ONT-023

Maintenance of the Highway Infrastructure: Data Collection for Pavement Management

Ontario

TRANSPORTATION

Research & Development Branch

Maintenance of the Highway Infrastructure

Data Collection for Pavement Management

W. Phang
D. Kobi

Workshop Paper
Presented at the Symposium on Transportation Technology
Riyadh, Saudi Arabia
April 13-15, 1985

Hosted by the Ministry of Communications
Kingdom of Saudi Arabia
in co-operation with
the Ministry of Transportation and Communications
Province of Ontario, Canada

Published by:
Ontario Ministry of Transportation and Communications
Hon. George McCague, Minister
H.F. Gilbert, Deputy Minister

For additional copies, contact:
Transportation Industry Office
Ministry of Transportation and Communications
1201 Wilson Avenue
Downsview, Ontario
Canada M3M 1J8
(416) 248-3807

March 1985

ABSTRACT

Effective management of a highway system is difficult without accurate and current information on the status and physical condition of every part of the system. The information which is needed for pavement management is principally pavement condition and riding quality data, but some pavement-load-response data and skid resistance data are used at times.

Details are given of the data which is collected for network pavement management in Ontario, how it is evaluated, and how it is used. Brief descriptions of the equipment used and the costs of operation are provided. The frequency and timing of the measurements and visual assessments of conditions are described, and reference is made to the manuals prepared for identifying and describing distress manifestations.

The measurement and use of pavement-response-to-load data in overlay design is also briefly described.

The data bank for storage and retrieval of these and other data used in pavement management is outlined.

TABLE OF CONTENTS

LIST OF FIGURES

1/ INTRODUCTION

One can gain a quite useful impression of the general condition of highways in a region by inspecting a portion of the system. However a general impression is not adequate information to allow one to develop the plans needed to effectively manage the maintenance and rehabilitation activity needs of the system. One must collect in a systematic way, data on the present condition, structural adequacy, and traffic loading of the total system, and keep this information updated at suitable intervals. The more complete and timely this data is, the sharper will be the picture one can build of the system, and the more certain one will be of the accuracy of estimates and of the effectiveness of programs for maintenance and rehabilitation. The picture of system condition and the needs for maintenance and rehabilitation derived from systematically collected data, are a convincing argument for the requisition of funds, particularly when the consequences of different expenditure levels are quantified.

The kinds of data which are needed to develop this picture, the tools which are appropriate for collection of this data, and timing and costs for data collection are discussed. Data storage and retrieval are outlined.

2/ PAVEMENT CONDITION DATA

The present serviceability of a pavement and its functional performance history were defined at the AASHO Test Road (1) by the PSI (Present Serviceability Index) equation which uses terms for Slope Variance, Rut Depth, and Cracking and Patching.

For roughness measurement, more practical high-speed equipment than the CHLOE profilometer for Slope Variance have been developed over the past 20 years, such as the GM profilometer, the May's meter, and the PURD which will be briefly described later. High speed measurement of rut depths is also possible with equipment such as the ARAN (which will be described later), and with Swedish and Japanese laser equipment. However cracking and patching assessments are still carried out by visual means, although recording of the data can be automated.

The condition rating scheme which is used in Ontario is different to PSI, but is similar in that the same parameters of ride quality, and distress manifestations are used (includes rutting and cracking). Manuals for condition rating of flexible and rigid pavements (2.3) illustrate the types of distress observed in the province, and define the terms used during visual inspection, to describe the severity of the distress and the extent of its occurrence. The evaluation procedure involves (1) measuring the riding quality with a response type road roughness meter and using a correlation curve to derive a ride comfort rating (RCR) number, and (2) observing pavement distresses from a slowly moving vehicle driving on the shoulder (stopping where necessary to make measurements of rut depth and crack width). A value is calculated for distress manifestations (DM) using weighted values for distress types, severity and density. The ride quality rating and the distress manifestations value are combined by the following equation for Pavement Condition Index:-

$$PCI = 100\,(0.1 \times RCR)^{1/2} \times \frac{320-DM}{320} \qquad (1)$$

where RCR = Ride Comfort Rating, derived from correlation curve of RCR vs measured roughness

$$DM = \sum_{i=1}^{27} C_i(S_i + D_i)$$

where C_i, S_i, D_i are weighting values for different crack types, severity and density respectively.

Further details are available in Appendix A.

The picture of system condition which is defined from this collection of data can be expressed as a distribution of kilometres in different condition classes, with a comment on changes from one class to another over a given time. As well, colour coded maps can be used to illustrate regional disparities.

3/ MEASUREMENT EQUIPMENT

Roughness - The equipment which appears most appropriate for measuring ride quality or pavement roughness is the Portable Universal Roughness Device (PURD). See Figure 1. This equipment consists of a trailer in which an accelerometer mounted on the axle measures the vertical acceleration produced by unevenness in the pavement surface as it is driven at speed over the highway. The acceleration is integrated and summed over a pre-selected interval such as 50 m by an on-board micro-processor. These roughness values are corrected for speed changes and then recorded on magnetic tape together with data on location of the measurement, vehicle speed at the time of the measurement, and date. These roughness values are also displayed on a monitor in the tow vehicle, in real time.

Unlike other types of Response Type Road Roughness Measurement (RTRRM) devices such as the Mays meter, the PURD has only one variable which can change the calibration of the equipment, and that is the tire condition and air pressure. As long as attention is paid to these, there should be no need, as with other RTRRM devices, to constantly check calibration. Small speed changes during the PURD measurement will not invalidate the results since correction for speed changes are constantly applied.

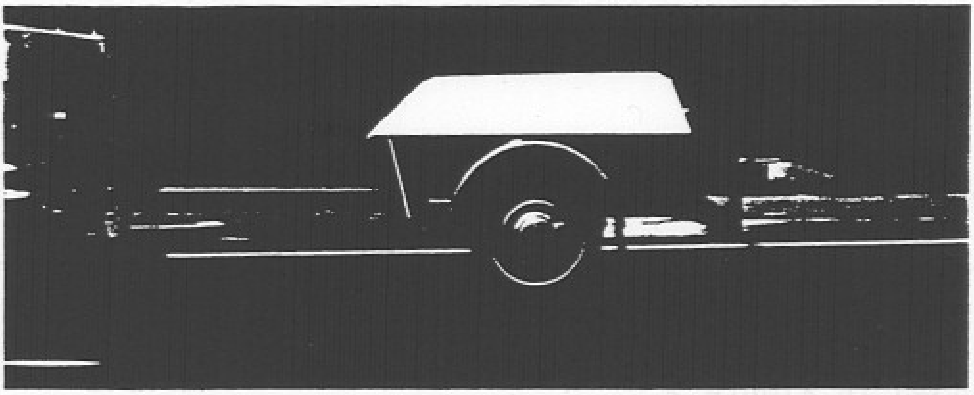


Figure 1/ The PURD

PURD ROUGHNESS SURVEY

Kingston District Highway 2 Inner Westbound Lane Survey Date
Location : Aug 16 1984
Start LHRS/O.S. 10590/ 0.0 Length 6.71 mi Mean Roughness 20.7 Std. Dev. 6.3 Min 11.6 at 6.619 Max 41.1 at 6.308
Remarks :

Distance (mi)	Landmarks		Roughness Rmi. Value Mean	S.D.	Roughness Profile 0 10 20 30 40 50	Comment
0.000	Int					
0.342	Twn Lmt		19.5	5.1		(15)@
0.500						
			17.3	1.7		(16)
1.000						
			17.9	3.4		(16)
1.500						
1.865	Bridge		19.6	5.0		(16)
2.000						
		2.144 Int	19.4	6.1		(16)
2.500						
			16.2	2.2		(16)
3.000						
			17.0	2.8		(16)
3.500						
			17.8	3.6		(16)
4.000						
			21.0	5.1		(16)
4.500						
			18.3	2.4		(16)
5.000						
		5.945 Int	31.7	4.5		(16)
5.500						
			26.9	4.7		(16)
6.000						
6.215	Twn Lmt	6.308 Int	27.0	7.5		(16)
6.500	Bridge					Slodown
			18.9	5.3		(8)

@ Sample(s) omitted due to large speed variation or rail road crossing.

Figure 2/ An Example of a Roughness Survey Report

The taped measurements are entered into the central base or office IBM PC XT and a hard copy graphical printout of the data is obtained. A typical example of a roughness survey report is shown in Figure 2.

Distress Manifestations (DM) - This part of the condition evaluation is currently done by visual observation.

The equipment needed consists of a copy of the guidelines (2) for assessing severity and extent of each distress type, a record of reference points defining the beginning and end points of the highway sections which are to be evaluated, and a set of check-off sheets on which to record the visual observations. An example of the check-off sheet is shown in Figure 3.

Equipment, in the form of dual keyboards hooked-up to the PURD microprocessor, is also available to automate the recording of visual observation of Distress Manifestations. These keyboards have the capacity to handle up to 20 distress types in 3 severity classes and 5 degree-of-extent classes. There are also 8 special event keys to record the presence of landmarks such as bridges, railway crossings, etc. Operation of this system of observation differs from the manual system in that the observer in the automated system is in the passenger seat of the tow vehicle, and is moving at speeds of up to 50 km/h with no opportunity to stop to verify an observation. In the manual system, stopping is part of the procedure.

Ministry of Transportation and Communications
Ontario

URGENCY RATING		
	DELAY	1
	SLIGHTLY DELAY	2
	NO CHANGE	3
	SLIGHTLY ACCELERATE	4
	ACCELERATE	5

CARD 1

FLEXIBLE PAVEMENT CONDITION EVALUATION FORM

CONTRACT No (2–6) ← TP → ← NC → HIGHWAY No (8–11) LHRS (12–17) BEGINS (18–22) OFFSET km

PCR (24–26) RCR (28–30) SURVEY DATE (32) YR. (35) MO. AADT (38–43)

NUMBER OF DISTRESSES × 3 (45) MAINTENANCE PATCHING (48) (50) CONTRACT LENGTH (53–56) km

URGENCY RATING (58) DISTRICT ____ W.P. No ________ PAVEMENT TYPE ______ WIDTH ______

LOCATION ________________ SHOULDER TYPE ______ WIDTH ______

RIDING COMFORT RATING (AT 80 km/h)	EXCELLENT		GOOD		FAIR		POOR		VERY POOR
	9	8	7	6	5	4	3	2	1

CARD 2

START IN COL (2)

PAVEMENT DISTRESS MANIFESTATIONS				SEVERITY OF PAVEMENT DISTRESS: VERY SLIGHT	SLIGHT	MODERATE	SEVERE	VERY SEVERE	DENSITY OF PAVEMENT DISTRESS (EXTENT OF OCCURRENCE): FEW 10%	INTERMITTENT 10–20%	FREQUENT 20–50%	EXTENSIVE 50–80%	THROUGHOUT 80–100%	CHARACTERISTICS OF PAVEMENT DISTRESSES: REFLECTION CRACKING	PAVEMENT EDGE CRACK: PROGRESSIVE (30 cm from edge)	PAVEMENT EDGE CRACK: NON PROGRESSIVE (30 cm from edge)	TRANSVERSE CRACK SPACING m	ALLIGATOR CRACKING: ALLIGATOR BLOCK SIZE mm	ALLIGATOR CRACKING: DISTORTION OF ALLIGATOR AREAS mm
				1	2	3	4	5	6	7	8	9	10						
SURFACE DEFECTS		COARSE AGGREGATE LOSS	1																
		RAVELLING	2																
		FLUSHING	3																
SURFACE DEFORMATION		RIPPLING	4																
		SHOVING	5																
		WHEEL TRACK RUTTING	6																
		DISTORTION	7																
CRACKING	LONGITUDINAL WHEEL TRACK	SINGLE	8																
		MULTIPLE	9																
		ALLIGATOR	10																
	MID-LANE	SINGLE	11																
		MULTIPLE	12																
	CENTER LINE	SINGLE	13																
		MULTIPLE	14																
		ALLIGATOR	15																
	MEANDER	SINGLE	16																
		MULTIPLE	17																
	PAVEMENT EDGE	SINGLE	18																
		MULTIPLE	19																
		ALLIGATOR	20																
	TRANSVERSE	PARTIAL	21																
		HALF	22																
		FULL	23																
		MULTIPLE	24																
		ALLIGATOR	25																
	RANDOM																		
	SLIPPAGE																		
									6	7	8	9	10						
MAINTENANCE PATCHING		SPRAY	1																
		SKIN (Hot or Cold-Mix)	2																
		HOT/COLD-MIX PATCH	3																
		HOT-MIX (Full-width)	4																
		CRACK-SEALING	5																
		CRACK ROUTED & SEALED	6																
REMARKS																			

PH-D-39 82-04 (Formerly OB-MT-317)

Figure 3/ Flexible Pavement Condition Evaluation Check-off Sheet

Rut Depths - An optional rut depth measurement bar, 8 ft. in width, can be mounted transversely on the PURD trailer. 9 Ultrasonic transducers spaced 12 inches apart on the bar, take measurements of the distances to the road surface at specified intervals as the trailer moves forward along the road. This record of the transverse profile of the road surface relative to the bar is subsequently used in the IBM PCXT computer to calculate rut depths. The measurements are automatically compensated in the computer for changes in air density due to temperature variation.

4/ STRUCTURAL ADEQUACY DATA

Loads applied to a pavement structure cause the pavement to bend and deflect. If the pavement bends more than its fatigue limits it will crack or if the pavement deflects more than the subgrade soil can accept without permanent deformation or failure, then the pavement is not structurally adequate for the imposed load.

Pavements can be tested for structural adequacy by full scale load deflection tests using a truck and Benkelman Beam to measure deflection, as is shown in Figure 4. Deflection criteria for assessing structural adequacy are shown in Figure 5.

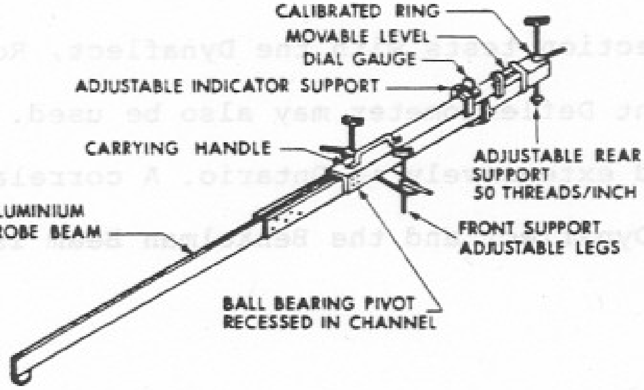


Figure 4/ The Benkelman Beam

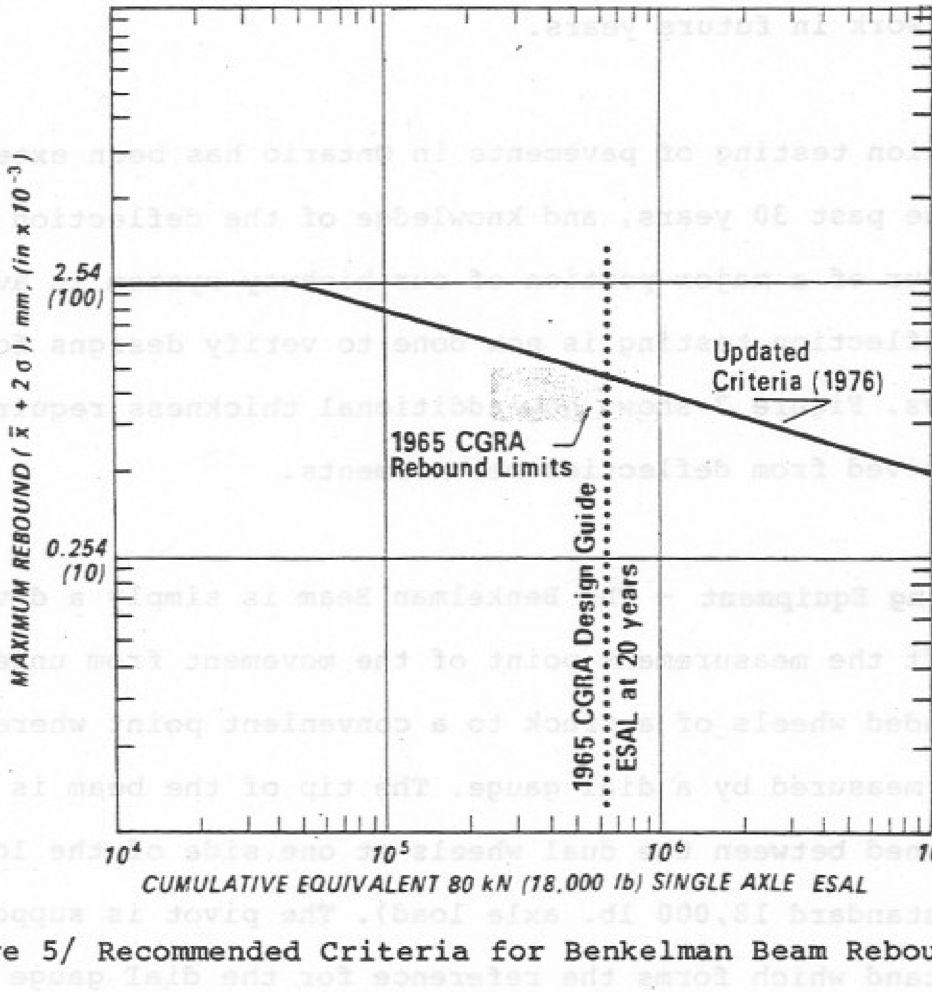


Figure 5/ Recommended Criteria for Benkelman Beam Rebound

Versus Cumulative Axle Loads

Dynamic deflection tests with the Dynaflect, Road Rater, or Falling Weight Deflectometer may also be used. The Dynaflect has been used extensively in Ontario. A correlation of results between the Dynaflect and the Benkelman Beam is shown in Figure 6.

Knowledge of the structural adequacy of a pavement is helpful in developing a forecast of the future performance of the pavement. This forecast is needed for developing needs of the network in future years.

Deflection testing of pavements in Ontario has been extensive over the past 30 years, and knowledge of the deflection behaviour of a major portion of our highway system is available. Most deflection testing is now done to verify designs for overlays. Figure 7 shows how additional thickness requirements are derived from deflection measurements.

Measuring Equipment - The Benkelman Beam is simply a device to shift the measurement point of the movement from under the loaded wheels of a truck to a convenient point where it can be measured by a dial gauge. The tip of the beam is positioned between the dual wheels at one side of the loaded axle (standard 18,000 lb. axle load). The pivot is supported on a stand which forms the reference for the dial gauge which measures the movement of the other end of the beam as the pavement rebounds when the load is moved away at creep speed.

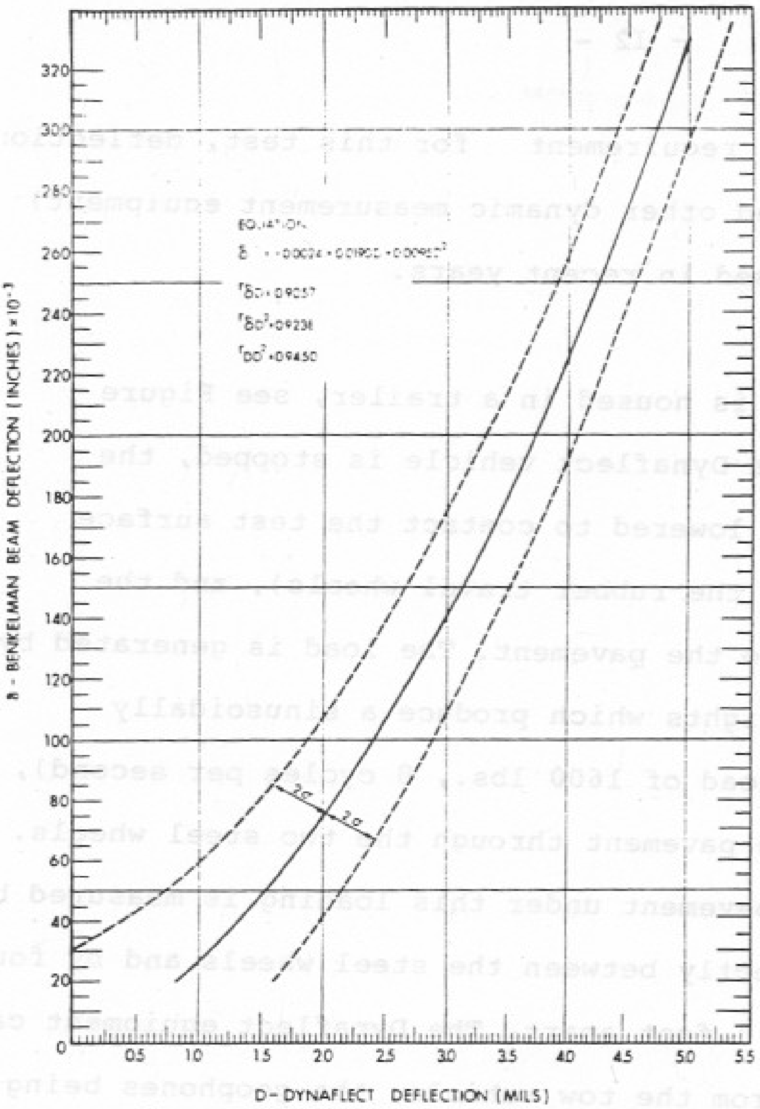
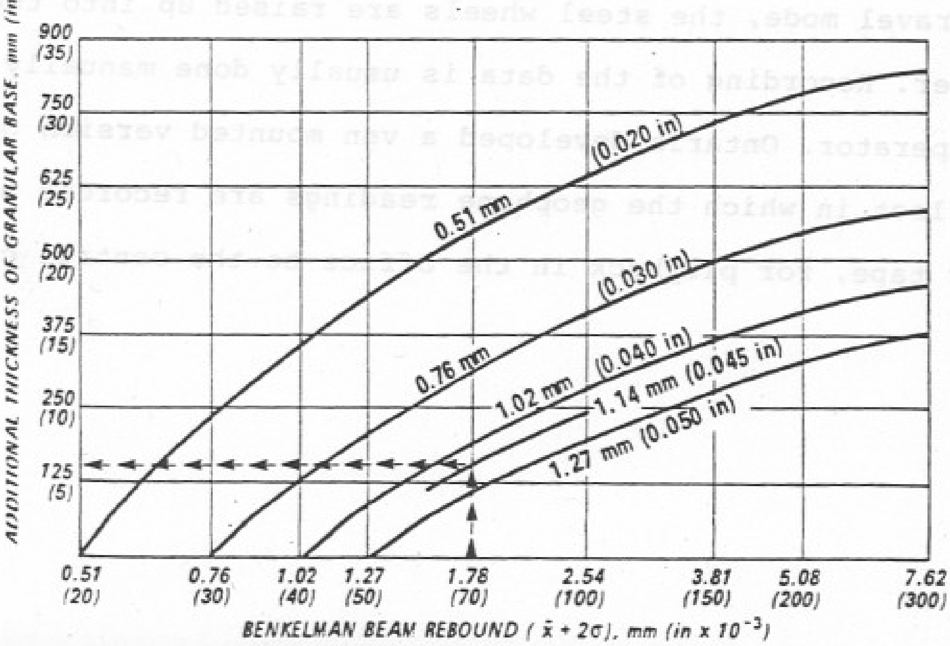


Figure 6/ Relation Between Dynaflect and Benkelman Beam Measurements

Figure 7/ Additional Thickness of Granular Base Required to Reduce a Benkelman Beam Rebound on an Existing Surface to a Designated or Design Rebound



Because of high manpower requirement for this test, deflection testing by Dynaflect (and other dynamic measurement equipment) has been increasingly used in recent years.

The Dynaflect equipment is housed in a trailer, see Figure 8. In the Test Mode, the Dynaflect vehicle is stopped, the steel impact wheels are lowered to contact the test surface (simultaneously raising the rubber travel wheels), and the geophones are lowered to the pavement. The load is generated by two counter rotating weights which produce a sinusoidally varying load (maximum load of 1600 lbs., 8 cycles per second), which is applied to the pavement through the two steel wheels. The deflection of the pavement under this loading is measured by a geophone located directly between the steel wheels and by four other geophones spaced 1 foot apart. The Dynaflect equipment can be remotely operated from the tow vehicle, the geophones being lowered (and raised) to contact the pavement automatically, and readings of the geophones are observed in the tow vehicle. In the travel mode, the steel wheels are raised up into the trailer. Recording of the data is usually done manually by the operator. Ontario developed a van mounted version of the Dynaflect in which the geophone readings are recorded on punched paper tape, for playback in the office to the central computer.

5/ PAVEMENT FRICTION DATA

Conceptually there ought to be technical reasons for setting levels for skid resistance of pavements. However the evidence for developing such values is rather sparse and there are many factors which can influence these values. No firm policies or guidelines about maintenance and rehabilitation treatments to remedy low skid resistance has yet been formulated, and skid resistance is not yet integrated into pavement management. Nevertheless skid resistance is of interest to network management planners and programmers.

The ASTM skid trailer is the standard tool used to measure skid resistance. However in areas where it is difficult to use the trailer such as near intersections, the technique developed in Ontario, of analyzing the pavement texture through stereophotographs, and relating texture to skid resistance (4), can be used.

6/ DATA STORAGE AND RETRIEVAL

The first stage in the systematic collection of pavement condition data for pavement management purposes is to set out and identify sections of highway which have uniform performance characteristics. These are likely to follow construction contract lengths, since there would be uniformity in materials, construction techniques and quality assurance practices. In

Ontario, sections are about 10 - 15 km long, and beginning and end points are identified by Linear Highway Reference System (LHRS) numbers and offset distances.

Recent developments in micro-computers have made it practical for data files to be stored in micro-computer files. Within the next few years it is planned to integrate the existing mainframe computer files for pavement management with micro-computers located at remote locations in the Regional offices. Regions may enter data and update performance files for highways under their control through these Regional terminals.

Equipment in use in Ontario are IBM mainframe and IBM PC.

7/ OTHER EQUIPMENT

Over the years, as new equipment has been developed to provide improved capability to monitor pavements, Ontario has tested and evaluated a large variety. Ontario has also cooperated with manufacturers in the development of these specialized equipment. The PURD for example is an offshoot of the Automated Roughness Analyzer (ARAN). This parent device is a sophisticated electronic package intended to collect a large variety of pavement data simultaneously at highway speeds. See Figure 9. Self-contained in a standard van is all the equipment to survey

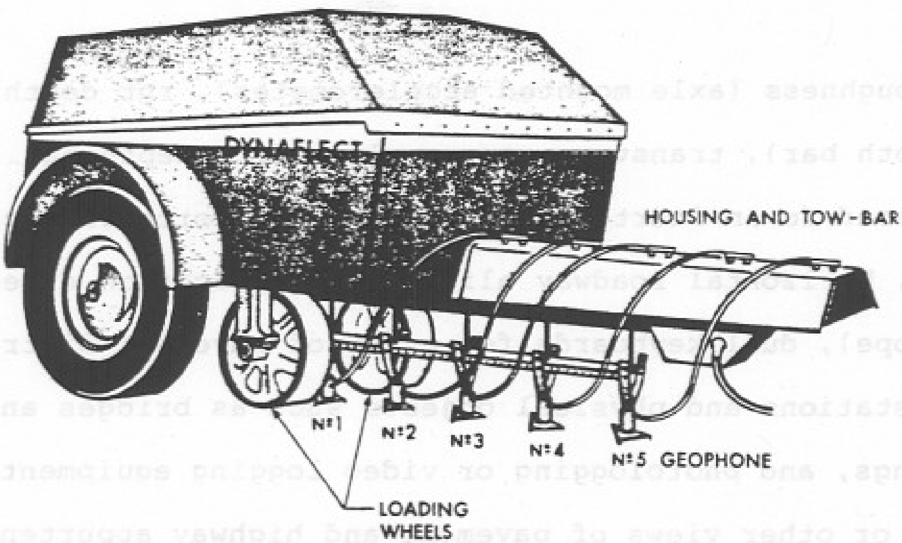


Figure 8/ Dynaflect in the Operating Position

Figure 9/ The Aran

road roughness (axle mounted accelerometer), rut depths (12 ft. rut depth bar), transverse cross slope (rut depth bar is referenced to an inertial gyroscope and a force balance accelerometer), horizontal roadway alignment (a precision directional gyroscope), dual keyboards for entry of pavement distress manifestations and physical objects such as bridges and railway crossings, and photologging or video logging equipment (windshield or other views of pavement and highway appurtenances). Because the ARAN can collect a great deal of data in a short time, interpretation of the data is best performed by office computers, even though the on-board facilities can be used to immediately process and show results of desired portions of the data.

Because of the specialized nature of the ARAN data collection system, it is necessary to have specialized office equipment and trained staff to make effective use of this device. The equipment developer, Highway Products International, has the necessary support staff and equipment available through their service company, Federal Technical Surveys.

8/ TIMING AND COSTS

Pavement condition data has to be collected periodically so that at any desired time an accurate picture of the overall condition of a highway system may be drawn. This means in practical terms, that measurements for any given section of highway should be no older than about two years for roads which are deteriorating normally, and no older than one year for pavements which are deteriorating more rapidly.

In areas subjected to seasonal frost effects such as Ontario, there is a need to also restrict the performance surveys to particular months of the year, usually summer, so as to avoid problems of seasonal effects.

The cost of acquiring this kind of data will vary depending upon a number of factors, but should in general be from about $15 per kilometre to about $50 per kilometre.

9/ REFERENCES

1) "The AASHO Road Test, Report 5, Pavement Research," Highway Research Board, Special Report 61E, 1962.

2) "Manual for Condition Rating of Flexible Pavements, Distress Manifestations", Chong, G.J., Phang, W.A., and Wrong, G.A., Ontario Ministry of Transportation and Communications, SP004, Second Edition, April 1982.

3) "Manual for Condition Rating of Rigid Pavements, Distress Manifestations", Chong, G.J., Phang, W.A., and Wrong, G.A., Ontario Ministry of Transportation and Communications, SP005, Second Edition, April 1982.

4) "Photo-Interpretation of Pavement Skid Resistance in Practice", Schonfeld, R., Ontario Ministry of Transportation and Communications, Research Report RR188.

APPENDIX A/ Distress Index (DI) -- an Alternative to Pavement
Condition Rating (PCR)

Appendix A. Distress Index (D1) — An Alternative to Pavement Condition Rating (PCR)

The Pavement Condition Rating (PCR) is the final result of the combined assessment of pavement riding quality and distress manifestations.

This assessment is generally made by one or more people as are available for the task. The PCR is the average value from these raters. The assessments are made in each of the five regions of the province by the engineering staff of the Geotechnical Office.

The engineering staff maintain their standard assessment procedures through periodic calibration over a training circuit established for such purpose in the region (Figure A-1). The circuits are also used for training of new and inexperienced staff members.

However, going one step further to minimize human bias, a more objective method of assessing the PCR value of a pavement section is under development in Ontario [1]. This method uses ride roughness (RCR) and the word descriptions of pavement distress to calculate a numerical value known as the Distress Index (DI), by means of the equation

$$DI = 100\,(0.1 \times RCR)^{1/2} \times \frac{320\text{-}DM}{320} \qquad (1)$$

where Riding Comfort Rating (RCR) is the riding quality which might be a measured quantity, converted to a scale of 0 to 10, through a correlation equation [2], e.g.,

$$RCR = a + b \log \text{“Q”}.$$

The DM (Distress Manifestations) is the sum of defects obtained by summing the products of the sum of the density and severity weights multiplied by the weight for the distress type [1].

The equation shows that

$$DM = \sum_{i=1}^{27} C_i\,(S_i + D_i) \qquad (2)$$

where

C_i = weighting value for a particular type of crack or other form of pavement distress (Table A-1),

S_i = weighting value for severity of crack or other form of distress (Table A-2),

D_i = weighting value for density of occurrence of the particular crack type or other form of distress (Table A-2),

and

320 is the probable maximum value of DM.

Figure A-2 shows the plot of the calculated DI against subjectively assigned PCRs. The plot shows excellent correlation of DI with PCR throughout the province.

This new methodology is being developed so that a more systematic way of combining riding quality and pavement distress may result in more consistent and unbiased ratings for use in priority planning and effective optimization.

Additionally, the effect of DM on DI was investigated [3]. The result indicates that on a province-wide basis, DM values are generally less than 100 and the effect on DI does not exceed 30% (Table A-3).

Since DI is a function of roughness as well as distress, the following must be concluded:

> firstly, that roughness is much more important in measurement of pavement serviceability (PCR) than distress, and secondly, that distresses which affect roughness are much more significant than distresses which do not.

Additional evidence to support the second conclusion are the high weighting values (Table A-1) determined for surface distortion, rutting and alligatoring longitudinally in wheel tracks and at transverse cracks.

References

[1] Phang, W.A., "Pavement Condition Ratings and Rehabilitation Needs," Transportation Research Record 700.

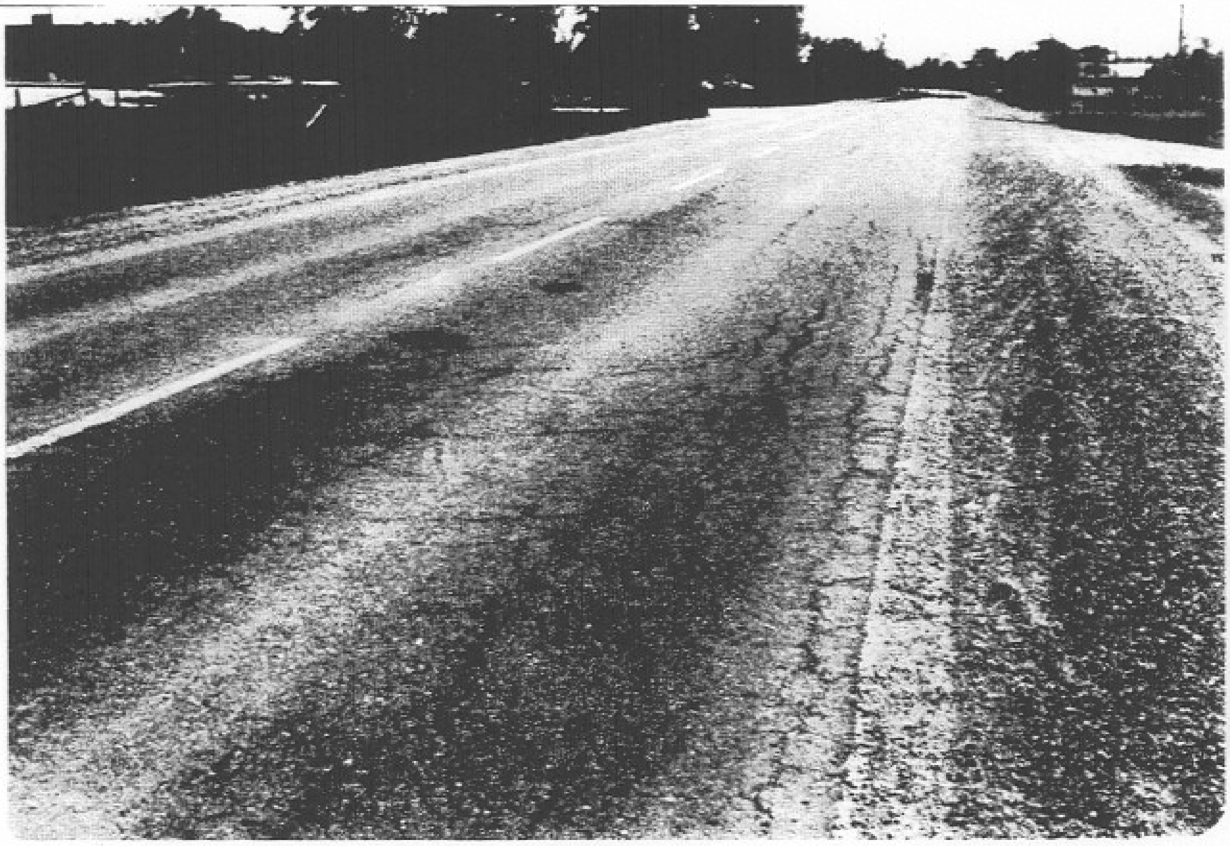
[2] Chong, G., "Measurement of Road Ridability in Ontario," Ontario Ministry of Transportation and Communications, Report IR29, March, 1969.

[3] Phang, W.A., "Pavement Condition and Performance Observations — Brampton Test Road," presented to AAPT, San Diego, 1981.

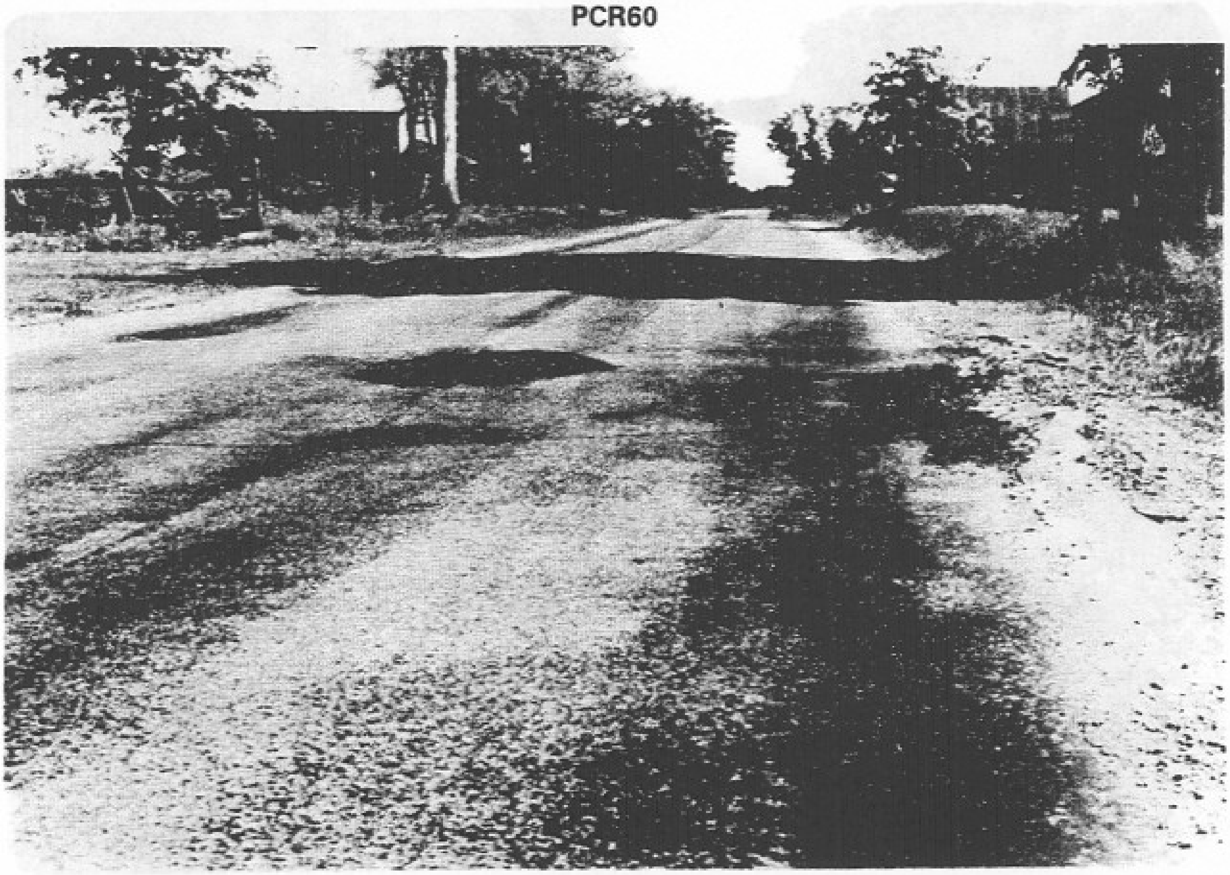
PCR95

PCR70

Figure A-1. Typical Sections Included in Training Circuits



PCR60



PCR40

Figure A-1. Continued

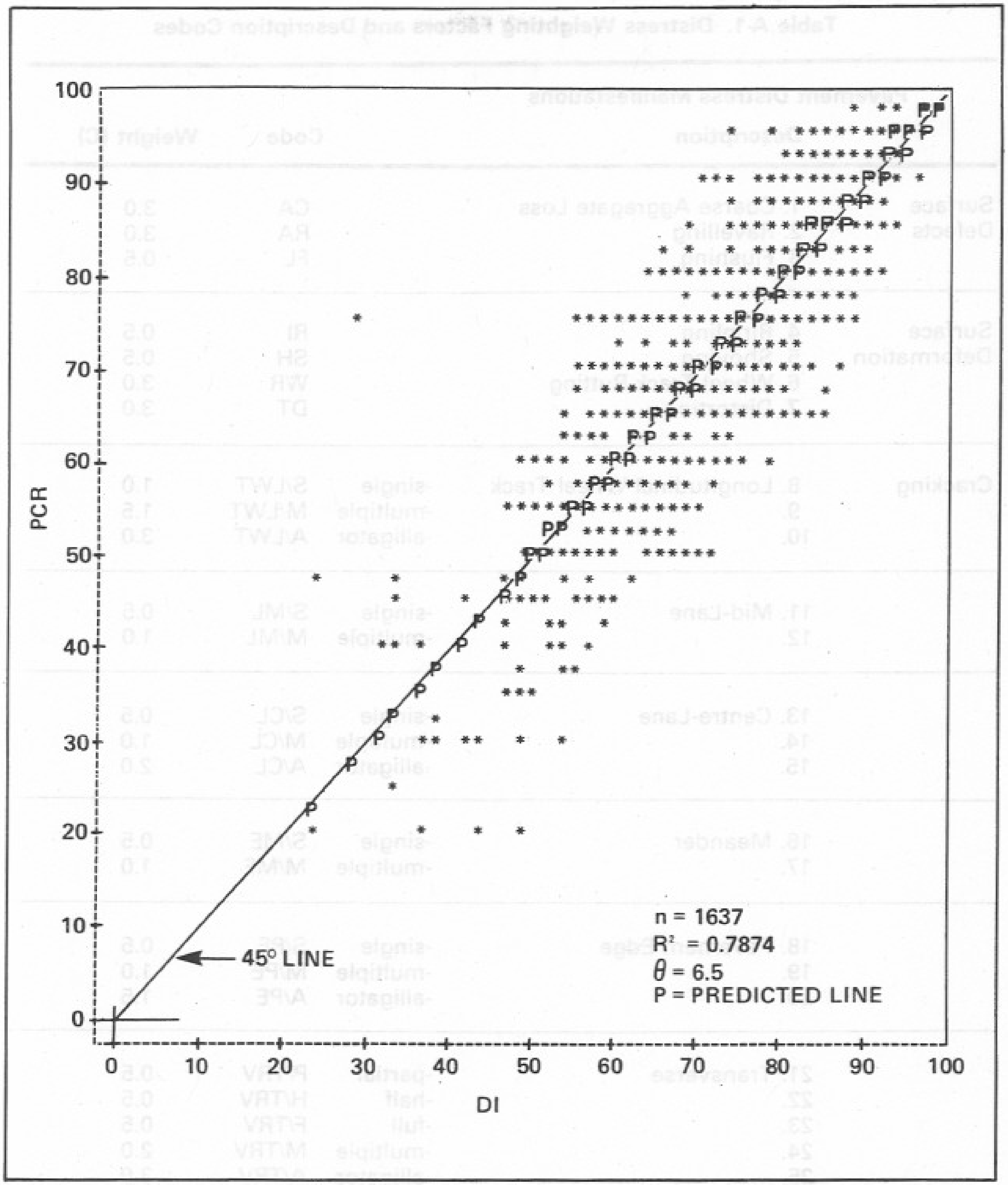


Figure A-2. PCR vs. Calculated DI (*) (based on evaluation of over 6000 km of highway in five Ontario regions)

Table A-1. Distress Weighting Factors and Description Codes

Pavement Distress Manifestations	Description		Code	Weight (C)
Surface Defects	1. Coarse Aggregate Loss		CA	3.0
	2. Ravelling		RA	3.0
	3. Flushing		FL	0.5
Surface Deformation	4. Rippling		RI	0.5
	5. Shoving		SH	0.5
	6. Wheel-Track Rutting		WR	3.0
	7. Distortion		DT	3.0
Cracking	8. Longitudinal Wheel Track	-single	S/LWT	1.0
	9.	-multiple	M/LWT	1.5
	10.	-alligator	A/LWT	3.0
	11. Mid-Lane	-single	S/ML	0.5
	12.	-multiple	M/ML	1.0
	13. Centre-Lane	-single	S/CL	0.5
	14.	-multiple	M/CL	1.0
	15.	-alligator	A/CL	2.0
	16. Meander	-single	S/ME	0.5
	17.	-multiple	M/ME	1.0
	18. Pavement Edge	-single	S/PE	0.5
	19.	-multiple	M/PE	1.0
	20.	-alligator	A/PE	1.5
	21. Transverse	-partial	P/TRV	0.5
	22.	-half	H/TRV	0.5
	23.	-full	F/TRV	0.5
	24.	-multiple	M/TRV	2.0
	25.	-alligator	A/TRV	3.0
	26. Random		RD	0.5
	27. Slippage		SL	0.5

Table A-2. Severity and Density Weights and Description Codes

Weight	Severity				Density		
D or S	Description	Code	Rut Depth cm	Crack* Width cm	Description	Code	% Length or Area
0	Very slight	0	<0.5	<0.7	Few	5	<10
1	Slight	1	0.5-1	0.7-1	Intermittent	6	10-20
2	Moderate	2	1-2	1-2	Frequent	7	20-50
3	Severe	3	2-5	2-3	Extensive	8	50-80
4	Very severe	4	>5	>3	Throughout	9	>80

*For cement-treated base, use 0.3 instead of 0.7.

Table A-3. The Effect of DM on DI

DM	Effect on DI
20	6%
40	12%
60	19%
80	25%
100	32%