THE NEW CONCRETE PAVEMENT MAINTENANCE AND REHABILITATION GUIDE FOR QUEBEC: A COMPREHENSIVE APPROACH

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ABSTRACT

The extent of cement concrete pavements in Quebec is quite limited (20% of expressways), so expertise in that field is held by only a few individuals. Therefore, it was decided to put together a guide that would provide a lot of useful information, readily usable by anyone involved in some way in the life of a concrete pavement. The main objectives of the guide are to standardize practices throughout the province and to disseminate expertise about concrete pavements.

The guide contains four main sections: the first describes 25 maintenance treatments or rehabilitation techniques applicable to rigid pavements, the second offers decision trees for maintenance treatment selection, the third presents a step-by-step method for carrying out a rehabilitation study, and the last section contains a series of forms used to record construction and periodic maintenance information specific to concrete pavements.

BACKGROUND

The road network under the jurisdiction of the *ministere des Transports du Quebec* (MTQ) covers approximately 28 700 two-lane kilometres, including some 1 200 two-lane kilometres of concrete pavement. Over the years, this network has aged and deteriorated at a rapid pace as a result of increased traffic and loads. Moreover, the deterioration of the road network has been accelerated by cutbacks in maintenance budgets. Concrete pavements have not escaped this trend.

A concrete pavement construction and conservation policy was adopted in 1995. One of the specific objectives of this policy was to slow down the deterioration of concrete pavements. The preparation of a concrete pavement maintenance and rehabilitation guide is one component of an action plan aimed at achieving this objective.

The Quebec Region of the Cement Association of Canada (CAC) had already started drafting a maintenance guide for concrete pavements. So the MTQ, the CAC, and the construction industry have pooled their efforts to produce a comprehensive guide on the maintenance and rehabilitation of concrete pavements.

OBJECTIVES OF THE GUIDE

The *Guide d'entretien et de rehabilitation des chaussees en beton de ciment* [1] (Cement Concrete Pavement Maintenance and Rehabilitation Guide) describes the practices recommended by the MTQ for the maintenance and rehabilitation of concrete pavements.

The contents of the guide are addressed primarily to personnel involved in maintenance and rehabilitation planning and operations. Concrete pavement experts will not find many new things but they may consider this a useful document that can be translated or adapted quite easily to their agency.

The guide is meant to disseminate expertise in concrete pavement maintenance and rehabilitation and to standardize practices, while allowing for solutions adapted to a local situation. Ultimately, this will serve to improve the quality and relevance of the interventions.

The principles and practices of pavement design, maintenance, and rehabilitation leave a lot of room for the designer's experience and judgment, in spite of constant technological and informational progress. This guide is not a substitute for experience or good judgment; it must first and foremost be considered as a reference and decision tool.

Several Quebec experts were consulted during the drafting of this guide, as were some 30 publications from various organizations, such as the American Concrete Pavement Association (ACPA); the Federal Highway Administration (FHWA); the American Association of State Highway Officials (AASHTO); the Portland Cement Association

(PCA); the Strategic Highway Research Program (SHRP); the World Road Association (PIARC); the Transportation Research Board (TRB); the Transportation Association of Canada (TAC); the Ministry of Transportation of Ontario; and the MTQ. This makes the guide a useful reference for any organization involved in concrete pavements.

MTQ also issued the *Manuel pour l'identification des degradations des chaussees en beton de ciment* [2] (Concrete Pavement Distress Identification Manual). This manual includes two separate sections, the first dealing with concrete pavements and the second with asphalt overlaid concrete pavements. Some sections of the maintenance and rehabilitation guide require the use of the *Manuel pour l'identification des degradations des chaussees en beton de ciment*, therefore the two documents are closely related.

DEFINITIONS

Since there are quite a few existing definition relating to maintenance and rehabilitation of rigid pavements, a preliminary definition of the terms used in the guide is required.

Rigid pavement

A rigid pavement is composed of a concrete slab with either an exposed concrete surface or overlaid with asphalt. The slab usually rests on an aggregate or stabilized base, with this base lying over a sub-base, itself covering the natural soil or a fill.

An original concrete pavement that is overlaid with a new aggregate base and asphalt surface coarse is no longer a concrete pavement; it becomes a flexible pavement, and as such, is not covered by this guide. Semi-rigid pavements (asphalt overlay on a concrete base, lean-concrete base, cement-treated base, or fractured slabs) are also excluded.

Maintenance

In this guide, four type of maintenance activities are considered : preventive, corrective, palliative or urgent actions.

Rehabilitation

The word rehabilitation means actions that are usually more involved but above all more extensive than maintenance operations. The same basic techniques may be used, but a rehabilitation project often combines several techniques, whereas a maintenance operation is generally limited to a single technique.

Even though they are considered as separate areas, maintenance and rehabilitation go hand in hand: any action taken in either area affects the other area's needs, and any operational strategy over time should take these two areas into account.

THE SECTIONS OF THE GUIDE AND THE PAVEMENT MAINTENANCE AND REHABILITATION FUNCTIONAL PROCESS

The guide contains four main sections: the first describes 25 maintenance treatments or rehabilitation techniques for rigid pavements, the second describes decision trees for maintenance treatment selection, the third presents a step-by-step method for carrying out a rehabilitation study, and the last section contains a series of forms used to record construction and periodic maintenance information specific to concrete pavements.

The decision process for pavement maintenance and rehabilitation refers to all sections of this guide. Any pavement operation is the end product of such a process, whose steps are as follows:

- detecting problems;
- surveying the condition of the pavement;
- diagnosing and analyzing solutions;
- choosing a solution;
- performing the work.

These steps are taken differently whether maintenance or rehabilitation is involved. The pavement maintenance and rehabilitation decision process is shown in Figure 1.

Maintenance decision process

Problems are detected through network monitoring, citizens' complaints, or systematic inspections.

The guidelines for the preventive maintenance program apply to the problem detection phase, because their objective is to avoid certain problems that have appeared previously on other pavements where no preventive action was taken.

Once the problem has been detected, it must be characterized, i.e., the type, density, and severity of the distress must be identified using the *Manuel d'identification des degradations des chaussees en beton de ciment*.

Rigid pavement maintenance decision trees are used to diagnose the problems and to choose feasible solutions. These trees contain recommended maintenance solutions according to type, density, severity, and distribution of each distress, depending on whether a concrete or asphalt surface is involved. When the conditions seem to warrant stronger action, typically where the distress is quite dense and severe, the advice of an expert may be suggested.

Decision trees can take into account the urgent, corrective, palliative, or preventive nature of the required action, depending on specific location, time, and budget constraints. Therefore, an urgent need will require a technique that can be carried out

quickly, whereas a less urgent need can wait for the action to be taken under optimum conditions, with potential economies of scale and best performance guarantee.

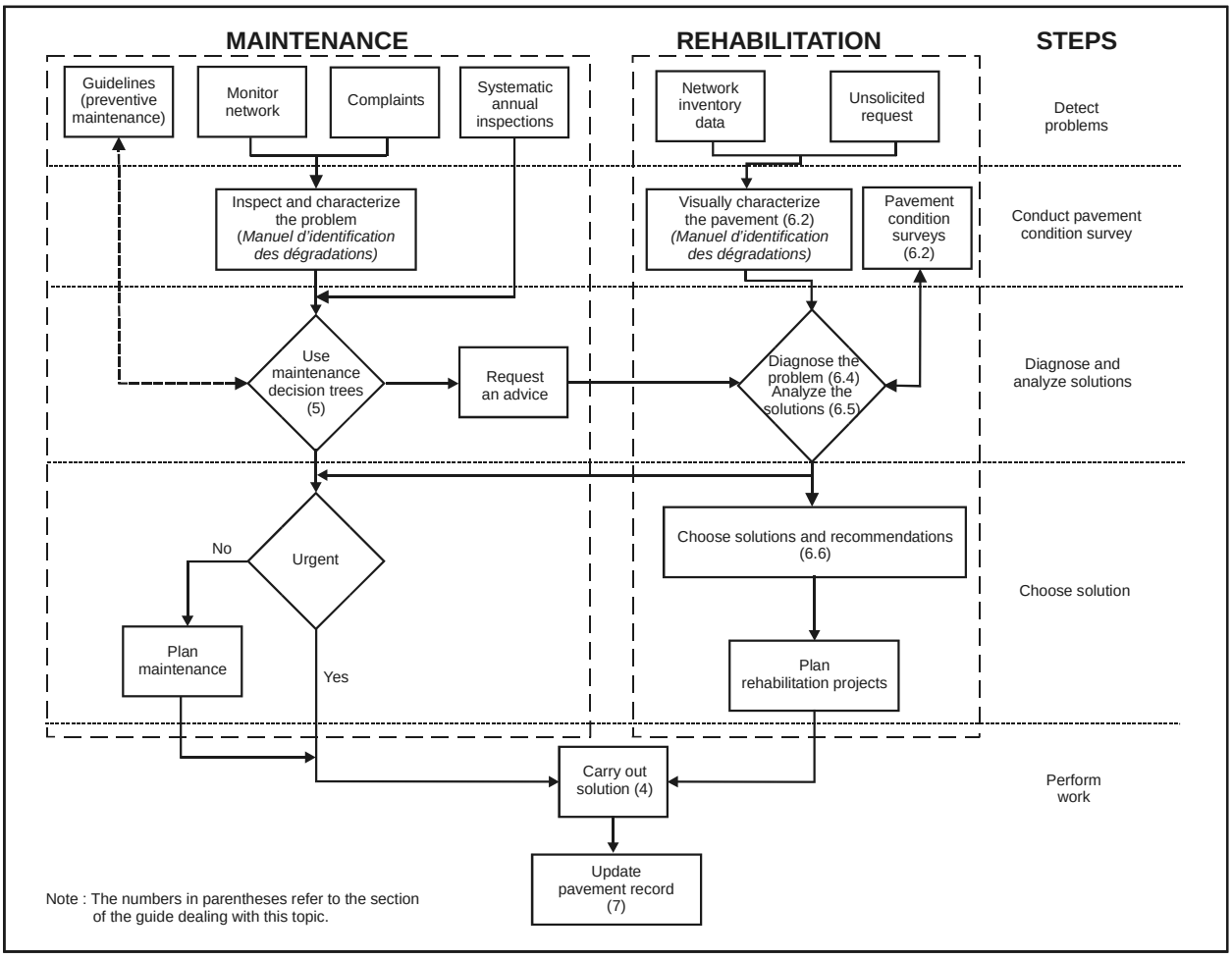

Figure 1 – Pavement maintenance and rehabilitation decision process

Rehabilitation decision process

Two main sources are used to detect problems: network inventory data and unsolicited requests.

The network inventory data (roughness, rut depth, cracking) feed the pavement management system. This system is used to detect problem sections and schedule projects in accordance with rehabilitation requirements and budget constraints.

Unsolicited requests comprise external requests (citizens' complaints, municipal resolutions, specific requests, etc.) and internal requests (requests for an advice from maintenance units, decisions of administrative authorities, detection of an anomaly in the network inventory data, detection of a distress undetected by the network inventory data, or a major distress arising between surveys, etc.)

In sections where problems are detected, the survey phase consists in visually characterizing the pavement, i.e., identifying the type, density, and severity of all distresses using the *Manuel d'identification des degradations des chaussees en beton de ciment*.

A diagnosis can be arrived at on the basis of the visual data and other available information. In some cases, the cause of the problem and the available solutions are obvious, and the solution can be readily chosen. In other cases, additional data is required for an adequate diagnosis. Pavement condition surveys that are more comprehensive and targeted to specific problem, such as profilometry and rutting surveys, borings, deflection tests, and other non-destructive tests, must be conducted.

Detailed surveys, diagnoses, and choice of solutions for rehabilitation of concrete pavements are covered in another part of the guide.

Performing the work

The last step in the process is to do the work. This is the common denominator for both the maintenance and rehabilitation of rigid pavements, since the basic techniques are the same, though the scope of the projects may be quite different.

These techniques are presented and described in one section of the guide, which covers the broad range of maintenance, restoration, recycling, overlay, and reconstruction operations done on rigid pavements.

Finally, the last step in this decision process is the updating of the pavement record using the forms proposed in the last section of the guide.

MAINTENANCE AND REHABILITATION TECHNIQUES

This section covers the various techniques used on pavements.

Technique description sheet

The 25 maintenance and rehabilitation techniques described in this guide comprise different types: they include the broad concepts of maintenance and rehabilitation, i.e., the repair, restoration, recycling, overlay, and partial or complete reconstruction of pavements. Most of these techniques are used and well mastered in Quebec, but some are less used or even new.

The list of techniques covered by the description sheets is given in Table 1.

Table 1. List of maintenance and rehabilitation techniques contained in the guide

Reference number	Name of technique
1.	Joint resealing
2.	Partial-depth concrete repair
3.	Slab fracturing
4.	Thin bonded concrete overlay
5.	Milling
6.	Asphalt recycling techniques
7.	Fine aggregate spreading
8.	Full-depth concrete repair
9.	Pressure relief joint
10.	Slab stabilization
11.	Load transfer restoration
12.	Cross-stitching
13.	Slab jacking
14.	Crack sealing
15.	Cold-mix patching
16.	Hot-mix patching
17.	Thin asphalt overlay
18.	Drainage improvement or restoration
19.	Diamond grinding
20.	Asphalt overlay
21.	Unbonded concrete overlay
22.	Transition
23.	Reconstruction
24.	Pavement insulation
25.	Sweeping

A description sheet is provided for each technique listed and each is assigned a reference number. This sheet includes a brief description of the technique, its purpose, targeted distresses, applications, associated maintenance, approximate cost, life expectancy, and useful references for obtaining more information. A example sheet is shown in Figure 2.

2	Partial-depth concrete repair	Construction guidelines Section 4.3.3

Description

This technique consists in marking off the repair area with a saw cut, then removing and replacing the damaged concrete. Joint and reservoir continuity is ensured with a compressible board. This technique is commonly used in Quebec.

Purpose

To correct surface distresses, to avoid accelerated deterioration of the overlay, and to reduce roughness.

Targeted distresses

- Pot holes.
- Spalling.

Applications

- Distresses affecting less than half the slab's thickness and extending less than 1,8 metres in length by a half-lane in width.
- Spalling over 40 mm wide by 3 to 40 mm deep.

Associated maintenance

Joint resealing.

Approximate cost

- From 225 to 275 $C/m^2.
- 100,00 $C/linear metre for spalling.

Life expectancy

10 to 15 years. The successful use of this technique depends on a number of factors: applicability, preparation, choice of product, carrying out, and curing.

References

MTQ

- *Cahier des charges et devis generaux* (CCDG) 1997.
- *Normes Ouvrages routiers, tome VI, Entretien*.

ACPA

- Guidelines for Partial Depth Repair (TB-003).
- Pavement Rehabilitation Strategy Selection (TB-015P).

Figure 2 – Example of a description sheet for partial-depth concrete repair

Construction guidelines for certain techniques

Construction guidelines are added to the description sheets for certain maintenance techniques used on concrete pavements. These techniques are either more sensitive to construction conditions (joint resealing, crack sealing, and partial-depth concrete repair), less known (pressure relief joints, slab stabilization, load transfer restoration by dowel bar retrofit, diamond grinding), or more elaborate (full-depth concrete repair).

This section covers the main construction steps, as well as the measures required to ensure an adequate level of quality. When preparing specifications or implementing one of these techniques, a review of the more detailed documents mentioned on the descriptive sheets is suggested.

Fast track

The last section of this chapter deals with quickly reopening a road to traffic, an increasingly necessary concern requiring an overall approach as opposed to a single technique.

Fast track has become a common practice in concrete pavement repair or reconstruction work. A number of techniques have been developed to ensure a long-lasting and quality product. Methods may vary according to available time and traffic constraints. ACPA brochure TB-004.02P (Fast-Track Concrete Pavements) covers this topic in detail.

When used judiciously, fast track techniques can reduce obstacles and construction schedules. In other words, these techniques are not necessarily advisable everywhere and anytime.

Fast track is not limited to using high early strength concrete. It is an overall approach that consists in considering and acting on all factors influencing lead times.

PAVEMENT MAINTENANCE DECISION TREE

The decision trees described in this guide are designed specifically for concrete pavement maintenance units. Work carried out by these units is normally aimed at one problem at a time; therefore, a tree has been developed for each concrete pavement distress included in the *Manuel d'identification des degradations des chaussees en beton de ciment*.

These trees suggest one or several maintenance techniques. The numbers in the tree refer to the 25 technique description sheets presented in the previous section. Whenever "ADVICE" appears in any decision tree, a specialized department should be consulted for a more in-depth analysis of the problem.
To use these trees effectively, the following information must be known:

- the severity, density, and distribution of a distress in a given area through network monitoring, annual survey, or complaints. A more systematic survey of the entire network covered by a maintenance unit can also be done to better monitor its condition and assess its maintenance requirements.

- the type of maintenance available, as defined in Table 2;

Table 2. Types of maintenance addressed in trees

Type of maintenance	Definition of maintenance activity
Preventive	Action taken before or as soon as a deterioration appears.
Corrective	Action taken to restore the pavement's integrity, i.e., to correct the problem definitively.
Palliative	Action taken to maintain the mobility and/or safety of users (temporary solution).
Urgent	Action taken when user safety is suddenly threatened.

- the age of the slab referring to the number of years it has been in service.

Figure 3 shows an example of a maintenance decision tree.

Severity	Density	Distribution	Type of maintenance	Techniques reference numbers according to age of slab (years)		
				Less than 10	10 to 25	More than 25
Moderate	Low	—	Preventive	—	—	—
			Corrective	8	8, 11	11
			Palliative	14	14	14
			Urgent	—	—	—
	High	—	Preventive	—	—	—
			Corrective	Advice	Advice	Advice
			Palliative	—	—	—
			Urgent	—	—	—
High	Low	—	Preventive	—	—	—
			Corrective	8	8, 11	11
			Palliative	16	16	16
			Urgent	—	—	—
	High	—	Preventive	—	—	—
			Corrective	Advice	Advice	Advice
			Palliative	16, 17	16, 17	16, 17
			Urgent	—	—	—

Figure 3 - Maintenance decision tree for transverse cracking in a pavement with concrete surface

CONCRETE PAVEMENT REHABILITATION STUDY

The next section of the guide deals with more in-depth studies for rehabilitation projects. The various steps of a rehabilitation study are described, from field survey to diagnosis, and to choice of solution.

As shown in the decision process (Figure 1), when a section of pavement is identified as defective or requiring rehabilitation, either on the basis of network inventory data, requests for an advice, or unsolicited requests, a rehabilitation study should be

undertaken. This study consists in conducting a more in-depth survey of the pavement's condition, arriving at a diagnosis, and finding the most appropriate rehabilitation solution, in accordance with objectives that have been clearly defined initially.

Pavement condition survey

A pavement condition survey consists in collecting data to determine the structural capacity and functional condition of the pavement, gathering any information for diagnostic purposes, and identifying the physical constraints influencing the choice of a rehabilitation scenario.

The data from the first visual survey (on-site inspection) and information from existing documents and discussions with the personnel concerned must first be assembled. Then, the relevance of making additional surveys is assessed. A brief description of the most common additional surveys done in a rehabilitation study is provided below:

- visual – visual surveys are usually done in summer and winter, in order to:
  - identify the main distresses in each area;
  - draw a parallel between these distresses and the observable characteristics of the pavement and the environment;
  - identify the constraints that may influence the choice of solution;
  - subjectively rate the functional condition of each area.

- profilometry – a profilometry survey assesses the roughness of the pavement, i.e., irregularities in the longitudinal profile in the wheel path as compared with a perfectly level reference surface. An inertial profilometer is the device most commonly used for rehabilitation studies.

- borings – the purpose of borings is to determine the thickness of the layers of materials, and to characterize the soils and materials. This is usually done with a truck-mounted drill using auger bits and core cutters.

- deflection – measuring the deflection of a pavement under a known load can provide valuable information on the mechanical properties of the pavement's component layers and its ability to support a given traffic during its anticipated life expectancy. These tests are usually conducted with a falling weight deflectometer (FWD).

- rut measurements – information on rutting type and depth, as well as the age of the overlay, is helpful in arriving at a diagnosis, since the causes of rutting are quite easy to determine.

- skid and texture testing – these tests are done when a slippery surface or a surface with a slippery appearance has been detected, or when clues (e.g., accidents) indicate that a pavement may be slippery. Skid resistance is measured with a SCRIM device. Texture is usually measured using the sand patch method.

Data segmentation and processing

Using the data collected during the survey phase, a project can be divided into homogeneous segments with a separate diagnosis for each segment. A diagnosis will be valid only if the section is divided into relatively homogeneous segments in terms of behaviour and physical characteristics.

Data segmentation and processing are done simultaneously, since they depend on each other. In this guide, they are covered in succession to simplify the presentation.

Diagnosis

A diagnosis consists in identifying the causes of problems observed and determining the potential solutions.

Diagnosing is not a predetermined, systematic process resembling a flow chart or decision tree. Instead, it is a synthesizing operation based on hypotheses, knowledge, intuition, and experience. While knowledge, intuition, and experience serve mainly to develop hypotheses about the most probable cause, these hypotheses must be examined rigorously to see if they account for the entire body of available information. The least plausible hypotheses can thus be detected and discarded.

A pavement diagnosis includes many interdependent factors;

- field data;
- causal links;
- structural capacity;
- frost protection;
- functional condition;
- rehabilitation techniques.

Each of these factors is related to all of the others, the purpose of the diagnosis being to combine these various sources of information to determine the causes of the problems, and to assess the relevance and feasibility of potential solutions.

Analysis of solutions

Diagnosing the pavement for a given project should always lead to several potential solutions, including doing nothing. Each solution has its own cost, impact on traffic during implementation, and performance and maintenance requirements.

Analyzing the solutions consists in assessing them to identify the optimum solution that meets the project criteria, such as budget, performance objectives, or total cost over the service life of the pavement.

Three assessment methods are commonly used to compare and classify the scenarios according to the criteria chosen for each method: advantages and disadvantages, non-monetary criteria (multiple criteria decision analysis), and economic criteria (LCCA).

In general, however, a great deal of judgment is required to choose the most appropriate solution for a project. This means there are no strict rules, but a systematic decision approach is presented in the guide. It need not be followed to the letter; it is more important to understand the principles.

- Analysis of advantages and disadvantages

With this method, the advantages and disadvantages of each scenario are first listed. The scenarios with unacceptable disadvantages are then eliminated. Finally, the scenarios are classified by weight of advantage over disadvantage. This method has a strong subjective component, but it takes into account dissimilar elements of comparison, such as cost, reliability of technique, future performance, etc.

- Multiple criteria decision analysis

A multiple criteria decision analysis compares different scenarios using decision criteria (monetary or non-monetary), and weighting them by importance. This analytical method can be particularly useful when several scenarios seem equivalent.

- Life Cycle Cost Analysis

A comparison based on LCCA should be a major decision factor in choosing a scenario. The objective of such an analysis is to select the least expensive option by taking into account the total costs incurred throughout the service life of the pavement. The costs included in the analysis are the following:

- Construction costs
  - cost of the initial construction;
  - future maintenance and rehabilitation costs;
  - residual value.

- User Costs
  - costs associated with construction-related delays;
  - vehicle operating costs;
  - accident-related costs;
  - environmental costs.

User costs, particularly the environmental and accident-related costs, are more difficult to estimate than construction costs.

CONSTRUCTION HISTORY

It is suggested in this guide that pavement maintenance and rehabilitation personnel record the main data on a pavement's construction and all maintenance and rehabilitation actions taken afterwards in a single file, so as to have a useful history for later diagnostic purposes.

The last section of the guide presents model forms to record all relevant and useful information.

CONCLUSION

One of the most useful features of the MTQ *Guide d'entretien et de rehabilitation des chaussees en beton de ciment* is that it links distress evaluation to the selection of maintenance treatments or rehabilitation techniques and performance follow through of concrete pavements.

Another interesting aspect of this guide is that it deals with two types of rigid pavements: concrete pavements and asphalt overlaid concrete pavements.

This guide is practical, includes up-to-date, tried and tested technologies and offers useful references to readers wanting to deepen their knowledge. It could easily be translated or adapted to the ways and customs of any foreign Administration.

The guide is published officially and is available in French. Copies may be obtained at the following address:

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Quebec (Quebec)
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References:

[1] Transports Quebec (1999), *Guide d'entretien et de rehabilitation des chaussees en beton de ciment*, 137 p., Quebec, Canada.

[2] Transports Quebec (1997), *Manuel d'identification des degradations des chaussees en beton de ciment*, 81 p., Quebec, Canada.