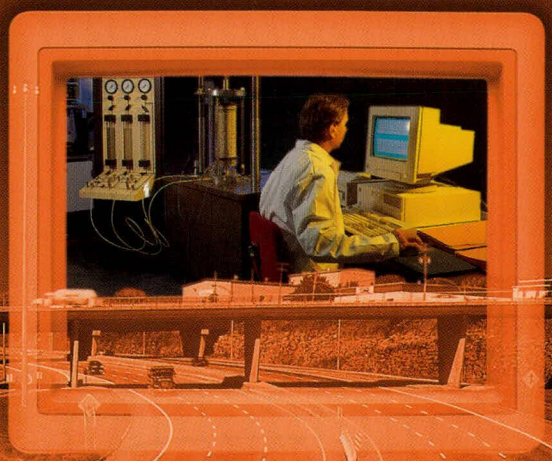
Research and Development at the Laboratoire des chaussées



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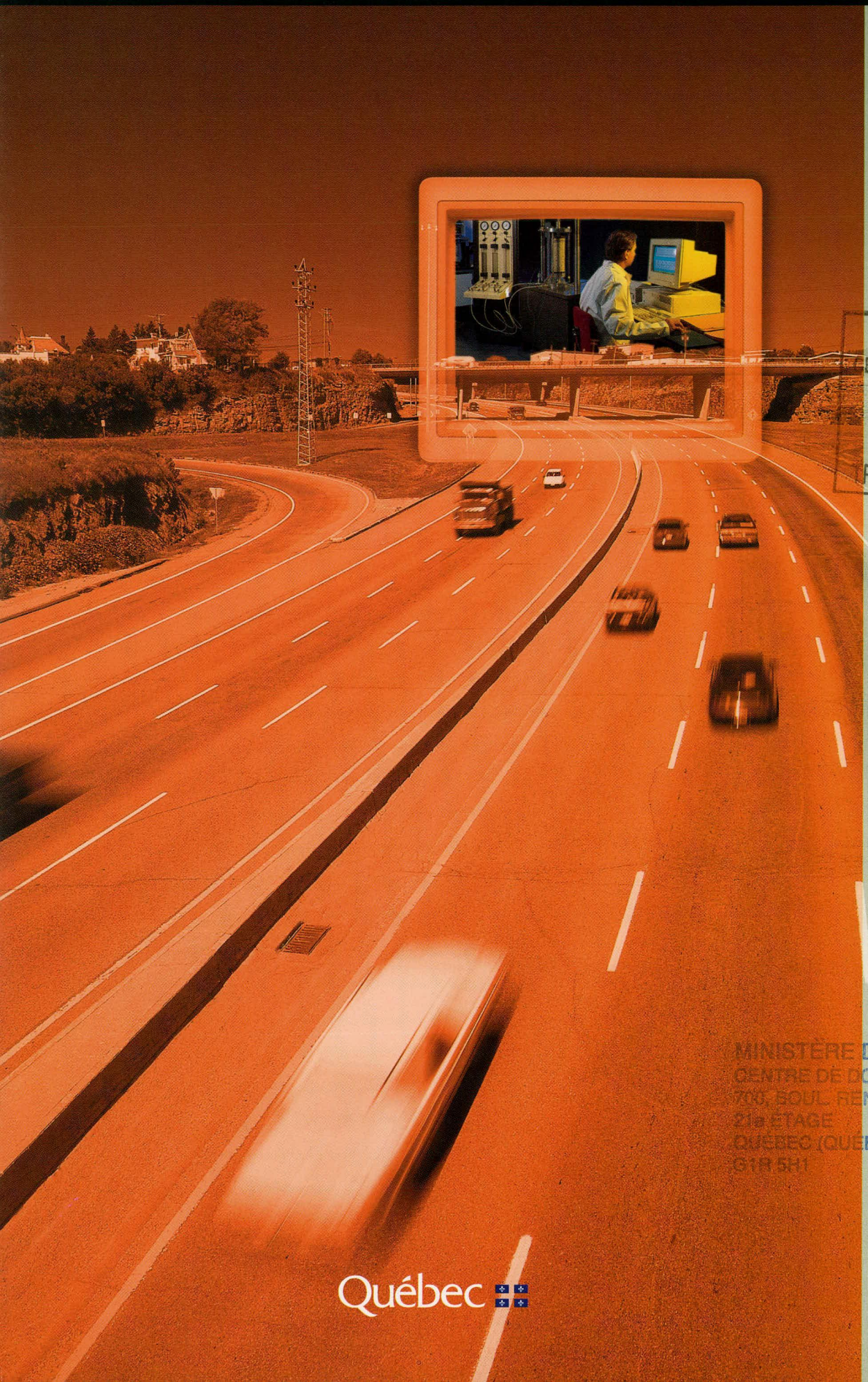

Research and Development at the Laboratoire des chaussées

Québec

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QUÉBEC: A UNIQUE ENVIRONMENT

Its vast territory, low population density, harsh climatic conditions, and heavy traffic around major urban centres make Québec one of the most challenging places in the world in which to maintain and operate a road network.

Although half the province's population is concentrated in the Montréal and Québec City areas, the road network covers all of Québec's inhabited territory.

Over the past 20 years, the number of passenger vehicles and heavy vehicles has doubled, now totalling close to four million. In the 1970s, the legal axle load rose from eight to ten tonnes.

Québec's climatic conditions are particularly severe: in the space of a few hours, temperatures can fluctuate as much as 25°C. For more than four months, the soil freezes at depths that may vary, depending on the region, from 1.2 to 3 metres. Precipitation (rain and snow) is abundant; an equivalent of 1000 ml falls each year. After resisting strain due to deep frost in winter, Québec roads must still be capable of bearing heavy loads during spring thaw, when the pavement is 40 % less resistant.

Due to these unique conditions, it is difficult to compare the road surfaces of Québec with those of other countries and to import technologies without first carrying out in-depth analyses.

Priority to Research and Development

The Québec road network, most of which dates from the 1960s and 1970s, is definitely showing signs of aging. The Ministère des Transports du Québec (MTQ) is responsible for some 28 000 km of road infrastructures, including highways and national, regional and collector roads.

This means that, despite today's difficult economic context, the MTQ is faced with numerous in-depth maintenance and repair projects; hence the importance of using more high-performance techniques and materials to increase the service life of the structures.

Given the rapid development of methods and expertise in the field of pavement design, as well as the emergence of new technologies and products, the MTQ has chosen to focus on research and development. This is a major policy change which has enabled the Laboratoire des chaussées to implement innovative techniques, adapt technologies to the Québec context, and design and develop new tools.

The Ministère des Transports du Québec is responsible for some 28 000 km of road infrastructures, including highways and national, regional and collector roads. (Photo: Louis Rioux)

The Laboratoire des chaussées

The Laboratoire des chaussées team is composed of approximately 100 technicians, professionals and specialists in the following fields: pavements, pavement materials, geotechnology and geology, and industrial products. In the laboratory and on site, aided by increasingly sophisticated equipment, they seek to maximize the security and comfort of users and preserve the Québec road network.

The primary mandate of the Laboratoire is to meet the needs of the MTQ. However, it may occasionally respond to requests for expertise, consultation, or action on the part of other government agencies, engineering-consulting firms, private laboratories or municipalities.

In certain fields such as pavements, geotechnology, and materials, research is carried out in conjunction with several Québec universities. Also, each year, the Laboratoire takes on master's and doctoral student trainees, and entrusts certain research projects to the university community to meet some of the MTQ's more pressing needs.

In addition to working with the universities, the Laboratoire team also attends meetings, conducts joint research projects, and participates in technical exchanges with several countries, especially France and the United States. One example of this is the Laboratoire des chaussées' participation in SHRP and C-SHRP research programs.

PAVEMENTS

The increase in traffic and authorized loads, abundant precipitation, and the impact of thawing and freezing on the water table are the main causes of pavement distress. Pavement is a major component of the road infrastructures for which the MTQ is responsible.

Pavement Design and Management

The Laboratoire des chaussées has devoted a great deal of time and effort to the development of a pavement management system that integrates road network design, maintenance and repair.

To improve the precision and reliability of structural evaluation data, the Laboratoire uses maximum-efficiency condition survey equipment to establish an exhaustive, accurate portrait of the road network. It is also devising a process whereby the appropriate treatment method can be selected based on the type of pavement distress.

The Laboratoire also works to formulate pavement design methods, and experiments with and validates new techniques and procedures for maintaining and restoring pavement surfaces.

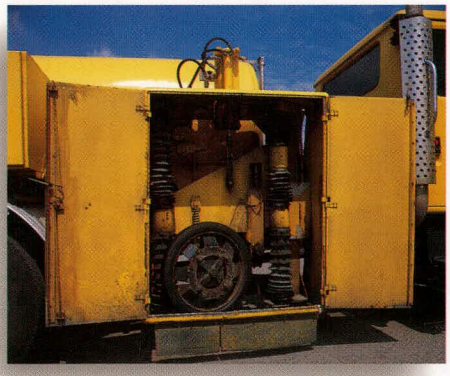
The inertia profilometer takes precision measurements which are used to assess pavement profile and the application of roughness clauses in documents authorizing road construction. (Photo: Jacques Lessard)

Pavement Mechanics

The Laboratoire has acquired state-of-the-art expertise in a number of areas, including the application of geophysical methods to site investigation and pavement assessment, and the design and repair of airport runway surfaces.

It has also developed a method of evaluating the effects of heavy vehicles and loads on pavement performance, based on climatic conditions.

Finally, via experimental monitoring, Laboratoire specialists assess the long-term performance of new techniques and procedures, and issue recommendations regarding their usage.



The SCRIM measures the quality of pavement-tire contact on wet surfaces, thereby indicating the level of skid resistance. Good skid resistance limits the danger of hydroplaning and skidding. (Photo: Jacques Lessard)

In 1993, the Laboratoire des chaussées developed the rut laser, a maximum-efficiency condition survey system used to measure rut depth and shape. A laser beam is projected onto the road surface and the distortion of the beam, emitted at a given angle, is intercepted by an infrared camera. The analogic signals from the camera are converted by a computer into numerical coordinates, enabling the depth and shape of the ruts to be defined in real time. (Photo: Jacques Lessard)

Research and Development

Various research projects are currently under way to:

- devise analytical or semi-empirical pavement design methods that are better adapted to the Québec context and offer greater leeway to designers;
- enhance design method precision through more in-depth knowledge of the phenomena that interact to cause pavement structure distress;
- improve the efficiency of actions taken through responsible use of new or non-traditional materials;
- improve current repair methods through the use of techniques such as cold-in-place recycling;
- improve the drainability of pavement structures;
- acquire knowledge on the effects of freezing and thawing on pavements, their performance, and various distress phenomena, in order to integrate these parameters into design methods and enhance protection techniques against frost.

PAVEMENT MATERIALS

This field comprises the following sectors of activity: soils and foundations, aggregates, bituminous binders, and asphalt mixes. Researchers in these areas seek to develop pavement materials that are highly efficient yet wear-resistant under harsh conditions.

Through its many research projects, the Laboratoire des chaussées seeks to:

- develop, in a laboratory setting, performance tests reliable enough to predict the behaviour of a paving material;
- take action before the materials are laid to reduce the risk of poor performance;
- develop tests that are more representative of the reality of the territory, as well as materials that are less sensitive to laying conditions and better able to withstand the harsh Québec climate.

Laboratory evaluation of materials performance facilitates the development of new materials and the responsible use of non-traditional sources, and fosters the development and application of new techniques and products.

Soils and Foundations

Currently, in the field of pavement design, there is a tendency to discard the empirical approach in favour of analytical methods which foster the responsible use of local materials. In addition, the role played by fines in the sensitivity to freezing of granular materials remains an area ripe for exploration.

Research and Development

The analytical approach to pavement structure design calls for greater precision in the evaluation of the resilient modulus of sub-base course granular materials, which are subject to stress due to saturation, freezing and thawing. The classification of materials based on the resilient modulus contributes to optimal use of the aggregates available. This aspect alone thus requires a major research effort.

Finally, since the MTQ uses aggregate sizes 40-0, 56-0, and even 112-0 in its base and sub-base courses, researchers use a high-capacity Proctor mold to study the density of coarse granular materials.

The cyclic triaxial compression machine is used in compliance with SHRP test protocols. It measures the resilient modulus of soils and unbound granular materials. The test consists of a cyclical application of an axle load to a sample 150 mm in diameter and 305 mm thick, in order to simulate the repeated passage of vehicles on pavement. The value of the resilient modulus is a measure of the material's elastic modulus, and is used in the AASHTO's flexible pavement design procedure.
(Photo: Jacques Lessard)

Aggregates

The Laboratoire des chaussées conducts petrographic analyses to determine mineral components and assess alkali-aggregate reactivity in cement concrete.

Used in asphalt mixes applied as a surface course, aggregates play a key role in skid resistance (tire-pavement contact). Due to traffic flow, surface aggregates tend to become polished more or less rapidly depending on their nature and component minerals; therefore, depending on traffic density, the pavement eventually becomes slippery.

The polishing-by-projection device (CPP-LPC) and the skid resistance tester are used to determine aggregates' resistance to polishing. The result, expressed as a polishing-by-projection coefficient (CPP), is correlated with on-road skid resistance tests performed using the SCRIM. (Photo: Jacques Lessard)

Research and Development

Specialists study aggregates in road surfacings using polishing-by-projection tests (CPP-LCPC), the skid resistance tester, and the British PSV test (UK). These laboratory tests help determine the aggregates' resistance to polishing. The data obtained are validated through on-road surveys, and any changes in skid-resistant properties caused by traffic flow are measured over time.

The MTQ spreads some 625 000 tonnes of abrasives annually. Via laboratory and on-road performance tests, the Laboratoire des chaussées seeks to optimize the particle size and application rate of its abrasives in order to reduce quantities and costs and, most importantly, maximize road safety during the winter.

Bituminous Binders

Asphalt is what gives asphalt mixes their viscoelastic properties. Appropriate characteristics ensure high resistance to thermal and fatigue cracking and ravelling.

Traditional characterization of bituminous binders does not appear to convey an accurate impression of their behaviour. Since 1993, in-depth laboratory studies have been conducted on the performance of asphalt at different operating temperatures.

Research and Development

The SHRP asphalt characterization method allows a suitable mix to be chosen based on performance objectives. All research and development activities aim to make this new method more functional and operational.

SHRP asphalt characterization tests are based on an evaluation of their viscoelastic properties. Two basic tests have been developed: the dynamic shear rheometer test, conducted at high operating temperatures, and the bending beam rheometer test, conducted at low operating temperatures. The results enable users to select an asphalt appropriate to the climatic conditions of a given site. (Photo: Jacques Lessard)

Thus, the characterization of asphalt types based on their performance at various operating temperatures specific to a given climate is now possible thanks to the following: the dynamic shear rheometer (SHRP), the bending beam rheometer (SHRP), the direct tension test (SHRP), the pressure-aging vessel (SHRP), and the Brookfield viscometer.

The SHRP gyratory compactor is a device used to mix-design asphalt mixes and determine their workability. (Photo: Jacques Lessard)

Asphalt Mixes

Under current conditions, use of the traditional Marshall method results in asphalt mixes posting substandard safety and durability performance. The Laboratoire des chaussées is working to develop a new mix-design method based on a combination of SHRP and European performance tests.

Research and Development

The criteria used to develop this new method are linked to pavement performance objectives. They include workability and resistance to rutting, resistance to thermal and fatigue cracking, and moisture sensitivity.

Tests are conducted using a gyratory compactor (LCPC and SHRP 1014) to determine the mix's workability, the rutting test machine (LPC) for resistance to rutting, the tempered heat shrinkage test (TSRST-SHRP 1021) for resistance to cracking at low temperatures, the moisture sensitivity test for resistance to ravelling and, finally, the fatigue cracking test (SHRP 1019).

The MTQ-automated LPC rutting test machine analyzes the performance of asphalt mixes when subjected to plastic deformations such as rutting or flow under conditions resembling pavement stress. (Photo: Jacques Lessard)

Thanks to this new method, the Laboratoire des chaussées developed, in 1993, the EG-10 grained asphalt mix. Its particle size distribution is situated below the maximum density curve and it is to be applied as a surface course.

Since this time, the Laboratoire has been active in the design and on-site validation of other asphalt mixes which better comply with users' needs and designers' constraints.

Much of Québec's road network borders watercourses. The clay content of these soils combined with erosion processes generates major landslide risks and thereby threatens the infrastructures. The preventive work done by Laboratoire des chaussées specialists consists in evaluating the risks and recommending stabilization work or the moving of infrastructures as needed. (Photo: Robert Bergeron)

GEOTECHNOLOGY AND GEOLOGY

Most of Québec's populated territory is made up of clay soil deposited in glacial lakes and seas during the latter part of the Wisconsin Glacial Stage.

The construction of road infrastructures on this sensitive soil requires geotechnical studies to verify its stability and bearing capacity, since it is sometimes unable to support an embankment barely two metres thick.

Geotechnical studies are also called for in virtually all engineering construction projects. They seek solutions to structural performance problems in pavement and engineering works, which can be caused by settling or low bearing capacity, especially in peat bogs.

The very presence of these peat bogs in a number of Québec regions is what led the MTQ to develop expertise in the field of construction on organic soil.

Soil stability studies carried out during the preparatory phase of construction projects help determine the route the road should follow. They also help pinpoint instability problems on natural slopes and restore land following landslides.

Environmental protection is a constant concern for the Laboratoire des chaussées, which has developed advanced expertise in the field of hydrogeology as a result. This expertise has proven useful in carrying out impact studies on groundwater reservoirs and the domestic, municipal and industrial wells they supply.

The restoration of sand and gravel pits is also one of the Laboratoire des chaussées' environmental concerns, as is the study of vibrations caused by blasting or road traffic.

In the field of rock mechanics, geological studies are carried out to determine rock face design and secure unstable rocky cliffs. Finally, the design of riprap protection against water-induced erosion is another activity performed by rock mechanics specialists.

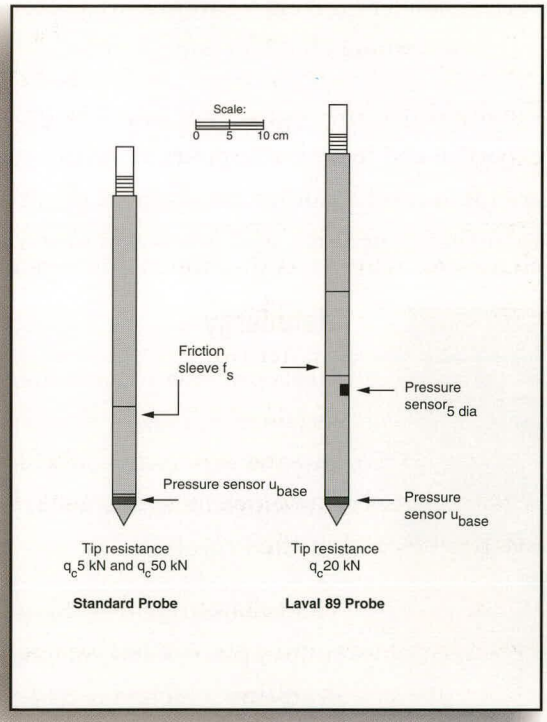
Recognized Expertise

The Laboratoire des chaussées boasts the Québec government's only group of experts in geotechnology. They provide consulting services to government agencies following natural disasters such as cave-ins, landslides, and rock-slides.

Research and Development

The Laboratoire acts as a technological watchdog in the field of geotechnology and in this regard, the MTQ finances several research projects in various Québec universities. Projects currently under way target the improvement of the bearing capacity of clay soil through electro-injection or vacuum consolidation.

Use of the piezocone as a design device in geotechnology and the engineering properties of unstable clay slopes have also been studied over the past few years.



Piezocone: standard model and model developed at Université Laval, in Québec City, in 1989. The friction sleeve was moved and an extra pressure sensor installed near it. Since 1990, the Laboratoire des chaussées has participated in piezocone applicability studies in the fields of deep foundations, slope stability, and the behaviour of soil under embankments. The results are promising.

INDUSTRIAL PRODUCTS

This field comprises four sectors of activity: chemistry, metallurgy, paint, and concrete cement.

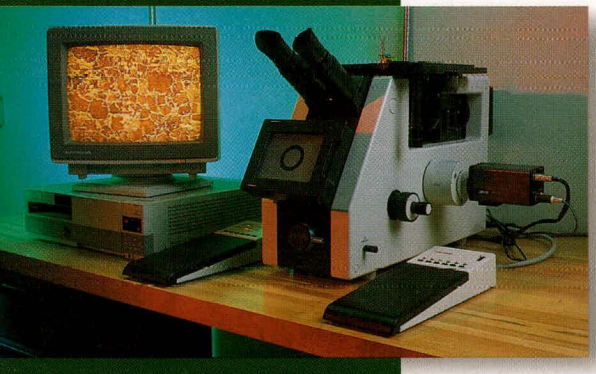
Chemistry

Much of the MTQ's activities deal with engineering as applied to quality control, expertise and research. To assess the behaviour of industrial products and the materials used in structures and pavement, both physical and chemical testing are required.

The Laboratoire des chaussées is equipped to carry out chemical analyses, tests, studies and assessments on industrial products and materials used by the MTQ, including soils and aggregates, cement, cement concrete and related materials, structural and reinforcing metals, treated wood, dust control materials, de-icing chemicals, and petroleum products.

The Laboratoire also supplies the equipment and expertise required in the use of infrared and UV-visible spectrometry techniques, as well as in high-performance liquid chromatography procedures, which are used to characterize bituminous binders and identify addition polymers.

Finally, since this is the only Québec government laboratory that offers expertise and technical support in the petroleum products sector, its services are often used by other government departments, as well as by parapublic agencies, companies, and private laboratories.



The metallograph is a video optical device used to examine the internal structure of metals. It is indispensable in characterizing materials and explaining their performance, and enables the visualization of the inter-metallic layers of anti-corrosion coatings. (Photo: Jacques Lessard)

Metallurgy

Steel corrosion reduces the life of bridges and, by weakening certain components, may jeopardize user safety. Also, to prolong the service life of bridges and ensure the safety of road users, products, materials and protection methods must be selected carefully.

The Laboratoire des chaussées evaluates metals and alloys, rubber, plastics and composites to determine the cause of any problems which may arise. The MTQ can then select the most appropriate materials and methods.

Research and Development

The Laboratoire carries out applied research designed to identify the most high-performing materials. For example, it has initiated on-site and laboratory studies on the impact of the physical, chemical and bacteriological parameters of surface water on the deterioration of metal culverts. The MTQ will henceforth be able to choose the most efficient materials for culvert construction and thereby prolong their service life.

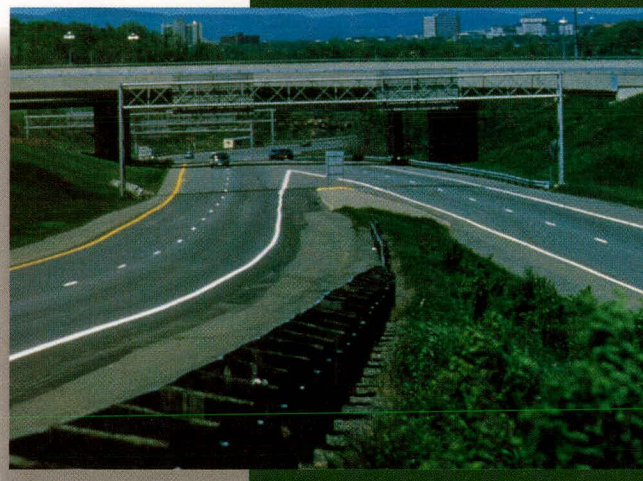
Paint

Since road safety is a priority for the MTQ, the Laboratoire des chaussées is studying highway marking products and reflective sheeting used in road signs, as well as anti-corrosive paint for metal structures.

Research and Development

The service life of alkyd marking products is less than a year, and the absence of marking increases accident risk. The Laboratoire conducts a systematic evaluation of the performance of new pavement surface marking and road signage products, including:

- medium- and long-term pavement surface markings (prefab strips, thermoplastics, epoxide, etc.);
- a new substance that replaces alkyd-based paint and exceeds current standards for retroreflection and durability;
- new, safer road signage products such as temporary and permanent delineators and new reflective sheeting.



The Laboratoire des chaussées is currently evaluating a new paint which provides greater retroreflection and durability than alkyd-based paint. (Photo: Louis Rioux)

Dry-mix and wet-mix shotcrete is used to repair concrete structures.
(Photo: Daniel Vézina)

Concrete cement

Concrete cement is the basic material used to build engineering structures. MTQ initiatives include repairing existing works which have deteriorated due to weakened concrete, alkali-aggregate reactivity, or corrosion of the reinforcing steel.

The Laboratoire's aim is to increase its expertise on the condition of concrete structures thanks to the development and integration of new technologies, and to develop new materials and repair methods for concrete structures.

Research and Development

Research projects aim mainly to enhance the durability of concrete works. To better assess the damage to bridge crossing slabs, the MTQ is working in conjunction with the private sector to design and develop radar condition survey techniques, which have the advantage of being non-destructive.

With regard to concrete deterioration, the Laboratoire is conducting characterization studies of sources of concrete aggregates that are susceptible to damage from alkaline reactivity. These studies also aim to characterize damage to engineering works and propose action plans and repair methods.

Studies are also conducted on the development of high-performance concrete and its use in building and repairing bridges. Dry-mix and wet-mix shotcrete used for repair purposes are also the object of active research.

Research on corrosion damage to reinforcing steel and various prevention methods is also ongoing. Certain projects under way deal with the performance of corrosion inhibitors and the possibility of using these products to repair engineering structures.

Other techniques under study include the assessment of various types of concrete sealer, protective coatings, and damp-proof membranes.

The Laboratoire des chaussées is working to develop engineering structure repair methods which will prolong service life by over 20 years. To this end, the use of high-performance concrete of 60 MPa or more and the development of dry-mix shotcrete with polypropylene fibres, silica fume, and air-entraining agents constitute interesting research projects for the future.

The Portneuf bridge
For the first time in fall 1992, the MTQ used high-performance concrete to build a new engineering structure. (Photo: Christian Bibeau)

This document was prepared by the Laboratoire des chaussées and published by the Direction des communications of the Ministère des Transports du Québec.

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