

Quebec Contractor Experience with Unbonded Concrete Overlays

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Abstract

With Quebec's aging road network and increasing truck traffic, rehabilitation of the province's main highways is an important issue for Quebec's transportation ministry (MTQ). The use of a concrete overlay is an economical and environmentally sustainable solution, for both old concrete and old asphalt roads. This paper describes two concrete overlay projects for the rehabilitation of two sections of Highway 40 in the Greater Montreal Area: one over concrete pavement and one over asphalt pavement. The very first concrete overlay done for MTQ was applied on a 5 km stretch of 40-year-old concrete pavement in Vaudreuil. The project included the design, construction, and maintenance of the pavement for 10 years. The second unbonded overlay—and the first “whitetopping” in Quebec—was conducted in 2010. A 7 km portion of Highway A40 in L'Assomption with recurrent rutting problem was resurfaced with a concrete pavement.

Introduction

The aging road network and increased heavy vehicle traffic have made it necessary to quickly and economically rehabilitate the road network with as little impact as possible on road users. One way to achieve these goals is to apply a concrete overlay, regardless of the existing pavement type (concrete or asphalt).

Concrete overlays are not only inexpensive, but also boast a variety of factors that make them more attractive from a sustainable development perspective. Here are just some of the advantages these overlays offer in this regard: The surface improves heavy vehicle fuel economy by up to 6%; its higher albedo reflects solar radiation, which helps reduce urban heat islands; concrete is 100% recyclable and reusable; cement producers are increasingly turning to alternative energy sources; and more and more industrial byproducts (e.g., slag, flyash, silica fume, etc.) are being incorporated into concrete production.

This paper will present two rehabilitation projects to demonstrate the feasibility of this technique on two different types of existing pavement: concrete and asphalt. The issues and solutions for each project will be discussed.

Highway 40 Concrete Overlay Project in Vaudreuil

This project was conducted as part of the “performance contracting” concept introduced in the mid-90s by Ministère des Transports du Québec (MTQ). The objective of performance contracting was to optimize road work operations by allowing contractors to propose innovative methods backed by a warranty period. Under such calls for tenders, contractors were therefore responsible for a larger number of tasks, from preparing, designing, and carrying out the work to performing

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monitoring, quality control, and maintenance activities and guaranteeing the project for a set period of time.

The project is located in Montreal's western suburbs on Highway 40 between the bridge at the exit of the Island of Montreal and the junction with Highway 540 (Figure 1). This stretch, which was built in 1966, is subject to heavy truck traffic for the transport of materials between Quebec and the neighboring province of Ontario. The volume of traffic (AADT) has grown considerably over the years, rising from 19,376 in the year after construction (1967) to over 56,000 by the time the stretch was rehabilitated in 1994. Furthermore, the percentage of truck traffic has increased from about 10% after construction (1967) to over 16% when rehabilitation work was performed.

This increase in heavy vehicle traffic was paired with a change in load regulations that saw load limits increase from 18.1 tons to 28.5 tons.

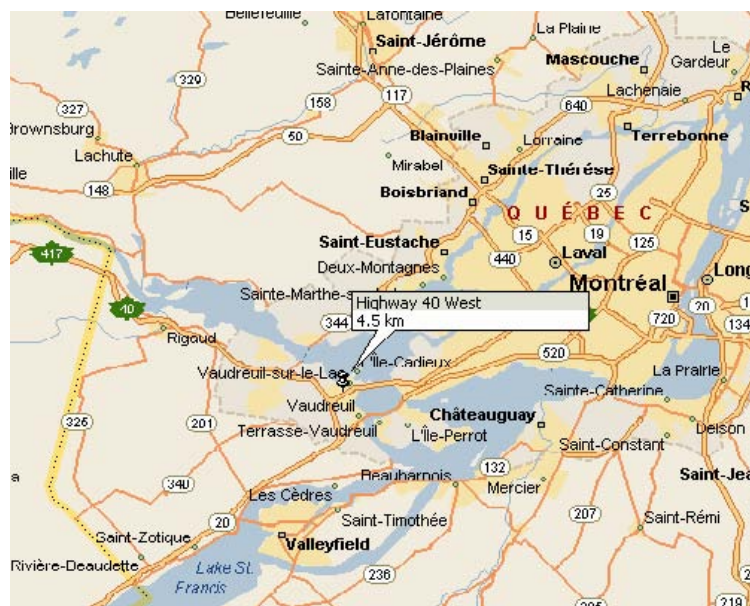


Figure 1 – Location of Vaudreuil A40 Project

The existing concrete pavement built in 1966 was severely deteriorated (Figure 2) mainly due to the considerable volume of heavy vehicles and poor subbase drainage. In addition, the long slabs reinforced with a metal mesh presented transverse cracking and deterioration at the joints.



Figure 2 – Deteriorated Pavement

In this call for tenders, MTQ received 10 proposals, of which 6 met the necessary technical criteria and qualified for cost estimates.

The accepted proposal involved using an unbonded concrete overlay for a total cost of \$4.2 million, with a 10 year warranty.

Tender specifications

In addition to requirements with regard to maintaining the flow of traffic during the work, the call for tenders documents included plans of the existing pavement, a description of the test bores and core samples collected, the results of compressive strength tests and soil analyses, defect maps, raw data from FWD deflection tests (Falling Weight Deflectometer), profilometry data, SCRIM (Sideways Force Coefficient Routine Investigation Machine) skid resistance data, statistical data on daily traffic fluctuations, rigid and flexible equivalent single axial loads (ESAL) estimated on an annual basis, and the forecasted rate of increase in traffic flow. The required maintenance warranty had to be in the form of a maintenance bond equal in value to 50% of the contract, and its duration had to correspond to the warranty period proposed by the tenderer. The defects covered by the warranty period included potholes, peeling, spalling, cracks, silted-up joints, ruts, skid resistance, and unevenness. The thresholds and action deadlines applicable throughout the warranty period for each type of defect per 100 meter stretch in one traffic lane are presented in Table 1.

Table 1: Action Thresholds per 100 m Section

Defect	Upon Delivery	At Any Time	Annually
Unevenness	PRI < 180 mm/km		IRI < 3.5 m/km
Skid resistance	SCRIM > 40		SCRIM > 40
Macrotexture	SP > 0.6 mm		
Final profile	Comply with initial overpass roadway clearance		
Pothole (150 mm)		< 4	
Peeling (0.5 m ²)		< 2	
Ruts			< 15 mm
Crack (< 3 mm)			< 20 m
Joint filler			< 10%
Spalling (50–75 mm)			< 20 m

Design parameter for slab thickness

Historical traffic over 34 years:

1960 to 1970 6 million ESALS
 1971 to 1980 14 million ESALS
 1981 to 1990 29 million ESALS
 1990 to 1994 17 million ESALS

Traffic in 1994: ADT: 32 000 and ADTT: 5 100

Truck traffic increase per year: 4 %

Amplification coefficient: 3.1

Truck traffic distribution used according AASHTO

59% in right lane (9300 ESALS / day)
 39% in central lane (6200 ESALS / day)
 8% in left lane (1200 ESALS / day)

Design life 20 years

Joints:

Longitudinal: tied

Transversal: right and central lane doweled, left lane undoweled

Accepted Proposal

The accepted proposal consisted of a cement structural reinforcement by means of an unbonded concrete slab with a trapezoidal cross section sized for 20 years and covered by a 10 year warranty. The cost of this solution was \$4.2 million (Figure 3). This solution was proposed by a team made up of contractor DEMIX Construction and engineering firm Dessau Inc., which was responsible for the design.

The distinctive feature of the proposed design is the use of a slab of variable thickness based on the volume of traffic per lane. The right-hand lane, which gets the heaviest traffic, has a thickness of 235 mm across the board, while that of the center lane varies between 235 and 215 mm, and the left-hand lane, which gets the least traffic, has a thickness of 215 mm.

In addition to the new concrete slab, work was also carried out to improve drainage by adding side drains to accelerate the drainage of water in the pavement structure via lateral slopes, replacing severely deteriorated existing slabs, and

applying a 25 mm layer of asphalt mix to prevent bonding between the two concrete slabs. Applying this 25 mm thick asphalt mix separating course to the existing slab helps prevent underlying joints from appearing through the new slab, and inserting this more flexible layer between two more rigid layers minimizes punching caused by curling and warping.

Three sectors of the rehabilitated section of highway were handled differently: both ends of the section where they connect to the existing slabs and a stretch of highway that passes underneath an existing overpass in order to maintain overpass roadway clearance. In these three sectors, the old slab was completely removed over a length of approximately 75 m at both ends of this section of road and over a 150 m length for the stretch passing underneath the overpass. The subbase was corrected with new granular materials before the new concrete pavement was applied. In these sectors, slab thickness was increased by 60 mm since the slab was sitting on a granular subbase.

The existing shoulders were reloaded with granular materials then recovered with asphalt mix.

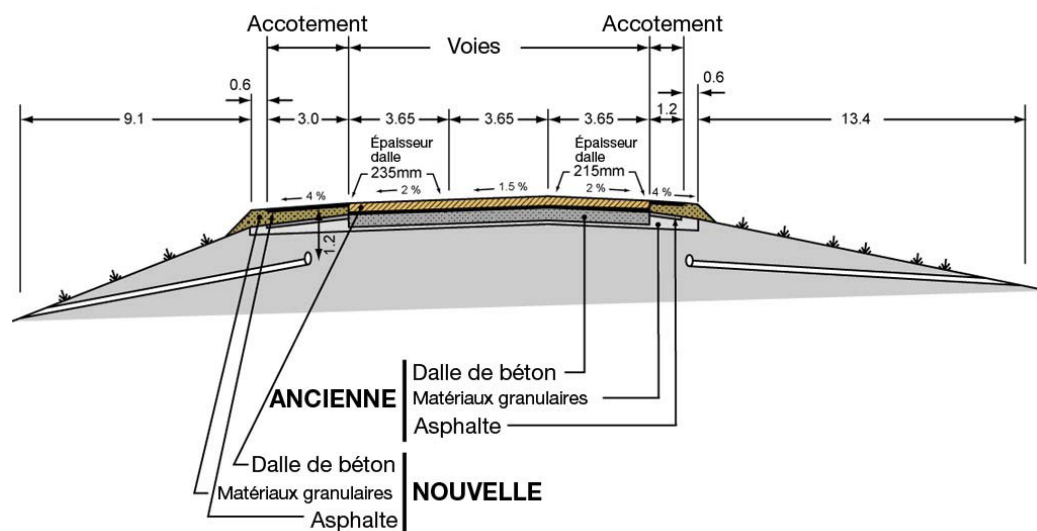


Figure 3 – Pavement Cross Section

Figure 3. Legend

French	English
Accotement	Shoulder
Voies	Lanes
Épaisseur dalle	Slab thickness
ANCIENNE	OLD
Dalle de béton	Concrete slab
Matériaux granulaires	Granular materials
Asphalte	Asphalt
NOUVELLE	NEW

Characteristics of the materials used for the concrete pavement:

- Concrete:
- Compressive strength: 35 MPa
 - Modulus of rupture (flexural strength): 4.5 MPa
 - Aggregate: syenite (trap-rock): 40 mm

Dowel bars: – Epoxy-coated

- Spaced at 300 mm
- Middle and right-hand lanes: 450 mm (l) x 25mm (φ)
- Passing lane: no dowel bars

Joint sand: – Premolded EPDM (Phoenix)

Texture: – Longitudinal Astroturf drag

Performance Monitoring

As per project specifications, warranty criteria were measured and tested once a year in May by MTQ or its authorized agent.

The contractor took part in the inspections and in validating procedures and results.

Maintenance Performed During the Warranty Period:

The maintenance operations carried out during the 10 year warranty period are listed in Table 2. Excluding the last year, when 65 one-hundred-meter sections required shotblasting to restore skid resistance, the scope and cost of work was fairly minimal. Moreover, the majority of operations was preventive in nature and intended to avoid costlier work down the line, without exceeding warranty criteria. No work regarding pavement evenness or rut depth was required.

Table 2: Maintenance Conducted During the Warranty Period

	1996	1997	1998	1999	2000	2001	2003	2005	Total
Partial repair < 75 mm		10	71	9	6	7	10		103
Partial repair > 75 mm	23	12	25	42	19	15	20	66	222
Full depth repair		1						2	3
Seal cracks (m)			4	6	2	5	10	20	47
Joint filler (m)	180	60	145	20	7			2440	2852
Shotblasting (m2)								23725	23725
Cost of traffic management (\$000)	2	3	3	2	2	2	2	21	37
Cost of repairs (\$000)	3	6	6	3	3	3	3	115	142
Total cost (\$000)	5	9	9	5	5	5	5	136	179

Highway 40 Concrete Overlay Project in L'Assomption

The second project involved installing an unbonded concrete overlay on an asphalt pavement in L'Assomption in 2010. This was the first whitetopping project carried out in Quebec.

The project came about after the ministerial guidelines on choosing pavement types were updated in 2009.

In 2001 MTQ adopted a road network approach that, after a life cycle cost analysis and a multicriteria analysis, led to the definition of a white road network (concrete) and a black road network (asphalt). When the first guideline was issued in 2001, the white road network, which represented 779 km of the road network, expanded to 1,341 km once the guidelines were updated in 2009. This expansion of the white road network is due primarily to the sharp increase in heavy vehicle traffic as well as the rising costs of asphalt. The new map of the white road network now

includes sections of highway located further from major urban centers, which was conducive to the whitetopping solution.

The project is located in a rural area in an east-end Montreal suburb. Compared to the section of highway discussed above, this section is used mainly for the transportation of goods between Montreal and Quebec City and between the Mauricie and Saguenay regions. The rehabilitated sector was approximately 6.5 km long and included two 3.7 m wide traffic lanes in each direction with shoulders 3 m and 1.3 m wide.

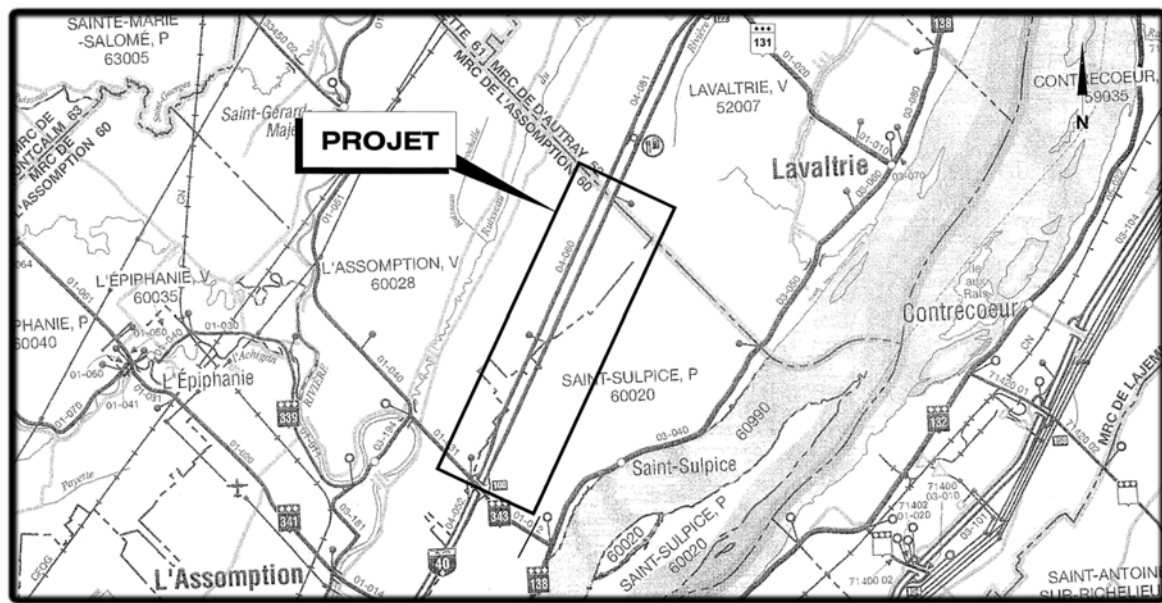


Figure 4 – Project Location

This section of highway was built in the 1970s. The issues encountered in this sector mainly concern the surface course. The right-hand lane is subject to intense heavy vehicle traffic and was showing significant and recurring rutting despite numerous asphalt mix resurfacing operations. Bore samples show that the asphalt mix was up to 350 mm thick in places and that the subbase was made up of granular materials on a sand subgrade. These materials are not susceptible to frost and their behavior is well suited to their use. They also provide sufficient drainage.

The solution selected by the designers was to apply a concrete slab on top of the existing asphalt mix in a technique called “whitetopping.” This solution is particularly well suited to the project because the existing subbases had not been replaced, drainage was provided by ditches on either side of the road, and there were no overpasses above the lanes. In addition, the problem had to do with the existing pavement. Whitetopping served as an effective, long term solution to the recurring rutting problem. It also helped distance the road from the frost line and boosted its structural capacity by using old pavement as a foundation.



Figure 5 – Condition of Existing Pavement

Overlay Design

The recommended solution consisted of applying short 4.5 m slabs that were doweled in the right-hand lane and non-doweled in the left-hand lane (Figure 6). The minimum thickness required was 225 mm. However, over time and after numerous resurfacing efforts, the road's cross slope had reached 4%. In order to correct the cross slope and bring it back to 2%, the concrete could be as thick as 350 mm on the outer edges of the slab. (Figure 7)

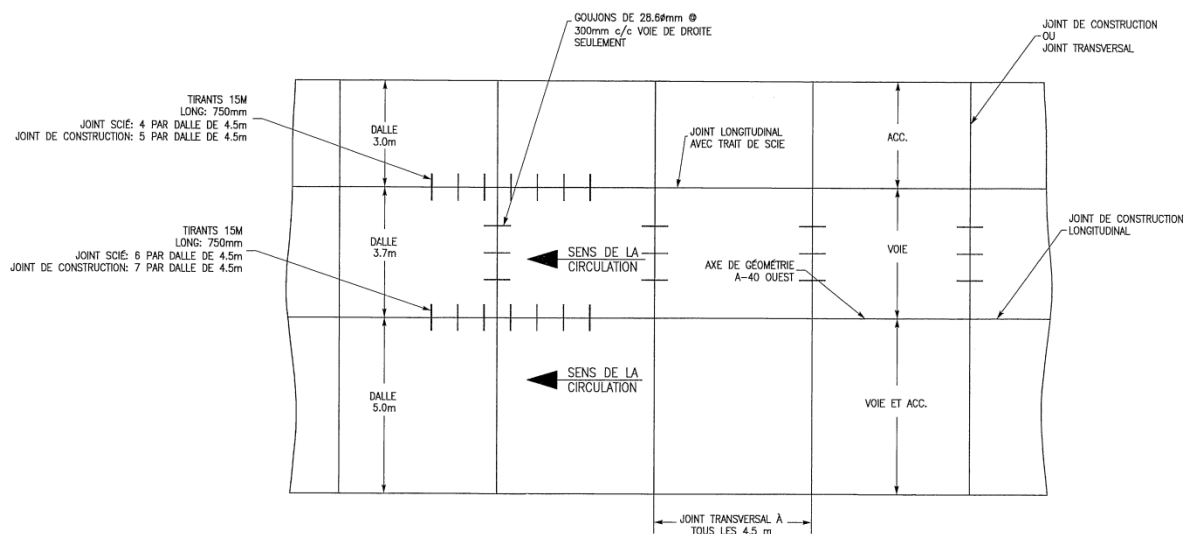


Figure 6 – Sample Configuration of Slabs, Joints, Dowels, and Tie Bars

Fig.6 legend

French	English
Tirants 15M long. 750 mm	Tie bars 15M ,750 mm length
Joint scié: 4 par dalle de 4.5 m	Sawn joint: 4 per 4.5 m slab
Joint de construction: 5 par dalle de 4.5 m	Construction joint: 5 per 4.5 m slab
Goujons de 28.5 mm @ 300 mm c/c	28.5 mm dowels @ 300 mm c/c
Voie de droite seulement	Right lane only
Joint de construction ou joint transversal	Construction joint or transverse joint
Joint longitudinal avec trait de scie	Longitudinal joint with saw cut
Sens de la circulation	Direction of traffic
Axe de géométrie	Geometric axis
Acc.	Shldr.
Voie	Lane
Voie et acc.	Lane and shldr.
Joint transversal à tous les 4.5 m	Transverse joint every 4.5 m

Figure 7 – Cross Profile Correction

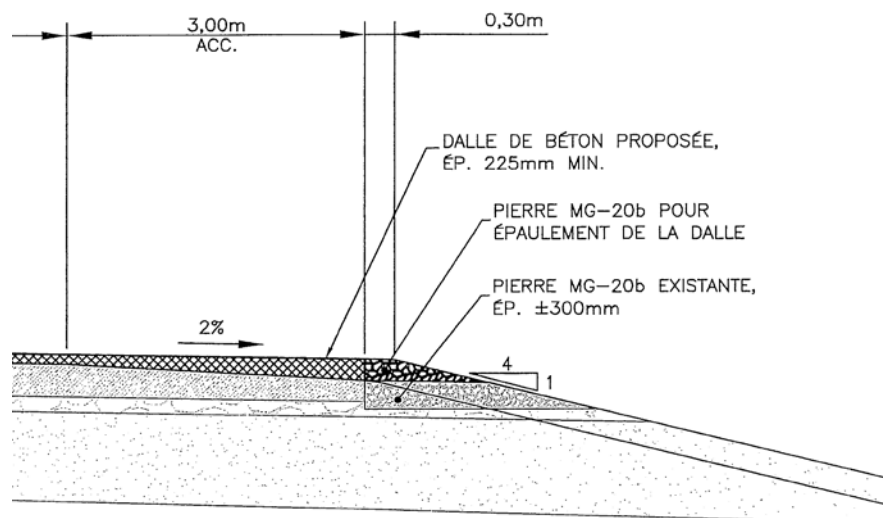


Fig. 7 legend

French	English
Dalle de béton proposée ép. 225 mm min.	Min. concrete slab thickness 225 mm
Pierre MG-20b pour épaulement de la dalle	Mg-20b crush stone for slab shoulder
Pierre MG-20b existante ép.300 mm	Existing Mg-20b crush stone 300 mm thick

Transitions with the existing pavement at the two ends of the road section in this project were built over a length of 75 m. One transition was done with concrete

and the other with asphalt to make it possible to extend the whitetopping further at a later date.

Traffic Management

MTQ's specifications included the requirement that 4 lanes had to be open to traffic at all times. The following traffic management measures were implemented:

- Opposite direction: Two lanes for traffic heading one direction and one lane for traffic in the other direction
- Work area: 1 lane for traffic and the work area
- This was done in deriving one lane from the west direction to the opposite side of the highway where the existing shoulders were enlarged and paved in order to accommodate 3 lanes, 2 in east direction and 1 in west direction. A concrete median barrier was installed for safety

The second lane in west direction was isolated from the construction site with a concrete median barrier. Then the first phase of the overlay, right shoulder and right lane was constructed.

For the second and last phase, the traffic in west direction was allowed to use the newly constructed overlay while the left lane and left shoulder were constructed. The figure 8 shows the arrangement of the lane and the phases.

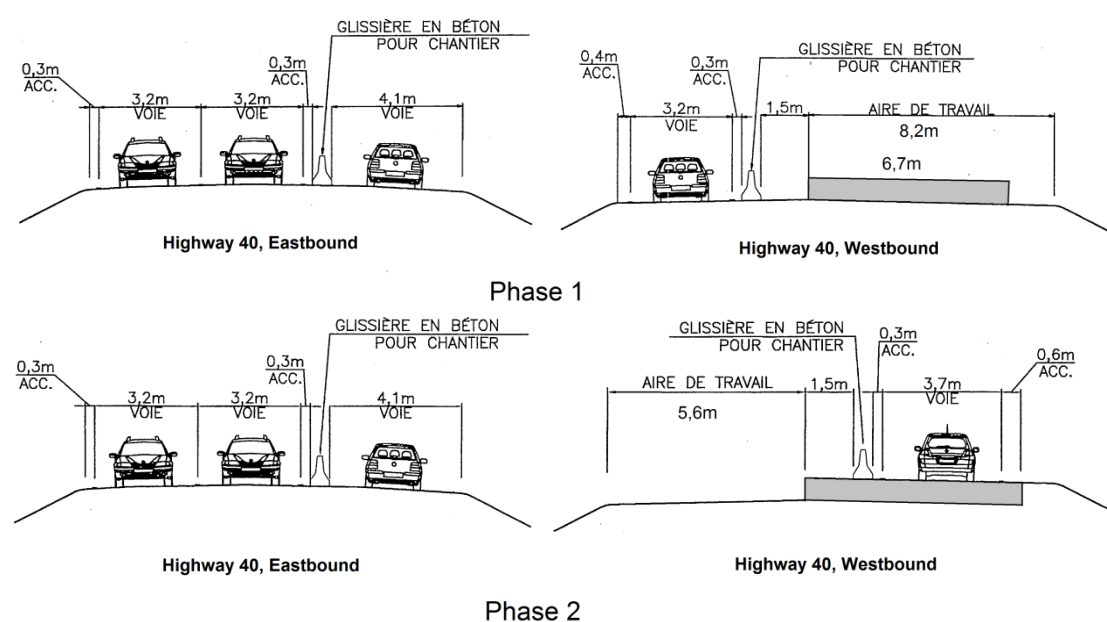


Figure 8 – Traffic management

Fig. 8 legend

French	English
Glissière en béton pour chantier	Concrete median barrier
Aire de travail	Work zone
Voie	Lane
Acc.	Shoulder

This arrangement slowed down the work because trucks delivering the concrete had to back up long distances in addition to dealing with the regular flow of traffic.

Preparation Prior to Concrete Paving

The asphalt mix surface required a few repairs before concrete could be applied. Transverse cracks were milled and then filled with asphalt to allow the concrete to shrink freely. For the same reasons, the shoulder rumble strips were filled. Ruts were left as is because they measured only 15 to 20 mm. The shoulders were reloaded and widened to allow for temporary traffic flow and concrete supply. Furthermore, on hot days of concrete paving, a layer consisting of a mixture of water and lime were applied before the concrete in order to comply with the maximum temperature requirement (35°C) set out in the technical specifications.

Placement of Dowel Baskets

The baskets of dowels, which are usually nailed to the granular subbase, in this case had to be screwed into the asphalt pavement to prevent them from moving when the concrete pavement was applied.

Placement of Concrete, Texturing, Curing, and Joint Treatment

A material transfer vehicle was used in Phase 1 of the work (right-hand shoulder and lane) to convey concrete from the trucks to the front of the paver (Figure 9).



Figure 9 – Concrete Distribution in Front of the Paver

In Phase 2, the concrete was delivered directly in front of the paver because no dowels were used in the left-hand lane.

The specified surface texture was longitudinal tining (Figure 10) applied immediately after paver finishing and was followed by application of the curing compound.

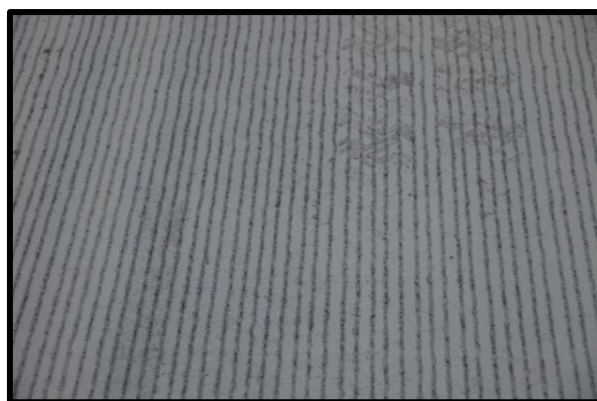


Figure 10 – Longitudinal Tining

Transverse joints that were left 10 mm wide to accommodate a premolded joint were sawn to $\frac{1}{3}$ of the slab's depth.

The quality control of materials and their implementation was provided by an independent laboratory commissioned by the Ministry of Transportation throughout the job. The results are consistent with requirements in the specifications. Charts 2 and 3 respectively show the results of roughness index, thickness and mechanical properties of hardened concrete.

Table 3: Results of quality control

Characteristics	Requirements	Results	
		Left lane	Right lane
Roughness Index IRI	<1,2 m/km	1,17 m/km	0,95 m/km
Slab Thickness	>225 mm	302 mm	273 mm

Table 4: Mechanical properties of concrete

Tests	Requirements	Results
Compressive strenght, 28 days	35 MPa	40,35 MPa
Resistance to flexion 28 days	4,5 MPa	4,98 MPa

Conclusion

Although some 15 years have passed between these two projects and despite the fact that the context of each project was quite different, concrete overlay has proven to be one of the best solutions for performing major road rehabilitation at a minimal cost.

The method draws on the residual capacity of the existing pavement, helps distance the road from the frost line, provides an anticipated service life of 35 to 45 years, and has a smaller environmental impact than rebuilding the road completely. In addition, this technique can be used both on concrete and asphalt mix pavements.

References:

Berthiaume, J.-F., and Cormier B. (2006), *Bilan d'un contrat de performance d'une durée de 10 ans : l'autoroute 40 à Vaudreuil*, AQTR, Quebec.