

**A Unique Pavement Rehabilitation Treatment for  
6<sup>th</sup> Avenue SE Calgary – Concrete Overlay**

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## **ABSTRACT**

Maintenance and rehabilitation strategies are critical components of a pavement management system. Effective rehabilitation improves the pavement performance and prolongs the service life of an existing pavement. Strategies for rehabilitation of flexible pavements in Calgary traditionally included mill and overlay or reconstruction. Less common is partial depth in-place recycling and full depth in-place recycling. While the selection of the optimal rehabilitation strategy can be straightforward when the distress is confined to the upper layers, much more complex and expensive repairs are required when the surface problems are related to structural deficiencies in the base or subgrade.

Westbound 6<sup>th</sup> Avenue SE in Calgary between 3<sup>rd</sup> Street and Macleod Trail is a four-lane roadway (one-way direction) that experienced moderate severity transverse cracking, extreme rutting and ravelling. Most of the distress was noted in the right most bus lane and at the bus stop. A coring program to determine the pavement layer thickness and a FWD survey to determine the back-calculated modulus of the subgrade ( $M_R$ ) formed the basis for the selection of a rehabilitation strategy. A bonded concrete overlay was selected as a cost-effective methodology while assuring an extended service life. Detailed materials and construction specifications were developed for the project. The initial construction was carried out in September 2010 and was not successful due to the contractor's inexperience. Investigation of the project indicated that the bond between the concrete overlay and asphalt surface was not achieved, the thickness of overlay varied, the concrete used was not suitable for the application and the control joints were not correctly installed. The re-construction commenced in May 2013 over a long weekend. Within 48 hours, the existing concrete overlay was removed, pre-overlay repairs were conducted, surfaces were cleaned to provide a good bond with concrete, and, the overlay was placed followed by curing compound application and control joints construction. Post-construction inspection indicated no major reflective cracking and a good quality surfacing for the bus lane. This rehabilitation project confirms that bonded concrete overlays provide an alternate solution to flexible pavement rehabilitation particularly for high volume heavy traffic sections with frequent stops and take-offs. The construction experience from this project also emphasized the need for well-defined specifications, experienced contractors and a quality management program during the pre-construction, construction and post-construction activities. This paper discusses all the above activities and the challenges with the construction in detail.

## **INTRODUCTION**

Concrete overlay technology has been used as a rehabilitation technique for flexible pavements. The use of Portland Cement Concrete (PCC) overlays offer a potential for extending service life, increased structural capacity, reduced maintenance requirement,

and lower life-cycle cost when compared with other overlay alternatives (Van Dam, et al., 2011). In the last decade, there has been an increase of the use of PCC overlays due to improvements in PCC paving technology and development of PCC mixes allowing for reduced construction time (James A. Corvetti and Lev Khazanovich, 2005). Traffic load distribution is different for rigid and flexible pavements. Since concrete distributes loads over a wide area, the underlying pavement does not experience highly concentrated stresses. This offers a great advantage as the need for base and subbase improvements may be eliminated.

In 2009, The City of Calgary expressed an interest in providing a concrete overlay alternative to rehabilitate a number of locations within the city core. Several locations were assessed for suitability of the concrete overlay and one location was selected based on the type of distresses, existing pavement structure and the traffic data.

The location selected for the concrete overlay was at 6 Avenue SE (westbound) between 3 Street SE and Macleod Trail. A site plan is presented below.

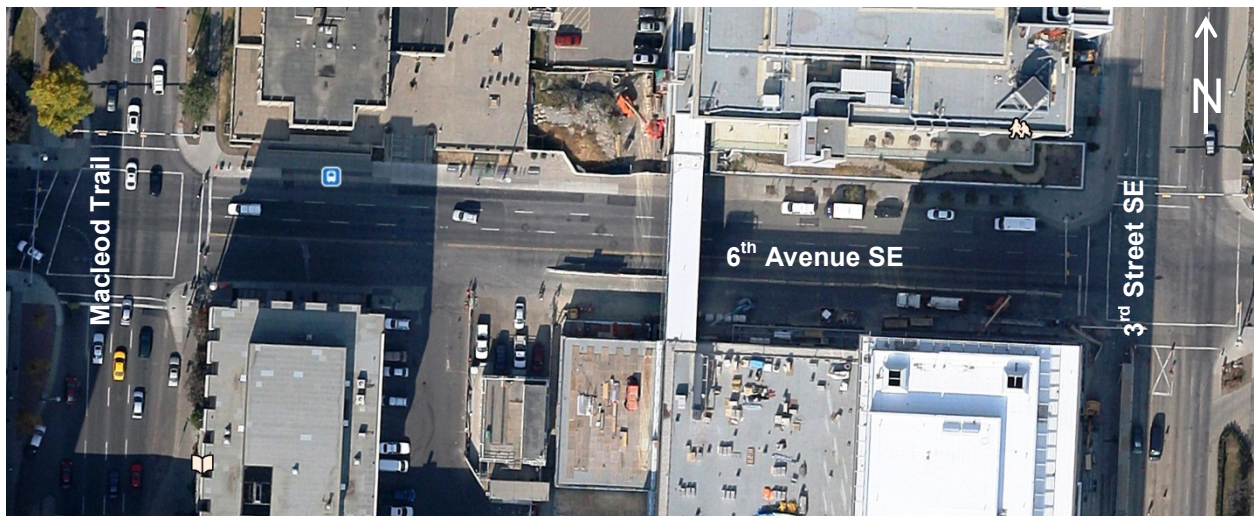


Figure 1. 6<sup>th</sup> Avenue SE Site Plan

## SITE DESCRIPTION

The section is a four-lane urban roadway (one-way direction), which consists of four lanes in the westbound direction. Signalized intersections exist at 3 Street SE and Macleod Trail. The posted speed limit is 50 km/h.

Based on the visual condition survey data, the most prevalent pavement distresses were transverse cracking with slight to moderate severity, asphalt concrete pavement (ACP) patches in the north outside lane, rutting of slight severity, and ravelling of slight severity. A coring program confirmed the consistent asphalt thickness ranging from 295 mm to 305 mm, with an average of 300 mm. A Falling Weight Deflectometer (FWD) survey was also conducted.

## **DESIGN METHODOLOGY AND STRUCTURAL ASSESSMENT**

Traffic loading was estimated in order to assess the structural adequacy, and was used as an input into the pavement assessment. The following assumptions were made to determine the traffic loading.

- 2007 AADT of 22,000.
- 5% truck traffic from 3 Street SE to Macleod Trail, with 50% in the design lane.
- Traffic loading in each direction – 100% loading (one-way direction).
- Total number of transit busses travelling this section – 179 buses/day.

With the data from the FWD survey and the pavement layer thickness information from the coring program, an analysis of the FWD data following the AASHTO design methodology was carried out using a computer program. The objective of the analysis was to determine the back-calculated subgrade modulus ( $M_R$ ) for this section. The subgrade modulus ranged from 37 to 60 MPa, with an average of 51 MPa.

The pavement structural designs for this section of 6 Avenue were based on the American Concrete Pavement Association (ACPA) Method. In addition, the 1993 Edition for AASHTO (Section II-39, figure 3.3) method was used to compute the composite modulus of subgrade reaction using the remaining asphalt thickness, modulus of elasticity for the remaining asphalt, and the existing subgrade modulus.

The ACPA design confirmed that milling 100 mm from the existing asphalt thickness and replacement with 100 mm PCC would accommodate 1,137 trucks/busses per lane and that exceeded the current traffic loading of this section.

In addition to the traffic loading and the back-calculated subgrade modulus, the following design inputs and assumptions were also used to determine the structural adequacy and assess the potential for concrete overlay construction.

- Modulus of subgrade reaction – 57 MPa/m.
- Axle-load category – B (for medium truck-volume facilities).
- Joint spacing – 1.8 m.
- Modulus of rupture of concrete – 4.8 MPa.
- Remaining asphalt thickness after milling – 200 mm.

## **CONSTRUCTION RECOMMENDATIONS**

The recommended rehabilitation strategy consisted of milling and removal of the upper 100 mm of the ACP in the outside lane (bus lane) and conducting pre-overlay repairs

prior to placement of the concrete overlay to prevent reflective cracking and placing a 100 mm of PCC.

The concrete was to satisfy the requirements of CSA A23.1 Class C-2 requirements and the flexural strength requirements of 4.8 MPa. In addition, a synthetic fibre was specified at the rate of 1 kg/m<sup>3</sup>. Since the construction was scheduled over a long weekend in September of 2010 and the lane was to be returned to traffic at the end of the weekend, the concrete design was to allow for a compressive strength of 20 MPa at two days.

Proper joint spacing and construction techniques were considered critical in constructing a durable concrete pavement. Transverse and longitudinal joints were to be constructed using maximum 1.8 m spacing and cut to one-third of the pavement thickness as early as the concrete was finished.

Curing compound was recommended right after concrete finishing operations followed by silane application after 28 days and before expected winter road salt applications.

## **PAVEMENT REHABILITATION**

The pavement rehabilitation was conducted in September 2010. EBA was not present at the time of construction and the following information was provided by The City.

- Lafarge Construction was the contractor.
- The asphalt, after milling, was reported to be in good condition with no repairs needed.
- Lafarge Concrete supplied the concrete. The mix design was not reviewed for compliance with the project recommendations.
- The concrete testing conducted within The City's Concrete Compliance Program indicated that high performance concrete (HPC) was utilized and the concrete was placed with 100 mm slump and had 5.4% plastic air content. The compressive strengths were 31.3 MPa at 3 days, 38.4 MPa at 7 days, and 48.6 MPa at 28 days. The flexural strength of the concrete was not determined.
- The concrete was placed on Saturday, September 4, 2010, and the lane was open to traffic on Tuesday, September 7, 2010.
- A curing compound was applied to the surface of the concrete; however, the timing of the curing compound application and the type of curing aid were not identified.
- The joints were tooled into the concrete about a half an hour to an hour after the concrete was finished.

In 2011 EBA was requested to investigate the causes of premature failure of the concrete.

## SITE SURVEY AND CORING PROGRAM

Numerous cracks were noted, with the cracking predominantly located around manholes, the bus stop and in mid-sections between tooled joints (Photos 1, 2 and 3).



Photo 1. Extensive cracking around the manhole



Photo 2. Concrete cracking at the bus stop



Photo 3. Cracking between tooled joints

The actual construction practices were compared with the construction recommendations and with acceptable practices for bonded concrete overlays of asphalt pavements. The findings from the site survey and the core analysis provided the likely causes of overlay failure.

- Bonding – The purpose of the milling prior to placing a bonded concrete overlay is to remove compromised asphalt (which would result in an inadequate bonding surface), to ensure designed overlay thickness, and to roughen the surface for enhanced bonding with the concrete. Following milling, the asphalt surface needs to be cleaned to ensure adequate bonding. Significant amounts of fines were identified in all four core bottoms (asphalt/concrete interface); only partial bond was achieved in core 1 and there was no bond between the milled asphalt surface and the concrete overlay. There was no information available about the timing of milling and the overlay construction, but it is likely that there was traffic on the milled surface and the fines originated not only from the milling operations but also from the traffic. In addition, in the areas of extensive cracking, more fines were introduced through the cracks formed in the concrete overlay.
- Concrete overlay thickness – The design thickness was 100 mm. The core thickness was between 82 mm and 109 mm. The highest severity cracking coincides with the below design thickness area of the overlay and with the bus stop location.
- Joint spacing – The design joint spacing of 1.8 m squares took into consideration the lane width and the concrete overlay thickness. The actual spacing of about 3 m was random and did very little to prevent random shrinkage cracking and warping. The cracking was exacerbated by the lack of longitudinal joints and by the lack of joint detail around the manholes. In addition, transverse joint spacing of 2.4 m in

some areas produced rectangular panels, which are more prone to cracking than the recommended square design.

- Joint construction – Timely joint sawing is necessary to prevent random cracking. Soff-cutt<sup>®</sup> technology was recommended to a depth of one third of the concrete overlay thickness. Instead, the joints were tooled to a depth of one quarter of the overlay, which reduced the ability to control cracking.
- Concrete mix – HPC was utilized for the overlay. The flexural strength was not determined; however, with a compressive strength of 48.6 MPa at 28 days, it is likely that the concrete achieved a flexural strength of 4.8 MPa at 28 days. The concrete met the durability requirements of CSA exposure Class C-2. The high compressive strength and higher cement content of a 45 MPa concrete increases the shrinkage potential and random cracking. While the demand for high early strength was satisfied, the shrinkage potential was also increased. This, combined with the improper joint spacing and joint construction practice, contributed to the cracking observed on site.
- Fibre – Synthetic fibre was to minimize plastic shrinkage and to control cracking due to concrete shrinkage as the concrete ages. The elimination of fibres from the concrete mix reduced the ability to prevent/control shrinkage cracking.
- Curing – There was little information about curing on site other than that some curing compound was used. Inadequate curing at the initial stage after overlay construction may have been contributed to increased plastic shrinkage.

In conclusion, the failure of the concrete overlay is a result of poor construction practices and materials selection. The design was based on a bonded overlay to produce a monolithic section of asphalt and concrete to improve the structural capacity; however, there was very little or no bond identified at the concrete/asphalt interface. A combination of (1) joint spacing and joint detail, (2) joint construction and depth, (3) concrete mix selection, (4) lack of fibres, and (5) curing regime resulted in uncontrolled and excessive shrinkage and warping. Extensive cracking followed due to the heavy traffic on the un-bonded, warped, and too thin concrete overlay.

## **CONCRETE OVERLAY RE-CONSTRUCTION**

In 2013, The City decided to remove and re-construct the concrete overlay. The same contractor and concrete supplier provided construction services. During the pre-construction meeting the specifications, construction practices and the materials were reviewed and a construction plan was developed for the long weekend of May 2013.

Special care was taken to clean the milled ACP surface after removal of concrete overlay. The surface was very dirty and power washing the sweep cleaning was necessary to achieve a good bond with the PCC overlay. Significant repairs were needed for the areas around the manholes and at the curb at the bus stop to assure PCC overlay performance.



In general, all construction recommendations were followed and the properties of concrete met the specification requirements for concrete overlays. Construction of control joints and the layout followed good construction practices. Since the construction was done in the spring, a white pigmented curing compound was used and the requirement to use silanes was waived.

## POST-CONSTRUCTION SURVEY

The PCC overlay was inspected and, in general, the concrete was found to be in a good condition (Photo 4). Some preferential cracking was identified extending from the adjacent sidewalk control joint (Photo 5). Transverse and random cracking around manhole was noted as the control joint pattern did not accommodate for a round manhole cover (Photo 6). The curing compound was evenly applied and the surface texturing tines were consistent.



Photo 4. Concrete overlay – general view



Photo 5. Preferential crack at adjacent sidewalk control joint



Photo 6. Transverse and random cracking around manhole

## DISCUSSION

Concrete overlays are considered a sustainable solution for resurfacing and rehabilitating existing pavements. This pilot project demonstrated that the recommended construction practices need to be followed in detail and provided a valuable experience for the contractor. Additional cracks may develop in the future but the functionality of the overlay is not expected to be drastically reduced. The failure analysis of the initial construction confirmed that the success of concrete overlays depends on the strict adherence to the construction specifications. Good construction practices combined with the proper materials will ensure the extended life cycle of rehabilitated pavements.

As the pavement rehabilitation with concrete overlays is increasing in popularity, much more experience is needed for successful construction. However, each site will require a unique approach based on the survey of existing pavement, an overlay design for expected service life and constructability.

This pilot project emphasized the need for the strict adherence to all recommendations to avoid premature failure of the overlay and the experience gained in post-construction investigation lead to the success of the reconstructed PCC overlay.

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