Paper title:

Adapting pavement evaluation methodology to the performance based contract of the Fredericton-Moncton Highway Project (A Public-Private Partnership)

Authors:

Mr. Richard Scott, P. Eng.
General Manager
rscott@mrdc.ca

Mr. Michael Gorman, P. Eng.
President
mgorman@mrdc.ca

MRDC Operations Corporation
203, Pioneer Avenue
Oromocto (New Brunswick) E2V 4L7
Phone : (506) 357-1240

Mr. Louis D'Amours, P.Eng. M.A.Sc.
Project director
CRCAC inc. (member of group Qualitas inc.)
3420, St-Joseph Boulevard East
Montreal (Quebec) H1X 1W6
Phone :(514) 255-0613
damours.louis@qualitas.qc.ca

Session for which paper is intended:

Maintenance and construction / innovation and best practices for end-result construction specification approach

2004 Annual Conference of the Transportation Association of Canada
Québec City, Québec

Abstract:

In 1996, the New Brunswick Government embarked on a public-private partnership process for the construction of a 4-lane, 195 km Fredericton - Moncton Highway. Maritime Road Development Corporation was selected as the preferred proponent in September 1997 and contracts were signed in January 1998. A Develop, Design and Build (DDB) contract for the construction of the highway, and a Operate, Maintain, Manage, & Rehabilitate (OMM) contract with a thirty year 30 year term, 1998 to 2028 were the primary contract documents.

The project was constructed in four years (1998 to 2001) and was delivered ahead of schedule. The highway was opened in various segments throughout construction and is now being maintained under performance based criteria. The completed highway consists of 195 km, four lane controlled access highway, 12 km of four lane, high speed connector highways, 20 interchanges, 73 bridges and 4 maintenance facilities.

The OMM contract addresses many operational issues including line painting, crack sealing, asphalt repairs, re-shouldering, bridge maintenance, signs, barriers, illumination systems, among many others. One of the most important criteria however is pavement management.

The pavement management contract requirements require continuous monitoring of various pavement parameters including, surface distress (including rutting), ride quality and pavement structural strength. Each of these pavement parameters has an associated trigger value to initiate rehabilitative or restorative actions. Concerns were raised that the maintenance standards were too rigid particularly as pavements approached the trigger values and that these trigger values were based on older performance measurement technologies.

This paper will explain how a pavement evaluation methodology has been adapted to satisfy the monitoring and evaluation of the pavement performance requirements in this performance based contract. The data’s analysis in the contract’s context will also be discussed. It also demonstrates how specifications must allow management of maintenance and rehabilitation programs to address the life cycle of highway pavements.

Background

In 1996, the New Brunswick Government embarked on a public-private partnership process for the construction of a 4-lane, 195 km Fredericton - Moncton Highway. After the issue of a Request for Qualifications and a subsequent Request for Proposals, Maritime Road Development Corporation was selected as the preferred proponent in September 1997 and contracts were signed in January 1998. Two contracts, the Develop, Design and Build (DDB) contract for the construction of the highway, and the (Operate, Maintain, Manage, & Rehabilitate (OMM) contract with a thirty year 30 year term, (1998 to 2028) were the primary contractual documents.

The Fredericton-Moncton Highway (the "Highway") consists of 195 kilometers of four-lane, controlled access highway between Longs Creek, west of the City of Fredericton and the City of Moncton in the Province of New Brunswick. The Highway forms a part of the Trans Canada Highway system and is operated and maintained to the high standard of a national highway system. The Highway has a total of 20 interchanges, two high level structures, each being approximately 1 kilometer in length, 180 watercourse crossings and a 5 kilometer section through a wetlands of international importance.

The Highway was largely constructed between 1998 and 2001 and was fully opened to traffic in October 2001. Prior to the full opening, approximately 40 lane kilometers of highway previously open and maintained by NBDOT were transferred to MRDC control and newly constructed segments of highway were subsequently opened by MRDC.

MRDC Operations Corporation (MRDC) is responsible for all infrastructure maintenance within the highway corridor throughout the operating period of 30 years. The work of MRDC is carried out in accordance with the very detailed Operations and Maintenance Standards as set out in the OMM Agreement with the Province and which Standards were specifically developed for the Highway.

The Highway is patrolled on a daily basis in the summer and twice daily in the winter period and more often as required. These patrols confirm highway user safety, identify defects, prioritize repairs required, respond to complaints/concerns by users, the Province, the Police or other local authorities, respond to motor vehicle accidents and evaluate and assess on an ongoing basis maintenance priorities. Additionally, on an annual basis, each highway and bridge component are given a detailed inspection to monitor and access its ongoing condition. A state of the art Pavement Management System has been put in place to monitor the condition of the asphalt pavement of the Highway and this system is the primary focus of this paper.

MRDC's mission is to operate, manage, maintain and rehabilitate the Fredericton – Moncton Highway with the highest regard for the Province of New Brunswick's stated objectives and the safety, convenience and economic well-being of its primary users, the people of New Brunswick.

Pavement Management

The pavements of the Fredericton-Moncton Highway represent the largest single asset of the highway and a key part of the OMM Contract deals with the maintenance, preservation, and rehabilitation of these pavements.

Basically, the OMM Contract requires continuous monitoring of the asphalt pavement surface distress, ride quality and strength and provides stipulated numerical indices (as defined by NBDOT) as trigger values, below which the pavement surfaces are to be rehabilitated. These NBDOT numerical indices are described later in the report and are largely based on the past practices and measurement techniques of the NBDOT.

Additionally, the OMM Contract requires MRDC to concurrently address all forms of asphalt pavement distress through various maintenance techniques such as patching or crack sealing within specific timeframes or at least on an annual or programmed periodic basis.

Early in the contract, MRDC raised concerns over the practical implementation of the application of the OMM Standards dealing with asphalt pavements. The focus of these discussions was primarily on the level of acceptable distresses within an asphalt pavement prior to a scheduled rehabilitative treatment. Numerous discussions with NBDOT staff on these standards have taken place and a number of modifications and clarifications to the Standards have occurred as a result. These review processes are anticipated to continue for the duration of the contract and this is viewed as a normal part of the contract process for such a long term contract.

To assist MRDC with the development of a Pavement Management System (PMS), which meets and address the concerns of both MRDC and NBDOT, MRDC contracted the services of group Qualitas Inc. to develop and implement a PMS to meet the OMM Contract criteria and intent, but at the same time using more advanced technology and techniques to measure and record the various pavement performance parameters.

The resulting PMS consists of basically three components, a Network level, a Project level, and various Analysis tools to review and analyze both or either the Network or Project level data. At present both Network and Project level data have been collected and analyzed, and the development of the Analysis and presentation tools are currently underway.

Network Level

The Network level PMS provides a synopsis of the overall condition of the pavement network at any point in time and identifies areas of concern or potential concern for further Project level assessment.

The initial mandate included a pavement surface evaluation of the highway in both directions representing 195 km in each direction, as well as the three high-speed connector ramps. The total length of evaluated pavement being 409.7 km.

Four parameters were analysed to evaluate the pavement performance: Surface Distress, Roughness, Rutting, and Structural Adequacy. It is important to note that the evaluation carried out in 2003 is based on these four parameters for the entire length of the highway and serves as a baseline for future monitoring and comparisons.

This survey establishes the 2003 highway condition as of the date of the surveys for the surface distress, roughness, and rutting; and for structural adequacy.

These surveys were performed prior to previously planned and identified rehabilitation work subsequently carried out (surface treatment: westbound 347+000 to 339+000) and (mill and overlay: westbound 446+000 to 437+000 and eastbound 437+000 to 439+000). These rehabilitative works were part of an earlier Project Level Analyses conducted late in the fall of 2002. While normally, Project Level analysis would follow the Network Level Analysis, seasonal timing and start up issues precluded this hierarchy in this circumstance.

The following section describe the methodology used to evaluate the pavement and presents a summary of the results. Is also includes a discussion on some segments of concern regarding their performance or where future monitoring may be enhanced.

Methodology of Network Level Pavement Evaluation and Summary of Results

In order to objectively and efficiently determine the nature and scope of the maintenance work to be undertaken, it is essential to clearly establish the road condition using standard procedures. The first procedure involved breaking down the road network into logical, physical, pavement segments for evaluation.

For the Fredericton-Moncton highway, we established that each segment would equal one kilometer and be synchronised with the kilometer marker posts present along the roadway. This type of segmentation allowed easier management and divided the road into identifiable autonomous units for evaluation. Numerical codes were developed for each pavement segment where; the first two digits related to the MRDC construction segmentation, the next three digits identify the chainage, and the last digit identifies the direction of travel. The following is a example of the numbering system used to identify individual pavement sections:

1 2	3 4 5	1
Section #	Chainage	Direction
Construction Sections	Kilometre Marker	EB or WB
[1 to 12]	[256 to 451]	[1 or 2]

For the purpose of the evaluation, the highway is therefore composed of 416, two lane, kilometer segments.

For each of these 416 segments, a multifunction pavement data collection vehicle traveled the driving lane, to evaluate surface distress, roughness or riding comfort, and rutting. The survey was performed on all the segments including bridge decks and other structures. More detailed information on the data collection and analysis of these parameters is presented below.

To address structural adequacy, a trailer mounted Falling Weight Deflectometer (FWD) was used. The methodology and the results of these measurements are also discussed in more detail later in the report. FWD testing was not performed on bridge decks.

The results of the Network data collection once analyzed are compared to the Contractual trigger values of the project at the conclusion of the report.

Surface Distress Evaluation

The multifunction vehicle was equipped with a camera capturing sequential numerical images of the pavement surface. In this case, the sequence was established at 10 meter intervals. The field-acquired images were then later analyzed by trained technicians using software developed by CRCAC Inc. The software is based on the Federal Highways Administration (FHWA) protocol dividing the driving lane in five strips (two wheel paths, between and outside wheel paths) permitting the evaluator to identify and quantify pavement surface distresses.

The evaluation data was compiled for each pavement segment, (approximately 100 photographs) in order to produce a Surface Distress Index (SDI). Number, length or area of the different types of cracks and/or surface defects observed on the pavement were used to calculate the surface distress index (SDI). The SDI scale varies from 0 to 100 where 100 is attributed to new pavement and 0 to severely deteriorated pavement. The details of SDI calculation and correlation between CRCAC Inc. and NBDOT indices are presented later in the report.

The surface distress can be related to the structural performance of the pavement. Therefore, the surface distress provides a diagnostic tool as to the origin and the cause of degradation of the pavement. A summary of the results are presented on figure 1 below as a bar chart of the proportion of length of roadway in relation with the observed and measured surface condition.

Surface Distress Index	Surface condition	Length (km)	Proportion (%)
80 - 100	Very good	363.8	89
60 - 79	Good	43	10
40 - 59	Fair	3	1
20 - 39	Poor	0	0
0 - 19	Very poor	0	0

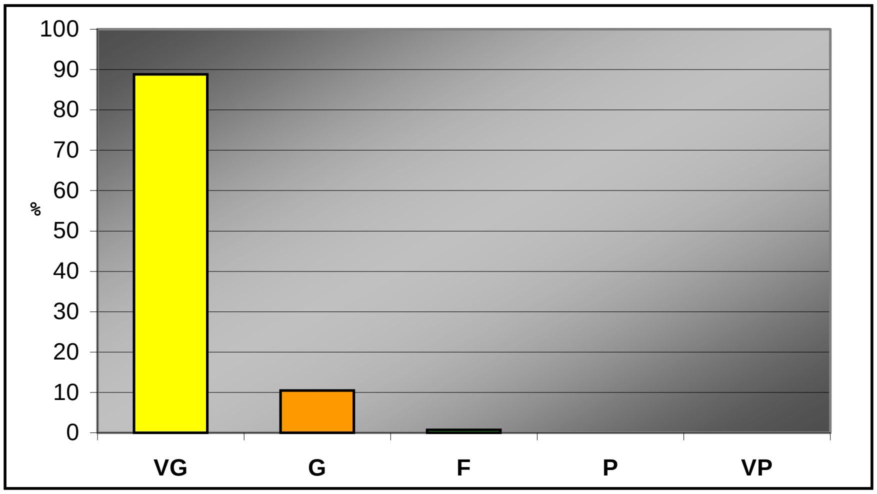

Figure 1 – Surface distress

Riding Comfort Evaluation

The multifunction vehicle is also equipped with an inertial profilometer to measure the longitudinal profile of the road surface and to evaluate the surface roughness. These two parameters can used to evaluate the ride comfort.

The ride comfort allows the identification of the pavement deformations which can affect the security and the comfort of the highway users and also can be related to the cost of operation of vehicles. Measurement of the riding comfort is an important characteristic for road maintenance staff and is of primary concern for road users. The unit of measurement is the IRI (International Roughness Index). The IRI was calculated as specified in ASTM E 1926, *"Standard Practice for Computing International Roughness Index for Roads from Longitudinal Profile Measurements"* and averaged for the two wheel paths for each pavement segment. To ease comparison of the various condition indicators, the international roughness index was transformed in a riding index from a scale 0 to 100 where 100 is attributed to new pavement with perfect riding comfort and 0 to a very bumpy pavement with a very poor riding comfort. The results are grouped in different class conditions as shown in figure 2 below.

Riding index	Riding comfort class	Length (km)	Proportion (%)	Equivalent IRI
80 - 100	Very good	267.3	65	< 1.10
60 - 79	Good	135.4	33	1.10 - 1.60
40 - 59	Fair	7	2	1.61 - 2.5
20 - 39	Poor	0	0	2.51 – 3.50
0 - 19	Very poor	0	0	> 3.5

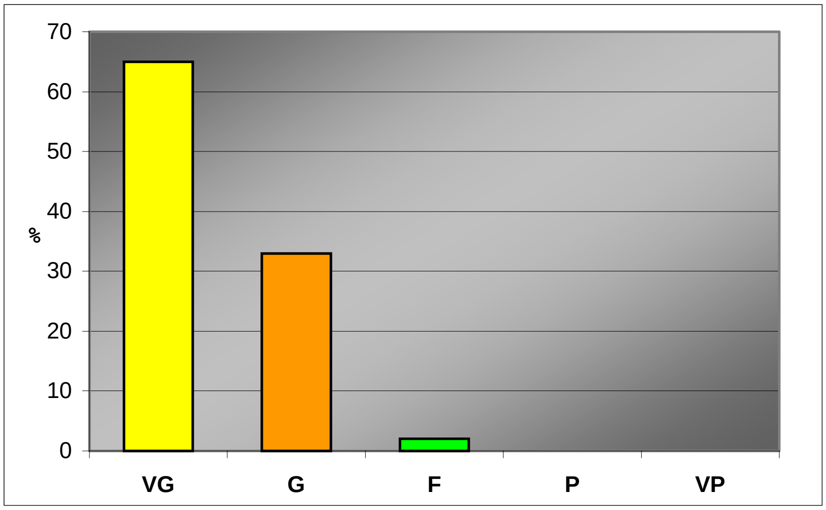

Figure 2 – Ride Comfort

<u>Rutting Evaluation</u>

The transverse profile and the rut-depth were measured every 10 meters in the driving lane of each pavement segment simultaneously during the collection of the Surface Distress and Ride Comfort Data.

The deformation of the transverse profile of a pavement, depending on the amplitude of the deformation, can lead to major problems regarding user safety and security. These problems deal primarily with drainage of the highway and snow plowing operations, both of which are safety concerns for road users. The rutting measurement was subject to a

Contractual maintenance trigger value of 20 mm, whereby ruts exceeding this depth require corrective action.

The multifunction pavement data collection vehicle was used to measure rut depth using a laser rut-depth measuring system that captures the transverse profile of the entire traffic lane. The device projects a laser beam at the surface of the pavement and the image of the line which takes the exact shape of the transverse profile is captured. The transverse profile obtained is made up of 1,280 points and covers a width of 4 meters. The digitization of the image obtained and the simulation of a 1.8 meter ruler are then used to determine the rut-depth for each wheel path in compliance with standard ASTM E 1703 *"Standard Test Method for Measuring Rut-Depth of Pavement Surfaces Using a Straight-Edge"*. The rut-depth of each segment is calculated by taking the maximum of the two rut depths obtained over each ten meters of travel and calculating an average of these maximum values plus a standard deviation. Four different levels of severity are used; none, slight, moderate, and severe. The summary results are presented in figure 3 as the degree of severity as function of proportion of length of highway.

Rut-depth (mm)	Severity	Length (km)	Proportion (%)
0 – 4	none	0	0
5 – 9	Slight	281.4	69
10 – 19	Moderate	128.3	31
≥ 20	Severe	0	0

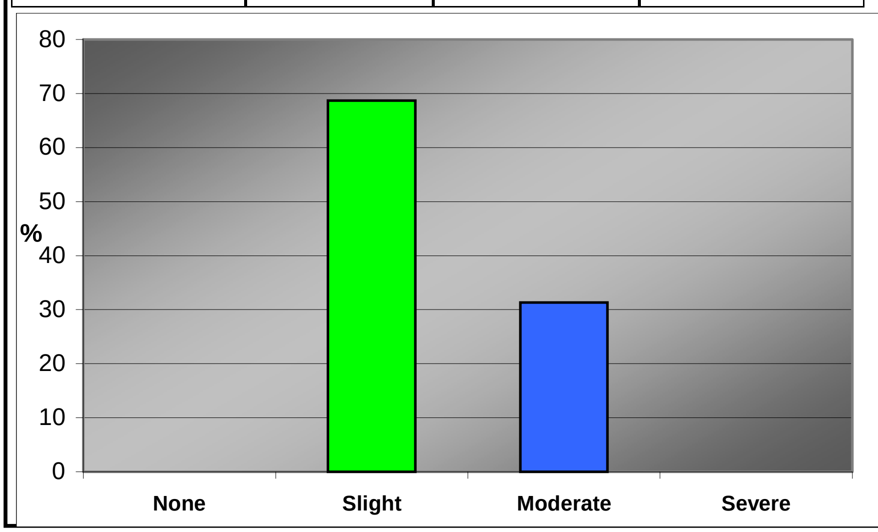

Figure 3 – Rutting

Present Serviceability Index

The surface distress, the riding comfort and the rutting were each measured individually in order to permit the overall evaluation of the pavement condition with an indicator representative of the current level of service. The summary of these indicators permits the evaluation of the overall performance of the pavement. The index obtained with the combination of the different condition indicators is called the Present Serviceability Index (PSI) and is scaled from 0 to 100 where 100 is attributed to a pavement with a very good level of service and 0 a very poor level of service. The details of the PSI calculation are presented later in this report. The serviceability index is an excellent indicator of the road network quality. The proportion of road length with respect to the level of service is shown below in figure 4.

Present serviceability index	Level of service	Length (km)	Proportion (%)
80 - 100	Very good	141.5	35
60 - 79	Good	256	62
40 - 59	Fair	12.2	3
20 - 39	Poor	0	0
0 - 19	Very poor	0	0

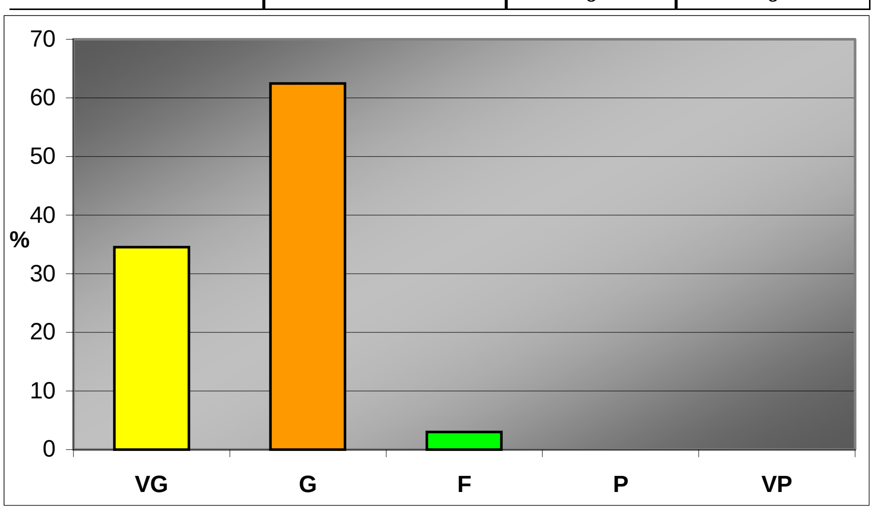

Figure 4 – Level of service

Structural adequacy

Strength and structural adequacy of the pavement structure were determined by the measurement of the road deflection using a falling weight deflectometer (F.W.D.). For the network level purpose, measurements were taken in the driving lane of both directions at 250 meter intervals (4 points per kilometer: xxx+000, xxx+250, xxx+500, xxx+750).

The FWD is a trailer mounted non-destructive pavement testing device that provides data on pavement response to dynamic wheel loads. Equipment used for the evaluation complies with standard ASTM D4694 *"Standard test method for Deflections with Falling-weight-type impulse load device"*.

Dropping a mass from a known height onto a dampening system and a loading plate generates a dynamic load. For the purpose of this project, a 40 kN load level was applied to the pavement by a 300 mm segmented load plate. The 40 kN load level simulates the wheel load of a standard heavy truck (80 kN single axle load). A load cell and nine geophones placed at a distance of 0, 200, 300, 450, 600, 750, 900, 1200 and 1500 mm from the center of the load plate were used to measure the magnitude of the load and the pavement deflection respectively.

Pavement structural adequacy is in direct relation with the maximum pavement deflection and with the anticipated traffic for coming years. Table 1 below shows an estimation of the future traffic for the next 10 years as established from data obtained from MRDC and NBDOT traffic counters on the highway. It should be noted that the predicted traffic volumes below are significantly higher than the original traffic volume predictions used at the time of the design and construction of the highway. This will be of concern as the pavements age and the cumulative affect of these increased traffic volumes are experienced.

Table 1
Traffic estimation

Marker		AADT (1)	% of heavy vehicle (1)	ESAL (10 years)
From	To			
256+000	280+000	7633	25	8 160 000
280+000	294+000	3384	25	3 620 000
294+000	301+000	14480	12	7 500 000
301+000	303+000	12480	14	7 540 000
303+000	306+000	11480	15	7 430 000
306+000	333+000	5975	24	6 190 000
333+000	347+000	6462	22	6 140 000
347+000	365+000	5963	25	6 430 000
365+000	423+000	5514	25	5 970 000
423+000	446+000	12708	21	11 630 000
446+000	450+000	10708	20	9 240 000
Route 1	-	7194	15	4 660 000
Route 8	-	4249	15	2 750 000
Route 7	-	11096	9	4 310 000

The FWD data were analyzed using software developed by *CRCAC inc*. to determine the structural integrity of the pavement structure. These measurements were in turn appropriately compared to the Contractual Maximum Peak Spring Defection as presented in the Contract Standards and which are based on the Benkelman Beam.

Prior to the comparison, the measured FWD dynamic deflections were first normalized to represent the equivalent deflection for a standard wheel load of 40 kN and a standard asphalt concrete temperature of 20°C. Then the normalized dynamic deflections were converted to static deflections, to simulate the Benkelman Beam deflection, using a dynamic to static adjustment ratio of 1.55. Since the FWD tests were not completed during thawing period, the last step involved a spring adjustment factor of 1.2 to obtain a representative Spring Static Deflection (SSD).

A Representative Spring Static Deflection (RSSD) was calculated for each 1 km section by adding two standard deviations to the mean value of SSD. It was noted that all the pavement segments show a representative spring static deflection well below NBDOT’s maximum trigger value.

The residual structural pavement life for each pavement segment was then estimated from the RSSD, fatigue curve published by the Asphalt Institute (Asphalt Overlays for Highway and Street Rehabilitation, MS-17) and from ESAL numbers anticipated for the next 10 years on the Fredericton-Moncton Highway.

The results of the strength evaluation in relation to the pavement residual life of the Fredericton-Moncton Highway are shown on figure 5 below.

Residual Life (year)	Strength	Length (km)	Proportion (%)
≥ 10	Strong	172	59
7 – 9	Adequate	56	13
3 – 6	Weak	107	18
0 – 2	Very weak	75	10

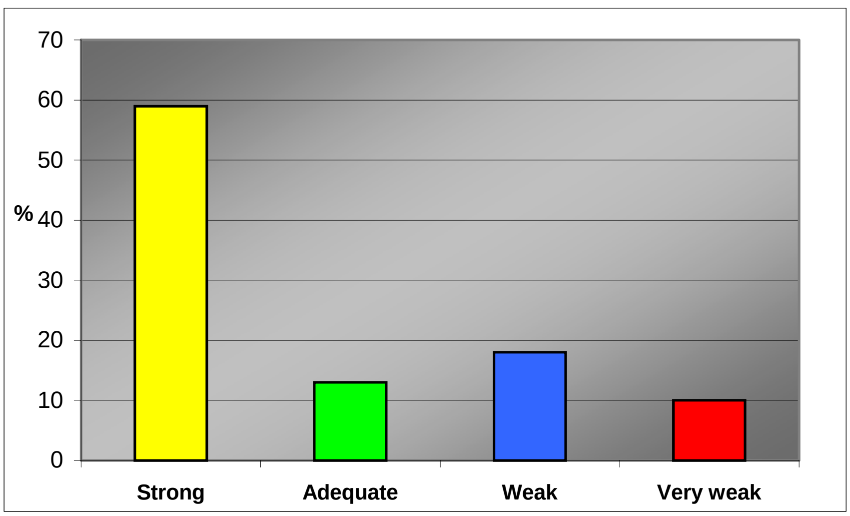

Figure 5 – Structural adequacy

It must be recognized however that the above data is based on theoretical projections of the current traffic growth and truck load distributions, both of which are being periodically monitored by MRDC.

Summary and Results

The condition of the Fredericton-Moncton Highway was evaluated with specific surveys regarding the distresses of the pavement, the riding comfort, the rutting and the structural adequacy of the pavement.

The result of the surveys can be compared to the contractual trigger values in order to identify segments of the highway which require interventions. However, for these comparisons to be valid there must be a direct and identifiable rationale for comparison between the NBDOT trigger values and the corresponding CRCAC Inc. equivalent trigger value.

The proposed CRCAC Inc. equivalent values for each of the NBDOT trigger values for the four indicators are presented in the following table:

Indicators	NBDOT's Trigger value	CRCAC recommended trigger value
Surface Distress Index (SDI)	7.9	55
Riding comfort index	5.5 (RCI)	2.5 m / km (IRI)
Rutting	20 mm	20 mm
Pavement strength (RSSD)	1 140 μm	1 140 μm

The CRCAC Inc. trigger value of 55 for the Surface Distress Index was derived from a CRCAC Inc. evaluation of the relationship between NBDOT SDI (rutting included) and CRCAC SDI (rutting excluded) using the detailed surface distress data weighted using the appropriate agency methodology. This evaluation produced a relationship with a good correlation. Additionally, the equivalent value presented above is somewhat conservative since rutting, included in the NBDOT SDI calculations, is associated with a large weighting factor, and rutting is not included in CRCAC SDI calculation.

Since the NBDOT SDI includes rutting, and the contract also includes a separate trigger threshold for rutting, there have been a number of discussions concerning the relative relationship between these two trigger values. These discussions are presently ongoing.

The CRCAC Inc. trigger value of 2.5 m/km for International Roughness Index was proposed based on TAC report *'Standardization of IRI data collection and reporting in Canada'* and maintenance practices in different provinces. It is important to consider the precision of the measurement results when we compare or apply theses trigger values since the SDI values show generally more variation than IRI which is measured with very high precision equipment. NBDOT have been receptive to the use of the IRI as a trigger value.

The contract trigger values were used for both the Rutting and Pavement strength measurement parameters however the tools used by NBDOT and MRDC via CRCAC Inc. are quite different in the method of data collection. Again the issue of correlation and precision of the measurements must be considered in comparing these measurements and therefore the associated trigger values.

The above conversions between the contractual trigger values and those proposed by CRCAC Inc. have been presented to NBDOT and are currently under review for acceptance.

The four trigger values were not exceeded for any of the 416 pavement segments analyzed. However, the analyses of the results with respect to the trigger values indicate that seven pavement segments could reach a trigger value within a relatively short term and could need corrective actions. These segments are listed below.

Segment	Direction	From	To
42962	Westbound	296+000	297+000
42972	Westbound	297+000	298+000
124371	Eastbound	437+000	438+000
124402	Westbound	440+000	441+000
124412	Westbound	441+000	442+000
124452	Westbound	445+000	446+000
300041	Eastbound	4+000	4+300

These segments all constitute portions of the older parts of the highway and were for the most part assessed through project level analysis in the fall of 2002 prior to the network level data collection. Rehabilitative measures have either been put in place or are planned for all of these pavement segments, with the only exception being section 300041 which is still being monitored by field staff to determine if appropriate corrective actions are warranted.

Conclusions

The results of the pavement structural analysis when coupled with the current and future estimated traffic volumes over the next ten years indicates that some segments of the highway could be cause for concern. These results indicate the possibility of accelerated deterioration along some segments.

Monitoring of the pavement structural adequacy, the traffic volumes, and traffic load distribution, for these pavement segments is considered appropriate to prevent the failure of these segments to meet the contract trigger values. To this end the continued monitoring of the Fredericton - Moncton Highway pavement through the PMS program described above will continue on a three year cycle to provide MRDC with the data to select and implement cost effective and timely rehabilitative interventions.