

Bridge Joint Maintenance

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Damage to bridges in the United States related to the deck expansion joint totals millions of dollars each year. This includes both damage to the joint and the portion of the bridge beneath the opening exposed to debris and contaminants. The magnitude of the problem is documented by engineers involved in the National Bridge Inspection Program. The number of deficient structures is growing much faster than replacement is possible. Administrators are seeking methods to preserve and extend the service life of their bridges. There are a variety of deck joints currently in service that depend on the age of the bridge and the type and magnitude of the movement. The earlier designs provided little or no protection to prohibit passage of deck drainage and debris. More recently, flexible materials are used to seal the opening. Although some perform better than others, none of the designs have succeeded in eliminating the problems. Engineers and suppliers continue to develop devices and materials intended to improve serviceability. The goal is to have a joint that is watertight, capable of accommodating the movement, as durable as the adjacent deck, and maintenance free. Until such a "wonder drug" is available, preventative maintenance seems the best medicine to keep joints functioning and avoid more costly structural damage.

The function of a bridge deck expansion joint is to accommodate movement of the superstructure or articulation. This movement emanates from live loads, environmental characteristics, and the physical properties of the materials that make up the bridge. Longitudinal and transverse movements occur as the result of temperature change, creep, and shrinkage. Rotational movements occur as the result of live load deflection and substructure settlement. Transverse movement can be particularly troublesome on skewed bridges.

Movement is usually accommodated by providing a space between rigid sections of the superstructure equal to or greater than the anticipated movement. As a result, discontinuity is created in the surface of the deck that impairs the riding quality of the roadway, and the opening can become a conduit through which foreign materials are deposited on the supporting elements beneath the deck surface.

A variety of devices have been developed in the design of bridge deck expansion joints. Variance in materials and details intended for the same function are common. Some of these devices have been effective while others have performed poorly. The following discussion reviews the various types of joints, the related problems in maintenance, and the impact that poorly maintained joints can have on other parts of the structure.

IN-SERVICE JOINTS

In the very broad sense, joints can be subdivided into two classifications--those that are closed and those that are open. Closed joints are those that are designed to be waterproof while open joints are not.

Open Joints

Common types of open joints are butt (either with or without face reinforcing), plate bearing, and toothed. In older structures, these joints were almost exclusively used. The butt joint is used normally for movement less than 1 in, the plate bearing for movements between 1 and 3 in, and the toothed or cantilever joint for movements in excess of 3 in.

To alleviate the impact of water reaching components of the structure beneath the roadway surface, drainage systems have been installed to carry the runoff away from the joint. Usually, this has been

in the form of a drainage trough placed beneath the joint.

For the most part, the success record of the drainage trough has not been good. Not only are they very expensive to construct, but they soon fill with debris and cease to function properly. Due to the limited space under the joint, the trough usually has very little slope with several bends or small openings. The debris soon piles up in the trough and spills over onto the seat below. Also, cleaning the trough normally ranges from difficult to impossible. In many situations where troughs were used in the past, it would probably have been as effective to regularly clean the debris from the bearings and seats and eliminate the trough.

Because this design permits deck contaminants to pass through the opening and the drainage trough is normally not effective, the open joint has lost favor with most bridge engineers.

Butt Joint

Butt joints are commonly used where only rotation must be accommodated, or with minor thermal movement, since this joint provides no transition for traffic between adjacent edges of the deck. Armoring is usually provided, although installations have been used without it. A typical detail is shown in Figure 1.

It is difficult to protect the metal facing from corrosion. The joint will often fill with noncompressible materials and thus become inoperable. When used with asphalt overlays, the armoring should extend to the surface elevation. A joint transitional dam is required to achieve this. Otherwise, raveling of the wearing surface can occur over the joint. Normal maintenance includes periodic clearing of roadway debris from the opening, painting, and roadway surface repair adjacent to the armor plate or dam.

When unarmored joints are used, the concrete surface edge can be damaged during construction or by traffic. Once started, the process will continue and eventually require recasting of the slab edge.

Plate Joint

Plate joints are used for movements between 1 and 3 in. It was the predominant type of bridge expansion joint used with steel-framed structures prior to the development of neoprene joints. The joint is normally designed to be self-supporting without reliance on the concrete deck for support. This is accomplished by supporting the joint on the end diaphragm and/or the ends of stringers. A typical detail is shown in Figure 2. A similar detail has been used on concrete structures.

These joints are difficult to maintain. It is common for plates to become loose, which creates a loud noise as traffic crosses, and occasionally they become completely detached, which results in a safety hazard. There are several reasons for this, depending on the particular design. Much of the problem can be attributed to the inadequate consolidation of the concrete under and around the plates. Also, the anchors corrode and are subject to fatigue under the continuous pounding of the traffic. In other instances, the roadway surface around the plates deteriorates, which increases the impact on

the joint from traffic and dislodges the plates. Extensive buildup of debris in the joint will often prevent the joint from operating as intended.

In order to permit satisfactory operation of the joint, it is necessary to periodically clean the joint and keep the exposed metal painted and free from corrosion. When breakdown of any portion occurs, it should be repaired immediately.

Figure 1. Open butt joints.

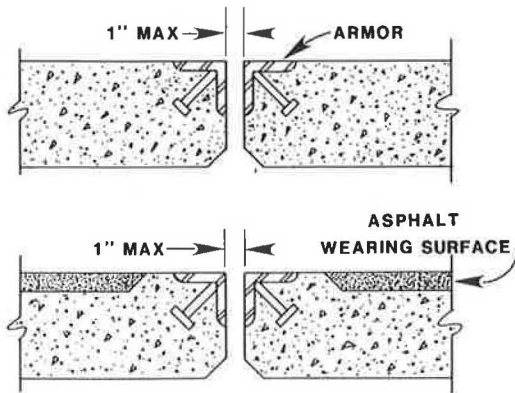


Figure 2. Plate joint.

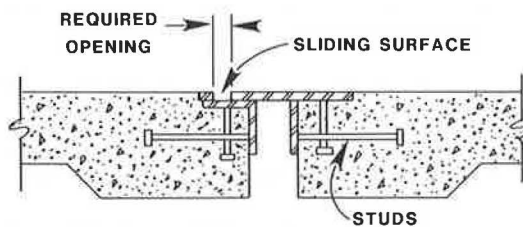


Figure 3. Tooth joint with drainage trough.

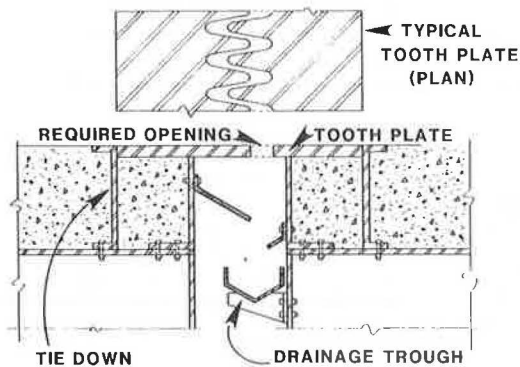
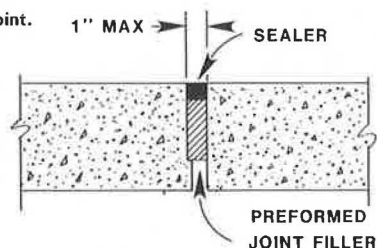


Figure 4. Filled joint.



Tooth Joint

When accommodation for movements greater than 3 in is needed, a tooth or cantilever joint can be used. A typical detail is shown in Figure 3. These joints operate well when properly maintained. Maintenance requirements are similar to those required for plate dams.

Closed Joints

Several categories of closed joints are discussed. These include the filled butt joint, compression seals, and membrane and cushion joints.

Filled Joint

A filled joint is similar to the butt joint already described and is used to accommodate the same degree of movement. Usually a premolded joint material is attached to one face of the joint or supported from below by an offset in the vertical face of the slab. A sealing compound is poured at the roadway surface to seal the opening. Figure 4 shows details of a typical filled joint.

Maintenance requirements include periodic cleaning, replacement of the surface seal and filler as necessary, and repairs to the roadway surface adjacent to the joint.

Experience has shown that poured-in-place seals work best when movement is less than 0.5 in and, even then, the adhesive and cohesive properties are very limited. The best products, when placed with strict quality controls, tend to remain watertight a maximum of two years. In many situations, inspectors have observed both cold-poured and hot-poured seals leaking after being in place less than six months. Power cleaning of the concrete surface prior to placing the seal improves the adhesion and often improves performance. If this type of seal is not kept watertight, the filler below will deteriorate and make resealing difficult. Noncompressibles work their way into the seal and, over a period of time, can cause the joint to jam.

Compression Seal

Compression seals are used for movements up to 2.5 in. A typical detail is shown in Figure 5. Considering the limited time of use, they seem to have the best success record for remaining watertight if constructed properly. Tests by the Florida Department of Transportation (DOT) have shown that premolded compression joint seals in place for 15 years have performed superior to previously used materials (1, p. 463). Because it is squeezed into the opening so that it expands and is compressed with the joint movement, it is critical that the opening be dimensioned properly for the particular size seal. If the opening is too large, it will separate from the deck in cold weather. If the opening is too small, the seal will be damaged by the compressive forces in hot weather. Also, if the opening is too small or the seal is placed too close to the surface, it will be damaged by traffic in hot weather as it bulges due to compression. Particular problem areas on these seals are the cuts necessary to make bends around curbs and parapets.

As with other seals, keeping the deck and approaches clean decreases the problems associated with damage from debris, particularly noncompressibles. Because the success of this type of sealer depends on an ability to return to its original shape after many cycles of being compressed, it is more likely not to be watertight as weathering and fatigue weaken the material.

Figure 5. Compression seal.

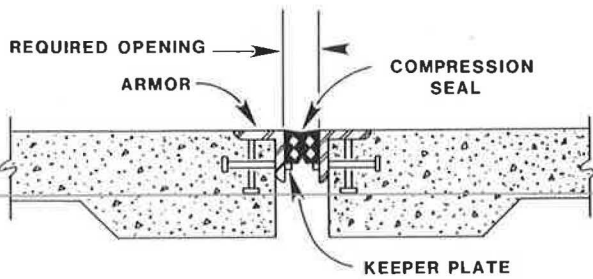


Figure 6. Membrane seal.

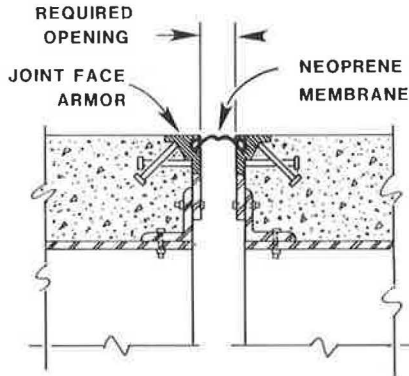
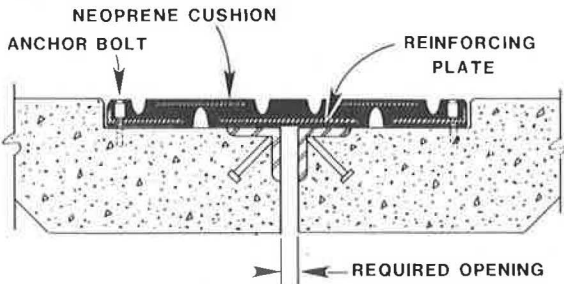


Figure 7. Cushion joint.



Compression seals can be used for large movements when multiple units are used. Careful attention must be made to detailing to ensure proper performance.

With the size unit shown in Figure 5, maintenance requirements are minimal. Periodic cleaning and roadway repair are normally all that is required. When evidence of leakage is discovered, immediate steps should be taken to correct the situation by repair or replacement of the seal.

Membrane Joint

A membrane joint consists of a flexible sheet of neoprene rigidly attached to the two metal facings of the joint. The material is bent in the shape of a "U" and flexes with the movement of the bridge. This joint can accommodate movements of ± 6 in. A typical detail is shown in Figure 6.

When properly installed, these joints are very effective in making a watertight joint. Problem areas are at gutter lines and similar areas where breaks in the cross section occur.

Breakdown of the membrane usually occurs as the result of noncompressible material being lodged in the joint when the opening is expanded. When the

joint then closes, these materials become wedged in the membrane and can cause a rupture, with a resulting breakdown in the watertightness of the joint. Breakdown can also occur as the result of traffic movements over debris-filled joints.

Maintenance requirements include cleaning the joints periodically to remove debris and sealing or replacing defective membranes. As with the compression seals, these units can be used in multiple units with special details to accommodate much larger movements.

Cushion Joint

The cushion seal joint is made up of a reinforced neoprene pad that is rigidly attached to each side of the joint. The inherent characteristics of the material permit it to expand as the joint opens and to shrink as the joint closes. The internal reinforcement permits the neoprene slab to span the joint. These joints have been used to accommodate movements of 4 in and more. A typical detail is shown in Figure 7.

Cushion joints have been in use for more than 10 years and in some instances have performed in a satisfactory manner. One of the more difficult problems in maintaining these joints is the anchorage system. High tension stresses in the neoprene pad are developed as the bridge contracts. This creates subsequent high stresses in the anchoring system and, if not properly designed, can result in failure.

Details at the curb line are particularly troublesome. If not properly developed or if not installed correctly, this area can be a continual maintenance concern. Also, the units are normally provided in nominal increments of length and require field splicing. This connection is difficult to make for long-lasting maintenance-free service, especially under heavy traffic pounding.

Caps that seal the anchorage are usually installed with an adhesive. An adhesive at the interface between the cushion and the concrete is used to maintain watertightness. These routinely break down, thereby resulting in loss of caps and leakage of the joint.

When the units have been used in areas where snowplowing is required, severe maintenance problems have developed. Plowing can tear the joint from the support or otherwise damage the cushion, which then requires extensive repair or replacement. Maintenance requirements include periodic cleaning, inspection of anchoring devices and replacement when required, and repair of the seal between the units.

PREVENTATIVE MAINTENANCE

Historically, bridge maintenance has been given a low priority. There are several reasons for this. The primary reason is the inadequacy of funds provided for maintenance. There is the "oil the squeaky wheel" philosophy. Bridge problems, particularly those related to the joints, have to become severe before they are obvious to the traveling public. Also, preventative maintenance is often viewed as a luxury by administrators and is either eliminated altogether or cut back significantly when budget constraints are imposed by management. Attitudes and policies are changing slowly in this respect as the problems increase with our crumbling bridge system, as seen in the following quotes: "The adage 'prevention is better than cure' is eminently true for bridges where defects can rapidly have serious consequences if action is not taken" (2, p. 10), and "Preventative maintenance applied to structures in good condition appears to be a very cost-effective strategy" (3, p. 8).

Preventative maintenance is most effective if it begins when a bridge is new and continues throughout the service life. There are more than 570 000 bridges in the United States; approximately 248 500 are structurally deficient or functionally obsolete (4, p. 6). The majority of the bridges have deck expansion joints. This problem is not restricted to the United States. The 1981 Report on Bridge Maintenance states that, in Italy, "79 percent of special maintenance and repair operations on bridges arise due to poor sealing of the expansion joints" (2, p. 42). Discussions with engineers directly associated with bridge inspection in the United States indicate that more than half of the problems reported on concrete deck bridges are related to the expansion joints or are caused by leakage through the joint.

Inspection

With the 1968 National Bridge Inspection Act came the opportunity to identify and quantify the current problems that relate to specific parts of all bridges in the United States. The next step is to expand this computerized system to relate the inspection data to maintenance tasks and schedules. In many localities today, the only information uncovered by the inspection that is transmitted to the people responsible for maintenance are the problems that require immediate attention.

The computerized bridge inventory system may soon be expanded to convert the condition ratings into maintenance priorities, which would then facilitate more realistic budgeting and effective scheduling. For instance, from the inspection data it is noted that the bond is beginning to fail on a poured-in-place joint seal and moisture seepage has begun through the joint, or considerable debris has accumulated on a deck with neoprene compression seals. Preventative maintenance is then scheduled in a timely manner.

One of the repeated complaints of the individuals involved in bridge inspection is that the information from the inspection often does not get to the people in the highway organization who need it to make decisions. Some of the groups that would benefit from this feedback are those responsible for money allocations, repair and replacement scheduling, and the design section so that designs that obviously cause problems may be modified.

Design to Minimize Maintenance

When the structure is being designed, careful attention should be given to the selection and detailing of proper joints. The designer should consult with construction personnel, as well as with maintenance experts, to ensure that practices that result in poor constructability and performance are not perpetuated. More often than not, the designer's experience with the problems of installation and maintenance are extremely limited. The construction inspector also often lacks sufficient appreciation of the critical importance of proper installation of the joint with strict adherence to the specified dimensions.

For the person making the original maintenance inspection to assume that because the bridge is new the expansion joints are watertight and require no attention is inappropriate. It is good practice to have someone from the maintenance section make their initial inspection before the structure is accepted from the contractor. Problems such as openings for compression seals that are too wide or not uniform, adhesives that did not bond properly, premolded sealer placed too high, or joint plates that are

loose because of anchorage or sound hollow due to improper concrete consolidation are then corrected at that time. For a preventative maintenance system to be effective, the joint must originally function properly.

The current philosophy among bridge engineers and administrators seems to be that a device, material, or design scheme has to be developed that will solve the joint problem for the life of the structure. This may or may not happen. There is a less glamorous, more pragmatic approach to solving the problem. This approach is to gear the maintenance of the joint to the proven effectiveness of the particular design, which considers such variables as climate, type and volume of traffic, debris accumulation, age, and inspector's appraisal. With each location, there is an optimum length of time that a joint seal will function properly. If proper maintenance is provided regularly before the sealant becomes ineffective, the more serious problems related to structural damage are minimized.

SPECIFIC JOINT PROBLEMS

There are a number of joint problems that seem to routinely occur. These include edge and surface damage and structural breakdown. Following is a discussion of these problems and some suggested repair techniques.

Edge Damage

Damage to the edge of the concrete adjacent to joints often results in leakage and a poor riding surface. This could be caused by poor design or construction. Figure 8 shows an example of this. An armor joint design could prevent the problem or the concrete chamber may be insufficient. Sometimes the initial damage is caused during construction by using the deck before the concrete has reached adequate cure. Excessive edge pressure on the concrete at any time, either during or after construction, caused by crossing the deck with steel-wheeled rollers or steel track equipment without adequate protection will also cause this damage. Irregularities in the grade of the deck between the two spans will also contribute to edge failure.

The width of the damaged area around the joint and other maintenance or repair work needed on the bridge will influence the method used to correct this damage. If the damaged area is narrow and the remaining concrete in the deck is sound, the joint may be widened by sawcutting and adding a compression seal. A more durable solution, particularly if the joint must be recast, is to add an armored device to reinforce the edge of the concrete.

Attempts have been made to repair the damaged edge with cement or epoxy mortar. This type of repair is not durable, particularly if the feathered edges are not eliminated by sawcutting.

Raveling of Wearing Surface over Joint

In the past it has been common practice to pave over a concrete deck with a bituminous wearing surface, thereby completely covering and obscuring the deck joints. This temporarily hides the joint problems while improving the riding surface. The deck movement causes cracking and raveling of the surface at the joints. Figure 9 shows an example of this.

The wearing surface prohibits inspection and maintenance of the joint seal. If wearing surfaces or overlays are required on a bridge, the joints should be redesigned to accommodate the change. The joint opening may be continued to the elevation of the new surface by adding joint transition dams. If

Figure 8. Joint edge damage.

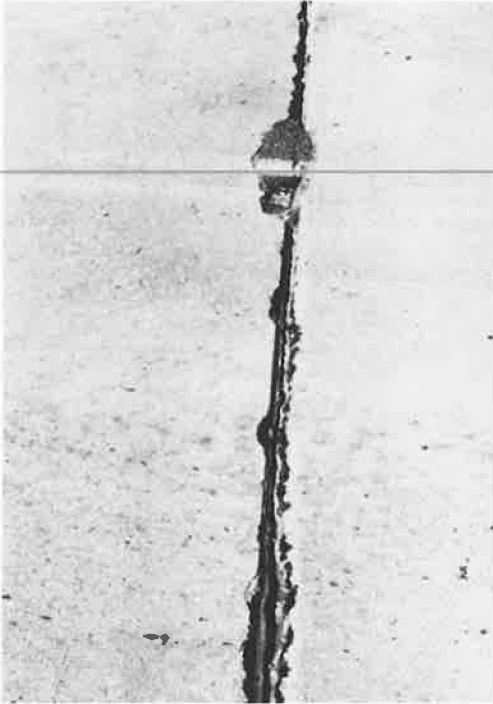


Figure 9. Wearing surface raveling.



the dams are constructed prior to the placement of the new overlay or wearing surface, it often results in a rough riding transition. This may be avoided by placing the new surface, ignoring the joint, and then removing the material over the joint. The top of the dam is installed to match the grade of the new surface.

Loose Joint Plate

As stated previously, it is common for steel plates to become dislodged from the anchoring system. Figure 10 shows an example of this. Because these joints are not watertight, repairs often include redesigning the opening to include a waterproof seal. This can be done by adding a lip to hold the seal in place, injecting epoxy to fill voids, or removing and replacing a portion of the deck around the joint.

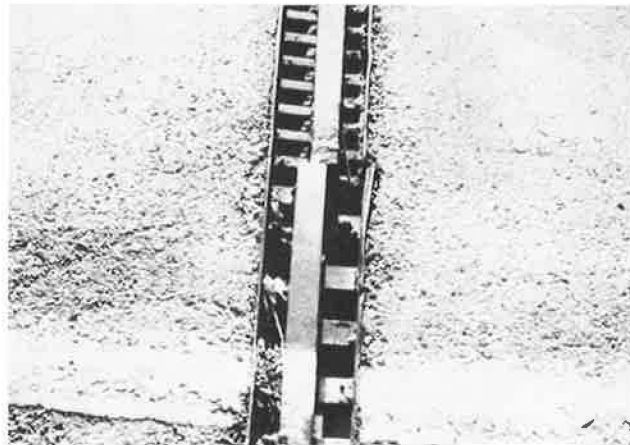
Joint Filler

Premolded joint fillers frequently deteriorate or become loose and fall out of the joint. Figures 11 and 12 show examples of the filler material protruding below the deck surface. Repairs in instances such as this should include removal of all joint material, followed by thoroughly cleaning the opening. A compression seal should then be installed. This may require removal of a portion of the deck and recasting to accommodate the joint armor and anchorage.

Elastomeric Seals

As stated previously, one of the major problems with the use of elastomeric cushion seals is the failure of the anchoring device and the subsequent loss of the joint. Figure 13 shows the loss of entire sections of the joint. The voided areas have been filled with bituminous material as a stop-gap repair. Ultimately, a new elastomeric cushion must be

Figure 10. Loose joint plate.



installed or the entire joint must be replaced.

IMPACT OF POOR MAINTENANCE

We have discussed deterioration, maintenance, and repair of bridge deck joints. We have also stated that it is mandatory to design, install, and maintain waterproof joints in order to preserve other portions of the structure. Following are some of the problems that can develop when joints are not adequate.

End Diaphragms

On bridges with painted steel superstructures, normally the first members to show discoloration due to rust are the end diaphragms. This is caused by moisture and salts that pass through the joints (see Figure 14). In some areas, this has become evident

Figure 11. Dislodged joint filler.

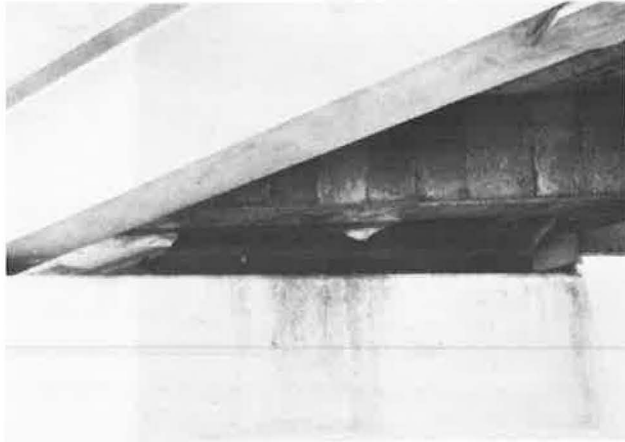
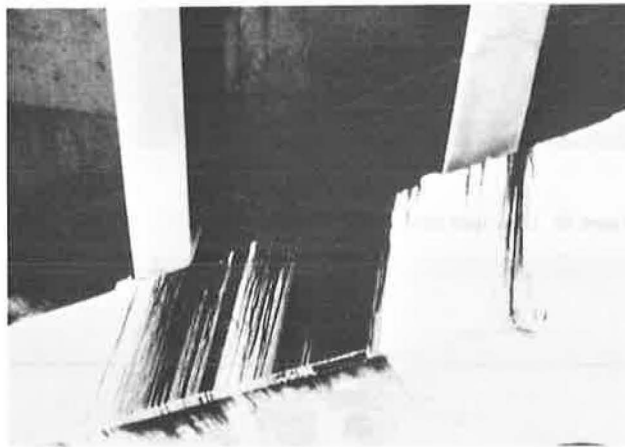


Figure 12. Dislodged joint filler.



in bridges less than two years old. If this corrosion is permitted to advance, serious section loss will occur in the steel. Also, the corrosion on the top flange of the diaphragms expands the metal, which causes the deck to rise. This not only results in an irregular riding surface, but in time causes transverse cracking in the deck near the joint.

Reinforced-concrete diaphragms are slower to show problems than steel diaphragms. The moisture penetrates the concrete and corrodes the rebars, which causes spalling of the concrete and section loss to the reinforced steel (see Figure 15). The practice of designing a drip bead on the bottom of the deck between the joint and the diaphragm has been used to try to eliminate this problem.

Beam Ends

The beam ends are affected in a similar manner as the end diaphragms. Paint systems normally break down more rapidly in this area, and corrosion damage is worse than elsewhere on beams (see Figure 16). On bridges where the joints are not kept watertight, the time span between required repainting and repair of superstructure elements is greatly reduced.

Bearings

When joint leakage problems occur, the bridge bear-

Figure 13. Cushion seal failure.

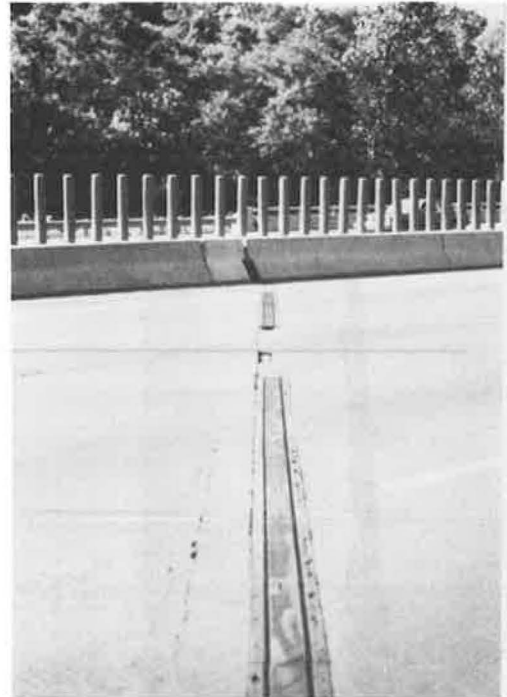
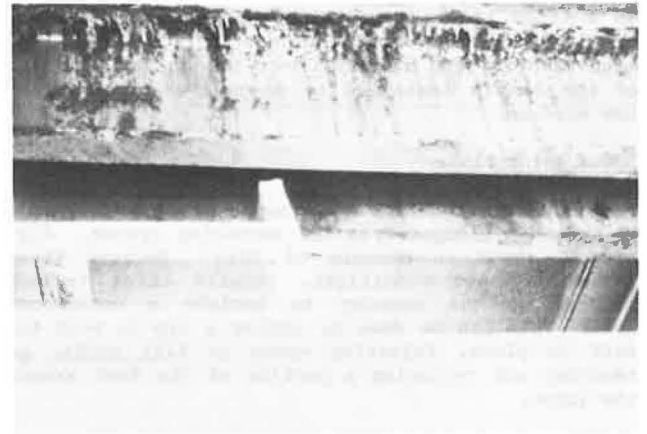


Figure 14. Steel diaphragm corrosion.



ings are exposed to moisture and debris, which cause deterioration and corrosion (see Figure 17). Often the bearings that were designed to accommodate the superstructure movement will become frozen due to the corrosion, which places stresses in other members of the structure that have not been designed to resist these forces. This causes serious distress problems in members, such as beams, seats, or substructure supports. Often a concrete beam will develop a diagonal crack that begins on the bottom of the beam at the end of the bearing and extends back and upward (see Figure 18). The force may also cause the cap to crack in a similar manner (see Figure 19). When bearings become frozen, the movement is transferred to other bearings, which causes joints to jam or open excessively. It may also cause adjacent bearings to tilt or slide beyond their design limits. The pressure created by the frozen bearings has been known to cause substructure

columns to crack or tilt. On skewed bridges, this problem can cause the superstructure to be forced out of alignment (see Figure 20).

Seats and Top of Cap

Moisture, deicing salts, and debris that spill

Figure 15. Concrete diaphragm deterioration.

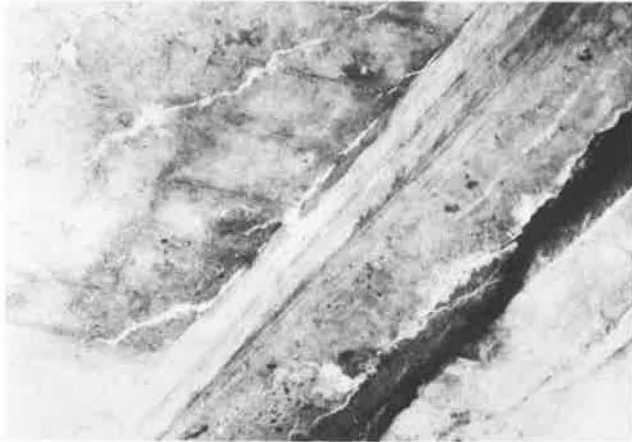


Figure 16. Steel beam corrosion.

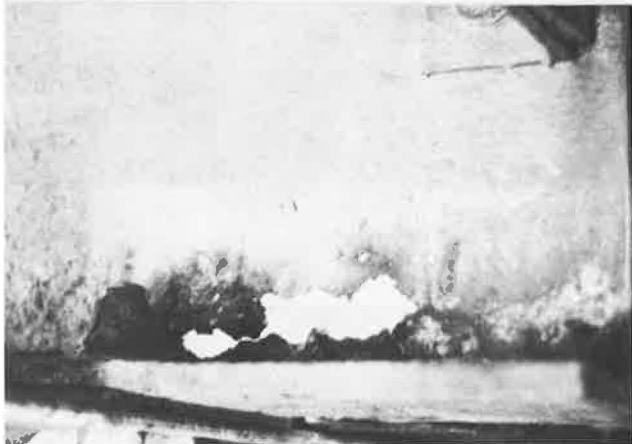


Figure 17. Bearing deterioration.



through the joints tend to accumulate and pile up on the seats and top of the cap. This debris holds the moisture, which keeps the area constantly damp. The result is that the moisture and salt deteriorate the concrete at an accelerated rate and penetrate to the reinforcing steel. This causes the bearing areas to be damaged by the disintegration of the concrete. On many concrete caps there will be a crack approximately 3 in from the top that extends horizontally along the face of the cap (see Figure 21). This is caused when the top mat of reinforcement expands due to corrosive forces and lifts the concrete.

Sides of Cap and Columns or Breast Wall

Leaking joints are commonly evidenced by discoloration on the sides of the substructure (see Figure 22). This causes eventual concrete deterioration

Figure 18. Concrete beam crack.



Figure 19. Pier cap crack.



and spalling. On structures with end diaphragms that extend down to the top of the cap, the water drains down the end of each cap, thereby causing significant concrete deterioration (see Figures 23 and 24).

Figure 20. Misalignment.



Figure 21. Cap cracking.

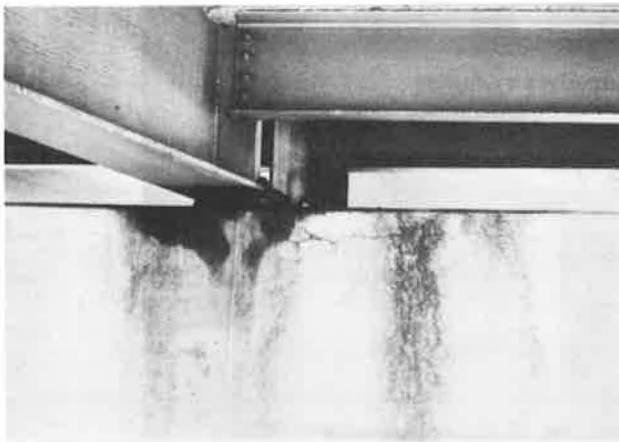
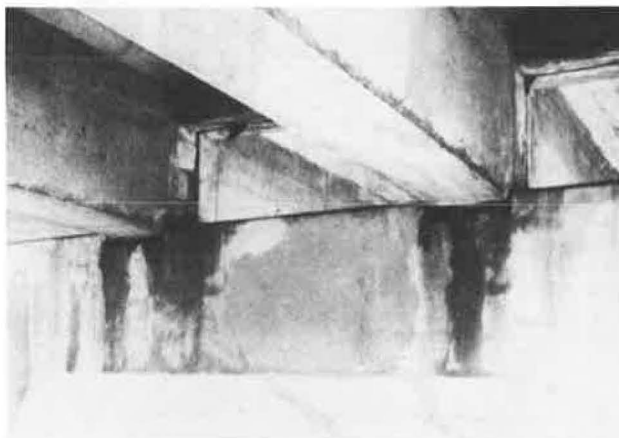


Figure 22. Cap damage.



Embankment Erosion

Drainage through joints at abutments can cause erosion of the soil embankment (see Figure 25). If no provisions are made to check this erosion, it can undermine the footing and expose the piles.

IDEAL JOINT

To estimate the damage to bridges in the United States each year due to joint problems is very difficult, but the cost would likely be in the billion dollar range. The funds currently available for maintenance and repair are only a small fraction of the need. Bridge engineers responsible for structures have given high priority to the development of a solution. Many manufacturers and suppliers have new improved products that promise to perform better

Figure 23. Cap damage.



Figure 24. Cap damage.



Figure 25. Embankment erosion.



than last year's model. Although these products have improved considerably, there is in fact no product that will make the opening created by the expansion joint as watertight and durable as the remainder of the deck and at the same time accommodate the required movement.

An approach that several states are taking to reduce the deck joint problem is to eliminate the joints wherever possible. The Federal Highway Administration recommended the following (5):

That bridges with their overall length less than the following values be constructed continuous and, if unrestrained, have integral abutments. Greater values may be used when experience indicates such design satisfactory.

Steel	300 feet
CIP	500 feet
Pre- or post-tensioned concrete ..	600 feet

The longest jointless bridge to date has recently been completed over the Holston River in Tennessee. This structure is more than 2650 ft long with 29 spans and no interior expansion joints. There are roadway expansion joints adjacent to each abutment. The bridge consists of prestressed box beams with precast, prestressed deck slab form panels integrated with a cast-in-place (CIP) deck. The hammerhead pier columns are designed to accommodate the anticipated superstructure movements. This bridge is in keeping with policy of the Tennessee DOT to build continuous bridges with no deck joints unless absolutely necessary. Research is currently being conducted on the performance of the Holston River structure by the University of Tennessee under contract with the Tennessee DOT.

In the future, the ideal joint may turn out to be no joint. Currently, however, there is a need to prevent the damage caused by joints. Many of the newer designs incorporate thinner walled, more structurally efficient bridge members. These members are more vulnerable with less tolerance of deterioration than the former heavier elements. They are often precast, which results in more construction joints, which complicates repairs necessitated when deterioration takes place. The need for emphasis on watertight joint seals that provide maximum protection with minimum maintenance requirements continues to be of prime importance.

Designers of new or rehabilitation bridges should select the types of expansion joint to use that consider all of the available alternatives. The final

selection should satisfactorily answer the following questions:

1. Has it proven to be effective?
2. What are the maintenance requirements, considering the location and climate, and are they realistically given to the controlling agency?
3. What will be the total cost for the life of the deck, considering construction costs as well as operational cost?
4. Does the design permit efficient replacement of the seal?

Past experience has taught that the following things are important in the design of the ideal deck expansion joint:

1. The opening should be adequate to accommodate all movement at the joint;
2. The joint should be accessible for inspection and maintenance;
3. The seal should be continuous and monolithic;
4. There should be minimum area for debris accumulation, and debris expulsion is desirable;
5. The interfacial bond between the seal and deck should not rely solely on adhesive action;
6. The material and anchors should be durable against puncture, mechanical wear (especially snowplows), impact, and corrosion;
7. Attention should be given to anchors to see that they are of sufficient number and size and securely attached to deck reinforcement to ensure the stability of the joint;
8. It should be immune to attack from typical bridge deck chemicals, such as chlorides, sulfuric acid, acid rain, sunlight, soil bacteria, and animal waste;
9. It should remain flexible and structurally sound during high and low temperature extremes;
10. It should function quietly with no loose parts;
11. There should be no edge raveling;
12. It should permit a smooth transition between spans; and
13. It should be waterproof as installed and remain so.

A joint design that could satisfy all of these requirements could be identified as the perfect joint.

SUMMARY AND CONCLUSIONS

The major problem with the deck expansion joint is that it exposes elements of the structure that are otherwise protected by the deck. The opening becomes a conduit by which moisture, deicing salts, abrasives, chemicals, and other debris are deposited on the superstructure and substructure below the opening, thereby causing extensive damage.

In localities where deicing chemicals and abrasives are used, the leaking joints create a faster and more serious deterioration problem on the bridges. Much attention has been given to the effect of deicing chemicals on the deterioration of the deck. New and rehabilitated decks are being constructed with epoxy-coated rebars in the top mat and surface sealing systems. When these same contaminants are permitted to seep through the joints, their adverse effects are just as dramatic on the bridge elements below as they are with the deck. The sand and dirt combined with moisture holds the contaminating chemicals against the elements. Chloride contamination is often greater in this area than on the deck. Attempts have been made to seal the concrete with coatings, such as asphalt, coal-tar epoxy, or clear epoxy, but with limited suc-

cess. Some agencies that use deicing chemicals during the winter months try to clean the seats and bearing areas where possible with a power water spray each spring.

The solution to the problem of protecting the elements below the joint is normally to add a flexible seal in the opening or a drainage trough under the opening. Neither of these solutions has a very good success record. The flexible seals tend to leak. They are damaged by the mechanical wear of the traffic and the noncompressible debris that jam the space above the seal and eventually cause a puncture. The adhesive fails in bonding the seal to the concrete or the surface of the concrete fails adjacent to the adhesive. The seal deteriorates by weathering, and its elastic properties are diminished by many cycles of being stretched and compressed.

Thousands of bridges currently in service have been seriously damaged by joint problems. Repairs are difficult and expensive. The repair dollar buys less than the new construction dollar due to the traffic problems involved, the smaller quantities, the estimating uncertainties, and the fact that much of the work is labor intensive. User costs are significantly increased, since motorists are delayed while the repairs are in progress.

Choosing the best available alternative for the deck expansion joint will continue to be an important consideration in the design, rehabilitation, and maintenance of bridges. Requirements for ensuring long-term service for deck joints in a given situation are a thorough knowledge of the past performance of available products, construction quality control procedures that ensure proper installation, and a responsive maintenance organization with the knowledge and capability to ensure that the joint performs properly.

Past attitudes have often been not to worry about a disintegrating structure unless there were traffic problems, as it would be obsolete or the roadway

alignment would be relocated before the condition became unsafe. With three out of four bridges in the United States more than 45 years old (6, p. 5), replacement obviously cannot solve the problem. The current system of bridges has to be repaired and maintained, which places greater emphasis on resolving the bridge joint problem.

In most areas, the first step has been initiated. The problems are being documented by inspection. Current funding for repairs, however, permits only a feeble attempt to buy time. As funds become available, a consistent policy of systematic rehabilitation and preservation is needed. Rehabilitation will be useless and preservation impossible if funding is not linked with a commitment to maintenance.

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Detecting Deterioration in Asphalt-Covered Bridge Decks

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Information on the condition of bridge decks is required for reasons of safety and to develop a comprehensive program of maintenance, rehabilitation, and replacement. Where the deck has a bituminous surfacing, detecting deterioration in the concrete slab presents serious technical difficulties. In many cases, existing procedures are not adequate to produce reliable information. This paper reports the technical and economic evaluation of the following test techniques: chain drag, sonic reflection, ultrasonic transmission, microseismology, resistivity, electrical potential, radar, and thermography. All of the techniques were investigated under controlled conditions at a full-scale test site. The results were compared with the criteria developed for an ideal test method. Radar and thermography were found to have the most potential for development into routine operational procedures for detecting deterioration in asphalt-covered bridge decks. Also, additional development work needed was identified.

Knowledge of the condition of the bridges within its jurisdiction is essential for a highway agency to ensure a safe and adequate system and to develop a comprehensive program of maintenance, rehabilitation, and replacement. In recent years, bridge decks have been especially prone to rapid deterioration wherever deicing salts are used. Although time

consuming, collecting reliable information on the condition of exposed concrete decks is relatively straightforward (1,2). Determining the condition of asphalt-covered decks presents an entirely different set of problems. Not only can the asphalt hide defects until they are well advanced, but it is often difficult to distinguish between deterioration in the concrete deck slab and debonding of the overlay.

The investigation that is reported here was undertaken to identify those procedures that have the potential to detect deterioration in asphalt-covered bridge decks more accurately than conventional procedures. Although the prime objective of the study was to improve the quality of information supplied by the traditional method of visual inspection supplemented by coring, reducing costs would be an important secondary benefit.

REQUIREMENTS FOR TEST PROCEDURE

The requirements for the ideal test procedure can be defined as follows: