

# Evaluation of Pressure Relief Joint Installations

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Pressure relief joints are used to reduce compressive stresses in concrete pavements and thereby to reduce pressure-related damage. In recent years, their use has become so commonplace that they are frequently overused or used inappropriately. To evaluate the effectiveness of pressure relief joints, representative pressure relief joint installations around the United States were reviewed to identify, define, and document the criteria for the use of these joints. These installations included several climatic zones, placement in both short- and long-jointed concrete pavements, relief joints that were placed prior to overlay, wide joints filled with asphalt concrete, narrow joints filled with foam, and other factors of interest. It was determined that the use of pressure relief joints was often unwarranted and that good contraction joint maintenance programs would have prevented the development of pressure-related problems. The unnecessary or excessive use of pressure relief joints was found to cause damage that was more costly to repair than the damage that would have resulted without the relief joints. Where appropriate, pressure relief joints were found to close rapidly during their first year and to be effective in preventing pressure damage for 3 to 7 years.

Net increases in concrete pavement length are often caused by such factors as the intrusion of incompressibles into poorly sealed joints, the pumping of base materials into joints, and/or the expansion of reactive aggregates in the concrete. If left untreated, these increases in length create compressive forces in the concrete pavement and result in blowups and/or bridge pushing. One means of addressing this problem is through the use of pressure relief joints, the function of which is to relieve compressive stresses in the concrete pavement and thereby to prevent blowups, shattered slabs, severe joint spalling, and damage to secondary structures.

In 1983, a research study entitled "Pressure Relief and Other Joint Rehabilitation Techniques" was sponsored by the Federal Highway Administration (FHWA). Primary objectives of this study included the identification of criteria for the use of pressure relief joints and the development of a set of guidelines for the design and installation of pressure relief joints (1). To fulfill these objectives, a field survey of thirty-six rehabilitated projects was conducted in 1985 and 1986; extensive condition, design, traffic, and other data were collected. Twenty-five of these projects, listed in Table 1, included pressure relief joint installations. Detailed, comprehensive project evaluation reports were prepared for each of these projects.

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The performance information obtained from these in-service projects was supplemented with the knowledge and expertise of an advisory panel of state highway engineers. The resulting information was used to assist in the development of decision trees, improved design guidelines, and guide specifications for the use and construction of the selected joint rehabilitation techniques (1, 2). Those projects that provide the most insight regarding the use and performance of pressure relief joints are presented here.

## PRESSURE RELIEF JOINTS (PRJs) IN JOINTED CONCRETE PAVEMENT

### Louisiana, I-55, Milepost 32

The original pavement was a 10-in., jointed reinforced concrete pavement (JRCP) with 58.5-ft contraction joints, constructed and opened to traffic in 1966. Four-inch wide, cellular plastic-filled, pressure relief joints were installed in the northbound lanes in 1980 at 0.5-mile intervals to relieve expansive pressures and eliminate blowups. The southbound lanes served as a "control" section in which no relief joints were placed. This rehabilitation project was constructed to evaluate the performance of relief joints and analyze the economics of using them (3).

By 1985, the pressure relief joints had sustained about 2.7 million, 18-kip, equivalent single-axle loads (ESALs) in the outer lane. The condition surveys conducted in 1985 revealed some low-severity, transverse slab cracking in both directions and one full-depth repair in the southbound sample where a blowup had occurred at a joint. The Louisiana Department of Transportation and Development (LDOTD) reported a total of fifteen blowups in the southbound lane over the 25-mile section, while none occurred in the northbound lane where the pressure relief joints were placed (3).

Forty-five percent of the southbound lane original contraction joints and 39 percent of the northbound lane original contraction joints exhibited medium-severity transverse joint and corner spalling; a few displayed high-severity spalling. No significant difference in joint faulting was noted between the two sections. Pavement Serviceability Index (PSI) values determined in 1983 by LDOTD were 3.7 and 3.4 for the northbound and southbound lanes, respectively.

The pressure relief joints had closed to an average width of 1.5 in. and had faulted an average of 0.13 in. The filler was generally absent from these joints, and the joints were full of foreign materials. The contraction joints adjacent to the

TABLE 1 SUMMARY OF PRESSURE RELIEF JOINT INSTALLATIONS

ORIGINAL PAVEMENT				PRESSURE RELIEF JOINT			
State/Location	Year Built	Pavement Type	It Spacing	Year	Width	Filler	Spacing
IL I-55, mp 98	1963	10-in JRCF	100-ft	1973	4-in	Foam	1320-ft
IL I-55, mp 102	1963	10-in JRCF	100-ft	1973	4-in	Foam	1320-ft
IL I-55, mp 252	1956	10-in JRCF	100-ft	1975	4-in	Foam	1500-ft
IL I-72, mp 67	1970	7-in CRCP	--	1983	4-ft	AC	1000-ft
IL I-80, mp 105	1960	10-in JRCF	100-ft	1984	4-in	Foam	1320-ft
IN I-69, mp 64	1964	10-in JRCF	40-ft	1975	3-ft	AC	40/500/1000-ft
IA US 30, mp 156	1964	10-in JPCF	20-ft	1980	4-in	Foam	1000-ft
IA I-35, mp 86	1965	10-in JRCF	76-ft	1980	4-in	Foam	1000-ft
KY I-65, mp 12	1966	10-in JRCF	50-ft	1982	6-in	Foam	1000-ft
LA I-55, mp 32	1966	10-in JRCF	58-ft	1980	4-in	Foam	2640-ft
OH I-70, mp 66	1969	8-in CRCP	--	1970	2-ft	AC	2640-ft
OH I-71, mp 210	1959	10-in JRCF	60-ft	1973	2-ft	AC	2640-ft
OH I-270, mp 29	1969	8-in CRCP	--	1973	4-in	AC	2000-ft
OH I-270, mp 31	1969	8-in CRCP	--	1983	4-in	AC	2000-ft
MI US 127	1956	9-in JRCF	99-ft	1972	4-in	Foam	200-1200 ft
NE I-80, mp 189	1965	9-in JRCF	46-ft	1981	4.5-in	Foam	2000-ft
NE I-80, mp 210	1964	9-in JRCF	46-ft	1980	4.5-in	Foam	2000-ft
NE I-80, mp 256	1963	9-in JRCF	46-ft	1980	4.5-in	Foam	2000-ft
NE I-80, mp 279	1964	9-in JRCF	46-ft	1980	4.5-in	Foam	2000-ft
NE I-80, mp 382	1962	9-in JRCF	46-ft	1982	4.5-in	Foam	5280-ft
VA SR 44, mp 0	1967	9-in JRCF	61-ft	1984	4-in	Foam	1000-ft
VA I-64, mp 202	1965	9-in JRCF	61-ft	1982	4-in	Foam	1000-ft
VA I-64, mp 279	1967	9-in JRCF	61-ft	1981	4-in	Foam	1000-ft
VA I-64, mp 284	1968	9-in JRCF	61-ft	1978	4-in	Foam	1000-ft
VA I-81, mp 148	1965	9-in JRCF	61-ft	1976	4-in	Foam	1000-ft

relief joints had opened to an average width of 0.8 in., and most of these adjacent joints were also filled with incompressibles.

Figure 1 is a typical plot of contraction joint width versus station for the northbound section and shows that contraction joint widths tended to increase in the vicinity of the relief joints. Figure 2 provides a similar picture for the southbound section where relief joints were not provided but a blowup occurred. Contraction joints were very wide near the blowup location and then became narrower as the distance from the blowup increased.

#### Analysis

The LDOTD monitored the performance of this project as part of their own research project. Two conclusions reached by LDOTD were that pressure relief joints are effective in eliminating blowups, thereby saving the cost of blowup repair and eliminating a hazard to the motoring public, and that pressure relief joints are effective in prolonging the life of PCC pavements by reducing premature pavement distress due to contraction joint failure (3). However, the results of the 1985 field surveys support only the first conclusion. The pressure relief joints installed in the northbound lanes did indeed prevent blowups, but recall that the joint spalling was approximately the same for the lanes in each direction. This could be attributed to the fact that the adjacent regular contraction

joints near the relief joints have opened and are often filled with incompressibles.

It is doubtful that the pavement expansion problem would have developed had a good joint maintenance program been in place. Cleaning the incompressibles from the joints and resealing prior to the occurrence of blowups would significantly have reduced the deterioration of this pavement and resulted in a higher overall level of serviceability.

#### Michigan, U.S. 127, South of Lansing

The original pavement was a 9-in. JRCF with 99-ft contraction joints that was constructed and opened to traffic in 1956. In 1972, this pavement was selected by the Michigan Department of Transportation (MDOT) to serve as an experimental project for evaluating the merit of preventive maintenance of concrete joints (4).

Pressure relief joints were installed in the southbound lanes using diamond saws. The northbound lanes served as a "control" section where no relief joints were installed. Full-depth repairs with 2-in.-wide, nondoweled expansion joints were placed in both lanes just prior to installation of the relief joints to repair existing joint distress. They were also placed in the northbound lanes on an annual basis to repair new joint distress as it developed.

The 4-in.-wide, polyethylene-filled, pressure relief joints

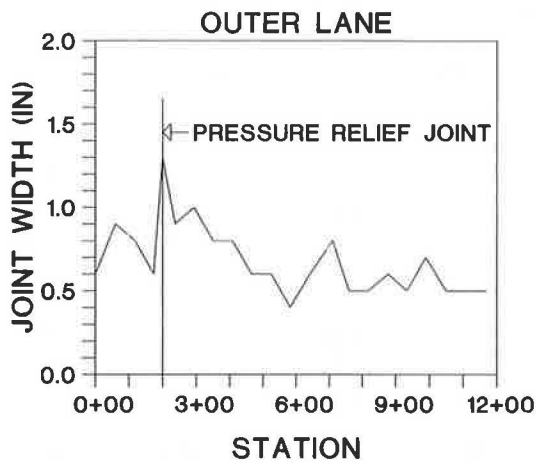


FIGURE 1 Plot of joint width versus station for the northbound outer lane of I-55 in Louisiana (1).

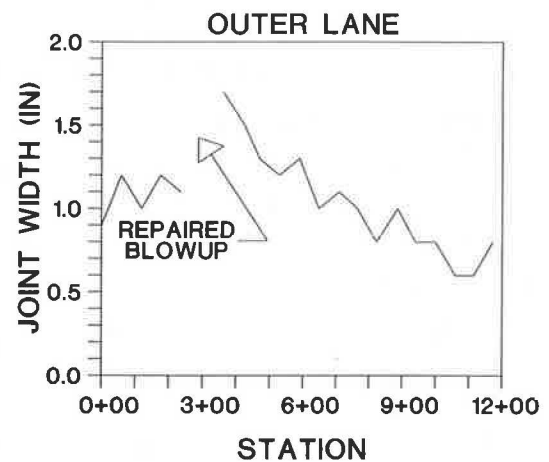


FIGURE 2 Plot of joint width versus station for the southbound outer lane of I-55 in Louisiana (1).

were placed at intervals so that each was a minimum of 200 ft and a maximum of 1,200 ft from the nearest full-depth repairs, which were assumed to relieve compressive stresses locally. The relief joints were also placed 6 ft away from the nearest contraction joint. By 1985, the pressure relief joints had sustained about 2.8 million, 18-kip ESALs in the outer lane.

The condition surveys conducted in 1985 revealed all levels of transverse slab cracking in both directions. However, the density and severity of cracking found in the southbound (relieved) lanes were much higher than that found in the northbound (control) lanes, as shown in Table 2.

The contraction joints contained incompressibles and consistently exhibited medium-severity joint and corner spalling throughout all of the surveyed sections. Figure 3 shows the average length of transverse joint spalling observed at each contraction joint for the years 1972–1979, as measured by MDOT. The figure indicates that joint spalling continued to increase in both the relieved and nonrelieved lanes after the relief joint placement. The rate of increase appears to be slightly lower for the relieved lanes, although the spalls observed from the 1985 condition surveys were more severe (deeper and longer over a given width) in the northbound lanes. Comparing the location and severity of the spalls in the two directions suggests that, although the average length of spalling at

the joints is approximately equal, the northbound spalls are more pressure-related than the southbound spalls.

Contraction joint faulting was generally about twice as high in the northbound (nonrelieved and more damaged) lanes as in the southbound lanes (0.11 in. versus 0.05 in.). The largest faults and joint widths in either direction were often found near relief joints or full-depth repairs.

The pressure relief joints had closed from 4 in. to an average width of 0.55 in. and had faulted an average of 0.27 in. The joint filler was still intact and was keeping incompressibles from entering. Transverse joint and corner spalling was not exhibited in or along any of the relief joints.

Summer and winter measurements of the relief joints made by MDOT during each year between 1973 and 1979 as part of their own research study are summarized in Figure 4 (4). This figure shows that the largest amount of relief joint closure generally took place in the first year after installation. It also indicates that the period of effectiveness of these relief joints ranged from about 3 to 7 years, as indicated by the constant joint openings observed after this period.

#### Analysis

The pressure relief joints installed in 1972 were apparently an effective means of preventing blowups and pressure-related

TABLE 2 TRANSVERSE CRACKING ON U.S. 127 IN MICHIGAN (1)

Crack Severity	AVG. NO. OF CRACKS/MILE (AVG. NO. OF CRACKS/SLAB)			
	SOUTHBOUND		NORTHBOUND	
	Outer	Inner	Outer	Inner
Low (hairline)	134 (2.52)	53 (0.99)	79 (1.49)	41 (0.77)
Medium (working)	57 (1.06)	75 (1.41)	18 (0.33)	18 (0.33)
High (badly spalled)	34 (0.64)	34 (0.64)	9 (0.17)	6 (0.11)
TOTAL	225 (4.22)	162 (3.04)	106 (1.99)	65 (1.21)

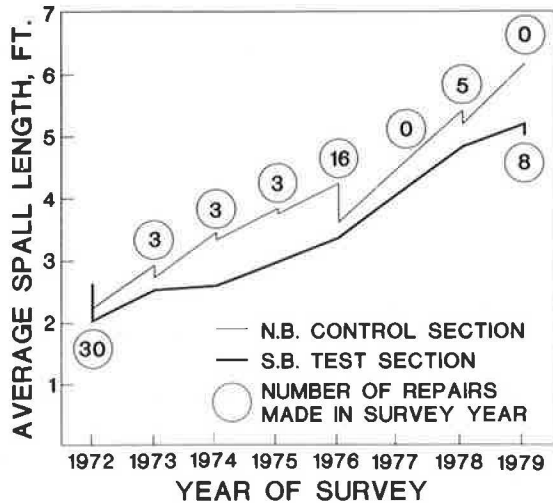


FIGURE 3 Average joint spall length from 1972 to 1979 before and after repair for U.S. 127, Michigan (4).

joint damage from occurring in the southbound lanes. Fifty percent of the joints in the southbound lanes were deteriorated, compared with 77 percent in the northbound lanes.

The relief joints have allowed the transverse cracks to deteriorate to the point where the relieved southbound lanes require more repair than the nonrelieved northbound lanes. Successful rehabilitation of the northbound lanes would require full-depth joint repairs, installation of subdrains, and diamond grinding, whereas the southbound lanes would require extensive slab and joint repairs, a structural overlay, or total reconstruction.

This project presents evidence that the installation of relief joints should be kept to a minimum when well-developed transverse cracks are present. An alternative to the installation of pressure relief joints in this case would have been to clean and reseal thoroughly the transverse joints and working cracks. The placement of full-depth repairs with load transfer devices and without expansion joints would have relieved any built-up pressure without allowing the adjacent cracks to open further. Where pressure relief joints were used, additional separation from full-depth repairs might have been desirable.

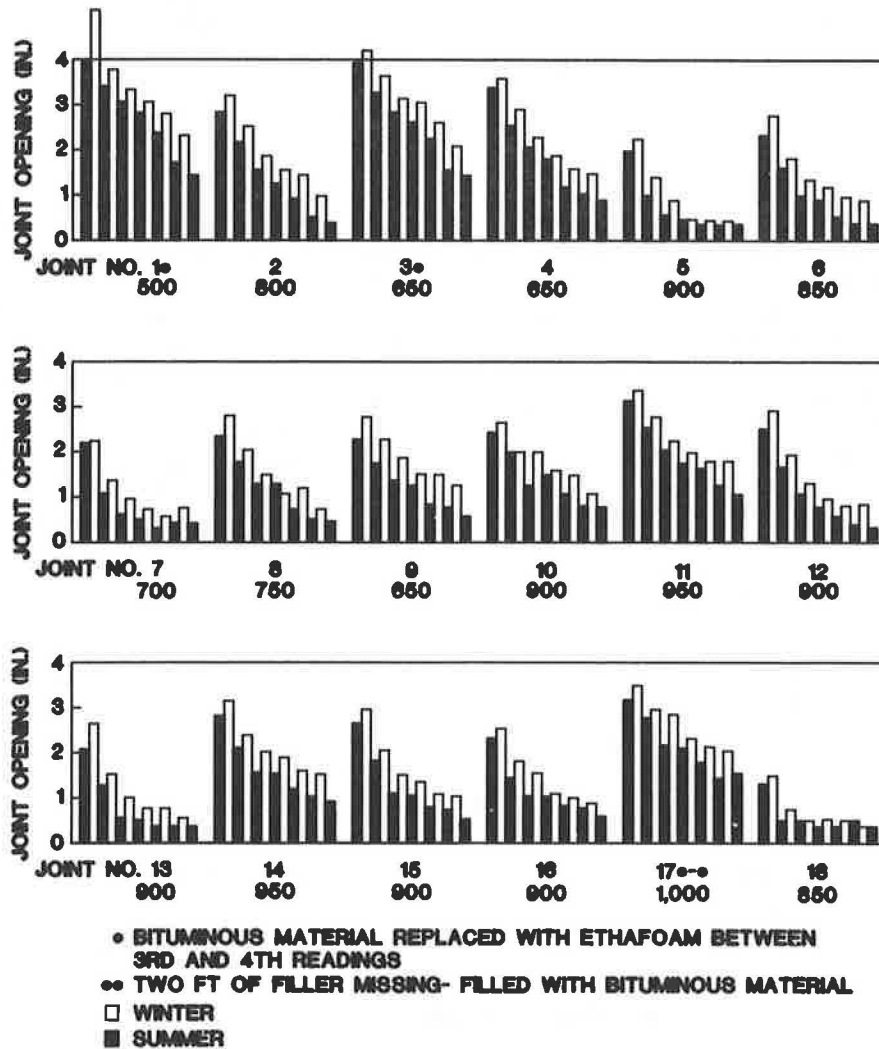


FIGURE 4 Summer/winter relief joint opening from 1973 to 1979 for U.S 127, Michigan (numbers below each joint indicate pavement length in feet contributing to joint closure) (4).

### Nebraska, I-80, Milepost 189

The original pavement was a 9-in. JRCP with 46.5-ft contraction joints that was constructed and opened to traffic in 1965. Pressure relief joints 4.5 in. wide and filled with a preformed cellular joint filler were installed in 1981 at 2,000-ft intervals to reduce expansive pressures caused by reactive aggregate.

By 1985, the pressure relief joints had sustained about 4 million, 18-kip ESALs in the outer lane. The condition surveys conducted in 1985 showed extensive reactive aggregate distress, low- and medium-severity transverse cracking, poor joint sealant conditions, and medium-severity transverse joint and corner spalling. The remaining transverse contraction joints were faulted an average of 0.02 in. and were open an average of 0.3 in. An average Roughness Index of 120 (fair-good) was obtained by the Nebraska Department of Roads in 1985 using a Mays Ride Meter.

The pressure relief joints had closed to an average width of 0.8 in. and had faulted an average of 0.09 in., more than four times the contraction joint average faulting. The filler was still intact, and only low-severity spalling was observed. The adjacent contraction joints had not opened appreciably wider than the project average joint width. Figure 5 illustrates the closure of the pressure relief joints on this project over time, as measured by the Nebraska Department of Roads.

#### Analysis

The pressure relief joints were an appropriate measure taken to combat the compressive stresses caused by the reactive aggregate. This need for relief was evidenced by the amount of closure of the relief joints (average amount of closure, 3.7 in.). It is interesting, however, that the average amount of closure is approximately equal to the total amount that the intermediate contraction joints have opened (0.1-in. opening  $\times$  45 joints = 4.5 in.).

Overall, this rehabilitation project was considered successful. The pressure relief joints were probably an appropriate effort to reduce pressure damage caused by the reactive aggregate

included in the original pavement. It should be noted, however, that the pressure relief joints did fault rapidly after placement and served to open adjacent contraction joints slightly.

### Nebraska, I-80, Milepost 382

The original pavement was a 9-in. JRCP with 46.5-ft contraction joints. It was constructed and opened to traffic in 1962. Pressure relief joints 4.5 in. wide were installed in 1982 at 1-mile intervals to reduce the expansive pressures caused by reactive aggregate. A preformed cellular plastic filler was used to fill the joint. Several other rehabilitation techniques, including full- and partial-depth repairs and joint resealing, were applied concurrently.

By 1985, the pressure relief joints had sustained approximately 5 million, 18-kip ESALs in the outer lane. The condition surveys conducted in 1985 found low- and medium-severity transverse cracks at approximately 15- to 20-ft intervals, although some localized areas displayed transverse cracks at much closer intervals. Low-severity reactive aggregate distress was consistently identified throughout the condition surveys.

Incompressibles were observed in several of the original contraction joints; as a result, medium-severity transverse joint spalling and corner spalling were frequently found in both sections of the project. The average faulting and joint width measurements for the original contraction joints were 0.14 in. and 0.68 in., respectively, in the outer lane. An average Roughness Index of 191 (fair) was obtained in 1985 by the Nebraska Department of Roads using a Mays Ride Meter.

The pressure relief joints had closed to an average width of 1.3 in. and had faulted an average of 0.16 in. The filler was still partially intact in the relief joints; where it was absent, however, the joints contained incompressibles and spalling was observed. Contraction joints adjacent to the relief joints had opened little more than the average observed width of 0.68 in. Figure 6 presents a plot of the relief joint closure over time as measured by the Nebraska Department of Roads.

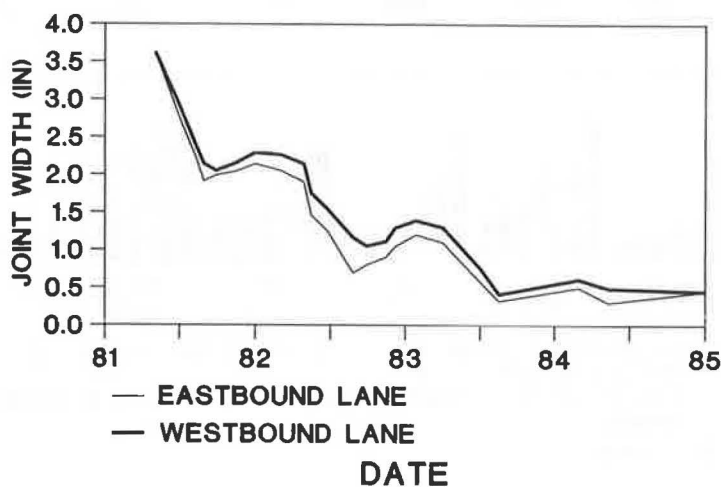


FIGURE 5 Pressure relief joint closure over time on I-80 in Nebraska (milepost 189) (1).

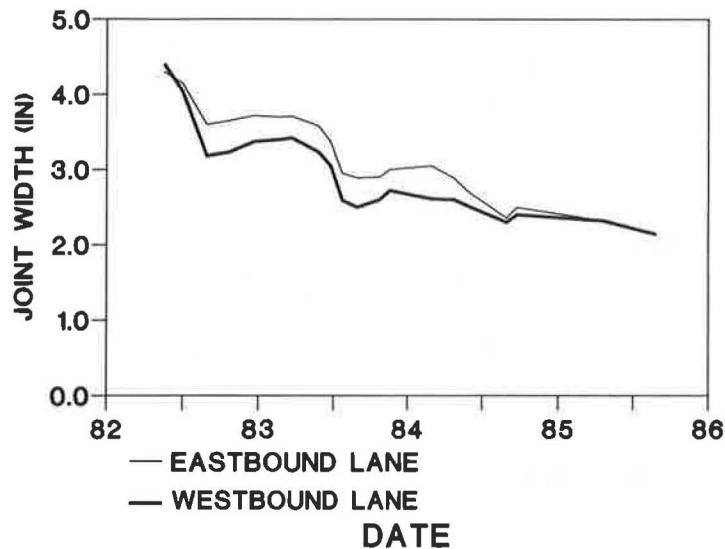


FIGURE 6 Pressure relief joint closure over time on I-80 in Nebraska (milepost 382) (1).

#### Analysis

The pressure relief joints that were installed on this project may not have been necessary. Although the aggregate used in the original pavement was somewhat reactive, it was not the highly reactive North Platte River gravel that had produced problems on other concrete pavements in Nebraska. In addition, any built-up pressure would have been relieved during placement of the full-depth repairs. Much higher rates of relief joint closure were observed on other Nebraska projects (e.g., at milepost 189, as previously described) where full-depth repairs were not placed concurrently with the relief joints.

While the use of relief joints on this project may have been questionable, their presence had apparently not affected the project adversely. The faulting and opening of adjacent contraction joints were average, and nearby slabs exhibited typical types and amounts of distress.

#### PRJs IN CONTINUOUSLY REINFORCED CONCRETE PAVEMENT

##### Ohio, I-270, Milepost 29

The original pavement was an 8-in., continuously reinforced concrete pavement (CRCP), constructed and opened to traffic in 1968. Asphalt concrete-filled pressure relief joints 4 in. wide were installed in 1983 at 2,000-ft intervals because of perceived pressure problems.

By 1985, the pressure relief joints had sustained about 1 million, 18-kip ESALs in the outer lane. A few edge punchouts and deteriorated transverse cracks were observed in the original pavement. A Roughness Index (GM Profilometer) of 112 (fair) and a Present Serviceability Index of 3.0 were computed by the Ohio Department of Transportation (ODOT) in 1984.

The pressure relief joints exhibited extensive joint spalling. Transverse cracks adjacent to the pressure relief joints had

deteriorated from tight, nonworking cracks to spalled, working cracks. Punchouts were frequently located near the pressure relief joints.

#### Analysis

The installation of pressure relief joints on this project was inappropriate because any excessive compressive stresses in the pavement had probably been relieved by the blowups that had occurred. When CRCP is repaired, it appears unlikely that there will be a further buildup of stresses since tight cracks do not permit the infiltration of incompressibles. Further, the interruption of the continuous reinforcing steel resulted in premature deterioration of adjacent transverse cracks. If pressure relief was necessary, a better approach might have been to remove pavement sections for the placement of traditional CRCP repairs and leave these areas open for 24–72 hours. A properly constructed repair could then have been installed by carrying the steel through the repair to keep the cracks tight. This would also have reduced the possibility of loss of support caused by allowing water to enter a wide relief joint.

#### PRJs IN ASPHALT CONCRETE OVERLAID CONCRETE PAVEMENT

##### Kentucky I-65, Milepost 12

The original pavement was a 10-in. JRCP with 50.0-ft contraction joints, constructed and opened to traffic in 1966. Skewed pressure relief joints 6 in. wide were installed in 1982 at 1,000-ft intervals and filled with asphalt concrete. They were installed because blowups had previously occurred and additional pressure problems were anticipated. In addition, the original aggregate was known to be expansive. Six-inch perpendicular relief joints were also incorporated as approach or leave joints in some of the full-depth repairs that were placed as part of the preoverlay repair. The entire rehabili-

tation project received a 4.0-in. asphalt concrete overlay after the placement of the repairs.

By 1985, the relief joints had sustained approximately 4.5 million, 18-kip ESALs in the outer lane. About one-half of the original contraction joints had reflected through the overlay, whereas very few of the repair joints had reflected through. Rutting measurements in the outer lane averaged 0.13 in.

The condition surveys revealed that the pressure relief joints had reflected through the overlay and the overlay was "humped" above the relief joints, although the hump over one of the relief joints had been milled off. Only one of the three sections surveyed appeared to indicate a relationship between pressure relief joint location and the location of reflective cracks above contraction joints. In this section, more cracks of higher severity were observed near the relief joint than away from it. Overall, the rehabilitated pavement had performed well except for the roughness where the overlay had "humped."

### Analysis

The pressure relief joints were probably appropriate for this project since many blowups had previously occurred and were expected to continue owing to the presence of expansive aggregate. It is possible, however, that the construction of full-depth repairs at blowup locations would have provided equal or better service without the localized roughness and risk of more rapid joint and overlay deterioration that often accompanies pressure relief joints.

### Illinois I-55, Milepost 252

The original pavement was a 10-in. JRCPC with 100-ft contraction joints, constructed and opened to traffic in 1956. Special "heavy-duty" expansion joints with dowels for load transfer were constructed in 1975 at 1500-ft intervals because blowups had occurred previously and future pressure damage was anticipated. The relief joints were 6-ft minimum length, full-depth concrete repairs, tied to the existing slab, that contained a 4-in. formed pressure relief joint incorporating dowel bars (see Figure 7). The repair/relief joint was constructed higher than the existing pavement so that the new asphalt

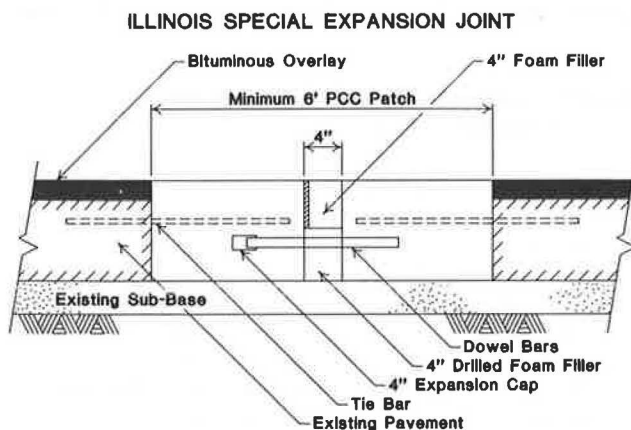


FIGURE 7 Illinois Department of Transportation heavy-duty pressure relief joint design (1).

concrete overlay could be constructed flush with the repair. A 3.5-in. asphalt concrete binder course was placed in late 1975, followed with a 1.5-in. asphalt concrete surface course in 1976.

The condition surveys performed on the project revealed medium-severity longitudinal cracking, transverse reflection cracking, and an average rut depth of 0.34 in. A Roughness Index of 75 (smooth) was obtained by the Illinois Department of Transportation in 1985 using a BPR Roughometer.

By 1985, the relief joints had sustained about 10 million, 18-kip ESALs in the outer lane. They had closed to an average width of 2.2 in. and had faulted an average of 0.08 in. While the relief joints themselves were not extremely rough, a significant bump could be felt when driving across the joint between the overlay and the concrete repair. The overlay had shoved and rutted at this location, significantly contributing to the overall pavement roughness.

### Analysis

These "heavy-duty" pressure relief joints have performed well. They have withstood 10 years and approximately 10 million, 18-kip ESALs without exhibiting excessive faulting or significant spalling. While this relief joint design is expensive, it does allow a structural overlay of the pavement using asphalt concrete without the humping of the surface and loss of load transfer that often occur when more traditional relief joint designs are used. This relief joint design could also be used for nonoverlaid concrete pavements where relief joint load transfer is desired.

The need for pressure relief joints on this project was questionable since the relief joints had closed only 2.0 in. over 10 years. The placement of full-depth repairs probably relieved any pressure problems that existed at the time of overlay. The use of relief joints where they were not required may have resulted in premature reflection of the contraction and repair joints as they opened in response to the available expansion capacity of the pavement. In spite of this, the relief joints have performed very satisfactorily, and it cannot be determined that they have adversely affected the performance of the adjacent joints.

### Indiana, I-69, Milepost 64

The original pavement was a 10-in. JRCPC with 40-ft joint spacing, constructed and opened to traffic in 1964. Three-foot wide, asphalt concrete-filled pressure relief joints were installed in 1975 in five experimental sections using three different relief joint spacings: 1,000 ft, 500 ft, and 40 ft. One 0.5-mile section served as a control and contained no relief joints. The relief joints were installed because of bridge pushing, in anticipation of pressure buildup problems, and as part of state policy to prevent blowups of overlaid D-cracked pavements. A 4.25-in. asphalt concrete overlay was placed after the installation of the relief joints.

By 1985, the overlay and repairs had sustained approximately 6.1 million, 18-kip ESALs in the outer lane. All of the relief joints had reflected through the overlay, and many of these reflective cracks had begun to spall, particularly in the section with the short relief joint spacing (40 ft). It was

TABLE 3 "HUMPING" OF AC OVERLAY AT PRESSURE RELIEF JOINT LOCATIONS ALONG I-69 IN INDIANA (1)

Section	INNER LANE			OUTER LANE	
	Left Wheelpath Hump, in	Right Wheelpath Hump, in	Center Line Hump, in	Left Wheelpath Hump, in	Right Wheelpath Hump, in
01*	1.00	---	---	0.60	0.40
01	0.50	1.10	0.60	0.80	0.70
02	0.75	0.90	0.80	0.50	0.50
02	0.80	0.80	0.60	0.60	0.50
02	0.70	0.60	0.60	0.50	0.60
03	NO APPRECIABLE HUMPING OF PRESSURE RELIEF JOINTS				
Avg	0.75	0.85	0.65	0.60	0.54
Std. Dev.	0.18	0.18	0.10	0.12	0.11

\* This relief joint had been milled off once.

also noted that there were more medium-severity transverse cracks in the vicinity of the relief joints, and these cracks were wider than those located farther away. This is indicative of the movement of the underlying pavement into the relief joints.

The asphalt overlay above the relief joints was generally humped as a result of the expansion of the pavement into the relief joint area. Table 3 summarizes the measured relief joint humping. Sections utilizing different relief joint spacings had different performance characteristics. Section 01 (1,000-ft relief joint spacing) had large "hump" measurements and slightly opened adjacent cracks. Section 02 (500-ft relief joint spacing) had slightly smaller "hump" measurements, but adjacent cracks were wider and spalled slightly. Both of these sections caused a fairly rough ride. Section 03 (40-ft relief joint spacing) was not humped, and the ride was noticeably smoother. However, the transverse reflective cracks above the relief joints had spalled rather severely, and there were many more deteriorated transverse cracks. The control section was not extensively cracked and performed relatively well.

#### Analysis

The use of pressure relief joints on this project resulted in varying degrees of pavement roughness due to "humping," reflective cracking, and deterioration of the overlay near the cracks. Deterioration of the overlay was most severe where the D-cracking of the original pavement had reflected through the overlay.

The placement of full-depth repairs would probably have reduced any pressure buildup in the pavement. Since the pavement was to be overlaid, however, it is likely that "D" cracking would rapidly have redeveloped outside of any full-depth concrete repairs, causing the overlay to deteriorate. Thus, the asphalt concrete overlay of this severely D-cracked pavement could be expected to provide good serviceability for only a short period of time, regardless of the preoverlay rehabilitation.

#### CONCLUSIONS

The following conclusions were drawn from the twenty-five individual pressure relief project summary reports (1).

1. The use of pressure relief joints was unwarranted on most of the projects surveyed and often caused more distress than would have been prevented.
2. The use of pressure relief joints was generally warranted on projects that included reactive aggregates in the concrete.
3. The unnecessary or excessive use of pressure relief joints often results in the excessive opening of adjacent cracks and contraction joints, the shearing of longitudinal joint ties, the premature failure of load transfer shear devices and of adjacent contraction joint sealant (particularly preformed compression seals), and the loss of load transfer and pavement support, resulting in increased pumping, faulting, corner breaks, and punchouts.
4. Pressure relief joints are not likely to be as detrimental to pavement performance when the existing pavement is free of working transverse cracks and only low volumes of heavy truck traffic are present.
5. The installation of full-depth repairs provides relief of built-up pressure and decreases the need for pressure relief joints in the vicinity of the repair.
6. Where used and constructed appropriately, pressure relief joints have been found to be effective in preventing the development of pressure damage for 3 to 7 years. New or additional joints must be considered when the old ones become ineffective.
7. The largest portion of relief joint closure occurs within the first year after installation.
8. Relief and expansion joints near secondary structures may provide relief as far as 2,000 ft away. Adjacent contraction joints exhibited greater widths and faults and higher incidences of sealant failure than more distant joints.
9. Pressure relief joints placed without load transfer devices fault rapidly.



10. The placement of a joint sealant material over the relief joint filler material improves retention of the filler material.

11. Blowups have about the same effect as pressure relief joints on the total movements at adjacent contraction joints.

12. Wide asphalt concrete-filled pressure relief joints installed in concrete pavements that are to be overlaid can result in "humping" of the overlay over the relief joint, deterioration of adjacent cracks and joints, and increased incidence and severity of reflection cracking. Larger relief joint spacings tend to produce less joint and crack deterioration and reflection cracking but larger "humps." Shorter spacings produce little "humping" but very high densities and severities of reflection cracking, including at the relief joint.

13. Foam-filled pressure relief joints installed in concrete pavements that are to be overlaid can result in deterioration of the overlay directly over the relief joint since the filler material provides no support to the overlay.

14. Overlays placed over pressure relief joints that have been in place for several years may perform well since much of the pavement movement will already have taken place.

15. Illinois DOT's "heavy-duty" pressure relief joints have performed well under heavy traffic, although excessive rutting produces considerable roughness at the transition between the asphalt concrete overlay and the concrete surface.

## RECOMMENDATIONS

The following recommendations were developed based on the preceding findings and on the professional experience of the advisory panel members (1, 2).

1. In general, the installation of pressure relief joints is recommended only where reactive aggregates are present and a pressure buildup problem exists, or where an asphalt concrete overlay is to be placed over a concrete pavement that is expected to develop pressure buildup problems.

2. The installation of pressure relief joints in continuously reinforced concrete pavements is not recommended.

3. The installation of pressure relief joints is not recommended for pavements with short joint spacing except for protection of secondary structures.

4. The continued use of pressure relief and expansion joints to protect bridges is recommended for all pavement types.

5. Where blowups have occurred recently (not due to expansive or reactive aggregate), thus relieving pressure, joint cleaning and resealing should be considered as an alternative to pressure relief joint installation.

6. The use of pressure relief joints in pavements that are about to be overlaid is not generally recommended. However, it may occasionally be desirable to provide pressure relief joints in concrete pavements prior to placing asphalt concrete overlays. Candidate projects include those with long joint spacings and joints filled with incompressibles when the built-up pressure has not been relieved by blowups, repairs, or other pressure-relieving features. Asphalt concrete is recommended as the joint filler material for relief joints that are constructed in concrete pavements that will be overlaid.

7. Pressure relief joint placement (where appropriate) must consider the rate of pavement growth and the location and effectiveness of other pressure-relieving features.

8. Most new pressure relief joint widths should be limited

to 1 to 2 in. to reduce the possibility and severity of over-relief of the pavement. New pressure relief joints should be placed at least 1,000 ft from active pressure-relieving features. Pavements with reactive aggregates may require greater relief joint widths or more frequent relief joint installations.

9. Sealant caps should be placed over the relief joint filler material in all narrow relief joints to help retain the filler and to keep incompressibles from infiltrating. The sealant cap should be recessed appropriately so that it does not extrude as the pavement closes.

10. Deep cleaning of joints and cracks with high-pressure water to remove trapped incompressibles followed by joint resealing should be tried on an experimental basis to relieve pressure buildup.

11. An alternative to the installation of nondoweled pressure relief joints is the placement of doweled full-depth repairs. Pressure relief might be accomplished either by leaving the repair open for 24 hours or by incorporating a narrow (1-in.) expansion joint at one repair joint.

12. An alternate approach to pressure relief in CRCP that could be tried experimentally is to remove small sections of the pavement (at typical relief joint intervals) and leave the repair hole open for 24 hours or more to allow the pavement to expand slightly before placement of a concrete repair.

13. The reservoir dimensions and sealant material properties of adjacent contraction joints should be checked prior to the installation of pressure relief joints to ensure that the expected movement of the joint will not cause the sealant to fail.

14. On an experimental basis, dowels placed in slots across a pressure relief joint may be tried to evaluate the performance and cost-effectiveness of providing load transfer across such a joint.

## ACKNOWLEDGMENTS

This paper describes the results of a research study funded by the Federal Highway Administration. Many thanks are extended to the state highway engineers who served on the advisory panel: Emmitt Chastain of Illinois, Eugene B. Drake of Kentucky, Roger L. Green of Ohio, Vernon J. Marks of Iowa, Ken McGhee of Virginia, William Ramsey of Nebraska, Gary Robson of West Virginia, and Joseph Sudol of Indiana. Gratitude is also expressed for the assistance provided by the following state highway engineers: David Lippert of Illinois, Masood Rasoulia of Louisiana, Larry Scofield of Arizona, and Jens Simonsen of Michigan. Special thanks are also due to Michael Reiter and Kathleen Hall for their assistance in the data collection, evaluation, and report-writing activities.

Peter Kopac of the Federal Highway Administration served as contract manager on this project. The project team is grateful for his help in facilitating contacts with the advisory panel, reviewing volumes of material, and providing guidance and general assistance to the project.

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*This paper is based on research performed under contract by the FHWA, U.S. Department of Transportation. The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official view or policy of the Department of Transportation or the Federal Highway Administration. This paper does not constitute a standard, specification, or regulation.*

*Publication of this paper sponsored by Committee on Pavement Rehabilitation.*