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Final Report

PRECAST CONCRETE PAVING PANELS: THE COLORADO DEPARTMENT OF TRANSPORTATION REGION 4 EXPERIENCE, 2000 TO 2006

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August 2006

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH BRANCH

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16. Abstract

Beginning with a pilot project in December 2000, the Colorado Department of Transportation, Region 4 (northeast corner of Colorado), pursued the use of precast concrete panels as a means to speed repair of concrete pavements. The outcome of the repair techniques occurring within 8 to 9 hours has provided a means to minimize traffic disruption at peak traffic hours. A description of construction concerns and techniques is included.

While a high success rate has occurred with thicker panel depths (8 inches and above), shallower panel depths (7 inches and below) have had a higher failure rate than was expected. Panels have been installed in high traffic areas principally I-25 north of Denver. Additional sites with fewer panels have been on US Hwy 287 north of Fort Collins and US Hwy 85 near Greeley.

Implementation: Repairing concrete pavement with precast concrete paving panels is recommended as a means to minimize traffic disruption during peak hours. The precast concrete panel depth should be 8 inches and above.

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by

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CDOT Maintenance:
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Todd Gonser, Rick Chapman, Rose McDonald, Mike Command, Rick Gabel, Dave Davis, retired; and Lloyd Johnson

Many other CDOT employees helped tremendously in areas of budget, coordination, construction and ideas.

EXECUTIVE SUMMARY

In Region 4 of the Colorado Department of Transportation, I-25 spans the north-south width of the region. Of this distance, a length of 26 miles (between Hwy 66 and Hwy 14) consists of 8 inch concrete pavement built in the 1960's and overlaid with a concrete whitetopping (5" to 7" thick). The pavements are separated by a bond beaker varying from a HBP layer to a chip seal. The AADT in 2006 is 60,000 with approximately13% trucks. The pavement condition is identified from poor to fair within the Colorado Department of Transportation Pavement Management System (Remaining Service Life **RSL** ranges from 0 to 8 years). The operational condition of the roadway identifies over 500 concrete panels that have 3 or more full-depth cracks. Often concrete "chunks" fly out of the roadway after vehicle passage. The high traffic numbers have dictated that repair work can only occur during night hours from approximately 9:00 P.M. to 5:00 A.M. Conventional repair methods have been primarily asphalt patches that could be performed quickly.

It is desirable to develop a longer term repair method that will sustain the pavement system until complete reconstruction can occur. Precast concrete panel use was chosen as a possible repair method because it was envisioned that the benefits would be:

1. Placement could occur in a variety of weather
2. Curing of the panels would be in controlled conditions
3. Manufacturers could attain any panel configuration
4. A pre-caster could be found locally that had talents to develop a panel
5. Two or three panels congregated together for replacement would be a feasible 8 hour project

Known available construction techniques that would compliment efforts include:

1. Portable concrete saws were available that could cut through existing concrete panels in a relatively short time
2. Region 4 had good performance with URETEK[1] products to level bridge approach slabs utilizing polyurethane foam as a lifting medium
3. Handling equipment existed that could readily remove existing concrete panels and correspondingly place precast concrete panels

The precast concrete panels utilized have been reinforced with reinforcing steel. Later projects have involved some cast–in-place reinforced panels as well as comparisons to asphalt patching of panels.

The pilot project and subsequent panel installation involved the following activities:

1. Selection of site
2. Measurement of panel size and depth
3. Placement of injection voids in the panel as well as "dowel slots"
4. After extraction of the existing concrete pavement the new precast panel is placed
5. Injection of polyurethane via the URETEK process, levels the panel
6. "Dowel slots" are continued into adjacent panels followed by fiberglass "dowel" sections epoxied in place

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INTRODUCTION

In July 2000, Mike Hern, John Springer Jr., and Gary DeWitt, all CDOT employees, discussed options for replacing concrete pavement on I-25 north of Hwy 7 in Region 4. A contractor that had been retained to do repairs on the I-25 project had submitted a proposal outlining a minimum 48 hour closing of a lane to allow for concrete panel repair. Due to high traffic volumes it had become region policy to not allow lane closure for more than 8 hours: 9 P.M. to 5 A.M on I-25 unless warranted by accident or crisis.

Mike Hern and John Springer Jr. pursued and obtained approximately $50,000 to develop a pilot project to focus on precast concrete panels. Precast concrete panels were chosen to highlight because it was felt that with innovativeness that placement could occur within an 8 hour time frame. Gary DeWitt developed the design and basic construction sequence for installation.

GOALS OF PROJECT

1. Determine feasibility of utilizing precast concrete panels to replace cast-in-place failed panels
2. Feasibility evaluation included:
    - A. Disruption to traffic for no more than 8 hours
    - B. Installation difficulty at non-uniform cross sections
    - C. Installation difficulty with various weather impending
    - D. Joint transfer and development
3. Determining if industry could reasonably afford installation techniques
4. Determine durability and other advantages
5. Determine failure mechanisms and disadvantages

EXTENT OF PROBLEM

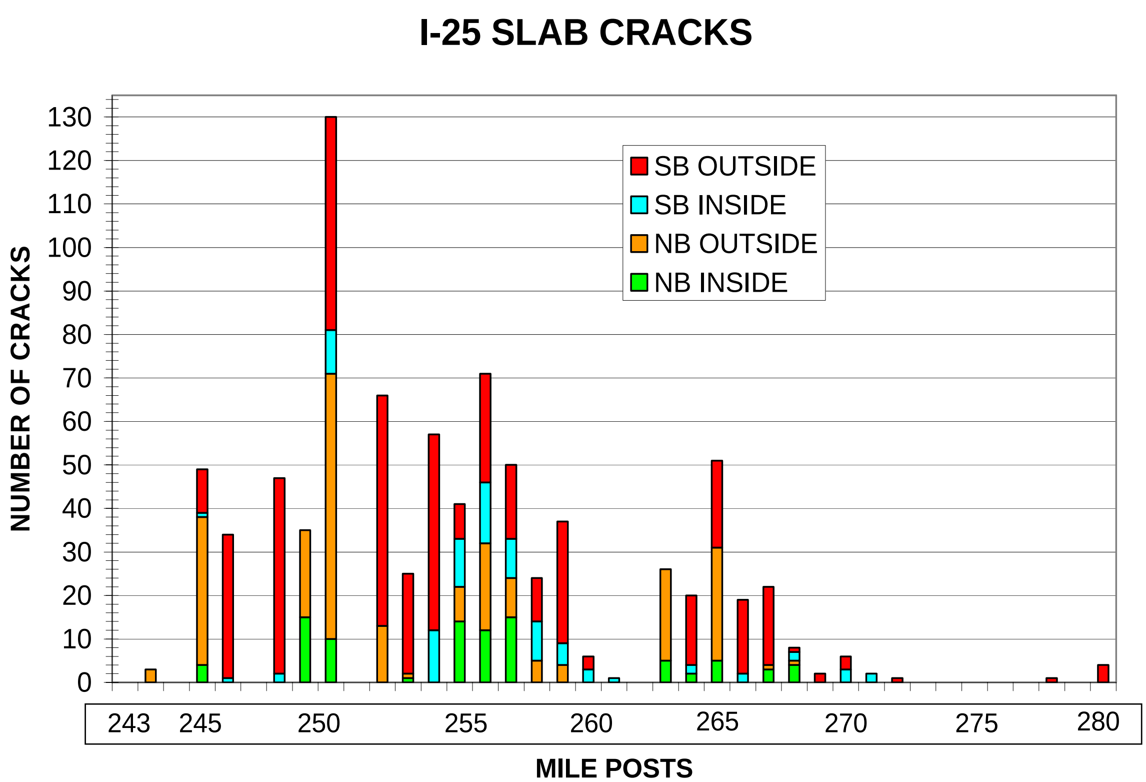
September 2000

A windshield survey was conducted and determined that 500 panels existed between Hwy 52 and Hwy 14 that had at least 3 full-depth cracks. In several areas it was not uncommon to witness "flying concrete chunks" as pavement sections failed. The focus of this repair technique was to address these failed areas regardless of the failure mechanism. AADT traffic on the I-25 area ranged between 22,900 to 60,000 with 10% truck traffic. The present daily repair technique was to put hot mix asphalt into the failed areas. Often placement was by manually casting asphalt from the shoulder in-between moving vehicles.

October 2004 - I 25 & I-76 Region 4

A field survey was conducted for the I-25 corridor to record the number of slabs that had 3 or more full-depth cracks.

FIGURE 1 PANELS WITH 3 PLUS FULL-DEPTH CRACKS I-25



TOTALS
Inside slabs ……..83
Outside slabs…..352

FIGURE 2
PANELS WITH 3 PLUS FULL-DEPTH CRACKS, MP 31 TO MP 108 I-76

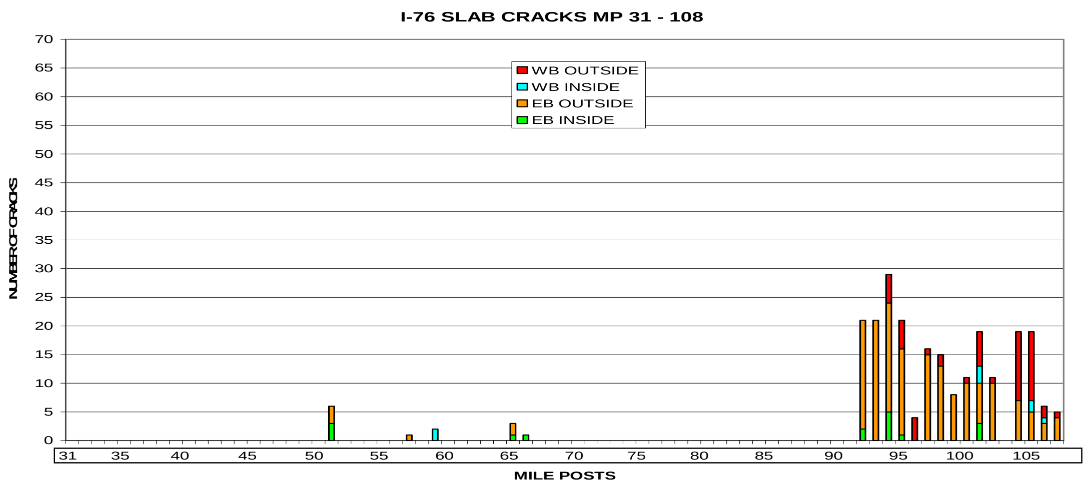
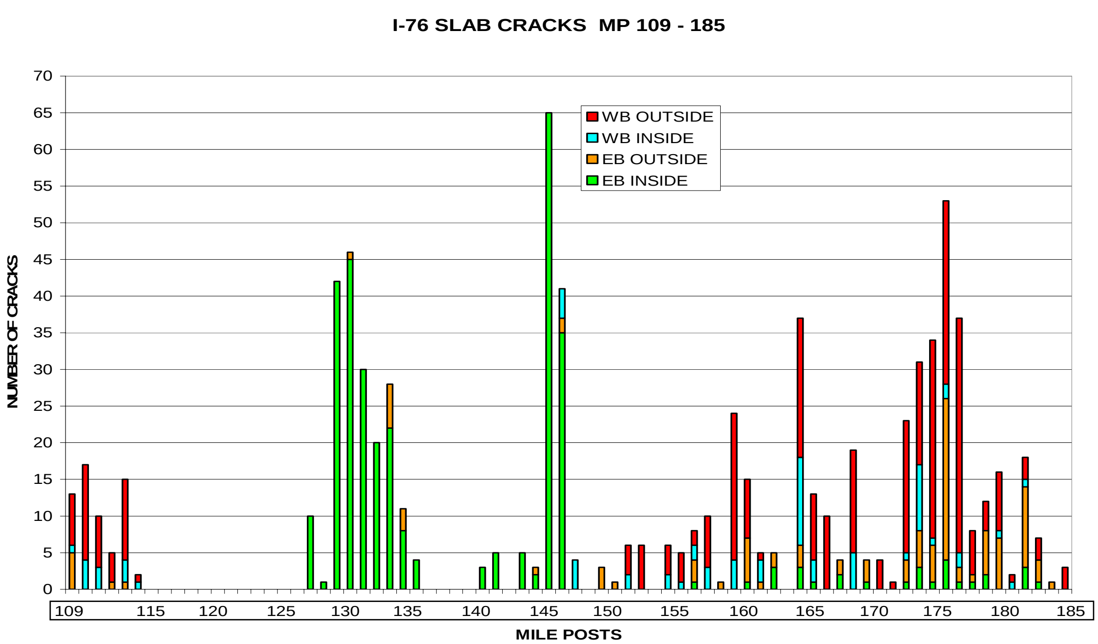


FIGURE 3
PANELS WITH 3 PLUS FULL-DEPTH CRACKS, MP 109 TO MP 185, I-76



TOTALS
Inside slabs…….179
Outside slabs……659

LOCATION

The final placement of the precast concrete panels was focused on I-25 north of Hwy 52. But due to construction concerns, it was felt that an area with less traffic that would allow work to be conducted during the daytime was a reasonable initial test of the concept.

To "test" the feasibility of the precast concrete panel repair technique an area north of Fort Collins on Hwy 287 was chosen near the intersection of Larimer County Road 19 with Hwy 287. The highway at this point was 2-lane with a deceleration East Bound left lane and a West Bound acceleration lane widening. The area had historic pavement failures over an unstable base. The highway geometry placed the proposed section on a superelevated portion of approximately 4%.

Backup roadway operation was present with a four lane configuration—2 opposing thru lanes and 2 opposing speed change lanes. This would allow handling of traffic if any part of the repair sequence reached a stalemate. Also a nearby portion of "Old Highway 287" through LaPorte was available for diversion of traffic.

Daylight repair could occur on this portion as traffic volumes were less than on the I-25 corridor. This would allow some "learning curve" time for everyone involved in the repair process.

PANEL CONFIGURATION

To test several expected future installation challenges various configurations of panels were chosen:

- A complete panel the same shape and size as the original that matched transverse and longitudinal joints
- A small portion of a panel
- An irregular sized panel

The shapes and locations of the panels were chosen: 12 ft wide x 15 ft long, 10 inch thickness.

The repair area was in an approximately 4% superelevated portion, intentionally chosen as perhaps the worst cross slope for installation that would be experienced on I 25 or other concrete roads within Region 4.

OPERATIONAL CONSTRAINTS

Knowing that if the concept was to be feasible on I 25, several operational constraints were identified:

1. Two-way traffic had to be maintained throughout the process
2. Only an 8 hour time frame would be allowed to perform the work
3. An acceptable ride must result after placement
4. All debris had to be removed during the 8 hour work period
5. Any base repair had to occur prior to the precast slab placement
6. Widths of joints could not exceed ½ inch for longitudinal joints and 5/8" for transverse joints

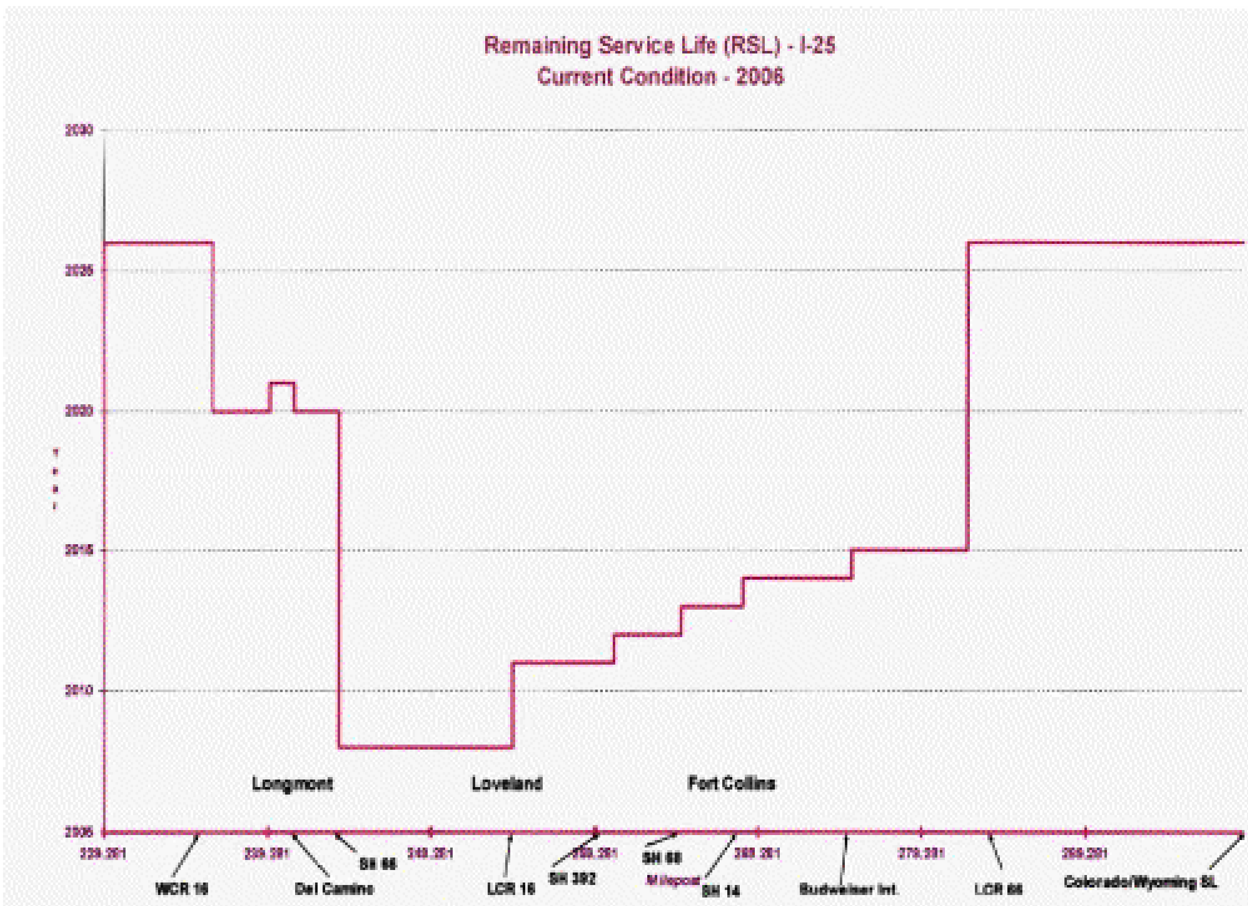


FIGURE 4
REMAINING SERVICE LIFE (RSL) I-25

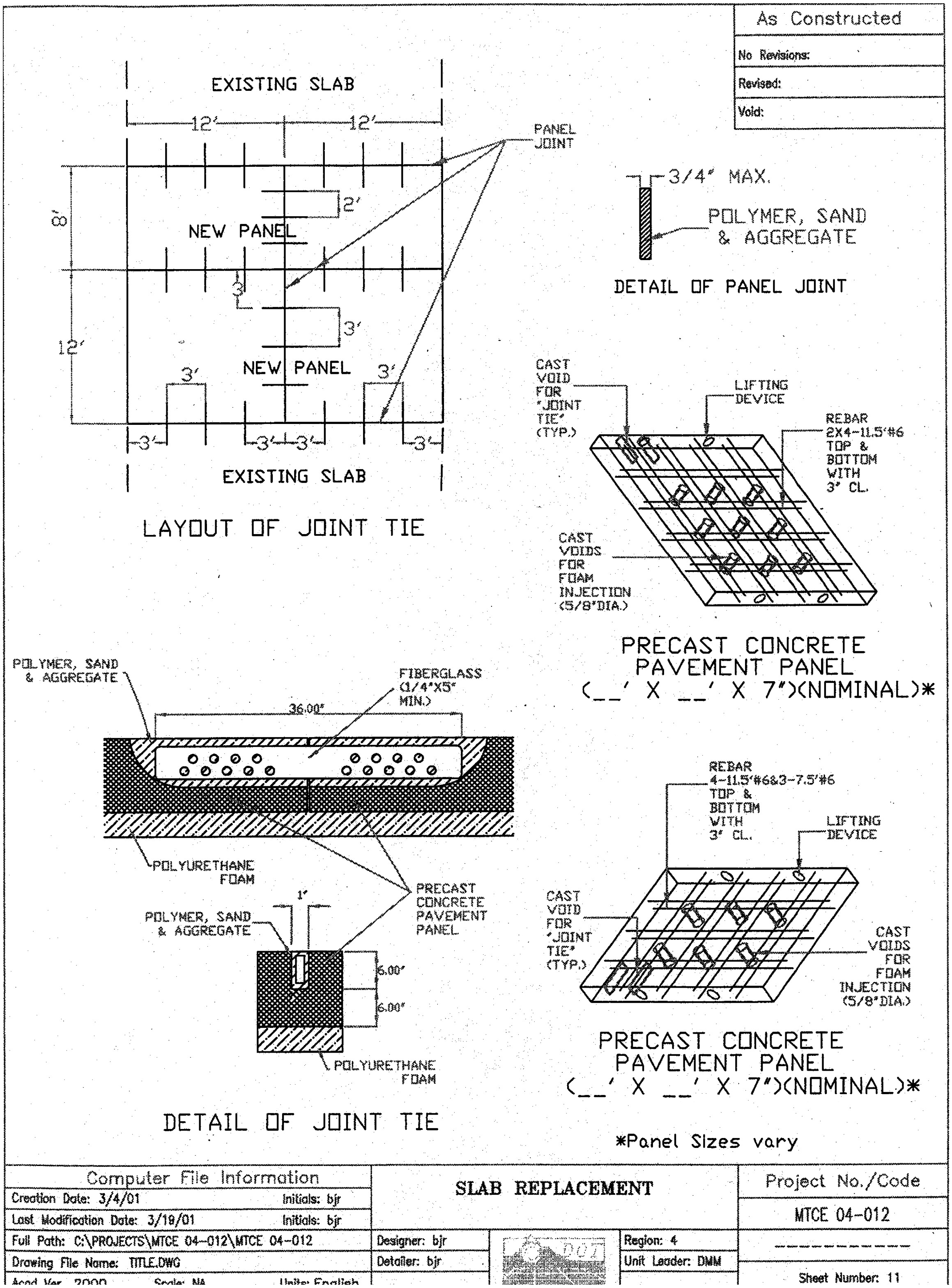


FIGURE 5
SLAB REPLACEMENT DETAILS

PRE-CONSTRUCTION ACTIVITIES

In order to maximize construction time, obstacles were identified that could be solved before the panel installation:

1. The concrete precast contractor measured the panels to their manufacturing tolerances and cored the existing panel for depth determination
2. Panels were poured and cured with injection holes cast-in-place
3. The panels were cast 1 inch thinner than required to allow the URETEK foam to flow under the panel
4. The total sequence of panel installation was reviewed and duties at 15 minute intervals were identified
5. Backup sequences were identified in case events did not go as planned: Asphalt would be used to fill the panel void if needed

LOADING CONFIGURATIONS CONSIDERED

It was determined that plain jointed concrete panel should perform as well as cast-in-place if uniform support were provided. With the polyurethane foam injected at different locations the uniform support should occur.

Types of loads

1. Live load from traffic analyzed AASHTO 1993 Design of Pavement Structures via Darwin[2] software
2. Handling loads analyzed via PCI Design Handbook[3] for precast structures
3. Uniform loading analyzed as simple beam
4. Uniform loading considered point support resulting in negative and positive moments

The worst condition was determined to be **Uniform loading with point supports.** As a result 2 mats of rebar were identified for negative or positive moment resistance.

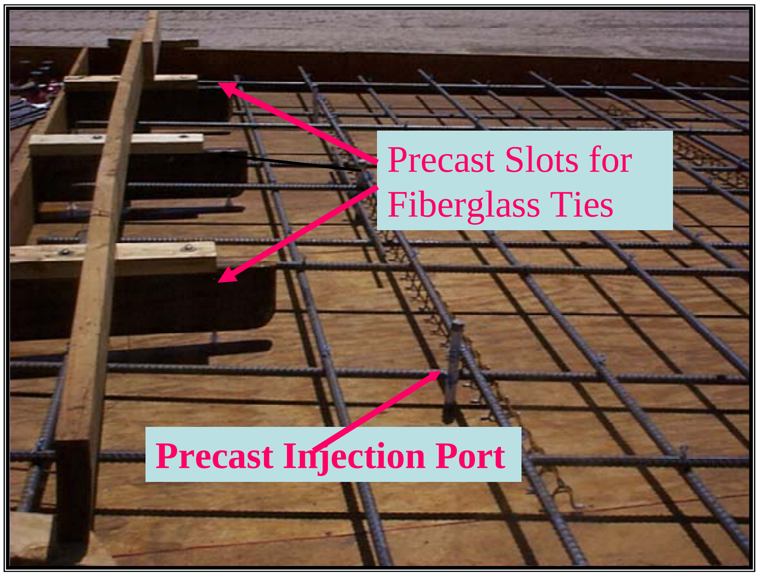


FIGURE 6
PRECASTING: REBAR PLACEMENT

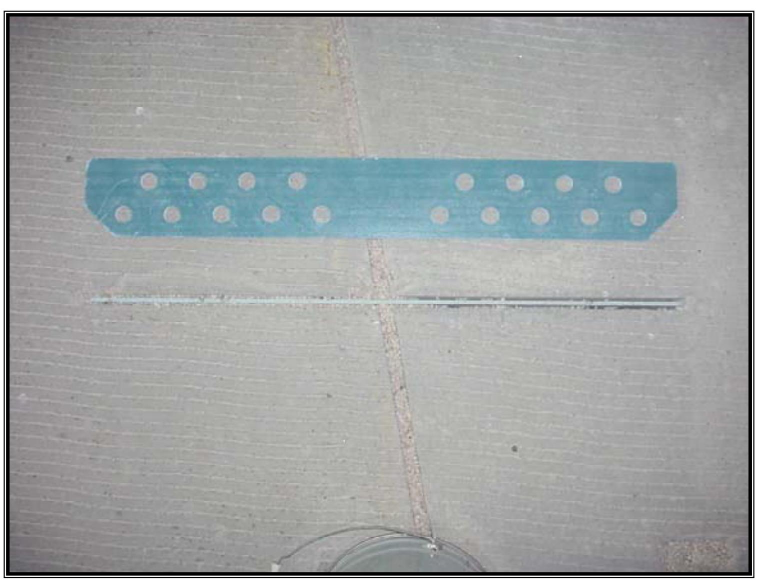


FIGURE 7
FIBERGLASS TIES

CONCRETE MIX DESIGN

All plans required concrete to meet CDOT Class D concrete specifications:

Compressive strengthen at 28 days ---- 4500 psi
Minimum or Range Cement Content--- 615 to 660 Lbs/ cu yd
Air content % Range -- 5-8 %
Aggregate Requirements:

Nominal coarse aggregate size 1 ½" or smaller
100 % passing the 2" sieve
95 % to 100 % passing 1 ½" sieve
Fine aggregate for the concrete shall conform to AASHTO M 6
(the amount of material finer than No 200 sieve shall not
Exceed three percent by weight of fine aggregate)

The cement conformed to one of the following:

1. Type V cement
2. Type II with a maximum C_3A content of 5% and maximum content Of (C_4AF + 2[C_3A}) of 25%
3. Type II and 15 to 20% of the cement replaced with an approved Type F fly ash
4. Blended cement conforming to ASTM C1157 Type HS

FIBERGLASS REINFORCED PLASTIC TIE

Shall be manufactured specifically for pavement tie use. It was required to meet the following mechanical properties:

Longitudinal Properties

PROPERTIES	ASTM Test Method	Value
Ultimate Tensile Strength, Psi min	D-638	30,000
Ultimate Compressive Strength, psi, min	D-695	30,000
Ultimate Flexural Strength, psi, min	D-970	30,000
Tensile Modulus, psi x 10^5 minimum		2.5
Flexure Modulus, psi x 10^5, psi, minimum		2.5
Flexure Modulus, psi x 10^5, psi, minimum		1.6
Ultimate Shear Strength, psi, minimum		5,500
Ultimate Bearing Strength, psi, minimum		30,000
Izod Impact Strength, ft/lb per inch of notch (Sample thickness 1/8" except ¼" for rod)	D-258	25

Transverse Direction

Properties	ASTM Test Method	Value
Ultimate Tensile Strength, psi, minimum	D-638	7,000
Ultimate Compressive Strength, psi, min	D-695	15,000
Ultimate Flexural Strength, psi, minimum	D-970	10,000
Tensile Modulus, psi x 10^5 psi, minimum		0.8
Flexural Modulus, psi x 10^5psi, minimum		1.0
Flexure Modulus, psi x 10^5 psi, minimum		0.8
Ultimate Shear Strength, psi, Minimum		5,500
Ultimate Bearing Strength, psi, minimum		30,000
Izod Impact Strength, ft/lb per inch of notch	D-258	4
Barcol Hardness	D-2583-75	50

SLAB JACKING

The material used for raising concrete slabs shall be water blown formulation of high density polyurethane conforming to the following:

Property	ASTM Test Method	Value
Density, lbs/ft^3 minimum	D1622 without conditioning	4
Compressive Strength at yield point, psi, minimum	D1621 without conditioning	90
Volume Change % of original	D2126 (Temperature to be Selected)	0.0%

The polyurethane material shall reach 90% of full compressive strength within 15 minutes from injection.

PANEL INSTALLATION

Day of Installation: November 30, 2000
Weather of Day: Windy 25-40 MPH. Partly Cloudy 41 to 55 degrees Fahrenheit

It was determined that only 1 panel would be installed today to allow for “learning curve” time. Several pre-installation day meetings were held outlining expected subcontractor performance every 15 minutes. Some base repair was necessary with ABC (Cl 6). The panel was placed at 10:30 A.M. It was necessary to rig the chokers to allow panel alignment with the cross slope. The resultant panel entered the panel void in a skewed configuration. Within 2 hours of installation of the panel, prior to sealing the joints a snow storm occurred. The remainder of the procedure was delayed until the next day.

Construction time accounting is listed in Appendix A (On-site repair Process)

LESSONS LEARNED FROM PILOT INSTALLATION

1. Planning is very worthwhile and bears continued review
2. Sawing panels the night before saves time the day of installation
3. The weather can change quickly requiring a backup plan to be utilized
4. Joint tolerances can be narrowed
5. Provisions for installing panels into superelevated sections need to be considered including adjustable rigging
6. A delivery truck for the precast slabs that has a hydraulic boom is invaluable.

PANEL PERFORMANCE

Weather: Clear
Date of observation: February 12, 2005
Location:
North of Fort Collins on Hwy 287 just west of intersection Larimer County Rd 19
MP 350.9
Dates of installation: November 30 – December 3, 2000
No cracks are apparent from installation, slab remains in same position with no horizontal or vertical movement. Performance rating is excellent.

PICTURES 1 & 2.
Precast panels installed November 30 –December 3, 2000 On Hwy 287 MP 350.9
Performance: excellent

PICTURE 3

MTCE 04 --012 **10 inch precast panels adjacent St Vrain Bridge under 5 inch HMA. I 25 at MP 241**
Performance: excellent

PICTURE 4
MTCE 04-012 CRACK AT BRIDGE ABUTMENT. 10 inch precast panels adjacent to St. Vrain Bridge. I-25 at MP 241 **Performance:** excellent

PICTURE 5

MTCE 04-012 10 inch precast concrete slabs with fiberglass ties skewed
Hwy 85H in Greeley near MP 1.1

Series of 5 panels that fiberglass ties on transverse joint were not placed parallel with traffic flow. **Performance**: excellent

PICTURE 6

MTCE 04-040 Typical crack failure on thin 5” to 7” precast slab
On the away side (last traffic impact section)… I 25 MP

Traffic moves right to left on the picture. The crack leading to failure has been generally in this location for thin 5 “to 7” panels. **Performance:** poor

CHRONOLOGICAL LISTING OF CONCRETE PANEL PROJECTS

December 1994 Project: C 0253-118 Sub Account: 10157
Cast in place concrete panels placed between MP 243 to MP 254

Discussion: Difficulties were experienced with finishing of “fast track” high strength concrete. Much cracking occurred. Contractors estimated at least 48 hour lane closure to construct this process

December 2000 Project: Pilot Project
5 Precast panels place on Hwy 287 near Larimer County Rd 19

Discussion: Utilized reinforced precast concrete panels to replace existing concrete pavement on superelevated portion of roadway. A polyurethane "lifting" foam product by Uretek was utilized to level panels. Also fiberglass stitches were used to connect to adjacent panels

January 2002 Project: MTCE 04-049 Sub Account: M4049
Placed Precast Panels between MP 243 to 269

Discussion: Experimented with "Deep injection polyurethane" and also slab jacking with same material. Precast panels were same dimensions as replaced concrete sections—all skewed joints matched

August 2002 Project: MTCE 04-012 Sub Account: M4012
Placed Precast panels between MP 244 and MP 258. Polyurethane and slab jacking used

Discussion: Deleted matching joint requirements from precast slabs and established a standard transverse joint spacing of 15 feet. Removal cut line on existing pavement was outside original joint in order to establish a cleaner joint face

December 2003 Project: MTCE 04-040 Sub Account: M4040
Place Precast panels between MP 244 and 269 in driving lanes
Polyurethane slab jacking used

January 2003 Project: MTCE 04-024 Sub Account: M4024
Placed precast panels between MP 244 and MP 269 only in driving Lanes. Polyurethane slab jacking used

Present Project: MTCE 04-061R Sub Account: M4061R
Utilizing three methods to replace existing concrete panels:
- Cast in place concrete
- Precast concrete
- Hot Mix Asphalt (HMA)

CONCRETE SLAB REPLACEMENT COSTS

in Region 4 Colorado Department of Transportation by Gary DeWitt Feb-06

Project	SubAcc	Location	Year Awarded	Item	Description	Depth	Quantity	Units	Cost per Unit	Total Cost
Concrete Cast-In-Place										
C0253-118	10157	I-25	May-93	210-03100	Replace Conc	8" to 10"	5790	SY	$43.95	$254,471
C0253-118		I-25	May-93	412-14000	S&Seal Joint		437,785	LF	$1.07	$468,430
IM 0761-186	13978	I-76	May-03	210-03100	Replace Conc	8"	1848	SY	$90.00	$166,320
MTCE 04-061R	MM4061R	I-25	Jun-06	601-04000	Conc Cl E	6" to 7"	298.7	CY	$685.00	$204,610
Pre-Cast Concrete										
MTCE 04-012	CM4012	I-25/SH 85	Apr-02	412-04000	Conc Pvt Pan	5"- 8"	7271	SF	$34.00	$247,214
MTCE 04-012	CM4012	I-25/SH 85	Apr-02	601-10250	Slab Jacking		1000	LB	$8.36	$8,360
MTCE 04-024	MM4024	I-25	Jan-03	412-04000	Conc Pvt Pan	5" to 10"	27318	SF	$20.00	$546,360
MTCE 04-024	MM4024	I-25	Jan-03	601-10250	Slab Jacking	5"to 10"	30300	LB	$7.00	$212,100
MTCE 04-024	MM4024	I-25	Jan-03	202-00170	Grind & Tex	5" to 10"	3035	SY	$20.00	$60,700
MTCE 04-040	MM4040	I-25	Jun-03	202-00170	Grind & Tex	5" to 7"	2541	SY	$11.50	$29,222
MTCE 04-040	MM4040	I-25	Jun-03	412-04000	Conc Pvt Pan	5" to 7"	22870	SF	$24.15	$552,311
MTCE 04-040	MM4040	I-25	Jun-03	601-10250	Slab Jacking	5" to 7"	22200	LB	$9.30	$206,460
MTCE 04-049	MM4049	I-25	Mar-04	202-00170	Grind & Tex	5" to 7"	5360	SY	$9.00	$48,240
MTCE 04-049	MM4049	I-25	Mar-04	412-04000	Conc Pvt Pan	5" to 7"	48216	SF	$22.00	$1,060,752
MTCE 04-049	MM4049	I-25	Mar-04	601-10250	Slab Jacking	5" to 7"	49573	LB	$9.00	$446,157
MTCE 04-061R	MM4061R	I-25	Oct-05	202-00170	Grind & Tex	5" to 7"	1474	SY	$16.00	$23,584
MTCE 04-061R	MM4061R	I-25	Oct-05	412-04000	Conc Pvt Pan	5" to 7"	1161	SF	$28.00	$32,508
MTCE 04-061R	MM4061R	I-25	Oct-05	601-10250	Slab Jacking	5" to 7"	929.28	LB	$12.00	$11,151
Asphalt Patching										
MTCE 04-061R	MM4061R	I-25	Oct-05	202-00210	Rem Conc	5" to 7"	2477.81	SY	$47.00	$116,457
MTCE 04-061R	MM4061R	I-25	Oct-05	403-00270	HBP (Patch)	5" to 7"	441.892	TN	$190.00	$83,959

TABLE 1
CONCRETE SLAB REPLACEMENT COSTS

CONCRETE SLAB REPLACEMENT COSTS

in Region 4 Colorado Department of Transportation by Gary DeWitt

SUMMARY Feb-06

For comparison purposes consider cost of 12 ft x 15 ft concrete slab, depth 10" to 7 "

PROJECT CAST-IN-PLACE	cost/unit	unit	cost/SF	cost/180 SF	cost/slab	Tot Cost	Description
C0253-118	$43.95	SQ YD	5	879			concrete
C0253-118	$1.07	LF			$58		sealing
						$936.78	
IM 0761-186	$90.00	SQ YD	12			2160	concrete
MTCE 04-061R	$685.00	CY	17			3000	concrete

PRECAST CONCRETE PANEL

MTCE 04-012	$34.00	SF	34	6,120			concrete
MTCE 04-012	$8.36	LB	$1.15		$207		slab jacking
						$6,327	
MTCE 04-024	$20.00	SF	20	3,600			concrete
MTCE 04-024	$7.00	LB	$7.76		$1,398		slab jacking
						4,998	
MTCE 04-040	$24.15	SF	24	4,347			concrete
MTCE 04-040	$9.30	LB	$9.56		$1,721		slab jacking
						6,068	
MTCE 04-049	$22.00	SF	22	3,960			concrete
MTCE 04-049	$9.00	LB	$9.25		$1,666		slab jacking
						5,626	
MTCE 04-061R	$28.00	SF	28	5,040			concrete
MTCE 04-061R	$12.00	LB	10		$1,729		slab jacking
						6,769	

ASPHALT (PATCHING)

MTCE 04-061R	$47.00	SY	$5.22		$245		Removal
MTCE 04-061R	$190.00	TN	$11.61		$2,090		HBP
						$2,335	

Comparison Cost by Square Foot

Cast-in-Place	$5.20 to $16.67
Precast	$27.77 to $37.61
Asphalt	$12.97

TABLE 2
SLAB REPLACEMENT COSTS SUMMARY

USER COSTS

From program "Workzone"

CDOT REPORT - Summary Input and Output for the Single Lane Closure Strategy

	INPUT DATA	
Project Name	precast slabs	
Freeway Name	I 25	
Input Filename		
Project Start Date		
Project End Date		
Design Speed	80 mph	
Speed Limit	75 mph	
Workzone Speed Limit	55 mph	
Grade	4.0 %	
Work Zone Length	0.25 miles	
Total Number of Lanes	2	
Number of Open Lanes	1	
Number of Temporary Lanes	0	
AADT, Directional	60000	
Percentage of Single Unit Trucks	4.5 %	
Percentage of Combination Trucks	8.5 %	
Functional Class	Rural Interstate (Weekday)	
	OUTPUT SUMMARY	
TYPE OF WORK	**ADDITIONAL USER COST** **DUE TO WORKZONE**	**DURATION**
202-Removal of Concrete	$63,673,596.61	4
TOTAL ADDL. USER COST	$63,673,596.61	4
TOTAL USER COST FOR NORMAL CONDITION (WITH NO WORKZONE)		
FOR A DURATION OF 4 DAYS = $71,482.32		
Disclaimer:		
The values presented in this program are intended to provide guidelines only.		
Engineering judgement must be applied to use these values.		
No one but the user can assure that these results are properly applied.		

4

TABLE 3
USER COSTS

CDOT - REPORT - Hourly Distribution of User Costs and Queue Lengths

Volume	Normal Capacity	Work Zone Capacity	Approach Speed	Work Zone Speed	Queued Traffic	Queue Length	Additional User Costs
1519.54	2779.78	976.08	59.97	30.00	543.46	1.03	5913.87
1234.63	2779.78	976.08	62.23	30.00	802.01	2.55	13662.80
1044.69	2779.78	976.08	63.73	30.00	870.61	3.17	16781.14
1044.69	2779.78	976.08	63.73	30.00	939.22	3.43	18125.27
1329.60	2779.78	976.08	61.48	30.00	1292.74	4.23	22405.67
2279.32	2779.78	976.08	53.96	30.00	2595.97	7.36	39244.29
3798.86	2779.78	976.08	30.00	30.00	5418.75	15.18	81345.01
5033.49	2779.78	976.08	30.00	30.00	9476.15	28.21	151470.83
4843.55	2779.78	976.08	30.00	30.00	13343.62	43.22	230662.39
5033.49	2779.78	976.08	30.00	30.00	17401.03	58.23	310523.81
5128.46	2779.78	976.08	30.00	30.00	21553.40	73.78	393168.59
5223.43	2779.78	976.08	30.00	30.00	25800.75	89.69	477815.00
5223.43	2779.78	976.08	30.00	30.00	30048.10	105.77	563156.31
5508.35	2779.78	976.08	30.00	30.00	34580.37	122.40	652575.44
5888.23	2779.78	976.08	30.00	30.00	39492.52	140.29	749454.38
6458.06	2779.78	976.08	30.00	30.00	44974.50	159.98	857399.38
6648.00	2779.78	976.08	30.00	30.00	50646.42	181.10	971443.13
6553.03	2779.78	976.08	30.00	30.00	56223.37	202.40	1084768.00
5223.43	2779.78	976.08	30.00	30.00	60470.72	221.01	1174433.13
4178.75	2779.78	976.08	30.00	30.00	63673.39	235.12	1241100.88
3608.92	2779.78	976.08	30.00	30.00	66306.22	246.17	1294701.88
3229.03	2779.78	976.08	30.00	30.00	68559.17	255.43	1340096.63
2659.20	2779.78	976.08	30.00	30.00	70242.29	262.88	1374209.25
2184.34	2779.78	976.08	30.00	30.00	71450.55	268.36	1398597.25
Type of Work:	202-Removal of Concrete						

TABLE 4
HOURLY USER COSTS

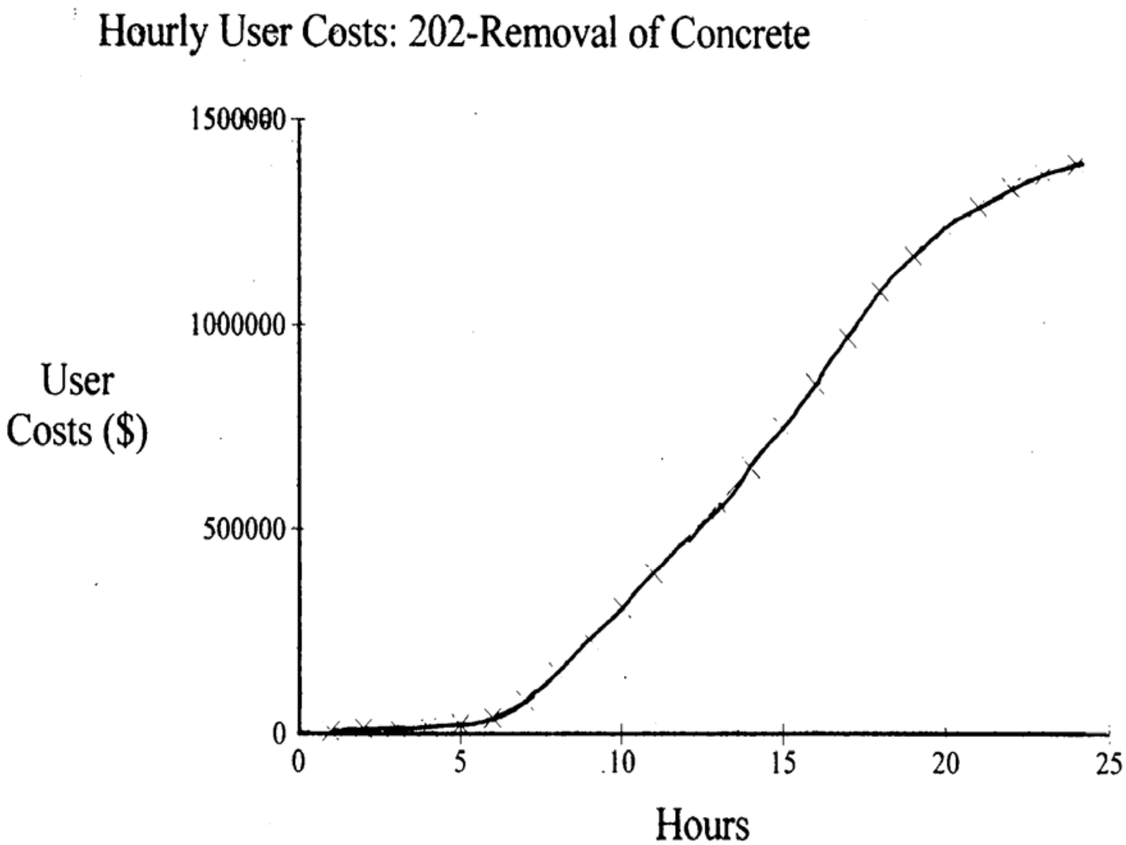


FIGURE 8
REMOVAL OF CONCRETE (Cost vs time)

The results of the Workzone program suggest a cost of $63,673,596 for a 4 day shut down of one lane during a conventional concrete removal program whereas a normal user cost of $71,482 would exist if the construction work wasn't being conducted. From Figure 6 User costs vs. hours the user cost is approximately $25,000 for an 8 hour shut down of a lane for concrete removal and correspondingly $145,000 for a 24 hour shut down.

If we used the scenario of shutting down one lane for 8 hours while 3 panels were repair versus 24 hour shutdown for a conventional repair the difference in user costs is significant.

User cost for 8 hours ---- $25,000
<u>User cost for 24 hours ---$145,000</u>
Difference --- $120,000
Normal User cost $71,482 / 4 days or $17,870

Additional user cost saved for 8 hours shut down vs. 24 hour shutdown = $102,130

CONCLUSIONS

The utilization of precast slabs in high traffic areas is feasible as a repair technique for small groups of distressed slabs. The process explored utilizing polyurethane foam as a lifting mechanism, it works well for slabs 8 inch in depth and greater. A survey conducted by Brain Meeker and documented in “I-25 Pre-Cast Concrete Panel Distress 11 March 2005”[5] indicates that of the 429 panels installed at that time, 24% of the panels 6-1/4” or less have a significant failure and that 1.5% of the panels 7-1/4 inch or more are experiencing failure. Investigation regarding why this high failure rate occurred will continue and will include considerations such as:

Failure of polyurethane foam to reach density under light dead loads
Lack of uniform distribution of foam under the panel
Structurally deficient panels

Panel configuration features, when placed in service in a severely deteriorated roadway, that can save money and increase the durability of the panel:

1. do not tie the longitudinal joint, it saves installation time and when placed next to an existing panel that would provide only marginal support, the joint can be eliminated
2. do not provide collinear new transverse joints with existing skewed transverse joints in a severely deteriorated roadway, it is not detrimental to new panels

Having a process that repairs distressed slabs that can be done in 8 hours or less saves tremendously on user costs. While this cannot be directly transferred into construction dollars, users vote and are more likely to be supportive of a considerate DOT that is aware of user costs.

VIDEO

Produced with the sponsorship of the FHWA. The video details the construction process and also mentions the Michigan technique. It is available from the FHWA[6]

REFERENCES

1. URETEK USA, Inc. 9422 Hammerly, Houston, Texas 77080 Ph. 713-973-0125

2. *DARWIN*, computer software AASHTO

3. *PCI Design Handbook 5th edition*, Precast/Prestressed Concrete Institute 175 W. Jackson Boulevard Chicago, Illinois 60604

4. *Workzone*, computer software, Colorado Department of Transportation

5. "I-25 Pre-cast Concrete Panel Distress 11 March 2005" Brian Meeker Colorado Department of Transportation March 2005

6. "Pre-Cast-Concrete Patch Paving" Federal Highway Administration

7. Concrete Stabilization Technologies, 58 Mule Creek Road, P.O. Box 793 Wheatland, WY. 82213, www.uretekusa.com

8. Colorado Pre-cast Concrete, Inc. 1820 S.E. 14th Street, Loveland, Colorado 80537, www.coloprecast.com

APPENDIX A

On-Site Repair Process @ Hwy 287 & County Rd 19
courtesy of Mike Command

Day One (11/30/2000)

Time	Work Description
6:30 A.M.	Started set up of traffic control devices
7:45 A.M.	Concrete Stabilization Technologies (CST)[7] arrives on site
8:00 A.M.	Saw cutting crew arrives on site. CST started drilling holes in adjacent slabs for stabilization
8:20 A.M.	Started saw cutting (Saw cutting crew ran out of cooling water Took 30 minutes to find refill)
9:15 A.M.	Started injecting polyurethane. (Injected polyurethane along the perimeter of adjacent slabs to prevent water from seeping into slabs)
11:40 A.M.	Started patching an existing panel # 2 with cold mix
12:15 P.M.	Moved southbound traffic over to allow slab injecting adjacent to # 3 panel
1:00 P.M.	Opened up traffic and started drilling
1:10 P.M.	Started polyurethane jacking (URETEK)
1:30 P.M.	Finished polyurethane jacking. Started picking up traffic control devices
Total Time	Approximately 7.5 hours from lane closure to open

Weather Conditions: Partly cloudy and windy

On-site Repair Process –Day Two (12/5/2000)

Time	Work Description
7:45 A.M.	Started removal of 10-inch concrete slab. Slab was resting on Class 6 roadbase material. Equipment: one ballpricker and one "jaw" loader.
8:45 A.M.	Finished removing slab, clearing debris and rough leveling of roadbase. Equipment: one tamper
9:00 A.M.	Finished rough leveling and compaction. Measuring across open section to check 1 inch tolerance
9:30 A.M.	Started sandblasting. One laborer. Time was spent evaluating and correcting soft spot in roadbase

9:40 A.M.	Finished sandblasting
9:45 A.M.	Hammered loose concrete along saw cut joint to provide more clearance with the precast slab. One laborer
9:50 A.M.	Colorado Precast Concrete[8] in position to place slab. One boom operator and three laborers
10:07 A.M.	Concrete slab taken out of hole since it was above the existing pavement elevation. Workmen went back to remove the high spots in the roadbase
10:30 A.M.	Finished resetting slab into position
10:35 A.M.	Concrete Stabilization Technologies truck moved into position to start jacking slab with polyurethane. Four laborers
12:20 P.M.	Finished final leveling of slab. Some grinding of existing pavement needed to prevent snow plows from catching the bottom edge of the plow blade
12:30 P.M.	Start drilling holes in adjacent slabs for jacking operation. This was done to bring the existing pavement to the same elevation as the newly installed slab
12:45 P.M.	Started saw cutting of stitching joints. Two operators with two saw cutters
2:15 P.M.	Finished saw cutting. Started cleaning joints with compressed air One laborer
2:55 P.M.	Finished cleaning joints. Started drying joints with propane torch One laborer
3:30 P.M.	Finished drying all joints. Snow flurries began. Finished working for the day
Total time:	Approximately 9.5 hours
Weather Conditions:	Overcast with moderate winds, 30 to 40 degrees Fahrenheit. Late afternoon snow flurries

On-Site Repair Process—Day Three (December 6, 2000)

Time	**Work Description**
11:30 A.M.	Traffic control in place by 11:30. CDOT crews
12:05 P.M.	Stitching crew arrived on site at 12:05 P.M.
12:25 P.M.	Sandblasted cold patch area
12:35 P.M.	Finished sandblasting
12:40 P.M.	Started drying joints with propane torch
12:45 P.M.	Started filling in joints with dry sand, up to six inches Finished heating joints
12:50 P.M.	Started placing fiberglass stitches
1:00 P.M.	Started placing crumb rubber in joint on south end This was followed with backer rod on top of rubber filler

1:20 P.M.	Started applying URETEK 600 joint sealant.
2:40 P.M.	Finished sealing joints with URETEK 600
2:50 P.M.	Prepared to fill south transverse joint with URETEK 800
3:00 P.M.	Finished sealing south transverse joint. Began preparations for grinding high edge on north end between the existing and new panels
3:30 P.M.	Recut joint in east end of panel #2 due to bow in original joint (straightened out joint)
4:00 P.M.	Completed job
Total time:	Approximately 5.5 hours
Weather Conditions:	Clear with light wind.

<u>On-Site Repair Process—Day Four (December 7, 2000)</u>

Time	**Work Description**
8:15 A.M.	Started removal of 10-inch concrete panels. Panels were resting on moist Class 6 roadbase material. Material was excavated to a depth of about two inches below existing pavement. Equipment: One ballpricker and one "jaw" loader.
8:25 A.M.	Finished removing two panels, started cleaning off sides, rough grading of subgrade. Two laborers.
8:55 A.M.	Started placing Class 6 for level grade. New material was placed to a depth that was about 11 to 12 inches below surface of existing pavement. Equipment: One Bobcat loader.
9:00 A.M.	Continued cleaning saw cut joints. One to three laborers.
9:05 A.M.	Finished cleaning along edges. Continued fine leveling of subgrade.
9:15 A.M.	Finished fine grading, start tamping. Equipment: one laborer
9:25 A.M.	Finished tamping, started sand blasting along edges. One laborer
9:45 A.M.	Finished sandblasting
9:50 A.M.	Colorado Precast Concrete boom truck moved into position to set panels. One operator and three others guiding slab.
10:15 A.M.	Finished placing two panels Concrete Stabilization Technologies started setting up polyurethane jacking. CDOT plows move into position over opposite corners of the panels. (This operation was done relatively quickly due to the amount of space available) Three to four CST laborers with two applicators
11:50 A.M.	West panel jacking complete
12.05 P.M.	Crack occurred in existing panel while jacking it
12:45 P.M.	Completely finished with pavement jacking. Start preparation for saw cutting. Equipment: two diamond concrete saw cutters

1:40 P.M.	Finished saw cutting. Continued cleaning joints. Five to six laborers.
2:00 P.M.	Started blowing out all joints with compressed air. One laborer
2:10 P.M.	Finished blowing out joints. Started drying out saw cuts with propane torch. One laborer.
2:30 P.M.	Started placing fiberglass stitches and filling perimeter joint with "pea gravel". Gravel was placed to about one inch below top of pavement. (Top of joints seems to be sufficiently dry). Four laborers.
2:45 P.M.	Started applying URETEK 600 joint sealant. One laborer.
2:50 P.M.	Finished drying with propane torch. (Sealant has a tendency to flow out of joints due to its high viscosity. Material will react with any moisture that is in the crack and cause it to expand above pavement surface). Two laborers using scrapers to clean off excess sealant.
4:10 P.M.	Finished sealing joints.
4:!5 P.M.	Started grinding south edge of east panel. Equipment: one push grinder.
4:30 P.M.	Finished grinding.
4:35 P.M.	Finished clean up.
Total time:	Approximately 10.5 hours. This does not include the time to make the initial saw cuts around the perimeter of the slab removal
Weather conditions:	Overcast

Observations/Comments on Repair Process:

On day two, the subgrade was excavated and rough leveled to a minimum depth of one inch below the bottom of the existing slabs. The slope of the roadway and a high spot in the subgrade resulted in the newly placed panel sticking slightly above the existing roadway in one corner. This resulted in loss of about 20 minutes as the subgrade was further excavated and the pre-cast panel reset. For the next slab replacement, the subgrade was excavated to two inches below the bottom of the existing slabs. The extra depth allowed the two pre-cast panels to be installed without resetting either of them.

The width of the roadway at the repair site allowed ample space for construction vehicles to be parked next to each other. This may not be the case when work is being done at locations where space is more limited. Hence, an increase in construction time can be expected.

It took about one hour and 30 minutes for one applicator to apply the joint sealant within the saw cuts. The amount of time for this operation could be reduced by using fewer stitches, adding another applicator wand and/or increasing the flow rate of the applicator.

On day two, it took about one hour and 45 minutes to jack the new pre-cast panel with polyurethane. On day four it took about one hour and 45 minutes to jack two pre-cast panels.

Conclusion:

Overall the repair process progressed quite smoothly. The only real problem occurred on day two when inclement weather prevented work from being completed. On day two it took nearly eight hours to place and jack one pre-cast panel, not including sealing the saw cuts. On the fourth workday two panels were replaced in about nine and a half hours. (For both days, this time does not include the time required for initial saw cuts or setting up and breaking down traffic control devices). As work crews become more familiar with pre-cast repair process, it is expected that more time will be saved.