid resistance surveys. As mechanical surveys are relatively expensive, in relation to declining road budgets, coarse surveys should be directed to planning detailed surveys, which can in turn be used for budget analysis and maintenance design. Some typical survey costs are given for different methods. Increasing demands for assessment surveys indicate the need for better use of survey vehicles, combined with the development of an automated coarse survey vehicle to provide a network analysis before more detailed project analysis. It is essential to obtain enough data on which to base the allocation of scarce resources. For the covering abstract see IRRD 867382.
This paper describes various instruments and techniques for monitoring the English trunk road network. The Department of Transport (DOT) uses two visual condition survey techniques cyclically to assess the pavement conditions of trunk roads: (1) CHART (Computerised Highway Assessment of Ratings and Treatments), which uses computer programs to process visually surveyed road condition data; and (2) VCSC (Visual Condition Survey of Concrete pavements). Deflectograph surveys have been used widely during the last 30 years, and routinely every three years since 1984. The SCRIM (Sideways force Coefficient Routine Investigation Machine) measures the wet skidding resistance of a pavement. In 1990, the DTp introduced the HRM (High-speed Road Monitor), which can survey up to 500 km of road per day. It consists of a van and trailer containing recording equipment, inclinometers and laser sensors. Continuous surface properties of a pavement that can be measured are: (1) skid resistance, using the SCRIM; (2) macrotexture, using the Transport Research Laboratory (TRL) high-speed texture meter; (3) rutting and transverse profile, using the HRM; and (4) longitudinal profile, using the TRM. Measurement methods are also available for: (1) discontinuous surface properties such as cracking and edge and surface deterioration; (2) continuous in-depth properties, using deflectographs; (3) discontinuous in-depth properties; and (4) location referencing, using radio tags and satellite navigation. For the covering abstract see IRRD 867382.

DE: MAINTENANCE-; 3847-; SURVEILLANCE-; 9101-; ROAD-NETWORK; 2743-; MAIN-ROAD; 2748-; DAMAGE-; 1614-; DETERIORATION-; 5255-; DEFLECTOGRAPH-; 6187-; SKIDDING-RESISTANCE; 3031-; RUTTING-WHEEL; 3081-
SC: EQUIPMENT-AND-MAINTENANCE-METHODS (61); PROPERTIES-OF-ROAD-SURFACES (23)
AN: 867383
UD: 199511
CN: 9412TR050E
A rational approach to road maintenance management has been achieved in Singapore through the introduction of a network based Pavement Management System (PMS). Engineers from the Public Works Department are currently using the PMS to plan and control maintenance activities in 2,780 kilometres of road in a predominantly heavily urbanised environment. This paper describes the main features of the PMS. A relational database management system is used to organise the data and present it in a user-friendly way. Great emphasis is placed on the use of objective pavement condition data collected in a continuous manner throughout the road network using the Deflectograph, SCRIM and High-speed Road Monitor. The pavement condition data is used in conjunction with performance models to predict the future condition of the network in terms of structural, skidding resistance and riding quality. Automatic procedures use the trended survey data together with user defined intervention levels to identify road and junction maintenance schemes and to rank them into priority order. Iterative procedures enable the user to rapidly undertake consequential budget analyses over a user defined budget period. For the covering entry of this conference, see IRRD abstract number 843191.
In this paper, the authors are concerned with the Pavement Maintenance Management Unit and in particular with Road Assessment Survey Systems within the full Highway Management System. Road Assessment Survey Systems include the collection, storage and processing of measurements and their comparison with threshold or intervention levels. Detailed descriptions are given of the tools available to produce these measurements required for routine network monitoring, including the High Speed Road Monitor (HRM), the Sideway Force Coefficient Routine Investigation Machine (SCRIM), the High Speed Texture Meter (a single function version of the HRM) and the Pavement Deflection Data Logging Machine (PDDLM) or "Deflectograph".
Will be available after presentation in Durban 1998.
DEFLECTIEMETINGEN IN WEGBEHEER

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Summary

In this paper a method is presented to translate the results of a falling weight deflection measurement into a straightforward matrix in such a way that a practical implementation in a pavement management system (PMS), on network-level, will be possible. In this way a practical combination and translation from data collected during a visual inspection and data collected from a falling weight deflection measurement into a PMS has been made. The presented methods takes into account the effect of the category of road (traffic load). This paper ends with some conclusions concerning the use and benefit of falling weight deflection measurement in a PMS.
VERKORTE FWD-ANALYSE OP WEGEN IN DE PROVINCIE UTRECHT

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Summary

This paper presents a method which quickly analyses the structural condition of road pavements based on FWD-measurements. It is used to evaluate about 100 km of provincial road in the Province of Utrecht. The method has been verified using an available visual condition survey and the results of ARAN measurements.

Differences in results have been further investigated by additional core drilling in order to determine the cause of these differences like cracking in toplayers only or full depth cracking.
Summary

In the province of Zeeland Falling Weight Deflection measurements were used for determination of the life of road constructions and for determination of improvements with linear elastic multi layer systems. From practical experience it seemed that this could be done in a more simple way from these measurements with D0, D180 and IDK60. Temperature corrections for D0 seemed necessary. For this, relations have been developed. For D180 the thickness of the upper layer seemed to influence the level of this measurement because of dynamic effects. Here it has given a try correct it to a level compared with a subbase modulus without the influence of the upper layers.