MINISTRY OF TRANSPORTATION OF ONTARIO

A Continued Commitment to Research and Development

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The majesty of Canada stretches 3,400 miles from the Atlantic to the Pacific oceans. Within its immensity lie the Canadian Rockies, the Great Lakes, luxurious prairie wheat fields, and magnificent forests. One of the strengths of a country so rich in size and natural resources is its transportation system.

Transportation plays a vital role in many elements of Canadian life. Responsibility for providing a safe and dependable transportation network is shared by federal, provincial, and municipal agencies. For example: national and international services dealing with air, water, and rail fall under federal jurisdiction; the provincial governments provide and maintain the highway infrastructure as well as license drivers and vehicles; and roads, transit, and other local services are governed at the municipal level. Highway research is carried out primarily by provincial transportation agencies.

Ontario, the second largest province, has a population of approximately 10 million or 37 percent of the nation's total, according to the 1992 census. It produces about 60 percent of Canada's manufactured products.

The Ministry of Transportation of Ontario (MTO) has more than 13,500 miles of highway and nearly 3,000 bridges under its jurisdiction. These highways provide the primary link between northern and southern Ontario, and some must perform in environments that experience extreme temperature variations.

Despite its demanding conditions, Ontario's infrastructure is healthy. This is due, in part, to the continued provincial commitment to transportation research and development. MTO recently completed a review of Ontario's research and development activities in transportation. The outcome of the review led to some organizational restructuring but also to a renewed focus and emphasis on R&D. Several groups within MTO perform research-related activities. The R&D branch is responsible for fostering and implementing technical/technological innovations related to the highway infrastructure, environment, and safety. The achievements and activities of the R&D Branch will be the focus of this article.

Located at the MTO head office complex in Toronto, the Research and Development Branch is supported by laboratory and testing facilities on site. The staff is made up of more than 40 research scientists, engineers, technicians, and communications specialists. Most are active on national and international committees and technical forums and these activities facilitate the adoption or adaptation of research results conducted by other organizations. The Branch also employs university students enrolled in engineering/science cooperative education programs.

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Ontario has the largest provincial surface transportation R&D budget in Canada. The R&D Branch is funded by the province, and in 1992 its budget totaled $5.2 million (Canadian). Research projects are undertaken primarily in response to the needs of MTO operational offices. At any given time, approximately 100 research projects are under way representing both in-house and contracted-out assignments. In the future, the Branch will continue to strengthen the links it has already developed with Ontario municipalities, and will create new ones with private industry as partners and cosponsors of research projects.

Today's transportation network must be safe and cost-effective while resources continue to decrease and costs and public expectations increase. The R&D Branch is exploring methods and materials to satisfy these demands. In response, the management of research projects is being dramatically redesigned.

Bridge Developments

One of MTO's research programs conducted in the late 1960s examined the behavior and load-carrying capacity of concrete bridge decks. It was suspected at that time that conventional design methods required unnecessarily high steel reinforcement in these decks. An extensive program of laboratory testing of small-scale models (conducted mainly at Queen's University in Kingston, Ontario) and field testing of bridges led to the realization that the steel reinforcement could be reduced by up to 50 percent with no adverse effect on safety.

Although these findings were significant at the time, MTO researchers faced difficulty in having them adopted. Reluctance on the part of bridge engineers stemmed from the fact that the new design proposals were not endorsed by an approved design code such as that of the American Association of State Highway and Transportation Officials. Resolution of this problem was one of the driving forces behind the creation of the *Ontario Highway Bridge Design Code*, an internationally recognized, state-of-the-art design code. First issued in 1979, the third edition of this popular Code was released in 1993.

With the advent of advanced composite materials, the next step is the development of structural systems to eliminate the use of conventional steel reinforcement. A new design, in which the deck slab is reinforced internally by chemically inert fibers, is already in the testing stage.

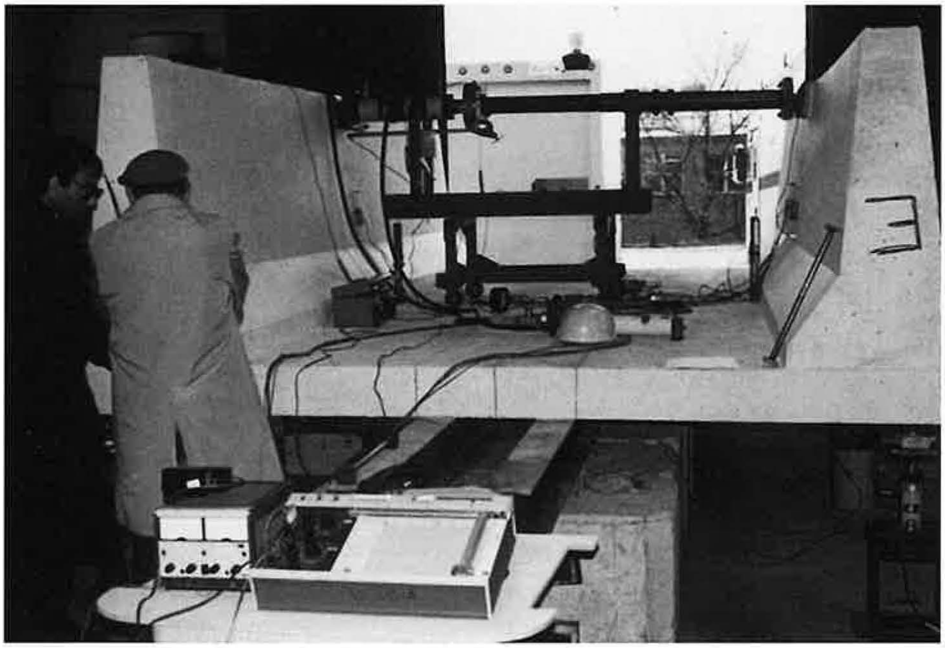
In northern Ontario, timber bridges are sometimes built because facilities for mixing concrete are too distant. MTO research has extended the use and acceptance of these bridges.

The concept of stress-laminated wood bridge decks was first developed in Ontario for the rehabilitation of nail-laminated wood decks. Customarily timber bridge decks experience limited life spans because the nail connections become loose under repeated heavy loadings. Transverse posttensioning of the wood laminates was studied as a way of solving this problem while at the same time increasing the load capacity. Its success as a rehabilitation method led to its subsequent adoption in the design of stress-laminated wood decks. This method is now being used extensively in North America.

Research of timber bridge decks continued and in 1987 the design for a wood-steel composite bridge was achieved. In this bridge, the laminates of the wood deck are placed along the bridge's steel girders, rather than perpendicular to them, thus taking advantage of the larger modulus of elasticity of wood in the longitudinal direction. The composite action between the deck and steel girders is achieved through concrete bulkheads located along the girder flanges. The first bridge of this type was built in northern Ontario in 1993.

A current project studying the application of used timber logs for building transversely stressed wood decks mixes old and new materials. In addition to recycling utility poles, this project is using nonferrous cables for transverse posttensioning. Following a successful model study, a full-size demonstration bridge will be constructed at the Toronto complex for testing.

More recently, improvements have been made in monitoring conduit distortion in soil-steel structures. Investigators looked for a quick method of recording the as-built shapes of the conduits as well as the current ones, making it possible to detect any significant change that may have occurred. Photogrammetry was found to be a cost-effective tool that could be incorporated easily into a regular bridge inspection program. Plans are under way to pass on this technology for adoption to other offices and agencies.



New method for anchoring barrier walls to deck slabs is tested at Ministry of Transportation of Ontario laboratory.

Bridge Rehabilitation

A unique testing program was introduced in the province in 1969 to determine the load-carrying capacity of existing highway bridges. Up until that time, most testing had been limited to laboratory work and the occasional venture into the field. Since the program began, more than 250 bridges have been tested in Ontario.

In most cases the proof type of test is done, in which a bridge is declared to be capable of carrying unrestricted traffic only if it can withstand safely the static proof load that is equivalent to the factored nominal failure design load. During the last two decades, almost every bridge test completed has revealed a significant aspect of bridge behavior that had been more or less ignored in the evaluation analysis of the bridge. A comprehensive program of testing provincial highway bridges is in place today and continues to save the province from posting or replacing bridges unnecessarily.

With the high number of bridges in the province and the extensive use of salt during the winter, successful rehabilitation of corroding structures has been a major concern in Ontario. In addition to developing standard procedures for the application of concrete overlays and waterproofing membranes, research activities have focused on cathodic protection and, more recently, electrochemical chloride removal.

MTO researchers pioneered the application of cathodic protection to bridge decks following the first installation in California in 1973. By 1978 it had become a recognized rehabilitation treatment on decks in Ontario when certain selection criteria were met. Then in 1981, research began to develop cathodic protection systems suitable for application to bridge substructure elements. Since the mid-1980s, most of the work has been in the use of systems using anode mesh or arc-sprayed zinc. The results have been applied in MTO construction contracts.

In 1989, the Burlington Skyway outside Hamilton was the first North American site for the application of electrochemical chloride removal. Since then, two more sites have been treated. Treatment of the abutments of the Montreal River Bridge in northwestern Ontario was undertaken as a joint MTO/Strategic Highway Research Program project in 1992. Preliminary results from these and other sites are promising and monitoring for long-term effectiveness of this rehabilitation treatment is planned.

The *Bridge Deck Manual,* outlining procedures for bridge deck rehabilitation, was introduced in 1981. To prepare the manual, research looked at methods of inspection, investigation, rehabilitation, and decision methodology. The recognized rehabilitation methods are the use of waterproofing membranes and concrete overlays, and cathodic protection.

Bridge deck rehabilitation is most successful when there is an accurate understanding of the structural condition of the deck. Research to develop methods for the rapid and automatic collection of such data was undertaken in the early 1980s. The result of the studies was the Deck Assessment by Radar and Thermography (DART) system, which used impulse radar and infrared thermography, a viable noncontact, nondestructive method. The system permits a reduction in scope and therefore cost saving in detailed bridge condition surveys. The system is now used routinely by MTO as part of its bridge management system.

Self-contained prototype vehicle that uses radar and thermography is now part of MTO's bridge management system. Vehicle detects deck deterioration and determines asphalt thickness over concrete and concrete cover over rebar.

Vehicle Weight Control

With the new construction and improvement of highways in Ontario in the 1960s, the demand for heavier vehicle weights increased. Before 1970 there was no direct relationship between vehicle weight regulations and the design loads for load-carrying capacities of bridges and pavements. The Ontario Bridge Formula was developed to provide that link between bridge strength and regulatory weight limits. The formula ensured maximum use of the highway system with a minimum of load-induced damage to bridges and pavements. It became the centerpiece for later structural research work.

The Ontario Bridge Formula was incorporated into the Highway Traffic Act for Ontario in 1971. The formula allowed a significant increase in gross vehicle weight limits that permit an increase in load effects on bridges. A set of simplified tables was subsequently developed and in 1978 these tables also became part of the Highway Traffic Act. The Bridge Formula was also used in conjunction with vehicle weight surveys to develop bridge design loads that were later incorporated into the Ontario Highway Bridge Design Code. The design standards were thus related directly to the regulatory loads through the Bridge Formula.

In order to move a heavy vehicle, load, object, or structure in excess of dimensional and weight limits allowed by law, a special permit is required. For practical, technical, or economic reasons, the legal limitations can often be exceeded for heavy, indivisible loads. The Bridge Formula was again used in the early 1980s to develop overweight permit guidelines. Speedy evaluation of permit applications without a detailed evaluation of the bridges and pavements en route is now possible. These guidelines are used extensively across the province by permit evaluation offices.

Pavement Performance and Management

The development of pavement management systems on a network level started in the late 1960s with the development of a series of pavement condition evaluation manuals. These manuals were issued to standardize the identification, rating, and treatment of pavement surface distresses. Extensive photographs identify the distress manifestations at different levels of severity and extent, and recommend specific maintenance treatments. Because the manuals filled an urgent need, they became the most widely distributed R&D Branch publication. The series has been updated and now includes all major pavement types.

In the early 1970s, a research team developed one of the first comprehensive project level pavement management systems in the world, the Ontario Pavement Analysis of Cost (OPAC). It contains a unique pavement performance predictive model that separately calculates pavement deterioration from environment and traffic. The system provides an excellent tool for quantifying trade-offs between various aspects of pavement design such as initial construction, resurfacing, maintenance, and user costs.

The OPAC system was supplemented in 1991 by the development of a life-cycle cost analysis program designed specifically for pavement rehabilitation projects. PRLEAM is an easy-to-use computer program that allows pavement designers to consider a range of specific future rehabilitation strategies.

The development of the network level pavement management system was completed in the late 1980s as the first fully functional comprehensive system in Canada.

Ontario has the highest allowable axle loads in Canada and the second highest allowable gross vehicle weight in North America. As a result, some of Ontario's pavements experienced severe problems with rutting. In 1987, a study recommended the use of rut-resistant mixes in binder courses. These mixes use high-quality crushed aggregates and some use modified asphalts. It was believed that asphalt modifiers may increase binder stiffness and therefore improve rutting resistance. A project was initiated in 1990 and initial field and laboratory test results indicated that certain polymers have the potential to increase the resistance to rutting and low-temperature cracking.

Vehicle conducts proof test on posted bridge to determine validity of restrictions.

Stone mastic asphalt (SMA) paving mix that uses crushed stone chips achieved considerable prominence in northern and central Europe. Three SMA pavement field demonstrations were conducted in Ontario between 1991 and 1992. The results show that SMA technology can be produced and put in place with good results employing local materials and equipment.

The falling-weight deflectometer (FWD) is a tool used for nondestructive testing of pavement performance. A computer program, PROBE, has been developed that interprets data from the FWD and is unique to other programs because it also analyses damaged asphaltic concrete pavements and systematically corrects for temperature. The PROBE program has been verified and calibrated with extensive data.

As part of a comprehensive program to select and use cost-effective pavement maintenance techniques, rout and seal treatment for cracks in flexible pavements was investigated. Preliminary studies led to a large-scale, province-wide study in 1986. Results indicated that crack sealing is a cost-effective pavement maintenance procedure under certain conditions.

To help implement these findings, a videotape was made available that demonstrated rout and crack-sealing procedures. A computer program, ROSE, was developed that identifies and ranks pavements suitable for this rehabilitation method. In addition, guidelines are being prepared to assist in the selection of pavements and timing of application and to establish priority for application under limited maintenance funding.

Pavement research has also made significant contributions to the development of weigh-in-motion scales, open-graded drainage materials, and rubberized asphalt mixes. Some of the current projects include performance of pavement drainage systems, measurement of segregations of asphaltic concrete mixes, and the use of recycled materials such as scrap tire rubber, steel slag, and blast furnace slag.

Snow and Ice Control

Ontario has a well-defined winter research program that concentrates on the control of drifting snow and deicing chemicals. In the early 1970s, researchers looked at ways of designing highways that would prevent the accumulation of drifting snow on the roadway. The shape of highway cross-sections, ditches, rights-of-way, and vegetation selection procedures were considered. The resulting design treatments now being used allow highways to be built so that drifting snow will accumulate in the ditch instead of on the highway's surface. A subsequent product is the computer program SNOWDRIFT, developed for highway designers as a tool to determine the effectiveness of their design.

Monitoring of a variety of deicing chemicals has supplemented field tests that have concentrated on calcium magnesium acetate (CMA). Following earlier U.S. testing that suggested CMA would be an effective alternative to salt, Ontario initiated a 5-year testing program in 1986. A model for quantitative analysis was developed to compare the effectiveness of salt and CMA by looking at the percentage of time each was effective under specified environment and traffic conditions. Results showed that CMA did not perform as well as salt under cold Ontario conditions. The published reports of these field trials drew great interest, especially from those jurisdictions intending to include CMA in their winter maintenance programs.

Much research has been done to evaluate salt alternatives and salt-reduction strategies. This includes developing methods for using salt and sand more effectively, investigating technology to apply salt in a more timely manner, and development of a policy for the use of salt and alternatives.

Environment

In the early 1970s, a trend was under way in the United States to reduce roadside mowing and maintenance costs. In response, several R&D Branch research projects investigated natural regeneration. The result has been the growth of natural grasses, tree, shrub, and wildflower cover along some highways in south and southwestern Ontario.

Natural regeneration of grasses, flowers, and trees along highways in southern Ontario helps to reduce maintenance costs.

Integrated vegetation management (IVM) is a program to control weeds and brush in non-crop situations such as highway rights-of-way. IVM is also seen as a way of reducing maintenance costs. An extensive review of IVM options completed in 1992 produced a hands-on guide that provides alternatives to weed and brush control and ideas on proactive maintenance.

Because of the harsh and snowy nature of Ontario winters, the use of salt is a constant environmental concern. Investigation of methods for measuring and mitigating the effects of road salt on the environment and of rehabilitating affected properties has therefore been ongoing. In the early 1980s, a full-scale demonstration for removing salt from groundwater surrounding an MTO patrol yard was initiated. This work led to recent efforts to evaluate other technologies for enhancing water quality. The objective of one study was to define the effectiveness of oil-water interceptors for removing contaminants from patrol yard wash water. In a second study, an engineering process-flow sheet for removing salt from contaminated groundwater has been defined.

The potential for stormwater runoff to have any toxic effects on the biota of receiving waters is another area of environmental research. Efforts have been made to measure levels of representative contaminants in snow melt runoff from two- and four-lane highways. From that, a model for forecasting the concentrations of contaminants on highway runoff was developed based on a Minnesota data set. A toxicity testing program was initiated in 1993.

Efforts in erosion and sediment control at construction sites led to the development and implementation of a protocol for testing surficial erosion-control materials. In 1989 and 1990 the procedure was tested to rate the performance of various products for their capability to control erosion in the field. The results allow designers to match a product's capability with the erosion susceptibility of a particular site.

In the last few years the number of environmental researchers in the Branch has increased. More research into programs such as fisheries-mitigation technologies and wetland impact analyses will be seen in the future.

Safety

Infrastructure-related safety research was initiated in the mid-1970s and included areas such as roadway lighting and roadside and crash barriers.

With the energy crunch of the early 1970s, researchers looked for ways to increase the efficiency of roadway lighting. Following the U.S. lead of looking at measurements of luminance rather than illuminance, MTO researchers developed a computer program for selecting lighting design. This energy-saving program is still in use today.

Keeping highways safe from automobiles or trucks crossing the median led to research into roadside barriers. The well-known Ontario tall wall is a successful adaptation of the New Jersey barrier. It is similar to other tall walls found in the United States except that there is no steel reinforcement and the economical slip-form construction is used. Researchers proved theoretically that stresses would not exceed those in the traditional New Jersey barrier, and thus would protect traffic from crossing vehicles. The Ontario tall wall is a cost-effective choice for certain roadway situations and can be found in use throughout Ontario.

Barriers are not limited to roadsides, and in the late 1970s researchers developed a crash cushion for trucks. Located at the back of a truck, plastic barrels act as a cushion against the force from a vehicle hitting it. Many MTO trucks are supplied with these crash cushions that offer extra protection to vehicle drivers.

Research into human factors has also been included in this area. The ability of drivers to read and understand highway signs helps them to make safe driving decisions. In 1989 provincial legislation required MTO to provide bilingual signs on freeways in and around the Toronto area. (Government services in Ontario are available in both official languages, English and French.)

Before implementation of bilingual signing, research was conducted to develop the new type of signs. One characteristic of Ontario that needed to be considered is the multicultural profile of its population. In 1993, signs that use a new color-coding system and graphic symbols were placed along Highway 401 through Toronto.

The New R&D Environment

Like any other research agency, the Research and Development Branch is now facing financial constraints and demands to expedite research results. Such a dramatic shift in its operating environment propelled R&D management to change its philosophy and style of managing research projects.

Multidisciplinary teams or clusters assembled under umbrella topics will research and manage a schedule of projects. These clusters incorporate the extensive range of expertise existing within the Branch and will be complemented by external experts or stakeholders including members from academia, other MTO offices, other government agencies, and Ontario industries to solve research problems. Of the 13 organizational clusters put together in the late fall of 1993, 11 are research-oriented, 1 is administrative, and 1 represents a management operational function. Along with the creation of clusters, the Branch has adopted a greater sensitivity to the business potential of research projects. Project proposals will undergo rigorous selection criteria that will include an assessment of the technical and commercial feasibility of each project.

R&D communications and marketing programs are being developed and will help to arrange traditional testing in the highway infrastructure as well as public demonstrations of R&D projects and products. One such site aimed at increasing public awareness was a newly constructed park built by the provincial government in downtown Toronto. Recycled materials were incorporated into the park for testing. Similar ventures with industries and other government agencies will encourage the development of partnerships and facilitate public understanding of R&D endeavors.

When asked to comment on where the Branch is going in the future, Director George Gera responded, "A comprehensive review of R&D activities in MTO recommended the amalgamation of all technical/technological research activities under one jurisdiction, the R&D Branch. The review also endorsed a new research unit to be established in the area of policy/planning to address socioeconomic issues. The Branch's mandate is to perform applied R&D. Research, of necessity, must seek to improve the value of government spending, the environment, and transportation safety. The new direction of the R&D Branch dictates that project priorities will be set by two factors: the project's anticipated impact and the time it will take for implementation of the results. The reorganization and new partnerships with industry and institutions will help us to achieve these goals."

Bilingual signs along Highway 401 through Toronto.