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Carl F. Stewart

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16. ABSTRACT
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The results show an apparent thermal coefficient of expansion 0.0000065 and 0.0000053 for steel and concrete superstructures respectively. These values were determined by the largest movements recorded for each structure type in each geographical area, except the mountain area. The mountain area data were in variance with data from other areas and was therefore not used. Coefficients based on the average movement are somewhat less, but the higher value is recognized because during the study many examples of restricted joint movement were found, and it is concluded that the average movement would have been higher had all joints had more freedom for movement. A further limitation on the coefficients given is that they represent structures with expansion facilities at their abutments. Values for structures without abutment expansion facilities is somewhat less.

17. KEYWORDS
Expansion joints, annual movement of structures, movements per unit length, thermal coefficient of expansion, movement of structure type, movement measuring scribes

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BUSINESS AND TRANSPORTATION AGENCY
DEPARTMENT OF PUBLIC WORKS
BRIDGE DEPARTMENT
Division of Highways

June 1969

ANNUAL MOVEMENT STUDY of BRIDGE DECK EXPANSION JOINTS

Final Report

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R&D No. 2-69

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ANNUAL MOVEMENT STUDY

of

BRIDGE DECK EXPANSION JOINTS

FINAL REPORT

Report prepared in the Research and Development

Section of the Bridge Department by Carl F. Stewart.

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J. E. McMahon, Assistant State Highway Engineer - Bridges

J. W. Legarra, State Highway Engineer

In Cooperation with

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ABSTRACT: For the purpose of refining bridge deck expansion joint details, the annual movement of approximately 231 expansion joints was recorded each year over a period of three years. The movement was traced by a sharp pointed metal scribe on a target painted on the metal tube of the bridge railing. The recorded movement was reduced by a correction factor, which included allowances for: differences in thermal coefficient of expansion and temperature conductivity between metal rail and concrete structure, span end rotation, incompressible debris in the deck joint, and truck impact. How the value of these corrections was determined is explained. Both the actual and corrected measurements are given.

The results show an apparent thermal coefficient of expansion of 0.0000065 and 0.0000053 for steel and concrete superstructures respectively. These values were determined by the largest movements recorded for each structure type in each geographical area, except the mountain area. The mountain area data were in variance with data from other areas and was therefore not used. Coefficients based on the average movement are somewhat less, but the higher

value is recognized because during the study many examples of restricted joint movement were found, and it is concluded that the average movement would have been higher had all joints had more freedom for movement. A further limitation on the coefficients given is that they represent structures with expansion facilities at their abutments. Values for structures without abutment expansion facilities is somewhat less.

A phase of the study was to determine the effect of shrinkage and temperature during and subsequent to the construction curing period on the movement capacity of expansion joints. The report outlines why this phase was not completed, and recommends the subject be studied by future research.

KEY WORDS: Expansion joints, annual movement of structures, movement per unit length, thermal coefficient of expansion, movement of structure type, movement measuring scribes.

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ANNUAL MOVEMENT STUDY

OF

BRIDGE DECK EXPANSION JOINTS

June 1969

INTRODUCTION

Bridge deck expansion joints are troublesome to maintain. Some of the maintenance problems are caused by malfunctioning expansion devices, concrete spalls along the edge of joint, water flowing through the joint, or impaction of debris in the joint. Most of the problems would be eliminated by proper design and construction of the joint together with an effective joint sealant. A completely effective joint sealant has not yet been found, although research is being actively performed on this subject. Furthermore, although not strictly a maintenance problem, the roughness and noise usually experienced at expansion joints is disconcerting to motorists.

For the purpose of minimizing joint maintenance and increasing motorists' comfort, it is good design practice to reduce the number of joints in structures to the absolute minimum required. A reduction in the number of joints, however, introduces another problem. The lesser number of joints must each be wider to compensate for the greater overall movement required. Wide joints and large movements amplify joint problems. Hence, not only should the number of joints be reduced to the minimum required, but also the width of joints should be accurately determined for the type of structure, geometric configuration and environmental conditions at each unique location.

It has been suspected that the time of year, or more accurately, the ambient temperatures during and just after construction, along with concrete shrinkage, greatly influence the movement capacity of a given width joint. For instance, consider two joints in identical structures having the same construction widths, with one constructed during the colder part of winter and the other during the hotter part of summer. The one constructed during the winter would require a greater closing capacity because the temperature change would be a seasonal increase, thus causing structure expansion. In a similar manner, the summer constructed joint would require a greater opening capacity as the temperature declined with the approach of winter. Since closing capacity is apparently the controlling factor of joint movement, the constructed width of joint would be more critical when built in the winter than in the summer.

OBJECTIVE

The objective of this study is to refine our current design specification that affect expansion joint details.

STUDY PROCEDURE

For the purpose of gathering additional joint movement data to be applied to better engineered expansion joints, the total annual movement of approximately 231 expansion joints (80 structures) in various climatic environments was recorded over a three year period. To determine the influence of weather at time of construction on joint width requirements, ten structures were selected for study.

The initial intent was to record the movement of at least 3 each of steel, reinforced concrete (including box, "T" and slab) and prestressed superstructures in desert, mountain, valley and coast environments. After the study was underway, it was found there were not enough structures of each type in each environment to satisfy the initial intent. For instance, in the high mountain environment there were no box girder or slab structures with expansion joints. Hence, it was decided to select as many of each superstructure type as available in each environment, or select a number which would provide a good average when several were available.

Method of Measuring

Joint movement was recorded on the aluminum tube portion of the barrier rail by a sharp pointed metal scribe. ne scribe was fixed to the rail on one side of the joint - traced a mark on a painted target on the other side as the joint moved. The spring steel scribe dimensions are given in Figure 1 and it is shown mounted to the rail in Figure 2.

The target was painted with a mixture of non-flaking vinyl wash primer and lampblack.

The scribe mark was measured with a 0.01 inch graduated scale and a 10X magnifying glass.

To determine the effect of seasonal construction on joint width requirements, copper nails, each with a thin saw-slot in its head, were imbedded in the deck as the concrete was placed on each side of the joint. The original distance between the slotted heads was recorded at time of placement of the second nail. After the railing was constructed, a regular marking scribe was mounted on it. Through a comparison of original distance, the distance at time of measurement, and expansion and contraction tracings of the marking scribe, the movement history of the joint was determined.

<u>Correction Factors</u>

Movement in an aluminum rail joint at a bridge deck expansion joint is not the same as the movement in the deck joint. Factors which cause the movement differ- are: different thermal coefficients of expansion and te- perature conductivity of metal rail and concrete deck, incompressible debris in the deck joint, and end rotat caused by span deflection.

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Since aluminum has a thermal coefficient of expansion twice that of concrete, the approximately 9-foot clear span of rail tubing at the joint has a greater length change than a corresponding section of deck for a given temperature change. For example, an 80° temperature differential causes a theoretical movement difference of 0.05".

Being a thin and more exposed element than the deck, the tube railing reacts faster to a temperature change than the deck. This faster reaction causes a greater movement in the rail when peak temperatures are of short duration. This movement difference is impossible to calculate precisely, but since it only occurs when peak temperatures are of short duration, it probably has no significant effect on total annual movement.

Differences caused by end rotations can be calculated accurately, if actual span deflections are known. The actual deflections of the structures studied were not measured; therefore, the end rotation effects were not calculated, but as described later, were compensated for empirically along with truck impact.

Any obstructions or imperfections in the deck joint, such as incompressible debris or non-parallel joint faces, restrict deck joint movement. The joint of the approximately 9' metal rail tube, without similar restrictions, moves freely.

Most of these factors which cause movement differences between the metal tube and concrete parapet at an expansion joint were considered before the study began. It was decided, however, that the ease and economy of obtaining joint movement data by the scribe method was so attractive that the method would be used, with a correction factor, which was suspected to be small, applied to the final results. To determine what this correction factor should be, an additional scribe was placed across the concrete portion of the barrier rail at 30 deck joints. (Figure 3.) A comparison of scribe marks on the metal and concrete portion of the rail in various environments show the aluminum rail to have an average total annual movement greater than the concrete by the following amounts: coast, 0.02 inches; valley, 0.04 inches; desert, 0.06 inches. Comparisons were not made in the mountain area. A correction factor of 0.04 inches was deducted from the mountain readings because the collected data indicated that the greatest difference in movement occurred during high temperature cycles and it was assumed, therefore, that the mountain area would be less affected in this respect than the desert. So, the more moderate valley correction factor was chosen for the mountain area.

The correction factors as measured in the various environments were slightly less than what the <u>theoretical</u>

difference in movement between the metal rail and concrete structure would be due to annual temperature differentials.

Structures used to measure the correction factor were affected very little by truck impact. Therefore, in addition to the correction factor discussed, another correction factor was applied to some readings to compensate for longitudinal movement and end rotation caused by heavy truck traffic. Longitudinal movement of structures from truck impact varies according to the type of soil supporting the structure, column rigidity, type of bearings, type of superstructure, and freedom of joints. End rotation varies according to the type of superstructure. Under some combinations, joint movement from truck traffic is so small it is not measurable by a scribe and can be ignored in an expansion joint study. There are combinations, however, where the movement is significant and needs to be considered, especially if the truck crosses the structure when the joint is already at its extreme position due either to maximum high or low temperatures.

During this study, the impact movement, a combination of longitudinal movement and end rotation, caused by trucks was either measured or estimated for each joint. Measurements were made by holding a scribe across the joint as a heavy truck crossed the structure. After some experience was gained in actually measuring impact movement, it was easy to estimate it. Most often the scribe mark indentation into the aluminum rail by the measuring scribe during the year was a positive indication of impact movement. If traffic did cause appreciable movement, the scribe dug deeply into the rail. If the movement was very small, the scribe would barely scratch the aluminum. Most often the impact movement was much less than 0.01 inch and no correction was made. The maximum impact movement measured was 0.05 inch.

The impact movement correction factor applied was one-half the measured or assumed value. The more realistic value of one-half was used because of the improbability that a heavy truck would pass over the structure when it was in both the maximum expanded and contracted state, a combination which would be necessary before an additive correction would be required to both extremes of movement.

The maximum combined correction factor applied to a single joint was 0.08 inch: the sum of 0.06 for temperature related corrections and 0.02 for truck impact movement. (Total impact movement corrections for each structure are shown in the "Comments" column of Figure 6.)

Temperature Determination

Temperatures used to calculate the assumed coefficient of expansion were obtained from local Government gage stations. Generally, a station was sufficiently close to each structure so that interpolation was not required. However, interpolation between stations was required for a couple of structures. The differences in temperature range between the two stations were usually small. Hence, the error from this method was small.

Average temperature range over the three year period for each environment was: coast, 61°; valley, 81°; mountain, 87°; and desert, 91°.

RESULTS

Each year's scribe measurement for each joint is shown in Figure 5. Besides showing the movement occurring in typical expansion joints and the relative consistency obtained during the study, the measurements given in Figure 5 also show joint movement irregularities which have heretofore been suspected but never measured. Often there have been approximately equally spaced expansion joints in long structures which did not appear to move the same amounts even though the resistance to movement by the substructure between the joints appeared to be the same. The same movement difference appeared to occur on shorter structures with symmetrically placed joints and on parallel structures with identical joint layouts. There are numerous examples in the Figure 5 data which show this non-uniform movement does occur.

Yearly movements shown for Bridge 22-45L are good examples of unequal movements in equally spaced joints. This bridge crosses a causeway on equal height, trestle type pile bents, with all deck joints 160 feet apart; hence, each joint should move the same. Yet, Joint 2 moved approximately 55% less each year than Joint 1. Joint 8 moved approximately 22% less than Joint 1. All joints, however, were consistent in their individual movement patterns.

No attempt will be made to list the many conditions which cause unequal expansion movement. Most instances of irregular joint movements arise from construction and maintenance factors which are unpredictable and, therefore, uncontrollable with our present technology. Of more importance is to be aware of the fact that unequal movement can and often does occur so that a safety factor can be designed into the joints to handle these greater than theoretical movements.

In addition to a general recapitulation of the data, Figure 6 gives movement per unit length; apparent thermal coefficient of expansion; and an elevation line diagram, with locations of the expansion joints, for each structure studied.

Figures 7 through 11 group the data into various combinations for ease of comparison. Note that the data are subdivided into two groups under each category as to whether expansion is provided at the abutments. (California builds a large percent of its structures with what is commonly called "diaphragm type" abutments. This type of abutment is usually a two-foot wide concrete diaphragm, monolithic with the girders, extending below the structure approximately five feet and supported on a single row of piles or spread footing.)

A review of the data shows that the influence of expansion joints at abutments on the total movement of all expansion joints is so great that it has to be considered when comparing the effect of other variables on joint movement. Figure 7 shows this effect very graphically. The percent increase of movement capability of structures with expansion joints at the abutments over that of structures with no expansion joints at the abutments ranges from 31 percent in the valley area to 58 percent in the desert area. The high value for the desert area probably is not realistic since only two structures without expansion joints at the abutments were included in the desert study. However, the overall comparison shows without question that expansion joints at the abutments on moderate length structures with few expansion joints significantly increases total joint movement.

Whenever possible, comparison of variables is made only on structures with expansion joints at the abutments. Comparisons are also usually made on the basis of average joint movement per unit length of structure. The purpose of using unit length instead of some other criteria, such as apparent coefficient of expansion, is because California presently uses the unit length criteria in designing for thermal movement of highway structures.

Comparison of movement per unit length for concrete structures in the various climatic environments, Figure 7, shows the following three year averages: Coast, 0.00027; Valley, 0.00034; Desert, 0.00041; Mountain, 0.00046. Averages for steel structures, Figure 8, are: Coast, 0.00041; Valley, 0.00042; Desert, 0.00048; Mountain, 0.00060.

The mountain area data are in variance with those of other areas with respect to movement-temperature relationship. The mountain area has a much higher ratio of movement to temperature. No reason has been found for this variance, but from the excessively high apparent thermal coefficient of expansion for steel girders in the mountain area it is possible that temperatures at the sites were markedly greater than at the nearest recording stations.

Figure 9 is a comparison of design criteria and study data. In this figure both the average and high movement per unit length value of steel and concrete superstructure types in each area is given along with the apparent coefficient of expansion. A comparison of the "high" movement with the "design" value for concrete superstructures shows a deficiency in the design requirements. In each area there was at least one structure which moved greater than the design value, even though the actual temperature range experienced in each area was much less than that shown in the design manual as the expected range. The average apparent thermal coefficient of expansion, excluding the mountain area, for concrete superstructures is 0.0000053; for steel superstructures the coefficient is 0.0000065. The thermal coefficient was determined for each area by using the highest movement and the temperature range at the site of the structure on which it occurred, rather than the average temperature range of the area as given in Figure 9.

Figure 10 shows reinforced concrete box girder structures to average less movement than other concrete structures. This is as expected due to the insulating features of the trapped air volume inside box structures. There is little difference in movement between the other types of concrete structures.

A comparison of the effect of expansion bearing type on movement, Figure 11, shows no significant difference between them. Similarly, no significant difference in movement is caused by joint skew, Figure 12: The movement decreased as the skew increased on structures without expansion joints at the abutments, but it increased with increasing skews on structures with abutment expansion joints.

The phase of study which was directed towards determining the effect of shrinkage and time of year constructed on the width of joint was unsuccessful. Resident Engineers on several jobs were asked to insert reference nails as the concrete decks were placed and to make the initial measurements. At a later date a researcher was to mount marking scribes and conduct the study. Several reasons precluded finishing the study at all but one structure: In some instances the nails were put into drilled holes several weeks after the concrete was placed and most of the shrinkage had taken place; some of the original measurements were lost; the reference nails were covered with slurry seal or AC pavement; some nails were bent over or broken off by blade equipment cleaning the deck; some were lost in concrete spalls along the joint. As a result, this phase of the study was abandoned.

DISCUSSION

This study gives total annual movement of expansion joints. How this movement is to be coordinated with joint width at time of construction, so as to obtain total relationship of initial joint width and expected movement, was not determined during the study. This information is needed to completely fulfill the objective of the study. Joint movement data being collected on another ongoing study in Research and Development, "Expansion Joint Sealant Study," will be valuable in completing the total movement picture. The monthly movement and its relationship to the yearly movement is being measured under this study.

The scribes were very effective in tracing joint movement on the rail in all areas but the mountains. Their ineffectiveness in the mountain area was due to sand particles being forced under and lifting them as snow and sand were blown from the structures by snowplows. Protective hoods, Figure 4, were placed over the scribes after the first year, but they were only partially effective as sand continued to be lodged under a large number of scribes. The majority of incomplete readings were caused by the lodged sand problem. This problem could not have contributed to the apparent large movement in the mountain area, but it did cause the mountain data to be much less complete than the data from other areas.

Four other reasons accounted for the remaining incomplete readings in all the areas: (1) vandalism, about 6 scribes; (2) paint was too hard for the scribe to scratch it; (3) traffic damage; and (4) structures were included after the study began.

During the third year of the study, holes were drilled through the expansion joint in the deck overhang portion of three structures. The joints had become filled with silty debris which appeared to restrict joint movement. The holes were to provide drainage for flushing this debris. Each of these joints did show an increase in movement after the holes were drilled. Movement in the joint of two of the structures increased approximately 33 percent.

From the spalls found in the gutter area of the deck and concrete railing of several structures and from the tightly squeezed expansion joint paper often found, all of which are indicative of excessive joint pressure, it must be concluded that with more freedom, a large number of joints would have moved a greater amount than they did.

CONCLUSIONS

1. If the widely used premise that 0.0000065 is the thermal coefficient of expansion for steel girder superstructures is accepted, then it must be concluded that 0.0000053 is the thermal coefficient of expansion for concrete girder superstructures. This conclusion is based on the fact that the average apparent thermal coefficient of expansion of structures with the greatest movement in each environment was 0.0000065 for steel and 0.0000053 for concrete. An additional fact is that had there been greater freedom, most joints would have moved more than they did and there would have been more structures approaching the coefficient values derived from those with the maximum movement.

2. Structures with regular expansion facilities at the abutments will have a higher average movement per unit length than will those with no abutment expansion facilities. The larger the number of expansion joints in a structure the less significant is abutment expansion.

3. Box girder structures move less during thermal changes than do other concrete structures.

4. Type of expansion bearing has no significant effect on joint movement caused by thermal changes.

5. Steel girder structures are normally affected to a much greater degree by truck impact movement than are concrete girder structures.

6. Joint skew has no discernible effect on longitudinal movement. The joint does tend to slide along the skew during a closing cycle.

7. Uniformally spaced expansion joints on long structures do not necessarily move the same.

RECOMMENDATIONS

1. Increase the Movement/Unit Length criteria for design of thermal expansion movement for all concrete structures shown in the table under Article 2-18, "Thermal Forces," of Bridge Planning and Design Manual, Vol. 1, to those shown below:

Air Temperature Range	Concrete
Extreme: 120° F Certain Mountain and desert locations	Rise & Fall 60° F Movement/Unit Length .00032
Moderate: 100° F Interior valleys and most mountain locations	Rise & Fall 50° F Movement/Unit Length .00026
Mild: 80° F Coastal Areas, Los Angeles, and San Francisco Bay Area	Rise & Fall 40° F Movement/Unit Length .00021

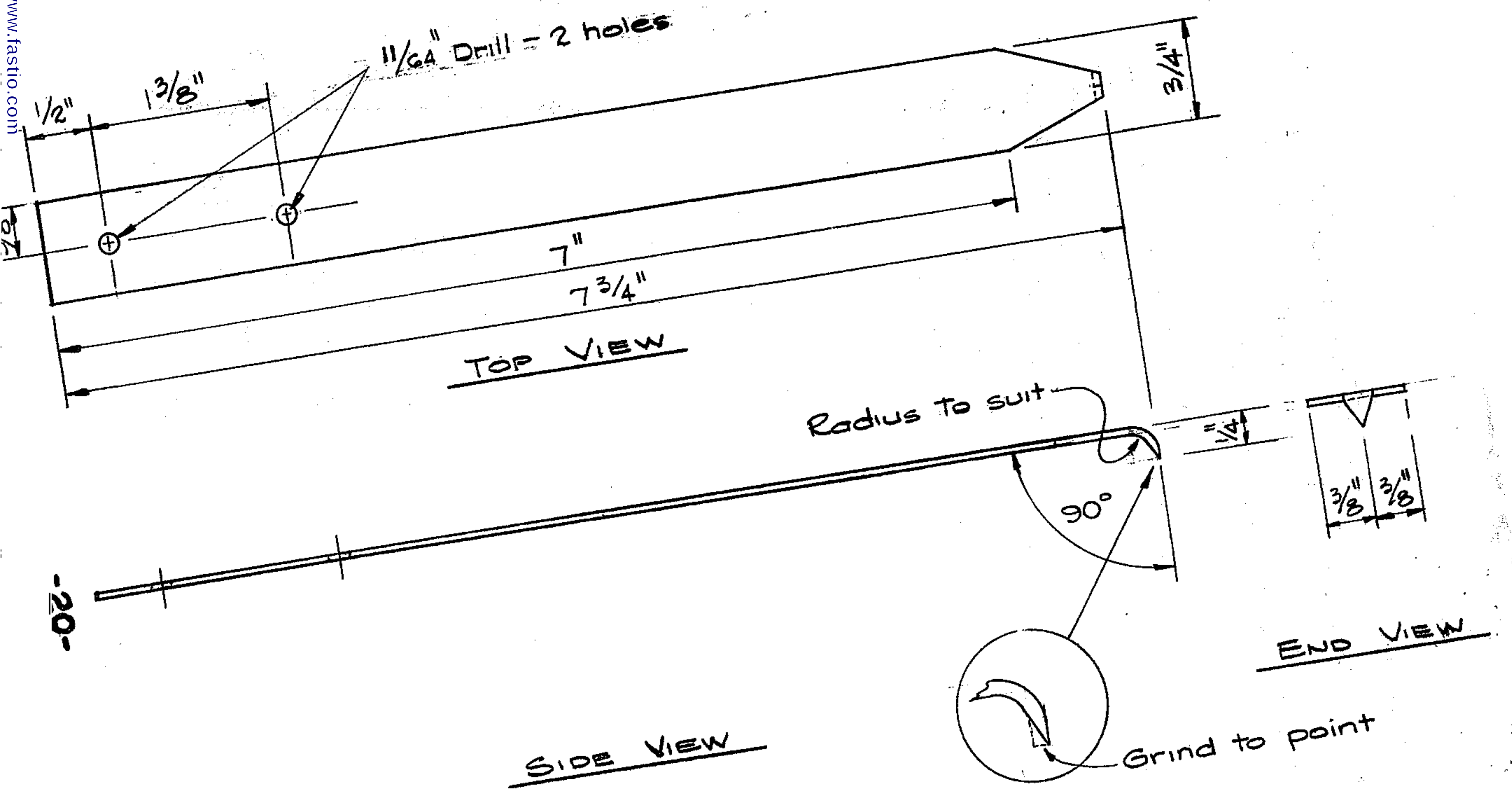
The movement criteria given for steel, based on a coefficient of expansion of 0.0000065, should not be changed.

2. In designing expansion joint movement for structures with one or two expansion joints and diaphragm type abutments, reduce the total length of structure

used in calculating total movement by 25% of the length between abutments and adjacent joints.

RECOMMENDED FUTURE RESEARCH

What effect the daily average temperature at time of construction and subsequent concrete shrinkage has on the movement capacity of expansion joints should be determined. Results from such a study could refine the expansion joint size requirements with an attendant improvement in joint sealant effectiveness.



Material: Spring Steel, 24 gauge × 3/4" × 8"

F... ING SCRIBE FOR EXPANSION JOINT MOVEMENT STUDY
full scale
Figure 1

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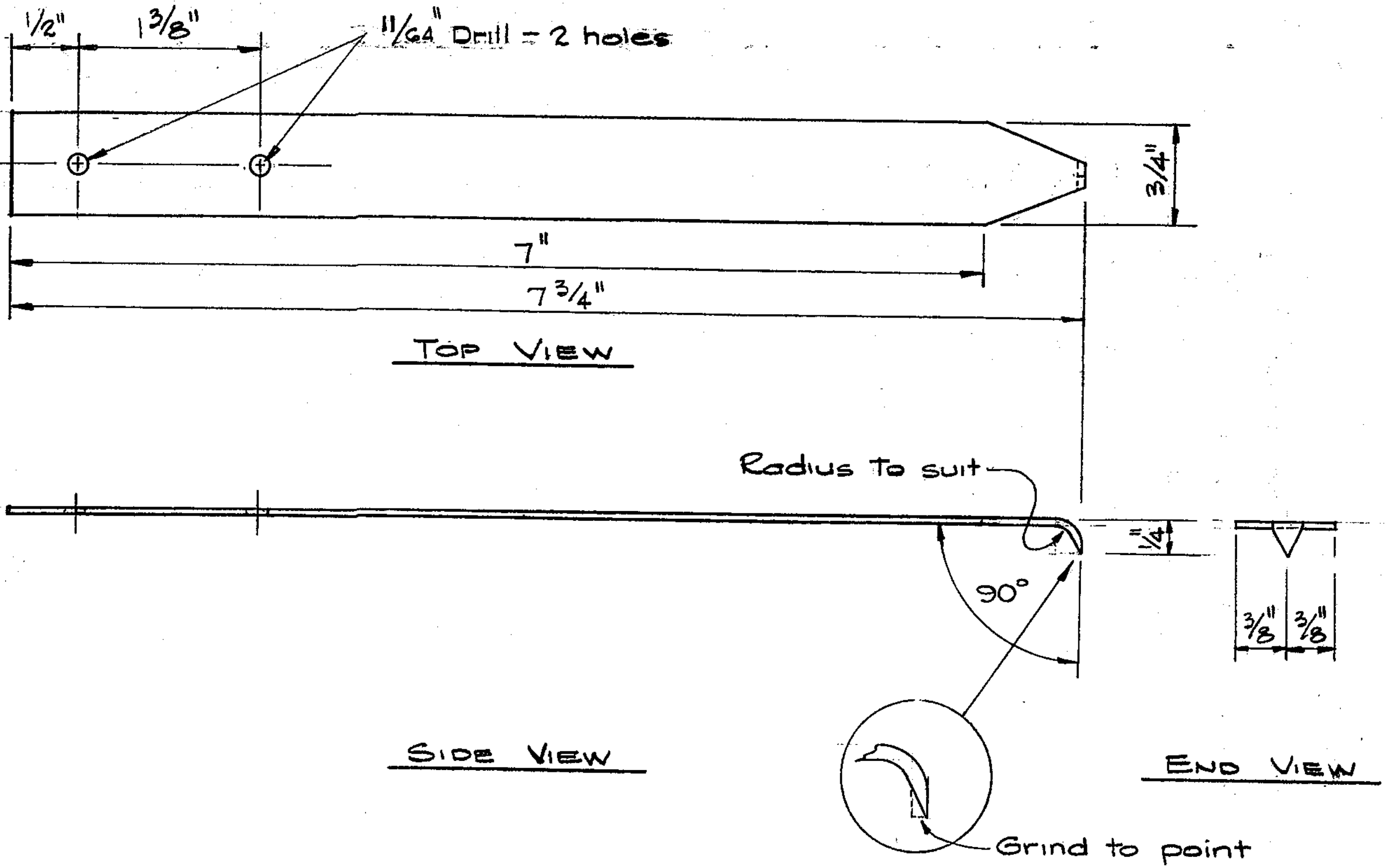
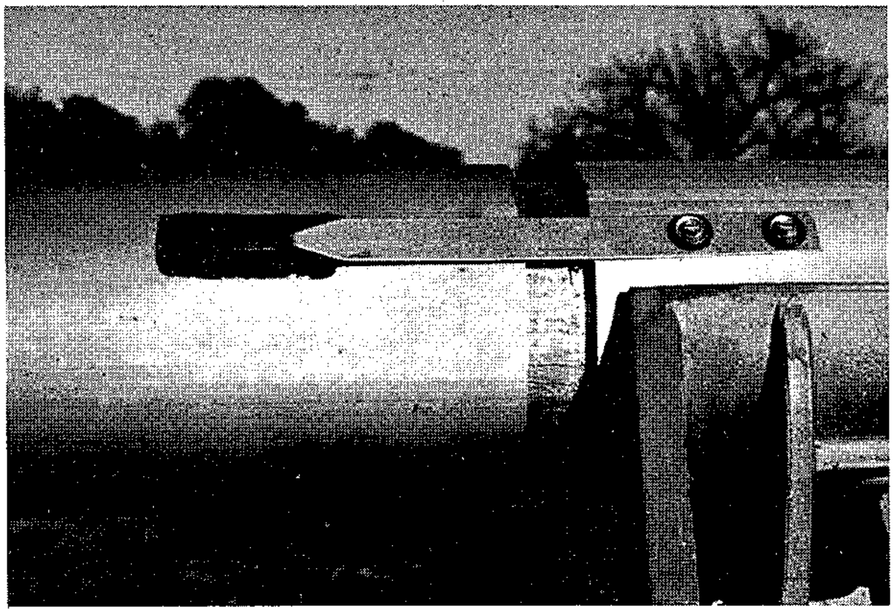


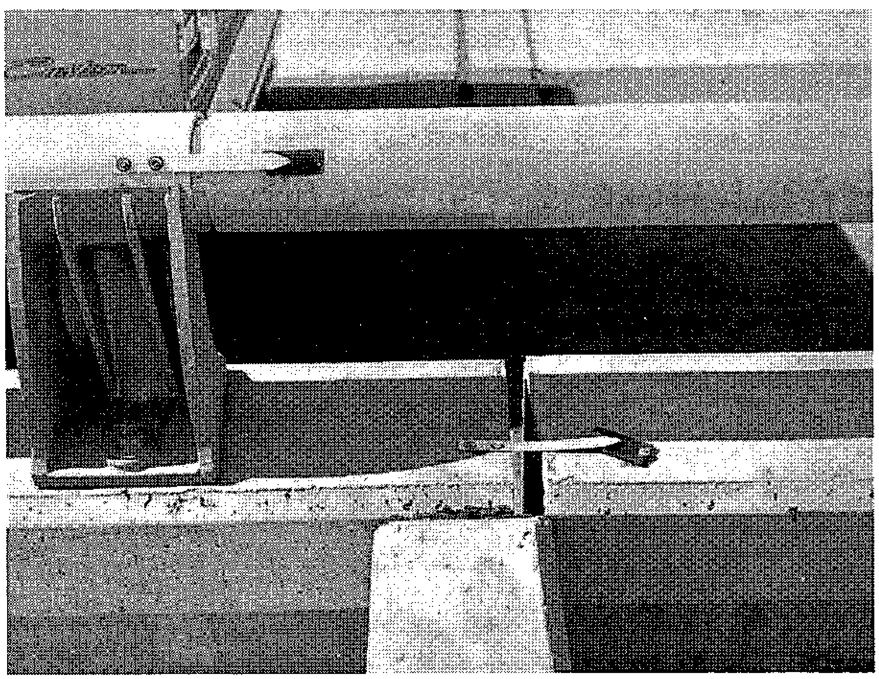
Material: Spring Steel, 24 gauge × 3/4" × 8"

Railing Scribe for Expansion Joint Movement Study
full scale
Figure 1



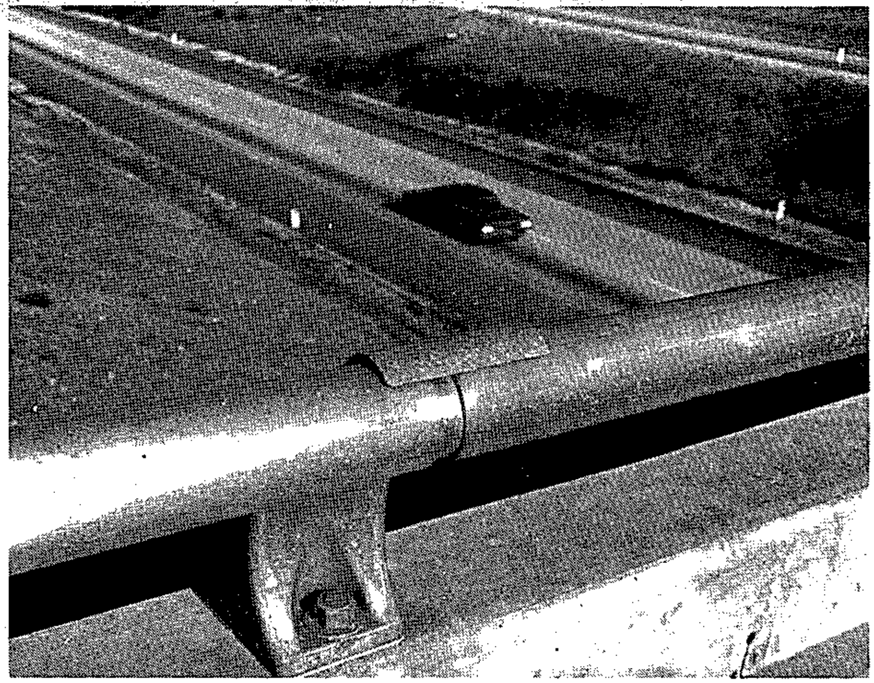
Marking scribe mounted on the railing.

Figure 2



Determining correction factor with scribes mounted on both the metal and concrete portion of railing.

Figure 3



Protective hood for scribes in high mountain areas.

Figure 4

EXPANSION JOINT MOVEMENT STUDY

Bridge No.	Bridge Type						Scribe Measurement																		
	Steel	RC		PS		Slab	Joint No.															Total		
		Box	"T"	Box	"I"		1			2			3			4			5					
							'66	'67	'68	'66	'67	'68	'66	'67	'68	'66	'67	'68	'66	'67	'68	'66	'67	'68
17-23R	X						1.04	1.14	1.36	.68	–	.73	1.30	1.36	1.61	.74	.72	–				3.76	–	–
17-23L	X						.88	–	1.26	.93	–	.98	–	1.70	2.00							–	–	4.24
17-70			X				.72	.81	.76	.86	.88	1.02										1.58	1.69	1.78
17-74			X				.85	.85	.75	.69	.70	.75										1.54	1.55	1.50
17-76L	X						–	–	.66	.54	.42	.42	.83	.85	.91							–	–	1.99
19-119L			X				.72	.70	.80	1.14	–	1.11										1.86	–	1.91
19-120L	X						.85	.82	.80	1.14	–	.80	.50	.51	.60							2.49	–	2.20
19-121R	X						1.00	–	–	1.07	–	1.27	.44	.44	.45	.65	.64	.52				3.16	–	–
19-124L			X				.82	.80	.86	.59	.55	.61										1.41	1.35	1.47
22-45L					X		.91	.92	.90	.41	.41	.48	.76	.73	.82	.82	.83	.82	.80	.79	.75			
								6			7			8										
"							.87	.91	.98	.83	.82	.74	.71	.71	.67							6.11	6.12	6.16

Figure 5

EXPANSION JOINT MOVEMENT STUDY

Bridge No.	Bridge Type						Scribe Measurement																	
							Joint No.															Total		
	Steel	RC		PS		Slab	1			2			3			4			5					
		Box	"T"	Box	"I"		'66	'67	'68	'66	'67	'68	'66	'67	'68	'66	'67	'68	'66	'67	'68	'66	'67	'68
23-104		X					1.28	1.33	1.40													1.28	1.33	1.40
23-144		X					—	.84	.98													—	.84	.98
23-148					X		.94	.92	.97													.94	.92	.97
23-149					X		1.21	1.26	1.07	.94	.91	1.03										2.15	2.17	2.10
23-151	X						.62	.61	.68	.76	.82	.88	.67	.73	.73							2.05	2.16	2.29
23-159	X						.53	.59	.56	.83	.88	.90	.62	.67	.69							1.98	2.14	2.15
24-188L		X					1.46	1.39	1.35	1.57	1.38	1.44	1.20	1.13	.96	1.61	1.52	1.55	1.13	1.13	1.17			
"								6			7			8										
							1.29	1.20	1.16	1.24	1.16	1.05	1.05	1.04	1.02							10.55	9.95	9.70
33-280L		X					.32	.23	.20	.74	.70	.75	.76	.87	.87	.69	.62	.62	.81	.89	.85			
"								6																
							.30	.27	.22													3.62	3.58	3.51
37-80					X		.71	.72	.80	.78	.75	.72										1.49	1.47	1.52

Figure 5 (Cont.)

EXPANSION JOINT MOVEMENT STUDY

Bridge No.	Bridge Type						Scribe Measurement																		
	Steel	RC		PS		Slab	Joint No.															Total		
		Box	"T"	Box	"I"		1			2			3			4			5					
							'66	'67	'68	'66	'67	'68	'66	'67	'68	'66	'67	'68	'66	'67	'68	'66	'67	'68
37-178					X		.53	.46	.56	.62	.58	.52										1.15	1.04	1.08
37-191		X					.72	.71	.73	.82	.82	.77										1.54	1.51	1.50
37-193	X						.79	.78	.73	.93	.95	.87	.52	.55	.55	.75	.72	.74	.50	.50	.56			
"								6			7			8			9			10				
							.69	.67	.71	.95	.95	.96	1.11	1.03	1.05	.37	.38	.43	.53	.50	.46	7.14	7.03	7.06
37-194R		X					.52	.53	.54	–	.62	.58										–	1.15	1.12
37-194L		X					.50	.52	.48	.54	.59	.60										1.04	1.11	1.08
38-78R		X						Outside		Rail			①	Inside		Rail		②		outside		–	2.01	2.17
							1.31	1.10	1.12	–	.91	1.05	–	1.18	1.16	–	1.06	1.06		Inside		–	2.24	2.22
38-78L		X					1.00	.93	1.00	.95	.92	1.00										1.95	1.85	2.00
39-34						X	1.51	1.42	1.50													1.51	1.42	1.50
24-04		X					–	.67	.64	–	.63	.58	–	3.85	4.07	–	3.77	4.22	–	.78	.92			
"								6																
							–	.66	.54													–	10.36	10.97

Figure 5 (Cont.)

EXPANSION JOINT MOVEMENT STUDY

Bridge No.	Bridge Type						Scribe Measurement																		
	Steel	RC		PS		Slab	Joint No.															Total		
							1			2			3			4			5					
		Box	"T"	Box	"I"		'66	'67	'68	'66	'67	'68	'66	'67	'68	'66	'67	'68	'66	'67	'68	'66	'67	'68
39-132R			X				.86	.86	.87													.86	.86	.87
39-132L			X				.68	.73	.86													.68	.73	.86
39-145R			X				1.15	1.02	1.00	.85	.83	.86										2.00	1.85	1.86
39-145L			X				.85	.81	.89	.81	-	.78										1.66	–	1.67
39-164R	X						–	1.06	1.11													–	1.06	1.11
39-164L	X						–	1.10	1.13													–	1.10	1.13
39-169		X					–	.92	.96	–	.58	.70										–	1.50	1.66
41-11L			X				1.54	1.47	1.43	1.02	.93	.90										2.56	2.40	2.33
42-216		X					.96	.91	.85	.85	.92	1.03	1.06	1.00	1.05							2.87	2.83	2.93
53-1166R			X				.60	.65	.61	.68	.65	–										1.28	1.30	–
53-1166L			X				.95	.90	–	.42	.41	–										1.37	1.31	–

Figure 5 (Cont.)

EXPANSION JOINT MOVEMENT STUDY

Bridge No.	Bridge Type						Scribe Measurement																	
							Joint No.															Total		
	Steel	RC		PS		Slab	1			2			3			4			5					
		Box	"T"	Box	"I"		'66	'67	'68	'66	'67	'68	'66	'67	'68	'66	'67	'68	'66	'67	'68	'66	'67	'68
53-1188			X				.23	.22	–	.26	.25	–										.49	.47*	–
53-1209(OR)	X						.17	.15	.15	.51	.42	.37	.54	.46	.45	.56	.44	.54	.51	.47	.50			
								6			7			8			9							
11							.46	.35	.42	.49	.36	.43	.56	.51	.53	.10	.14	.12				3.90	3.30*	3.51
53-1211		X					.78	.71	.75													.78	.71*	.75
53-1213(OL)					X		.40	.37	–	.40	.28	–										.80	.65*	–
53-1393R	X						.36	.32	.43	.61	.50	.73	.61	.46	.63	.52	.39	.45	.51	.39	.40	2.61	2.06*	2.64
53-1397R		X					.45	.50	.43	.70	.65	.73	.82	.73	.75	.46	.36	.35				2.43	2.24*	2.26
53-1560		X					.60	.45	–													.60	.45*	–
54-278R						X	1.19	1.29	1.28													1.19	1.29	1.28
54-278L						X	1.28	1.43	1.41													1.28	1.43	1.41
54-292L			X				–	.55	.56	.89	1.03	1.03	.83	.82	.81	.78	.84	.86				–	3.24	3.26

* Represents Less than One year of movement

EXPANSION JOINT MOVEMENT STUDY

Bridge No.	Bridge Type						Scribe Measurement																	
							Joint No.															Total		
	Steel	RC		PS		Slab	1			2			3			4			5					
		Box	"T"	Box	"I"		'66	'67	'68	'66	'67	'68	'66	'67	'68	'66	'67	'68	'66	'67	'68	'66	'67	'68
54-398	X						.46	.49	.44	.30	.33	.30	.36	.41	.40	.46	.48	.47				1.68	1.71	1.61
54-531					X		.72	.57	.67													.72	.57	.67
54-548 R			X				.71	.80	.78	.87	1.02	.89	1.02	1.15	1.05	.94	1.06	.98	.95	1.07	1.03	4.49	5.10	4.73
54-548L			X				.76	.83	.82	.94	1.07	.98	1.11	1.27	1.28	1.00	1.15	1.19	.99	1.06	.99	4.80	5.38	5.26
54-549R			X				.57	.64	.58	.44	.49	.44										1.01	1.13	1.02
54-549L			X				.53	.58	.55	.47	.51	.48										1.00	1.09	1.03
54-554L		X					.76	.85	.83	.54	.60	.60										1.30	1.45	1.43
54-556		X					.89	1.00	.93	.72	.85	.83										1.61	1.85	1.76
54-557		X					.65	.75	.70	.58	.70	.68										1.23	1.45	1.38
54-559					X		.39	.40	.37	.32	.33	.28										.71	.73	.65
54-592		X					.66	.67	*.85													[illegible]	.67	*.85

* Joint widened in curb area. Hence more space for closing movement.

Figure 5 (Cont.)

EXPANSION JOINT MOVEMENT STUDY

Bridge No.	Bridge Type: Steel	Bridge Type: RC Box	Bridge Type: RC "T"	Bridge Type: PS Box	Bridge Type: PS "I"	Bridge Type: Slab	Scribe Measurement, Joint No. 1 '66	Joint 1 '67	Joint 1 '68	Joint 2 '66	Joint 2 '67	Joint 2 '68	Joint 3 '66	Joint 3 '67	Joint 3 '68	Joint 4 '66	Joint 4 '67	Joint 4 '68	Joint 5 '66	Joint 5 '67	Joint 5 '68	Total '66	Total '67	Total '68
54-570L		X					.67	.58	*.85													.67	.58	*.85
54-510R		X					.86	.97	*1.08													.86	.97	*1.08
54-609	X						.50	.54	.53	.52	.57	.54	.37	.39	.37	.34	.38	.40	.57	.61	.60	2.30	2.49	2.44
54-611	X						.28	.33	.33	.34	.37	.36	.35	.39	.41	.47	.52	.50				1.44	1.61	1.60
54-665	X						.16	.20	.20	.53	.59	.59	.63	.70	.67	.56	.63	.54	.31	.38	.36	2.19	2.50	2.36
55-331R				X			.24	.12	–	1.41	1.20	–										1.65	**1.32	–
55-333L				X			.63	.55	–	–	.71	–										–	**1.26	–
55-413		X					– / –	– / –	.75 / .53	–	–	.33	–	–	.89	–	–	1.16	–	–	.72	–	–	4.38
56-450L		X					.57	.63	.68	.46	.58	.60	.52	.58	.61							1.55	1.79	1.89
56-452L		X					.66	.83	–	.76	.76	.80										1.42	1.59	–
56-474E	X						.47	.49	.51	.52	.47	.56	.62	.50	.64	.39	.42	.43				2.00	1.90	2.14

* Joint widened in curb area. Hence, more space for closing movement.

** Less than one year of movement

Figure 5 (Cont.)

EXPANSION JOINT MOVEMENT STUDY

Bridge No.	Bridge Type: Steel	RC Box	RC "T"	PS Box	PS "I"	Slab	Scribe Measurement, Joint No. 1 '66	1 '67	1 '68	2 '66	2 '67	2 '68	3 '66	3 '67	3 '68	4 '66	4 '67	4 '68	5 '66	5 '67	5 '68	Total '66	Total '67	Total '68
56-480					X		.82	.90	.99													.82	.90	.99
56-481					X		1.00	1.07	1.15													1.00	1.07	1.15
56-482					X		.91	1.02	1.12													.91	1.02	1.12
56-496					X		–	.91	.98													–	.91	.98
50-240	X						–	–	.97	–	–	.80										–	–	1.77
50-291	X						–	–	.74	–	–	.61										–	–	1.35
23-64					X		– / –	– / 6 –	2.22 / .55	–	–	1.51	–	–	3.60	–	–	2.74	–	–	1.65	–	–	12.27
24-248R		X					–	–	1.43	–	–	1.56	–	–	1.43	–	–	1.37	–	–	1.46	X	X	X
"							–	6 –	1.53	–	7 –	1.62	–	8 –	1.43							–	–	11.83
24-248L		X					–	–	1.37	–	–	1.25	–	–	1.43	–	–	1.50	–	–	1.37	X	X	X
"							–	6 –	1.43	–	7 –	1.53	–	8 –	1.09							–	–	10.97

Figure 5 (Cont.)

LEGEND

Type:	RCT	- Reinforced concrete "T" girder
	RC Slab	- Reinforced concrete slab span
	RCB	- Reinforced concrete box girder
	PSI	- Prestressed "I" girder
	PSM	- Prestressed "M" girder
	PSB	- Prestressed box girder
	S	- Steel girder
Bearings:	B	- 6" high by 4" wide steel bar with machined top and bottom of either 8" or 9" radius.
	EP	- Elastomeric bearing pads
	SP	- Steel plates with 1/16" asbestos sheet packing in between.
	R	- Rocker, 10" or higher
Environment:	M	- Mountain
	D	- Desert
	V	- Valley
	C	- Coast
Adjusted Movement:		Total movement less an adjusted thermal coefficient correction of 0.02", 0.04", 0.04" and 0.06" for each joint reading in the coastal, valley and mountainous and desert areas respectively; and longitudinal truck movement whenever applicable

Figure 6a

Structure elevation: E - Expansion

X - Hinge

TTT - Supports

Ave. M/UL - Average movement per unit length times 10^{-5}.

Comments: TM - One half the summation of the estimated maximum longitudinal and end rotation movement in each joint caused by truck impact.

Figure 6a (Cont'd.)

EXPANSION JOINT MOVEMENT STUDY

Bridge No.	Type	Bearings	Environment	Length - ft	Year	Total Movement-in	Adjusted Movement-ft	Movement/ Unit Length	Temperature Delta	Coeff. Expansion (x10-7)	Structure Elevation	Comments
17-70	RC T	B	M	258	66	1.58	.125	.00048	89	54	Ave. M/UL = 52	
					67	1.69	.134	.00052	89	58		
					68	1.78	.142	.00055	82	67		
17-74	RC T	B	M	316	66	1.54	.122	.00039	89	43	Ave. M/UL = 38	29° Skew
					67	1.55	.123	.00039	89	43		
					68	1.50	.118	.00037	82	46		
19-119L	RC T	B	M	309	66	1.86	.148	.00048	89	54	Ave. M/UL = 48	50° Skew TM=0.01
					67	-	-	-	-	-		
					68	1.91	.151	.00049	82	60		
19-124L	RC T	B	M	248	66	1.41	.111	.00045	89	50	Ave. M/UL = 45	
					67	1.35	.106	.00043	89	48		
					68	1.47	.116	.00047	82	57		
54-548R	RC T	B EP	D	1001	66	4.49	.355	.00035	92	39	Ave. M/UL = 38	Abut side wall. Cracked in a manner which implies excessive pressure against the back wall. TM=0.05"
					67	5.10	.406	.00041	94	43		
					68	4.73	.375	.00037	88	43		
54-548L	RC T	B EP	D	1001	66	4.80	.381	.00038	92	41	Ave. M/UL = 41	Incipient Spall in top of rail at joint 5 TM=0.05"
					67	5.38	.429	.00043	94	46		
					68	5.26	.419	.00042	88	48		

Figure 6

EXPANSION JOINT MOVEMENT STUDY

Bridge No.	Type	Bearings	Environment	Length - ft	Year	Total Movement-in	Adjusted Movement-ft	Movement/ Unit Length	Temperature Delta	Coeff. Expansion (x10-7)	Structure Elevation	Comments
54-549R	RC T	B	D	156	66	1.01	.073	.00047	92	51	E — E Ave. M/UL = 49	8° Skew TM=0.01"
					67	1.13	.083	.00053	94	57		
					68	1.02	.074	.00047	88	54		
54-549L	RC T	B	D	156	66	1.00	.072	.00046	92	51	E — E Ave. M/UL = 48	8° Skew TM=0.01"
					67	1.09	.080	.00051	94	55		
					68	1.03	.075	.00048	88	55		
54-278R	RC Slab	SP	D	400	66	1.19	.094	.00024	91	26	Ave M/UL = 25	Joint is on a 45° skew. Deck is off-set 1" at the joint.
					67	1.29	.102	.00026	94	28		
					68	1.28	.101	.00025	93	27		
54-278L	RC Slab	SP	D	400	66	1.28	.101	.00025	91	28	Ave. M/UL = 27	Joint is on a 45° skew. Deck is off-set 1/2" at the joint.
					67	1.43	.114	.00029	94	30		
					68	1.41	.112	.00028	93	30		
54-559	PS I	B	D	156	66	0.71	.049	.00031	92	34	E — E Ave. M/UL = 31	22° Skew
					67	0.73	.051	.00033	94	35		
					68	0.65	.044	.00028	90	31		
54-554L	RC Box	B	D	282	66	1.30	.099	.00035	92	38	E — E Ave. M/UL = 38	50° Skew
					67	1.45	.111	.00039	94	42		
					68	1.43	.109	.00039	88	44		

Figure 6 (Cont.)

EXPANSION JOINT MOVEMENT STUDY

Bridge No.	Type	Bearings	Environment	Length - ft	Year	Total Movement-in	Adjusted Movement-ft	Movement/ Unit Length	Temperature Delta	Coeff. Expansion (x10-7)	Structure Elevation	Comments
54-556	RC Box	B	D	339	66	1.61	.124	.00036	92	40	Ave. M/UL = 40	Small spall in top of rail at joint 2.
					67	1.85	.144	.00043	94	45		
					68	1.76	.136	.00040	88	46		
54-557	RC Box	B	D	254	66	1.23	.092	.00036	92	40	Ave. M/UL = 40	
					67	1.45	.111	.00044	94	46		
					68	1.38	.105	.00041	88	47		
39-132R	RC T	SP	V	270	66	0.86	.068	.00025	83	30	Ave. M/UL = 25	50° skew
					67	0.86	.068	.00025	81	31		
					68	0.87	.069	.00026	82	31		
39-132L	RC T	SP	V	270	66	0.68	.053	.00020	83	24	Ave. M/UL = 30	50° skew
					67	0.73	.058	.00021	81	26		
					68	0.86	.068	.00025	82	31		
39-145R	RC T	SP	V	558	66	2.00	.158	.00028	82	34	Ave. M/UL = 27	TM=0.02"
					67	1.85	.147	.00026	80	33		
					68	1.86	.148	.00026	79	33		
39-145L	RC T	SP	V	558	66	1.66	.132	.00024	82	29	Ave. M/UL = 24	TM=0
					67	-	-	-	-	-		
					68	1.67	.132	.00024	79	30		

Figure 6 (Cont.)

EXPANSION JOINT MOVEMENT STUDY

Bridge No.	Type	Bearings	Environment	Length - ft	Year	Total Movement-in	Adjusted Movement-ft	Movement/ Unit Length	Temperature Delta	Coeff. Expansion ($x10^{-7}$)	Structure Elevation	Comments
41-11L	RC T	SP	V	503	66	2.56	.207	.00041	83	49	Ave. M/UL = 38	Joints on 45° skew. Deck off-set 7/8"@ jt.1 & 1/4"@ jt. 2.
					67	2.40	.193	.00038	81	47		
					68	2.33	.187	.00037	84	44		
54-292L	RC T	SP	V	812	66	-	-	-	-	-	Ave. M/UL = 32	25° Skew
					67	3.24	.257	.00032	79	40		
					68	3.26	.258	.00032	75	42		
39-34	RC Slab	SP	V	405	66	1.51	.122	.00030	83	36	Ave. M/UL = 29	16° skew
					67	1.42	.115	.00028	81	35		
					68	1.50	.122	.00030	84	36		
22-45L	PS m	EP	V	1360	66	6.11	.480	.00035	83	43	Ave. M/UL = 36	
					67	6.12	.482	.00036	80	44		
					68	6.16	.486	.00036	84	43		
23-148	PS I	EP	V	266	66	0.94	.075	.00028	83	34	Ave. M/UL = 28	21° skew
					67	0.92	.073	.00028	81	34		
					68	0.97	.077	.00029	85	34		
23-149	PS I	EP	V	399	66	2.15	.172	.00043	83	52	Ave. M/UL = 43	45° skew
					67	2.17	.174	.00044	81	54		
					68	2.10	.168	.00042	85	50		

Figure 6 (Cont.)

EXPANSION JOINT MOVEMENT STUDY

Bridge No.	Type	Bearings	Environment	Length - ft	Year	Total Movement-in	Adjusted Movement-ft	Movement/ Unit Length	Temperature Delta	Coeff. Expansion (x10-7)	Structure Elevation	Comments
54-531	PS I	EP	V	237	66	0.72	.057	.00024	78	31	E E Ave. M/UL = 22	Joint filled with sand & other debris.
					67	0.57	.044	.00019	79	24		
					68	0.67	.052	.00022	75	30		
56-480	PS I	EP	V	247	66	0.82	.065	.00026	78	34	E E Ave. M/UL = 29	24° Skew
					67	0.90	.072	.00029	79	37		
					68	0.99	.079	.00032	78	41		
56-481	PS I	EP	V	271	66	1.00	.080	.00030	78	38	E E Ave. M/UL = 32	Small spalls along top of joint. Joint filled with debris. 30° Skew
					67	1.07	.085	.00031	79	40		
					68	1.15	.092	.00034	78	44		
56-482	PS I	EP	V	240	66	0.91	.072	.00030	78	39	E E Ave. M/UL = 34	Exp. jt m'tl squeezed from deck joint. 18° Skew
					67	1.02	.082	.00034	79	43		
					68	1.12	.090	.00038	78	48		
56-496	PS I	EP	V	223	66	-	-	-	-	-	E E Ave. M/UL = 33	5° Skew
					67	0.91	.073	.00032	79	41		
					68	0.98	.078	.00035	78	44		
23-104	RC Box	SP	V	454	66	1.28	.103	.00023	83	27	X Ave. M/UL = 24	45° Skew
					67	1.33	.107	.00024	81	29		
					68	1.40	.113	.00025	78	32		

Figure 6 (Cont.)

EXPANSION JOINT MOVEMENT STUDY

Bridge No.	Type	Bearings	Environment	Length - ft	Year	Total Movement-in	Adjusted Movement-ft	Movement/ Unit Length	Temperature Delta	Coeff. Expansion (x10-7)	Structure Elevation	Comments
23-144	RC Box	SP	V	382	66	-	-	-	-	-	Ave. M/UL = 18	48° Skew
					67	0.84	.067	.00017	81	22		
					68	0.98	.078	.00020	85	24		
24-188L	RC Box	EP	V	2403	66	10.55	.855	.00035	83	42	E; Ave. M/UL = 33	Deck spalls at 5 of the 8 joints in 1968.
					67	9.95	.800	.00033	79	42		
					68	9.70	.780	.00032	82	39		
38-78R	RC Box	SP	V	702	66	-	-	-	-	-	Ave. M/UL = 23	Spall in deck overhang at N'ly jt. 7° skew TM = 0.05"
					67	2.01	.156	.00022	80	28		
					68	2.17	.170	.00024	80	30		
38-78L	RC Box	SP	V	702	66	1.95	.152	.00022	82	26	Ave. M/UL = 21	Deep scribe groove at end of jt. closing cycle - jt 1 - indicates closing restriction. 7° skew TM = 0.05"
					67	1.85	.144	.00020	80	26		
					68	2.00	.155	.00022	80	28		
39-169	RC Box	EP	V	448	66	-	-	-	-	-	E, E; Ave. M/UL = 28	Binding between side of super-structure & W.W. appears to be restricting movement.
					67	1.50	.118	.00026	81	33		
					68	1.66	.132	.00029	84	35		
42-216	RC Box	B SP	V	661	66	2.87	.229	.00035	83	42	E, E; Ave. M/UL = 34	46° skew
					67	2.83	.226	.00034	82	42		
					68	2.93	.234	.00035	84	42		

Figure 6 (Cont.)

EXPANSION JOINT MOVEMENT STUDY

Bridge No.	Type	Bearings	Environment	Length - ft	Year	Total Movement-in	Adjusted Movement-ft	Movement/ Unit Length	Temperature Delta	Coeff. Expansion (x10-7)	Structure Elevation	Comments
54-592	RC Box	SP	V	363	66	0.66	.052	.00014	73	20	Ave. M/UL = 16	Pressure in jt. relieved in 1968 by drilling 4"ø cores through deck overhang. 36° skew
					67	0.67	.052	.00014	79	18		
					68	0.85	.067	.00019	75	25		
54-570R	RC Box	SP	V	373	66	0.86	.068	.00018	73	25	Ave. M/UL = 21	Do. 50° skew
					67	0.97	.078	.00021	79	26		
					68	1.08	.087	.00023	75	31		
54-570L	RC Box	SP	V	373	66	0.67	.052	.00014	73	19	Ave. M/UL = 15	Do. Less opening in joint of left bridge for closing cycle than in right bridge.
					67	0.58	.045	.00012	79	15		
					68	0.85	.068	.00018	75	24		
56-450L	RC Box	B SP	V	383	66	1.55	.119	.00031	78	40	E, E Closed Abut. Ave M/UL = 35	Abut. 1 on 20° skew. Joint offset 3/4".
					67	1.79	.139	.00036	79	46		
					68	1.89	.148	.00039	78	49		
56-452L	RC Box	B	V	370	66	1.42	.112	.00030	78	39	E, E Ave. M/UL = 32	Top of curb at S'ly jt. badly spalled; jt offset 1 1/2". 52° skew
					67	1.59	.126	.00034	79	43		
					68	–	–	–	–	–		
23-64	PS I	R And Self Lub Pad	C	3276	66	–	–	–	–	–	E E E E E E Ave M/UL = 31	
					67	–	–	–	–	–		
					68	12.27	1.009	.00031	70	44		

Figure 6 (Cont.)

EXPANSION JOINT MOVEMENT STUDY

Bridge No.	Type	Bearings	Environment	Length - ft	Year	Total Movement-in	Adjusted Movement-ft	Movement/ Unit Length	Temperature Delta	Coeff. Expansion (x10-7)	Structure Elevation	Comments
37-80	PS I	SP	C	422	66	1.49	.121	.00029	69	41	Ave. M/UL = 28	29° Skew
					67	1.47	.119	.00028	67	42		
					68	1.52	.124	.00029	71	41		
37-178	PS I	EP	C	323	66	1.15	.092	.00029	69	42	E E Ave. M/UL = 27	57° Skew
					67	1.04	.083	.00026	67	38		
					68	1.08	.087	.00027	71	37		
53-1213 OL	PS I	B	C	311	66	0.80	.063	.00020	64	32	E E Ave. M/UL = 20	Incipient spall in gutter of 5¼ joint. 20° skew. 1967 reading for less than a complete seasonal cycle
					67	0.65	.051	.00016	63	26		
					68	—	—	—	—	—		
37-191	RC Box	B	C	330	66	1.54	.125	.00038	69	55	E E Ave. M/UL = 37	
					67	1.51	.122	.00037	67	55		
					68	1.50	.121	.00037	71	52		
37-194R	RC Box	B	C	249	66	—	—	—	—	—	closed Abut. E E closed Abut Ave. M/UL = 36	
					67	1.15	.092	.00037	67	55		
					68	1.12	.090	.00036	71	51		
37-194L	RC Box	B	C	249	66	1.04	.083	.00034	69	49	closed Abut. E E closed Abut. Ave. M/UL = 35	
					67	1.11	.089	.00036	67	54		
					68	1.08	.087	.00035	71	49		

Figure 6 (Cont.)

EXPANSION JOINT MOVEMENT STUDY

Bridge No.	Type	Bearings	Environment	Length - ft	Year	Total Movement-in	Adjusted Movement-ft	Movement/ Unit Length	Temperature Delta	Coeff. Expansion (x10-7)	Structure Elevation	Comments
33-280L	RC Box	B SP	C	1067	66	3.62	.284	.00027	60	44	Ave. M/UL = 26	
					67	3.58	.288	.00027	56	48		
					68	3.51	.282	.00026	61	43		
53-1211	RC Box	SP	C	423	66	0.78	.063	.00015	64	23	Ave. M/UL = 14	'67 reading for less than a complete seasonal cycle 47° Skew
					67	0.71	.058	.00014	63	22		
					68	0.75	.061	.00014	69	21		
53-1397R	RC Box	B SP	C	644	66	2.43	.196	.00030	64	48	Ave. M/UL = 29	Do. 0° skew
					67	2.24	.180	.00028	58	48		
					68	2.26	.182	.00028	62	45		
53-1560	RC Box	SP	C	498	66	0.60	.048	.00010	64	15	Ave. M/UL = 8	'67 reading for less than a complete seasonal cycle. Railing spalled at joint.
					67	0.45	.036	.00007	55	13		
					68	0.46	.037	.00007	57	13		
55-333L	RC Box	B	C	455	66	-	-	-	-	-	Ave. M/UL = 22	'67 reading for less than a complete seasonal cycle. 52° skew
					67	1.26	.101	.00022	63	35		
					68	-	-	-	-	-		
55-413	RC Box	B SP	C	1796	66	-	-	-	-	-	Ave. M/UL = 20	
					67	-	-	-	-	-		
					68	4.38	.355	.00020	69	29		

Figure 6 (Cont.)

EXPANSION JOINT MOVEMENT STUDY

Bridge No.	Type	Bearings	Environment	Length - ft	Year	Total Movement-in	Adjusted Movement-ft	Movement/ Unit Length	Temperature Delta	Coeff. Expansion (x10-7)	Structure Elevation	Comments
55-331R	PS Box	R SP	C	568	66	1.65	.134	.00024	64	37	Ave. M/UL = 24	'67 reading for less than a complete seasonal cycle 63° skew
					67	1.32	.107	.00019	63	30		
					68	-	-	-	-	-		
53-1166R	RC T	B	C	428	66	1.28	.104	.00024	64	38	Ave. M/UL = 24	Do. 58° skew
					67	1.30	.105	.00025	63	39		
					68	-	-	-	-	-		
53-1166L	RC T	B	C	428	66	1.37	.111	.00026	64	41	Ave. M/UL = 25	Joint material being squeezed out of northerly joint. Do. 58° skew
					67	1.31	.106	.00025	63	39		
					68	-	-	-	-	-		
53-1188	RC T	EP	C	215	66	0.49	.038	.00017	64	27	Ave. M/UL = 17	Rt. Curb @ jt. 2 badly crushed. Do. 41° skew
					67	0.47	.036	.00017	63	27		
					68	-	-	-	-	-		
17-23R	S	R	M	450	66	3.76	.290	.00065	89	73	Ave. M/UL = 65	TM=0.12"
					67	-	-	-	-	-		
					68	-	-	-	-	-		
17-23L	S	R And Strap Hinge	M	515	66	-	-	-	-	-	Ave. M/UL = 65	TM=0.12"
					67	-	-	-	-	-		
					68	4.24	.333	.00065	82	79		

Figure 6 (Cont.)

EXPANSION JOINT MOVEMENT STUDY

Bridge No.	Type	Bearings	Environment	Length - ft	Year	Total Movement-in	Adjusted Movement-ft	Movement/ Unit Length	Temperature Delta	Coeff. Expansion (x10-7)	Structure Elevation	Comments
17-76L	S	B	M	273	66	-	-	-	-	-	Ave. M/UL = 55	22° Skew TM=0.08"
					67	-	-	-	-	-		
					68	1.99	.149	.00055	82	67		
19-120L	S	R	M	326	66	2.49	.193	.00059	89	66	Ave. M/UL = 56	TM=0.05"
					67	-	-	-	-	-		
					68	2.20	.169	.00052	82	63		
19-121R	S	R	M	413	66	3.16	.248	.00060	89	68	Ave. M/UL = 60	45° Skew TM=0.06"
					67	-	-	-	-	-		
					68	-	-	-	-	-		
54-398	S	B	D	256	66	1.68	.120	.00047	91	52	Ave M/UL = 47	
					67	1.71	.122	.00048	94	51		
					68	1.61	.114	.00045	91	49		
54-609	S	B	D	305	66	2.30	.165	.00054	91	60	Ave. M/UL = 58	37° Skew TM=0.10"
					67	2.49	.187	.00062	94	65		
					68	2.44	.175	.00057	93	62		
54-611	S	EP	D	248	66	1.44	.092	.00037	91	41	Ave. M/UL = 41	37° Skew TM=0.10"
					67	1.61	.106	.00043	94	46		
					68	1.60	.105	.00042	93	46		

Figure 6 (Cont.)

EXPANSION JOINT MOVEMENT STUDY

Bridge No.	Type	Bearings	Environment	Length - ft	Year	Total Movement-in	Adjusted Movement-ft	Movement/ Unit Length	Temperature Delta	Coeff. Expansion (x10-7)	Structure Elevation	Comments
54-665	S	EP	D	361	66	2.19	.158	.00044	86	51	E E E E E E E Ave. M/UL = 48	56° Skew TM = 0.05"
					67	2.50	.183	.00051	89	57		
					68	2.36	.171	.00048	83	57		
56-474E	S	EP	D	335	66	2.00	.146	.00044	92	48	E E E E Ave. M/UL = 44	38° Skew
					67	1.90	.138	.00041	90	46		
					68	2.14	.158	.00047	90	53		
23-151	S	EP	V	376	66	2.05	.154	.00041	83	50	E E E E E E E E Ave. M/UL = 43	45° Skew
					67	2.16	.164	.00043	81	54		
					68	2.29	.174	.00046	85	55		
23-159	S	EP	V	382	66	1.98	.148	.00040	83	47	E E E E E E E E Ave. M/UL = 41	45° Skew
					67	2.14	.161	.00042	81	52		
					68	2.15	.162	.00042	85	50		
39-164R	S	R	V	219	66	–	–	–	–	–	E Ave. M/UL = 40	Bottom of rail Spalled at exp. jt. 59° Skew
					67	1.06	.085	.00039	81	48		
					68	1.11	.089	.00041	82	50		
39-164L	S	R	V	219	66	–	–	–	–	–	E Ave. M/UL = 40	Bottom of rail Spalled at exp. jt. 59° Skew
					67	1.10	.088	.00040	81	50		
					68	1.13	.091	.00041	82	51		

Figure 6 (Cont.)

EXPANSION JOINT MOVEMENT STUDY

Bridge No.	Type	Bearings	Environment	Length - ft	Year	Total Movement-in	Adjusted Movement-ft	Movement/ Unit Length	Temperature Delta	Coeff. Expansion (x10-7)	Structure Elevation	Comments
24-04	S	R and Strap Hinge	V	1595	66	-	-	-	-	-	E E X X E E	
					67	10.36	.833	.00052	79	66		
					68	10.97	.884	.00055	82	67	Ave. M/UL = 54	TM = 0.12"
50-240	S	EP	V	362	66	-	-	-	-	-	E E	
					67	-	-	-	-	-		
					68	1.77	.141	.00039	84	46	Ave. M/UL = 39	60° Skew
50-291	S	EP	V	274	66	-	-	-	-	-	E E	
					67	-	-	-	-	-		
					68	1.35	.106	.00039	84	46	Ave. M/UL = 39	36° Skew
37-193	S	Self Lub Pads	C	1235	66	7.14	.560	.00045	69	66	E E E E E E E E X E	
					67	7.03	.550	.00045	67	67		
					68	7.06	.552	.00045	71	63	Ave. M/UL = 45	TM = 0.25"
53-1393R	S	B	C	494	66	2.61	.211	.00043	64	67	E E E E	'67 reading for less than a Complete seasonal cycle
					67	2.06	.165	.00034	58	58		
					68	2.64	.213	.00043	69	62	Ave. M/UL = 43	
53-1209 OR	S	B	C	809	66	3.90	.292	.00036	64	57	E E E E E E E E	Do. Deep groove in rail - jt. 2 - at end of closing cycle indicates closing restriction 35° Skew T.M. = 0.25"
					67	3.30	.243	.00030	63	48		
					68	3.51	.260	.00032	69	47	Ave. M/UL = 34	

Figure 6 (Cont.)

EXPANSION JOINT MOVEMENT STUDY

Bridge No.	Type	Bearings	Environment	Length - ft	Year	Total Movement-in	Adjusted Movement-ft	Movement/ Unit Length	Temperature Delta	Coeff. Expansion (x10-7)	Structure Elevation	Comments
24-248R	RC Box	EP	V	2549	66	–	–	–	–	–		
					67	–	–	–	–	–		
					68	11.83	.962	.00038	82	47	Ave. M/UL = 38	
24-248L	RC Box	EP	V	2549	66	–	–	–	–	–		
					67	–	–	–	–	–		
					68	10.97	.886	.00035	82	43	Ave. M/UL = 35	
					66							
					67							
					68							
					66							
					67							
					68							
					66							
					67							
					68							
					66							
					67							
					68							

Figure 6 (Cont.)

MOVEMENT COMPARISON OF CONCRETE SUPERSTRUCTURES

IN VARIOUS ENVIRONMENTS

Area	Mountain		Desert		Coast		Valley	
Abutment Expansion	Yes	No	Yes	No	Yes	No	Yes	No
Average Movement Per Unit Length (10^{-5})	52 38 48 45		38 41 49 48 31 38 40 40	25 27	31 20 37 36 35 26 29 22 20 24 24 25	28 27 14 8 17	36 43 33 28 34 35 32 31 35 32 38 35	25 30 27 24 38 32 29 28 22 29 32 34 33 24 18 23 21 16 21 15
Average	46		41	26	27	19	34	26
Increased Movement*			58%		42%		31%	
Combined Average	46		38		25		29	

*Increased movement capability of abutment expansion over no abutment expansion, in %.

Figure 7

MOVEMENT COMPARISON OF STEEL

SUPERSTRUCTURES IN VARIOUS ENVIRONMENTS

Area	Mountain	Desert	Coast	Valley
Average	65	47	45	43
Movement	65	58	43	41
Per Unit	55	41	34	54
Length	56	48		
(10^{-5})	60			40
(Expansion		44		40
at the				39
Abutments)				39
Average	60	48	41	42

Figure 8

COMPARISON OF DESIGN CRITERIA

AND STUDY DATA

Area	Air Temperature Range (°F)		Movement per Unit Length[1] ($x10^{-5}$) — Superstructure Type							
			Steel				Concrete			
	Design	Study (Ave)	Design[3]	Study Ave	Study Hi	Study ACE[2]	Design[3]	Study Ave	Study Hi	Study ACE[2]
Desert	120	91	78	48	58	63	48	41	49	54
Mountain	120	87	78	60	65	79	48	46	52	59
Valley	100	81	66	42	54	66	42	34	43	52
Coast	80	61	52	41	45	65	36	27	37	54

(Turn table 90°)

(1) Except for column under ACE.

(2) ACE: Apparent thermal coefficient of expansion ($x10^{-7}$) as determined by the high movement per unit length and average temperature range at the site of the structure with the high movement.

(3) Designed movement for maximum expected temperature range.

Figure 9

MOVEMENT COMPARISON OF CONCRETE

SUPERSTRUCTURE TYPES

(Valley Environment)

Type	RCT		RC Slab		RC Box		PSI or M		Steel	
Abutment Expansion	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Average Movement Per Unit Length (10^{-5})		25 30 27 24 38 32		29	33 28 34 35 32 38 35	24 18 23 21 16 21 15	36 43	28 22 29 32 34 33	43 41 54 40 40 39 39	
Average		29		29	34	20	40	30	42	
Combined Average	29		29		27		32		42	

Figure 10

EFFECT OF EXPANSION BEARING TYPE ON

EXPANSION JOINT MOVEMENT

Type	Bar		Elastomeric Pad		Sliding Plate	
Abutment Expansion	Yes	No	Yes	No	Yes	No
Average Movement Per Unit Length (10^{-5})	35 32		36 43 33 28 35 38	28 22 29 32 34 33	34 35	25 30 27 24 38 32 29 24 18 23 21 16 21 15
Average	33		36	30	34	24
Combined Average	33		32		26	

Figure 11

EFFECT OF SKEW ON

EXPANSION JOINT MOVEMENT

Skew	Less than 20°		Between 20°&40°		Over 40°	
Abutment Expansion	Yes	No	Yes	No	Yes	No
Average Movement Per Unit Length (10^{-5})	36 33 28 35 38 35	27 24 38 29 22 34 33 23 21		32 28 29 32 16	43 34 32	25 30 24 18 21 15
Average	34	28		27	36	22
Combined Average	30		27		27	

Figure 12