Precast Concrete Panel Systems for Full-Depth Pavement Repairs

Field Trials

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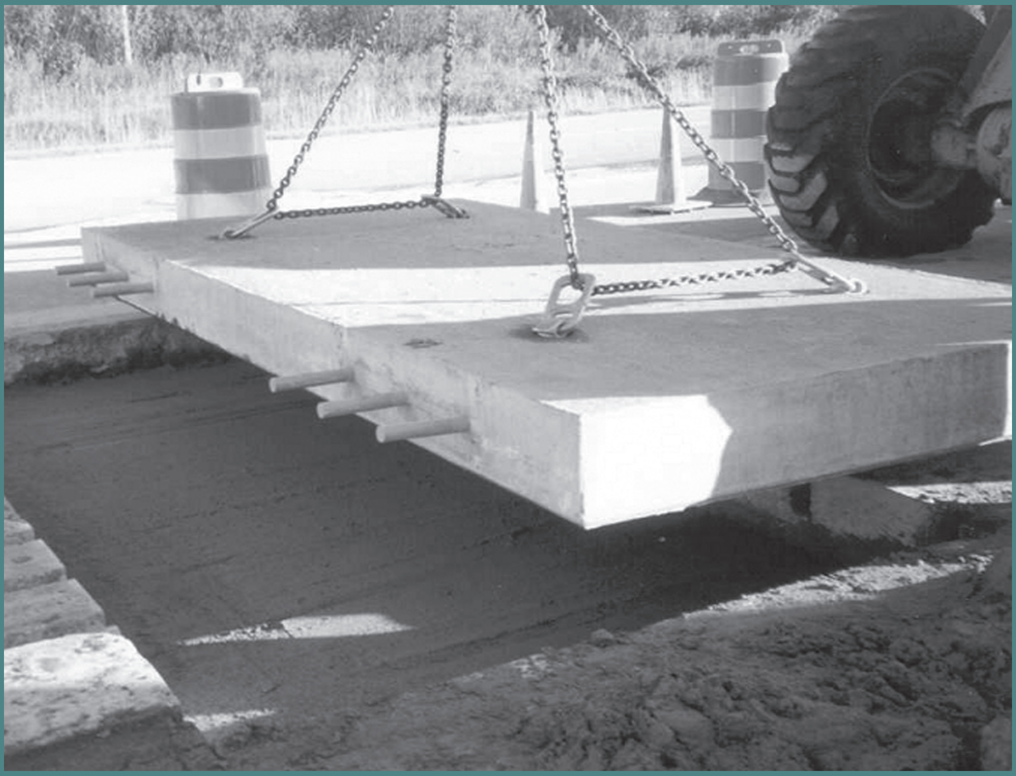

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16. Abstract

The use of precast slabs as an alternative to conventional cast-in-place repairs may be an effective means of reducing construction time, thereby minimizing user delay and travel costs while obtaining a long-lasting, durable repair. This report summarizes the 3-year study, "Field Trials of Concrete Pavement Product and Process Technology—Precast Concrete System for Rapid Repairs," in which precast slabs were used for joint repair and slab replacement on in-service Michigan and Colorado highways. Cast-in-place, full-depth patches were installed as controls. The report contains a summary of the relevant literature; summaries of the field trials and their findings regarding efficiency and durability; recommendations for precast panel installation; a sample distress documentation report; a presentation of construction guidelines; and a sample special provision specification developed as part of the study. Recommendations for consecutive slab repairs are to reduce slab length; use a slab thickness of 200 mm or greater; use dowels to connect precast panels to existing panels for joint flexibility and load transfer; maximize proximity of repair sections when planning and encourage multitasking during panel installation to reduce construction time. For isolated repairs it is recommended that four dowel bars be placed in the wheel path and provide an expansion cap at one end of the dowel bar to accommodate slab movement due to environmental loading and prevent closing of the joint.

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CHAPTER 1. INTRODUCTION

BACKGROUND

The traditional practice of rehabilitating concrete pavements is an excellent way to extend the remaining service life of the overall pavement network. In most instances, this method of paving has satisfied the requirements of the specifying agency. However, the luxury of prolonged lane closures is an option whose time is long gone. Increasing traffic volumes and sensitivity to user delays and costs have required pavement construction and rehabilitation to be put on a “fast track” as much as possible. The objective of fast-track paving is to minimize the time a roadway is out of service (Federal Highway Administration [FHWA] 1994). The resulting pavement can be opened to traffic (both construction and public) after adequate strength has been achieved. Fast-tracking has resulted in the use of chloride accelerators in combination with increased cement content to accommodate the short traffic opening times. These modified mixtures are susceptible to durability problems.

Precast structural elements have long been used successfully in the building and bridge industry. The authors of this study investigated the feasibility of doweled precast panels as an alternative full-depth repair strategy. The use of doweled precast panels provides an attractive alternative that can potentially address construction time, short-term and long-term concrete durability, and performance issues. The precast panels can be fabricated by using conventional concrete paving mixture designs (without the need for setting- or strength-accelerating admixtures) and cured under controlled conditions if necessary at a precast plant. Such “factory made” concrete is less susceptible to construction and material variability.

OBJECTIVES

The objectives of this study were as follows:

1. Review the literature and document the known practices.
2. Conceptualize various construction alternatives as they relate to precast concrete patches.
3. Identify potential preventative maintenance projects along in-service concrete pavements in Colorado and Michigan, and install precast concrete patches. For the purposes of comparison control, cast-in-place full-depth patches were also installed.
4. Investigate the effectiveness and efficiency of precast patches through the development of maintenance performance guidelines.
5. Recommend strategies for monitoring the “newly” installed precast patches.
6. Produce step-by-step guidelines for the construction of precast concrete patches.

The completion of these objectives is to assist in evaluating the feasibility of precast panels as an alternative to conventional full-depth repair of jointed concrete pavements.

ORGANIZATION OF THE REPORT

This final report, which consists of four chapters, summarizes the findings of the 3-year study. Chapter 2 provides a summary of the literature concerning precast concrete pavements, and Chapters 3 and 4 summarize the Michigan and Colorado field studies, respectively. A sample distress documentation report is presented in Appendix A, a presentation of construction guidelines is presented in Appendix B, and a sample special provision specification developed as part of the study is presented in Appendix C.

CHAPTER 2. SUMMARY OF THE LITERATURE REVIEW

A number of published reports and papers were collected that pertain to the use of precast slabs as pavement repair alternatives since the early 1970s. The summary of the reviewed literature is presented in Table 1.

Table 1. Summary of Reviewed Literature

Source	Location of Construction	Summary of Findings
Bull 1988		A series of laboratory tests on precast concrete slabs was conducted in the United Kingdom to develop a computer design program to study the impact of slab thickness, steel reinforcement, and subbase and subgrade characteristics on the performance of precast slabs.
Correa and Wong 2003		The design and construction practices of full-depth repair were summarized. Full-depth patches are a repair alternative for the following distresses in jointed concrete pavements: low severity (or more severe) blowup, corner break, medium-severity (or more severe) D-cracking, deterioration adjacent to existing repair, joint deterioration, spalling, reactive aggregate, transverse cracking, and high-severity longitudinal cracking. For a standard lane width of 3.6 m (12 ft), the length of the full-depth patch and the remainder are recommended not to be shorter than 1.8 m (6 ft) to provide stability and prevent longitudinal cracking. The length of the patch should also not exceed the length of the existing slab. The use of three dowel bars along each wheelpath was generally found sufficient; however, the use of four or five dowel bars along each wheelpath is recommended for interstate highways. The dowel diameter of 38 mm (1.5 in.) was found to be most cost effective.
Grimsley and Morris 1975	Interstate in an urban area in central Florida	A precast slab was used to replace the entire distressed slab, 3.7 m (12 ft) wide, 6.1 m (20 ft) long, and 200 mm (8 in.) thick. After removal of the existing slab, the precast slab was placed approximately 13 mm (0.5 in.) lower than regular surrounding elevation. The precast slab was slab-jacked to appropriate elevation. The construction caused 8 hours of nighttime traffic closure (10 p.m. to 6 a.m.).
Hachiya et al. 2001	Taxiway at the Sendai Airport, Japan	The construction project was to replace distressed slabs at the Sendai Airport taxiway with a series of pretensioned slabs connected at transverse joints through the application of posttensioning. Each slab was 10 m (33 ft) long, 2.5 m (8 ft) wide, and 240 mm (9.5 in.) thick. An appropriate posttensioning force was applied to prevent joint opening due to typical negative temperature gradients at the construction site. The entire construction process from removal of distressed slab to interconnection of slabs through posttensioning was completed within 10 nighttime hours, from 9 p.m. to 7 a.m. *continued*

Source	Location of Construction	Summary of Findings
Lane and Kazmierowski 2005	Highway 427, Toronto, Canada	The trial project investigated the efficacy of three precast concrete full-depth repair methods along Highway 427 in Toronto. The methods were the Fort Miller Super Slab^{TM} continuous method, the Fort Miller Super Slab^{TM} intermittent method, and the Michigan method. Based on the initial structural evaluation, it was concluded that all joints met the minimum 70% load transfer efficiency requirement. The precast repairs were similar in both ride and appearance to fast-track repairs along the same section of the highway. For acceptable elevation matching it was recommended that the proper preparation of the base layer is very essential.
Merritt, McCullough, and Burns 2003	Frontage road along northbound I-35 near Georgetown, Texas	The study was to demonstrate a construction method to replace the entire distressed portland cement concrete (PCC) pavement system through the use of a prestressed (both pretensioning and posttensioning) system. A series of 200-mm (8-in.) pretensioned precast slabs of varying sizes (pretensioning strands were in the traffic direction) were attached together through continuous shear key. When all pretensioned slabs were positioned, posttensioning strands in the transverse direction were stretched to tighten the slab together and then the posttensioning ducts were grouted. The reduction of the time delay of traffic is the main benefit of the proposed construction method.
Meyer and McCullough 1983	Eastbound of IH-30 near Mt. Pleasant, Texas	The construction was to repair 200-mm (8-in.) continuously reinforced concrete pavements with the use of precast slabs, 3.7 m by 3.7 m (12 ft by 12 ft) and 1.8 m by 1.8 m (6 ft by 6 ft). Polymer methyl-methacrylate was also used in the concrete. The construction process consisted of four steps: destroying the failed slab, removing the failed slab, installing and alignment the precast slab using a wooden frame and a crane, and connecting steel using welding and U-bolts. It was found that the connection of steel may not be necessary if the polymer is used in the concrete. The plan was to evaluate long-term performance of the repairs.
Overacker 1974	Niagara Section of the New York State Thruway, New York	Existing pavements that exhibited high-severity fatigue cracking were replaced with pretensioned precast slabs with slab sizes varying from 3.7 m by 6.1 m by 225 mm (12 ft by 20 ft by 9 in.) to 4.0 m by 9.1 m by 225 mm (13 ft by 30 ft by 9 in.). The construction work was only allowed from 6:30 p.m. to 6:30 a.m. and from 9 a.m. to 3:30 p.m. to avoid traffic congestion during commuter hours. The construction process consisted of three steps: the distressed roadway was sawed and removed, the precast slabs were installed, and the repair areas were overlaid with asphalt concrete.

continued

Source	Location of Construction	Summary of Findings
Sharma 1990	I-90 between STH 30 and USH 18 in Dane County, Wisconsin	Eight different construction variations were used to repair distressed joints. One repair method used precast slabs. The precast patch was 1.8 m (6 ft) wide and 8.5 in. (216 mm) thick and was without any load transfer device. A leveling bed of 13 mm (0.5 in.) of portland cement mortar grout was laid before the precast slab was placed. As compared with sections with load transfer devices, the precast section and other sections without load transfer devices were found to fault more in 5 years.
Simonsen 1971	M-59 about 2.5 miles east of I-96 in Livingston County, Michigan	Four distressed joints were replaced with precast slabs, 3.4 m (11 ft) long, 1.8 m (6 ft) wide and 200 mm (8 in.) thick. Dowel bars were used as a load transfer device for two of the slabs, while epoxy mortar and filler were used in the other two slabs. The construction process consisted of three steps: sawing distressed joints with the use of a propelled saw; removing failed slabs with the use of an air hammer, a crane, and a truck; and installing precast slabs with the use of a drill frame and four screw jacks. The lane closure times were about 3.5 and 2.5 hours for doweled and undoweled sections, respectively. It was found that partial-depth sawing and breaking up the slab with a pavement breaker resulted in undercutting and cracking of the existing slab. The plan was to construct more precast slabs along I-75 – US-23 near Flint in Genesee County, Michigan.
Simonsen 1972	I-75–US-23 west of the Flint in Genesee County, Michigan	This was phase II of the M-59 project. A similar technique was used to repair 24 lane joints with precast slabs. Unlike the M-59 project, this project experienced high traffic volumes where the traffic disruption period was required to be short. All the repairs were 3 m (10 ft) long and 3.7 m (12 ft) wide with varying thicknesses. A crew of seven completed the construction in 2 days. The average times for the entire process from the removal of the distressed slabs to the installation of the precast slabs were 2.5 and 4.25 hours for undoweled and doweled sections, respectively. The problem of traffic control was encountered as no work was permitted for several periods of time. The plan was to evaluate the performance of the repairs under high-volume traffic.
Speir et al. 2001	La Guardia Airport, New York	A feasibility study was conducted to provide preliminary design details for two precast PCC slab construction options and an asphalt concrete approach. The precast options were • conventional plain jointed panels in two sizes (3.8 m by 3.8 m [12.5 ft by 12.5 ft] and 7.6 m by 7.6 m [25 ft by 25 ft]) and slab thicknesses ranging from 30.5 to 40.6 cm (12 in. to 16 in.). • posttensioning of multiple slab panels to provide an effective slab size of 7.6 m by 7.6 m (25 ft by 25 ft). The initial cost of the asphalt concrete option was found to be the lowest among the three construction approaches. However, based on a 40-year life cycle cost comparison, both precast approaches were found to be more cost effective. *continued*

Source	Location of Construction	Summary of Findings
Tyson 1976	Culpeper, Richmond, and Fredericksburg, Virginia	Four full-depth pavement repair procedures were investigated, including rehabilitation by stress relief, cast-in-place restoration, precast replacement, and cast-in-place replacement. Elimination of curing time and potentially better concrete quality were emphasized as two major advantages of the precast procedure over the cast-in-place procedure. The main processes for the precast replacement procedure included precast slab fabrication, pavement removal, and precast slab installation. Since no dowel bars were used, the deflection test using the Benkelman beam was conducted. The results indicated that the precast slabs performed satisfactorily and had about three times smaller deflections than adjacent slabs. Three months after the construction, a precast slab was lifted to investigate the condition of the interface between the underlying mortar and the slab, which was found to be unbonded. It was recommended that the bedding mortar should have a slump exceeding 200 mm (8 in.) to provide uniform seating.

CHAPTER 3. MICHIGAN FIELD STUDY

SITE SELECTION

The test sections for the Michigan field study are located along I-675 in Zilwaukee and M-25 in Port Austin. For the existing portland cement concrete (PCC) pavement, cross section structural details, traffic, and number of panels installed are summarized in Table 2. The site was selected in concert with the Michigan Department of Transportation (MDOT's) Bay and Cass City Transportation Service Center (TSC) personnel.

Table 2. Summary of Precast Panel Test Sites

Project	Route Designation	Joint Spacing	Pavement Thickness	Base Type	Annual Average Daily Traffic (commercial)	No. of Panels Installed
I-675	Principal arterial	21.6 m (71 ft)	225 mm (9 in.)	Dense-graded select base	10,400 (5%)	8*
M-25	Minor arterial	30.2 m (99 ft)			900–4,000 (3–11%)	12

**Nine panels were installed; however, panel 1 is a conventional full-depth repair, and panels 2–9 are precast panels.*

PRECAST PANEL MIXTURE DESIGN AND FABRICATION DETAILS

The precast PCC panels were fabricated by the contractor and transported to the project site. The typical PCC mixture design for this study is summarized in Table 3.

Table 3. Portland Cement Concrete Mixture Designs for the Precast Panels

Mix Ingredients	Design	
Cement	312 kg/m^3	(526 lbs/yd^3)
Water	127 kg/m^3	(212 lbs/yd^3)
Fine aggregate	810 kg/m^3	(1,366 lbs/yd^3)
Coarse aggregate	10,908 kg/m^3	(1,838 lbs/yd^3)
Air-entraining agents	0.59 ml/kg	(0.9 fl oz/cwt)

The contractor was responsible for documenting the fresh and hardened concrete properties. Typical PCC concrete properties are summarized in Table 4. The average 28-day compressive strength based on 18 specimens was 30 MPa (4,300 lbf/in^2).

All panels were 1.8 m (6 ft) long, 3.7 m (12 ft) wide, and 250 mm (10 in.) thick. The precast panels were fitted with three dowel bars 38 mm (1.5 in.) in diameter, 450 mm (18 in.) long, and spaced at 300 mm (12 in.) on center along each wheelpath. Perimeter steel was included (#16 [#5] bars) to resist handling and transportation stresses. Steel mesh (10 mm [0.375 in.] in diameter placed at 150-mm [6-in.] intervals and held together with 6-mm [0.25-in.] ties) was placed at the panel mid depth to resist the potential of early-age cracking. The panels were wet-cured for 7 days using wet burlap covers. The 20 precast panels were stockpiled at the ready-mix concrete supplier's yard. Eight panels were installed at the I-675 site, and 12 were installed at the M-25 site. The typical structural details are illustrated in Figure 1.

Figure 2 summarizes the sequence of the fabrication process followed by the contractor. The standard hardware for lifting the slabs is visible in the figure. Figure 2 also illustrates the location and placement of dowel bars and temperature steel.

Table 4. Fresh and Hardened Property Results for the Portland Cement Concrete Mixture

Test data from June 3, 2003.

Time of Concrete casting	Specimen ID	Air (%)	Slump (in)	Conc Temp (^{0}F	Air Temp (^{0}F)	Age	Flex. Str. (psi)
3:10 PM	A	6.5	2	72	67	43 hrs	533
	B					43 hrs	544
	C						
	D						

Test data from June 6, 2003.

Time of Concrete casting	Specimen ID	Air (%)	Slump (in)	Conc Temp (^{0}F	Air Temp (^{0}F)	Age	Flex. Str. (psi)
3:15 PM	A	7	2.75	72	75	66 hrs	644
	B					66 hrs	688
	C						
	D						

Test data from June 10, 2003.

Time of Concrete casting	Specimen ID	Air (%)	Slump (in)	Conc Temp (^{0}F	Air Temp (^{0}F)	Age	Flex. Str. (psi)
8:55 AM	A	7	2.75	73	62	48 hrs	644
	B					48 hrs	622
	C						
	D						

Test data from June 12, 2003

Time of Concrete casting	Specimen ID	Air (%)	Slump (in)	Conc Temp (^{0}F	Air Temp (^{0}F)	Age	Flex. Str. (psi)
12:50 PM	A	6.5	3	73	65	93 hrs	800
	B					93 hrs	733
	C						
	D						

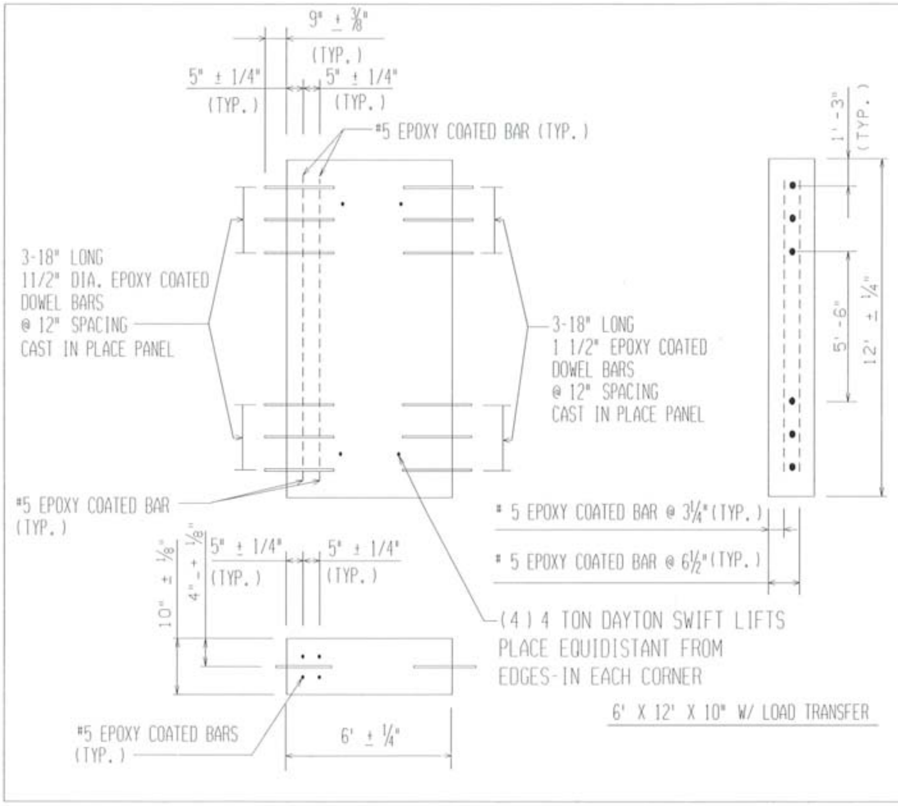
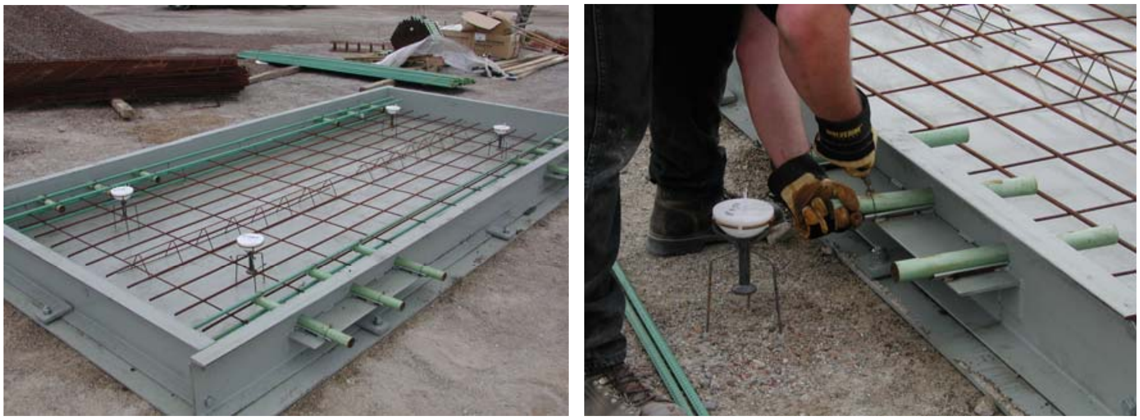


Figure 1. Structural details of the doweled precast panel.



a) Reinforcement and dowel bar placement in the formwork.

b) Concrete placement for precast panels.

c) Texturing of fresh concrete.

d) Curing of precast slabs.

Figure 2. Fabrication of the doweled precast panels.

CONSTRUCTION SEQUENCE

Prior to the removal of the candidate panels, a distress survey was conducted in accordance with the protocol laid out in the LTPP distress identification manual (FHWA 2003). Typical distresses observed during the survey included mid-panel transverse cracks with associated spalling and deteriorated joints with spalling and asphalt patch deterioration. Examples of the typical distresses are shown in Figure 3. During the field visit the distress information was recorded on a distress documentation form (a sample form is presented in Appendix A).

a) Deteriorated joint with cold patch with spalling.

b) Medium-severity transverse crack.

c) High-severity transverse crack.

d) Deteriorated joint with spalling.

Figure 3. Typical distresses.

The sequence of operations for offsite activities and onsite activities for the Michigan field study are listed below:

Offsite Activities

1. Fabrication of the precast panels.
2. Storage of the fabricated precast panels.

Onsite Activities

1. Documentation of distresses.
2. Identifying and marking of the repair boundary.

3. Sawcutting panel boundaries and slab removal.
4. Initial cleaning of the exposed base.
5. Jackhammering of the dowel slots.
6. Air cleaning and sandblasting of the dowel slots.
7. Final cleaning and grade adjustment of the base.
8. Placement of the leveling fill.*
9. Installation of the precast panel.
10. Adjustment of panel elevation with respect to the adjacent panels.
11. Backfilling of the dowel slots.
12. Sealing of joints.

*Step 8 of the construction process does not exist if the precast panel grade adjustment is done using high-density polyurethane (HDP) foam. In that case, after final cleaning and grade adjustment of the base, the precast panel is placed and portholes for injecting the HDP are drilled. The slab elevation adjustment is achieved by injecting the HDP foam.

Descriptions of the activities listed above are presented in the following section of the report. (The types of distresses addressed by the repair strategy and the panel fabrication process, illustrated in Figure 2, are presented above and will not be discussed further).

Sawcutting Panel Boundaries and Removal

The candidate repair sections were identified and marked by the MDOT personnel (Bay City and Cass City TSC). The slab boundaries were outlined by the contractor and sawcut. The limits of the pavement area to be removed were sawed in the transverse direction. Following the sawcutting operation, the lift hooks were inserted and the distressed slabs were removed using a front-end loader. During this process, the outlines for the dowel slots in the adjacent panels were also cut. This concrete was later carved out using pneumatic jackhammers. Figure 4 illustrates the slab sawing and removal process.

a) Sawcutting the existing slab.

b) The existing slab after sawcutting.

c) Removing the existing slab.

Figure 4. Sawcutting of slab boundaries and slab removal.

Initial Base Preparation

For all the panels the aggregate base was excavated 38–50 mm (1.5–2 in.) below the bottom of the existing slab to accommodate the thicker, 250-mm (10-in.) precast panel. At this point all concrete debris from the slab removal operation was removed. Dewatering of the base was not required at any of the project sites. Figure 5 illustrates the base preparation activity.

Figure 5. Initial cleaning and preparation of the base.

Preparation of Load Transfer Slots

As shown in Figure 6, there are three dowel bars in each wheelpath. The dowel slot cutting and preparation include initial grooving to the required depth with a concrete saw; jackhammering of the concrete to carve out the dowel slot; air cleaning of dowel slot to remove debris and any loose concrete pieces; and sandblasting of the dowel slots. The dowel slots were approximately 100 mm (4 in.) wide and 133 mm (5.25 in.) deep (base of the slot cut). Figure 6 illustrates the slot cutting and preparation process.

a) Jackhammering of dowel slots.

b) Debris removal from dowel slots.

c) Sandblasting of dowel slots.

d) Completed dowel slots.

Figure 6. Preparation of the load transfer slots.

The dowel slots were placed at 300 mm (12 in.) on center. The slots are 375 mm (15 in.) from the nearest longitudinal edge (shoulder or centerline). Figure 7 shows a schematic cross section of the dowel assembly.

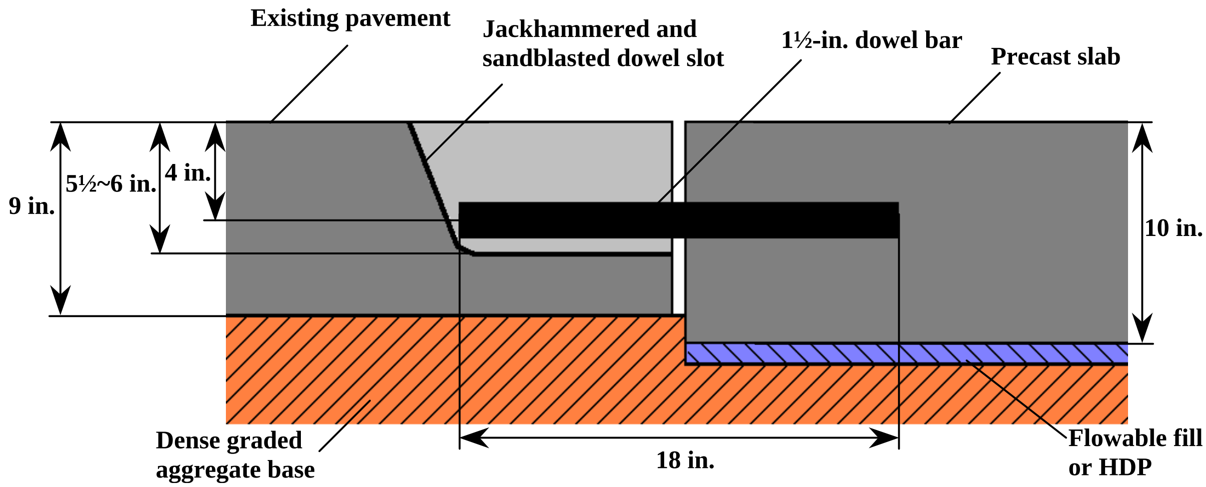


Figure 7. Schematic cross section of the dowel assembly.

Final Grading and Installation of the Precast Panel

This part of the installation process can be achieved by two different methods: slab grade adjustment using HDP foam or slab grade adjustment using flowable fill.

Elevation Adjustment Using High-Density Polyurethane Foam

Once the dowel slots were prepared and a final cleaning and grading of the base prepared the surface for receiving the precast panels, the precast panels were transported from the flat-bed truck to the excavation using a front-end loader. The HDP foam method of slab stabilization was used for 6 panels along the I-675 site and 10 panels along the M-25 site. Approximately 4–6 holes (16 mm [0.625 in.] in diameter) were drilled per panel to inject the foam. The polyurethane foam is made from two liquid chemicals that combine under heat to from a strong, lightweight, foam-like substance. The chemical reaction between the two materials causes the foam to expand and fill the voids. According to the manufacturer's specification, the HDP foam sets in approximately 15 minutes (approximately 90 percent of full compressive strength), and the precast panel is ready to carry load. For the purpose of slab stabilization, the foam density is about 64 kg/m^3 (4 lbs/ft^3) with a compressive strength range of 414 to 1,000 kPa (60 to 145 lbf/in^2).

Once the slab elevations were verified and deemed acceptable, the dowel slots were grouted and the joints were sealed. Figure 8 illustrates the slab installation process.

a) Panel installation.

b) Panel installation and alignment.

c) Drilling of injection portholes.

d) Stabilized slab.

Figure 8. Precast panel installation and stabilization using high-density polyurethane foam.

Elevation Adjustment Using Flowable Fill

Two precast panels were stabilized at each of the test sites using flowable fill. The excavation was 38–50 mm (1.5–2 in.) below the bottom of the existing slab to accommodate the thicker 250-mm (10-in.) precast panel. The flowable fill was transported to the project site in a ready mix concrete and discharged directly into the excavation. Figure 9 illustrates the flowable placement and the backfilling of the dowel slots. The fill was leveled to a depth of 250 mm (10 in.) from the surface of the existing slab. The flowable fill mixture design includes 1,020.6 kg (2,250 lb) of sand, 56.7 kg (125 lb) of cement, 136.1 kg (300 lb) of water, and 118 ml (4 fl oz) of air entraining admixture. The average 28-day compressive strength ranged from 1.0–1.2 MPa (150–175 lbf/in^2). Once the slab elevations were verified and deemed acceptable, the dowel slots were grouted and the joints were sealed.

After the slab was installed and leveled, the dowel slots were backfilled and transverse joints were sealed.

a) Placing of flowable fill.

b) Leveling of flowable fill.

c) Back filling of dowel slots.

d) Back-filled dowel slots.

e) Completed panel.

Figure 9. Flowable fill operation and dowel slot backfilling.

CONSTRUCTION PRODUCTIVITY

The construction productivity metrics include the documentation of time to complete the installation of one panel, list of possible concurrent activities, various equipment used for the installation of the panels, and panel installation crew size. The detailed panel installation activities include the following:

- Slab (existing) demolition—A1.
  - Sawcutting of the repair boundaries.
  - Sawcutting of dowel slot outlines in the adjacent panels.
  - Removal of distresses panel.
- Initial cleaning of the exposed base layer—A2.
  - Removal of debris.
  - Dewatering (if needed).
- Cutting (jackhammering) of dowel slots to specification depth—A3.
- Final cleaning and cleaning of the exposed base—A4.
- Air cleaning and sandblasting of the dowel slots—A5.
- Placement of the precast panel and final alignment—A6.
- Drill holes for the high-density polyurethane foam and inject foam to stabilize and level the slab—A7.
- Grout dowel slots and lift hook holes—A8.
- Seal joints and open to traffic—A9.

Typical individual times, labor requirements, and equipment needed to execute the activities listed above are summarized in Table 5. Based on the proximity of the candidate panels to each other, construction activities A2–A7 can be performed somewhat concurrently, resulting in increased productivity.

Table 5. Typical Construction Time, Labor, and Equipment Needs

Activity Code	Time, minutes	Recommended Equipment (labor needs)
A1	60	Concrete saw (1), front-end loader (1 operator)
A2	5	Nothing specific (2)
A3	20	Pneumatic jackhammers (2)
A4	15	Plate compactor (1)
A5	21	Sandblasting equipment (2)
A6	20	Front-end loader (1 operator, 3 additional to guide the alignment)
A7	25	Drills and high-density polyurethane injection equipment (2)
A8	26	Grout mixer (2)

Construction Activities—I-675

For the I-675 project, all nine panels were installed in 1 day under the same traffic control due to the close proximity of the panels. Figure 10 illustrates the relative location of the precast panels. Figure 11 illustrates the timeline (typical) for the installation of panel 5.

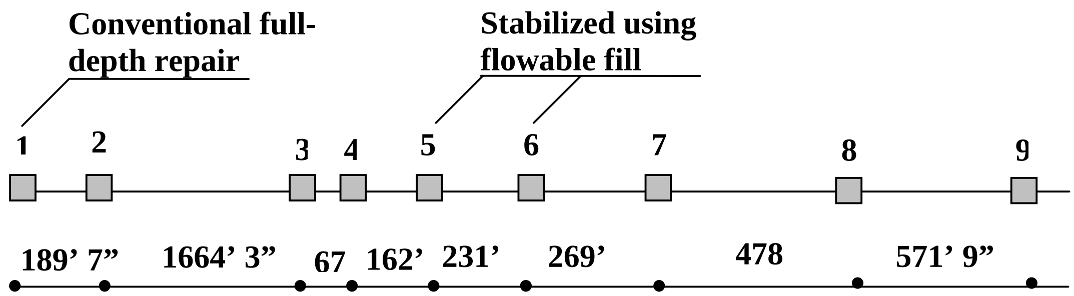


Figure 10. Relative distances of patches along the I-675 project.

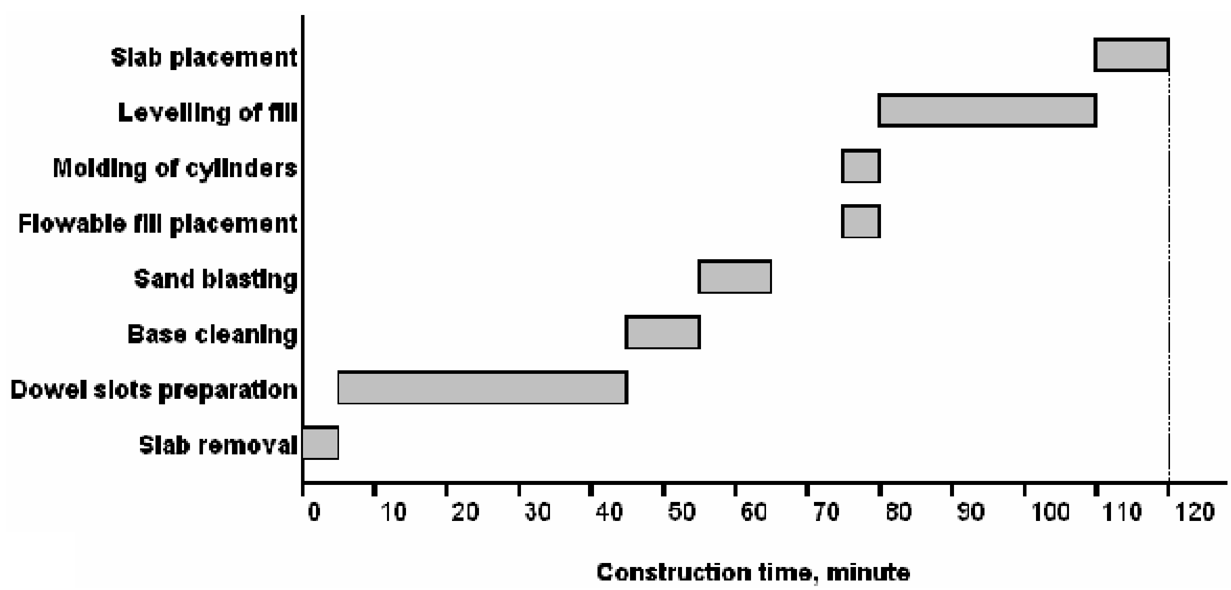


Figure 11. Construction timeline for panel 5.

The total time required to install the panel was less than 120 minutes. The two most time-consuming activities were the preparation of the dowel slots and adjustment of the panel elevation with respect to the existing concrete pavement. The dowel slot-cutting time can be shortened by reducing the dimensions of the slots.

Patch 1 in this project had to be converted to a conventional cast-in-place, full-depth repair because the pavement at this location was superelevated and the precast panel dimensions were such that the resulting joint openings would have been unacceptable. In the future, such issues can be resolved if the contractor makes exact measurements of the panels to be replaced. This measurement data can then be used during the manufacturing of the panels. Therefore, this panel will serve as the control. The performance of the precast panels (2 through 9) will be compared with that of panel 1. Also, panels 5 and 6 were stabilized using flowable fill, whereas as the other precast panels were stabilized using the HDP foam. The impact of these two methods of slab stabilization on panel performance will be monitored and evaluated over the next 2 years as part of this study.

Construction Activities—M-25

At the M-25 project site, 12 precast panels were installed over a period of 3 days. Contributing to the longer installation time were the distances between some of the panels and the construction interruptions due to rain. Figure 12 illustrates the relative location of the precast panels.

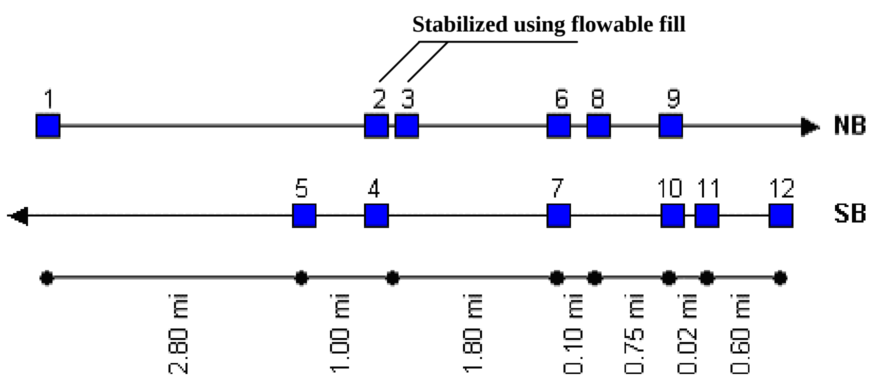


Figure 12. Relative distances of patches along the M-25 project.

Figure 13 illustrates the contruction timeline for panels 2 and 3. Due to the close proximity of these panels, some of the construction activities overlap. Panels 2 and 3 were stabilized using flowable fill, and the remaining panels were stabilized using HDP foam.

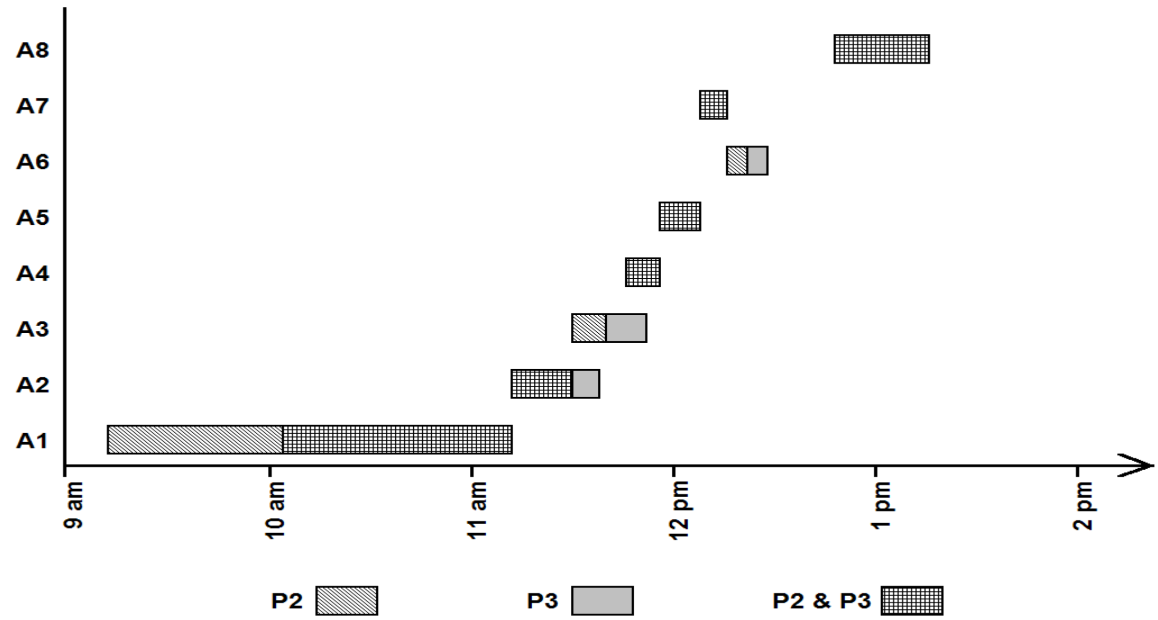


Figure 13. Construction timeline for patches 2 and 3.

REPAIR EFFECTIVENESS OF THE PRECAST PANELS

The repair effectiveness of the panels was determined by conducting distress surveys and falling-weight deflectometer (FWD) tests according to the protocol illustrated in Figure 14. Test locations 1 through 8 allowed for the computation of load transfer efficiency (LTE) across the approach and leave joints. The LTE was computed using the following equation, where LTE:

$$LTE_{\delta}(\%) = \frac{\delta_u}{\delta_L} \times 100$$

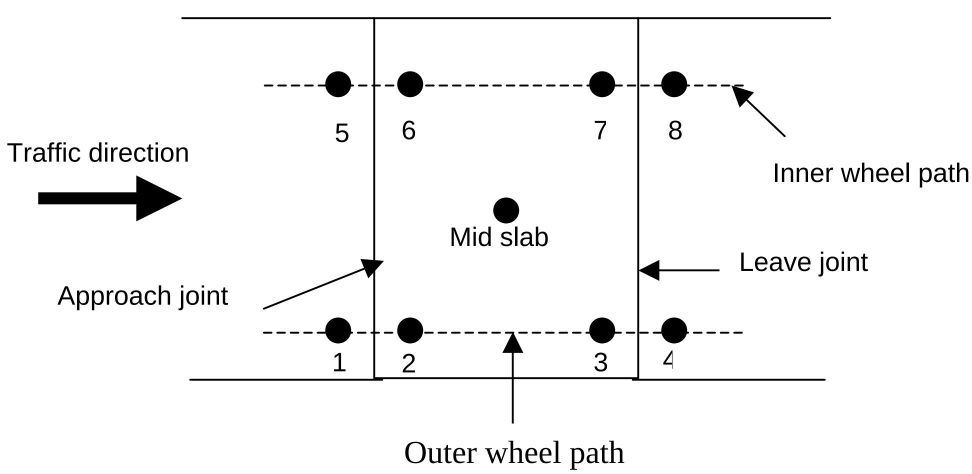


Figure 14. Falling-weight deflectometer test locations to evaluate panel effectiveness.

Field evaluations of the precast panels were conducted in October 2003, May 2004, October 2004, and May 2005.

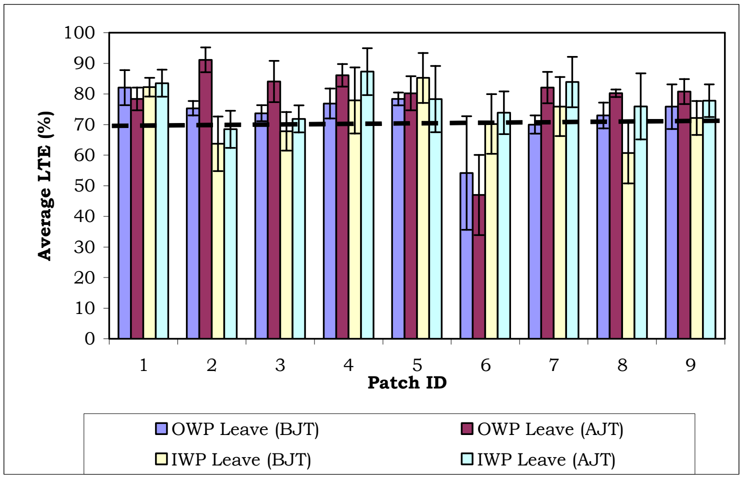
Field Evaluation Results

I-675 Test Site

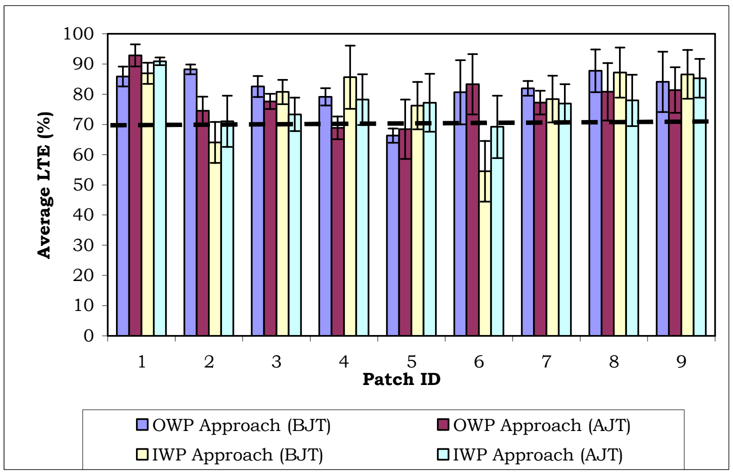
The FWD results are presented in Figure 15, in charts (a) through (c). The dashed lines in the charts represent the minimum LTE threshold of 70 percent and a deflection ratio threshold of 3 for doweled joints. On average, the approach and leave LTEs are in excess of 70 percent (the average LTEs range from 61 percent to 90 percent) as shown in Figure 15 (a) and (b) and in Table 6. Figure 15 (c) represents the relative deflections (peak) of the joint with respect to the mid-slab deflection (peak). The approach joint deflection ratios range from 1.2 to 2.1, whereas, the leave joint ratios range from 1.3 to 2.3, indicating an acceptable support under the panel.

Table 7 displays and summarizes the condition of the precast panels as of September 2005. The performance evaluation was conducted by MDOT. Panel 2 exhibited premature cracking along the leave joint; the remaining seven panels exhibited acceptable behavior at the time of the last performance evaluation.

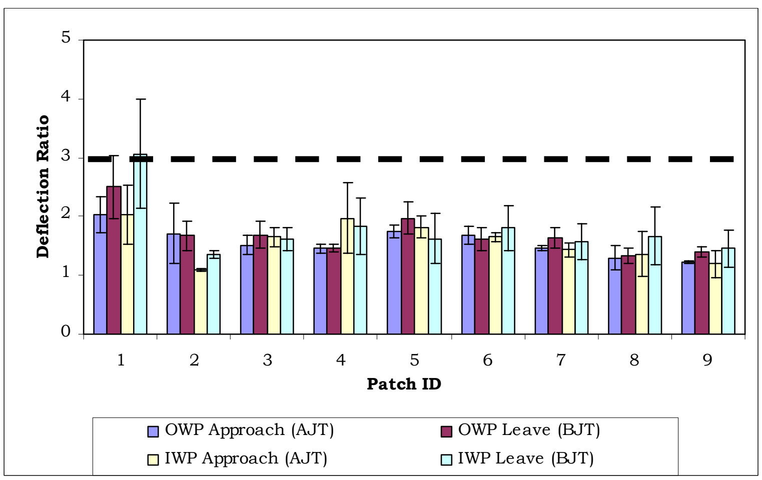
For panel 2, the average before-leave joint LTE (%) ranges from 63 to 75 whereas the after-leave joint LTE (%) ranges from 68 to 91. The type of distress observed in panel 2 looks like failure at the end of the dowels due to thermal movement of the pavement. The hot pour joint sealant is pushed up in the joint, indicating the pavement closing up on the leave side of the joint. Uniform restraint was not provided in the reservoir opening between the dowels, which may have resulted in high bearing stresses at the dowel ends. Another reason for this premature joint failure could be that the dowels along the leave joint were horizontally skewed as a result of the installation. This skewing could have resulted in “locking” of the joint and impeding joint movement under environmental and traffic loads.



(a) Leave slab loading.



(b) Approach slab loading.



(c) Deflection ratio.

Figure 15. Average load transfer efficiencies and deflection ratios for the I-675 test site.

Table 6. Summary of Approach and Leave Joint Load Transfer Efficiencies (LTE)

Panel Number	Average Approach Joint LTE (%)	Average Leave Joint LTE (%)
1	89.1	81.6
2	74.5	74.7
3	78.6	74.4
4	78.0	82.0
5	72.0	80.5
6	72.0	61.3
7	78.6	78.0
8	83.4	72.5
9	84.3	77.0

Table 7. Summary of Panel Performance, I-675 (Survey Date: 9/14/05)

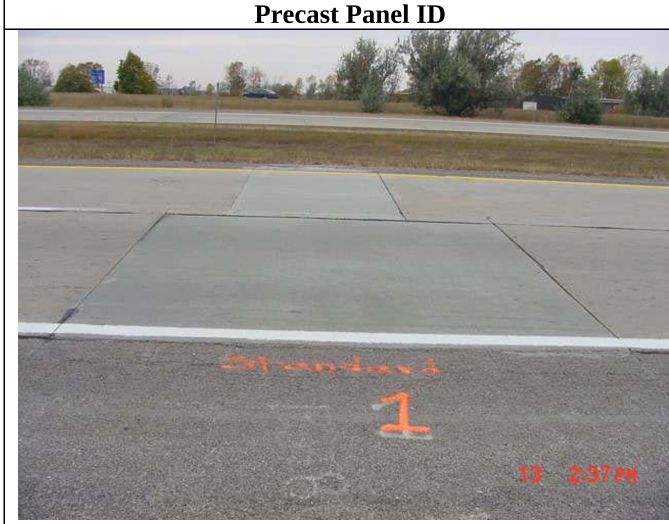
Precast Panel ID	Performance Description
 Panel 1	There is no evidence of distress. The average LTE ranges from 81% to 89%, and the deflection ratios are less than 2.5. *continued*

Table 7. Summary of Panel Performance, I-675 (Survey Date: 9/14/05) (continued)

Precast Panel ID	Performance Description
 Panel 2	Panel cracking observed in the vicinity of the dowel bars. The average joint LTE is 74.5%, and the deflection ratios are less than 2.
 Panel 3	Panel in good condition. Some spalling was observed along the joint. The average joint LTE ranges between 75% and 78%, and the deflection ratios are less than 2.
 Panel 4	The panel is in good condition. The average joint LTE ranges between 78% to 82%, and the deflection ratios are less than 2. *continued*

Table 7. Summary of Panel Performance, I-675 (Survey Date: 9/14/05) (continued)

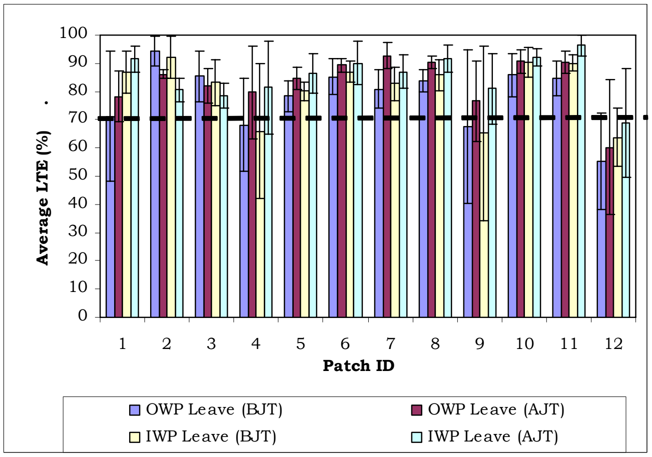
Precast Panel ID	Performance Description
 Panel 5	The panel is in good condition. The average joint LTE ranges between 73% to 80%, and the deflection ratios are less than 2. The panel was stabilized using flowable fill.
 Panel 6	Panel is in acceptable condition. Some spalling of the dowel slot back-fill was observed. The average joint LTE ranges between 61% and 70%, and the deflection ratios are less than 2. The panel was stabilized using flowable fill.
 Panel 7	The panel is in good condition. A high spot was observed at the leading edge of the repair. The average joint LTE 78%, and the deflection ratios are less than 2. *continued*

Table 7. Summary of Panel Performance, I-675 (Survey Date: 9/14/05) (continued)

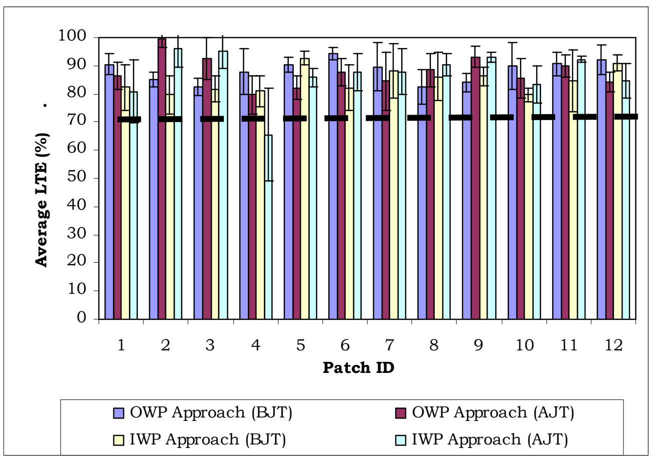
Precast Panel ID	Performance Description
 Panel 8	The panel is in good condition. The average joint LTE ranges from 73% to 80%, and the deflection ratios are less than 2.
 Panel 9	The panel is in good condition. A high spot was observed at one end of the repair. The average joint LTE ranges from 77% to 84%, and the deflection ratios are less than 2.

M-25 Test Site

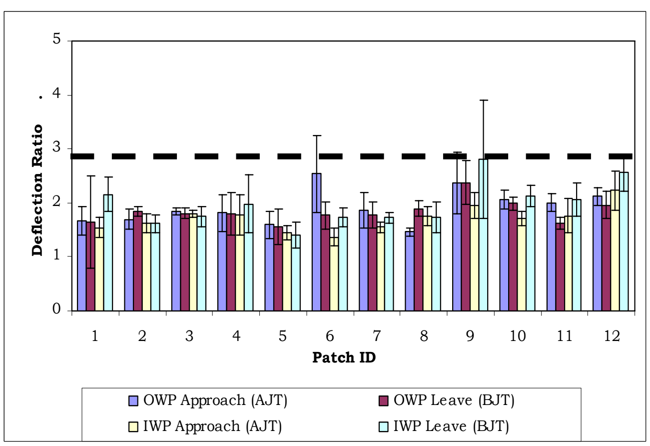
The FWD results are presented in Figure 16 (a) through (c). The dashed lines represent the minimum LTE threshold of 70 percent and a deflection ratio threshold of 3 for doweled joints. On average, the approach and leave LTEs are in excess of 70 percent (the average LTEs range from 72 percent to 90 percent) as shown in Figure 16 (a) and (b) and Table 8. Figure 16 (c) represents the relative deflections (peak) of the joint with respect to the mid-slab deflection (peak). The approach joint deflection ratios range from 1.2 to 2.3, whereas the leave joint ratios range from 1.0 to 3.0, indicating an acceptable support under the panel.



(a) Leave slab loading.



(b) Approach slab loading.



(c) Deflection ratio.

Figure 16. Average load transfer efficiencies and deflection ratios for the M-25 test site.

Table 8. Summary of Approach and Leave Joint Load Transfer Efficiencies (LTE)

Panel Number	Average Approach Joint LTE (%)	Average Leave Joint LTE (%)
1	85.0	82.0
2	90.2	88.3
3	88.0	82.2
4	78.5	73.8
5	87.8	82.4
6	87.9	87.9
7	87.5	85.8
8	86.9	87.8
9	89.1	72.6
10	84.6	89.7
11	89.4	90.3
12	88.0	62.0

Table 9 summarizes (by way of photographs) the condition of the precast panels in September 2005. The performance evaluation was conducted by MDOT. Of the 12 panels, 10 exhibited acceptable to good behavior at the time of the last performance evaluation.

Figure 17 summarizes the structural response of the leave and approach joints for panels 4 and 9. It is evident that for both panels there was a significant drop in leave joint efficiencies from October 2003 and May 2004. The plot also shows that there is also a significant loss in relative support along the distressed joint during the same time frame. During the summer of 2004 the thumb area of Michigan experienced a series of 32 ^{o}C (90 ^{o}F) days that may have resulted in "abnormal" expansion of the pavement slabs. Such expansion could have resulted in a joint blowout. A possible contributor to joint blowout is horizontal misalignment of dowel bars. If such misalignment occurred during installation of the panels, the joint may not have been flexible enough to accommodate slab expansion caused by the high ambient temperatures. Figure 18 illustrates how dowel misalignment could reduce joint flexibility.

The finite element model EverFE (Davids 2003) was used to model the effects of horizontal skew and high ambient temperatures on the tensile stresses on the precast concrete panel and vertical shear stresses in the dowel bars. Three variables are included in this analysis:

- Dowel horizontal skew angles: - 0, 3, 6, and 10 degrees.
- Temperature differential (maximum ambient–construction): -37 ^{o}C (-35 ^{o}F) and 16 ^{o}C (60 ^{o}F).
- Axial friction force: - 0, 45, 445, 4,448, 44,482 kN (- 0, 10,000, 100,000, 1,000,000, 10,000,000 lbf).

Figure 19 summarizes the findings of the analysis. From the analysis it is clear that high horizontal skew angles cause a high vertical shear force in the dowels, resulting high bearing stresses. The magnitude of the vertical dowel shear force is also impacted by the temperature differentials. The maximum tensile stress at the top fiber of the precast panel is significantly impacted by the difference in maximum ambient temperature and construction temperature.

Table 9. Summary of Panel Performance, M-25 (Survey Date: 9/14/05)

Precast Panel ID	Performance Description
 Panel 1	The panel is in good condition. The average joint LTE ranges from 82% to 85% and the deflection ratios are less than 2.
 Panel 2	The panel is in good condition. The average joint LTE ranges from 88% to 92% and the deflection ratios are less than 2. The panel was stabilized using flowable fill. *continued*

Table 9. Summary of Panel Performance, M-25 (Survey Date: 9/14/05) (continued)

Precast Panel ID	Performance Description
 Panel 3	The panel is in good condition. The average joint LTE ranges from 82% to 88% and the deflection ratios are less than 2. The panel was stabilized using flowable fill.
 Panel 4	The repair is severely deteriorated. The cracking along the dowels was first observed during the summer of 2004. The cracking was observed along the approach and leave joint of the panel. The average joint LTE ranges from 73% to 78% and the deflection ratios are less than 2.
 Panel 5	The panel is in good condition. The average joint LTE ranges from 82% to 88% and the deflection ratios are less than 2. *continued*

Table 9. Summary of Panel Performance, M-25 (Survey Date: 9/14/05) (continued)

Precast Panel ID	**Performance Description**
 Panel 6	The panel is in good condition. The average joint LTE is 88% and the deflection ratios are less than 2.5.
 Panel 7	The panel is broken in one corner most probably due to snowplow damage, as there was a high spot along the approach joint. The average joint LTE ranges from 86% to 88% and the deflection ratios are less than 2. *continued*

Table 9. Summary of Panel Performance, M-25 (Survey Date: 9/14/05) (continued.)

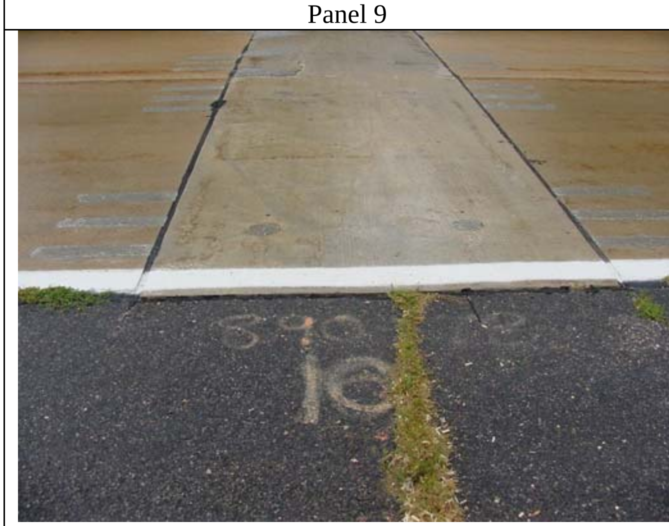
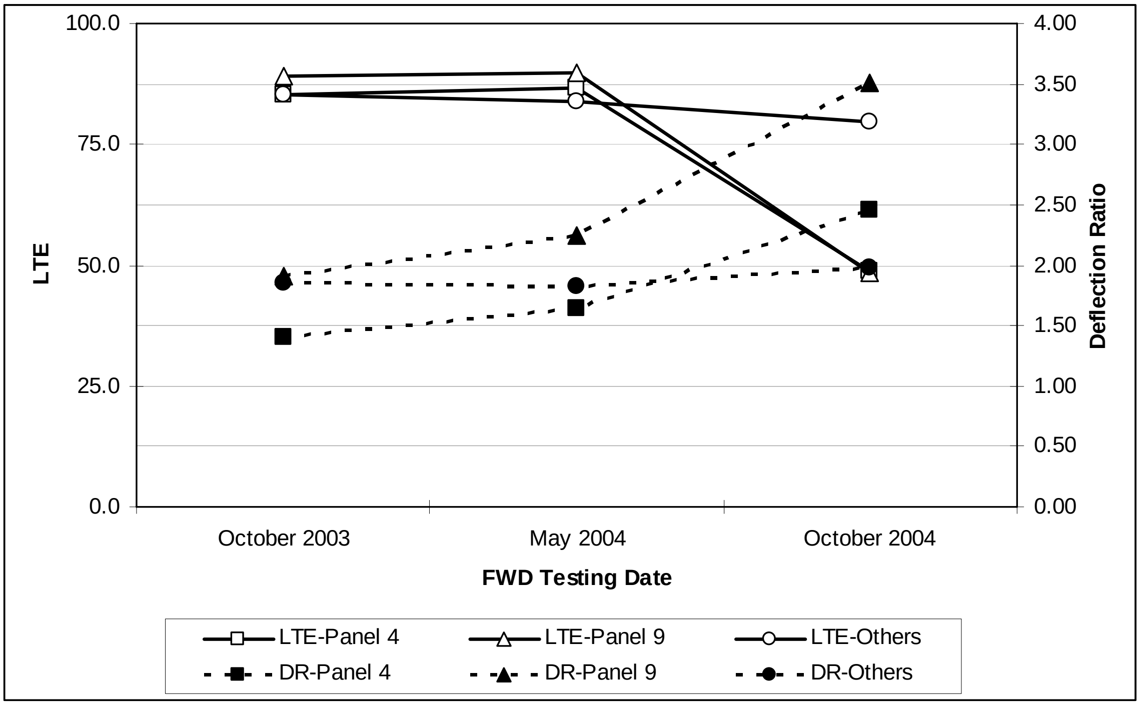
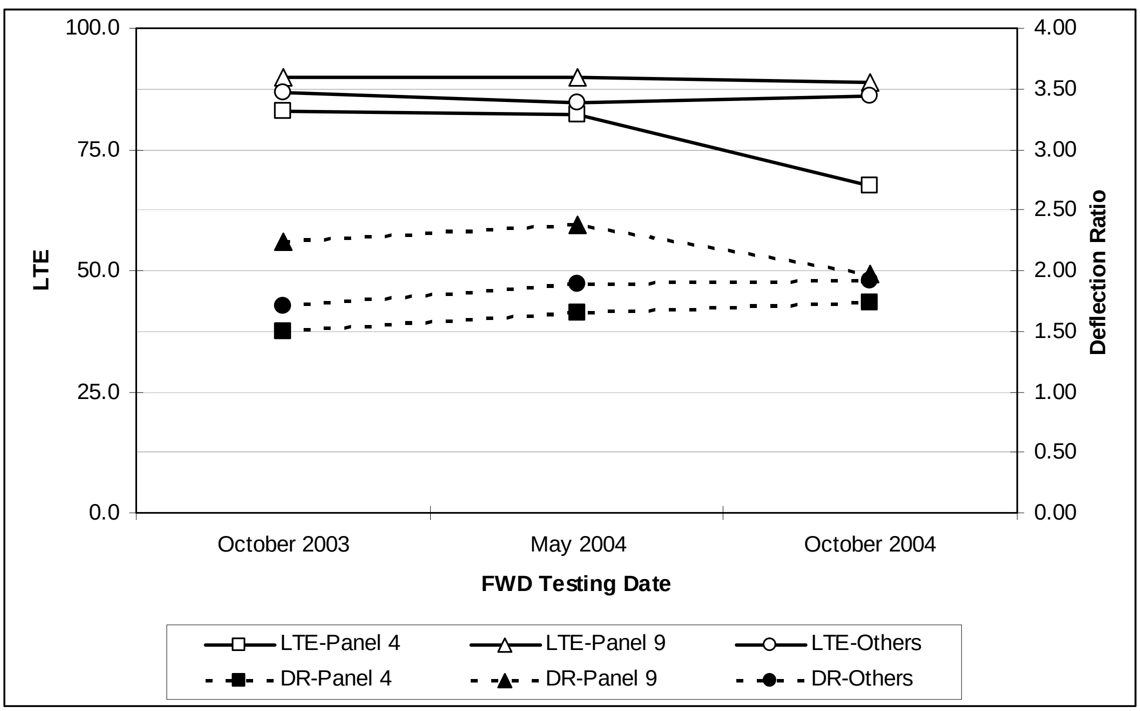
Precast Panel ID	**Performance Description**
 Panel 8	The panel is in good condition. The average joint LTE is 87% and the deflection ratios are less than 2.
 Panel 9	The repair is deteriorated. The cracking along the dowels was first observed during the summer of 2004. The cracking is along the leave joint of the panel. The average joint LTE ranges from 72% (leave joint of the panel) to 89% and the deflection ratios are approaching 3 along the leave joint of the panel.
 Panel 10	The panel is in good condition. The average joint LTE ranges from 85% to 90% and the deflection ratios are less than 2.5. *continued*

Table 9. Summary of Panel Performance, M-25 (Survey Date: 9/14/05) (continued.)

Precast Panel ID	Performance Description
 Panel 11	The panel is in good condition. The average joint LTE is 90% and the deflection ratios are less than 2.
 Panel 12	The panel is in acceptable condition. Trailing edge (leave joint of the panel) broken in the old concrete. The average joint LTE ranges from 62% (leave joint) to 88% and the deflection ratios are less than 2.5. However, the deflection ratio at the broken edge is approaching 3.



(a) Leave Joint



(b) Approach Joint

Figure 17. Structural response of panels 4 and 9.

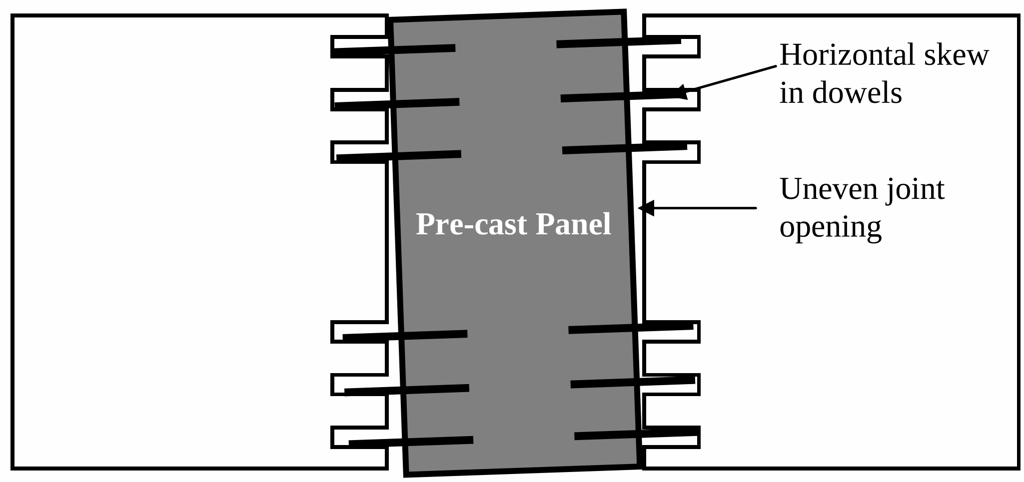
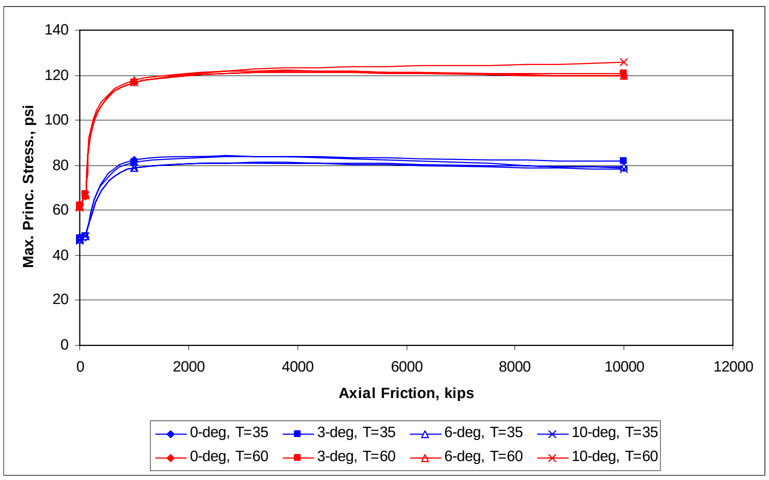
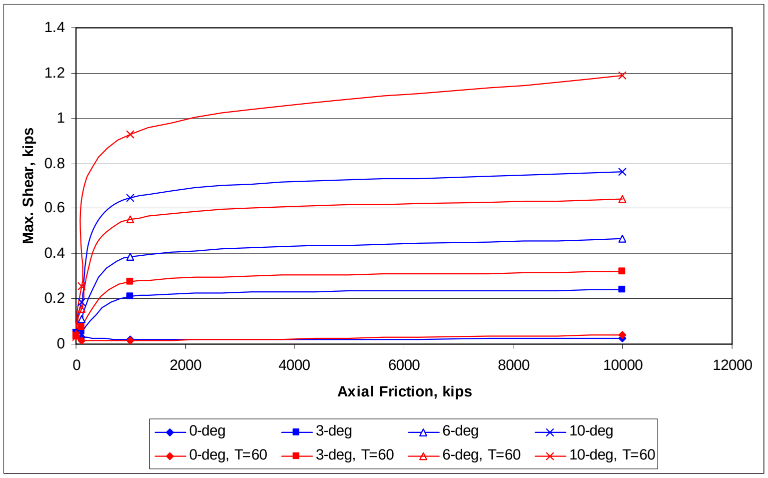


Figure 18. Line sketch illustrating the possible dowel skew and uneven joint opening.



(a) Effect of temperature differential on concrete tensile stresses.



(b) Effect of horizontal dowel skewness on dowel vertical shear force.

Figure 19. Results of the finite element analysis.

RECOMMENDATIONS FOR PRECAST PANEL INSTALLATION

Based on the experience of the Michigan field trials, the following practices are recommended for future precast panel installations for full-depth repair of jointed concrete pavements:

1. Provide an expansion cap at one end of the dowel bar to accommodate slab movement due to environmental loading and to prevent closing of the joint.
2. Provide expansion material along the joint to accommodate joint movement due to thermal expansion and contraction.
3. Diamond grinding of the panel, especially the joints, is recommended to remove high spots. These high spots have a potential to "break off" as a result of snowplowing operations.
4. The width of the dowel slot should be kept as small as possible to accommodate the dowel bar. This will reduce construction time and also reduce the potential for dowel skewing in the horizontal plane.
5. Care needs to be given to sawing the existing concrete for the outline of the patch. The saw cuts should be perpendicular to the centerline to avoid skewing the patch when it is placed (which leads to problems with the dowel bars locking in the slots).
6. To reduce construction time, multitasking during the installation process should be encouraged whenever possible. Construction and installation time can be positively impacted if the repair locations are close to each other, allowing for the installation of multiple panels under one traffic control setup.

CHAPTER 4. COLORADO FIELD STUDY

SITE SELECTION

Along the I-25 corridor north of Denver, 143 concrete slabs were replaced at 18 separate locations between Mead and Loveland (mileposts 244 to 270). The candidate sections were selected by the Colorado Department of Transportation (CDOT) maintenance crews. Due to large volumes of traffic, single-lane closures were permitted for construction for an 8-hour period between 9 p.m. and 5 a.m. Additionally, the construction areas were required to be open to unimpeded traffic during the higher volume times. Table 10 summarizes the locations of the 143 panels along I-25 between Mead and Loveland.

Table 10. Panel Location Summary Along the I-25 Corridor

Location	Location No.	Milepost and (Direction)	No. of Panels Installed	Panel Thickness, mm (in.)
Mead	1	244.41 (NB)	12	185 (7.25)
	2	244.83 (SB)	8	160 (6.25)
	3	244.90 (SB)	10	185 (7.25)
	4	244.96 (SB)	2	185 (7.25)
	5	245.19 (SB)	4	160 (6.25)
	6	245.45 (NB)	3	185 (7.25)
	7	245.46 (NB)	3	185 (7.25)
	8	247.46 (SB)	4	160 (6.25)
	9	247.68 (NB)	13	160 (6.25)
	10	249.41 (SB)	4	160 (6.25)
Loveland	1	256.41 (SB)	13	140 (5.5)
	2	256.49 (SB)	8	160 (6.25)
	3	257.46 (SB)	16	160 (6.25)
	4	257.99 (SB)	15	160 (6.25)
	5	258.02 (NB)	5	160 (6.25)
	6	258.12 (NB)	5	160 (6.25)
	7	258.14 (SB)	14	140 (5.5)
	8	269.84 (NB)	5	Cast-in-place
	Added work	258.72 (SB)	13	160 (6.25)

The average annual average daily traffic (AADT) and percentage of trucks along the construction corridor were 45,886 and 14 percent respectively based on year 2002 data. The contractor was responsible for making all the measurements prior to the fabrication of the panels. The measurements were made along the four sides and diagonals to account for any joint skewing. Multiple pavement cores were extracted at each location to determine variations in thickness from end to end as well as near the shoulder and centerline. The dimensional information was used in customizing the precast panel fabrication.

PRECAST PANEL MIXTURE DESIGN AND FABRICATION DETAILS

The precast PCC panels were fabricated by the contractor and transported to the project site. The typical structural details of the precast panels are illustrated in Figure 20. The tie bar slots, which were formed during the panel fabrication process, were placed at 0.91 m (3 ft) on center. The panel also consists of #4 or #5 steel depending on the panel thickness. The panel lengths were variable so as to match the contraction joint spacing. The typical PCC mixture designs for this study are summarized in Table 11, and the compressive strength data for the Mead and Loveland sites are summarized in Table 12.

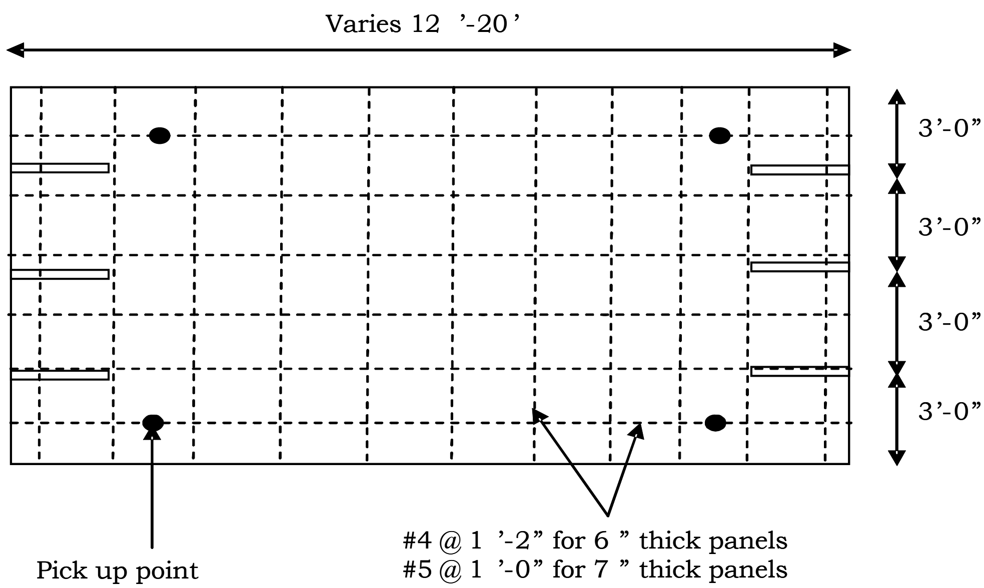


Figure 20. Structural details of the precast panel.

Table 11. Portland Cement Concrete Mixture Designs for the Precast Panels

Mix Ingredients	**Design, lbs/yd^3**
Cement	390.4 kg/m^3 (658 lbs/yd^3)
Water	128.7 kg/m^3 (217 lbs/yd^3)
Fine aggregate	811.6 kg/m^3 (1,368 lbs/yd^3)
Coarse aggregate	933.8 kg/m^3 (1,574 lbs/yd^3)
Air-entraining admixture	38.7 ml/m^3 (1.0 fl.oz/yd^3)
Water-reducing admixture	8.158 kg/m^3 (220 oz/yd^3)
High-range water reducer	1.854 kg/m^3 (50 oz/yd^3)
Nonchloride accelerator	10.753 kg/m^3 (290 oz/yd^3)

Table 12. Compressive Strength of Concrete From the Mead and Loveland Sites

Location	Average Compressive Strength Data, MPa (lbf/in^2)					
	<24 hours		7 days		28 days	
1 (Loveland)	19.3	(2,805)	28.5	(4,135)		
3 (Loveland)	20.4	(2,960)	29.2	(4,240)	35.6	(5,160)
7 (Loveland)	18.4	(2,665)	29.4	(4,265)		
1 (Mead)	24.7	(3,585)	32.4	(4,705)	37.9	(5,490)
3 (Mead)	24.9	(3,615)	29.4	(4,270)	35.2	(5,100)
7 (Mead)	21.4	(3,105)	35.1	(5,085)	43.0	(6,240)
9 (Mead, slabs 1–3)	20.9	(3,025)	34.2	(4,965)	40.3	(5,840)
9 (Mead, slabs 4–6)	23.9	(3,450)	38.2	(5,545)	46.2	(6,700)
9 (Mead, slabs 7–9)	23.4	(3,395)	37.6	(5,450)	42.5	(6,170)

CONSTRUCTION SEQUENCE

Prior to the removal of the candidate panels a distress survey was conducted. Typical distresses observed during the survey included midpanel transverse cracks with associated spalling; joint sealant damage, spalling, and asphalt patch deterioration; and corner cracking. Some examples of distresses are shown in Figure 21.

Figure 21. Examples of distresses.

The sequences of operation for offsite and onsite activities in the Colorado field study are listed below:

Offsite Activities

1. Fabrication of the precast panels.
2. Storage of the fabricated precast panels.

Onsite Activities
The onsite activities were divided into four construction operations:

1. Slab removal and base preparation:
   a. Sawcutting of panel boundaries.
   b. Demolition of distressed panels.
   c. Removal of the distressed panels.
   d. Cleaning of the exposed base.
   e. Heat-lancing the exposed concrete faces to remove traces of moisture.
2. Precast panel placement and alignment:
   a. Transporting precast panels from the storage yard.
   b. Placement of the precast panels into the prepared excavation.
3. Precast panel elevation adjustment:
   a. Drilling of injection portholes.
   b. Injection of HDP foam to adjust slab elevation.
   c. Filling of voids (if any) with HDP foam to ensure uniform support under the panel.
4. Joint preparation:
   a. Sawcutting of tie slots in the existing end panels to match with the slots in the precast panels.
   b. Removal of all extra foam that surfaced during the slab stabilization and void filling process.
   c. Air-cleaning and sandblasting all tie slots to ensure good bonding.
   d. Heat lance the tie slots to remove all traces of moisture.
   e. Insert the fiberglass tie bars.
   f. Backfill tie slots with prewashed dried aggregate.
   g. Apply the polyurethane joint bonding material.
   h. Seal injection ports using nonshrink grout.

The steps in a typical precast panel installation process in the field include are described below.

Slab Demolition and Removal

The perimeter of each of the distressed panel was sawcut. Additional transverse cuts were made to expedite the panel-breaking operation. The initial breaking of the concrete was done using a standard backhoe fitted with a jackhammer. An additional track-hoe was used to excavate and remove the demolished concrete. Figure 22 illustrates the slab demolition and removal process.

Base Cleaning and Preparation

The exposed base was swept and cleaned using compressed air. In addtion to the cleaning, the base and joint edges were dried (to remove any traces of moisture) using a hot-air lance. A secondary effect of using the hot-air lance was to expedite the curing of the slab-jacking foam. Figure 23 illustrates the base preparation activities.

a) Slab demolition b) Removal of debris

Figure 22. Slab demolition process.

Figure 23. Base preparation activities.

Panel Placement and Alignment

Panel Placement

The panels were brought to the site on a flatbed truck and lowered into the excavation using a 133-kN (30-kip), truck-mounted crane. Figure 24 illustrates the panel placement process.

a) Panel moved from flatbed truck.

b) Panel lowered into excavation.

c) Alignment of panel.

Figure 24. Panel placement process.

Panel Alignment

The precast panel elevations prior to jacking ranged from 0–75 mm (0–3 in.) below the passing lane or shoulder. A two-part polymer (486 Star) was mixed and simultaneously injected through the portholes 16 mm (0.625 in. diameter) to lift the precast panel. The polyurethane foam has a free-rise density of 48.1–51.3 kg/m^3 (3.0–3.2 lbs/ft^3), with a minimum compressive strength of 6.89 kPa (40 lbf/in^2) (ASTM 1621). According to the manufacturer specification the foam is expected to reach 90 percent of full compressive strength within 15 minutes. Dial indicators were mounted on the panel surface to monitor the change in the slab elevation relative to the adjacent pavement. The panel jacking commenced by lifting at the two corners on one side of the panel, followed by lifting of the slab at the other end, until the elevation was matched with the existing roadway. In addition, the foam also served to fill in voids under the panel after the slab jacking was completed. Uniform support under the panel is essential for good long-term performance.

Joint Stitching and Bonding

A good bonding surface was obtained by removing all the excess foam from the joint faces and formed stitch slots. This was accomplished by using a pavement saw to cut the foam on both sides of the construction joints. The joint faces were then sandblasted to ensure clean bonding surfaces. In addition to this the surfaces were hot-air-lanced to remove all traces of moisture. Stitch slots were saw cut in the existing approach and departure slabs. The entire sawcutting was done in the absence of water to prevent reaction with the slab-jacking foam and joint-bonding material (URETEK 600).

The fiberglass stitches were placed into the 19-mm (0.75-in.) slot using two guides wire spacers, one at each end. The fiberglass ties are 0.9 m long, 127 mm wide, and 6 mm thick (36 in. long, 5 in. wide, and 0.25 in. thick). A picture of the tie bar is shown in Figure 25.

Figure 25. Fiberglass stitches.

Table 13 summarizes the mechanical properties of the fiberglass stitches. This information was obtained from URETEK USA. The mechanical properties characterization was conducted by Wiss Janney and Elstner Associates, Inc.

Table 13. Mechanical Properties of the Fiberglass Stitch

Test Property	Measured Data
Ultimate load	9.689 kg (21,360 lb)
Relative joint displacement (at ultimate load)	(0.17 in. [0.01 in. at 8,000 lb])
Load at first softening	5.669 kg (12,500 lb)
Ultimate average stiffness	56, 925.842 kg (125,500 lb/in.)

Dried aggregate (3–6 mm [0.125–0.25 in.]) was used to backfill the stitch slots, and polyurethane foam was applied to bind the aggregates together.

The contractor also recommended that expansion joints be placed at intervals of 13.7–18.3 m (45–60 ft). The expansion joints were 19 mm (0.75 in.) wide and stitched together using the fiberglass ties. The joint consisted of a backer rod placed vertically at the longitudinal joint and stitches to isolate the polyurethane foam. The joint was then filled to approximately 50 mm (2 in.) from the top of the pavement with ground rubber, followed by a 13 mm (0.5 in.) bead of self-leveling silicone joint sealant.

The injection ports were sealed using a nonshrink grout. The procedure included drilling out leftover jacking foam; cleaning the surface of the concrete for proper adhesion; and placing the grout. Figure 26 illustrates a cluster of completed panels.

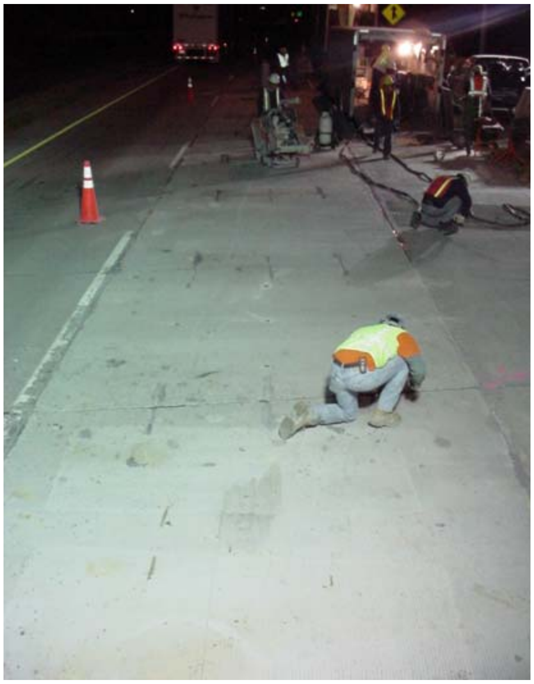


Figure 26. Completed cluster of panels.

CONSTRUCTION PRODUCTIVITY

The construction productivity metrics include documentation of the following:

- Time to complete the installation of one cluster of panels.
- List of possible concurrent activities.
- Panel installation equipment used.
- Panel installation crew size.

Table 14 lists the equipment needed to successfully install the precast panels. The approximate construction completion time for all the panel clusters is provided in Table 15.

Table 14. Equipment Used for Panel Installation

Equipment Type	Application in the Installation Process
Ingersoll L6 light plant	Work area lighting during night closures
CAT 416 back-hoe with jackhammer	Initial break up of concrete to be removed
CAT 325B track-hoe	Excavation of concrete to be removed
Two haul trucks	Haul concrete debris
Ingersoll 185 compressor	To remove debris from work area. Clean joints and stitch slots
Two pavement saws	To cut stitch slots in adjacent pavement slabs
Sandblasting equipment	To prepare joints and stitch slots
Hot-air lance	To prepare joints prior to bonding
Propane weed burner	To dry and heat aggregates used in the joint bonding operation
Portable concrete mixture	For aggregate mixing. Also used for mixing cement mortar for backfilling

Figure 27 shows the relationship between average elapsed time (start to finish) per panel (within a cluster) and number of panels in a given cluster. From this plot it can be surmized that as the cluster size increases the installation productivity improves. Figure 28 highlights the contractor's improving comfort level (in terms of production efficiency) with project progression. During the initial stages of the project the contractor was installing clusters with only one to two precast panels over a 9-hour construction window. After day 20, the production rate increased to four to eight precast panels per cluster. The increased productivity was a result of multitasking activities. Specific changes in the mode of operation made by the contractor included reduction in panel demolition time for the entire cluster of slabs; concurrence in the panel demolition, base preparation activity, and installation of new panels; and providing an additional applicator for joint bonding operations. The advantages of incorporating concurrent activities in the construction regime are illustrated in Figure 29. As the percentage (based on overall time per panel) of multitasking increases, the number of panels that can be installed within the allowable construction window increases.

Table 15. Approximate Installation Time for Patches (hours:minutes)

Day	Location/Panel No.	Number of Panels	Panel Excavation	Panel Placement	Panel Jacking	Joint-Stitch Prep.	Joint Bonding
13	M6, 1~3	3	1:39	1:12	1:27	1:29	1:15
14	M7, 1~3	3	1:42	0:49	1:38	1:55	1:18
15	M3, 18~16	3	1:02	0:23	1:59	1:40	1:05
16	M3, 11~10	2	1:49	0:08	0:40	1:35	1:10
17	M9, 1~4	4	1:18	0:37	0:53	2:20	2:38
18	M9, 5~8	4	1:26	0:25	1:15	1:31	1:39
19	M9, 9~13	5	1:32	0:19	1:18	0:53	3:12
20	M3, 15~12	4	1:31	0:21	0:54	2:28	2:22
21	M2, 8~5	4	1:06	1:12	2:34	N/A	2:29
22	M4, 20~19	2	1:02	0:11	N/A	N/A	N/A
22	M3, 9	1	N/A	N/A	0:20	N/A	N/A
23	Night of saw cutting only						
24	M5, 24~21	4	1:31	0:25	N/A	N/A	2:30
25	M2, 4~1	4	1:20	0:57	1:47	N/A	2:14
26	M1, 9~12	4	1:38	0:28	N/A	3:02	2:20
27	M1, 5~8	4	1:36	0:19	1:42	N/A	1:26
28	M1, 1~4	4	1:38	0:45	N/A	N/A	1:10
29	L5, 1~5	5	1:28	0:32	1:43	N/A	1:55
30	L6, 1~5	5	1:34	0:39	1:20	N/A	2:35
31	M10, 1~4	4	2:19	N/A	N/A	N/A	N/A
32	M8, 1~4	4	1:50	0:38	1:41	N/A	2:21
33	L4, 10~14	6	N/A	0:51	1:58	N/A	2:15
34	L4, 9~2	8	N/A	2:00	2:35	N/A	2:25
35	L4, 1	1	0:37	0:10	N/A	N/A	N/A
35	L3	4	N/A	N/A	3:30	N/A	N/A
36	L3, 5~10	6	2:03	0:44	1:56	N/A	2:20
37	L3, 11~16	6	N/A	N/A	2:03	N/A	1:40
38	L2, 1~8	8	2:15	1:30	N/A	N/A	2:10
39	Surface grinding and repairs only						
40	Surface grinding and repairs only						
41	L7, 1~7	7	N/A	N/A	N/A	N/A	N/A
42	L7, 8~14	6	N/A	N/A	3:57	N/A	3:12
43	L1, 1~6	6	N/A	N/A	3:03	N/A	N/A
44	L1, 7~13	7	N/A	1:00	N/A	N/A	N/A
50	L7, 14	1	N/A	0:05	N/A	N/A	0:33
51	E.P., 1~5	5	1:40	0:39	1:15	N/A	2:38
52	E.P., 6~9	4	N/A	0:41	1:13	N/A	1:03
53	E.P., 10~13	4	2:02	0:48	1:15	N/A	1:04

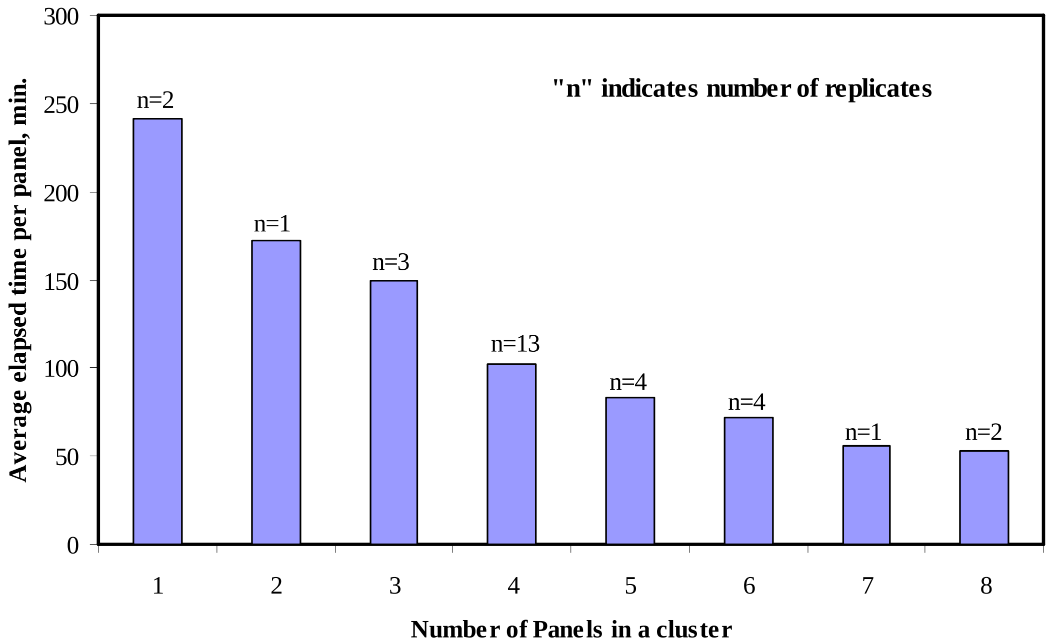


Figure 27. Relationship between average elapsed time per panel and the number of panels.

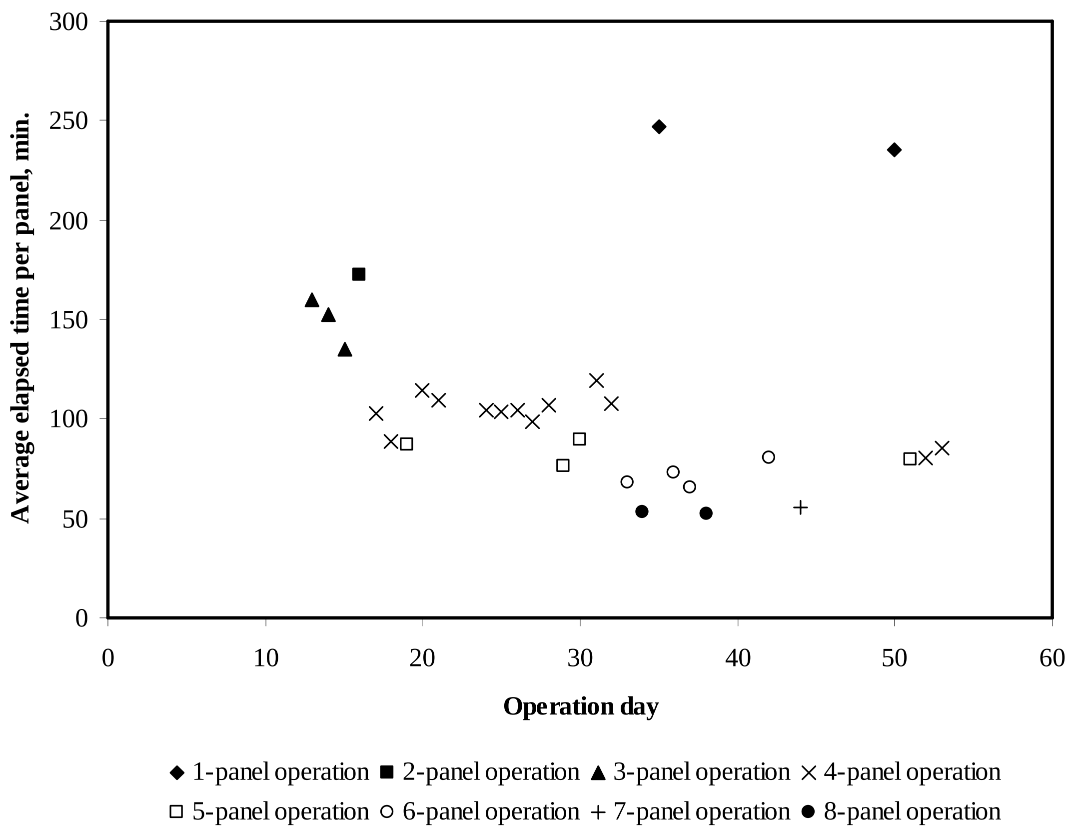


Figure 28. Illustration of improvement in operators' comfort level.

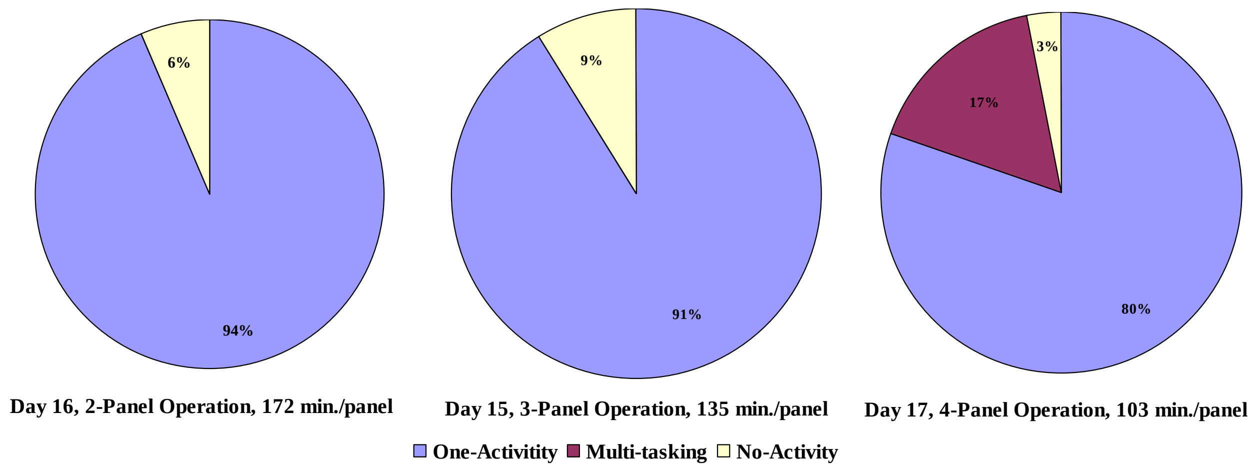


Figure 29. Illustration of advantages of incorporating concurrent activities.

REPAIR EFFECTIVENESS OF THE PRECAST PANELS

One cycle of performance evaluation has been conducted at the Colorado sites since the inception of the project. The performance evaluation consisted of falling-weight deflectometer (FWD) testing and documenting the initiation (if any) of distresses. During June 2004, 81 precast panels along I-25 between Loveland and Mead were tested. Testing was conducted between 9 p.m. and 5 a.m. Data from positions 1 and 3 were collected to monitor joint deflection. Position 2 deflection data were used to monitor edge support, whereas deflection data from position 4 provided information about midpanel support. The FWD testing and distress surveys were done concurrently. The FWD testing pattern is summarized in Figure 30.

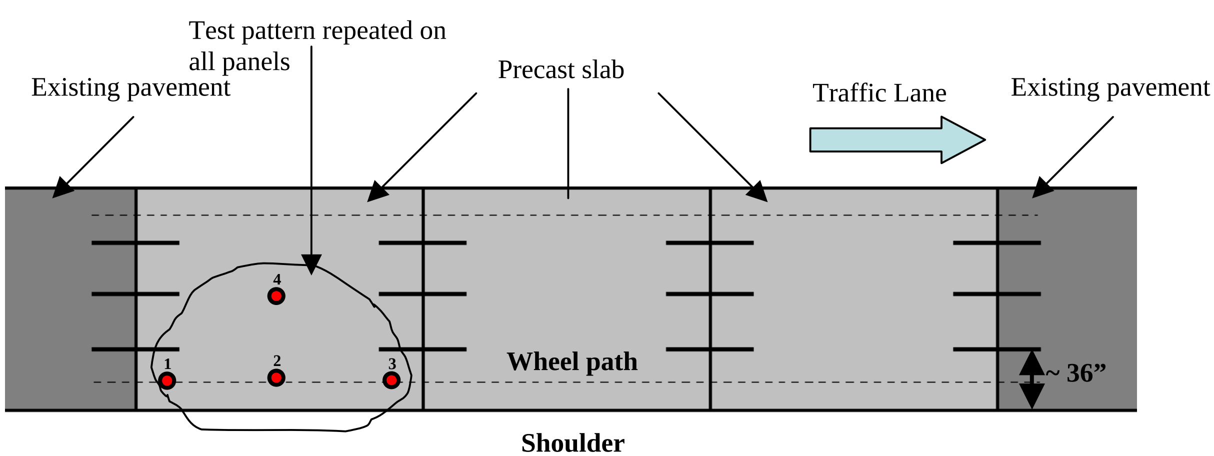


Figure 30. Falling-weight deflectometer testing pattern.

Performance Evaluation at I-25 Test Site

Figure 31 illustrates the peak (midslab) average deflections measured at location 4 for 81 panels. The thickness ranges from 140 to 184 mm (5.5 to 7.25 in.). The peak (average) deflections range from 0.14 to 0.30 mm (5.6 to 12.1 mils). On average the thinner panel sections experience higher deflections than thicker panels. Figure 32 illustrates the peak (edge) average deflections measured at location 2 on the precast panels. The relationship between the deflection magnitude and slab thickness is similar to the one observed in Figure 31. Figures 33 and 34 illustrate the peak joint deflections. The error bars indicate the scatter in the measured deflection data. This scatter can be attributed to the possible variability in support under the panel in the vicinity of the joint. Based on the data presented in Figures 31 through 33, the following observations can be made:

- On average, the peak deflections at the joints for thinner slabs are higher than the thicker slab joint deflections.
- Irrespective of slab thickness, joints between the precast panels and the existing slab (approach or departure) deflect less than the joint between two new precast panels.
- The deflection data scatter (as seen in the error plots) is more for joints between two new precast panels than for joints between the existing slab and the precast panel. It is premature to speculate on the reasons for this differential behavior.

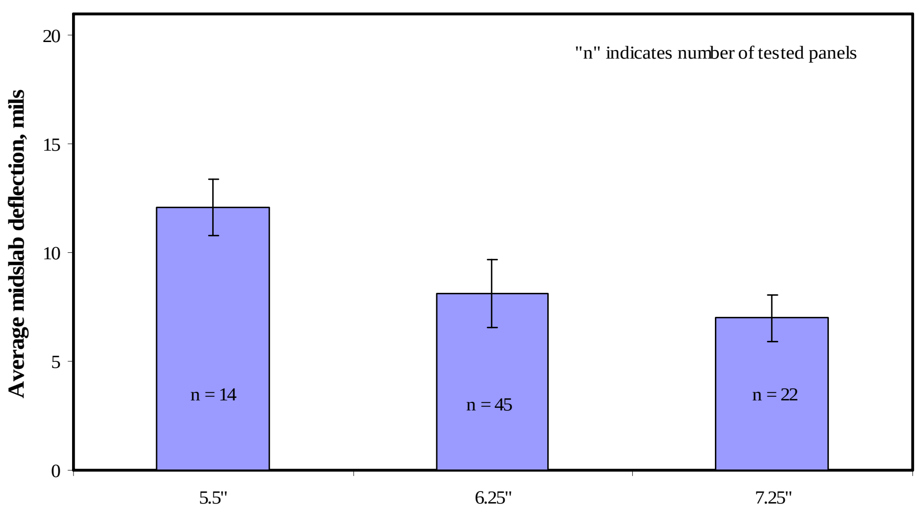


Figure 31. Average midslab deflections as a function of slab thickness.

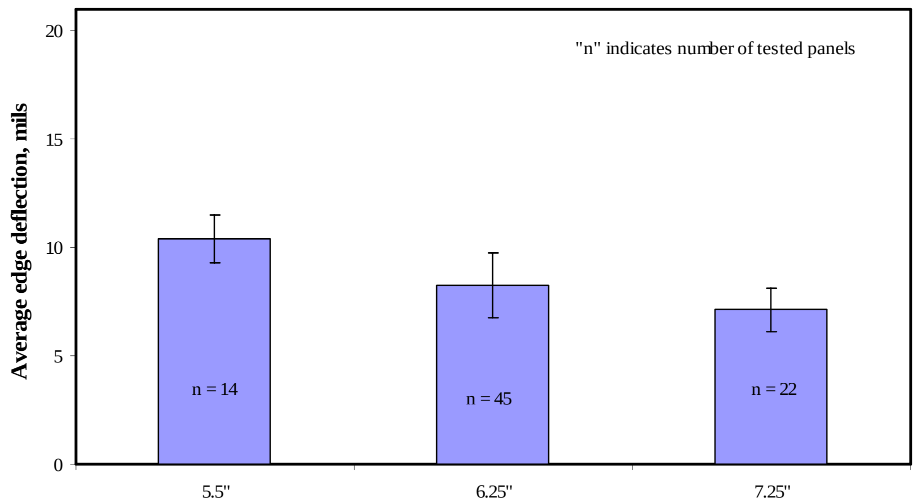


Figure 32. Average edge deflections as a function of slab thickness.

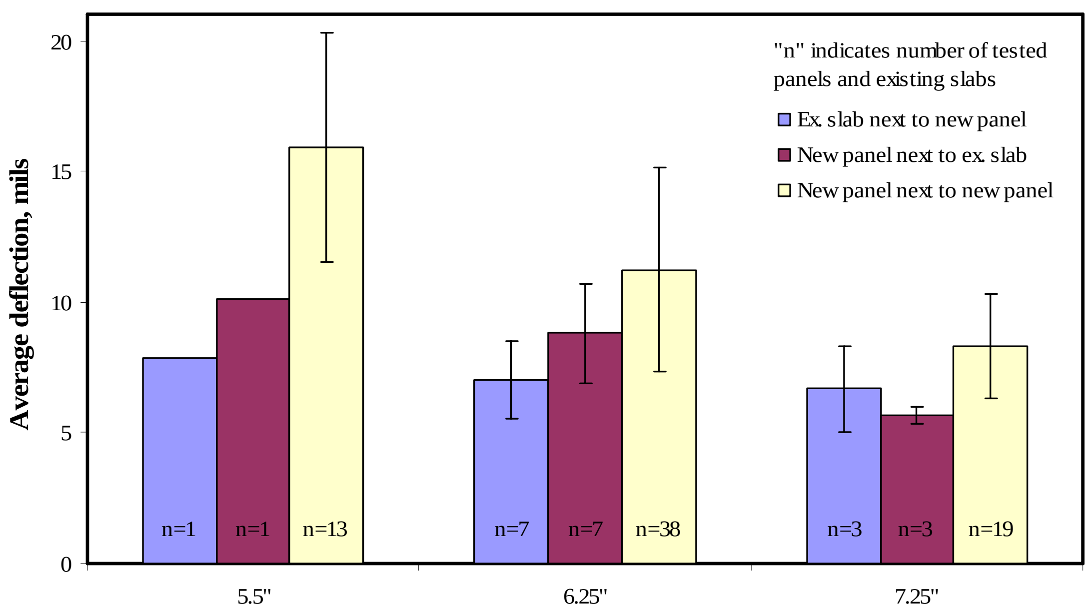


Figure 33. Average joint deflections (approach) as a function of slab thickness.

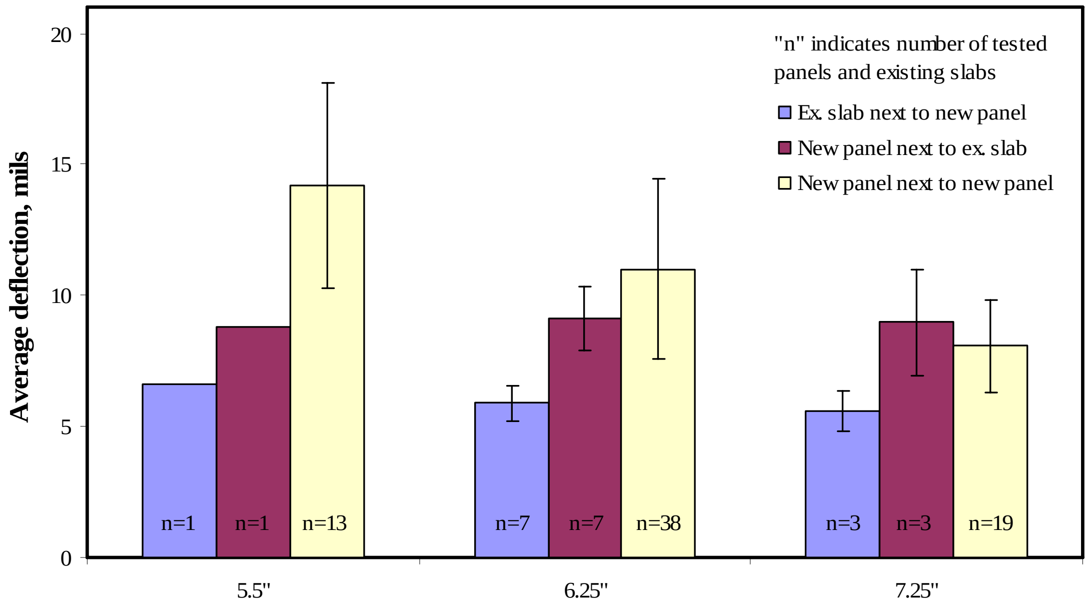


Figure 34. Average joint deflections (leave) as a function of slab thickness.

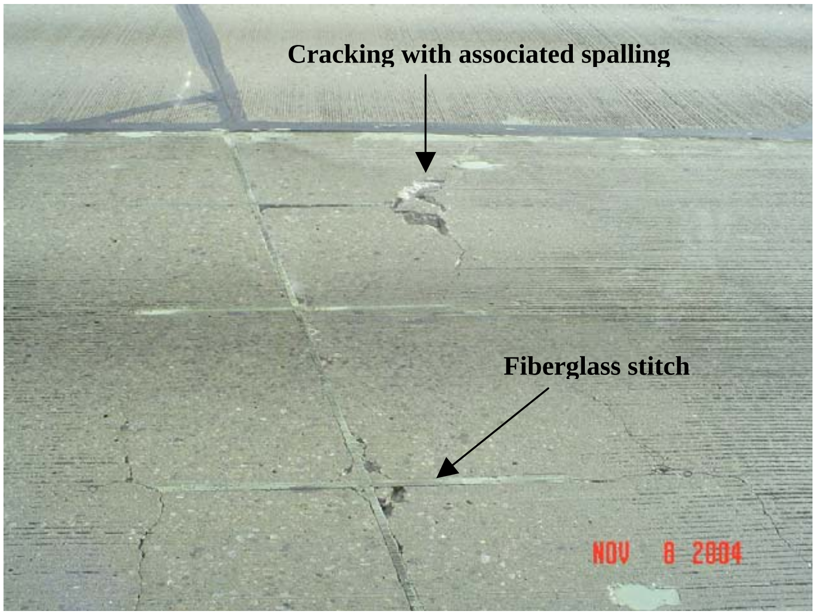
Multiple performance evaluation surveys were conducted by CDOT personnel. The panel distresses as classified by the CDOT inspectors are as follows:

- TYPE I: Corner or tab of panel has a full-depth crack, however, the slab is still stable and on grade.
- TYPE II: Corner or tab of panel has a full-depth crack, and is experiencing minimal vertical movement under load.
- TYPE III: Corner or tab of panel has one or more working cracks and is experiencing vertical movement under load.

The distribution of distress is as follows:

1. 85 percent (23 out of 27) of the panels that are 140 mm (5.5 in.) thick have at least one tab that has failed or exhibits some level of distress.
2. 24 percent (23 out of 97) of the panels that are 160 mm (6.25 in.) thick have at least one tab that has failed or exhibits some level of distress.
3. 3 percent (1 out of 30) of the panels that are 185 mm (7.25 in.) thick have at least one tab that has failed or exhibits some level of distress.

The majority of these cracks were in the vicinity of the fiberglass stitches. A typical crack pattern is illustrated in Figure 35.



(a)

(b)

Figure 35. Typical crack patterns.

The possible reasons for this premature failure include nonuniform support in the vicinity of the stitches resulting in tensile stresses at the top fibers of the panel; inadequate slab thickness to carry the axle loads; and longer effective slab lengths due to joint ties.

RECOMMENDATIONS FOR PRECAST PANEL INSTALLATION

Based on this experience the following recommendations are suggested for future precast panel installations for full-depth repair of jointed concrete pavements:

1. Reduce the slab length.
2. Slab thicknesses less than 200 mm (8 in.) should not be used.
3. The precast panel should be connected to the existing panels through dowels to ensure joint flexibility and load transfer.
4. Whenever possible, multi-tasking during the installation process should be encouraged to reduce construction time. Construction and installation time can be positively impacted if the repair locations are in close proximity of each other, allowing for the installation of multiple panels under one traffic control setup.

APPENDIX A

Example of Field Data Sheet

Pre-cast Concrete Panel System for Full Depth Pavement Repairs

Field Data Sheets

Date: ___________________

PROJECT LOCATION

Location*:____

____

____

____

***Be sure to include mileposts or exit numbers**

INVENTORY INFORMATION

Cross-section details:

Slab thickness: ___________________________

Base thickness and type: ___________________________

Subbase thickness and type: ___________________________

Subgrade type: ___________________________

Pavement Type: JPCP or JRCP

Joint spacing: ______________________________

Shoulder type and width: ______________________________

Traffic:

AADT: ______________________________

%Commercial: ______________________________

DISTRESS INFORMATION*

Patch ID #: ______________________________

Location: ______________________________

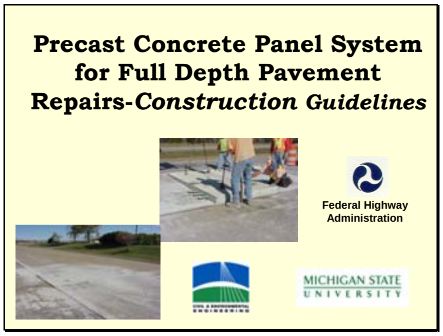
***Record the extent and severity of the distress. Photograph ALL representative distresses.**

Example distress types: Transverse and longitudinal cracking, spalling, faulting, ASR, D-Cracking, corner cracks, pop-out, sealant damage, asphalt patches.

APPENDIX B

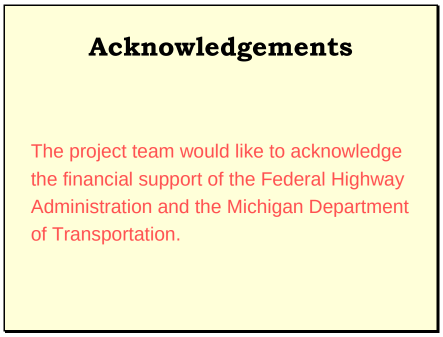
Construction Guidelines Presentation

Slide 1



This presentation is intended to provide guidance on the installation of precast concrete panels as a full-depth repair alternative.

Slide 2

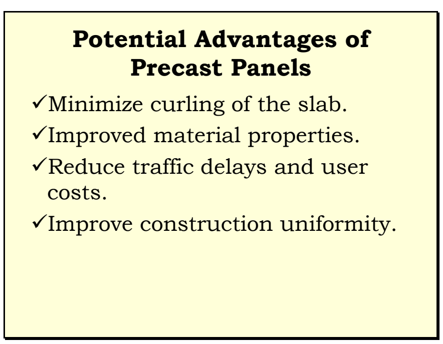


The project was sponsored by the Federal Highway Administration under the Concrete Pavement Technology Program Task 7. Additional financial assistance was provided by the Michigan Department of Transportation, which also provided the project sites along M-25 and I-675.

Slide 3

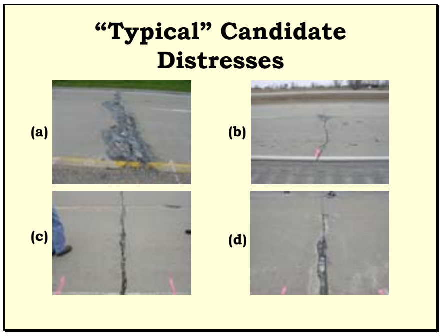
The traditional practice of rehabilitating existing concrete pavements is an excellent method to extend the remaining service life of the overall network. However, increasing traffic volumes and sensitivity to user delays and costs have required pavement construction and rehabilitation to be put on a "fast track" as much as possible.

Slide 4



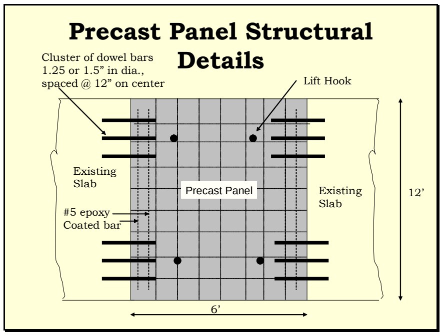
Structural precast concrete elements have been successfully used in the building and bridge industry. Precast concrete elements are constructed under controlled curing conditions, resulting in improved short- and long-term durability properties. Since the panels are cured under controlled conditions the mechanical properties of the resulting concrete are not compromised. Since multiple slabs are fabricated at the same time, this leads to uniformity of construction.

Slide 5



Typical distresses include (a) deteriorated joints with asphalt cold patch (b) medium severity mid panel cracking with associated spalling, (c) high severity transverse cracking, and (d) deteriorated joint (sealant damage) with associated spalling.

Slide 6



Three 1.25" diameter dowels (10" thick slab) or 1.5" diameter dowels (12" thick slab) are placed at 12" on center along the wheel path. This placement is very similar to dowel bar retrofit construction. The mid panel temperature steel is optional. The temperature steel consists of 3/8" steel bars placed at 6" on center held together by ¼" ties. The panels are 6 feet long and 12 feet wide.

Slide 7

Construction Sequence using HDP foam (typical)

- ✓ **Offsite activities**
  - ❑ Casting of the panels (precast or ready mix plant).
  - ❑ Storage of fabricated precast panels.
- ✓ **Onsite activities**
  - ❑ Documentation of distresses
    - *Type, extent and severity levels*
  - ❑ Slab (existing) demolition
    - *Saw cutting of the repair boundaries*
    - *Saw cutting of dowel slot outlines in the existing panel*
    - *Removal of distressed panel*

The construction process includes a variety of operations.

Slide 8

Construction Sequence (typical)

- ✓ **Onsite activities, *contd.***
  - ❑ Initial cleaning of the base layer
    - *Removal of debris*
    - *Dewatering (if needed)*
  - ❑ Cutting (jack hammering) of dowel slots to specification depth.
  - ❑ Final cleaning and grading of base layer.
  - ❑ Cleaning (pneumatic) and sand blasting of dowel slots.

Slide 9

Construction Sequence (typical)

✓ **Onsite activities, *contd.***

- Check base grade and elevation.
- Transport precast panel to the repair site and check initial panel alignment and elevation.
- Conduct final adjustments.
- Final placement of panel
- Drill holes for the injection of HDP foam.
- Inject HDP foam to stabilize and level the panel.
- Grout dowel slots and lift hook holes.
- Seal joints and open to traffic.

Slide 10

Fabrication of Precast Panels- *Offsite Activity*

Placement of panel steel and dowel bars

Completed mold for precast panels

The precast panels can be fabricated at either a precast plant or a ready-mix concrete yard. A series of slab forms are fabricated with the appropriate joint and panel reinforcement.

Slide 11

Fabrication of Precast Panels- *Offsite Activity*

Placement of fresh concrete

Completed precast panel

It is recommended that fresh concrete property tests be performed. The mechanical property tests should include flexural and compressive strength tests.

Slide 12

Fabrication of Precast Panels- *Offsite Activity*

Surface texturing

Concrete curing

It is recommended that the completed panels be textured and cured.

Slide 13

Typical PCC Mixture Design

Cement (type I):	500-650 lbs*
Water:	200-250 lbs
Coarse Agg:	1500-2000 lbs
Fine Agg:	1200-1400 lbs
Admixtures:	AEA, WRA (if needed)
Target 28-day f'_c:	4000-6000 psi
Target slump:	1-3”

**All weights are for 1 yd^3 of concrete.*

Standard concrete paving mixture designs are suitable for precast concrete fabrication.

Slide 14

Installation of Precast Panels-
On site activities

Saw-cutting of panel boundaries and dowel slots

The slab removal boundaries are outlined and saw cut. The limits of the pavement area to be removed are sawed in the transverse direction.

Slide 15

Installation of Precast Panels-
On site activities

Removal of distressed panel

Following the saw cutting operation, the lift hooks are inserted and the distressed slabs are removed using a front-end loader. During this process, the outline for the dowel slots in the adjacent panels is also cut.

Slide 16

Installation of Precast Panels-
On site activities

Initial cleaning and grading of base course

It is recommended that the base be excavated 1.5-2” below the bottom of the existing slab to accommodate the precast panel. The base should be cleaned and dewatered (if necessary).

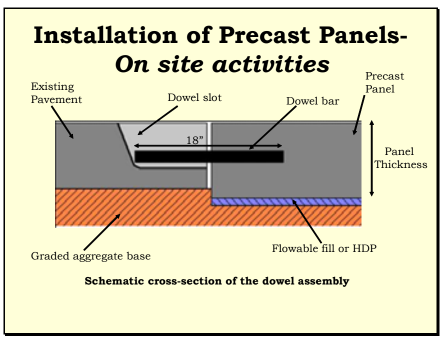
Slide 17

The dowel slot cutting and preparation includes (i) initial grooving to the required depth with a concrete saw; (ii) jack hammering of the concrete to carve out the dowel slot.

Slide 18

The dowel slot preparation also includes (i) air cleaning of dowel slot to remove debris and any loose concrete pieces; and (ii) sand blasting of the dowel slots. The dowel slots are approximately 4” wide and 5.25” deep (base of the slot cut).

Slide 19



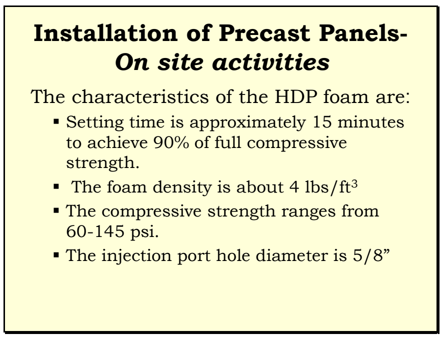
Slide 20

The precast panels are transported from the flat-bed truck to the excavation using a front-end loader.

Slide 21

A series (approximately 4–6 holes/panel) of holes (5/8” in diameter) are drilled to inject the foam. The polyurethane foam is made from two liquid chemicals that combine under heat to form a strong, lightweight, foam-like substance. The chemical reaction between the two materials causes the foam to expand and fill the voids. According to the manufacturer’s specification, the HDP foam sets in approximately 15 minutes (approximately 90% of full compressive strength), and the precast panel is ready to carry load. For the purpose of slab stabilization, the foam density is about 4 lbs/ft^3 with a compressive strength range of 60 psi to 145 psi.

Slide 22



Slide 23

Once the slab elevations are verified and deemed acceptable, the dowel slots are grouted and the joints are sealed.

Slide 24

Slide 25

Construction Activity – *Typical Timeline*

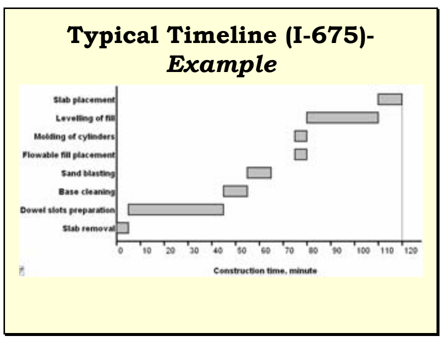
Activity	Description
A1	Slab demolition • *Saw cutting of repair boundaries* • *Saw cutting of dowel outlines* • *Removal of distressed panel*
A2	Initial cleaning of the exposed base layer •*Removal debris* •*Dewatering (if needed)*
A3	Cutting (jack hammering) of dowel slots •*Saw cutting of repair boundaries* •*Saw cutting of dowel outlines* •*Removal of distressed panel*
A4	Final cleaning and grading of the exposed base layer

Slide 26

Construction Activity – *Typical Timeline, contd*

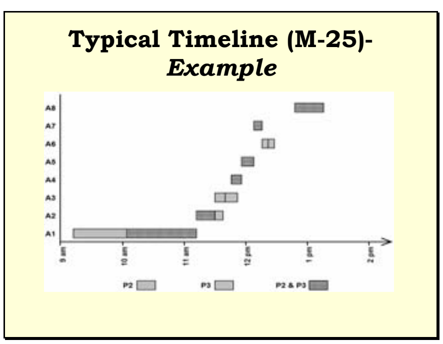
Activity	Description
A5	Air cleaning and sand blasting of dowel slots
A6	Transport, placement and alignment of precast panels
A7	Drill port holes and inject foam to support and align the panels.
A8	Grout dowel slots, seal joints and open to traffic

Slide 27



Example Gantt Chart illustrating time taken to complete installation of one panel.

Slide 28



Example Gantt Chart illustrating time to complete the installation of two panels (multitasking and overlapping of activities).

Slide 29

Construction Activity – *Typical Timeline*

Activity Code	Time, minutes	Recommended Equipment (labor needs)
A1	60	Concrete saw (1), front end loader (1 operator)
A2	5	Nothing specific (2)
A3	20	Two Pnuematic jackhammers (2)
A4	15	Plate compactor (1)
A5	21	Sand blasting equipment (2)
A6	20	Front end loader (1 operator), 3 additional to guide the alignment
A7	25	Drills and HDP injection equipment (2)
A8	26	Grout mixer (2)

Slide 30

Repair Effectiveness

- ✓Measure joint widths along transverse and longitudinal joints.
- ✓Determine panel deflections using the falling deflectometer (FWD)

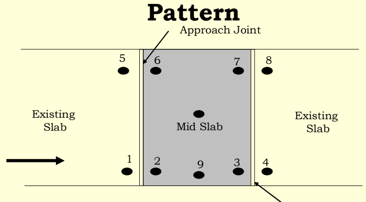
Slide 31

Repair Effectiveness- *Structural*

Photograph of a falling weight deflectometer (FWD).

Slide 32

Recommended FWD Test Pattern



1 = Approach OWP (BJT); 2 = Approach OWP (AJT)
3 = Leave OWP (BJT); 4 = Leave OWP (AJT)
5 = Approach IWP (BJT); 6 = Approach IWP (AJT)
7 = Leave IWP (BJT); 8 = Leave IWP (AJT)
9 = Edge

Load positions of the FWD to determine structural effectiveness.

Slide 33

Repair Effectiveness-
Structural

✓Data from locations 1, 2, 3, 4, 5, 6, 7 and 8 can be used to determine approach and leave load transfer efficiencies (LTEs) along the wheel paths.

$$LTE(\%) = \frac{\Delta_u}{\Delta_L} \bullet 100$$

Unloaded side deflection (Δ_u)
Loaded side deflection (Δ_L)

Slide 34

Repair Effectiveness-
Structural

✓Peak deflections from locations 1, 2, 3, 4, 5, 6, 7 and 8 can be compared with the peak deflection at location 9. This comparison gives information about the uniformity (or lack of it) of support.

APPENDIX C

Sample Specification for Precast Full-Depth Concrete Pavement Repair

MICHIGAN
DEPARTMENT OF TRANSPORTATION

SPECIAL PROVISION
FOR
PRECAST FULL DEPTH
CONCRETE PAVEMENT REPAIR

a. Description. The work consists of fabricating and installing precast full-depth concrete pavement repairs at locations shown on the plans, or as directed by the Engineer. All work shall be according to the Standard Specifications for Construction and this special provision.

b. Materials. The concrete used in the fabrication of the precast panels shall be MDOT Grade P1 according to the Standard Specifications for Construction. The Engineer will provide the concrete mix proportions based on the contractor's materials selection.

The fabrication of the precast panels shall be done according to the special details included in this special provision.

Prior to stripping the forms, the precast panels shall have a minimum flexural strength of 500 psi. The precast panels shall have a 7 day continuous wet cure commencing immediately after final finishing with all exposed surfaces covered. The precast panels shall have a minimum cure of 14 days prior to placement.

The Contractor shall supply test data (slump, air voids, unit weight) for the fresh concrete, and flexural and compressive strengths for the hardened concrete after 7, 14, and 28 days (if applicable).

Concrete patching materials used to backfill the slots shall be selected from the Qualified Products List for Prepackaged Hydraulic Fast-Set Patching included in the Materials Source Guide. The patching material shall be extended with aggregate, up to the maximum amount specified in the Qualified Products List. If a curing compound is recommended by the manufacturer of the patching material, it shall be in accordance with subsection 903.05 of the Standard Specifications for Construction.

The leveling material shall be a flowable fill. The Engineer will provide the mix design.

The aggregate used in the patching materials shall be a dry, clean, crushed 26A gradation conforming to subsection 902.03 of the Standard Specifications for Construction, or equivalent as approved by the Engineer.

c. Construction. All the saw cutting on the existing concrete pavement shall be done in accordance with paragraph six of Section 603.03.B.1.b of the Standard Specifications for Construction. The Contractor is responsible for insuring that the precast patch and dowels will properly align with the removal area and the dowel bar slots.

The slots for the dowel bars shall be cut using a diamond-bladed saw machine. The machine shall be capable of cutting a minimum of three slots simultaneously that are centered over the edge of the repair. Three slots will be made in each wheel path. The bottom of the slots shall be have a minimum flat distance of 10 inches into the existing concrete pavement.

Any loose concrete shall be vacuumed or removed from the slots and all surfaces shall be dry, abrasive blast cleaned. Any exposed steel shall be blast cleaned to remove any rust or laitance. Immediately prior to placement of the patching material, the slots shall be final cleaned with moisture-free, oil-free compressed air having a minimum pressure of 90 psi.

The slot walls and bottom must be dry before placement of the patching material, unless otherwise recommended by the manufacturer.

The patching material shall be mixed with a portable or mobile mixer. The patching material shall be extended, by weight of the cement, with 26A aggregate up to a maximum extension rate as specified in the Qualified Products List, and placed according to the manufacturer's recommendations. The patching material shall then be consolidated using a hand-held vibrator if recommended by the manufacturer. The surface of each dowel-bar patch shall be finished flush with the surrounding concrete and cured according to manufacturer's recommendations, even if diamond-grinding of the concrete surface is to occur afterward.

The Engineer reserves the right to sample the patching material and conduct compressive strength testing to verify that the mixture is meeting the requirements stated below.

Age of sample	Minimum Compressive Strength (psi)
2 hrs.	2000
4 hrs.	2500
28 days	4500

The area where the precast patch is to be placed shall be excavated to a minimum of 12 inches below the top of the existing concrete pavement and shall be free of all debris and standing water.

The existing granular base material shall be moistened just prior to the placement of the flowable fill to prevent absorption of mix water into the underlying granular base material.

Flowable fill shall be placed in the excavated pavement area and leveled to the appropriate depth below the top of the existing pavement to allow the precast panel to be placed level with the top of the existing concrete pavement.

The width of the transverse joints between the precast panel and the existing pavement shall be equal on both sides of the precast panel with a width of 3/4 inch ± 1/4 inch.

The smoothness of the roadway after placement of the precast pavement patches shall meet the straightedge requirements in paragraph three of subsection 603.03.B.8 of the Standard Specifications for Construction.

Joint sealing shall be done in according to requirements specified for resealing transverse and longitudinal pavement joints described in Section 603.03 of the Standard Specifications for Construction.

Patching of the lift holes shall be done using the same material used to back fill the dowel bars.

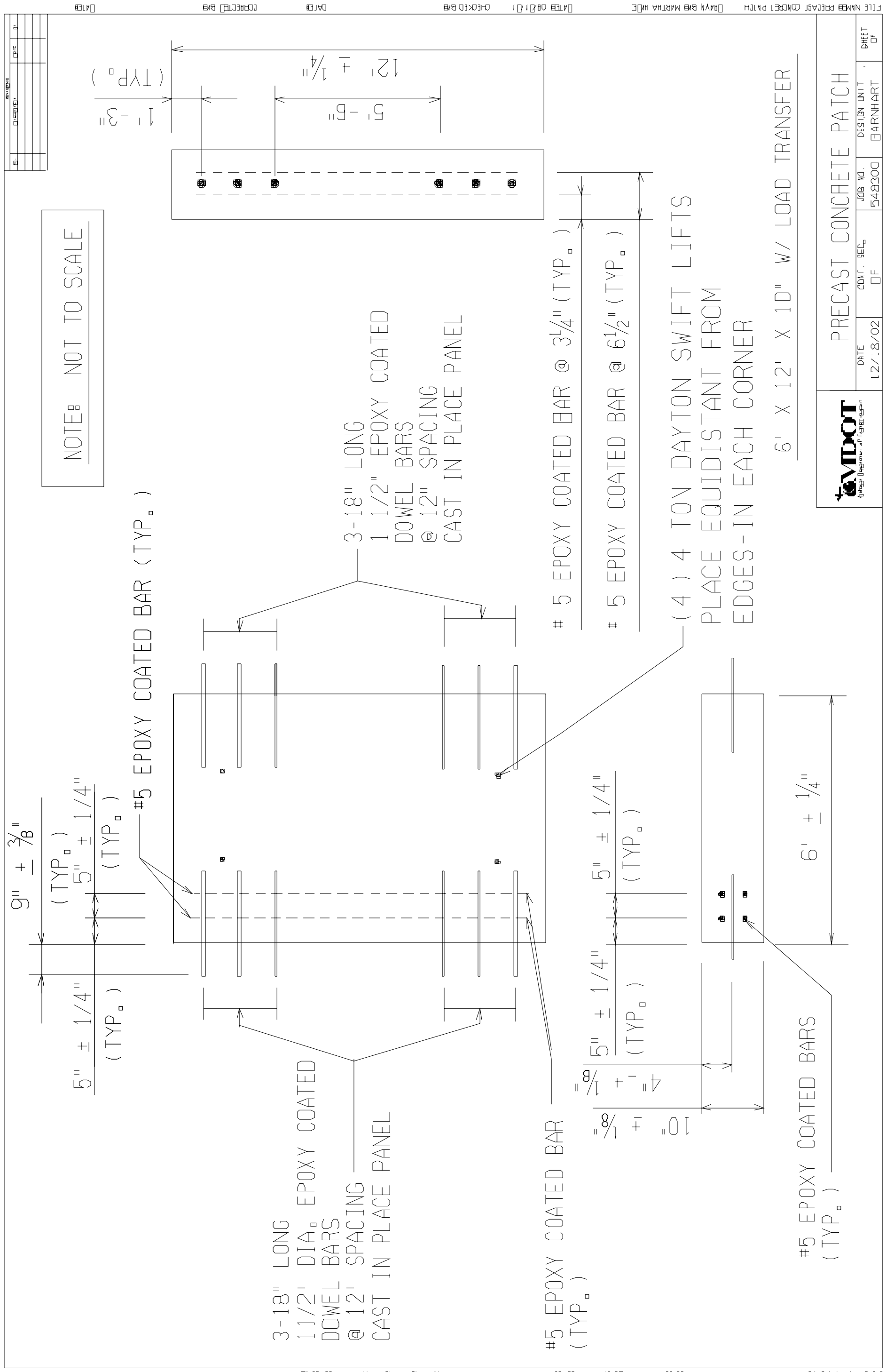
d. Opening to Traffic. Vehicular traffic shall not be permitted on the panel area until the prepackaged hydraulic fast set material used to fill the dowel bar retrofit slots has attained the proper curing time and compressive strength as specified by the product manufacturer.

e. Measurement and Payment.

Contract Item (Pay Item)	**Pay Unit**
Precast Pavement Patch, 10 inch	Each

Measurement for **Precast Pavement Patch,10 inch** is based on each in-place precast patch.

Payment for **Precast Pavement Patch,10 inch** includes all labor, equipment, and materials required to remove, and dispose of the existing concrete in the patch area, cut and clean the dowel bar slots, repair spalls, place the flowable fill, cast the precast patch, transport and install the precast patch, backfill the dowel bar slots and lift holes with a concrete patching material, sealing the joints, and cure the backfill material.


NOTE: NOT TO SCALE
PRECAST CONCRETE PATCH
6' X 12' X 10" W/ LOAD TRANSFER
DATE 12/18/02
JOB NO 54830G
DESIGN UNIT BARNHART
#5 EPOXY COATED BAR (TYP.)
3-18" LONG 1 1/2" EPOXY COATED DOWEL BARS @ 12" SPACING CAST IN PLACE PANEL
3-18" LONG 11/2" DIA. EPOXY COATED DOWEL BARS @ 12" SPACING CAST IN PLACE PANEL
5 EPOXY COATED BAR @ 3¼" (TYP.)
5 EPOXY COATED BAR @ 6½" (TYP.)
(4) 4 TON DAYTON SWIFT LIFTS PLACE EQUIDISTANT FROM EDGES-IN EACH CORNER
#5 EPOXY COATED BAR (TYP.)
#5 EPOXY COATED BARS (TYP.)
9" ± ⅜" (TYP.)
5" ± 1/4" (TYP.)
4" ± ⅛"
10" ± ⅛"
6' ± ¼"
12' ± ¼"
5' - 6"
1' - 3" (TYP.)

REFERENCES

ASTM International. Oct 1, 2004. *ASTM D 1621 REV A: Standard Test Method for Compressive Properties of Rigid Cellular Plastics.* ASTM International, West Conshohocken, PA.

Bull, J. W. 1988. "The Use of Precast Concrete Raft Units for Roads." *Highways*, vol. 56, no. 1936, London, England, U.K., April, pp. 35–36.

Correa, A. L., and B. Wong. 2003. *Concrete pavement rehabilitation guide for full-depth repairs.* Federal Highway Administration, FHWA-RC Atlanta 1/10-03 (5M), August.

Davids, Bill. 2003. *EverFE Theory Manual.* University of Maine, Orono.

FHWA. 1994. *Accelerated Rigid Paving Techniques, State-of-the-Art Report, Special Project 201.* (FHWA-SA-94-080). Federal Highway Administration, Washington, DC.

FHWA. 2003. *LTPP Distress Identification Manual for the Long-Term Pavement Performance Program* (FHWA-RD-03-031). Federal Highway Administration, Washington, DC.

Grimsley, R. F., and B. G. Morris. 1975. *An Approach to Concrete Pavement Replacement That Minimizes Disruption of Traffic. Special Report 153.* Transportation Research Board, National Research Council, Washington, DC, pp. 107–110.

Hachiya, Y., F. Akamine, O. Takahashi, and Y. Miyaji. 2001. "Rapid Repair With Precast Prestressed Concrete Slab Pavements Using Compression Joint System." *Proceedings of 7th International Conference on Concrete Pavements*. International Society for Concrete Pavements, Orlando, FL, September, pp. 891–905.

Lane, R., and T. Kazmierowski. 2005. "Use of Innovative Pre-Cast Concrete Slab Repair Technology in Canada." *Proceedings, 8th International Conference on Concrete Pavements,* Colorado Springs, Colorado, August 2005, pp. 771–789.

Merritt, D. K., B. F. McCullough, and N. H. Burns. 2003. "Precast Prestressed Concrete Pavement Pilot Project Near Georgetown, Texas." *Transportation Research Record 1823.* Transportation Research Board, National Research Council, Washington, DC, pp. 11–17.

Meyer, A. H., and B. F. McCullough. 1983. "Precast Repair of CRC Pavement." *Journal of Transportation Engineering*, vol. 109, no. 5, American Society of Civil Engineers, New York, NY, pp. 615–630.

Overacker, J. W. 1974. "Thruway Repairs Concrete Slabs Overnight." *Public Works,* vol. 105, no. 3, New York, NY, March 1974, pp. 63.

Sharma, A. K. 1990. "Experimental Rehabilitation of Jointed Portland Cement Concrete Pavement." *Transportation Research Record 1272.* Transportation Research Board, National Research Council, Washington, DC, pp. 27–34.

Simonsen, J. E. 1971. *Concrete Pavement Joint Repair With Pre-cast Slabs, Progress Report.* Research project 68 F-102, Research report R-762. Michigan State Highway Commission, Lansing. April 1971.

Simonsen, J. E. 1972. *Concrete Pavement Joint Repair With Pre-cast Slabs, Construction Report.* Research project 68 F-102, Research report R-804, Michigan State Highway Commission, Lansing. February 1972.

Speir, R. H., S. D. Tayabji, G. R. Rada, Y. S. Chen, and S. Murrell. 2001. "Feasibility Study for the Use of Precast Portland Cement Concrete Panels for Rehabilitation of Airfield Pavements." *Proceedings of 7th International Conference on Concrete Pavements, International Society for Concrete Pavements*, Orlando, FL, pp. 907–922.

Tyson, S. S. 1976. *Full-depth Repair of Jointed PCC Pavements Cast-in-place and Precast Procedures.* Virginia Highway and Transportation Research Council, VHTRC 76-R44, Charlottesville.

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