Bridge Joint Systems—A Performance Evaluation

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ABSTRACT

In this paper bridge joints in Minnesota, from open joints to relatively waterproof strip seals and modular sealed expansion joints, are evaluated. Performance evaluations along with special designs that prevent damage from high-speed snowplow operations are included. Maintenance procedures for rehabilitating joints that leak are also discussed.

Many different types of joint systems have been used in bridge construction in Minnesota during the past three decades. The evolution process in the use of these different systems has primarily been guided by the need to devise and use leak-proof, trouble-free, and zero or low maintenance expansion-contraction joints. The objective of this paper is to review this process and to present an evaluation of different types of joint systems based on performance of more than 2,000 bridge joints in Minnesota.

AVAILABLE DATA

Figure 1 shows commonly used bridge joint systems. The data in Table 1 provide information such as advantages and disadvantages, typical problems, and installed costs of these different joint systems. For the purposes of this evaluation, information such as type and age of installation, current condition, special problems, and type of maintenance required was collected for 2,271 bridge joints. The number of each type of joint evaluated, as well as the number and corresponding percentage of joints that were reported to be leaking, are given in Table 2.

DEVELOPMENT AND USE OF DIFFERENT BRIDGE JOINT SYSTEMS

The original expansion and contraction joints in bridge decks merely consisted of sliding plates as shown in types G, F, and L (see Figure 1). These systems were intended only to carry wheel loads across the joint opening in bridge decks, and movement of water and finer materials were allowed to go unimpeded. As debris and corrosion problems became apparent in joints, bearings, and beam seats, elastomeric and other compression joint seals were used in the attempt to seal deck joints (types J and K). Because of their inability to adhere to the adjacent materials, these seals worked out of the joints. Further, dirt and debris built up over these types of compression seals and caused rapid deterioration of the seals.

The next developmental stage was the use of a variety of concrete joint sealers and waterstops (type Q). These waterstops failed to function when bridge decks expanded and contracted; as a result they tore apart. Further, during construction ends of waterstops make concrete placement difficult. However, because of better performance of some waterstop installations, use of joint systems such as types A, B, C, E, and F became more common. Most of these systems were segmental and experienced leakage through joints between segments. The type C system used a continuous neoprene gland and performed satisfactorily. However, in these systems bolting down of the claw was difficult, and in some instances glands came out of the claw quite readily.

An extrusion type claw (type H) was then used, which held the neoprene glad effectively. Ends of these glands were shaped to conform to the inside of the claw. These glands, when kneaded into the extruded claw, generally became secure. Despite debris collection problems, the glands performed satisfactorily and remained in the claws.

PERFORMANCE EVALUATION OF BRIDGE JOINTS

Data available up to and including 1983 were reviewed to determine the degree to which different joint systems performed satisfactorily. The unsatisfactory performance of various joint systems was found to have caused some damage to adjacent bridge components as well. Common problems experienced with expansion joint devices were investigated.

Leakage

Leaking has been by far the most common problem associated with bridge joints in Minnesota. Fifty-five percent of the 2,271 joints investigated exhibited this problem. Leakage was typically at curb lines, through joints between segments, along the edge of seal bordering the deck, or through the interface between gland and claw. Of 496 segmental joint systems investigated, 366 (74 percent) were leaking. Concentrated leakage through joints between segments of segmental devices of types A, B, E, and F was observed. In some instances leakage was observed between the expansion devices and the adjacent end dam material.

As a result the end dam material was observed to break up, thereby exposing the expansion device directly to traffic. Gland or seal types of joint devices in some cases were found to be ruptured and failed because of traffic debris and tearing under traffic loads.

Remedial actions. The use of a continuous device eliminated the problem of leakage between joint segments. Application of sealers at edges and over end dams after installing the device was found to be effective. Partial repair of ruptured glands by patching a new piece of gland material over the damaged area was quite successful (see Figure 2). The procedure used for patching neoprene glands was as follows:

1. Blow out dirt with compressed air and clean the gland area with a solvent such as methyl ketone or toluene.
2. Place a 0.0625-in. neoprene sheet (0.5 in. wider than the gland and length of damaged area plus 6 in. each side is required) down into the valley of the in-place gland. Form it up each side and draw a line 0.25 in. above where the gland goes into the extrusion. Cut the patch along these lines.

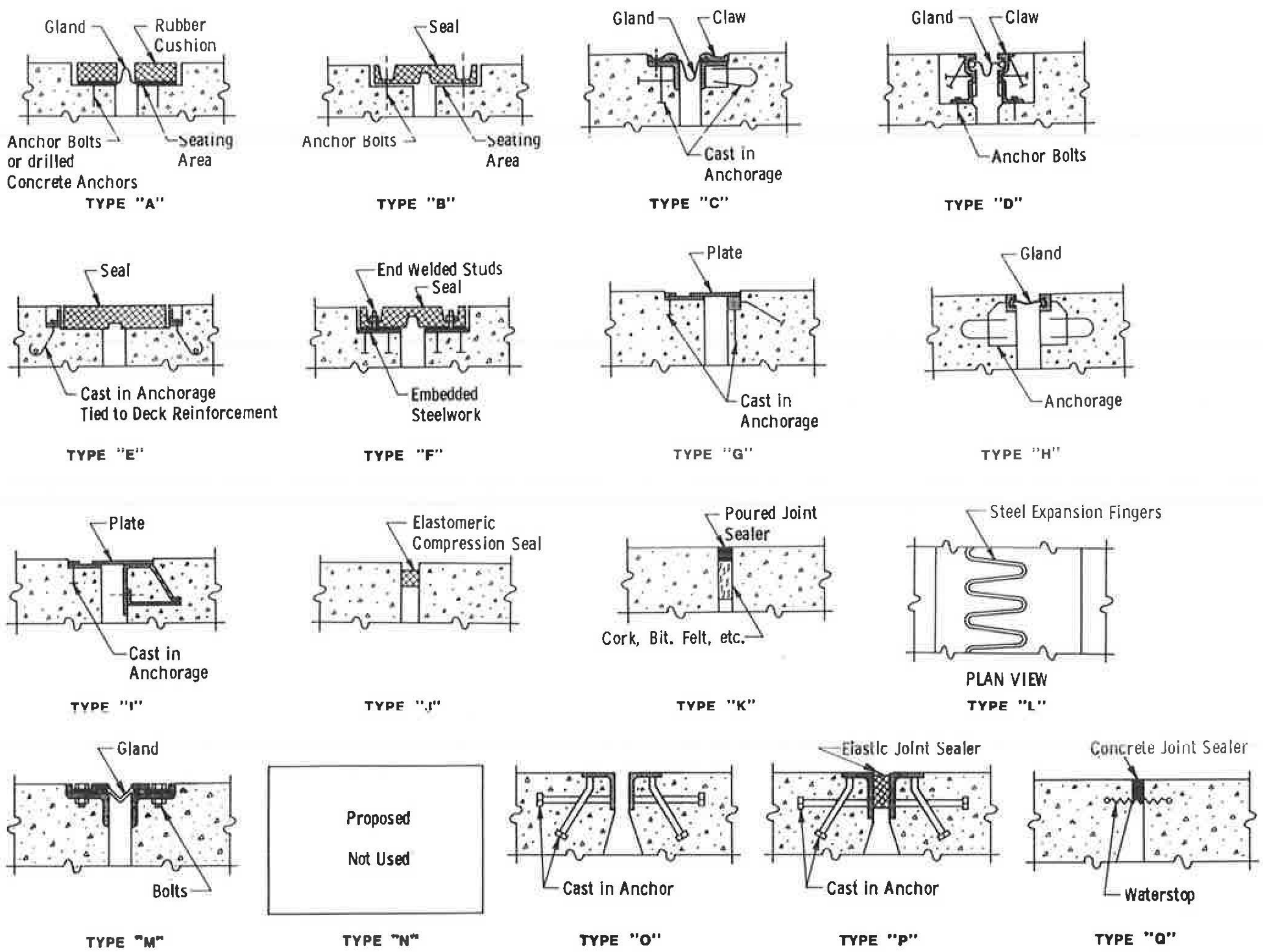

FIGURE 1 Types of expansion devices.

TABLE 1 Data on Types of Expansion Devices Studied

Expansion Device	Period Used From	Advantage	Disadvantage	Type of Problem	Typical Cost[a] ($/linear ft)
A	1975-1977	Easy to install; gland expanded and contracted well	Segmental; hard to recess	Leaked at joints and between rubber and concrete end dam; damaged by snow plows	138.27-151.30
B	1973-1977	Easy to tighten down	Seals above bolts come out	Leaks at joints; dirt fills into bolt holes and causes corrosion	88.12-121.53
C	1976-1980	Gland placement easy	Claw is too short and ineffective	Gland pulls out; hard to tighten down claws	43.50-60.00
D	1978-1981	Armored claw	Complex welding	Anchor bolts pull out	120.00
E	1975-1981	Easy to install	Segmental	Leaked at segment joints	45.50
F	1968-1978	Easy to tighten down	Studs worked loose	Leaked at segment joints	53.57-108.92
G	1965-1975	Simple to install	Leaked below sliding plate; sliding plate forces upward	Sliding plate breaks off	13.24-15.38
H	1977-present	Does not leak	Imported and patented product	Dirt accumulates in gland	85.00-100.00
I	1958-1975	Easy to install	Leaks between sliding plate and adjacent base plate	Sliding plates broken off by traffic and snow plows	25.00-40.00
J	1960-1975	Inexpensive	Seal comes out; leaks	Hard to keep seal in	3.00-5.00
K	1965-1973	Inexpensive	Does not allow compression	Hinders expansion of concrete slab	13.50-16.50
L	1960-present	Good for large expansions and contractions	Bolts in traffic wheel tracks break off and loosen and fall off	Binds up easily from horizontal misalignments	33.26-123.20
M	1958-1967	Easy to install	Joint opening does not stop water	Completely ineffective	60.00-80.00
P	1963-1969	Inexpensive	Compression seal works out of joint leaks	Somewhat ineffective, depends on bond between joint sealer and steel angles	20.00-30.00
Q	1958-1979	Does not leak	Hard to place rubber waterstop in concrete; concrete deteriorates above waterstop	Holds corrosive agents that deteriorate concrete	40.00-70.00

[a]Costs are in place as of time of installation.

TABLE 2 Joints Investigated

	All Joints			Segmental Joints		
Type	No.	No. Leaking	Leaking (%)	No.	No. Leaking	Leaking (%)
A	25	4	16	23	3	13
B	31	14	45	23	14	61
C	73	26	36	15	7	47
D	164	56	34	36	12	33
E	12	9	75	2	0	0
F	12	8	67	12	8	67
G	401	323	81	141	126	89
H	589	46	8	32	3	9
I	121	103	85	33	30	91
J	100	74	74	22	15	68
K	599	467	78	117	112	96
L	43	40	93	9	8	89
M	1	0	0	0	–	–
N	2	0	0	1	0	0
O	32	26	81	5	5	100
P	57	44	77	25	23	92
Q	5	2	40	0	–	–
S	1	0	0	0	–	–
T	3	3	100	0	–	–
Total	2,271	1,245	55	496	366	74

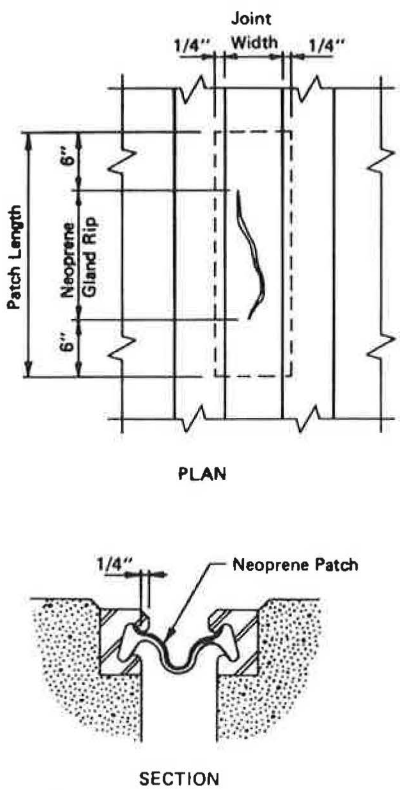

FIGURE 2 Patching neoprene glands.

3. Without puncturing the patch, tuck the extra 0.25 in. of patch on one side into the extrusion groove with a screwdriver or blunt tool.

4. Flip the patch over with a brush, coat the underside of the patch and the in-place gland with "crazy glue" or equal, beginning at the tucked in side. Make sure there are no wrinkles in the patch.

5. Tuck the extra 0.25 in. of patching on the remaining side into the extrusion groove.

6. Coat the exposed ends of the patch liberally with bonlastic adhesive to obtain a water tight patch.

Where ruptured areas were extensive, total gland or seal replacement was found to be desirable.

Corrosion

Uncoated expansion joint devices and those located where chemical debris could accumulate were found to corrode rapidly. Slot covers (mainly in types B, E, and F) were founded sheared off and missing, thereby allowing bolts to corrode and break off. As a result devices lifted up and became subject to severe traffic wear. Corrosion of steel plates used in expansion devices appears to have been accelerated by deleterious entrapments between the plates. Bronze and steel bearing plates corrode quickly and freeze. Such frozen bearings can cause additional stresses in adjacent structural components and shorten their service life.

Remedial actions. To eliminate problems associated with corrosion, it was necessary to remove, clean, straighten, protectively coat, and then replace the expansion device. Where corrosion damage was extensive, replacement of the entire device was considered desirable.

Deterioration

Heavy wheel loads pound improperly placed and exposed plates, angles, seals, and glands to cause rapid disintegration of adjacent materials. Plates and angles bend, warp, and sometimes break off from their anchorages. Types G, I, L, O, and P have been especially prone to this problem.

Remedial actions. Heating of warped plates to restore their original shape and welding back bits and pieces have been of questionable value. Complete replacement of a part or an entire expansion device is preferable.

Restrained Movement

Expansion joints that trap dirt and debris restrain free movement. This can cause disintegration of glands and seals. When seals and glands of types A, B, C, D, K, P, and Q are forced upwards, they are subjected to extreme traffic wear and tear. Restraint on movements at the joint causes spalling and breakup of adjacent materials.

Remedial actions. Movement restraints are located and removed. Partially or completely damaged areas are repaired or replaced. Most of the adverse effects of restrained movements can be prevented with a maintenance program of thorough cleaning, especially each spring.

Settlement and Misalignment

Uneven settlement and vertical misalignment can cause damage to types G, I, L, and Q. The devices warp and break off at their anchorage, thus causing further disintegration of surrounding concrete. Horizontal misalignments cause joint devices such as type L to bind and arrest movement of the bridge deck. As a result, surfaces adjacent to the device are damaged.

Remedial action. When settlement or misalignment results in the joint device failure, it is desirable to replace the device.

Vibrations and Accident Damage

Heavy moving loads cause vibrations that can distress joint devices and fracture joint assemblies. Further, fractured joint assemblies cause damage to adjacent components. Failures of anchorages from inadequate welds, fabrication, or drilled-in anchorages initiate and aggravate vibrational damage. Improperly placed bolts, plates, angles, or seals of expansive devices are easily damaged or sheared off by snowplows, other maintenance equipment, and heavy commercial traffic loads.

Remedial actions. Loose connections and inadequate anchorage generally cause a joint device to vibrate under traffic. In such cases the joint device and anchorage system surrounding the damaged area should be removed and replaced. Joint devices damaged by accidents are either modified in the field to make them secure or are replaced.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are drawn from the evaluation of expansion devices in Minnesota.

1. Joint devices and glands must be continuous and not segmental.
2. Concrete material should be used on either side of the expansion device and the joint should be sealed between the device and the concrete.
3. The expansion joint device should be recessed 0.25 to 0.5 in. below the adjacent concrete.
4. Snowplow guards for glands should be added on expansion devices placed at 20-degree or greater skews. Three-eighths steel bars placed out of wheel tracks will work adequately.
5. Claws of expansion device must hold the device securely. Bolted down claws generally loosen up and allow the gland to easily pull out.
6. Devices must be protected with a coating such as galvanizing.
7. Routine bridge maintenance should include cleaning the gland out and minor repairs to the gland.
8. Cast-in-place plate anchorage systems hold the device securely during construction and in service. Drilled-in anchorages work loose and expose the device and gland to potential damage.

Specification Writing for Bridge Deck Joint Sealing Systems

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ABSTRACT

In this paper a simple way to write specifications for expansion joint systems, so as to obtain an economical system with good performance characteristics, is demonstrated. The purpose of the paper is to bring to the design engineer's attention aspects of contract documents that, if not properly handled, can result in controversy or cost overruns. It is demonstrated that if the specifications clearly describe the desired expansion joint, and if the contract drawings show its characteristics and physical requirements and show how it is to be installed, then the right expansion joint can be obtained at the right price through competitive bidding.

The first breakthrough in the development of a satisfactory sealed expansion joint occurred in the early 1960s through the introduction of the elastomeric compression seal. Since then, many alternative expansion joint systems have been available for sealing expansion joints in bridges.

The proprietary nature of these systems made it difficult, if not impossible, to write a universal, meaningful specification. Also, some of the expansion joint systems were failing within a short period of time after installation.

In the quest for improving the performance of expansion joint systems, the Transportation Research Board funded a project to study criteria for developing specifications. Subsequently, a report was written suggesting various criteria for a performance specification. Initially, "segmented seals, bolted to the bridge deck, subjected to varying degrees of tension and compression" and having a moment range of 2 to 4 in. (1) were addressed in the report.

The basic premise was to test these expansion joints as a system in the laboratory and evaluate the results. The systems would be put through several thousand cycles of various testing procedures, which included flexing, impact loading, skew racking, leakage evaluation, and so forth. If the system did not exhibit signs of deterioration or fatigue due to stress and maintained its watertightness, it would be accepted for use in the project.

However, the described tests are valid only when applied within the context for which the report has been written. The report promoted a performance specification that would test tension-compression type solid elastomeric expansion joint systems, the deficiencies of which are well understood.

On the other hand, when applying these criteria to other types of systems, the specification requirements relegate the tests to a material evalua-