

## **Fast Track Precast Concrete Pavement Rehabilitation Pilot Project**

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Paper prepared for presentation at  
SES - Innovations in Pavement Management, Engineering and Technologies Session  
of the 2017 Conference of the  
Transportation Association of Canada  
St. John's, NL

## **ABSTRACT**

As Ontario's highway network expands and is subjected to increasing traffic volumes, the Ministry of Transportation Ontario (MTO) is challenged to look for new and innovative solutions to preserve and maintain the highway system. The ministry has identified a few high truck traffic sections having Average Annual Daily Truck Traffic (AADTT) greater than 25,000 that are experiencing progressively early rutting failure, and a few thick asphalt pavements experiencing full depth cracking. To reduce impacts to the travelling public, these high volume highways require all major maintenance and rehabilitation works to be performed under tight nightly construction closures. The typical rehabilitation holding treatment of mill and overlay at these locations may last only 3 to 5 years, rather than the expected 8 to 12 years, before the rutting and cracking return. Based on the progressively shorter lifecycles of this holding strategy, the ministry is investigating a potentially more life cycle friendly option of using overnight precast concrete mill and inlay techniques to mitigate this progressive rutting and cracking challenge.

This paper describes an MTO pilot project using precast concrete slabs to rehabilitate a deep strength flexible pavement. The paper discusses how three different slab support systems were evaluated based on factors such as load transfer and ease of construction; the challenges of construction staging based on an 8 hours work window, with adaptations of horizontal and longitudinal joint details for the anticipated temporary and permanent works; lessons learned and next steps. Furthermore, the paper presents post construction roughness, load transfer efficiency and friction results of the tined longitudinal texture on the precast slabs.

## **1. INTRODUCTION**

The Ministry of Transportation Ontario (MTO) is challenged to look at innovations to preserve and maintain the highway system. Several high volume flexible highways are experiencing progressive early rutting failure with full depth cracking issues. The typical holding strategy used is mill and overlay with HMA, which lasts only 3 to 5 years, rather than the expected 8 to 12 years, before the rutting and cracking issues return. To reduce the construction impact to the travelling public, these locations require all maintenance and rehabilitation work be performed under tight nightly closures. With this operational constraint, MTO is interested in studying a new method for rehabilitation that has a longer service life but can still be installed during overnight construction windows.

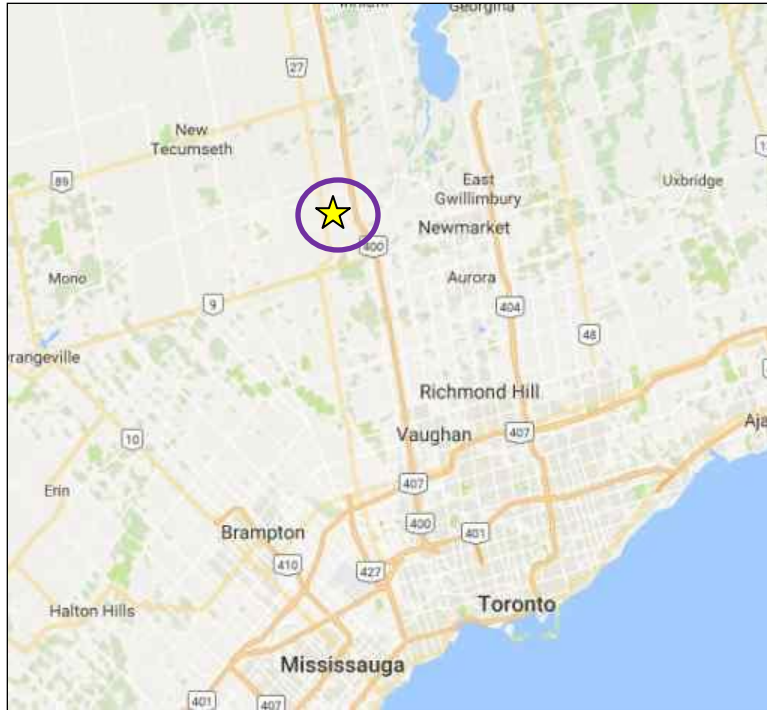
## **2. BACKGROUND**

The ministry investigated a potentially more life cycle friendly use of precast concrete inlay on deep strength flexible pavement to mitigate the progressive rutting and cracking performance. The idea was inspired by the use of precast concrete slabs to repair existing concrete on some high volume composite pavements in the Toronto area.

In 2004, MTO carried out its first trial project to evaluate construction techniques for precast concrete slab repairs on concrete/composite pavements. The initial trial was carried out on Highway 427, in Toronto (1). Based on MTO experience with this trial contract, a specification was developed and additional precast repair work carried out through the years. MTO has successful experience on the use of precast concrete repairs on concrete pavement, and this experience inspired the use of precast concrete slab to repair flexible pavement.

## **3. PROJECT LOCATION**

The pilot project is located on the northbound section of Highway 400 between the intersections of Highways 88 (to the south) and 89 (to the north). The 2013 average annual daily traffic (AADT) in both directions was estimated to be 87,300. Figure 1 below shows the approximate location of the pilot project.



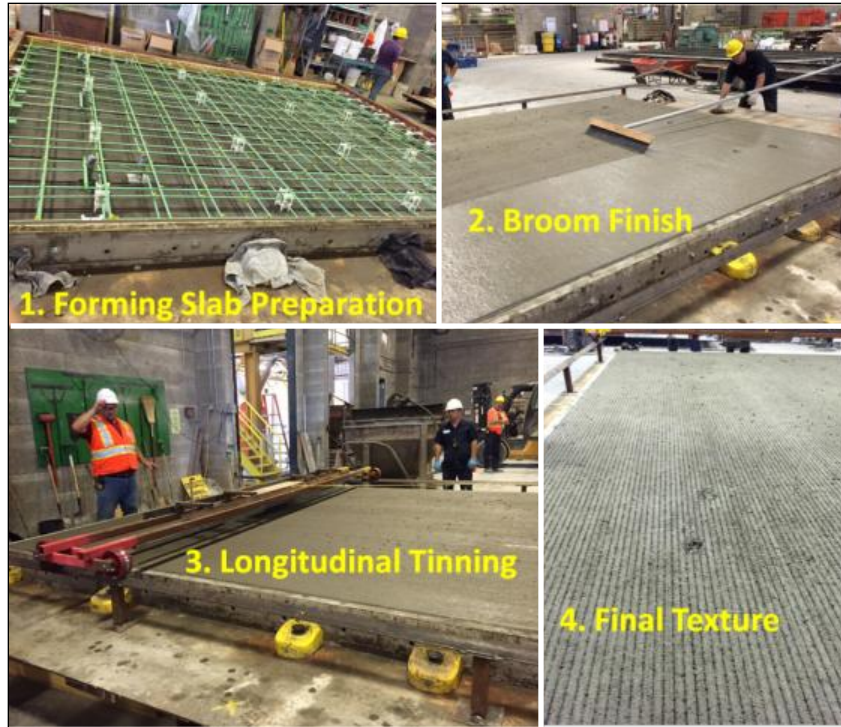
**Figure 1: Pilot Project Location on Highway 400 and between Highway 88 and 89  
(Source: Google Map)**

#### **4. METHODOLOGY**

The pilot project used precast concrete slabs based on the Fort Miller Super-Slab® Method. The hot mix asphalt (HMA) in lane 3 (outside lane) was milled partial depth and the precast slabs were placed within the milled-out recess. Three slab support methods or systems were employed for this pilot study: 1) Asphalt Supported Slab; 2) Graded Supported Slab; and 3) Grout Supported Slab. Also, long term monitoring instrumentation was installed as part of the work in partnership with University of Waterloo, Center for Pavement and Transportation Technology (CPATT).

##### **4.1 Precast Concrete Slab Fabrication**

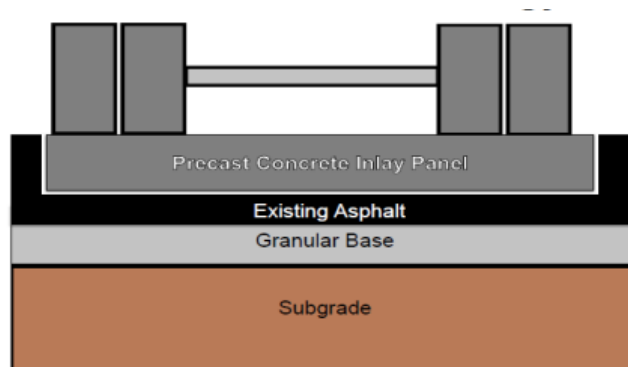
There were a total of 22 reinforced precast slabs required for this contract and they were fabricated in late August to early September 2016 at the Armttec production facility located in Mitchell, Ontario. To ensure good friction, sufficient micro and macro texture on the precast surface was mandatory. Several trials were performed on the precast concrete surface to produce an acceptable surface texture. The final surface texture was a broom finish, followed by longitudinal tining. Care was exercised to ensure a constant pressure was applied during the brooming and longitudinal tining processes to provide the required texture. Figure 2 below shows the precast concrete slab production.



**Figure 2: Precast Slab Production**

4.2 Design Considerations

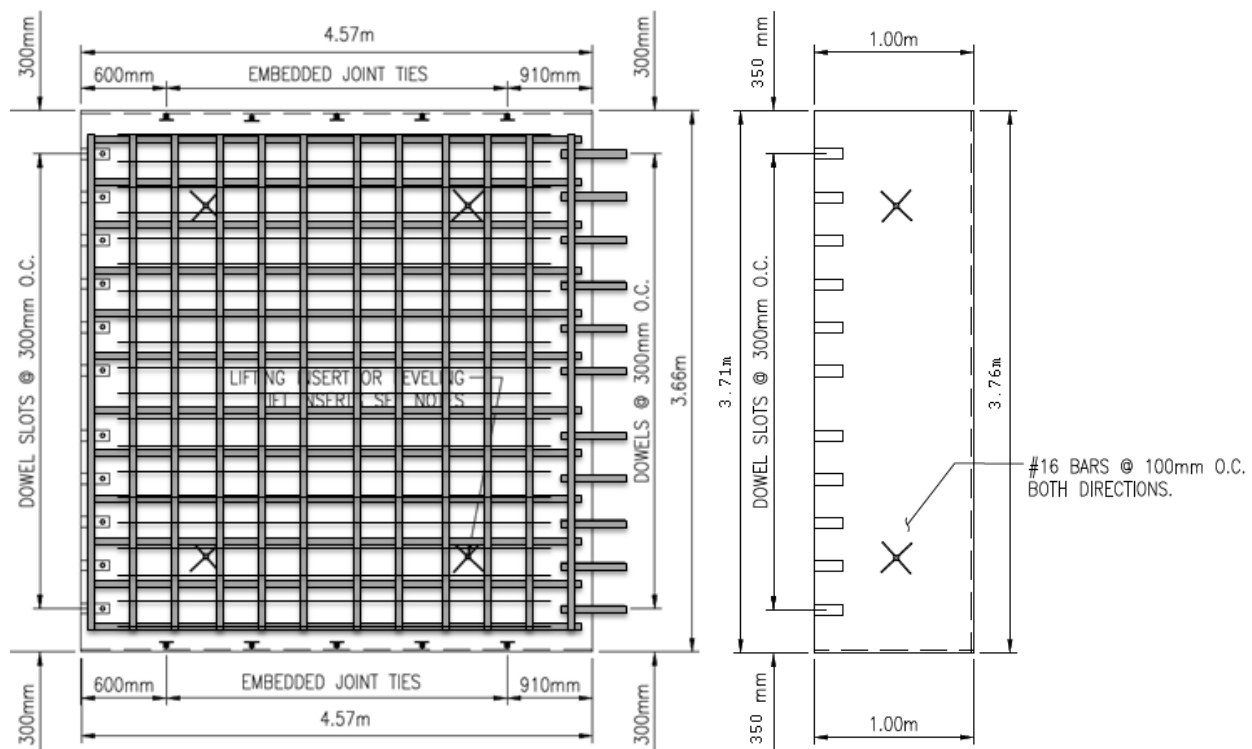
Cores of the site location were taken to ensure sufficient asphalt depth was available to provide uniform support of the precast slabs. Three cores indicated the northbound lane 3 asphalt thicknesses were 355, 375 and 375 mm. With a precast concrete slab of 205 mm, there was sufficient asphalt thickness to mill down and place the precast concrete inlay slab, with about 150 mm asphalt remaining as the base support. Figure 3 is the schematic of the precast concrete slab inlay repair of the flexible pavement.



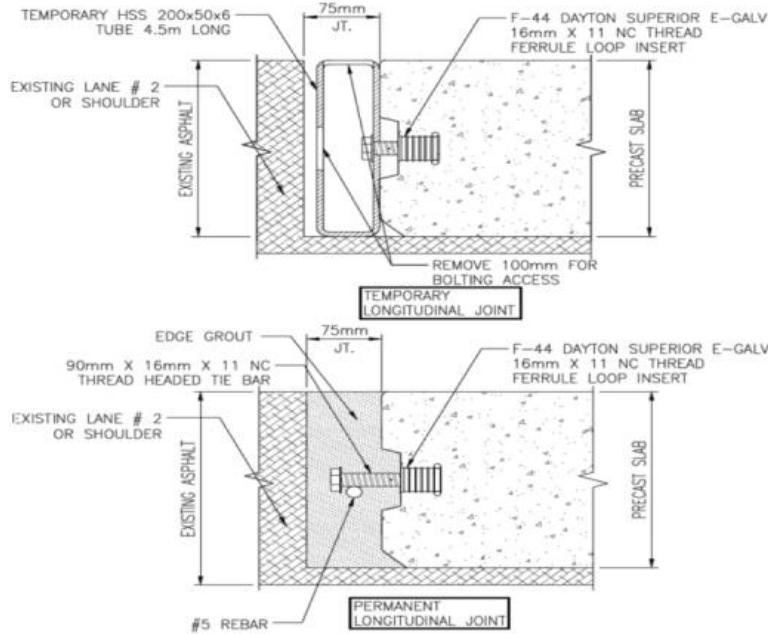
**Figure 3: Precast Concrete Slab Repair Rehabilitation on Asphalt Pavement**

The precast concrete slabs were 205 mm thick, 3.7 m wide (lane width) and 4.6 m long. Epoxy-coated dowels at 300 mm centers were embedded at the transverse joints. The precast concrete was designed for 30 MPa at 28 days with 3% air void. The precast slab was reinforced by 2 mats of 15M bars at 300 mm spacing.

Due to limited lane closure constraints, all the trial slabs needed to be installed over a few nights. To facilitate a better transition for the next night's operation, a temporary 1.0 meter longitudinal slab (sleeper slab) was employed. The temporary slab was placed over the exposed dowels to support traffic during the un-grouted condition. The temporary slab was removed prior to the next night's slab placement. Figure 4 below shows the schematic of the precast slab and temporary end slab details. Figure 5 below shows the temporary and permanent longitudinal joint details. The temporary HSS tube had been installed at the casting plant, but was removed after placing the slabs to facilitate the edge grouting.



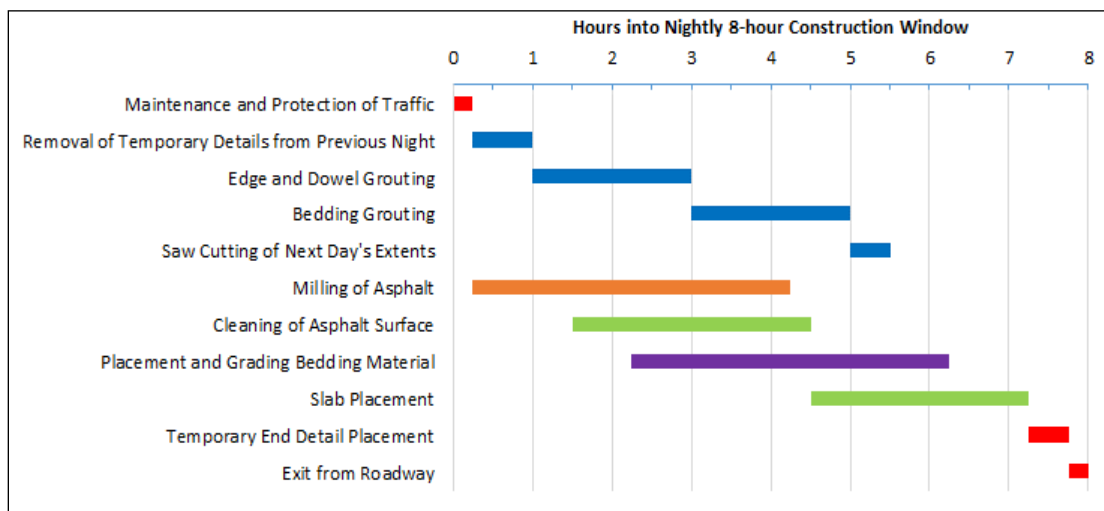
**Figure 4: Precast Concrete Slab and Temporary End Slab Details**



**Figure 5: Temporary and Permanent Longitudinal Joint Details**

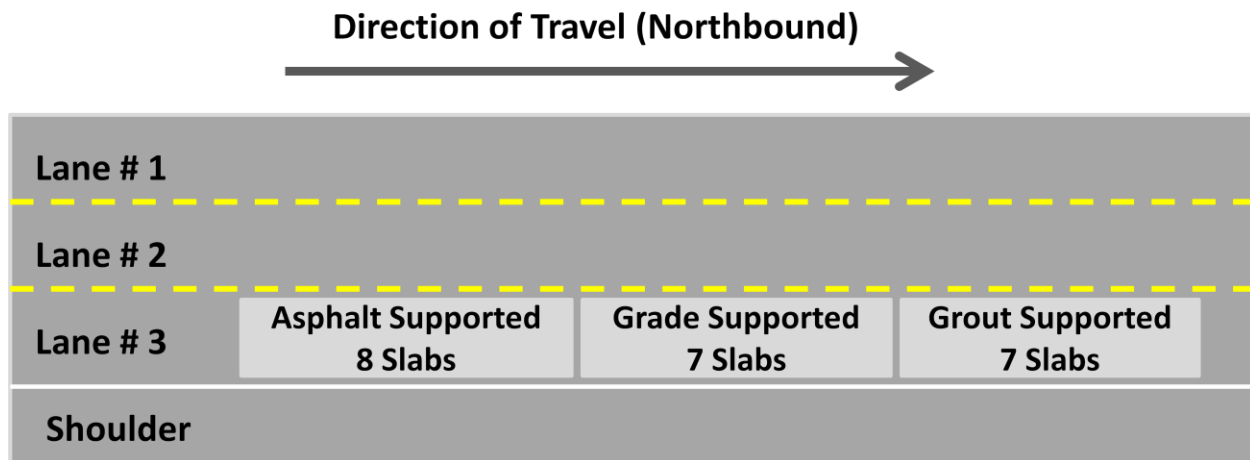
## **5. CONSTRUCTION**

There were a total of 22 precast concrete slabs with three support methods used in this pilot study. The contractor planned to install 7 to 8 slabs for each of the three methods in three consecutive nights. Due to the tight timeline, the nightly activity needed to be well planned in advance to avoid any possible construction delay. Figure 6 below is the nightly construction activity schedule.



**Figure 6: Precast Concrete Trial Activity Schedule**

The final site location and layout of the three installation methods was decided upon discussion with MTO, CPATT, the Consultant and the Contractor. Figure 7 below shows the planned layout of the installation method.



**Figure 7: Site Layout of the Three Support Methods**

The Contractor began the site layout on September 15<sup>th</sup>, 2016, followed by saw-cutting of the perimeter of the asphalt area to be milled on September 19<sup>th</sup>, 2016.

5.1 Option 1: Asphalt Supported Slab Method

The first night of slab installation commenced on Sept 20<sup>th</sup>, 2016 with the Asphalt Supported Slab method. This method requires the precast concrete slabs to be supported directly onto a precisely milled asphalt base and then grouted in place the following night.

The milling machine was a Wirtgen Model W120 CFI, with a 1.2 m-wide milling head. Three passes of the milling unit were carried out to mill to the required width. (Figure 8)



**Figure 8: Wirtgen Milling Machine**



Since the Asphalt Supported Slab method requires a precise milling depth of the asphalt (tolerance of  $\pm 3$  mm), the Fort Miller grade check apparatus was adopted to ensure milled surface tolerances were achieved prior to placing the slab (Figure 9). (2)



**Figure 9: Fort Miller Grade Checker Apparatus**

After first slab placement, the surface differential between the adjacent lane surface and the precast slab surface was found to be approximately 9 mm. This was corrected by slab removal and additional milling of 12 mm based on the readings from Fort Miller's grade checker. The surface differential between adjacent slabs was found to be small (within  $\pm 3$  mm tolerance as required in the specification) for the remainder of the slabs. The CPATT instrumentation was installed beneath the fourth and eighth Asphalt Supported Slab. Figure 10 shows the installation of the precast concrete slab.



**Figure 10: Precast Concrete Slab Installation (Asphalt Supported Slab)**

A total of 8 asphalt supported slabs were placed in approximately 1 hour 10 minutes, for an average placement time of approximately 9 minutes/slab. Following placement of the 8 slabs, the temporary end slab was then installed (Figure 11). The fast-setting bedding grouting, dowel grout and edge grout for longitudinal joints were applied the next night (Figure 12).



**Figure 11: Asphalt Supported Slab and Temporary End Slab**



**Figure 12: Pumping the Dowel Grout**

### 5.2 Option 2: Grade Supported Slab Method

The Grade Supported Slabs were placed on September 21<sup>st</sup>, 2016. This method involved milling of the asphalt, followed by placement, grading, and wetting of the cement-treated bedding material (CTBM) prior to placing the precast concrete slab on top.

The same milling machine (Figure 8) and Fort Miller Grade Checker (Figure 9) were used as in the Asphalt Supported Slab method. The CPATT instrumentation was installed underneath the second and fourth slabs prior to placement of the CTBM. The CTBM was graded using a manual leveling screed and compacted using the plate tamper to the correct elevation. The material was wetted to begin hydration and the slabs were placed directly on this bedding layer (Figure 13).



**Figure 13: Compaction of the CTBM Grade Supported Slab Method**

A total of 7 grade supported slabs were placed in approximately 90 minutes, for an average of approximately 13 minutes/slab. Following placement of the 7 slabs, the temporary end slab was then installed. The edge grout for longitudinal joints was applied the next night.

### 5.3 Option 3: Grout Supported Slab Method

The Grout Supported Slabs were placed on September 22<sup>nd</sup>, 2016. This method used built-in leveling screws (or jacking bolts) which rested on the milled asphalt surface. These leveling screws have the capability of adjusting the level of the concrete slab to the required elevation, Quick setting bedding grout was then injected to support the slab.

The same milling machine (Figure 8) used for the Asphalt Supported Slab method was used to remove the asphalt for this support method, and the CPATT instrumentation was installed prior to slab placement. Three grout mixers were used to produce the increased amount of bedding grout required to fill the void beneath the Grout Supported Slab. Figure 14 below shows the adjustment of the levelling screw for this method.



**Figure 14: Grout Supported Slab Levelling Screw and Adjustment**

A total of 7 grout supported slabs were placed in approximately 85 minutes, for an average placement time of approximately 12 minutes/slab.

### 5.4 Summary of Construction

Table 1 below shows the summary of the construction timing and usage of bedding grout for each installation method.

**Table 1: Summary of Construction Activity**

	<b>Asphalt Supported</b>	<b>Grade Supported</b>	<b>Grout Supported</b>
<b>Date Installed</b>	Sept 20, 2016	Sept 21, 2016	Sept 22, 2016
<b>Milling time (min)</b>	215	120	75
<b>Slab Placement Time (min)</b>	70	90	85
<b>Time per Slab (min/slab)</b>	9	13	12
<b>Bedding Grout per slab (bags)</b>	12	4	14

## 6. POST-CONSTRUCTION DATA ANALYSIS

The post construction data collected right after construction included Falling Weight Deflectometer (FWD), friction and roughness testing. Out of the 22 slabs placed, only one slab did not meet the 3 mm tolerance and needed to be diamond ground as per the specification.

### 6.1 Falling Weight Deflectometer

MTO retained a consultant to carry out the load transfer testing using the FWD at the transverse joints of the precast slabs. The testing was completed on October 6 and 7, 2016 according to ministry's requirement. (3) A total of 23 joints were tested for load transfer efficiency (LTE %) and void detection. Below is the summary table showing the FWD testing results.

**Table 2: FWD Testing Results Summary**

Joint	Station	Outer Wheelpath (OWP)			Inner Wheelpath (IWP)		
		Approach (LTE %)	Leave (LTE %)	Void	Approach (LTE %)	Leave (LTE %)	Void
1	17+550	67.8	66.7	No	66.6	87.8	No
2	17+555	73.3	84.4	No	81	74.3	No
3	17+560	84.3	81.7	No	81.3	81.4	No
4	17+565	85.3	83.4	No	79.5	75.7	No
5	17+570	81.5	81.6	No	83.6	85.1	No
6	17+575	78.1	79.3	No	79.1	77.6	No
7	17+580	86	82.2	No	80.2	78	No
8	17+585	77.7	79.9	No	78	80.3	No
9	17+590	78.8	85.4	No	75.7	77.7	No
10	17+595	76.7	79.8	No	80.2	83.1	No
11	17+600	77.1	77.5	No	83.8	76.3	No
12	17+605	77.5	81	No	82.3	79.3	No
13	17+610	80.8	79.2	No	84.8	82.9	No
14	17+615	80	82.8	No	81.9	82.2	No
15	17+620	78.8	83.5	No	83.6	78.4	No
16	17+625	83.3	82.3	No	82.6	76.3	No
17	17+630	80.4	79.5	No	79.9	77.7	No
18	17+635	86.8	84	No	84	83.4	No
19	17+640	87.2	83.3	No	79.8	77.5	No
20	17+645	89.3	87.2	No	83.7	80.9	No
21	17+650	88	82.6	No	83.4	77.9	No
22	17+655	89	81.4	No	82.5	82	No
23	17+660	90	78.2	No	54.5	50.9	No

As a general practice, the load transfer is considered to be acceptable when LTE is greater than 70%. The average LTE for all 23 joints was 80.3%, which indicates a relatively good load transfer for this precast concrete slab placement. Breaking it down to the different installation methods, joint 2 to 9 for asphalt supported method achieved an average 80.4% LTE; joint 10 to 16 for grade supported method averaged 80.6% LTE; and joint 17 to 22 for grout supported method averaged 83% LTE. The first and last joints were not counted in the breakdown because those joints were adjacent to the asphalt with no load transfer device installed. Overall, all three methods of support provided good load transfer efficiency and no voids were encountered, with the grout supported method providing slightly better LTE when compared to the 2 other support methods.

## 6.2 Roughness

Roughness was assessed by measuring the International Roughness Index (IRI) using the Automated Road Analyzer (ARAN). IRI is a roughness index with 0 mm/m representing a perfectly smooth pavement, and as the IRI increases, the measure represents a less smooth/rougher pavement. Typical IRI values for a concrete surface are higher than a HMA surface because the longitudinal profile measurement will capture the timing of the concrete surface resulting in a higher reading. The average IRI summarized in 10 m intervals for all the precast concrete inlay slabs was 2.14 mm/m and for the adjacent asphalt pavement was 0.76 mm/m.

Table 3 below is the breakdown of the IRI result for each installation method, and it appears Grout Supported Slab method was smoother when compared to the other 2 methods.

**Table 3: Summary of IRI Result**

	<b>Asphalt Supported</b>	<b>Grade Supported</b>	<b>Grout Supported</b>
<b>IRI (mm/m)</b>	2.39	2.57	1.81

## 6.3 Friction

Frictional resistance testing was performed using a locked wheel Friction Tester unit per ASTM E-274 with ASTM E 501 standard ribbed tire. The tined longitudinal texture provided friction numbers in excess of FN30.

## **7. LESSONS LEARNED**

Precast concrete slabs require a uniform base for support. The challenge of this pilot project was to precisely mill the asphalt to a specific depth and provide a uniform surface for the precast slab to sit on. Thus, precise surface measurement and milling head control is critical for the success of this process.

Base on this pilot experience, it was found that milling slightly deeper is better than under milling. The specialized milling machine was able to meet the specified grade requirement of  $\pm 3$  mm and provide a uniform milled surface texture.

Manual chipping of localized high spots and chipping of the asphalt rounding from the milling head delayed installation by about 1 hour. Therefore, it is recommended that Bobcat mounted chipping equipment be used to significantly reduce the chipping time.

The slabs should be broom finished and longitudinally grooved at the plant and then diamond ground or grooved on site as a post installation process.

Saw cutting of longitudinal joints prior to milling is not needed; however, transverse end joints should be sawcut.

The milling width dimension required over-milling by 75 mm to freely accommodate the precast slab. However, the installation process shows a need for only 25 mm of over-milling. With the narrower gap, the temporary longitudinal steel channel is not required.

In addition, the use of the temporary 1 meter long end slab was a success to facilitate the next day's start up.

In order to achieve full production speed, two crews with separate grout mixing equipment are required for the production of dowel grout and bedding grout as the two grouts have different mixing consistency. It was found that grouting slabs in the same night before opening to traffic provided sufficient set time to achieve the required grout strength.

## **8. CONCLUSIONS AND RECOMMENDATIONS**

This pilot project of installing precast concrete inlay slabs on a milled flexible pavement structure was a success. A total of 22 precast concrete slabs using three different slab support systems were successfully placed on three consecutive nights as per schedule. When the base support was prepared, each slab placement took about 10 minutes. At full production speed, 30 to 40 slabs could be placed in an 8 hour construction window.

Based on the post construction data collected to date, the Grout Supported Slab method is slightly superior in terms of load transfer and roughness. However, based on a constructability/cost perspective, the ministry prefers the Asphalt Supported Slab method as the final grading is achievable by the precision milling, and it does not require additional bedding grout. It is recommended that for future projects, the Asphalt Supported method be used incorporating embedded leveling screws in the precast slab as a contingency to correct any grade issues.

Ongoing performance monitoring will be carried out by MTO. Instrumentation installed beneath all trial inlay slabs will be monitored by CPATT in partnership with MTO. Revisions to the specification based on the lessons learned, and standardizing the method of installation is required prior to full implementation.

## **9. REFERENCES**

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2. **Tighe, Dan Pickel and Susanne.** *Precast Concrete Inlay Panel Installation on Highway 400: Construction Report.* Waterloo, Ontario : CPATT, 2017.
3. **Warren Lee, Fiona Leung, Susanne Chan and Becca Lane.** *Falling Weight Deflectometer (FWD) Testing Manual 2016 Edition.* Toronto, ON : MTO, MERO, 2016.

## **10. ACKNOWLEDGEMENTS**

This trial project would not have been completed without the technical input and leadership of Stephen Lee, Head, Pavements and Foundations Section and the support of MTO Central Region Operations and Geotechnical Section, Bill Cung, Head of Geotechnical Section and Fouad Tannous, Geotechnical Engineer.