EVALUATION OF THE EFFECTIVENESS OF PRESSURE RELIEF JOINTS IN REINFORCED CONCRETE PAVEMENTS

by

K. H. McGhee
Research Engineer

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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SUMMARY

Reported are studies of the effectiveness of a 4-inch (100 mm) wide compressible material installed at 1,000-ft. (305 m) intervals in a jointed, reinforced concrete pavement in reducing pavement blowups. The studies were made on an Interstate highway carrying some 30,000 vehicles per day, including approximately 7,000 trucks and buses. The study contrasts the behavior of the pavement before these pressure relief joints were installed with that observed afterwards. Brief discussions of the factors indicating the need for such joints, the problems associated with their use, and the potential for their use under overlays are included.

The following recommendations are presented.

1. The practice of providing pressure relief joints in pavements having blowup histories or exhibiting blowup tendencies should be continued.

2. The decision to provide pressure relief joints should be made only after due consideration of the pavement design and its performance history. The decision criteria enumerated herein are suggested as guidelines.

3. Pressure relief joints are not recommended within 500 ft. (150 m) of bridge protection expansion joints Type XJ-1 or of full pavement width blowups where pavement stresses have been relieved as evidenced by wide joints near the blowups.

4. Consideration should be given to omitting pressure relief joints at full-depth — full-width (all lanes) repairs. This omission should be accompanied by the greater use of relief joints at mid-slab length of blowup prone sections of pavement.

5. Pavements containing pressure relief joints should be inspected periodically for evidence that intermediate joints are opening excessively such that in-place preformed seals can no longer be accommodated. Conversely, such inspections may indicate the need for additional relief joints.

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INTRODUCTION

The performance of jointed concrete pavements in some areas of the state has been seriously impaired by the infiltration of incompressible materials into the joint and the resulting blowups. This infiltration can come from below the pavement due to slab pumping action related to water trapped below the pavement structure or from above because of poorly sealed transverse joints. Water can be entrapped because of densely graded subbase materials which prohibit drainage through the shoulder.(1) Joints can be poorly sealed because of the long slabs and narrow joints having seasonal hydrothermal movements in excess of the capabilities of the sealing materials.(2) The causes and mechanism of blowup occurrence have been thoroughly discussed in a recent report by Tyson and McGhee.(3)

Corrective action to overcome Virginia's pumping and blowup problems has not been totally successful. Pavement edge drains are effective in removing entrapped water, but are costly and time-consuming to install after the fact and are used only in the worst pumping cases. Maintenance contracts to replace or patch damaged joints and to furnish preformed seals have been successful in most cases, but in several instances the patches have failed very early and at a rapid rate.

One case of early patch failure took place on a maintenance contract executed in 1973 on I-95 in Spotsylvania County, where a study of the problem suggested that residual pressures in the pavement were among several factors causing premature patch failure.(4) On the other hand, joint movement studies in the same area over a period of several years had shown that the occurrence of a blowup tends to relieve pavement pressures for some 500 ft. (150 m) on either side. Consequently, it was concluded that the provision of special stress relieving joints might reduce pavement pressures so that subsequent pavement failures could be reduced.

With this in mind, the Materials and Maintenance Divisions and the Research Council cooperated with Fredericksburg District personnel in October 1973 to install a pilot experiment of three pressure relief joints in a Stafford County segment of I-95 where maintenance operations were under way. The joints were installed approximately 1,000 ft. (305 m) apart and extended the full-width of the 24 ft. (7.3 m) pavement. Because of the difficulty in sawing dowels and the danger of unstable subbase conditions near the old joints, the relief joints were installed mid-length of the 61.5 ft. (18.7 m) long slabs. Two parallel saw cuts spaced 4 in. (100 mm) apart were made full-depth of the slabs. After removal of the concrete, two of the openings were filled with a patented sponge rubber product sold under the trade name "Sealtite." The third opening was filled with a styrofoam rubber.

Movement measurements commenced as soon as the pressure relief joints were installed showed closures of from 1.1 to 3.2 in. (28 to 80 mm) during the spring of 1974 after about eight months in place. Clearly, such large movements show that pavement pressures have been significantly relieved by provision of the special joints. In addition, field personnel have been very pleased with the performance of the relief joints and report that no blowups have occurred in their vicinity and that no difficulties with the performance of the joints themselves have been noted. Finally, it has been noted that the relief joints are in themselves good indicators of pavement pressures. For example, the field engineer might decide that when a relief joint installed 4 in. (100 mm) wide has closed to less than 1 in. (25 mm) pavement pressures are approaching the point at which additional relief joints or restoration of the original 4 in. (100 mm) wide joint are justified.

With the above information in hand, the Department, in September 1974, let to contract pavement repair and resealing work on I-95 in Spotsylvania and Caroline Counties. As a part of this contract, pressure relief joints were installed in the above mentioned Spotsylvania County pavement where early distress of previous repairs had been noted. The relief joints were installed at approximately 1,000-ft. (305 m) intervals in both directions on this 15-mile (24 km) segment of I-95. In addition to this contract, at least one other is under way and some relief joints are being installed by the Department's maintenance personnel.

The increasing use of the pressure relief joints in various parts of the state has indicated a need for quantitative data concerning their effectiveness. The development of these data was the objective of the present study.

PURPOSE AND SCOPE

As indicated above, the purpose of the present study was to evaluate the effectiveness of pressure relief joints in protecting jointed concrete pavements from the self-destructive effects of joint infiltration and seasonal hydrothermal movements. The study included approximately 15 miles (24 km) of 4-lane divided I-95 in Spotsylvania County. Data were collected to provide a comparison of the performance of the 9-in. (230 mm) reinforced concrete pavement for eight months prior to installation of the pressure relief joints to the performance over a similar season and time period after installation of the relief joints. Information was developed as a basis for brief discussions of the factors leading to the need for relief joints and of their use under overlays.

RELIEF JOINT DESIGN

Pressure relief joints are 4 in. (100 mm) in width and are installed full-depth and full-width of the 9-in. (230 mm) thick by 24-ft. (7.3 m) wide pavement. The pavement has construction joints nominally 3/8 in. to 1/2 in. (10 mm to 13 mm) wide and spaced at 61.5 ft. (18.7 m) centers.

Where major joint repairs including full-depth joint replacement were required, the relief joints were installed as detailed in pavement repair contract PR-1-74(5) and illustrated in Appendix A. Pressure relief joints installed in conjunction with such full-depth repairs are designated Type A. For reasons given earlier, when no full-depth pavement repairs were necessary, the relief joints were installed at mid-length of the 61.5 ft. (18.7 m) long slabs. Installations of this type are designated Type B. A total of 142 relief joints were installed in the 15-mile (24 km) long segment of roadway.

The relief joint filler material is "Preformed Cellular Plastic Pressure Relief Joint Filler" meeting the requirements of ASTM Specification D 3204.

The projects in which pressure relief joints were installed were designated as projects 1, 2, and 3 as described in Appendix B.

PROCEDURES

Evaluation procedures consisted of pavement condition surveys and a study of the pavement movements as reflected in the closure of selected pressure relief joints.

Four condition surveys as outlined below were conducted.

1. Winter 1973-74

   The first survey was conducted in February 1974 as a part of other studies on the Spotsylvania County pavement.

2. Fall 1974

   A second survey was conducted immediately before repairs were begun on the study pavement and was completed in September 1974. The results were compared with those from the first survey to determine pavement damage during the spring and summer of 1974 which might be related to pavement pressures.

3. Winter 1974-75

   A third survey was conducted after the repairs had been completed and the pressure relief joints installed. The contractor began work on October 15, 1974, and the survey was completed in April 1975.

4. Fall 1975

   The final survey, completed in October 1975, was made to obtain data for determining damage subsequent to the repairs, that is, during the spring and summer of 1975.

Each condition survey comprises a detailed summary of pavement conditions at the time it was made. Every pavement joint was noted on a sketch in which defects from each survey were superimposed one on the other. In the survey made immediately after repairs were completed each pressure relief joint was noted. Defects, such as blowups, directly related to pavement pressures were especially identified.

To provide information concerning pavement movements as influenced by pressure relief, the width of each of the relief joints was measured soon after installation and at the time of the last condition survey. In addition, several sites were chosen for the installation of instrumentation at intermediate joints. This instrumentation, gage points imbedded in the pavement on either side of selected joints, made it possible to study the effect of the relief joints on adjacent joints. The last field work was completed in December 1975, when one section of pavement between pressure relief joints was chosen for detailed study of the joint movement associated with the release of pavement pressure. Joint cleaning and resealing work that had been done at about the same time the relief joints were installed had resulted in saw cuts in the bituminous shoulders so that the location of each joint prior to pressure relief could be established. Finally, information from the U. S. Weather Bureau station at Corbin in Caroline County was utilized to compare the two study periods in an effort to determine any effects of significant differences in weather patterns on pavement behavior in 1974 and 1975. This station is located approximately 8 miles (13 km) from the work site.

Each of the above aspects of the overall study is discussed below.

RESULTS AND DISCUSSION

Effect of Pressure Relief Joints On Blowup Development and Pavement Distress

The effectiveness of the pressure relief joints in halting the occurrence of blowups is demonstrated in Table 1. Note that 24 blowups occurred in the 15-mile (24 km) segment during the summer of 1974, before installation of the relief joints, while there were no occurrences in the summer of 1975 with the relief joints in place. It may, therefore, be concluded that the relief joints were totally effective during the first summer they were in service. Observations, discussed later, on the current widths of the relief joints suggest that they should be effective for several more years.

Table 1

Blowup Occurrence With and Without Pressure Relief Joints

Project	Lane	Number of Blowups		
		To February 1974	Without Relief Summer 1974	With Relief Summer 1975
1	NB	25	8	0
1	SB	29	5	0
2	NB	18	0	0
2	SB	18	4	0
3	NB	3	5	0
3	SB	2	2	0
		Total 95	24	0

The differences in pavement performance indicated by the number of blowups prior to February 1974 for the three projects are of some interest. There is ample evidence that performance differences are related to at least two factors: (1) The apparently lower strength concrete found in projects 1 and 2 (as evidenced by signs of poor consolidation or high water content), and (2) the presence of a better draining subbase and shoulder material under project 3. The relationship between blowup frequency and pavement strength is fairly evident in that weaker concrete will obviously fail at a lower pressure than stronger concrete. The relationship between blowup frequency and subbase type for these projects has been discussed in an earlier report, where it was pointed out that the pavement pumping associated with poor subbase material may result in the migration of fine, incompressible material into the joints from their outer edges and bottom portions.[3] The modified subbase used on project 3 was shown in that study to reduce pumping by approximately 75%.

Fredericksburg District personnel have expressed complete satisfaction with the stress relief joints as effective blowup arrestors.[6]

The same factors, along with the metal joint forming insert used on project No. 2, have contributed to differences in total joint distress experienced by the three projects. Total distress in terms of the number of joints affected is summarized in Table 2.

Table 2

Total Number of Distressed Joints
(Numbers in parentheses indicate the total joints surveyed)

Project	Lane	January 1974	September 1974	April 1975	October 1975
1	NB(418)	249	267	287	293
1	SB(412)	217	248	255	259
2	NB(395)	302	309	316	319
2	SB(402)	258	276	285	294
3	NB(488)	96	111	114	120
3	SB(493)	47	62	67	70

Note that while project 1 was shown above to have a greater blowup frequency, the total number of distressed joints is greater for project 2. This difference is due to the presence of the metal joint forming insert that results in numerous semicircular joint spalls located in the wheelpaths. This phenomenon has also been discussed in the earlier report mentioned above.(3)

An examination of the new occurrences of joint distress in the summers of 1974 and 1975 suggests that the pressure relief joints have been at least partially effective in reducing the rate of development of distress other than blowups. Note that the northbound lane of project 1 had 18 new occurrences of joint distress in the summer of 1974, but only 6 occurrences during the summer of 1975 after the relief joints were installed. Similarly, the southbound lane of project 3 had 15 occurrences and 3 occurrences for the summers of 1974 and 1975, respectively.

Pavement Movement as Influenced by Pressure Relief Joints

While the effectiveness of pressure relief joints in reducing pavement distress and, particularly, blowups was discussed earlier, there are some characteristics of pavement movement associated with the relief joints that are of interest in themselves. These are (1) the behavior of the relief joints, and (2) the effect of the relief joints on the movement of other joints in the vicinity of and between relief joints. These are discussed separately below.

Relief Joint Closure

In sections of roadway where there is any appreciable pressure the relief joints begin to close almost as soon as they are installed. Pavement pressures of some significance are indicated by difficulty in making the saw cut because of blade pinching and in difficulty in removing the sawed out segment.

Tests in the Research Council laboratories have shown that a pressure of approximately 24 psi (165 kPa) is required to compress the 4-in. (100 mm) wide pressure relief material to 50% of its original width. This is a negligible pressure even on very weak concrete, but is sufficient to hold the relief material tightly in place.

The widths of all pressure relief joints in the three study projects were measured soon after they were installed (October 1974 - March 1975) and at the end of the study period (October 1975). In addition, those in the southbound lane were measured at an intermediate stage (May 1975). These measurements are summarized in Table 3.

Table 3

Average Widths of Pressure Relief Joints
(Numbers in parentheses refer to the number of relief joints in each lane)

Project	Lane	As Installed Oct. 1974 - Mar. 1975	Joint Width (in.)* May 1975	Joint Width (in.)* Oct. 1975	Total Closure (in.)*
1	NB(23)	4.11	—	2.74	1.37
1	SB(20)	4.29	3.49	3.21	1.08
2	NB(20)	4.15	—	2.65	1.50
2	SB(21)	4.25	3.19	2.80	1.45
3	NB(30)	4.14	—	2.18	1.96
3	SB(26)	4.07	2.16	1.50	2.57
Grand Average		4.16	2.88	2.45	1.71

*Metric conversion 1 inch = 25.4 mm.

Several significant observations can be made on the data given in Table 3. First, the average relief joint closure of 1.71 inches (43 mm) during the first year suggests that there were very significant stresses remaining in the pavement even though numerous blowups had already relieved these stresses in many areas. Second, a careful study of the data shows that about 75% of the total closure occurred before the summer months when stresses, if unrelieved, would be highest. This finding clearly indicates that pavement stresses, even in the winter, were too high to be relieved by the natural tendency of the pavement to shrink in cold weather. Third, the project having the lowest blowup frequency (No. 3) showed significantly more closure of the relief joints during the summer of 1975 than did the other two projects, which suggests that Project No. 3 should be observed very closely to determine whether there is a need for additional relief joints. As indicated earlier, the higher strength concrete in this project will sustain more pressure without failure. However, the relative increase in blowups for this project just prior to installation of the relief joints, along with the behavior of these joints, indicates that the project was becoming highly subject to blowups which may still occur when the benefits of the relief joints are completely exhausted. Note that the southbound lane of this project has sustained only

4 blowups in its 10-year life but that after only one summer the relief joints have closed an average of 2.57 in. (65 mm) or about 65%. Such behavior reinforces the possibility mentioned earlier that pressure relief joints may be used as indicators of pavement pressures such that corrective action can be taken before pavement damage results.

The relative behaviors of the Types A and B relief joints are of some interest and are summarized in Table 4, where the annual relief joint closure is given for each project and each type of joint.

Table 4

Annual Relief Joint Closure

Project	Annual Average Closure by Relief Type (in.)*	
	A	B
1	1.08	1.37
2	1.45	1.50
3	1.89	2.57

*Metric conversion, 1 inch = 25.4 mm.

It should be recalled here that the Type A joints were installed in conjunction with full-depth pavement repairs while the Type B were installed at mid-slab length in sound pavement sections. In many cases the full-depth repairs were to blowups where pavement stresses had been at least partially relieved by the blowups. It is not, therefore, surprising to find that the Type B joints were somewhat more effective, because no natural stress relief had been provided prior to their installation. This finding suggests that in future installations it may be advisable to omit the Type A joints in lieu of providing more of the Type B at strategic locations.

Movement of Intermediate Joints

The movement of intermediate joints within a typical section having pressure relief joints at each end is indicated in Figure 1. The section comprised 17 slabs, each 61.5 ft. (18.8 m) long. Individual joint movements were measured from the saw marks in the asphaltic concrete shoulder, as mentioned earlier. As would be expected, the movement was maximum at the pressure relief joints, gradually decreased toward the center of the section, and was negligible at the center. This behavior is also indicated in Figures 2, 3, and 4 for the movements at the relief joints, at a joint 1/4 of the way through the section, and at the midpoint of the section, respectively. In all cases, joint movement was toward pressure relief joints with the node point at midsection, which indicated a balance of pavement pressures and movements.

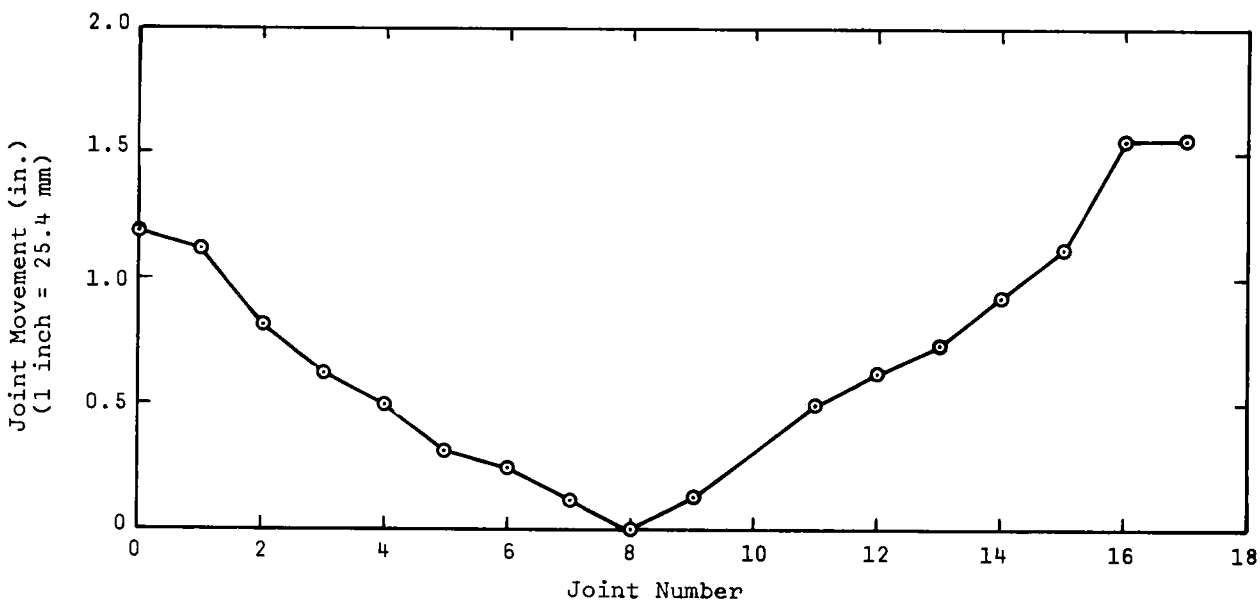

Figure 1. Joint shift between pressure relief joints.

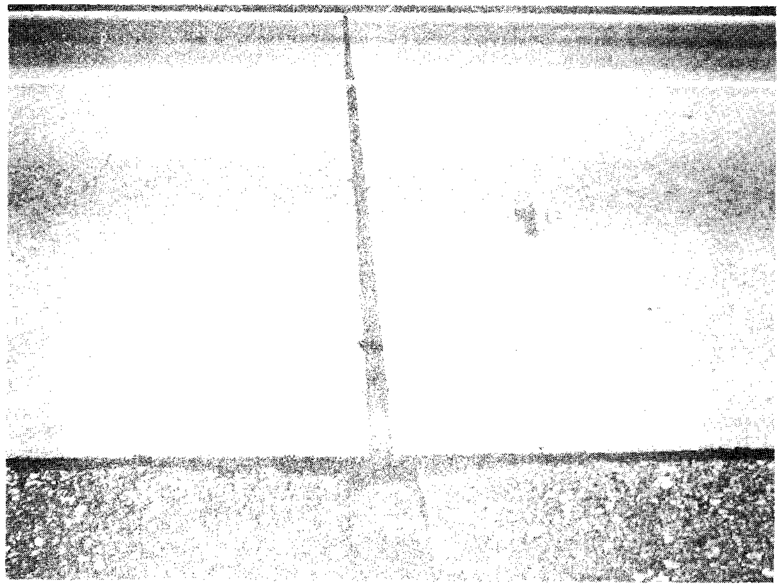

Figure 2. Closure of pressure relief joint after one year in service.

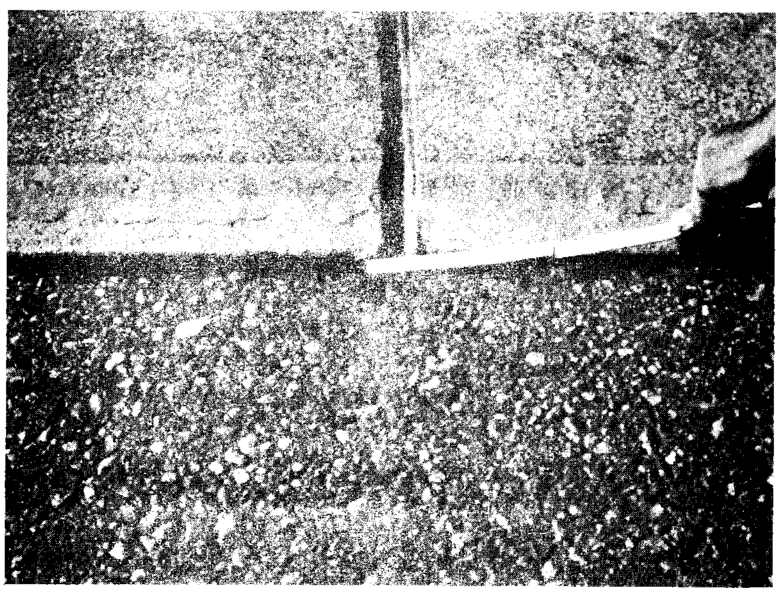

Figure 3. Shift of intermediate joint 246 ft. (75 m) from pressure relief joint.

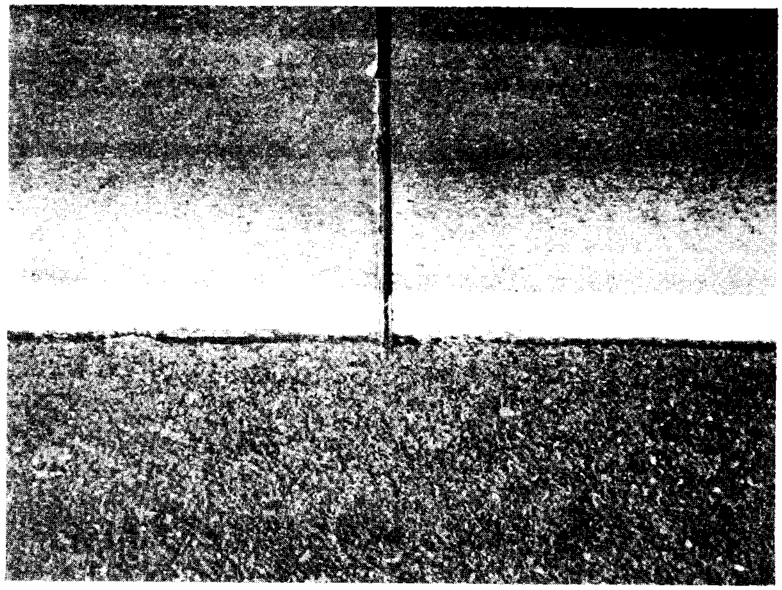

Figure 4. Node point midway between pressure relief joints.

It is clear from the above data that the relief joints provided were effective for at least the 1,000 ft. (300 m) contained in the typical section. Careful study of Figure 1 also suggests that the relief joints might have been capable of providing some stress relief for sections longer than 1,000 ft. (300 m). Theoretically, the joints are effective until there is more than one stationary joint at midsection. The determination of a maximum effective section length is not a straightforward procedure. A paradox develops when one considers that the more internal stresses a pavement contains, the longer will be effective section length. Conversely, when there are few internal stresses, the relief joints may be immediately effective over only a very short distance. In the latter case, the relief joints probably are not badly needed but will serve for a long period of time. Several examples of this type behavior occurred in Projects 1 and 2 where pressure relief joints were installed close to blowups. Because pavement pressures had already been relieved, these relief joints closed less than 1/2 inch (13 mm) during their first year in service.

One type of undesirable behavior of joints between relief joints is demonstrated by the photograph in Figure 5, which shows an intermediate joint that has opened so widely that a preformed compression seal is no longer in contact with the walls of the joint. This behavior gives rise to the possibility of initiating a vicious circle where the provision of too much freedom of joint movement can create conditions where joint infiltration is aggravated, and, in turn, can require the provision of more pressure relief. Such behavior occurs only at joints located very close to relief joints or to previous blowups. Since it is not possible to predict when excessive opening might occur, it appears that pavements having preformed seals should be observed very closely for some time after relief joints are installed. This possibility of excessive intermediate joint opening is one consideration which should not be overlooked when the decision to provide relief joints is being made. There may be instances where it would be advisable to install several relief joints for observation purposes, possibly one year before full pressure relief is contemplated. In this way, a final determination of the need for the joints could be made.

It is of some interest to compare the movement of joints in a pavement where no stress relief has been provided to that of joints where the relief joints are located at 1,000-ft. (300 m) intervals. This comparison is illustrated in Figure 6 for the April through September 1975 period. Note that while the seasonal movement for the control section was approximately 0.008 in. (0.20 mm), the joint located 61.5 ft. (18.7 m) from a pressure relief joint opened a total of 0.18 in. (4.5 mm). Similar but less severe movements were recorded for joints located 184.5 ft. (56.3 m) and 307.5 ft. (93.8 m) (not shown) from the pressure relief joints. The pavements contrasted in this figure are those discussed in an earlier report,[3] where the behaviors of blowup prone pavements were compared with that of the control section, which had no blowup history.

Figure 5. Excessive opening of joint near pressure relief joint. Note that the preformed seal is pulled away.

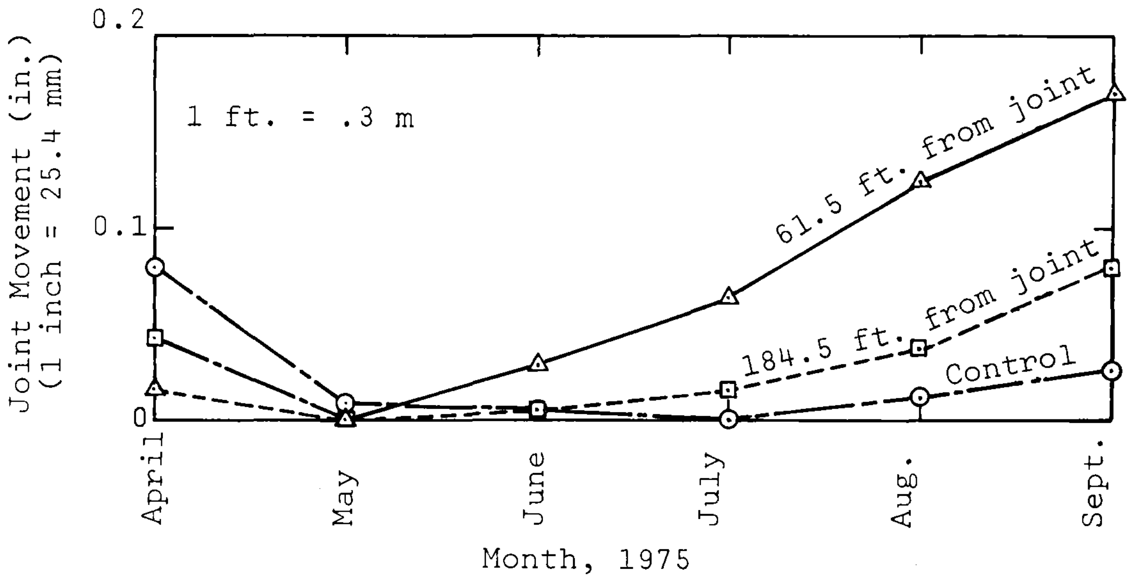

Figure 6. Comparison of pavements with and without pressure relief joints. Each curve is average for four joints.

Weather Considerations

Because the seasonal length changes of concrete pavements are closely related to the prevailing weather conditions, it was considered important to compare climatological data for 1974 and 1975 to determine the effect of weather on differences in pavement performance before and after the stress relief joints were installed. Mean monthly air temperatures for both 1974 and 1975 are plotted in Figure 7 from data collected at the U. S. Weather Station at Corbin, Virginia. The close similarity of the two curves suggests that mean temperature was not an important factor in differences in pavement behavior between 1974 and 1975. Precipitation data from the same station showed total annual rainfalls to be 39.02 in. (991 mm) and 47.32 in. (1202 mm) for 1974 and 1975, respectively. Slightly more severe conditions are indicated for 1975 when pavement performance was better.

From the above, it was concluded that weather conditions had no appreciable affect on the differences in pavement performance between 1974 and 1975, and that the differences shown earlier were due to the presence of the pressure relief joints.

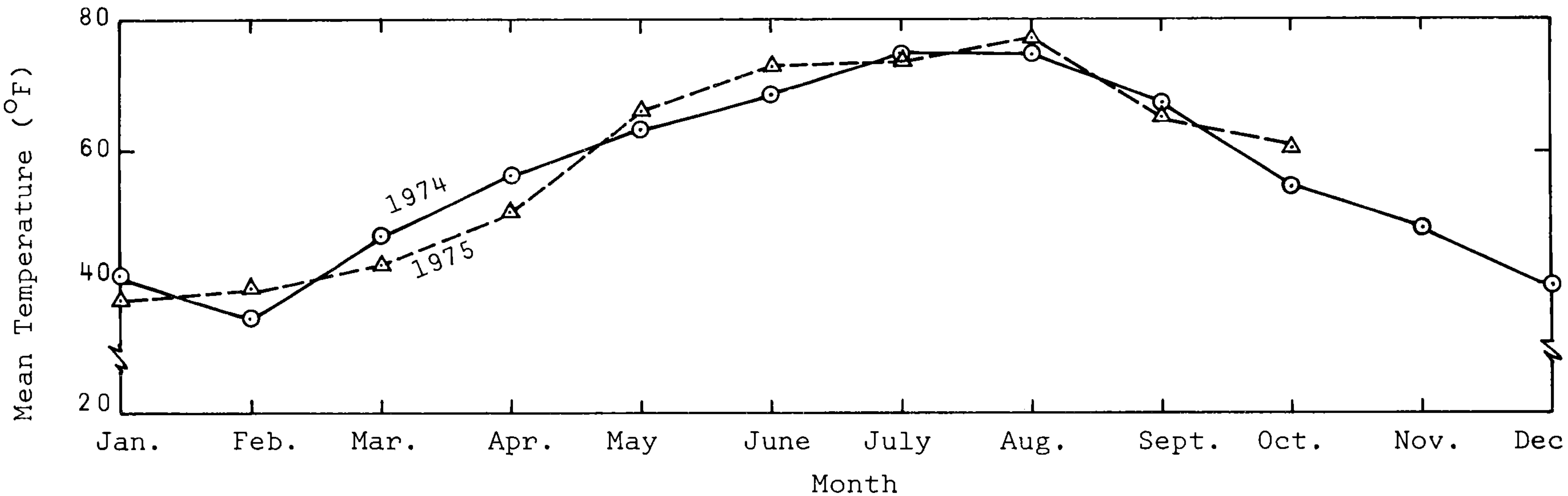

Figure 7. Mean monthly temperature, U. S. Weather Station at Corbin, Virginia.

Problems Encountered with Use of Pressure Relief Joints

As the Department has gained experience with the use of pressure relief joints in several locations, including the one discussed earlier, it has become evident that certain precautions are necessary to achieve the most effective use. Some of these precautions and the related problems are discussed briefly below. Several of these have been covered in recent specifications developed for installation of the pressure relief material.

Use on Multi-lane Pavements

The pressure relief material will almost always be used on pavements having more than one traffic lane, thus it usually will be impossible to install the material the full pavement width on the same day. However, the relief of pressure from one lane can substantially increase the pressures in other lanes so that the unrelieved lanes become highly subject to blowups. It is, therefore, necessary to install relief joints in all adjoining lanes in as short a time as possible. The photograph in Figure 8 is of a pavement on which repairs and pressure relief were provided in the near lane while the sound far lane was left until later. Unfortunately, several weeks of warm weather passed and a blowup occurred in the far lane before the work crew returned to install the pressure relief in that lane.

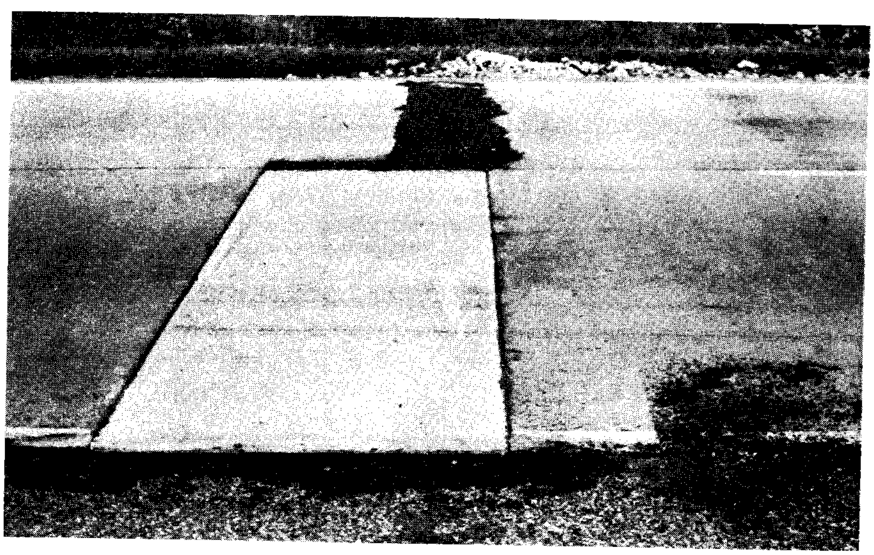

Figure 8. Failure due to redistribution of stresses between lanes. Repairs in near lane and new blowup in far lane.

In cases where the adjoining lane is of good quality concrete, restraint between the lanes has prevented functioning of the pressure relief joint so that the material is not tightly held in position and can float out during a heavy rain.

Both of these potential problems should be prevented by the new specifications that require installation of the pressure relief material in adjacent lanes within 48 hours. This specification also places restrictions on material width and requires the use of a lubricant-adhesive to install the material to provide further insurance against floating.

Installation in Hot Weather

The high pavement pressures encountered in hot weather make the summer a poor time for installing pressure relief joints, even though the need might be greatest in that season. Saw-pinching problems and the problem of unequal pressures between lanes are both aggravated during warm weather, so the new specifications mentioned above provide for the installation of pressure relief material in a temperature range of from 40°F (4°C) to 70°F (20°C).

Too Frequent Installation

In a few instances, pressure relief joints have been ineffective because of their proximity to other stress relieving features. While some judgement of pavement condition is necessary, the relief joints are not normally needed within 500-600 ft. (150-180 m) of a standard XJ-1 bridge approach expansion joint,[7] because such a joint inherently provides adequate pressure relief (Figure 9).

Pavements which have sustained full-width blowups may not need pressure relief joints within about 500 ft. (150 m) of the blowups, especially if the blowup has been temporarily repaired with bituminous concrete and has remained in that condition for some period of time. This natural relief of pavement pressures will be indicated by unusually wide joints in the vicinity of the blowup.

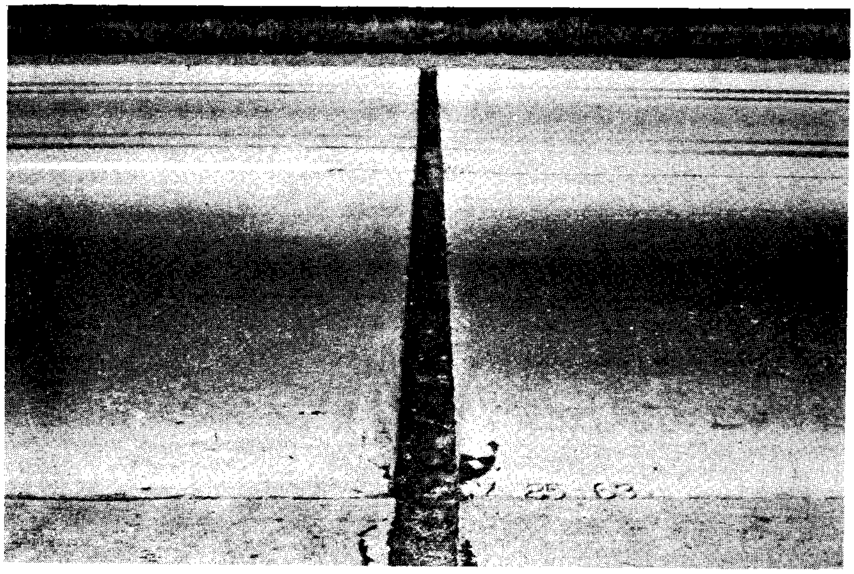

Figure 9. Joint next to bridge protection expansion joint type XJ-1.

Making the Decision to Provide Pressure Relief

Since the provision of pressure relief joints is a rather expensive and time-consuming operation, the following discussion is offered to help the field engineer make the decision concerning their need.

Pavements having no blowup history should not have pressure relief joints installed without careful consideration of the pavement history and condition. Extensive studies of blowup prone pavements in the state have shown that blowups will occur or are impending when some or all of the following factors exist:

1. The pavement is more than 5 or 6 years old,

2. transverse joints are poorly sealed,

3. the pavement is subject to joint or edge pumping due to poor quality subbase,

4. the pavement was constructed of concrete containing a siliceous coarse aggregate,

5. sand or other traction improving aids are used liberally on the pavement,

6. the pavement was constructed of slabs more than 20 (6 m) to 30 ft. (9 m) long,

7. the pavement was constructed of poor quality concrete,

8. dowel bars were misaligned during pavement construction, and

9. truck traffic volume is high.

Not all of the factors listed above will be present in every blowup prone pavement, and not all of the factors are of equal weight. For example, with other conditions equal, pavements with 61.5 ft. (18.8 m) long slabs appear to be much more subject to blowups than are those with shorter slabs. On the other hand, pavements with short slabs have been observed to blowup, but only after many years of service under adverse conditions. Similarly, pavements can become subject to blowups due to either surface infiltration, infiltration from the subbase, or a combination of the two.

Because the relative contributions of each of the above factors is so poorly defined it is necessary to make field inspections to determine blowup probability. In general, at least two or three of the following types of visual evidence will be present when blowups are impending.

1. Some transverse joints are tightly closed while others are wide and badly infiltrated.

2. Joint pumping is evidenced by the presence of fines on the shoulder or a shoulder depression at the pavement edge.

3. Joint faulting is evident.

4. Transverse joint misalignment is evident, especially at lane additions or drops.

5. Transverse joints show evidence of crushing.

Examples of the above types of distress are given in Figures 10-14. It should be noted that joint crushing is not to be confused with the joint spalling associated with metal joint forming inserts discussed in an earlier report.[3]

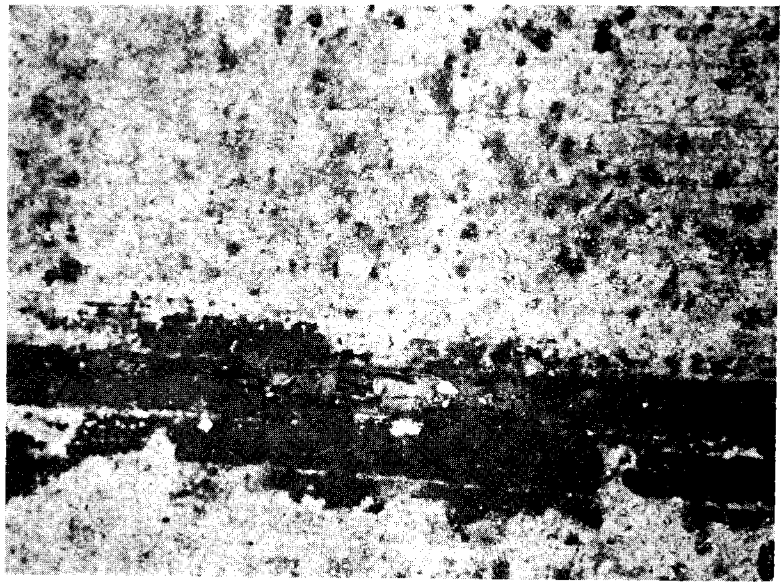

Figure 10. Joint infiltration.

Figure 11. Pavement pumping as evidenced by deposition of fines on the shoulder.

Figure 12. Joint faulting.

Figure 13. Misalignment of transverse joint due to pavement pressures.

Figure 14.Joint crushing due to pavement pressures.

Pressure Relief Under Overlays

Pavement performance observations have shown that pavements subject to blowups while in service as a wearing course will often be subject to blowups after they have been overlayed with a bituminous concrete surface. For this reason, the decision was made to provide pressure relief joints in the widening of I-495 in Northern Virginia. The 24-ft. (7.2 m) wide existing pavement had suffered a number of blowups in its approximately ten-year life. The primary factors contributing to these blowups were heavy traffic, poor subbase, difficult to maintain joints, and long slabs. Since these conditions could not be effectively corrected as a part of reconstruction, the provision of pressure relief joints was an acceptable effort to reduce future maintenance. To ensure that the old pavement and the 24 ft. (7.2 m) of widening base concrete would function together, relief joints were also called for in the base. While the project is still under construction, much of the pavement and widening has been overlayed with no apparent adverse effects other than a slight depression in the overlay at some relief joints. Many of the relief joints have closed up to 2 in. (50 mm), which is an indication that they are serving their intended purpose.

Based on this experience, it would appear reasonable to continue the use of pressure relief joints under overlays when the old pavement has demonstrated a blowup history or when the blowup causative factors discussed earlier are in evidence.

CONCLUSIONS

The conclusions below appear warranted from the data and discussion presented earlier.

1. Pressure relief joints can contribute substantially to the reduction of blowups and general distress of portland cement concrete pavements.

2. Pavements containing pressure relief joints can experience excessive opening of intermediate joints such that the effectiveness of preformed seals is impaired.

3. Rapid pressure relief joint closure may be an indication that additional relief is needed.

4. Pressure relief joints installed at mid-slab are somewhat more effective than those installed in conjunction with full-depth pavement repairs.

5. Pressure relief joints serve no useful purpose in close proximity to bridge protection expansion joints and to blowups where a full-depth — full-width portion of the pavement has been replaced with bituminous concrete.

6. In making the decision on whether or not to provide pressure relief joints, careful consideration should be given to the pavement design and performance history.

7. Pressure relief joints can be used effectively under bituminous concrete overlays on portland cement concrete pavements.

RECOMMENDATIONS

The following recommendations are offered for consideration by the Department.

1. The practice of providing pressure relief joints in pavements having blowup histories or exhibiting blowup tendencies should be continued.

2. Pavements containing pressure relief joints should be inspected periodically for evidence that intermediate joints are opening excessively such that preformed seals can no longer be accommodated. Such inspections may also indicate the need for additional relief joints.

3. Pressure relief joints are not recommended within 500 ft. (150 m) of bridge protection expansion joints Type XJ-1 or of full pavement width blowups where pavements stresses have been relieved as evidenced by wide joints near the blowups.

4. Consideration should be given to omitting pressure relief joints at full-depth — full-width (all lanes) repairs. This omission should be accompanied by the greater use of relief joints at mid-slab length of blowup prone sections of pavement.

5. The decision as to whether pressure relief joints should be provided should be made only after due consideration of the pavement design and its performance history. The decision criteria enumerated herein are suggested as guidelines.

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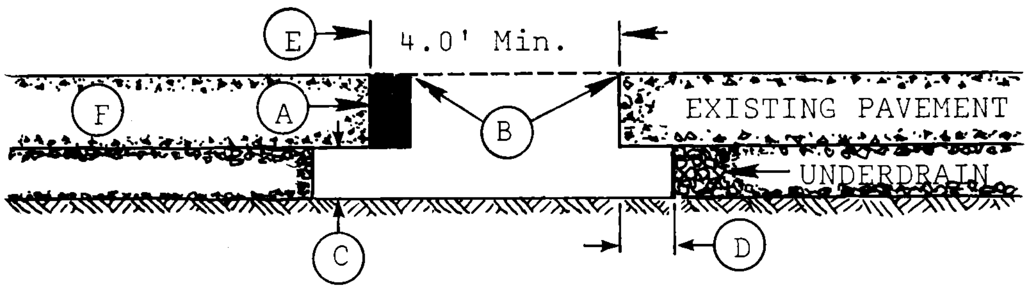
APPENDIX A

DESIGN OF PAVEMENT REPAIR INCORPORATING PRESSURE RELIEF JOINT



TYPICAL SECTION

ELEVATION VIEW

A. Preformed pressure relief material 4" x 10" x 12' (100 mm x 250 mm x 3.7 m).

B. All joints to be edged with a jointing tool. The joint shall extend into the concrete for at least ¼" (6 mm).

C. The depth of the excavation shall be 6-inches (150 mm) below existing pavement.

Excavation will replace dowelling into existing pavement. Do not replace dowell assembly at joint area.

Existing concrete to be sawed full-depth.

D. The excavation will extend back under the existing slab a minimum of 6-inches (150 mm).

E. The area measured for payment as pavement repair will be measured at the top surface of the existing pavement. The cost of excavating for and installing the 6" (150 mm) key on each side of the pavement repair shall be included in the square yards of pavement repair computed by the above method.

F. The concrete pavement shall be sawed full-depth for the purpose of installing pressure relief joints. Pressure relief material is to be installed in accordance with the manufacturer's installation recommendations. Adjacent pieces of joint material will be connected by the use of an approved adhesive. When a pressure relief joint is installed in one 12-foot (3.7 m) lane, the relief joint will be extended across the adjacent lane within 24 hours.

APPENDIX B

DESCRIPTION OF PRESSURE RELIEF STUDY PROJECTS

Project No. 1

No. 0095-088-101, P401

From: Caroline-Spotsylvania County Line

To: 5.019 mi. (8.076 km) north Caroline-Spotsylvania County Line

Length: 5.019 mi. (8.076 km)

Completion Date: 5-27-64

Pavement Design: 9 in. (225 mm) reinforced concrete pavement, 6 in. (150 mm) subbase material Grading I.

Remarks: Slabs 61.5 ft. (18.8 m) long.

Project No. 2

No. 0095-088-101, P401

From: 5.019 mi. (8.076 km) north Spotsylvania-Caroline County Line

To: 0.501 mi. (0.806 km) north Intersection Route 1

Length: 4.588 mi. (7.382 km)

Completion Date: 10-22-63

Pavement Design: 9 in. (225 mm) reinforced concrete pavement, 6 in. (150 mm) subbase material Grading I.

Remarks: Slabs 61.5 ft. (18.8 m) long. Joints formed with metal inserts.

Project No. 3

No. 0095-088-102, P401

From: 0.501 mi. (0.806 km) north Intersection Route 1

To: Spotsylvania-Stafford County Line

Length: 5.747 mi. (9.247 km)

Completion Date: 5-3-65

Pavement Design: 9 in. (225 mm) reinforced concrete pavement, 6 in. (150 mm) subbase material Grading I (Modified).

Remarks: Slabs 61.5 ft. (18.8 m) long. Modified subbase material is coarse graded and better draining than that on Projects 1 and 2.