# Spragues Road Rehabilitation with an Unbonded Concrete Overlay Region of Waterloo, Ontario, Canada.

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**Abstract**

The work of this project includes the rehabilitation and widening of a 1.2 km (0.75 mile) section of Spragues Road (Regional Road No. 75) from Wrigley Road to the Region of Waterloo boundary in the Township of North Dumfries. The existing road is a rural two-lane composite pavement with partially paved and gravel shoulders. An initial geotechnical investigation determined that conventional road resurfacing strategies of the asphalt / concrete composite pavement were no longer cost-effective and additional assessments were completed to evaluate alternate rehabilitation strategies. Through this process, non-destructive testing was conducted to determine the structural adequacy of the concrete base and suitability for pavement preservation. Comprehensive field investigations determined the 80-year old concrete base was generally in good condition and should be preserved as part of the project. The final pavement design consists of re-profiling or cold planing the existing asphalt surface to meet proposed design gradients, installation of an asphalt intermediate separation layer and placement on an Unbonded Concrete Overlay, a unique rehabilitation treatment in the Province of Ontario.

## Introduction

This section of Spragues Road is one of the main transportation routes between the City of Cambridge and Town of Paris, Ontario. The Average Annual Daily Traffic (AADT) is approximately 8,400 vehicles per day (veh/day) with a significant amount (8%) of trucks travelling through the corridor to access Highway 401 via the Wrigley Road intersection. Highway 401 is Ontario's primary transportation corridor and extends from the United States of America / Canada border at the City of Windsor, Ontario to the Province of Quebec.

A geotechnical engineering and consulting firm, Amec Foster Wheeler, was retained by the Region of Waterloo (Region) in 2011 to conduct a subsurface soil investigation and develop a series of road rehabilitation design alternatives for the Region's consideration. The initial geotechnical investigation determined the pavement consisted of an average of 150 mm (5.9") asphalt surface (in poor to very poor condition) and 180 mm (7.1") of underlying concrete base.

***Rehabilitation alternatives:*** The pavement design alternatives developed as part of this initial geotechnical investigation included:

- Option 1: Cold plane (mill) and overlay 100 mm (3.9") Hot Mix Asphalt (HMA);
- Option 2: Remove the existing asphalt and replace with HMA full-depth;
- Option 2b: Remove existing asphalt full-depth, install 150 mm (5.9") Granular 'A' and 145 mm (5.7") HMA overlay; and
- Option 3: Pulverize the existing asphalt 150 mm (5.9"), maintain the pulverized material in-place and overlay with an additional 145 mm (5.7") HMA.

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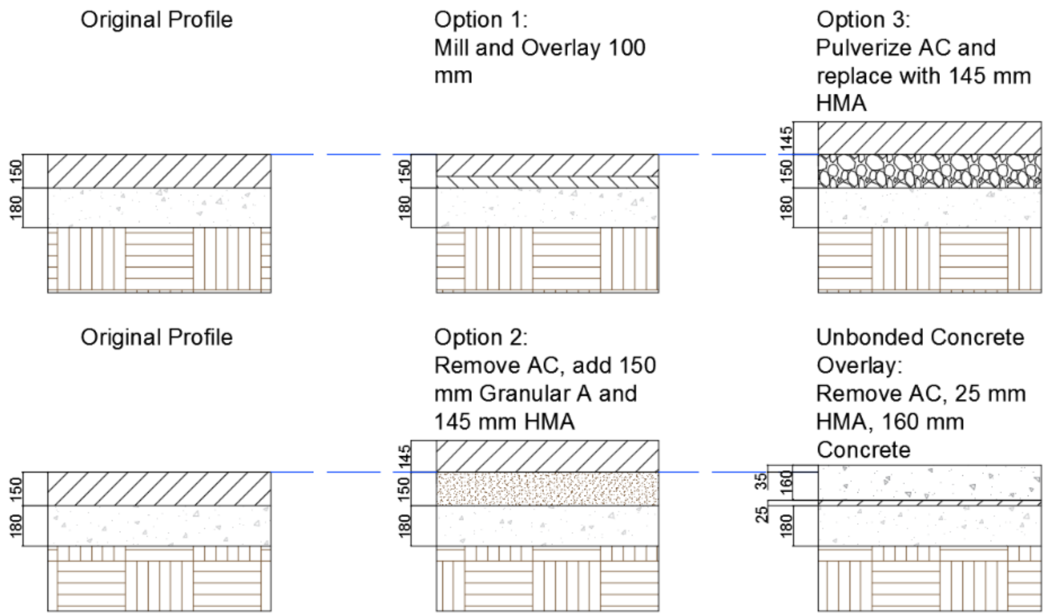


Figure 1: Pavement Design Alternatives (Prieur 2013).

This section of Spragues Road had been resurfaced with asphalt several times over the life of the pavement and it was determined that traditional resurfacing strategies proposed in Option 2 were no longer cost-effective due to reflective cracking from the underlying concrete base. *This Option involves the removal of the total asphalt thickness... The advantages of this option are the elimination of the surface defects and reflection cracking. However, it should be acknowledged that this option is not cost-effective.* (Sorour and Seddik 2011)

The conclusion of the geotechnical investigation led the Region to consider reconstructing the pavement structure and replacing the existing 80-year old concrete base with new granular material, including: full-depth road base excavation, shoulder widening; 650 mm (25.6”) Granular 'B'; 150 mm (5.9”) Granular 'A'; 145 mm (5.7”) HMA; 150 mm (5.9”) diameter sub-drain installations along the edge-of-pavement; and replacement of existing storm sewer culverts.

Table 1: Recommended Minimum Pavement Design (Sorour and Seddik 2011).

| Layer | Material Description | Coefficient | | AASHTO’93Darwin 3.1 AASHTO Ware ESALs = 2.9 X $10^6$ | MTO Rehabilitation Manual |
|---|---|---|---|---|---|
| | | Structure | Drainage | | |
| 1 | Hot Mix Asphalt Concrete | 0.42 | 1.0 | 145 mm | 130 mm |
| 2 | Granular Base ‘A’ | 0.14 | 1.0 | 150 mm | 150 mm |
| 3 | Granular ‘B’ Type I | 0.09 | 1.0 | 650 mm | 450-600 mm |
| **SN** | Design Structure Number | **137** | | **>137 ok** | **n/a** |
| | | | **Target GBE** | **873 mm** | **710-810 mm** |
| | | | **Total Pavement Thickness (mm)** | **945 mm** | **730-880 mm** |

Note: 1 mm of Asphaltic Concrete equal to 2 mm of Granular “A” Base and 3 mm of Granular “B” Sub-base

Given the extent of reconstruction work required, the Region consulted with the concrete industry and contacted the Ready-Mixed Concrete Association of Ontario (RMCAO) / Cement Association of Canada (CAC) to discuss alternate road rehabilitation strategies. The associations recommended an Unbonded Concrete Overlay similar to a pilot project that was constructed by the City of Toronto, Ontario in 2003 at the intersection of Bloor Street and Aukland Road. The pilot project is located next to a transit terminal and has performed quite well since installation. The concrete pavement design has reduced the ongoing maintenance issues associated with asphalt rutting or shoving from transit vehicles turning and stopping at the intersection.

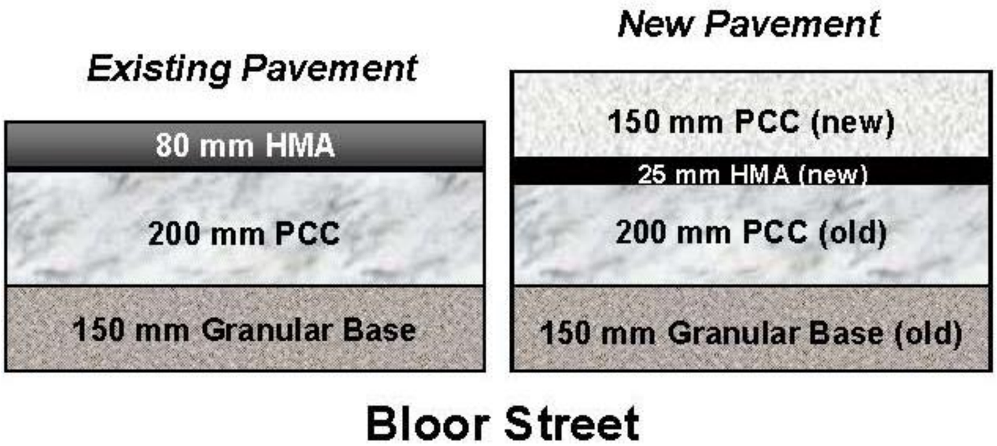


Figure 2: Bloor Street Design (Kivi, Tighe, Fung and Grajek 2013).

Based on these discussions, preservation of the existing concrete base was considered to be the most cost-effective rehabilitation solution and design alternative for Spragues Road. In 2013, the Region retained the services of a supplementing consultant firm, Applied Research Associates (ARA), to provide additional pavement investigations, assess the existing concrete base in greater detail and evaluate an Unbonded Concrete Overlay rehabilitation alternative. The primary intent of this assessment was to gather more information about the concrete base, confirm the feasibility of an Unbonded Concrete Overlay and determine the most optimal pavement design thickness. The additional field investigations included, but are not limited to;

- **Falling Weight Deflectometer (FWD)** testing to determine the structural adequacy, pavement deflection and load transfer of the concrete base between slabs; and
- **Ground Penetrating Radar (GPR)** to collect longitudinal / transverse thickness data to determine the depth and edge of the existing concrete base throughout the corridor.

Figure 3: FWD and GPR Investigations Photos (Holt 2014).

***Initial pavement design:*** The initial concrete overlay design considered by the Region, RMCAO and CAC is shown in Figure 4 below and included; re-profiling / cold planing of the existing asphalt surface to desired geometric design elevations; repair of deteriorated (or shattered) concrete base slabs; installation of 25 mm (1.0”) of a high stability HMA separation layer; and 125 mm (4.9”) concrete overlay for the travel lanes. The width of the existing concrete base was determined to be approximately 6.4 m (21.0’) and the required width of the new pavement was 9.7 m (31.8’) to accommodate two 1.5 m (4.9’) bike lanes. The proposed thickness design for the existing shoulders and/or new bike lanes included 200 mm (7.9”) of concrete with 750 mm (29.5”) epoxy coated tie-bars spaced at 600 mm (23.6”) o/c. The additional concrete thickness was anticipated due to inconsistent soil conditions in the shoulder and the potential that vehicles / trucks would track or wander into the bike lanes from the travel lanes.

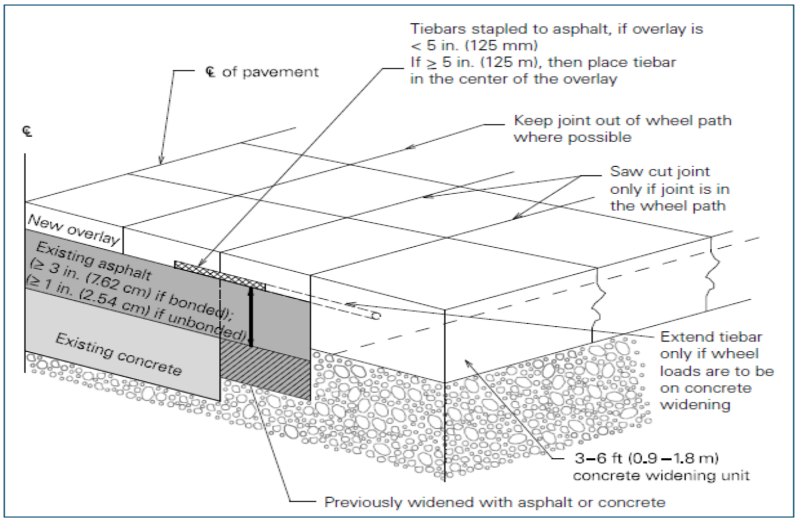


Figure 4: Initial Pavement Design Concept (Harrington 2008).

***Preferred pavement design:*** The supplementary pavement design investigation completed by ARA verified that the concrete base was in good condition although, concluded that (i) many sections of the concrete base experienced poor load transfer across the joints; and (ii) it was anticipated that the concrete base contained no dowels at the joints or steel reinforcement.

During this investigation, FWD testing was completed on the southbound and northbound travel lanes using rigid pavement testing protocols. The location of the load transfer testing for each joint or crack was completed on the shoulder side of the wheel-path for each direction. The testing apparatus was used to simulate standard vehicular loads and determine the corresponding strength of the pavement.

FWD is a non-destructive method of determining the structural adequacy of an existing pavement. The testing process involved a series of dynamic loads ranging from 40 kN to 70 kN (approx. 9,000 lbs-f to15,800 lbs-f), applied to the surface of the pavement by dropping a standard weight on a circular loading plate. FWD tests were completed for each location with a load applied to a plate positioned on the ‘approach’ side of the joint / crack and measurements were taken from deflection sensors at set distances from the load, some of which were on the ‘leave side’ of the joint / crack. For this particular investigation, one sensor was located at the centre of the loading plate with additional sensors located at intervals of 300 mm, 450 mm, 600 mm, 900 mm and 1,500 mm (11.8”, 17.7”, 23.6”, 35.4” and 59.1” respectively).

The 'Load Transfer' parameter was calculated based on the ratio of the unloaded to loaded slab, multiplied by 100. A testing location of 100% represents a joint or crack with a perfect deflection / load transfer whereas, a value of 0% represents no load transfer. The deflection measured on the approach side of the joint minus the deflection on the leave side of the joint represents deflection differential. This relationship is important in determining the performance of asphalt overlays, as larger values represent the rate and/or likelihood of reflective cracking from the concrete base. *Typically, it is desirable to have differential deflection values of less than 50 µm to provide good performance of an asphalt overlay* (Holt 2014).

Additionally, a loss of support analysis was conducted using test procedure NCHRP 1-21 (Crovetti 1985), which evaluates a series of loads applied at a particular test location and predicts a linear load–deflection relationship, corresponding to zero. A positive load–deflection value will indicate that voids are present beneath the pavement and a void intercept value greater than 50 µm will indicate loss of pavement support. Typically, the voids intercept value increases as the size of the void increases and the results will provide important information about the stability of the pavement joints.

Table 2: Composite Pavement FWD Load Transfer and Void Analysis Results (Holt 2014).

| **Stn.** | **Lane** | **Distress** | **Severity*** | **Load Transfer** | | **Quality of Load Transfer ** ** | **Void Intercept** | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **Approach** | **Leave** | | **App.** | **Leave** | **App.** | **Leave** |
| -0+018 | NBL1 | Crack | High | 67 | 40 | Poor | 6 | No | 62 | Yes |
| 0+116 | SBL1 | Crack | High | 78 | 78 | Good | 14 | No | 16 | No |
| 0+130 | NBL1 | Crack | High | 59 | 65 | Fair | -4 | No | 6 | No |
| 0+325 | SBL1 | Crack | High | 70 | 78 | Fair | 14 | No | 9 | No |
| 0+343 | NBL1 | Crack | High | 40 | 38 | Poor | 33 | No | 44 | No |
| 0+416 | SBL1 | Crack | High | 51 | 44 | Poor | 22 | No | 13 | No |
| 0+450 | NBL1 | Crack | High | 96 | 41 | Poor | 36 | No | 42 | No |
| 0+536 | SBL1 | Crack | High | 79 | 72 | Good | 11 | No | 10 | No |
| 0+570 | NBL1 | Crack | High | 53 | 50 | Fair | 29 | No | 22 | No |
| 0+671 | SBL1 | Crack | High | 63 | 48 | Poor | 22 | No | 21 | No |
| 0+731 | NBL1 | Crack | High | 66 | 43 | Poor | 21 | No | 42 | No |
| 0+813 | SBL1 | Crack | High | 52 | 60 | Fair | 13 | No | 24 | No |
| 0+924 | SBL1 | Crack | High | 62 | 54 | Fair | 13 | No | 113 | Yes |
| 0+932 | NBL1 | Crack | High | 40 | 46 | Poor | 8 | No | 10 | No |
| 1+075 | NBL1 | Crack | High | 54 | 45 | Poor | 29 | No | 40 | No |
| 1+017 | SBL1 | Crack | High | 30 | 26 | Poor | 28 | No | 46 | No |

* Crack / Joint Severity Low <0.5" (13mm) Medium 0.5-1.0" (13-25mm) High >1.0" (25mm)
** Load Transfer Poor <50% Fair 50-70% Good >70%

Based on the FWD findings, ARA concluded that the majority of the joints exhibited poor load transfer although, provided support for a concrete overlay providing a new thickness design was considered by the Region. The new rehabilitation design alternative included: removal / re-profiling of the existing asphalt to meet proposed geometric design elevations; HMA levelling course (where required); 25 mm (1.0") HMA separation (or de-bonding) layer; and 160 mm (6.3") concrete overlay, consisting of 32 MPa (4,600 psi) concrete, Class C-2, max. size agg. 37.5 mm (1.5"), 20-30mm slump, 5.5% air and 0.45 w/c ratio with no cementing supplements.

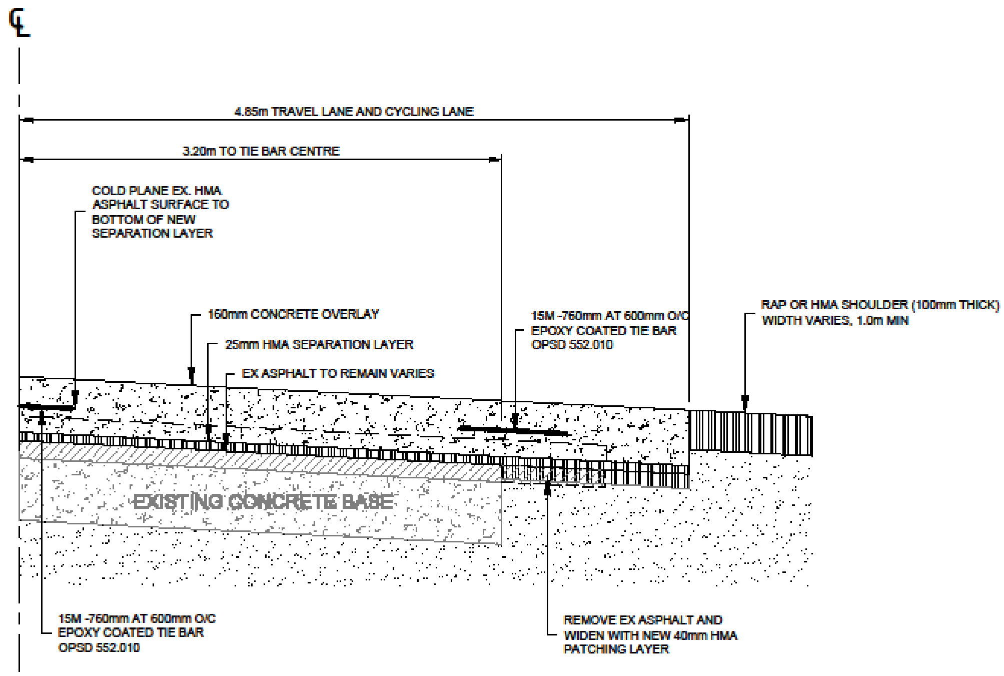


Figure 5: Unbonded Concrete Overlay Detail (Region Design Drawings 2014).

Although the additional thickness increased the volume of concrete required for the project, the design team believed this strategy would be cost-effective as the new concrete pavement would be continuously poured 4.85 m (15.9') wide with single-lane paving equipment in one direction for both, the travel lane and bike lane. Whereas, the construction approach for the initial pavement design required a total of four paving passes, including; two 3.20 m (10.5') wide pours for the travel lanes, and an additional two pours 1.65 m (5.3') wide for the bike lanes due to the thickness variation.

***Capital cost evaluation / comparison:*** In the summer of 2014, the Region released the contract for Spragues Road Rehabilitation through the public tendering process. Tenders were called for Spragues Road Rehabilitation, Brant / Waterloo Boundary to Wrigley Road, and were opened publically on July 30, 2014. A portion of this contract was undertaken on behalf of the County of Brant and includes approximately 100 centerline meters (328.1') of asphalt road resurfacing to improve a section of deteriorated road immediately south of the Region of Waterloo boundary and limit of concrete pavement.

Based the low tender submission, the Spragues Road contract was awarded to Capital Paving Inc. (Capital Paving) of Guelph, Ontario and subcontractors, The Miller Group of Markham, Ontario and Roto-Mill Inc. of Orangeville, Ontario. The total amount for the Unbonded Concrete Overlay portion of the project equated to $1,340,000 (excluding contingency & tax), complete with shoulder widening, slope enhancements, guiderails, landscaping restoration, etc.

For comparison purposes, the total cost estimate for full-depth pavement reconstruction referenced in Table 1: Recommended Minimum Pavement Design (Sorour and Seddik 2011) equated to $1,705,000 (excluding contingency & tax), complete with shoulder widening, slope enhancements, guiderails, landscaping restoration, etc.

When evaluating the cost of the Unbonded Concrete Overlay option in comparison with the full-depth road reconstruction strategy, the initial savings on capital investment is anticipated to be approximately $365,000 (or 20%). In addition to the initial savings, it is anticipated that additional savings and/or long-term benefits would be realized if a Life Cycle Cost Analysis (LCCA) was performed and considered various costs such as, routine maintenance, for each strategy over a 50-year time period.

***Construction methodology / traffic management:*** The general contractor, Capital Paving, mobilized to the site in the spring of 2015 and commenced the preparation phase of the project with the installation of a 3.5 m (11.5') temporary traffic lane using the existing asphalt shoulder and widened the lane where space was limited. A steel beam guiderail was removed on the west side of the road while the traffic lane was constructed and a temporary concrete barrier (TCB) was placed along the widened embankment to protect motorists during the first stage of construction. The Region determined during the planning stage of the project that northbound traffic would be permitted during construction and southbound traffic would be detoured throughout the duration of work. The detour route was approximately 15 km (9.3 miles) in length and traffic was diverted via Wrigley Road through the Village of Ayr towards a county road south of the project.

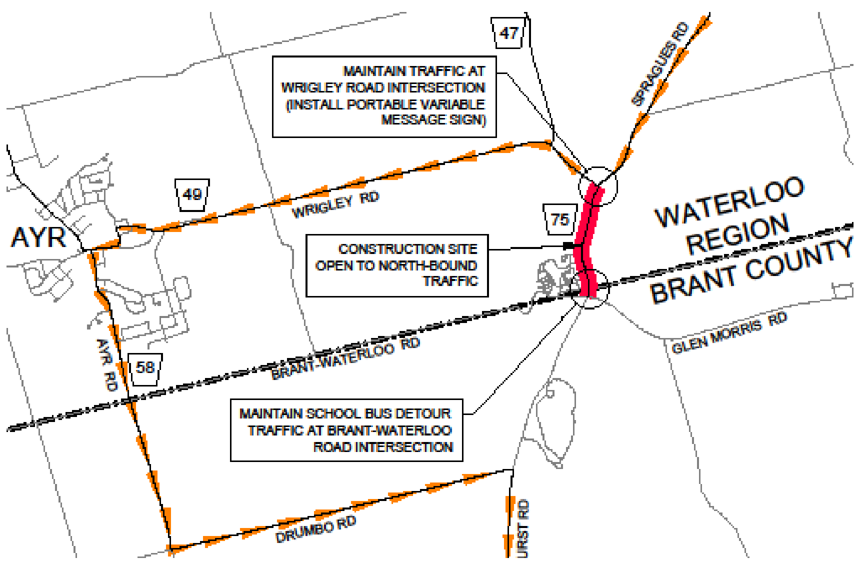


Figure 6: Traffic Detour Map (Region Contract Documents 2014).

The first stage of rehabilitation work was performed on the east side of the road and traffic control delineators were placed 1.5 m (5.9') between the limit of construction and northbound vehicular traffic. A minimum 1.5 m (5.9') offset was required to provide additional space beyond the centerline of the road to allow for cold planing, asphalt and concrete paving equipment. Roto-Mill Inc. was subcontracted to re-profile the existing asphalt surface to meet the proposed design depths / elevations in order to correct geometric deficiencies and improve super-elevations / vertical curves. Once the cold planing process was complete, Capital Paving placed an asphalt padding layer where additional material was required to meet proposed design gradients, followed by a 25 mm (1.0") separation layer throughout the limits of the concrete overlay. The separation layer was critical to ensure the overlay would be placed on a smooth surface and provide an unbonded plane to mitigate reflective cracking from the concrete base.


Figure 7: Northbound concrete pavement with RAP shoulder (Prieur 2015).

The Miller Group then placed the first pass of concrete over a 3-day period with a single-lane concrete paver. During construction, the total quantity of concrete pavement placed during this timeframe was approximately 850 $m^3$ (1,111 $yd^3$) for each direction over an area of 5,330 $m^2$ (6,374.6 $yd^2$). Driveways were reinstated within 20-24 hours after ‘soff-cut’ saw cutting of the concrete was completed in a 1.6m x 1.8m (5.3’ x 5.9’) pattern. The 3 mm (0.1”) wide x 50 mm (2.0”) deep max. saw cuts (with no sealant) were based the theory that the maximum spacing should not exceed 1.5 times the thickness of the pavement design in meters or feet. Therefore, the maximum spacing for a 160mm (6.3”) overlay should be less than 2.40 m (9.45’).

For this particular project, the 1.6m x 1.8m (5.3’ x 5.9’) spacing was developed based on the width of the existing 3.20m (10.5’) concrete base and design objective to place a longitudinal joint along the widened portion of the pavement / concrete base interface. It was anticipated that the overlay may experience differential support or settlement along this interface and cracking would occur when exposed to vehicular loading. The design team recognized that this interface would vary throughout the project and 1,000 mm (3.3’) epoxy coated tie-bars were installed to provide further support, spaced at 600 mm (2.0’) with the center of the bar located 1.6m (5.3’) from the edge of pavement.

Concrete maturity testing methods were used during construction in order to allow access to residential / commercial properties when the minimum concrete strengths had been achieved. The minimum specified strength of 20 MPa (2,900 psi) was reached in 15.84 hours on average.

Typically, the field cure concrete cylinders took 4 hours longer to reach the required strength than the maturity test results where, monitoring probes were placed in the concrete at strategic locations during placement to capture real-time curing data (eg. in-situ temperatures over time).

Table 3: Maturity Testing Results (RMCAO 2015).

**Summary Spragues Road Southbound Lane Construction**

| | Tag | 733 | 895 | 498 | 710 | 735 | 895 |
|---|---|---|---|---|---|---|---|
| | Station | 0+029 | Field Cure | 0+405 | 0+555 | 0+927 | 1+087 |
| Time to meet Opening Strength | Hours | 14.33 | 18.42 | 16.92 | 15.5 | 14.83 | 15.08 |
| Time to meet Specified Strength | Hours | 98 | 0 | 100.5 | 103.67 | 96.92 | 0 |
| Time to meet Specified Strength | Days | 4.1 | 0.0 | 4.2 | 4.3 | 4.0 | 0.0 |

**Summary Spragues Road Northbound Lane Construction**

| | Tag | 498 | 734 | 710 | 711 | 728 | 895 | 498 |
|---|---|---|---|---|---|---|---|---|
| | Station | 0+190 | 0+289 | Field Cure | 0+342 | 0+590 | 0+694 | 1+088 |
| Time to meet Opening Strength | Hours | 16.5 | 14.25 | 18.5 | 14.33 | 0 | 16.67 | 14.67 |
| Time to meet Specified Strength | Hours | | 92.75 | 116.25 | 109.25 | 0 | 114.5 | 117.67 |
| Time to meet Specified Strength | Days | | 3.9 | 4.8 | 4.6 | 0.0 | 4.8 | 4.9 |

Once the northbound lane was constructed, the temporary travel lane was relocated to the new concrete surface and the second stage of rehabilitation work (TCB removal, cold planing, HMA and concrete placement) progressed on the west side. Following completion of the concrete pavement, Capital Paving installed Reclaimed Asphalt Pavement (RAP) and HMA shoulders. The road was then cleaned and Methyl Methacrylate (MMA) pavement markings were installed with a black silhouette around the white lines to enhance visibility for motorists.

***Lessons learned:*** Overall, the project was a collaborative effort by all parties involved and this success has been recognized by agencies such as, the Ontario Public Works Association (OPWA "Project of the Year" award, under $2.0 million). The project was delivered on time and met the 35 working day required in the contract documents. Unfortunately though, the length / duration of the southbound traffic detour led to public frustration and the improper use or access of some motorists. Several safety concerns were documented where motorists disobeyed road closed signs and travelled the wrong direction in the northbound lanes. To address this concern, the Region made arrangements for a full-time traffic control person to be present during construction and an after-hours security guard during the weekend when the contractor was not on-site.

In the future, it would be beneficial to maintain two-way traffic where reasonable possible until such time that the contractor has to close the road for concrete paving operations. For example, the contractor could provide two-way traffic control during the evening / weekends prior to concrete placement and controlled flagging operations or pilot vehicles during normal working hours for the cold planning / asphalt paving operations. It is anticipated that the total duration of the work would be extended and an additional cost would be required to conduct the work in this fashion. Conversely though, the Region would be able to improve service to the public and reduce the duration of the traffic detour to a limited time period during concrete placement.

The Unbonded Concrete Overlay was completed in the summer of 2015 and has performed quite well with no signs of reflective cracking from the concrete base. The long-term performance will be monitored by the Region's Transportation staff for consideration and continuous improvement on future projects. One of the design elements to be monitored is the long-term performance and maintenance requirements of the saw-cut joints. It was the design team's preference to include closer joint spacing to minimize uncontrolled cracking in the concrete although, recognized joint sealant would not be practical and would require on-going maintenance to ensure effectiveness. With this in mind, the team decided to reduce the width of the saw-cuts to 3mm (0.1") in effort to minimize the amount of incompressible material entering the joints and causing the concrete to chip during seasonal freeze / thaw cycles. In hindsight, some sections of shoulders where placed using RAP and material has been observed in the joints which will require cleaning and sealing of the shoulders in the future to reduce further migration.

Figure 7: Unbonded Concrete Overlay with MMA Pavement Markings (Prieur 2015).

***Conclusion.*** The Unbonded Concrete Overlay option was a viable rehabilitation solution for Spragues Road and the Region has realized a 20% savings on initial construction costs versus the full-depth road reconstruction alternative. The use of maturity testing methods during concrete construction kept the project on schedule and provided the project team with the confidence to re-open residential / commercial driveways when minimum strengths were achieved.

Overall, this was a challenging project due to the time constraints, staging of work requirements and the geometric design improvements required for the roadway. Although, it is important to note that all of the contractors, consultants, suppliers, associations and agencies involved in the project provided a collaborative team-environment to ensure the project was a success.

**Acknowledgements**
The authors wish to acknowledge the technical support and contributions of the following partners that made this project a success: Ready-Mixed Concrete Association of Ontario (RMCAO - Concrete Ontario); Cement Association of Canada (CAC); Centre for Pavement and Transportation Technology (CPATT) - University of Waterloo, Department of Civil and Environmental Engineering; Amec Foster Wheeler; Applied Research Associates (ARA); The Miller Group (Brennan Paving); Roto-Mill Inc; and Hogg Fuel and Supply.

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