Short Term Performance of Innovative Precast Concrete Slab Repairs on Highway 427, Toronto

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ABSTRACT

In 2004, the Ministry of Transportation Ontario (MTO) carried out a trial project to evaluate construction techniques for precast concrete slab repairs in concrete pavement. The trial was carried out on Highway 427, in Toronto. The trial project included demonstrations of three precast concrete pavement full-depth repair methods: the Fort Miller Super-Slab™ Intermittent Method, the Fort Miller Super-Slab™ Continuous Method, and the Michigan Method. Each method involves designing and fabricating precast concrete slabs to replace deteriorated concrete pavement. The methods differ in how the base is prepared and how the precast slab is installed and dowelled into the existing concrete pavement. Non-destructive testing using a Falling Weight Deflectometer (FWD) was undertaken after construction to assess load transfer efficiency (LTE) and to detect loss of support underneath the precast slab. Details of the methodologies, site conditions, contract specifications, construction, FWD analysis and post construction monitoring are presented. Based on MTO experiences with this trial contract, a specification has been developed and additional precast work will be carried out in 2007. This is the first construction experience in Canada with innovative precast concrete slab repairs for concrete pavements. MTO will continue to monitor the field performance of these technologies and assess the cost effectiveness of this alternative to full-depth fast-track concrete repairs.

INTRODUCTION

In November 2004, the Ministry of Transportation Ontario (MTO) carried out a trial of three precast concrete pavement slab repair methods to replace deteriorating concrete pavement on Highway 427, a major urban freeway running north-south through the City of Toronto (Figure 1). The three methods evaluated were: the Fort Miller Intermittent and Fort Miller Continuous Super-Slab^{TM} Methods, originating from the Fort Miller Co., Schuylerville, New York; and the Michigan Method, originating from the Michigan Department of Transportation (DOT), Lansing, Michigan.

Figure 1. Location of Highway 427, west end of the City of Toronto, Ontario.

Heavy traffic volumes in the order of 330,000 vehicles per day on Highway 427 mean that repairs to the concrete freeway must be carried out in an overnight lane closure, typically using fast-track concrete mixes. The Ministry decided to evaluate precast concrete slab repairs as an alternative to fast-track concrete mixes which can be temperamental, with questionable long term durability. The advantages of precast slab repairs are thought to be better control over concrete quality, better curing conditions, minimal weather restrictions on placement, and reduced delay prior to opening to traffic.

Since construction of the three precast trials in November 2004, the Ministry has twice carried out non-destructive testing using a Falling Weight Deflectometer (FWD) to assess load transfer efficiency (LTE) and to detect any possible loss of support beneath the precast slab repairs. Annual field reviews were also carried out in 2005 and 2006 to assess performance of the slabs.

This paper outlines the precast concrete slab designs, the site conditions, contract specifications, construction, the results of FWD analysis, and the short-term performance of the three methods of precast slab repair.

BACKGROUND

Pavement History

Highway 427 is a 12-lane core-collector divided freeway, originally constructed between 1968-71. The concrete pavement had not received significant rehabilitation since it’s original construction. The existing pavement structure consists of approximately 230 mm of jointed plain concrete pavement (JPCP) over 150 mm of cement treated base (CTB). Skewed transverse joints are spaced at intervals of 3.7 m, 4.0 m, 5.5 m and 5.8 m. The transverse joints are dowelled with 32 mm dowel bars spaced every 300 mm across the joint. The pavement lanes are 3.65 m wide with hot mix asphalt shoulders ranging in width from 2.7 m to 3.0 m. Drainage is provided through subdrains and an urban cross-section of curb and gutter.

Pavement Condition

In 2003, the Pavement Condition Index (PCI) ranged from 46 to 58 out of 100. Major distresses included severe to very severe joint-stepping (50-80%), severe joint failures (10-20%), severe joint and crack spalling (10-20%), severe to very severe cracking (20-50%), and severe to very severe joint sealant loss (20-50%). Since construction, reactive (unscheduled) maintenance activities have included some full depth and partial depth concrete pavement repairs, asphalt pavement repairs, and diamond grinding to restore pavement friction and improve ride.

Traffic Volumes

The 2006 Annual Average Daily Traffic (AADT) was approximately 322,330 (two directions), with 8% commercial vehicles. Prior to rehabilitation in 2004, the highway has carried approximately 58 million Equivalent Single Axle Loads (ESALs) in the express lanes and 39 million ESALs in the collector lanes.

Design Considerations

Highway 427 is a major north-south commuter route through the City of Toronto. Due to the heavy traffic volumes, the Ministry’s Traffic Section requires that repairs to the freeway be carried out during overnight lane closures, the typical window being 11:00 pm to 5:00 am. Repairs to the highway are typically fast-track concrete repairs or in an emergency, hot mix patches.

The Ministry recognizes that fast-track concrete repairs are not ideal. They may be problematic to construct, they have a restricted time frame in which they can be constructed (May 1 – October 15), they require the use of autogenous cylinders and a maturity meter to determine opening time, and they may not be giving the desired life expectancy of 15 years.

Hot mix patches, used in emergency situations such as joint blow-ups or badly cracked and moving slabs, provide only a temporary fix, and contribute to a loss of connectivity between the concrete pavement slabs. It would be useful to have an alternative emergency repair method available to provide fast, high quality concrete repairs with good long-term performance.

For these reasons, the Ministry decided to investigate the possibility of using precast concrete slab repairs. The advantages to precast repairs would be better quality concrete, ideal curing conditions, minimal weather restrictions on placement and no wait time for the concrete to cure prior to opening to traffic.

PRECAST CONCRETE PAVEMENT METHODS

The Ministry decided to evaluate three different precast concrete pavement repair methods: the Michigan Method, the Fort Miller Super-Slab™ Intermittent Method, and the Fort Miller Continuous Super-Slab™ Method. The three precast methods all involve designing and fabricating precast concrete slabs to replace sections of deteriorated concrete pavement. The methods differ in how the underlying base course is prepared and how the precast slabs are installed and dowelled into the adjacent concrete.

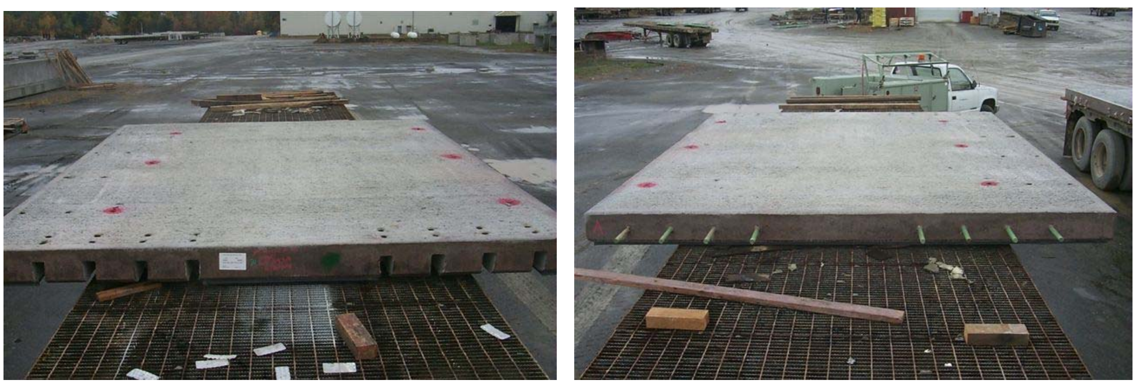
Michigan Method

In the Michigan Method, 2 m long by full lane width concrete slabs are fabricated off-site with three dowel bars per wheel path cast into the slabs at 300 mm spacing (Figure 2). To install the precast slabs, the deteriorated concrete pavement is first removed by sawcutting the perimeter and lifting out the concrete. Slots are then cut into the existing pavement to accommodate dowel bars cast into the slabs. The underlying base may be partially excavated with a backhoe to accommodate the precast slab. A cementitious flowable fill levelling material is placed on the base prior to setting the precast slab. Once the slab is set, the exposed dowel bars are grouted in their slots to connect the precast slab to the adjacent concrete pavement.

Figure 2. Fabricating Michigan Method slabs.

Fort Miller Intermittent Method

In the Fort Miller Intermittent Method, 2 m long by full lane width concrete slabs are fabricated off-site with block-outs cast into the slabs to accommodate four dowel bars in the wheel paths (Figure 3a). In the same manner as the Michigan Method, the deteriorated concrete pavement is removed by sawcutting the perimeter and lifting out the concrete. The underlying base may be partially excavated with a backhoe, then crusher screenings are placed on the existing base, precision graded and compacted. Four dowel bars per wheel path at 300 mm spacing are drilled and epoxied into the adjacent concrete. Once the slab is set, the dowel bars are grouted through ports in the precast slab to connect it to the adjacent concrete. Finally, bedding grout is injected through interconnected ports and channels in the bottom of the slab to fill any voids beneath the concrete.



a. b.

Figure 3 a) Four block-outs per wheel path are cast into the Fort Miller slabs **b)** dowel bars and block-outs are cast alternately into Fort Miller Continuous slabs.

Fort Miller Continuous Method

In the Fort Miller Continuous Method, dowel bars and block-outs are cast alternately into a set of 4 m long by full lane width concrete slabs, which fit together like puzzle pieces (Figure 3 a & b). Following removal of a continuous section of deteriorated concrete pavement, the underlying base may be partially excavated with a backhoe, then crusher screenings are placed on the existing base, precision graded and compacted. The first slab and last slab placed are dowelled into the existing pavement at each end of the excavation, in between the slabs are connected to each other. All slabs in the continuous repair are tied into the adjacent lane with drilled and epoxied tie bars. Once the slabs have been set, the dowel bars and tie bars are grouted through ports in the precast concrete slabs to connect the slabs to the existing pavement and to each other. Finally, bedding grout is injected through interconnected ports and channels in the bottom of the slabs to fill any voids beneath the concrete.

PRECAST CONCRETE PAVEMENT TRIALS

Three different precast concrete pavement trials were incorporated into Contract 2004-2002 on Highway 427. Repair locations were all in the northbound express, lane 3 (truck lane). Express lanes were selected to allow a full closure of the Express during construction of the trials. Overnight traffic northbound was readily accommodated in the Collector lanes.

The Contract specified three individual full depth precast concrete slab repairs, each 2 m x 3.65 m x 230 mm, to be carried out using the Fort Miller Intermittent Method and the Michigan Method. At a third location, a 25 m x 3.65 m x 230 mm trial section of the Fort Miller Continuous Method was also carried out.

Concrete Mix Design

The precast concrete slabs were required to meet a minimum compressive strength of 30 MPa at 28 days. The contract specified that the air void parameters of the hardened concrete be a minimum air content of 3% and have a maximum spacing factor of 0.200 mm. Aggregates used in the mix were required to meet Ministry specifications for physical properties and gradation. The nominal maximum size of the coarse aggregate was 19 mm.

Finishing

Before initial curing and protection of the concrete, the plastic surface of the precast concrete slab was required to have an initial and final texturing. Initial texturing was carried out using a longitudinal burlap dra. Final texturing was transverse tines 3 mm ± 1 mm wide, on 16 mm ± 3 mm centres, with a tine depth of 4 mm ± 1 mm (Figure 4). Tining was required to extend to within 75 mm ± 15 mm of the edge of slab. The surface was required to be free from displaced aggregate particles and local projections.

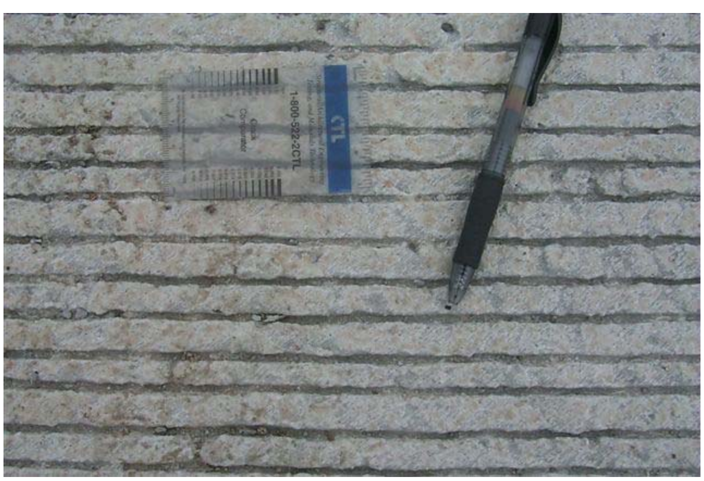


Figure 4. Transverse tining was the required surface texture.

Surface Tolerance

Specifications required that the surface of the precast concrete slab repair meet flush with the existing concrete pavement. Surface tolerance of the repair areas was measured with a 3 m long straight edge placed in any location and direction. There could not be a gap greater than 3 mm between the bottom of the straightedge and the surface of the slab. Precast concrete pavement slabs not meeting surface tolerance requirements were to be corrected by diamond grinding at the Contractor's expense.

CONSTRUCTION

Construction was carried out in mid November, beginning with the Michigan Method on Wednesday, November 16, the Fort Miller Intermittent Method on Thursday, November 17, and the Fort Miller Continuous Method on Friday, November 18, 2004. The weather was cool and damp with a temperature of 8ºC and intermittent light rain.

Concrete Removal

Concrete removal was carried out in the same manner for each method. The Contractor used a template to precisely delineate the areas to be removed and repaired. The outer limits of the concrete removal area were sawcut full depth and the specification required that sawcuts not extend by more than 250 mm into the adjacent concrete. Overcuts were to be filled with a proprietary product acceptable to the Ministry.

The Contract Documents allowed sawcutting up to one week in advance of the expected date of repair. The Contractor was concerned that sawcutting in advance of the repair would disturb the base material and perhaps cause the damaged slab to settle or rock. The Contractor made the decision to sawcut the night before each repair. Dual transverse cuts were made for ease of removal.

The specification required that concrete removal be carried out without damaging the adjacent concrete or disturbing the underlying base. Heavy breaking equipment such as a hoe ram was not permitted. Removal of the existing concrete was carried out using a backhoe. The Contractor first removed the double sawcut sections with a small hoe. The removal of this small section allowed a large grappling bucket to lift the existing concrete out. The Contractor also removed a 100 mm wedge of the adjacent hot mix shoulder to facilitate the removal. This area was later repaired with cold mix.

Base Excavation

The precast design concept set out in the Contract Documents did not require excavation of the CTB. It was presumed that once the concrete pavement had been removed, a leveling course would be placed directly on the undisturbed CTB prior to placing the precast slab. In the Michigan Method, flowable fill would be used and in the Fort Miller Methods, crusher screenings would be used to set the slabs. This concept works only if the precast slabs are thinner than the existing concrete. On this trial project, the Contractor precast the Michigan Method slabs to the exact dimensions 2 m x 3.65 m x 230 mm. Fort Miller slabs were precast 215 mm thick. Coring later revealed that the existing concrete pavement, which had been diamond ground the previous year, ranged in thickness from 200 – 230 mm. It became apparent that the CTB would need to be partially removed to allow for placement of the required leveling material and the precast slab. The Contractor brought in a large backhoe with a welded plate to scrape off the CTB to the required depth.

MICHIGAN METHOD

Dowel Bar Slots

Dowel bar slots were marked out and sawcut the previous night. Triple cuts were made at each dowel bar location, providing for three dowel bars in each wheel path. These were all over-cut significantly. Contract documents specified that hand held chipping hammers with a maximum weight of 9.0 kg and a maximum piston stroke of 102 mm be used to excavate the slots, to reduce damage to the adjacent concrete. Unfortunately, heavier jackhammers were used, resulting in spalling and cracking around the dowel slots. The dowel bar slots were excavated within minutes using jackhammers. Since removal of the dowel slots was not the controlling operation, more time should have been taken to carefully excavate the slots with chipping hammers and more thoroughly clean out the slots. Dowel bar slots were blown out with compressed air but it was still possible to remove dried slurry from the slots, which may have had a detrimental effect on bonding.

Base Preparation

The Michigan Method uses a flowable fill as a leveling material over the existing base. The specifications required a flowable fill consisting of a mixture of Portland cement (Type 10 cement conforming to CSA A 3000), ground granulated blast furnace slag (optional), granular material (fine aggregate meet the requirements of OPSS 1002 with a maximum aggregate size of 12.5 mm), fly ash (conforming to CSA A 3000), water, and air entraining admixture (optional). The compressive strength requirements of the flowable fill mixture were not less than 0.35 MPa at 3 days, nor less than 0.50 MPa and not exceeding 1.0 MPa at 28 days. The flowable fill is meant to be self-leveling when placed. The mix that arrived on site was fairly viscous, with the consistency of cake icing. It was entirely a sand mix, with no coarse aggregate, and required approximately 2 hours to set.

The flowable fill was placed in the excavation, raked evenly into all areas, then screeded off to a depth of 230 mm using a full lane width leveling screed that ran along the longitudinal joint between lane 2 and 3, and the shoulder. A few passes of the leveling float allowed the Contractor to achieve a smooth and even surface on the flowable fill, although the fill was higher at the edge of lane 2 than at the edge of pavement due to cross-fall in the shoulder.

Slab Placement

The Michigan slabs were lowered by crane onto the flowable fill with all 12 cast-in dowel bars fitting into the sawcut slots. The removal areas were larger than the precast slabs, with at least 25 mm clearance around the slabs. The first slab was placed slightly high. The contractor attempted to drive heavy equipment over the slab to settle it deeper in the flowable fill, but the slab was set. The end result was a slightly high spot on the leave edge of the slab.

Grouting

The grout (HD-50) was mixed on site and poured manually into the dowel slots from the small mixing unit. The grout was thin and watery, no vibration was used, and there was no curing compound, plastic or blankets. The grout required 3 hours to set, which meant that the first slab would have the required 3 hours curing time but the next two slabs would not (without an extension of the 5:00 am opening to traffic). The Contractor was required to cast grout cubes and complete testing before opening to traffic. Strength test results were 21 MPa in 3 hours.

Observations

All three Michigan Method slabs were placed between 10:00 pm and 3:00 am. The second slab was the best of the three slabs, being flush with the existing concrete pavement. The other two slabs sat slightly higher than the existing concrete. These slabs required diamond grinding to meet surface tolerances.

Excavation of the dowel bar slots was not carried out with a desirable level of care. Dowel bars were not centered in the dowel slots and where the dowel bars were resting against the walls or base of the dowel slots it would be difficult to get full encasement with grout. Some of the dowel bar slots were spalled down to the base and there were also cracks extending from some dowel slot removal areas into the existing concrete. This method requires good workmanship to ensure that the removal area is precisely delineated and the dowel bars slots are carefully chipped out without damaging the existing concrete.

Figure 5. Construction sequence for Michigan Method precast slab installation: a) perimeter sawcuts and sawcuts for dowel slots made the previous night, b) removal of dowel slots by jackhammer, c) scraping of CTB using a modified backhoe bucket, d) placement of flowable fill, e) lowering of precast slab, and f) final product (slab 3).

FORT MILLER INTERMITTENT METHOD

Base Preparation

The Fort Miller Method uses crusher screenings for leveling material beneath the precast slabs. Aggregate for base preparation was required to be 100% crushed fine aggregate, with a plasticity index of 0% according to LS-704 and a maximum micro-Deval abrasion loss of 35 according to LS-619.

The crusher screenings were placed, then screeded with the Contractor's full lane width leveling screed working off the longitudinal joint between lanes 2 and 3, and the shoulder. Crossfall on the shoulder meant that the crushed screenings were higher at the edge of lane 2 than at the edge of pavement due to cross-fall in the shoulder. A plate-packer was used to compact the fine aggregate base.

Installation of Dowel Bars

In the Fort Miller Intermittent Method, dowel bars are drilled into the existing concrete. The precast slabs have block-outs to allow the slabs to be placed over the protruding dowel bars. A gang-drill consisting of four independently powered pneumatic drills was used to drill four dowel bars per wheel path. The location of the dowel bars was accurately marked with a template. The dowel bar slots were then blown out and epoxy adhesive was used to secure the dowel bars.

Slab Placement

A crane was used to lower the precast slabs in place. The first two slabs matched flush with the existing concrete pavement. The third precast slab was placed low. The slab was lifted out and screenings were added, however because the dowel bars were installed, the leveling float and plate packer could not be used. The third slab was eventually levelled and met flush.

Grouting

In the Fort Miller Method, the dowel bars are grouted through ports in the precast slab. Grouting of the dowel bars was carried out with a manually operated grout pump. The grouting operation was slow. It was decided not to grout the third slab, due to problems with a clogged grout hose. The grouting was carried out the next night. Bedding grout is also required for the Fort Miller Method, to ensure that there are no voids beneath the slab. Bedding grout was injected the following night through ports in the concrete slab.

Observations

The ride over all three Fort Miller Intermittent slabs is good, although the third slab, which was not grouted, did settle slightly overnight.

Figure 6. Construction sequence for Fort Miller Intermittent precast slab installation: a) using full lane width leveling screed to fine grade crusher screenings, b) compacting crusher screenings using plate packer, c) dowel bars installed, ready to place precast slab, d) lowering precast slab, e) grout pump for grouting dowel bars, and f) final product, prior to grouting.

FORT MILLER CONTINUOUS METHOD

Installation of Dowel Bars and Tie Bars

The Contractor used a gang-drill to install dowel bars and the north and south ends of the 25 m excavation. The drill holes were blown out with compressed air. Dowel bars were secured in the drill holes with epoxy adhesive. Longitudinal tie bar locations were drilled individually. The Contractor measured the depth at each tie bar location to ensure the tie bars would fit into the block-outs in the precast slabs.

Slab Placement

The six precast slabs which make up the 25 m long continuous slab replacement arrived on site by flat bed truck and a crane was used to lower the slabs in place. The first slab was placed too low, with a gap of 35 mm between the slab and the existing concrete.

The crane placed the second slab with a 35 mm to 50 mm gap between slab 1 and 2. It became apparent that the Contractor was intentionally spacing the slabs 35 mm apart. After some discussion, it was agreed that the slabs needed to be placed closer together. The second slab was lifted and placed with an 8 mm gap between slabs 1 and 2. The gap between the second slab and the existing lane 2 was variable (5 mm at approach end, 35 mm at leave end), and the second slab was higher than the first slab by about 12 mm at the approach side near the shoulder.

Three attempts were made to place the third slab, which would not sit flush with the longitudinal joint between lanes 2 and 3. The fourth and fifth slabs were placed without incident. Due to over-excavation, a gap of 180 mm was left between slab 6 and the existing concrete. The Contractor mixed grout with pea gravel to temporarily fill the gap. This area was repaired in 2005 with a fast-track repair.

Grouting

Grouting of the dowel bars and tie bars was carried out using an automatic grout pump. The HD-50 grout flowed well and the grouting operation was very fast. The grout was pumped in through one grout port and quickly flowed out of the other. The grouting of the dowel bars and tie bars at the first slab took only 5 minutes. Grouting of all six of the slabs took less than an hour.

Midway through grouting the continuous slab repairs, the Contractor ran out of HD-50, and switched to CPD rapidcrete. Test results on the CPD rapidcrete gave 28.8 MPa at 3 hours (20 MPa at 2 hours).

Observations

The ride over the six Fort Miller Continuous slabs is uneven. The slabs do not match flush with each other and do not meet surface tolerance requirements. Diamond grinding would improve the ride.

Figure 7. Construction sequence for Fort Miller Continuous precast slab installation: a) placing screenings, b) compacting, c) gang-drilling dowel bar locations, d) fixing dowel bars with epoxy adhesive, e) lowering precast slab, f) 180 mm gap between slab 6 and existing concrete.

DISCUSSION AND RECOMMENDATIONS

The overall assessment of the Ministry is that the precast trials went well. The work was carried out within the required timeframes, and the slabs seem to be performing well. The precast repairs are similar in both ride and appearance to fast-track repairs along the same section of highway. Surface tolerances were not met and diamond grinding would improve the ride.

Workmanship issues were identified, such as over-cutting, cracking and spalling of the adjacent concrete pavement. However, the work was undertaken by a Contractor carrying out precast repairs for the first time and under difficult conditions: night work in cold, wet weather with a 6-hour work window. Some of the issues and recommendations to improve construction practices are:

- Ministry standard practice does not allow the Contractor to over-cut when sawcutting for removal. The specification for this work allowed over-cuts up to 250 mm for both the perimeter cuts and the dowel bars slots. The relaxed specification resulted in over-zealous sawcutting and poor workmanship.

- When chipping out the dowel bar slots for the Michigan Method, spalling and cracking occurred. The contract specified the use of light-weight chipping hammers, but jack-hammers were used. Since the dowel bar slots are crucial to performance of the slabs, more time should have been taken to carefully excavate the slots with chipping hammers and thoroughly clean the slots.

- Gang saws, like those used for dowel bar retrofit, are recommended for sawing dowel bar slots in the Michigan Method. A template is also required to mark out the dowel bar slots to ensure that dowel bars fit and are centered in dowel bar slots.

- Excavations for existing concrete removal were typically larger than the precast slabs, resulting in a 25 mm gap around the slabs. The excavation for the continuous method was 180 mm longer than required, leaving a large gap between the precast slab and existing concrete. Tighter tolerances on size of the removal area are needed.

- The base preparation method was not accurate enough to place the slabs to meet surface tolerances. Precision grading is recommended.

- Existing concrete varied in thickness throughout the Contract. The actual thickness of concrete pavement at each location may need to be verified prior to precasting each repair. Alternately, the precast slabs could be cast thinner than the existing concrete pavement to accommodate fine grading material beneath the slab. It would be advantageous to avoid excavating the base to accommodate the precast slab.

- An automatic pump is recommended for the grouting operations.

FALLING WEIGHT DEFLECTOMETER TESTING

Post Construction FWD Testing

FWD testing was carried out shortly following construction, on November 22, 2004, at each precast slab to determine the load transfer efficiency across the transverse joints. Three FWD measurements were taken at the approach and leave joint of each slab, in the left wheel path and between wheel paths (12 tests per slab). Contract Documents indicated that precast slabs with FWD results of less than 70% LTE should be rejected. Results of the FWD testing are presented in Table 1.

Table 1. Results of FWD Testing of Three Precast Pavement Trials, Nov. 2004

Method	**Slab**	**Left wheel path**		**Between wheel paths**		**Avg for slab**
		LTE	# < 70%	LTE	# < 70%	LTE
Michigan Method	slab 1	90	0	66	7	78%
	slab 2	92	0	73	5	82%
	slab 3	94	0	70	6	82%
	avg	92		70		81%
Fort Miller Intermittent Method	slab 1	82	0	76	2	78%
	slab 2	91	0	85	0	88%
	slab 3	83	2	76	2	79%
	avg	85		79		82%
Fort Miller Continuous Method	slab 1	78	3	74	0	75%
	slab 2	86	0	84	0	84%
	slab 3	87	0	87	0	87%
	slab 4	83	0	76	1	79%
	slab 5	76	2	68	3	72%
	slab 6	91	0	90	0	90%
	avg	83		80		81%

Only Fort Miller Intermittent slab 2 and Fort Miller Continuous Slabs 2, 3 and 6 fully met LTE requirements. However, if the FWD tests are averaged at each location, then all the slabs have acceptable LTE in the left wheel path and only two slabs (Michigan Method slab 1 and Fort Miller Continuous slab 5) fail in between the wheel paths.

For the Michigan Method, all tests in the left wheel path met the criteria of >70% LTE, but between wheel paths, only half of the tests passed (18/36). Of the three methods, the Michigan method had the best load transfer, in the left wheel path (92.2%). This could be because the dowel bar slots were open and could be readily grouted to encase the dowel bars. None of the tests in the wheel path gave < 70% LTE. Of the three methods, the Michigan method had the worst load transfer between wheel paths. This could be because the Michigan method used only three dowel bars per wheel path, whereas the Fort Miller method used 4 bars in each wheel path, giving more effective load transfer across the joint.

The Fort Miller Intermittent slabs seemed to give slightly better LTE than the Fort Miller Continuous slabs. This may be because the intermittent slabs are tied into existing concrete on either side, whereas the continuous slabs are connected to each other.

Based on the average FWD results meeting the minimum requirement of 70% LTE, the precast slabs were not rejected. The Ministry typically specifies 32 mm dowel bars across the transverse joints at 300 mm spacings. FWD testing supported the need to dowel all the way across the joint rather than just in the wheel path.

Follow up FWD testing

FWD testing was carried out again on June 1, 2005, in the year after construction. The FWD testing was carried out in the left wheel path, between wheel paths and right wheel path of the approach and leave of each precast slab. Twelve FWD tests carried out at each precast slab. The FWD results are presented in Table 2.

Table 2. Results of FWD Testing of Three Precast Pavement Trials, June 2005

Method	Slab	Left wheel path		Centreline		Right wheel path		Avg for slab
		LTE	# < 70%	LTE	# < 70%	LTE	# < 70%	
Michigan Method	slab 1	84	0	92	0	98.9	0	91%
	slab 2	42	8	62	9	88.6	0	64%
	slab 3	N/A	N/A	72	6	N/A	N/A	N/A
	avg	**63**		**75**		**94**		**77**
Fort Miller Intermittent Method	slab 1	40	11	100	0	101	0	80%
	slab 2	36	12	45	12	60	11	47%
	slab 3	62	7	57	9	57	10	59%
	avg	**46**		**68**		**73**		**62**
Fort Miller Continuous Method	slab 1	42	6	56	6	94	0	64%
	slab 2	76	0	94	0	100	0	90%
	slab 3	78	1	83	0	101	0	87%
	slab 4	82	0	91	0	87	0	87%
	slab 5	89	0	84	0	86	0	86%
	slab 6	79	1	84	1	79	1	81%
	avg	**74**		**82**		**91**		**82**

From these FWD results, taken in the second year following construction of the precast trials, it is interesting to note that the Fort Miller Continuous Slabs continue to give good load transfer efficiency. In particular, slabs 2 through 5, which are only connected to each other are providing the best load transfer.

Based on an FWD minimum requirement of 70% LTE, the Fort Miller Continuous Slab replacement continue to provide good load transfer, however only Michigan Method slab 1 and Fort Miller Intermittent Method slab 1 are performing well.

FIELD REVIEWS

Field reviews were carried out in June 2005 and in May 2006 to observe the performance of the three precast trials.

Michigan Method

The Michigan Method slabs were found to be in excellent condition (Figure 8), however failures were observed in some areas of the grouted dowel bars slots.

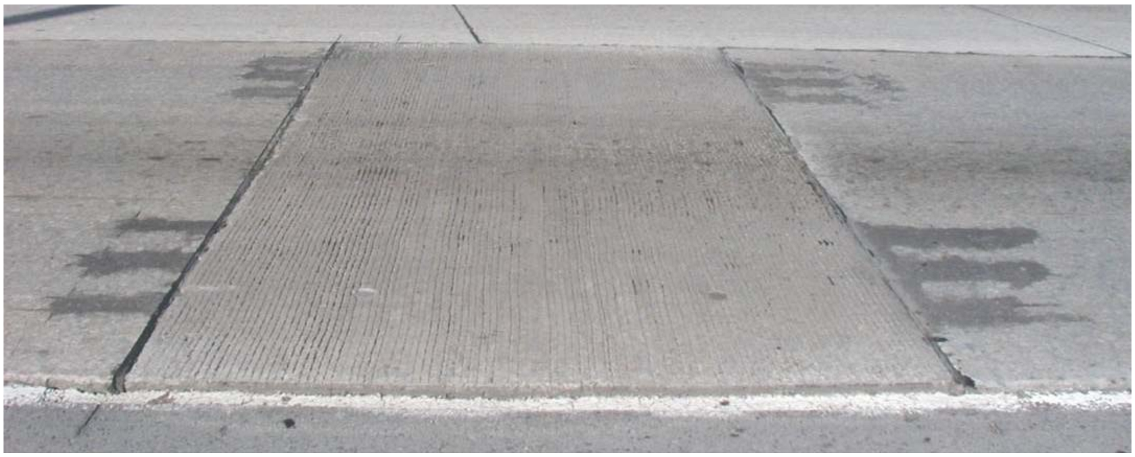


Figure 8. Michigan Method precast slab, May 2006.

Dowel slots showed some cracking and spalling and in some instances the dowel bars were exposed. Figure 8 shows a crack, which appeared during construction near a dowel bar slot in slab 2. By June 2005, the crack had progressed to block cracking in the dowel slot, with spalling of the dowel slot observed in May 2006.

a. **b.** **c.**

Figure 9. Michigan Method Slab 2 **a)** during construction in November 2004 **b)** June 2005 at one-year field review **c)** May 2006 in second year field review.

It is likely that cracking and spalling at the dowel bar slots is the direct result of the removal method, which included over-cutting the slots and jack-hammering to remove concrete from the slots. The Ministry is confident that an improved method of excavating the slots, such as use of gang-saws, light-weight chipping hammers and sand-blasting to clean the slots will improve performance of the Michigan Method.

Fort Miller Intermittent Method

The Fort Miller Intermittent Method slabs are performing very well (Figure 10). In the June 2005 field review no defects were observed in any of the intermittent slabs. In the May 2006 field review, the only distress that could be detected was very minor cracking a few locations over the dowel bars (Figure 11).

Figure 10. Fort Miller Intermittent Method precast slab, May 2006.

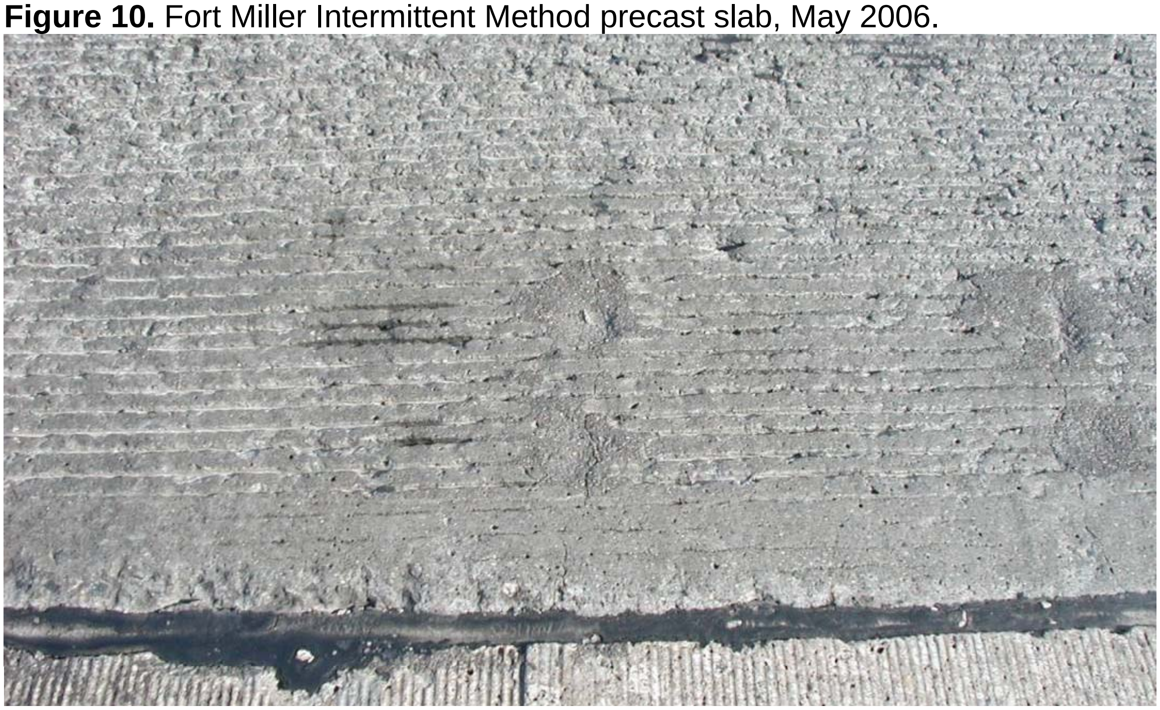


Figure 11. Slight cracking over dowel bars in Fort Miller Intermittent slab.

It is likely that the slight cracking at a few dowel bar locations in the Fort Miller Intermittent slab repairs was caused by non-uniform support beneath the slab. In the cracked areas, the slabs may be resting on the dowel bars due to poor base excavation and levelling practices during construction.

Fort Miller Continuous Method

The Fort Miller Continuous Method slabs are performing very well (Figure 12). No cracking or spalling was observed in any of the six continuous slabs during the June 2005 and May 2006 field reviews. The gap resulting from over-excavation during concrete removal at the end of the continuous slab replacement area had been repaired with a fast track concrete repair and was performing well.

Figure 11. Performance of Fort Miller Continuous Slab repairs, May 2006.

CONCLUSIONS

This was the first construction experience in Canada with innovative precast concrete slab technology for repairs to concrete pavements. The overall assessment of the Ministry is that the precast trials went well. The precast slabs did not crack, spall or rock. The FWD results met the minimum requirement of 70% LTE. Other than workmanship issues, the work was carried out within the required timeframes.

The precast repairs are similar in both ride and appearance to fast-track repairs along the same section of highway. The surface tolerances were not met, and diamond grinding will improve the ride.

Workmanship was a concern, however this work was undertaken by a Contractor carrying out precast repairs for the first time and under difficult conditions, including night work, in cold wet weather, with a 6-hour work window.

MTO will continue to monitor the field performance of these innovative precast technologies and assess the cost effectiveness of this alternative to full-depth fast-track concrete repairs.

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