Observations from a Field Study of Expansion Joint Seals in Bridges

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Expansion joint seals in bridges continue to be a problem in that their success rate is far from an acceptable level. In a recent field study in Ohio, a significant percentage of seals were observed to be performing poorly in preventing passage of water and intrusion of debris into the expansion joint. The field study included rating of about 360 seals in eight rating categories based on visual inspection. Twenty-four different types of sealing systems were included, ranging in age from less than 1 month to 15 years or more. The resulting data were subjected to statistical analysis to determine average rating for each type of seal, correlation factors, and so forth. The calculated correlations were much weaker than intuitively expected and in some cases nonexistent. Few of the rated items showed significant correlation to either age or traffic count, which was attributable to several factors. This study by its nature included only those seals that survived long enough to be included. Some groups of seals included products of several different manufacturers. The seals were also operated under varying environmental conditions. Poor workmanship in installation was observed in many cases, causing poor performance at an early age. Several cases of faulty design details were observed. At least 5 percent of the observed seals suffered abuses that would not normally be expected or considered in the design, such as being covered over when the adjacent pavement was overlaid.

Attempts have been made to seal the expansion joints in bridges since 1914 *(1)*. Permitting water and debris to enter the expansion joints is detrimental to the structural components located below the bridge deck.

Special expansion joint seal designs have been patented as early as 1936. Today there are at least 30 different basic types of sealing systems being placed *(2)*, ranging from simple applications of poured-in-place asphalt-based compounds that are inexpensive but short lived and not very effective to rather complex and often expensive configurations composed of metal and elastomeric materials.

Tens of thousands of bridge expansion joint seals are now in place throughout the United States. Of course, all expansion joints in bridges are not sealed. Based on interviews with Ohio Department of Transportation (ODOT) bridge engineers, it is estimated that less than 10 percent of all bridge joints in the state system have been sealed. But it is not common to routinely specify particular sealing systems for new bridge pavements or those being overlaid or restored.

Experience has shown that installing successful expansion joint seals could be routinely accomplished. However, recent field observations suggest that expansion joint seals should not be taken for granted and at times actually obtaining a successful seal may be due cause for celebrating. The problems with expansion joint seals can be quite significant, leading the state of Tennessee, for example, to begin designing jointless bridges *(3)* despite the difficulties introduced in dealing with thermally induced stresses.

There are two main objectives in sealing expansion joints in bridges: to prevent the passage of water through the deck to the bridge components below and to prevent the intrusion of debris into the joint itself, which may render it inoperative. Additionally, there are many secondary but important objectives to be met in specifying, detailing, and installing these seals. The first cost, useful life, ease of maintenance, vulnerability to damage, esthetics, ride quality, and other factors must be considered in selecting a seal for a specific project. Certainly, too, the sealing system design process should include consideration of the specific circumstances of the application such as expected joint movement, skew angle, and traffic count.

The intent of this paper is to share some of the observations of a recent study of bridge expansion joint seals. This study, funded through a contract with ODOT, involved over 360 seals installed in about 120 bridges. Twenty-four different types of seals were observed. A few of the seals were less than 1 month old when inspected and a few had been in place for over 15 years. This set of seals constitutes a reasonably broad cross section of the seals in place in Ohio bridges.

The observations and data summary recounted in this paper may be useful to those concerned with expansion joint seals in bridges located in many geographic regions. A full account of the project, including study procedures and all data on the seals observed, is available in the project report.

SUMMARY OF STUDY PROCEDURES

It is necessary to briefly summarize the procedure used in the study in order to put the following presentation of results and the subsequent discussion in perspective.

The fundamental goals of this project were the following:

- Inspect a large variety of seals in place in a wide variety of circumstances,
- Rate the effectiveness and condition of the seals in several categories,
- Compare the types of seals to correlate seal effectiveness and site conditions, and
- Make observations and draw conclusions useful to future specifications of seals.

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Based on visual inspection, each seal was rated in each of seven categories: general appearance, condition of anchorage, debris accumulation, watertightness, surface damage, noise under traffic, and ease of maintenance. The ease of maintenance category was further divided into ease of cleaning and ease of replacement to make a total of eight categories. In the subsequent discussions, the categories are referred to in similar terms but are renamed to reflect desirable attributes. For example, debris accumulation became debris exclusion.

In each category the seal was rated numerically from 5 to 0, with 5 indicating perfect condition or effectiveness and 0 indicating failure. Detailed definition of the intermediate ratings 1–4 is outside the scope of this paper, but in general 4 indicates satisfactory condition, 3 represents marginal acceptability, 2 indicates unacceptable condition, and 1 indicates severe deficiency. The rating range of 5 to 0 has been used in studies conducted in several other states by other investigators, but it must be noted that the meaning of a particular value, for example, 3 in watertightness, varies from study to study. Moreover, composite ratings have been calculated differently in different studies in that some use an unweighted average of the seven main categories whereas others use a weighted average. Consequently, it is not appropriate to directly compare numerical results among studies conducted in different states.

Also, the rating scheme is prone to include subjectivity. In order to maintain consistency within the present study, the three investigators involved performed practice observations and ratings in the field until consistency was maintained, performed most ratings in teams of two, and occasionally repeated the rating for certain seals by a different team of investigators.

All of the data obtained, including the ratings just discussed and the parameters such as traffic counts, skew angles, and age of the seal were maintained in computer files. This process made it convenient to obtain statistical information using the SPSSx statistical analysis package *(4)*. The statistical analysis included finding the average rating in each category for each type of seal, an overall average for each type of seal, averages with respect to type and age of seal, standard deviations, and so forth. Also, correlation factors were calculated in order to determine how strongly the various items were related. Some of the results of this analysis are presented in the following section.

In addition to gathering data on the seals from site visits and from the plans and other records kept on file in the ODOT district offices, information was gathered from interviewing a bridge engineer in each of the 12 districts in Ohio. The authors take this opportunity to note their appreciation for the cooperation they received from these gentlemen. Many of the bridge engineers accompanied the investigators on inspection visits and were able to provide much valuable background and insights relative to the expansion joint seals.

SUMMARY OF RESULTS

The field study includes neoprene troughs, elastomeric compounds poured into sliding-plate joints, metal-faced joints, foam strips, and others. But three general types of seals together account for about 75 percent of all the seals observed in this study: compression seals (45%), strip seals (8%), and steel-reinforced modular seals (22%). Each of these three types includes the products of several different manufacturers grouped together. Figure 1 shows example illustrations of the seals included in each group. The two profiles shown to represent steel-reinforced modular seals are combined in one group because they both include steel reinforcement and both are typically installed in segments.

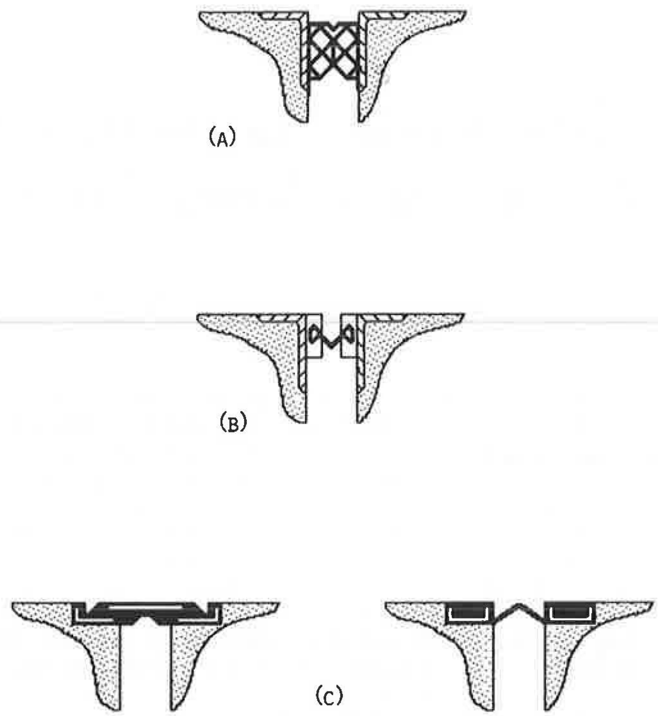

FIGURE 1 General types of bridge expansion joint seals: *(a)* compression seals, *(b)* strip seals, and *(c)* steel-reinforced modular seals.

Table 1 gives the average rating in each category for each general type of seal along with a composite rating average and the average age. In most items, the differences in average rating are small and probably of small significance. However, the differences in watertightness are large enough to be considered significant and seem to give the advantage to the strip seal over both the compression seal and the modular seal. The modular seals, on the other hand, are significantly better with respect to debris accumulation and ease of replacement. Compression seals are also easy to replace and the deck construction at the

TABLE 1 AVERAGE RATING BY GENERAL TYPE OF SEAL

Category	Strip Seals	Compression Seals	Steel-Reinforced Seals
General appearance	3.83	3.71	3.25
Condition of anchorage	3.83	3.96	3.66
Debris accumulation	3.20	3.15	3.76
Watertightness	3.93	3.44	3.11
Surface damage	3.93	3.79	3.35
Noise under traffic	3.93	3.61	3.79
Ease of cleaning	3.63	3.87	3.76
Ease of replacement	3.33	3.77	3.76
Straight average	3.70	3.66	3.56
Age (years)	8.27	6.83	8.73

TABLE 2 CORRELATION FACTORS FOR COMPRESSION SEALS

	TRAF	SKEW	MVT	AGE	ANCH	DEBR	WAT	DAM	SAVG
ANCH	–0.08	–0.02	–0.02	–0.18	1.00	0.37	0.50	0.62	0.81
DEBR	–0.17	–0.44	–0.05	0.09	0.37	1.00	0.33	0.22	0.47
WAT	–0.04	–0.48	–0.05	0.06	0.50	0.33	1.00	0.47	0.69
DAM	–0.11	–0.18	–0.22	–0.13	0.62	0.22	0.47	1.00	0.78
SAVG	–0.19	–0.32	–0.20	–0.07	0.81	0.47	0.69	0.78	1.00

NOTE: TRAF = average daily truck traffic; SKEW = skew angle of expansion joint; MVT = theoretical joint movement; AGE = age of seals in years; ANCH = condition of anchorage; DEBR = debris accumulation; WAT = watertightness; DAM = surface damage; and SAVG = unweighted average of all eight categories.

TABLE 3 CORRELATION FACTORS FOR STEEL-REINFORCED SEALS

	TRAF	SKEW	MVT	AGE	ANCH	DEBR	WAT	DAM	SAVG
ANCH	–0.29	–0.20	0.08	–0.25	1.00	0.12	0.36	0.69	0.74
DEBR	0.34	0.17	0.13	–0.08	0.12	1.00	0.49	0.11	0.46
WAT	0.01	0.00	–0.01	–0.29	0.36	0.49	1.00	0.51	0.81
DAM	–0.32	–0.22	0.03	–0.35	0.69	0.11	0.51	1.00	0.84
SAVG	–0.17	–0.16	0.05	–0.35	0.74	0.46	0.81	0.84	1.00

TABLE 4 CORRELATION FACTORS FOR STRIP SEALS

	TRAF	SKEW	MVT	AGE	ANCH	DEBR	WAT	DAM	SAVG
ANCH	0.25	0.05	0.01	–0.64	1.00	0.31	0.60	0.37	0.76
DEBR	–0.14	–0.01	–0.38	–0.32	0.31	1.00	0.45	0.16	0.64
WAT	0.25	–0.13	0.15	–0.78	0.60	0.45	1.00	0.47	0.76
DAM	0.55	0.23	–0.28	–0.39	0.37	0.16	0.47	1.00	0.71
SAVG	0.38	0.03	–0.28	–0.71	0.76	0.64	0.76	0.71	1.00

edge of the compression seal (the condition of anchorage) is least likely to deteriorate. The straight average, which is simply the average of all eight rating categories with equal weight, differs little between the types.

In an effort to discern which seal types might be more effective in certain circumstances, correlation factors were calculated. Two parameters with a correlation factor equal to 0 are totally unrelated. A correlation factor equal to 1 indicates a perfect relationship; a correlation factor equal to –1 a perfect inverse relationship.

Table 2 gives the correlation factors calculated for compression seals; Table 3, the correlation factors for seal-reinforced modular seals; and Table 4 the factors for strip seals.

In some regards, the results shown are disturbing. Correlations that were expected are in many instances much weaker than expected or virtually nonexistent. For example, Table 2 indicates that for compression seals both watertightness and surface condition are practically unrelated to traffic count (correlation factors of –0.04 and –0.11, respectively) although one might intuitively guess that some significant inverse relationship should exist. Table 3 indicates there is no correlation (0.01) between watertightness and traffic count for steel-reinforced modular seals, but there is some slight inverse correlation (–0.32) between traffic count and surface damage—that is, surface condition degenerates with increased traffic as expected. More disturbingly, Table 4 indicates that watertightness of strip seals slightly increases, in general, with traffic count (0.25) and further that the surface damage rating improves significantly (0.55) with traffic count.

Some calculated correlation factors do conform to expectations. In general, the strip seal watertightness strongly degenerates (–0.78) with age; condition of anchorage is at least moderately correlated to watertightness (0.50, 0.36, and 0.60); and watertightness and debris exclusion are somewhat related for all three types of seal. Nevertheless, overall the correlations appear to fail to substantiate some intuitive expectations.

DISCUSSION AND INTERPRETATION OF RESULTS

It is, for example, highly unlikely that surface condition or watertightness could actually improve with age or higher traffic count. However, in looking closely several factors were revealed that could at least partially explain why intuitive correlations did not manifest themselves in the data collected.

One major factor is that by and large this study included, as it must by its nature, only the surviving expansion joint seals. As previously noted, only a small percentage of all bridge joints are sealed. But once a given expansion joint is sealed, there is at least some effort made to keep it sealed; if a seal fails it is replaced or restored. Thus the only aged seals included in the study are ones that ought to have a decent rating in most categories—they are survivors. Seals that would have shown significant deterioration with age had been replaced. This situation tended to deemphasize correlations between condition and age. Interestingly, strip seals, the seal type judged most difficult of the three to replace, displayed the nearest to the expected condition of correlation with age, tending to confirm this explanation.

Another factor that conceivably influences the data is that there is an observed geographic clumping of seal types. Some seal types are used frequently in some districts and rarely in others. Although Ohio is not one of the largest states in terms of area, its geologic and climatic circumstances differ significantly from corner to corner. Consequently, in some ways, the different types of seals were compared under different service conditions. This variation should be expected to influence the data in an unpredictable manner.

Also each of the three general types of seals for which average data are given actually includes several varieties of seals as produced by different manufacturers. It is possible, indeed likely and expected, that a strip seal produced by one firm will behave better or worse than one produced by another firm. Statistical analysis has been performed to compare the various brands of the seal types but the results are not given here. In several cases only two or three samples of a specific brand were included in the study, an insufficient number to give statistically reliable results; thus to show preference for or against a specific brand would not be justified, especially in view of the other observations made in this paper.

The factors most responsible for the distributing features of the numerical data were related to the following three field observations:

1. The workmanship associated with installing the various seals was obviously poor in 5 to 10 percent of the cases and suspect in many more. Seals were set higher than the deck surface, joints between modular seals were sloppily made, some seals were cut too short, and so forth. This poor workmanship lead to poor performance and therefore low ratings even though the seal system itself was apparently capable of very good performance.

2. In some cases the seals were installed with care just as detailed, but the details themselves were faulty. In a few cases the seals themselves appeared impervious to water but the runoff from the deck was directed to the berm area from which it was permitted to fall directly on the shelf on which the bearings were placed. This water then ran along the shelf and caused considerable deterioration in the bearings and spalling of the headwalls. There were also several other details that lead to similarly undesirable results.

3. In some cases, seals that may have been detailed well and installed with care performed poorly and thus received lower ratings because they had been abused after installation. Some 12 steel-reinforced modular seals in one stretch of pavement were covered over when the adjacent pavement was overlaid. It is difficult to say how much effect this had on watertightness, but it hurt the rating for general appearance significantly.

CONCLUSION

It would be inappropriate to draw hard and fast conclusions directly from the correlation factors shown here because of the points brought up in the foregoing discussion, and because the data are based on grouping the products of many manufacturers.

Despite the nature of some of the statistical data noted, the study has yielded results that should help future attempts at sealing the expansion joints in bridges. Observations on the workmanship and details indicates closer attention must be paid to these factors. Some of the numerical data suggest certain seals should be reconsidered before further use.

This study also suggests that further investigation is desirable and helps to direct future work, in which better general control should be maintained on the specimens observed, as implied by the discussion on the age-versus-performance data. This might be done by permitting certain test seals to deteriorate further before replacement or by maintaining long-term records including replacement data. Long-term records of failed joints in the present study could not be readily retrieved, if they existed at all. Obviously a follow-up study that reexamines the present subject seals periodically over a number of years should be initiated. It is also desirable to study more seals of certain types to gain statistical significance.

Because this study is quite recent, additional work is planned but not yet completed. Scheduled to be completed soon is performance of the statistical analysis described herein on data collected in similar studies conducted in other states.

The most important general observation made during this study is that the condition of the bridge structure located below the deck, including headwalls, bearings, girders, and other structural members, was directly dependent on the watertightness of the expansion joint. Good expansion joint seals save a great deal in terms of deterioration of the structures.

ACKNOWLEDGMENT

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