

Interim Report  
JOINTLESS BRIDGES

by

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Faculty Research Scientist

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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## ABSTRACT

Presented is a summary of jointless bridge designs as used by twelve states; namely, California, Colorado, Idaho, Iowa, Kansas, Missouri, Nebraska, North Dakota, South Dakota, Tennessee, Virginia, and Wisconsin.

Most of these states use some form of integral abutments for their steel or concrete structures. Bridges of lengths up to about 600 ft. (180 m) constructed with integral abutments have performed satisfactorily over a number of years. Projected are jointless bridges over 900 ft. (270 m) in length.

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## INTRODUCTION

The Working Plan "Jointless Bridges", dated June 1980, calls for a study involving two phases. The first deals with an evaluation of present methods of constructing jointless bridge structures and the second with new methods. This report, requested by the Federal Highway Administration, is a presentation of information developed in the first phase. A final report on the entire project is scheduled for June 1982.

## PHASE I ACTIVITIES

The collection of information on current methods of analyzing, designing, constructing, and maintaining jointless bridges was the first step taken in this phase of work. To that end, highway departments in twelve states known to have some type of jointless bridges were contacted. These states were California, Colorado, Idaho, Iowa, Kansas, Missouri, Nebraska, North Dakota, South Dakota, Tennessee, Virginia, and Wisconsin. An assortment of letters, bridge drawings, and methods of design and analysis were received from these state agencies. It is to be noted that the existing jointless bridges in Virginia are of a special type of limited application in that the abutments are cantilevered from the ends of the girders.

Recently published literature on the subject was also investigated. From a search by the Highway Research Information Service of the National Research Council, twenty-two abstracts were obtained. Full reports of several of the more relevant publications were obtained. These include "Analysis of Integral Abutment Bridges" by H. W. Lee and M. B. Sarsam, South Dakota State University, and "A Report on Continuity Between Reinforced Concrete Pavement and a Continuous Slab Bridge" by B. F. McCullough and F. Herber of the Texas Highway Department.

An additional publication obtained is the Federal Highway Administration Technical Advisory T 5140.13, January 28, 1980, entitled "Integral, No-joint Structures and Required Provisions for Movement".

After the collection of a representative quantity of information on jointless bridges, a meeting between the writer and several senior staff members of the Bridge Division of the Virginia Department of Highways and Transportation was arranged. At this meeting, current design methods were discussed and it was tentatively agreed that consideration would be given to incorporating some suitable method of eliminating joints in several future bridge designs. Information compiled by the writer was made available for reference.

Subsequently, three new bridges in Virginia were selected for designs that would have integral abutments. These are as follows:

1. A 130 ft. (39 m) steel bridge on Rte. 752 over Muddy Creek in Rockingham County.
2. A 242 ft. (72.6 m) steel bridge on Rte. 631 over Rte. 460 in Appomattox County.
3. A 454 ft. (136 m) prestressed concrete bridge on Rte. 3 over Rapidan River in Culpeper County.

Details for these structures are not yet complete, but it is expected that the integral abutment details will not be unlike those used in other states and described in this report.

## SUMMARIES FROM STATES

### California

Received from California was a description of their project entitled "Long Structures Without Expansion Joints". An interim report on this project states that twenty-one jointless bridges were surveyed and that five were instrumented for movement. The survey showed no difference in performance between conventional structures with expansion joints and jointless structures with lengths ranging from 350 ft. (105 m) to 496 ft. (149 m).

Distress, however, was noted in asphalt concrete approaches to jointless bridges, but not in portland cement concrete approaches. In some cases, cracking of the concrete parapet where it joined the guardrail approach also occurred in these jointless bridges. It was recommended that all jointless structures have a concrete approach and that the guardrail attachments have slotted holes to allow for movement.

Further data on this project will be included in a future report.

### Colorado

Colorado has a number of fixed abutment bridges of both steel and prestressed concrete for structures up to about 400 ft. (120 m) in total length. Typical plans of these jointless structures show the abutments to be fixed to the superstructure, resting on a single row of flexible piles and detailed essentially as illustrated in Figures 3 and 4 of the FHWA Technical Advisory T 5140.13 dated January 28, 1980, a copy of which is attached to this interim report.

The major point of distress in these jointless bridges is in settlement of the asphalt approaches, particularly for bridges in excess of 200 ft. long (60 m). For that reason, concrete approach slabs are recommended and are being used.

It was reported that jointless bridges still require some maintenance, but do eliminate damage to the costly expansion devices by snowplows.

### Idaho

Information from Idaho related to two bridges constructed there without expansion joints.

One is a 147 ft. (44 m) steel girder skewed bridge in which the end spans are cantilevered. A concrete end wall butts against the superstructure. As built originally, the girders over the piers rested freely on elastomeric bearings. However, because of the skew, torsional expansion of the bridge caused cracking at the end of the pier. Fixing all girders to the piers corrected this problem.

A second bridge, 413 ft. (124 m) long with prestressed concrete girders and with fixed bearings but with no skew, has performed with no problems. It is believed that if proper consideration is given to passive earth pressures at the end, much longer jointless bridges would function satisfactorily. Due consideration should also be given the approach pavement to account for longitudinal movement.

### Iowa

The Iowa Department of Transportation has constructed a number of integral abutment bridges over the last fifteen years that are performing well and have proven to require less maintenance than bridges with joints at the abutments. Their typical integral abutment is illustrated in Figure 1 of this report. The sand around the top 8 ft. (2.4 m) of the pile allows for greater flexibility of the pile and is used for bridge lengths in excess of 130 ft. (39 m).

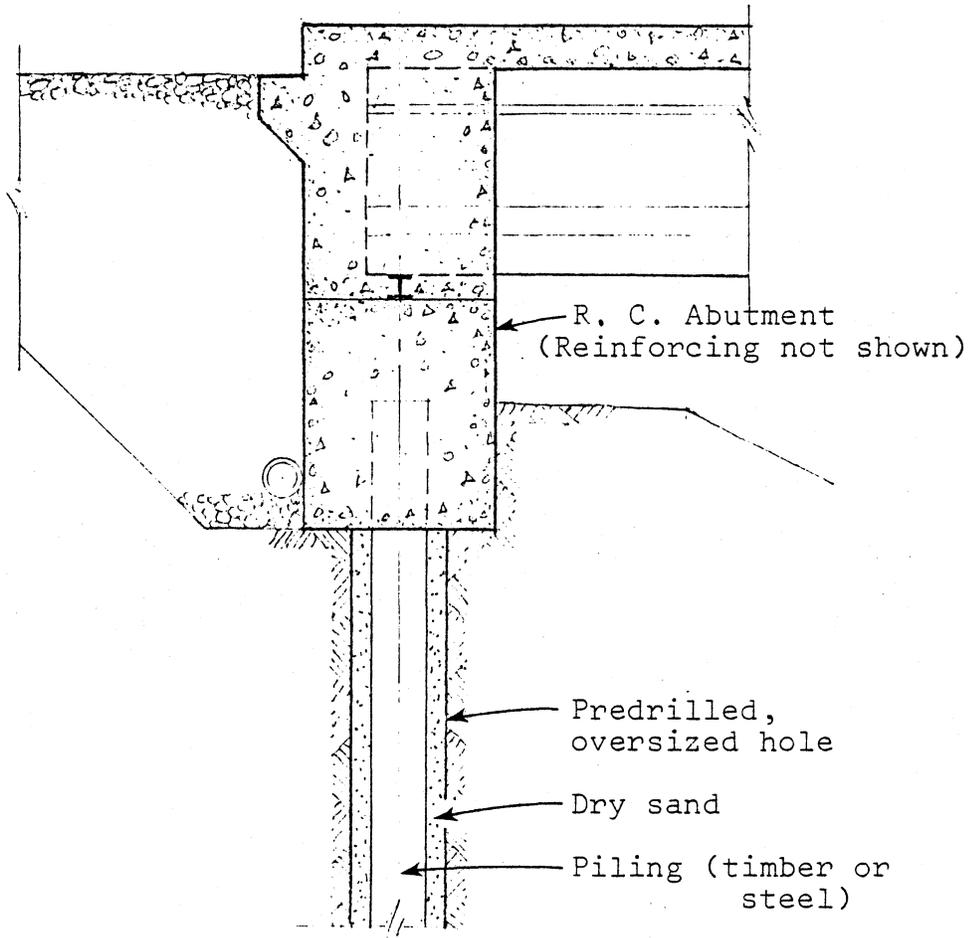


Figure 1. Iowa integral abutment.

For bridges between 150 (45 m) and 200 ft. (60 m) in length, the portion of the pile embedded in the concrete pile cap beam must be wrapped with a flexible material to provide even more flexibility of the pile against longitudinal movement. Integral abutments are not used for bridges longer than 265 ft. (79.5 m).

### Kansas

The state of Kansas has a number of different types of jointless bridges. They have constructed cast-in-place concrete structures up to 600 ft. (180 m) in length that are monolithic throughout. Piles for the terminal abutments are in a single row to permit end movement. Kansas has a prestressed concrete bridge with an overall length of 800 ft. (240 m) with no joints in the deck. The abutments are of the integral type on a single row of piles. However, at intervals of about 240 ft. (72 m), expansion bearings are used between the girders and the piers.

Another type of bridge is a 902 ft. (270.6 m) long steel girder structure with expansion joints at only the abutments and center pier. Also constructed are continuous jointless concrete decks of lengths over 1,400 ft. (420 m) supported by steel girders.

They have had no problems they can relate to design.

### Missouri

The design manual of Missouri's Highway Bridge Division includes provisions and details for integral abutment structures. Integral abutments of the type shown in Figure 2 in this report are permitted for prestressed concrete girder bridges of lengths up to 500 ft. (150 m). Although Missouri does not have any 500 ft. (150 m) integral abutment bridges, it does have 300 ft. (90 m) ones, which are holding up well.

Steel bridges are designed with semi-integral abutments as seen in Figure 3. The bond break between the girder and the rest of the abutment is to allow for rotation of the relatively flexible steel girders. At present, such steel bridges are limited to 200 ft. (60 m), but this will probably be changed to 400 ft. (120 m) in the near future.

There is some concern with integral abutments for bridges with large skews, so that non-integral abutments are used with skews over 40 degrees.

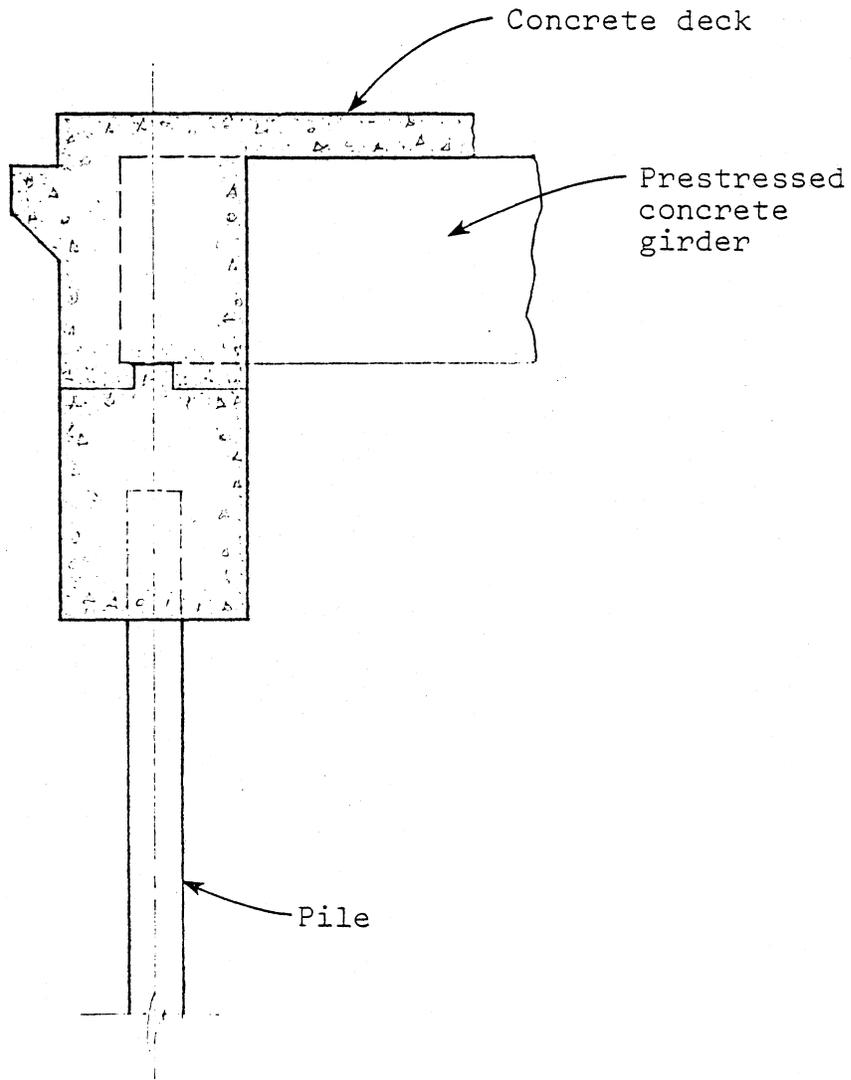


Figure 2. Missouri integral abutment.

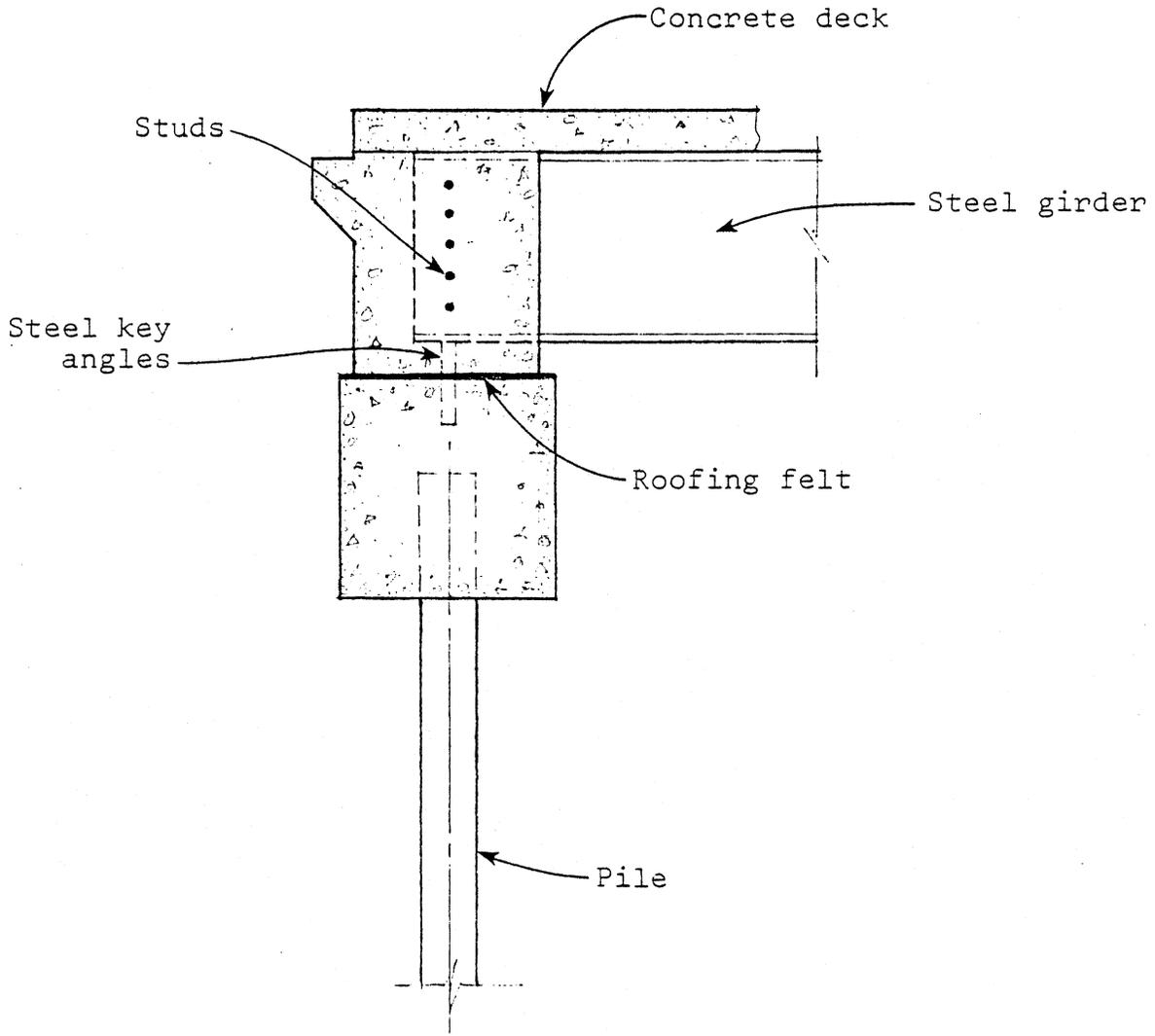


Figure 3. Missouri semi-integral abutment.

Nebraska

Nebraska has about 20 integral abutment bridges, mostly steel girder bridges, to lengths of about 300 ft. (90 m). Except for one structure improperly detailed, there have been no problems with them. The abutment design essentially conforms to the FHWA Technical Advisory T 5140.13 recommendations. To simplify construction, the approach pavement sill is detailed as shown in Figure 4, instead of as a ledge such as in Figures 1, 2 or 3. Note that the pile extends deep into the concrete abutment for extra security.

The statement below, prepared by a FHWA Regional Bridge Engineer to Nebraska, has served as a design guideline for Nebraska's integral abutments.

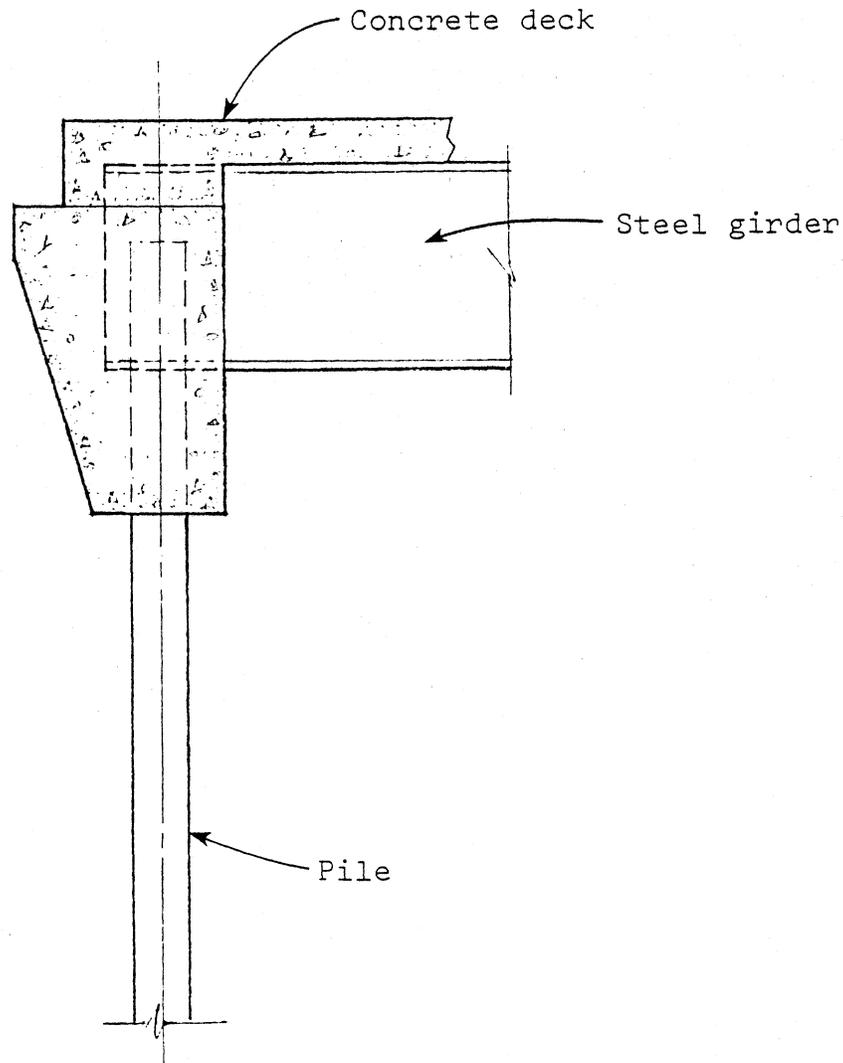


Figure 4. Nebraska integral abutment.

"The advantages of integral abutments have been proven beyond question. The elimination of expensive bearings, joint material, piles to resist horizontal earth loads, and leakage of water through the joints has resulted in improved performance in hundreds of installations. The sizeable economies resulting, due to the smaller quantities of concrete, excavation and other material have accrued over a long period to those States using this detail.

"The nature of the forces to be used in design is very indefinite. The observations of this office have led to several conclusions concerning the most important considerations.

1. The sill should be firmly attached to the superstructure. Provision for the resistance of forces generated when the deck is contracting is necessary. The area of the sill bearing against the embankment should be as small as possible. The passive earth loads developed by movement should be resisted by the deck with minimum eccentricity.
2. Expansion and contraction of the deck should be anticipated and provisions made for movement in the approach slab joints.
3. The abutment can be subject to frost heaving; therefore, adequate drainage and other precautions are necessary.
4. The piles offer adequate flexibility for structural rotation and the details should be rigid enough to insure that necessary rotation will be in the piles.
5. Adequately designed piles can resist dragdown due to embankment settlement. The small vertical capacity required and the elimination of battered piles in this design adapt it to locations where settlement is anticipated. Many existing structures have withstood extensive embankment settlement without distress where the piles have been driven to adequate capacity below the consolidating layers.
6. The integral abutment can resist uplift loads in superstructure configurations where uplift is produced.
7. The riding qualities at bridge ends are generally better on structures with integral abutments than on those structures having conventional abutments. Structures of his type withstand pavement pushing better than conventional types.

8. Structures of lengths greater than that considered prudent for this type design can utilize battered piles in this same detail and still retain most of the advantages of integral construction. Of course, provision for expansion must be incorporated elsewhere.
9. This same detail has been used in rock cuts by providing two or more pedestal foundations and supporting the end sill on elastomeric pads. Major economies in rock excavation and footing concrete are thus realized. This design is much more adaptable to uneven rock situations than details requiring large footing areas. Spread footings on erodible material are not recommended.
10. The complete elimination of water on the backslopes under structures has resulted in many satisfactory installations without slope protection. Slope protection should be prescribed in areas subject to wind erosion.
11. Skews over 30° require special consideration.

"Integral abutments are recommended for steel structures up to 300 feet [90 m] long and concrete structures up to 400 feet [120 m] in length. No provision for transverse expansion in structures having great width is necessary. The exposed pile areas should be painted in the normal manner. High capacity piles are recommended and the number should be as small as possible."

#### North Dakota

The North Dakota State Highway Department has been using integral abutments for all their bridges since 1964 for lengths up to 400 ft. (120 m). Their designs are basically similar to those shown in the FHWA Technical Advisory 5140.13, Figure 4, except that in some cases, the notch in the abutment for the approach pavement is replaced with an extension ledge as in Figures 1, 2, or 3 of this report.

Because of the satisfactory performance of the existing bridges, it is believed that structures with integral abutments of lengths greater than 400 ft. (120 m) could be built satisfactorily.

#### South Dakota

South Dakota uses integral abutments for steel bridges, prestressed concrete girder bridges, and concrete slab bridges.

The abutment details generally follow those presented in the FHWA Technical Advisory T 5140.13. These abutments are used for bridges up to 300 ft. (90 m) in length and with 30° skew.

It is estimated that this design saves approximately \$10,000 in first cost per structure as compared to conventional abutments. Long-term maintenance costs are also less.

It is to be noted that the South Dakota Department of Highways supported an extensive research project on integral abutment bridges with the South Dakota State University. A 1973 report entitled "Analysis of Integral Abutment Bridges" by H. W. Lee of the South Dakota State University and M. B. Sarsam of the South Dakota Department of Highways resulted. In this report, a full-scale model test is described and analyzed.

### Tennessee

Reports from Tennessee indicate that they have many bridges constructed without joints. It is their policy to build continuous bridges with no deck joints, unless joints are absolutely necessary, as they believe joints create more problems than they solve. Although some structures do have a few cracks, the cracks present no significant problems.

A typical integral abutment used for prestressed concrete box girders is shown in Figure 5. Note that the approach pavement is also concrete and is integral with the abutment.

Recently completed is a continuous concrete box girder bridge 2,700 ft. (810 m) long with joints at the abutments only. The girders are doweled to the concrete piers, spaced approximately 100 ft. (30 m) apart. This structure has been instrumented by the University of Tennessee for field testing and evaluation. To date, the structure is doing well and the end movements are only a fraction of that expected for free expansion or contraction.

Soon to be constructed is a 927 ft. (278 m) long continuous precast, prestressed concrete box girder bridge with no joints at all.

Because of the innovations undertaken by Tennessee, that state has become a pacesetter in jointless bridge construction.

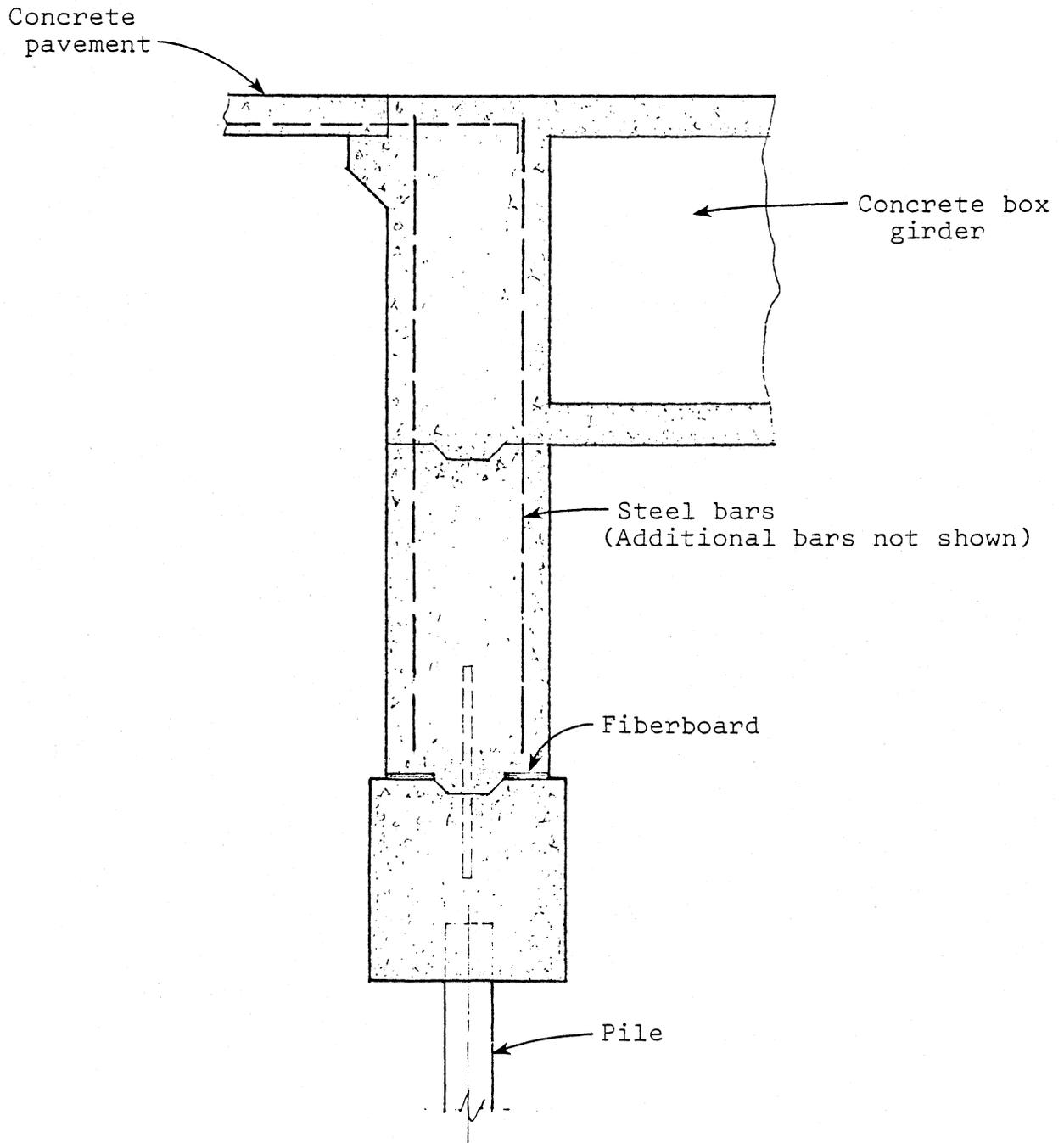


Figure 5. Tennessee integral abutment.

Virginia

Virginia has a few novel jointless bridges in which there are no conventional abutments. Rather the end spans of the girders cantilever from the piers to support a concrete end wall. See Figure 6. There is a joint between the pavement and the bridge superstructure, however.

This type of structure has limited application as the outside piers have to be located no greater than about 20 ft. (6 m) from the ends of the bridges in order to minimize end deflection.

As described earlier in this report, three new bridges with integral abutments as used by other states are under design.

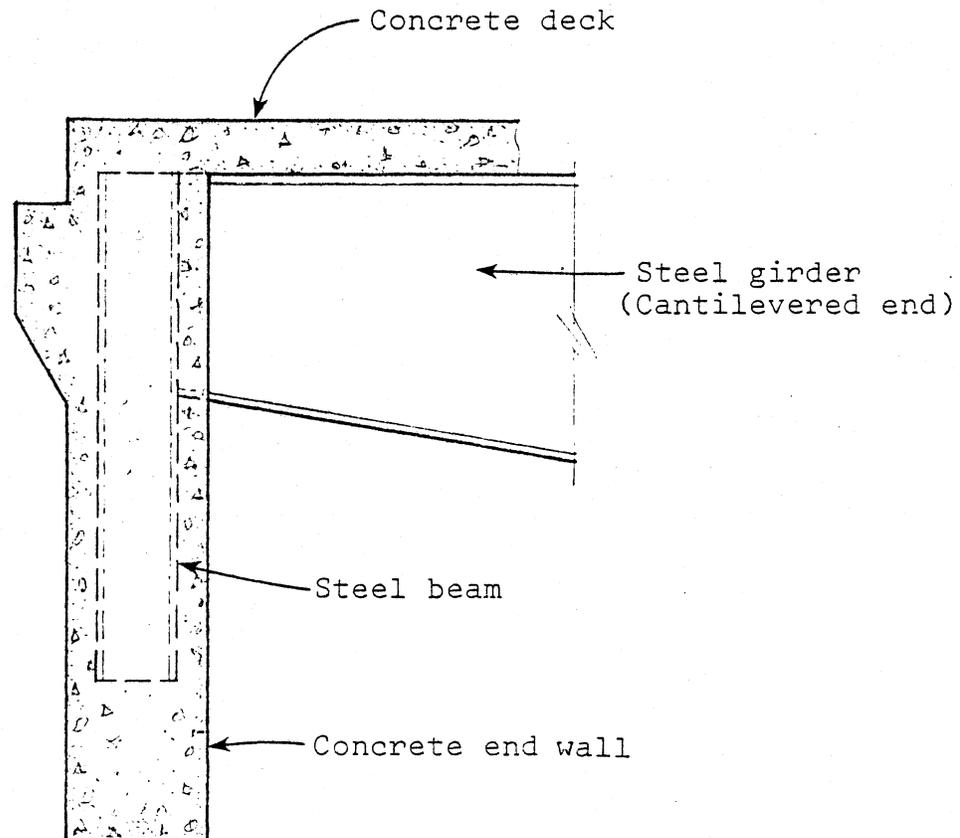


Figure 6. Virginia cantilevered end wall.

Wisconsin

The Wisconsin Department of Transportation has been using integral abutments for their bridges since about 1960. Almost all these structures have been built of concrete and in lengths up to 300 ft. (90 m). The results have been good, except on bridges with large skews. On these skewed bridges, some cracking has occurred in the end diaphragms around the girders.

Currently, the Department is experimenting with integral abutments for steel girder bridges and with a variation of the integral abutment that permits some expansion of the superstructure.

## CONCLUSIONS AND RECOMMENDATIONS

Of the states contacted that have jointless bridges, most use some type of integral abutments. In this type of abutment, a single row of piles is used to allow for flexing. A concrete pile cap is used to tie the piles to the bridge superstructure. Most designs provide a concrete sill extending from the end of the abutment to provide support for the approach pavement. The approach pavement should be of portland cement concrete, as bituminous pavements tend to crack as a result of the movement of the bridge. The concrete pavement should be anchored to the abutment with reinforcing steel. This approach pavement should be designed in accordance with existing AASHTO specifications.

Other attachments extending from the approach to the bridge, as guardrails, should provide for some movement, as by slotting bolt holes.

To avoid possible frost heaving of the abutment, water drains should be provided below the surface. Flexure stresses in the piles can be kept low if necessary by packing sand around the tops of the piles to allow for flexibility.

Skew angles over 30° can potentially cause problems in regard to cracking, torsion, or lateral slip. Until or unless further analysis is done on integral abutment bridges with large skews, they should not be used.

Some states have used integral abutments for as long as 20 years with good results. Different states have set different limits on the overall length of bridges with such abutments; however, in general, steel bridges up to about 300 ft. (90 m) and concrete bridges up to about 500 ft. (120 m) appear to perform satisfactorily. Several states, including Kansas and Tennessee, have integral abutment

bridges of much greater length. Kansas has an 800 ft. (240 m) prestressed concrete bridge and Tennessee is building a prestressed concrete one 927 ft. (278 m) long; both with jointless decks and integral abutments.

The use of jointless decks and integral abutments has resulted in savings in the order of \$10,000 for construction costs and even more in maintenance costs over time.

On the basis of this investigation, there is every reason to believe that if the three integral abutment bridges selected for construction in Virginia are designed in accordance with these conclusions, the results will prove beneficial. However, because local climatic and traffic conditions must always be taken into account, it would be wise to monitor the performance of these three Virginia bridges.

10:00

 <p><b>U.S. DEPARTMENT OF TRANSPORTATION</b> <b>FEDERAL HIGHWAY ADMINISTRATION</b></p>	
<b>SUBJECT</b> Integral, No-Joint Structures and Required Provisions for Movement	<b>FHWA TECHNICAL ADVISORY</b> T 5140.13 January 28, 1980

- Par. 1. Purpose
2. Integral Abutment
  3. Provision for Movement

1. PURPOSE. To provide State and local highway agencies with currently available data and the state-of-the-art pertaining to integral abutments, continuous bridge lengths, and specification oriented movement requirements.

2. INTEGRAL ABUTMENT

a. Background. After observing the successful performance of many older structures either constructed without joints or performing with inoperative joints, several States have elected to design and construct short and moderate length bridges without joints.

- (1) In July 1972, South Dakota State University issued a study report entitled "Analysis of Integral Abutment Bridges" by Henry W. Lee and Mumtaz B. Sarsam. This study was conducted to investigate the stresses induced by thermal movements in the girder and upper portion of steel bearing piles of integral abutment-type bridges. It is considered a good reference.

A quote from a State of Tennessee "Structure Memorandum" defines an unrestrained abutment as follows:

"When the total anticipated movement at an abutment is less than two (2) inches and the abutment is not restrained against movement, no joint will be required and the superstructure, abutment beam and reinforced pavement at bridge ends will be constructed integrally. An unrestrained abutment is one that is free to rotate such as a stub abutment on one row of piles or an abutment hinged at the footing."

-W(EO/RD)-1;H-W(HO/NG/TO)-2

OPI: HNG-32

I-W(DV/RS)-3

-D-1;H-D(BR/CM/FH/FP/WB)-3

-M-1;H-M(BR/EC/FO/FP/SH)-4

- (3) Continuous steel bridges with integral abutments have performed successfully for years in the 300-foot range, notably in North Dakota and Tennessee. Continuous concrete structures 500-600 feet long with monolithic abutments have given excellent long-term performance in Kansas, California, Colorado and Tennessee.

b. Recommendation. It is recommended that bridges with their overall length less than the following values be constructed continuous and, if unrestrained, have integral abutments. Greater values may be used when experience indicates such designs satisfactory.

Steel . . . . .	300 feet
CIP . . . . .	500 feet
Pre- or Post-tensioned Concrete. .	600 feet

- (1) Approach slabs are needed to span the area immediately behind integral abutments to prevent traffic compaction of material where the fill is partially disturbed by abutment movement. The approach slab should be anchored with reinforcing steel to the superstructure and have a minimum span length equal to the depth of abutment (1 to 1 slope from the bottom of the rear face of the abutment) plus a 4-foot minimum soil bearing area. A practical minimum length of slab would be 14 feet. See Figure 1 for details.

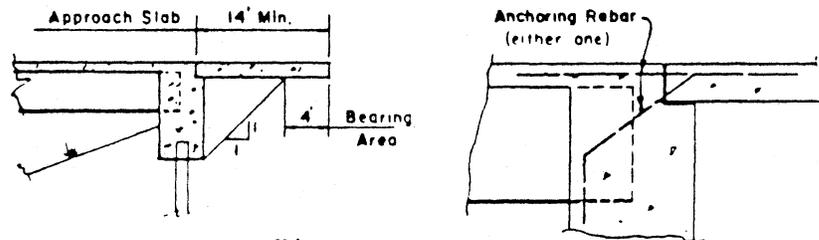


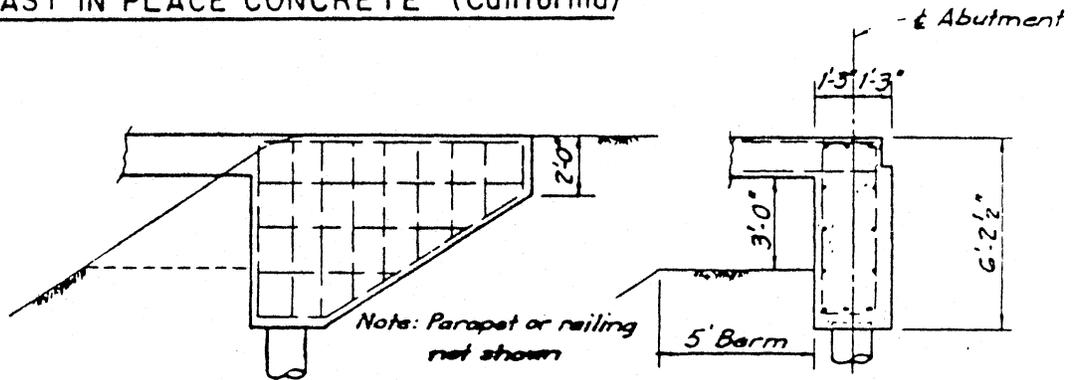
Figure 1

- (2) The design of the approach slab should be based on the American Association of State Highway and Transportation Officials (AASHTO) Specifications for Highway Bridges, Article 1.3.2(3) Case B, where design span "S" equals slab length minus 2 feet.
- (3) Positive anchorage of integral abutments to the superstructure is strongly recommended.

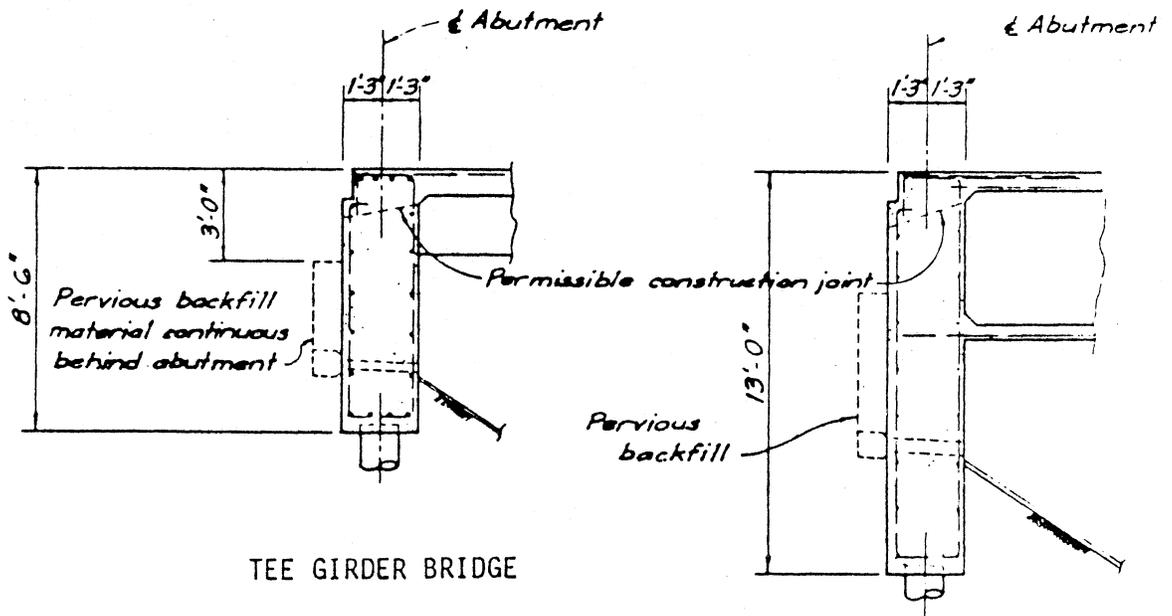
(4) North Dakota provides a roadway expansion joint 50 feet from end of bridge to accommodate any pavement growth or bridge movement. This is considered desirable.

c. Typical Integral Abutment Details. Figures 2, 3, and 4 show examples of typical details used by some highway agencies. (Even though not included in the details shown below, anchorage of the approach slab in accordance with paragraph 2b(1) above is strongly recommended.)

CAST IN PLACE CONCRETE (California)



SLAB BRIDGE



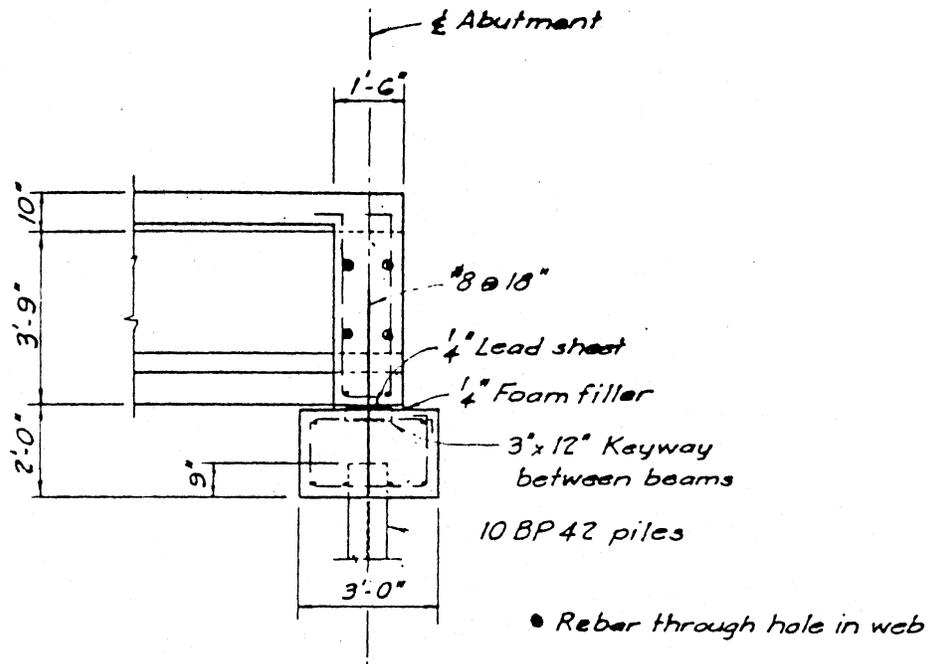
TEE GIRDER BRIDGE

BOX GIRDER BRIDGE

Figure 2

1904

### PRESTRESSED CONCRETE I-BEAM



FEDERAL HIGHWAY ADMINISTRATION - REGION 15

Figure 3

### STRUCTURAL STEEL

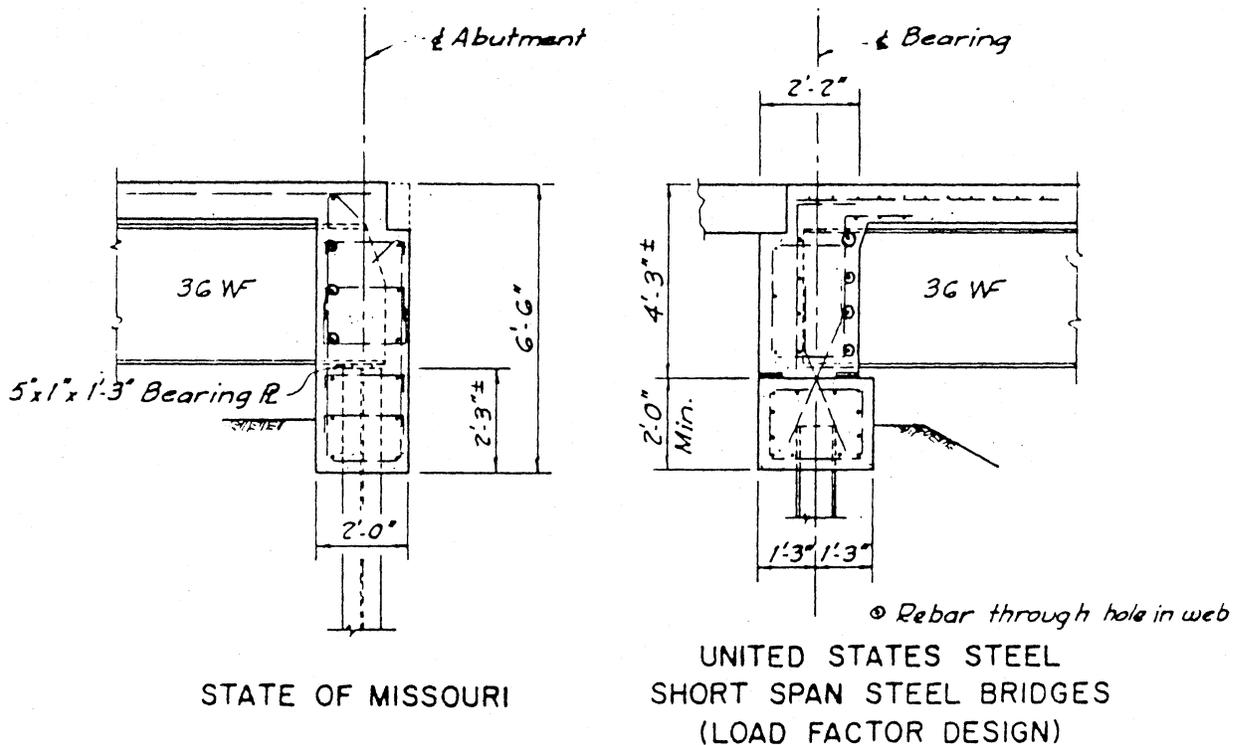


Figure 4

### 3. PROVISION FOR MOVEMENT

- a. Background. Thermal movements are predicted on the cold climate temperature ranges specified in the AASHTO bridge specifications, Article 1.2.15. State standards specifying other temperature ranges require adjustment of those values indicated.
- (1) For structural steel supported bridges, Article 1.2.15 specifies cold climate temperature range of 150 degrees F with a thermal coefficient of 0.0000065, resulting in a total thermal movement of 1 1/4 inches (32 mm) of movement per 100 feet (30.5 m) of structure.
  - (2) For concrete superstructures, the AASHTO bridge specification specifies a cold climate temperature range of 80 degrees F, a thermal coefficient of 0.0000060 and a shrinkage factor of 0.0002. However, this shrinkage effect can be reduced provided the normal construction sequence allows the initial shrinkage to occur prior to completion of the concrete operations. Based on an assumed shrinkage reduction of 50 percent, total allowance for thermal and shrinkage movement in a concrete structure would be approximately 3/4 inches (19 mm) per 100 feet (30.5 m).
  - (3) For prestressed concrete structures, a somewhat smaller total movement will occur once the prestressing shortening has taken place. Movement of 5/8 inch (15.9 mm) per 100 feet (30.5 m) of structure would be a reasonable value. This allows for thermal movement and assumes no effect from shrinkage and long-term creep. This value has been substantiated in the field as reasonable for normal highway overcrossing structures.
  - (4) In long pre- or post-tensioned concrete structures long-term creep may occur but is normally insignificant insofar as provision for movement is concerned and, therefore, has not been included in paragraph 3a(3) above.
  - (5) The flexibility of individual substructure units will affect the distribution of the total movement between specified joints.

b. Recommendations.

- (1) Cold Climate Conditions. Based on paragraph 3a above, consider adoption of Figure 5 for determining the required provision for total movement under cold climate conditions.

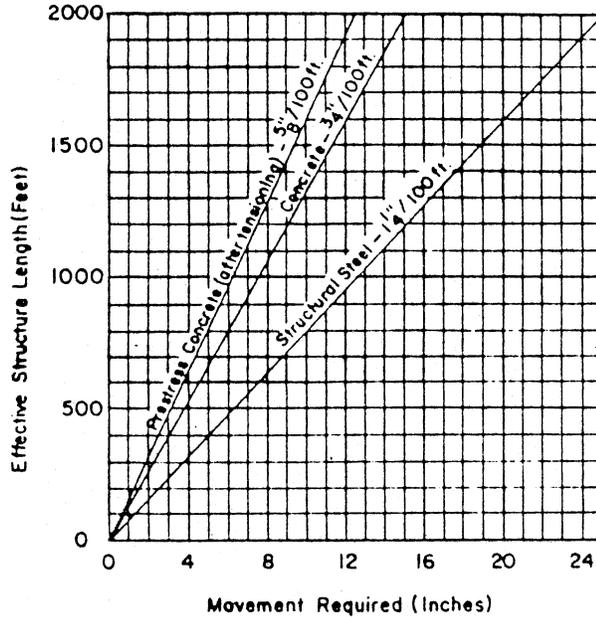


Figure 5

- (2) Moderate Climate Conditions. In accordance with AASHTO Article 1.2.15 for moderate climate conditions using temperature ranges of 120 degrees F (steel) and 70 degrees F (concrete) a 20 percent reduction of the above values may be used.

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