EVALUATION OF THE ON-FLEX EXPANSION JOINT SEALING SYSTEM FOR BRIDGE DECKS

by

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ABSTRACT

Seven ON-FLEX bridge deck expansion joints were installed as experimental features on four bridges in Virginia. Each joint was evaluated with respect to its ease of installation, ability to accommodate thermal and structural movements, ability to prevent debris and water from entering the joint, and its performance over a four-year period (two years for one bridge). The joints on two of the bridges were placed using drilled-hole anchorage systems, and a cast-in-place anchorage system was used on the remaining two bridges. In addition, different wedge anchor bolts were used on the two bridges having drilled-hole anchorages.

The joints appear to adequately accommodate structural movements, although one appears to be closing due, possibly, to shifting of the bridge superstructure or the abutment. The joints prevent debris from entering the normal joint opening but they are not completely waterproof. The inexperience of the contractors installing the joints and, in some instances, uneven surfaces in the concrete trough area as well as other construction related difficulties may have contributed to the leakage problems observed.

There was considerable difficulty with drilling holes in the deck since reinforcing steel would often be struck. Although one of the wedge type anchor bolts used gave better torquing results than the other, there was more difficulty in installing the joints using drilled-anchorage systems than there was using the cast-in-place systems.

Because of the short period the joints have been in service, no conclusions were drawn regarding the maintenance-free life of the joints.

It was recommended that an anchor bolt which incorporates a cylindrical expansion shield be tried on some drilled-hole anchorages for joints of the type investigated. Consideration should also be given to allowing for drilled-hole anchorage systems in the design of the deck reinforcing steel.

RECOMMENDATIONS

It is difficult to set anchorage systems in the concrete during construction of a bridge deck, and the operation often requires more time and effort than drilling holes in the finished concrete and inserting the anchor bolts at the time the joint is installed. Thus, many contractors prefer the latter procedure. Neither of the two types of anchor bolts used with drilled holes on this project, however, were entirely satisfactory.

A promising anchor bolt for use in drilled holes that has recently been introduced in this country should be tried on joint installations of the type investigated. This more sophisticated anchor bolt incorporates dual cones, a cylindrical expansion shield, and a dome washer to develop compression between the concrete and the bolt. An anchorage system that could be used to expedite construction and increase the reliability of the finished product could more than offset its higher cost.

An attempt should be made to allow for the drilling of holes for joint anchorage in the design and placement of the deck reinforcing steel.

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INTRODUCTION

This report is presented to supply information concerning the installation and performance of the ON-FLEX bridge deck expansion joint. This joint, which is a proprietary design, was installed on four bridges in Virginia and was incorporated as an experimental feature on each.

GENERAL DESCRIPTION OF THE ON-FLEX JOINT

There are several models of the ON-FLEX joint. For the most part, the differences in the models relate to the size of the expansion joint and the amount of expansion that can be accommodated. A typical section of the ON-FLEX 25 model, which was used on three of the four bridges included in this project, is shown in Figure 1. This design incorporates a continuing elastomeric membrane held in place by two aluminum channels anchored to the concrete deck as shown in Figure 1. The wedge type anchor bolts shown are designed to be placed in holes drilled in the concrete at the time the joint is installed. One of the features of the joint is that it permits movements in all directions, including vertical deflections. The accommodation of moments in directions other than normal to the axis of the joint is a useful feature when the joint is to be used on a skewed bridge deck.

In an earlier study of the first use of the ON-FLEX joint in Virginia, it was noted that several problems associated with the drilling of the anchor bolt holes made the installation of the joint difficult.(1) Besides being a slow process, the location of deck reinforcing steel often interfered with the drilling process. As a result, some irregular spacing of the anchor bolts was required because the holes could not be drilled at the proper locations. In addition, some of the holes were drilled too deep and when the wedge type bolts were inserted they also were too deep, which decreased the thread available for the nut and washer. Therefore, one of the recommendations of the study was that the anchor bolts for the joint should be preset during construction of the bridge deck. Subsequent to that evaluation, an appropriate anchor bolt design was incorporated to allow for presetting inserts

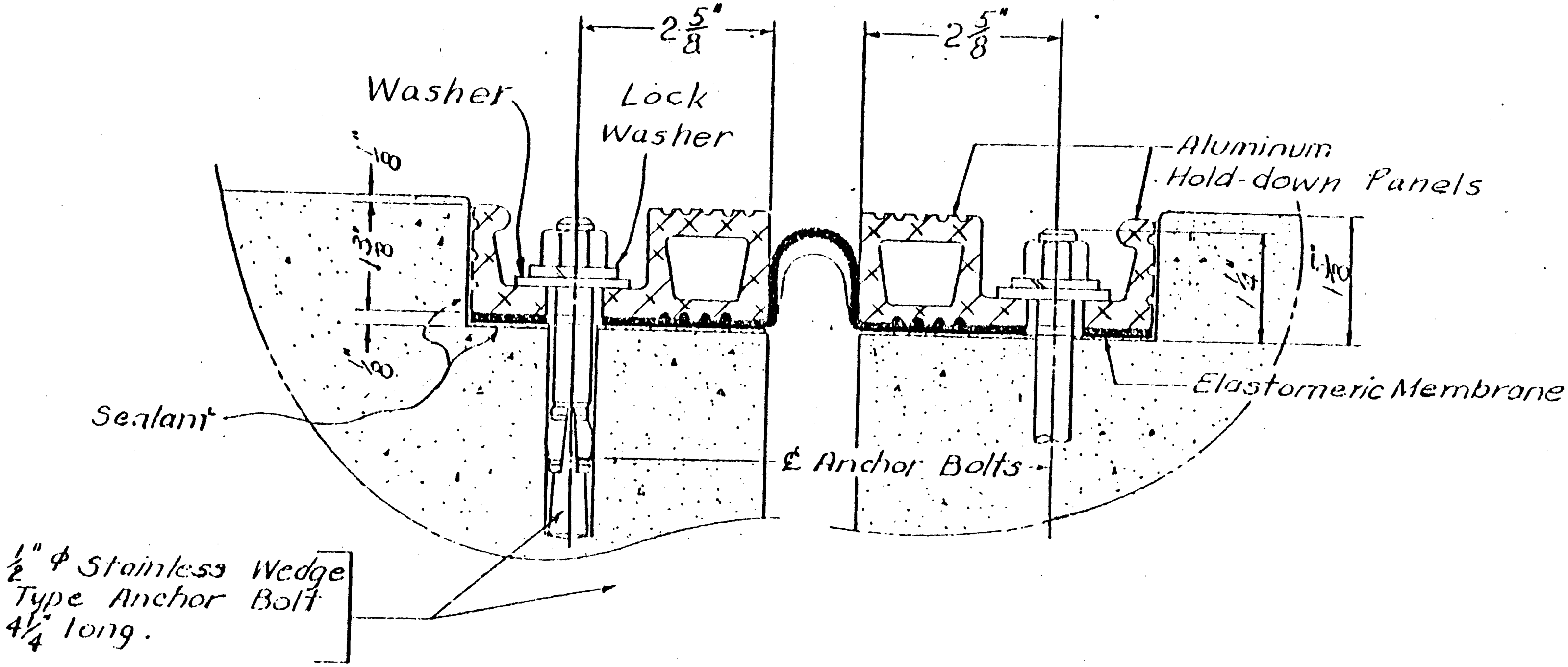

Figure 1. Typical section through the ON-FLEX 25 bridge deck expansion joint showing wedge type anchor bolt. 1 in. = 2.54 cm.

in the forms prior to placement of the deck concrete. A typical section of this cast-in-place anchorage system is shown in Figure 2. Although an ON-FLEX 45 joint is shown, the cast-in-place anchorage system can be used on the 25 model as well. Of the four bridges included in this study, two were constructed with the cast-in-place type anchorage and two with the wedge type anchorage.

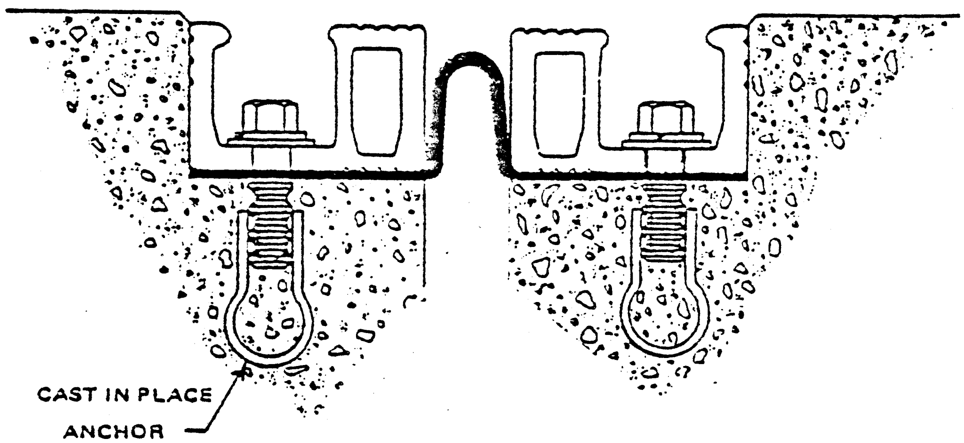

Figure 2. Typical section of the ON-FLEX 45 bridge deck expansion joint showing the cast-in-place type anchorage.

PURPOSE AND SCOPE

An effective bridge deck expansion joint system should provide the following:

1. It should accommodate all thermal and structural movements for which the bridge is designed.

2. It should keep all foreign material out of the joint openings and away from the lower bearing area.

3. It should prevent leakage to the lower structural elements.

4. It should be relatively easy and inexpensive to install.

5. It should provide long, maintenance-free service.

The primary purpose of this study was to evaluate the ON-FLEX joint with respect to the above aspects insofar as possible. It was not possible to evaluate the service life of the expansion joint since, at this writing, one of the installations has been in service for two years and the remaining three for approximately four years.

BRIDGE DESCRIPTIONS

The ON-FLEX joint was included as an experimental feature on the following bridge structures:

1. Route 95, NBL connection over the WBL of Route 295, Project No. 0095-043-107, B665, Henrico County (two joints; one at each abutment).

2. Route 95, SBL connection over the WBL of Route 295, Project No. 0095-043-107, B666, Henrico County (two joints; one at each abutment).

3. Route 195, Connection "NN" over the NBL and SBL of Route 95, Project No. 0095-043-107, B667, Henrico County (one joint at pier 1 and one joint at pier 3).

4. Route 236 (Duke Street) over the RF&P railroad, Project No. 236-100-101, B602, city of Alexandria (one joint at abutment B).

The first three bridges are located several miles north of the city of Richmond, and are all in close proximity to each other. The first two bridges are very similar and are comprised, respectively, of 69-136-69 and 65-123-65 foot (21-41.5-21 and 19.8-37.5-19.8 meter) continuous curved plate girder spans. The bridges are skewed, respectively, at approximately 38° and 43°. The third bridge is the longer of the four studied, having two 224 ft. (68.3 m) continuous plate girder spans crossing the NB and SB lanes of Route 95. It has approach spans at each end measuring, respectively, 75 ft. (22.9 m) and 85 ft. (25.9 m) in length. The last bridge has only a single 200 ft. (61 m) plate girder span and is skewed at 58°. All four bridges are constructed with ASTM A-588 weathering steel and are unpainted.

JOINT INSTALLATION

As stated earlier, a bridge deck joint should be relatively easy and inexpensive to install. To evaluate these characteristics of the joint and to record any problems during construction that might bear on subsequent performance, the installation of each joint was observed.

Anchor Bolt Placement

Installation of the first joint began in June 1979 on the bridge having the two longest spans (Route 195 connection "NN" over the NBL and SBL of Route 95). On this structure, holes were drilled into the concrete deck (Figure 3) and the wedge type anchor bolts shown earlier in Figure 1 were used. Prior to drilling the holes, however, it was discovered that the seat for the joint was too shallow and had to be lowered by removing some of the concrete. The application of an epoxy mortar was then required to smooth the surface upon which the joint was to be placed.

During drilling of the holes in the concrete deck, the reinforcing steel was hit in a number of instances. When this happened, the hole was abandoned and a hole was drilled approximately 2 in. (5.08 cm) on each side of the original. As a result, a large number of extra holes were drilled into the deck in order to ensure the minimum original spacing of 1 ft. (30.5-cm) between anchor bolts. Thus, the bolt spacing in several areas appeared as shown in Figure 4, as opposed to the planned 1-ft. (30.5-cm) spacing along the length of the joint.

Of the remaining three bridges included in the evaluation, the anchor bolt holes were drilled in the concrete deck on the Route 95 SBL connection over the WBL of Route 295, and cast-in-place anchorages (Figure 2) were used on the Route 95 NBL connection over the WBL of Route 295 and on the Duke Street bridge over the RF&P Railroad. In this second experience with drilling the anchor bolt holes, some of the same problems encountered with hitting the reinforcing steel on the Route 195 connection "NN" bridge were again experienced. On the other two bridges, the use of the cast-in-place anchorage system appeared to be a better alternative. The use of this technique requires more effort during the construction of the deck, but the final placement of the joint was observed to be much easier and less time consuming.

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Figure 3. Drilling anchor bolt holes for an ON-FLEX joint.

Figure 4. View showing irregular anchor bolt spacing required when reinforcing steel in the concrete prevented hole drilling at the planned location. Note also, at the center of the photograph, the extra washers used to elevate the nut after pullout of some of the anchor bolts occurred during tightening.

In addition to the problem of the deck reinforcing steel hindering drilling operations, other problems related to this anchorage technique can arise. First, if the holes are drilled too deep, the anchor bolts can be driven too far into the concrete and insufficient thread is left above the surface for tightening the bolt nuts. Secondly, if the bolts do not wedge tightly in the concrete, they can pull outward during torquing. While the first potential problem did not occur on the two bridges investigated in this study, the need to control the depth of the drilling (or depth of placement of the bolt) must not be overlooked. The second potential problem did occur on the Route 195 connection "NN" bridge. Approximately 10% to 15% of these bolts were pulled outward during torquing to the specified 50 ft. lb. (68 N.m). In some instances, insufficient threading was left on the bolts to allow for tightening the nuts, so additional washers were added to elevate the nut. One such case can be observed at the center portion of Figure 4. A few of the bolts were extracted during torquing and these were epoxied back into the holes. At the joint on the north end of the bridge 17 nuts could not be removed due to stripping of the threads after the bolt had moved upward. In addition, several bolts were broken off during this effort. Due to these problems, the contractor ran out of bolts and the joint installation was delayed. Approximately 75 extra bolts were used to complete the installation of the two joints on the connection "NN" bridge. As a result of the problems encountered with the wedge anchor bolts, a different type bolt was used on the SBL of the Route 95 connection over the WBL of Route 295. A view of the anchor bolt that was used is shown in Figure 5. The contractor selected this design since, from his experience, he believed that the gripping strength would be greater than that developed by the bolt used on the connection "NN" bridge.

There were fewer problems with the second bridge as compared to the first. As a precaution, however, the anchor bolts were coated with epoxy when driven into the deck. There were no problems with torquing and re-torquing the anchor bolts on the SBL of the Route 95 connection bridge. The contractor, however, spent about 12 hours locating, drilling, and placing the bolts for each of the two approximately 90 ft. (27.4 m) long joints.

For the NBL of the Route 95 connection bridge and the Duke Street bridge the anchorages were preset during the construction of the deck, so no work on the bolts was required prior to placement of the joint materials.

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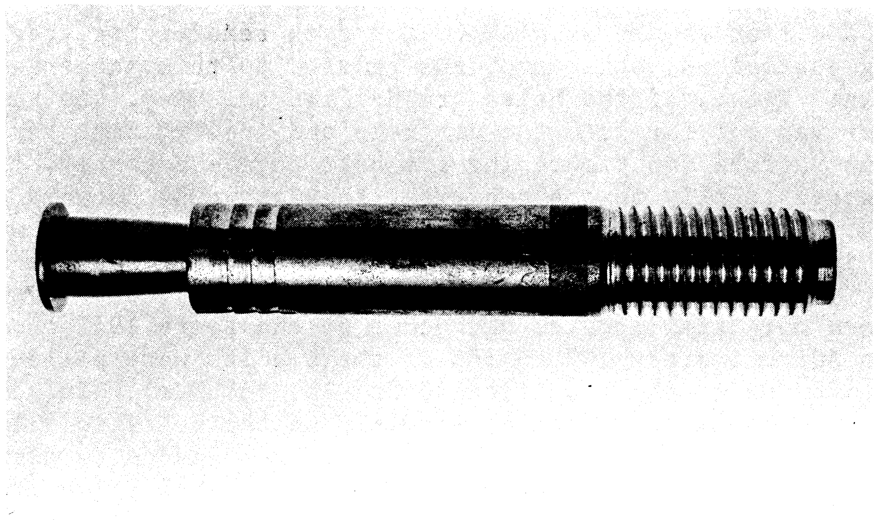

Figure 5. Typical anchor bolt used in the drilled holes on the SBL Route 95 connection over the WBL of Route 295.

Elastomeric Membrane Placement

The elastomeric membranes were delivered to the sites with the parapet wall sections vulcanized to the main sections of the material. In most all cases the material was vulcanized at the wrong skew angle and did not fit into the parapet wall joint trough. A typical misfit of the membrane as delivered to one of the three bridge sites in Henrico County is shown in Figure 6. This problem caused considerable delay in the installation of the joints, since the material was sent back to be corrected. On one of the structures the material was returned several times because it was either the wrong size or the skew angle for the parapet wall was incorrect.

On the NBL of Route 95 connection bridge the neoprene material for the south joint was too long. In this case the material was cut to the desired length, spliced, and vulcanizing chemicals applied on the job site (Figure 7). On the north joint of the same bridge the skew angle was spliced and vulcanized in the field to correct the error.

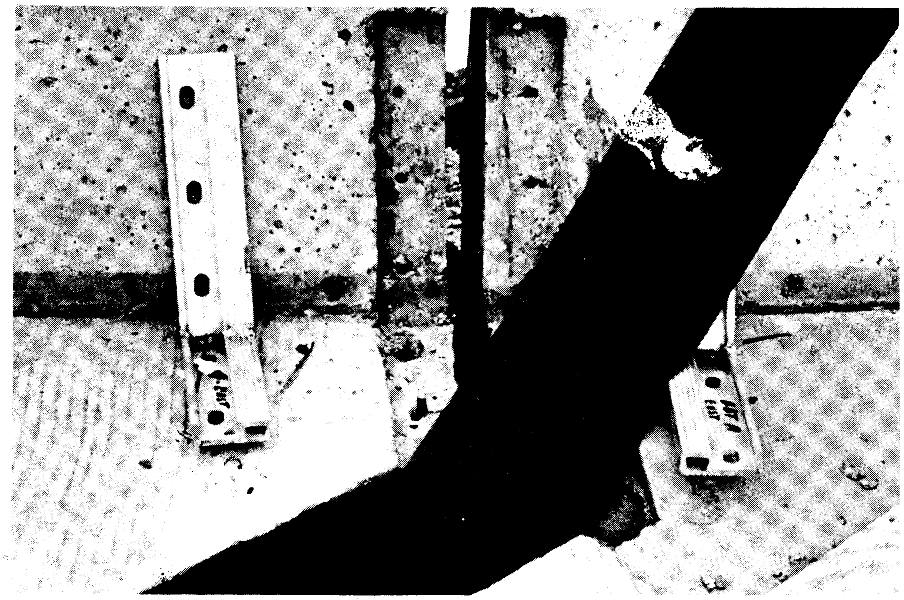

Figure 6. A view of the misfit of the elastomeric membrane at the parapet wall on one of the three Henrico County bridges.

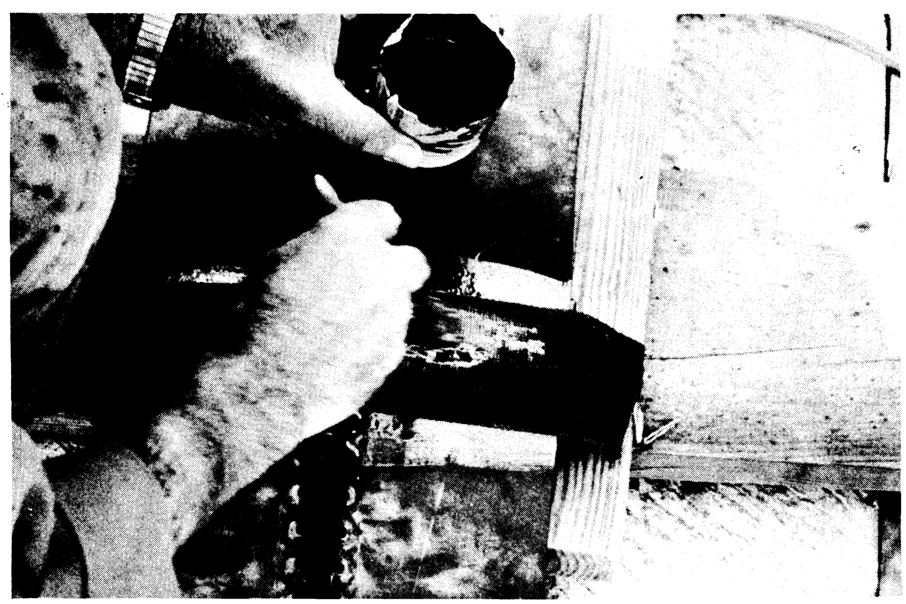

Figure 7. Application of sealing materials to complete the splicing of two sections of neoprene.

Prior to installing the neoprene, the joint trough is cleaned, holes are punched in the material at each anchor bolt location, and a sealant material placed in the trough. At first, a considerable amount of sealant material was placed in the trough, as shown in Figure 8. This was later reduced because it was thought that some of the difficulty in obtaining the specified torque on the anchor bolts was due to the heavy application of sealant. The reduced amount of sealant used on a subsequent installation can be seen in Figure 9, which also shows the elastomeric membrane being installed.

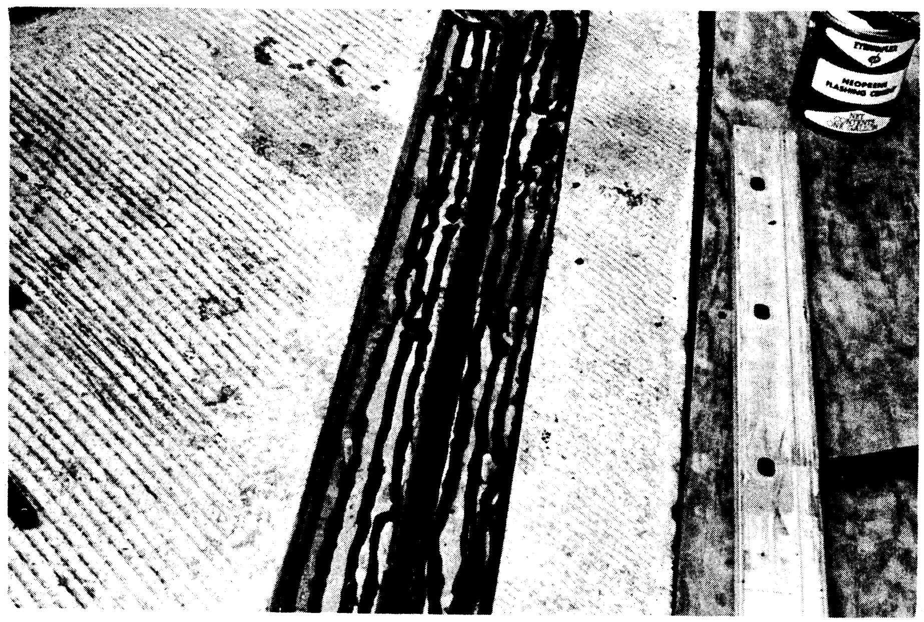

Figure 8. Heavy application of joint sealant material in joint trough.

Figure 9. Placement of elastomeric membrane over a lighter application of sealant material.

Hold-Down Channel Placement

The hold-down channels can be placed rather rapidly, if all the holes are drilled in the proper location to fit the anchor bolts. In some instances, however, the holes had to be enlarged (Figure 10) to fit the anchor bolts.

Before the hold-down channels were placed, additional sealant was placed on top of the elastomeric material. The nuts were tightened and later re-torqued to the specified amount. The use of a lighter application of sealant did appear to reduce the need for several re-torques to complete tightening of the nuts. The last operation involved placing the sealant material along the edge of the hold-down channels at the face of the concrete deck (Figure 11).

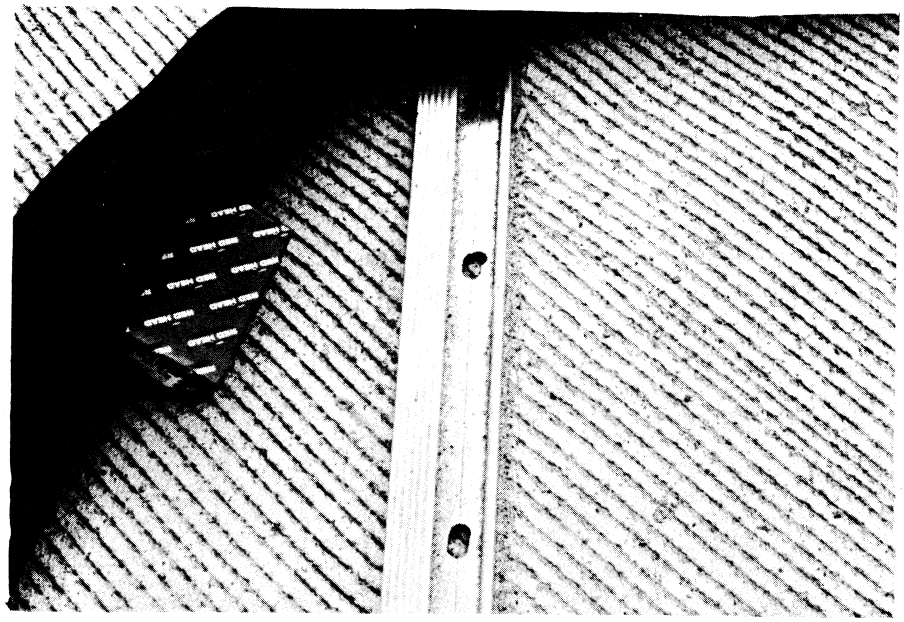

Figure 10. View of hold-down channel with enlarged holes.

Figure 11. Placing sealant along edge of hold-down channel and concrete deck.

General Observations

The installation of the ON-FLEX joint is much easier and requires less time when cast-in-place anchorage systems are used. Once all the proper joint materials are on the bridge site, and assuming all skew angles are prefabricated into the materials correctly, the installation of the joint can be accomplished reasonably fast. The materials, however, were not supplied with the correct dimensions and angles for most of the joints on the four bridges investigated. This, of course, frustrated the contractor in his efforts and caused a number of delays. The contractor's inexperience with installing the joint was in all likelihood an additional factor which contributed to inefficiency during installation.

Fitting the joint materials to vertical faces such as curbs and parapets was a problem on all four bridges. The neoprene was cut and re-spliced to fit on several occasions. On the Duke Street bridge, the last of the four bridges to be completed, the hold-down channels did not fit well at the curbs and median strip. Because of the skew and the difficult fit, sharp edges of the channels protruded at the top of the curb of the sidewalk (Figure 12) and the median strip (Figure 13). A special plate was later installed to cover these edges and to improve the appearance of the joint.

Roughness on the surface of the concrete in the trough had to be ground smooth in several areas to provide a smooth bed for the joint material and to decrease the chances for leakage through the trough. It would appear important that the trough be smooth and uniform if leakage is to be avoided.

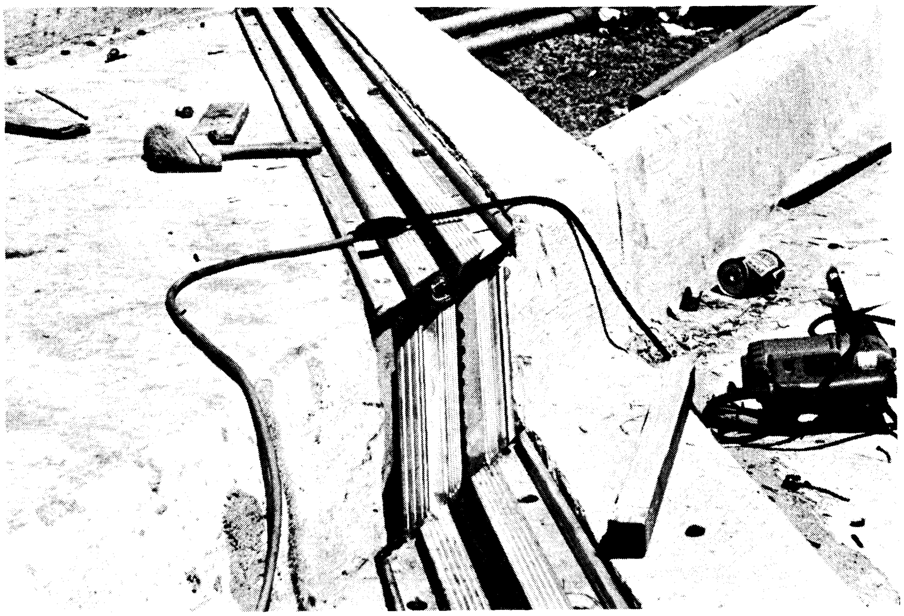

Figure 12. Appearance of the joint at the face of a sidewalk curb on the Duke Street bridge.

Figure 13. Appearance of the joint at the face of the median strip on the Duke Street bridge.

PERFORMANCE

It was originally intended that the joints would be inspected at 6-month to 1-year intervals for the first 2 years of service under traffic.(2) The Duke Street bridge was not completed until September 1981, whereas the Route 95 bridges in Henrico County were completed 2 years earlier in 1979. Therefore, at this writing, the joints on the three structures in Henrico County have been in service for 4 years and the Duke Street bridge has been in service for 2 years.

All the joints on the four bridges appear to be adequately accommodating all thermal and structural movements. On the Duke Street bridge, however, which has a 58° skew, the joint appears to be closing. It appears likely that either the span or the abutment has shifted slightly and tended to close the joint. If this continues, the elastomeric material will fail or it will be forced upward and be worn by traffic. Both conditions will probably occur simultaneously if the joint closes much further.

The sealing system serves well in keeping debris such as sand and gravel from entering the joint.

The only serious leak found was at the south joint over a pier on the connection "NN" bridge. The water comes through the joint in an area about 18 to 24 ft. (5.5 to 7.3 m) from the face of the east parapet wall and drains down on the south end of the center pier of a three-pier design (Figure 14). It should be noted that during the installation of the joint there was trouble tightening the nuts on the wedge type anchor bolts in this area. Also, some grinding of the concrete in the trough had been necessary during construction. While the joint did not appear to be loose under the impact of the traffic, the problems discussed earlier concerning the installation of the anchor bolts could be directly related to the leak.

Several small areas of leakage were observed after a heavy rain on both the NBL and SBL connection bridges. Typical of these areas is the leakage shown on the face of the abutment in Figure 15. While holes for the anchor bolts were drilled on the SBL and cast-in-place anchors used on the NBL, there did not appear to be any difference in the amounts of leakage on the two bridges. While there was an average of two leakage points under each joint, no water was getting to the girder bearing areas. Of the total of seven joints on the four bridges, no leakage was observed on one and only minor leakage on five. Long sections of some of the joints did not show evidence of leakage, which indicates that the joint can be waterproof if installed properly.

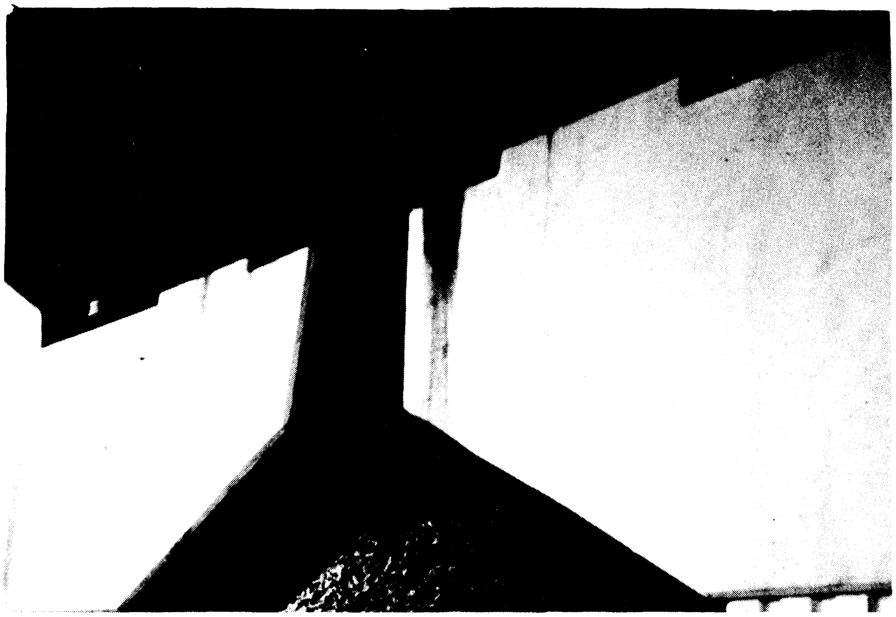

Figure 14. Stained pier cap caused by leakage through the south joint on the Route 195 connection "NN" bridge.

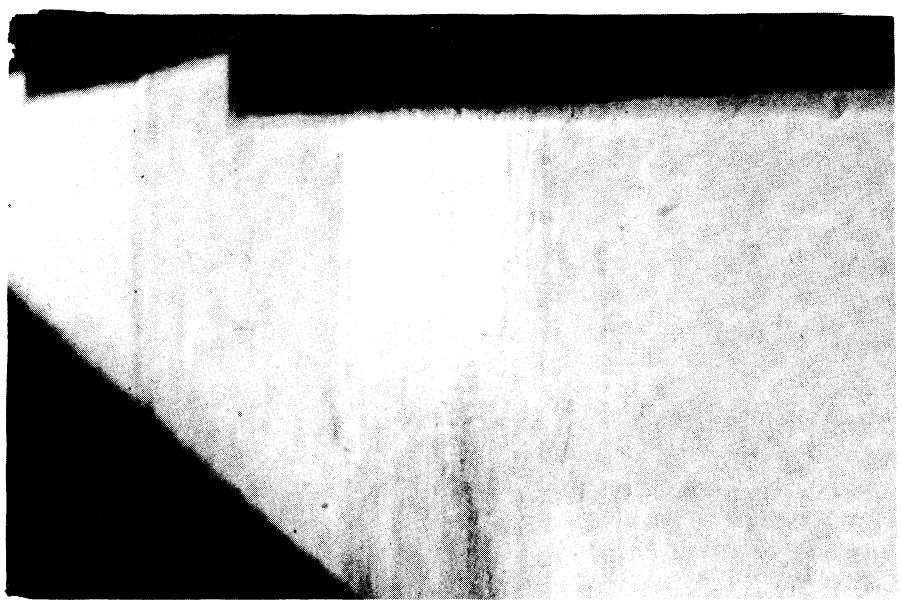

Figure 15. Spot leakage through a joint at an abutment.

Since this inspection covered only 4 years of service on six of the joints and 2 years on the last one to be installed, it cannot be concluded how long the installation will provide maintenance-free service. The performance to date, however, suggests that the joint should serve for a considerable length of time under normal traffic impact and environmental stresses.

SUMMARY OF FINDINGS

Based on observations made during the installation of the joints on the four bridges studied and on their service performance over a 4-year period (only 2 years for one of the seven joints), the following conclusions are made.

1. The joint accommodates the thermal and structural movement for which it was designed. It should be noted that all four of the bridges were designed with a considerable degree of skew angle at the joint. It should also be noted that the joint on the Duke Street bridge appears to be closing due possibly to a slight shifting of the superstructure or the abutment. If the joint closes much further, it is likely that the elastomeric membrane will fail from a simultaneous crushing effect and wear by traffic contacting the upwardly compressed material.

2. The sealing system serves well in preventing debris from entering the joint or falling to the structure below.

3. The joints were not completely waterproof. It is likely, however, that the inexperience of the two contractors installing the joints, rough or uneven surfaces in the concrete trough, and other difficulties encountered during installation were related to the leakage observed.

4. Assuming all materials are correctly sized and correctly spliced at the required angle points, it appears that the joint can be easily and quickly installed. This, however, was not the case for the bridges studied. Unfortunately, the contractors experienced considerable frustration when the joint materials delivered to the job did not fit.

5. Because of the short period the joints have been in service, no conclusions can be drawn with regard to the maintenance-free life of this type joint.

6. The installation of the ON-FLEX joint appears to proceed more rapidly and with fewer problems associated with the anchorage system when a cast-in-place anchorage is used.

7. There can be considerable difficulty with drilling holes in the deck for the anchor bolts. Based on the observations made during their use on one of the bridges included in this evaluation, the wedge type anchor bolts illustrated in Figure 1 cannot be recommended for use in drilled holes. An anchor bolt similar to that shown in Figure 5 appeared to give better results when used in drilled holes.

8. Considerable attention should be given to obtaining a smooth and plane surface in the trough where the joint is to be installed.

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REFERENCES

1. Hilton, M. H., "Installation of an ON-FLEX Bridge Deck Expansion Joint," VHTRC 77-R60, June 1977.

2. Hilton, M. H., Working Plan, "Evaluation of the ON-FLEX Expansion Joint Sealing System for Bridge Decks," VHTRC 77-WP55, February 1977.

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