

Alberta Transportation's First Concrete Pavement Preservation and Rehabilitation Project

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Abstract

In 2010, Alberta Transportation completed its first concrete pavement preservation and rehabilitation project on Highway 1 through Medicine Hat. Preservation and rehabilitation were seen as the best options to treat the sections of concrete due to their existing condition and constraining infrastructure and despite the fact that the initial design was for an asphalt overlay. Given that Alberta Transportation owns few concrete pavements and has little experience with concrete pavement preservation or rehabilitation, this project presented numerous unique challenges. These included treatment option identification, treatment design and specification development. The treatments that were ultimately used included diamond grinding, dowel bar retrofit and cross-stitching. The project involved undertaking these treatments while maintaining traffic on this busy section of the Trans-Canada highway. This paper will discuss the details of this project from initiation to treatment selection to design and construction. Performance of the treatments to date will also be presented.

Introduction

In 2010, Alberta Transportation completed its first major concrete pavement preservation and rehabilitation project on Highway 1 through Medicine Hat. This project was the first concrete pavement preservation and rehabilitation work undertaken by the department and presented a number of unique challenges from identification of appropriate rehabilitation options to specification development and construction. In context, Alberta Transportation's network consists of approximately 31,600 2-lane kilometres of highways; however concrete pavements make up only 60 of these kilometres.

Research Significance

The significance of this work was the unique challenges that this project presented to an agency with little experience building let alone restoring concrete pavements. This paper presents the department's approach to undertaking this work, in particular treatment selection and specification development. This will help provide a framework for other agencies new to concrete pavement rehabilitation.

Background

Highway 1 runs through the city of Medicine Hat which is located in the south-eastern part of the province of Alberta as shown in Figure 1. This highway is an interprovincial route that is part of the Trans-Canada highway system. Through Medicine Hat the

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highway is a divided urban roadway that is provincially owned and operated but was originally constructed and maintained by the city.

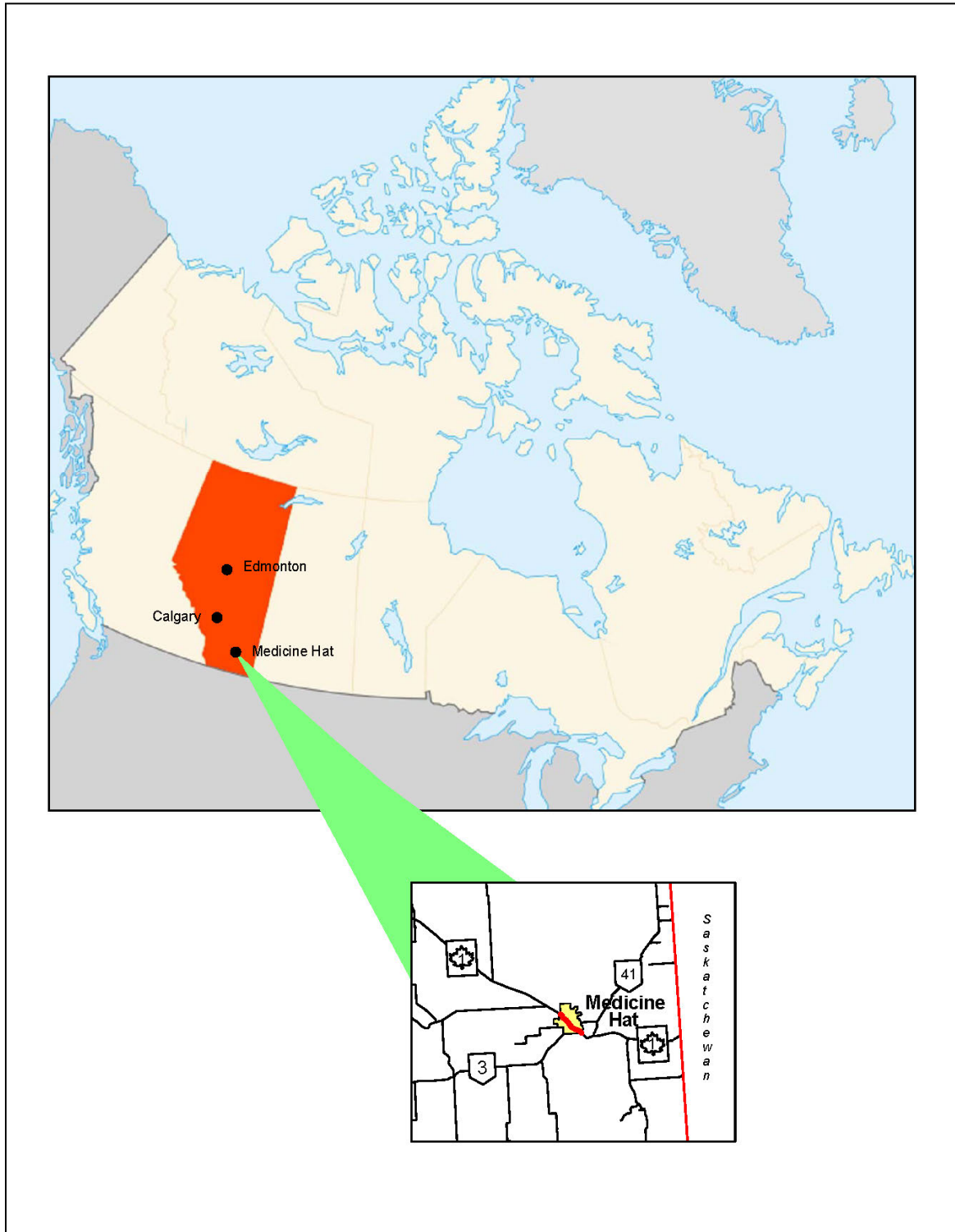


Figure 1. Location map of Medicine Hat and Highway 1

There are four concrete pavement sections along Highway 1 through Medicine Hat and they are essentially located within the two driving lanes that are in each direction. The concrete sections are located prior, through and after two signalized intersections. The inner lane of concrete is adjacent to median curb and gutter or a left turning lane while the outer lane of concrete is adjacent to an asphalt shoulder that ties into curb and gutter. The average annual daily traffic (AADT) is approximately 27,000 with 9.0 % trucks and an equivalent single axle load (ESAL) value of 2,000 per day per direction. The speed limit is 80 km/hr. The concrete was thought to have been constructed in the mid 1980s. As-built drawings were not available and therefore a limited coring program had been undertaken as part of previous design work completed in 2005 to determine the concrete and underlying materials' thicknesses. Table 1 provides a summary of the concrete pavement section locations, lengths and pavement structures obtained from the coring.

Table 1. Highway 1 concrete pavement locations, lengths and structures

Section	Location	Kilometre		Material and Thicknesses	
		From	To	Granular Subbase	Concrete
1	Hwy. 1:21 ¹ eastbound	5.450	6.080	420 mm (was in fact found to be mostly asphalt during construction)	190 mm
2	Hwy. 1:21 westbound	5.650	5.860	360 mm	210 mm
3	Hwy. 1:21 eastbound	6.500	6.990	460 mm	225 mm
4	Hwy. 1:21 westbound	6.770	7.110	380 mm	245 mm

¹The first number represents the highway number and the second number after the colon represents the department's control section number for that highway.

Because there were only a total of 1.67 2-lane kilometers of concrete pavement, this project was viewed as a good candidate for concrete preservation and rehabilitation since the shorter length limited the department's risk. Additionally, because of the relatively small amount of concrete work, the concrete rehabilitation was combined with the rehabilitation of the adjacent asphalt pavement which was a much larger project in terms of length and dollar value. This helped ensure that bids to do the concrete work were received. The concrete work represented approximately 10% of the estimated total contract value.

Condition

The condition of the concrete pavement prior to rehabilitation was poor. The concrete, which was thought to be undowelled, has skewed transverse joints spaced randomly at 2.0 to 5.9 m. 115 of the 976 through lane panels were cracked with nearly 50% of these being in section 1. Asphalt patching had been used to repair a number of these cracks. Joint faulting was measured from 0 to 20 mm. The faulting and patching resulted in a rough ride with average IRI values within the four sections ranging from 3.6 to 4.4 mm/m. Figures 2 and 3 show the concrete pavement prior to rehabilitation.



Figure 2. Photo of cracked concrete panel in the outer lane of section 1



Figure 3. Photo of cracked concrete panels section 3

Rehabilitation Options and Design

The initial strategy for rehabilitating the concrete pavement was to overlay it with 70 mm of asphalt as had occurred for portions of department owned concrete pavement located within the city of Calgary. However, this was ultimately not deemed feasible by the department's technical standards branch (TSB) because of performance concerns with reflective cracking; the number of cracked panels; adjacent lane, intersection and curb and gutter tie-in requirements; and the presence of a pedestrian overpass (the department's practice is to not reduce clearance heights). Concrete pavement restoration was viewed as the only option.

Because of limited consultant experience within the Province related to concrete pavement restoration as well as the 6 week turnaround required from design to tender advertising, TSB undertook the initial and detailed design of rehabilitation options. It is important to note that typically design, tender preparation and construction supervision is undertaken by consultants as the department outsourced all maintenance and most engineering work 15 years ago and retains only a review, standards setting, programming and high level project management role.

Although the department had essentially no experience with this kind of design work, one month prior to this project the department had hosted a two day Federal Highway Administration technology transfer session on concrete pavement best practices. Based on what was learned at that session, the department was keen on evaluating a number of restoration techniques and ultimately opted to try as many new procedures as possible. These included: dowel bar retrofit; cross-stitching; partial depth spall repair; full depth full and partial panel replacement; and diamond grinding. The department was also interested in leaving new narrow joints unsealed although ultimately all joints were sealed. As noted previously, one advantage with this project was that the relatively short length limited the department's risk, i.e. a wide array of new techniques were tried but in there were not large quantities of any.

Based on a detailed field inspection that involved the examination and condition recording of each concrete panel, the following restoration techniques were selected:

- 132 full depth panel replacements ranging from single to over 70 panels in a row;
- 10 full depth partial panel replacements;
- Dowel bar retrofit of the outer lane of section 2 (50 joints);
- 5 m² of partial depth spall repair;
- 15 panels for longitudinal cross-stitching repair;
- Diamond grinding of the entire concrete surface (13,000 m²).

Of note is that the full depth panel replacement number exceeded the number of cracked panels. This is because there were a number of un-cracked panels interspersed between the cracked panels in section 1. However, for ease of construction and because of the deteriorated condition of some joints, it was decided to replace one long continuous stretch in section 1. The depth of new concrete for all panel replacements was chosen to be 230 mm or the depth of existing concrete pavement, whichever was greater.

Specification Development

The department already had a specification for the construction of Portland Cement Concrete Pavement (PCCP) but did not have one related to concrete rehabilitation activities; thus, a quick search was undertaken for specifications and design drawings used by other agencies. The specification developed for this work, Specification 3.71 Concrete Pavement Rehabilitation, was written with much content borrowed from Washington State Department of Transportation (WSDOT) Specification 5-01 Cement Concrete Rehabilitation (Washington State Department of Transportation, 2010). That specification contained nearly all the work elements needed for this project and was written in a style and manner consistent to that used by Alberta Transportation. WSDOT is also well known for its work involving dowel bar retrofitting which was an important component of this project (Washington State Department of Transportation, 2009).

One work element not included within the WSDOT specification was the cross-stitching of longitudinal cracks. For this work the department reviewed the specification used by the Ontario Ministry of Transportation (MTO) under Ontario Provincial Standards Specification (OPSS) 365 Construction Specification for Cross-Stitching Longitudinal Cracks in Concrete Pavement and Concrete Base (Ontario Ministry of Transportation, 2010).

Because of the urban environment and relatively high AADT, another major consideration in preparing the tender for this project was traffic accommodation and travel delays. Therefore, listed in the special provisions to minimize these delays, there was a unit bid item for the number of daily lane closures. The value for this bid item was listed at \$1,500 per day per lane closure per direction. The contractor would enter an estimate of the number of days required for a lane closure in either direction. This is administered as an incentive/disincentive payment. For example, if the contractor completes the construction with 10 fewer lane closure days than bid, a bonus payment of \$15,000 would be provided. Conversely, if the actual number of lane closure days is 10 greater than bid, \$15,000 would be deducted. To minimize the lane closures due to curing of the concrete, the department added a mix design requirement for the concrete to obtain a minimal flexural strength of 3.2 MPa at 7 days. Prior to opening to traffic the contractor was also required to provide test results on field cured cylinders indicating a minimum compressive strength of 20 MPa.

Tendering

During the tendering period, a meeting with the department, consultant and interested contractors was held in Medicine Hat. These meetings are commonly held and are intended for prospective contractors to ask project specific questions or address ambiguities in the tender. TSB staff do not typically attend these meetings but in this case did to deal with design or specification issues related to the concrete pavement rehabilitation.

After a three week advertising period, the tender opening was July 27th, 2011. The low tender bid and award was to South Rock Ltd., an asphalt paving contractor from Medicine Hat. All subcontractors except for the diamond grinding were Alberta based and included Can West Concrete Cutting & Sealing Inc. for cutting, removal, drilling and sealing services; Medican Construction Ltd. for the concrete placement and spall repairs; and Diamond Surface Inc. for the diamond grinding (based out of Minnesota). The ready-

mix concrete was locally supplied by Burnco Rock Products Ltd. AMEC Earth & Environmental was the department's consultant for this project and, among other duties, were responsible for construction project management and contract administration.

The tender bid amount for the concrete work was \$1,221,875 (all \$ values are CDN) versus the estimate of \$1,407,210, an underage of \$185,335 (13.2%). This variation is higher than that normally seen; however, the department and consultant had little experience in estimating this type of work.

Construction

Three weeks after tender opening, staff from TSB staff met on site with the contractor and consultant to walk the concrete sections and identify the specific locations for panel replacement and other work. The contract contained estimated quantities based on the detailed design and a general description of which sections required panel replacement but detailed location plans for the work were not included.

Concrete work began on September 7th, 2010 with all work completed, except for crack/joint sealing, by October 8th, 2010. Due to the late season conditions it was agreed that sealing should be completed the following spring. Joint sealing was completed between May 9th and June 5th, 2011. The total number of lane closure days incurred was exactly as estimated by the contractor in their tender submission at 56 days.

Concrete panel replacement. Prior to removing the existing concrete panels the joints were to be cut full depth. A key way cut was required anytime a separate panel was to be removed or at the start and end of continuous panel removals. The key way was cut approximately 150 mm from the transverse joint and was the first and last piece to be removed so as to protect adjacent panels. Tie bars at the longitudinal joints were encountered, as expected; however, most of the transverse joints were unexpectedly found to be dowelled except for those in section 2.

After the panels were removed subbase preparation was required. In most of section 1 the existing 180 to 190 mm of PCCP was found to be on top of an asphalt concrete pavement (ACP) of varying thickness. For the long continuous stretch of panel replacement in section 1, the contractor used a milling machine, as seen in Figure 4, to remove approximately 50 mm of ACP to obtain the 230 mm new concrete minimum thickness. Shorter single and double panel replacements could not accommodate a milling machine and therefore the ACP was removed and backfilled with granular subbase. Some of the existing ACP was extremely thick and difficult to remove without damaging the surrounding panels.

The subbase in the other three sections consisted of granular material and thus it was simpler to ensure an adequate new PCCP depth through leveling and re-compaction of the subbase. On one occasion there was an overnight rainfall after several panels had been removed. The contractor used large rolls of polyethylene sheeting to cover the exposed subbase material. For the most part this was successful in protecting the subbase; however, there were a few single panels that flooded. To minimize delays, the contractor was able to use a hydrovac unit to remove the water and then proceeded to remove and replace the saturated subbase material.



Figure 4. Milling of asphalt beneath concrete pavement

Dowel bars (32 mm by 450 mm) at a spacing of 300 mm were drilled into the existing concrete or placed in basket assemblies at all transverse joints. Tie bars (15 mm by 600 mm) were drilled at a spacing of 900 mm at all of the longitudinal joints.

Placement and finishing of the PCCP went smoothly. A power roller screed was used to finish the concrete surface. The roller screed straddled the adjacent concrete lane and shoulder and was pulled by hand across the fresh concrete. The roller screed had an internal vibrator to smooth the surface. A curing compound was used. Compressive strength tests were completed on field cured cylinders prior to opening to traffic. The minimum strength requirement of 20 MPa was met within 48 to 72 hours of placement.

Dowel bar retrofit. All the transverse joints in the outer lane of section 2, except for those adjacent to panel replacements, were treated with six dowel bar retrofits (three per wheel path). The cutting of the channels for the dowel bars needed to be precise for width and depth in order to ensure that the dowel chair properly supported the dowel bar and that the bar was at mid slab depth. After cutting, the channels were chipped out using a light duty jack hammer as seen in Figure 6. It was important to have a smooth and square



Figure 5. Power roller screed for concrete finishing



Figure 6. Saw cuts and jack hammering for the dowel bar retrofit

channel to allow for proper placement and alignment of the dowel bar. Each channel was sand blasted clean to remove all unsound concrete. The dowel chair and bar were positioned in the channel and then backfilled with a rapid setting chemical mortar (SikaSet® 45).

Partial depth spall repairs. Each area identified for spall repair was first straight-square cut to a depth of 50 mm. A light duty jack hammer was used to chip out all the unsound concrete. The surface was then sand or air blasted and back filled with the same rapid setting mortar used for the dowel bar retrofits. The actual area of spall repairs completed in 2010 was 20.2 m² versus the nominal contract estimate of 5 m². Part of the reason for the increased quantity was that additional spalling occurred during the cutting process for panel removal.

Random crack repairs and cross-stitching of longitudinal cracks. Less serious random cracks were repaired by routing, cleaning and sealing of the crack. Some of the longitudinal cracks were also reinforced by cross-stitching with tie bars inserted across the crack. The process involved drilling angled holes (35° from horizontal) spaced 600 mm apart at a specified offset from the crack. The drill holes, which proceeded along and alternated sides of the crack, are meant to intersect the crack at the mid-depth of the slab and extend nearly to the bottom of the slab. An epoxy was then poured into each hole and the tie bar inserted so as to be fully immersed in the epoxy and recessed for the surface. Some of the cross-stitched cracks also required partial depth spall repairs as can be seen in Figure 7.



Figure 7. Cross-stitched and spall repaired longitudinal crack

Diamond Grinding. The diamond grinding was intended to improve smoothness and was completed from September 30th to October 8th, 2010. Two milling machines or planers were used. The larger unit had a 1,220 mm wide milling head with approximately 200 diamond blades. Because a 0.5 m clearance was required for this larger machine, a second smaller unit was needed to mill up to the concrete curb of the raised median island. The only down time during the diamond grinding was for one and a half days when one of the 200 diamond blades broke and needed to be replaced.

The diamond grinding specification required a minimum of 3 mm of concrete removal. Because of the roughness, an average of 7 mm was removed eastbound (sections 1 and 3) and 11 mm westbound (sections 2 and 4). Most section of concrete required only one pass of the grinding machine; however, some areas of section 3 required a second pass.

The main milling unit did not have any automatic controls for grade or profile control. Accordingly, any ability to get a smooth profile was dependant on the expertise of the operator. In this case the operator seemed to have been well skilled as the riding quality of the final product was greatly improved. Alberta Transportation uses the California Profilograph method (5 mm blanking band) for measuring smoothness and provides bonus/penalty payment adjustments based upon that testing. Of the 26 sublots tested on this project, 7 were in bonus, 17 were zero adjustment, and 2 were in penalty with a net assessment of -\$90 (i.e. penalty). No individual bumps or dips (scalops greater than 8 mm) were identified.

Crack and joint sealing. Due to the fact that the diamond grinding and other rehabilitation activities were completed late in the 2010 construction season, it was decided to do the crack and joint sealing in the spring of 2011. During a site inspection that spring, project staff were surprised to find additional areas of the old concrete requiring spall repair along with one cross-stitched panel failure. The additional spalling was attributed to a long harsh winter that saw significant sand and salt application in combination with a freshly diamond ground surface.

Joint sealing consisted of resealing the existing transverse and longitudinal joints and sealing of the new joints. The existing joints varied significantly in width from approximately 10 mm to 50 mm. All joints were cut to achieve the desired sealant depth-to-width ratio of 1 to 1 including an allowance for the backer rod. The joints were sand blasted clean and hot air lanced to remove any moisture prior to insertion of the backer rod and sealant.

New transverse joints were specified to be 3 mm wide and sealed with a hot rubberized sealant (Crafco 522 or equivalent). During construction it was realized that the recommended minimum joint width for this type of sealant is 6 mm. Accordingly, the joints were widened to 6 mm, cleaned, inserted with backer rod and sealed.

Pavement damage occurred during joint cutting operations. This appeared to increase with late day warmer temperatures. An additional 42 m² of partial depth spall repairs was completed in 2011 to fix the joint cutting damage and the winter spalling.

Performance

Despite the issues with winter spalling, the performance of the concrete rehabilitation is very good as of fall 2011. All joints remain sealed and no additional spalling has been

noted. There are no performance concerns with the full or partial panel replacements. As reported in Table 2, smoothness testing, confirms a much improved riding quality. The improvement in mean IRI values (post versus pre rehabilitation) was on the order of 60% to 75%. The dowel bar retrofit is also performing well as seen in Figure 8.

Table 2. Pre and post rehabilitation IRI results

Section	Direction	Kilometre		Mean ¹ IRI (mm/km)	
		From	To	2009	2011
1	Eastbound	5.450	6.080	4.38	1.19
2	Westbound	5.650	5.860	4.43	1.63
3	Eastbound	6.500	6.990	3.69	1.35
4	Westbound	6.770	7.110	4.18	1.66

¹Mean value of the two wheel path measurements in the outer lane only.

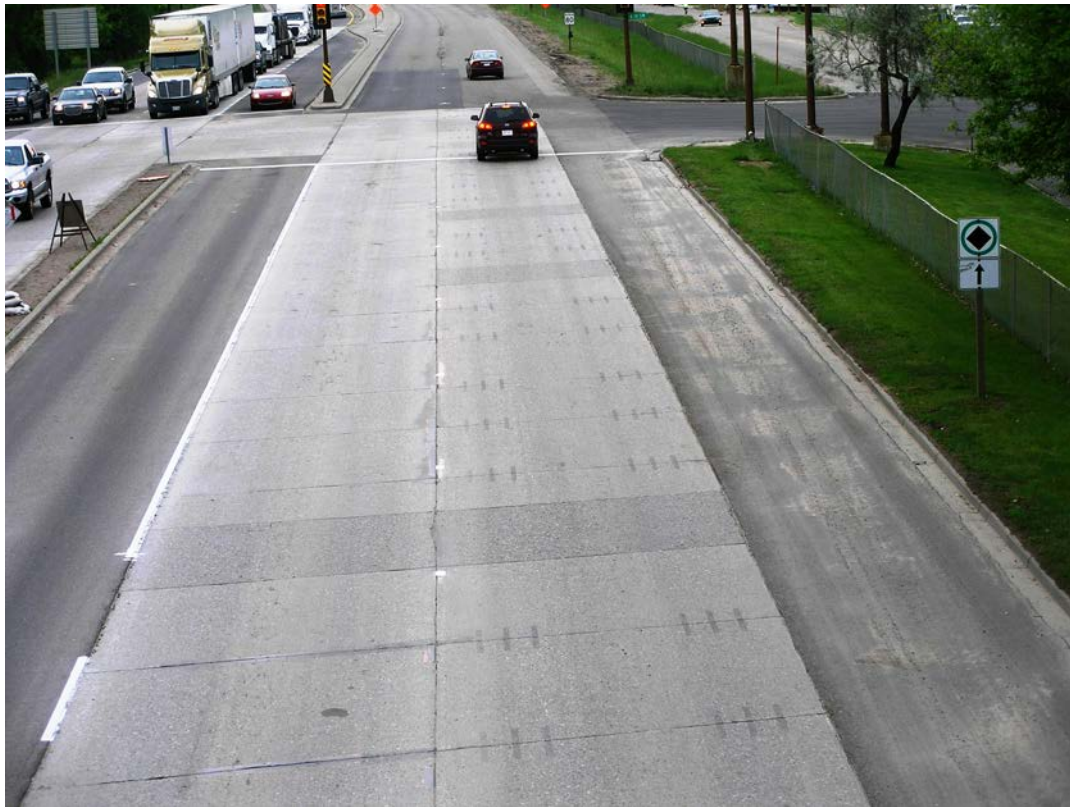


Figure 8. 2011 view of completed dowel bar retrofit and partial panel replacement

Conclusions and Future Considerations

Although it is still early in the life of the Highway 1:21 concrete pavement rehabilitation, Alberta Transportation is satisfied with the improvement in riding quality and performance of this project. The department plans to use all of these preservation and restoration techniques, as applicable, on future concrete pavement rehabilitation projects. Other changes that the department is considering include:

- using a 3 mm saw cut for transverse joints to be sealed with a self leveling silicone sealant and no insertion of backer rod; and
- the application of a concrete surface sealer after diamond grinding to help prevent spalling.

Based on the early success of the Medicine Hat project, work was tendered in 2011 for the rehabilitation of select portions of PCCP placed on Highway 216:06 (the southwest leg of the Anthony Henday ring road around the city of Edmonton) in 2004 and 2005. For the Highway 216:06 project, which is scheduled for 2012 construction, another relatively new restoration technique will also be used – slab stabilization using polyurethane foam injection. As was done for the project in Medicine Hat, the concrete rehabilitation on Highway 216:06 was included within a larger ACP paving contract.

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