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Current design practice for bridge superstructures connected to flexible superstructures

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INTRODUCTION

This survey was conducted as part of a Missouri Highway Department Cooperative Research Study entitled "An Investigation of Design Criteria for Stresses Induced by Semi-Integral End Bents: Phase I--Feasibility Study." The long range goal of the research study was the development of design criteria for bridges whose superstructures are supported by flexible substructures without expansion type supporting devices.

This method of construction is becoming generally accepted, but opinions vary among bridge design engineers as to design procedures and limitations. During the course of the research study, it became apparent that a survey of current design practice should be conducted to supplement the literature review and establish the basis for current design practice. Thus, in February, 1972, the questionnaire and cover letter shown in Appendix A were mailed to the 50 state highway bridge engineers and to 5 governmental agencies. Current design practice was surveyed for Non-Integral, Semi-Integral, and Integral abutments for both steel and concrete bridges as described in Appendix A.

The response to the questionnaire and the interest expressed by the respondents were most encouraging, and their cooperation is gratefully acknowledged. Many bridge engineers requested that they be sent a copy of the results of the survey. Thus, this report has been prepared in response to these requests. It is hoped that the report will be of interest and value to bridge design engineers.

OBJECTIVES OF THE SURVEY

The primary objectives of the survey were:

1. To determine the present design criteria used for bridge
superstructures supported by flexible substructures, and the extent of current usage of this type of construction.

2. To establish if there exists a rational design criteria which takes into account the effects of such factors as shrinkage, creep, temperature, substructure flexibility, etc.

3. To identify the factors considered by bridge engineers to be significant to bridge behavior.

4. To identify potentially significant parameters which might be indicated through problems encountered or by objections to usage.

5. To establish a maximum workable length between positive expansion devices, or in the case of restrained structures a practicable design length, based on past performance.

6. To establish whether or not there is a need for future research in the area of restrained structures, taking into account time dependent factors.

7. To determine the field behavior of bridges in service and under construction with superstructures connected to flexible substructures.

8. To better establish the feasibility and value of further research in the area of restrained structures.

DESCRIPTION OF THE SURVEY AND QUESTIONNAIRE

The cover letter and questionnaire shown in Appendix A were sent to the 50 state highway departments and to 5 governmental agencies. Replies were received from 43 state highway departments and 3 governmental agencies, resulting in a total response of almost 84 percent and a
response from state highway departments of 86 percent.

As explained in the cover letter, the study of design criteria for stresses induced by Semi-Integral abutments was limited to continuous composite steel structures. However, in order to compare similarities and differences of current design practice for Non-Integral, Semi-Integral, and Integral types of construction for both steel and concrete structures, the questionnaire encompassed design practice for the three types of construction.

The replies reflect a wide range of design practice and limitations—not readily tabulated by simple arithmetic summation or graphical representation. In some cases, interpretation of the response to one question is dependent upon continuity with the response to prior questions. Thus, to provide a continuity of individual respondents and to aid in comparison of design practice among respondents, the states were grouped into six geographical areas and each of the respondents was assigned an identifying two digit number. The first digit represents the geographical area in which the respondent is located, and the second digit represents the particular state.

The six geographical areas, as shown in Fig. 1, are as follows:

Area 1 - Lower Middle States
Area 2 - Southeastern States
Area 3 - Northeastern States
Area 4 - Upper Midwestern States
Area 5 - Northwestern States
Area 6 - Southwestern States

The replies are tabulated and listed sequentially by questions in Appendix A. The continuity of replies by a given respondent is
Fig. 1. Geographical areas
 identifiable by the assigned respondent number. Questionnaires are naturally subject to differences in interpretation as to meaning and intent. Thus, a few replies, e.g., some replies to items 3(k) and (l), seemingly may not relate to their respective question. It will be noted, however, that, in an effort to avoid a compounding of misinterpretations, editorial license of revision and interpretation of the replies of the respondents has been reserved as the reader’s prerogative.

Some respondents included additional comments or explanatory remarks of interest to design engineers, and a few answers to specific questions were too detailed for tabulation under their item number. These comments and replies have been included under Item 7, Additional Comments and Suggestions.

SUMMARY AND CONCLUSIONS

From the response and the replies of the respondents, the following conclusions became apparent:

1. Although differences of opinion remain, the use of superstructures connected to flexible substructures is becoming generally accepted.

2. Current design criteria, or rather limitations, continue to be more restrictive for composite steel structures than for concrete structures.

3. There is no simple, rational design criteria currently available which takes into account the effects of such factors as shrinkage, creep, temperature, humidity, substructure flexibility, etc.

4. Maximum overall expansive lengths of up to 300 ft for steel structures and of 400-450 ft for concrete structures are
generally recognized by design engineers utilizing superstructures connected to flexible substructures. However, overall expansive lengths of 671 and 736 ft have been reported for Non-Integral and Semi-Integral steel structures, respectively, and lengths of approximately 500 ft have been reported for Non-Integral, Semi-Integral and Integral concrete structures.

5. Induced stresses resulting from thermal effects, creep, shrinkage, backfill movement and settlement, etc., are recognized by bridge design engineers as potentially significant. However, there is a wide variance in methods used for consideration, if any, of such stresses.

6. Some problems were reported for both steel and concrete structures for the three types of construction. It would appear that, in general, the problems reported are neither more prevalent nor of greater magnitude than those experienced when movable supporting and expansion devices are used. One respondent reported that asphalt concrete approach fills appear to settle more than at conventional structures.

7. Bridge design engineers are extremely interested in induced stresses and associated problems; are generally uncertain as to the significance of and suitable methods for consideration of these stresses; and would welcome a simple, rational design criteria and specific recommendations as to design details.
APPENDIX A

QUESTIONNAIRE AND SUMMARY OF REPLIES TO QUESTIONNAIRE
A study of design criteria for stresses induced by semi-integral end bents is being conducted as a Missouri Highway Department Cooperative Research Study by the Department of Civil Engineering, University of Missouri-Rolla. The long-range goal of the study is to develop design criteria for bridges whose superstructures are supported by flexible substructures.

The use of flexible piers and abutments without expansion type supporting devices has become generally accepted and is being used for quite long superstructures. However, opinions vary among bridge design engineers as to design limitations and how to determine and provide for the stresses induced in the structure as a result of this method of construction. Apparently, there is no rational method for handling this problem and it is believed that perhaps no allowance is made for these stresses in some cases.

For practical knowledge and to enlarge our findings, we are sending the enclosed short questionnaire to state highway bridge engineers. The purpose of the questionnaire is three-fold: to help define the parameters of the problem; to review and clarify current design practice; and to aid the course of the investigation.

Although we are concentrating on continuous composite steel superstructures with end diaphragms semi-integral with the abutment, any additional comments concerning procedures used by your organization for handling induced stresses, design details used, and suggestions toward our investigation will be greatly appreciated. Sketches defining the terms non-integral, semi-integral and integral as used in this study are enclosed.

Sincerely yours,

Jack H. Emanuel
Associate Professor of
Civil Engineering

JHE:pjs
Enclosure
QUESTIONNAIRE: Design Criteria for Stresses Induced by Semi-Integral End Bents

1. Do you approve the use of flexible stub abutments and piers without expansion or rocker type supporting devices; i.e., tying the girders directly to the abutments and piers
   a) for steel structures Yes ____ No ____
   b) for concrete structures? Yes ____ No ____

2. Are you using, or have you used, the above method
   I. Non-Integral  
   II. Semi-Integral  
   III. Integral
   a) for steel structures Yes ____ No ____ Yes ____ No ____ Yes ____ No ____
   b) for concrete structures? Yes ____ No ____ Yes ____ No ____

3. If any of the answers to 2 above was Yes, what limitations, if any, are imposed (I, II, or III)
   a) for steel structures __________________________________________________________________________
   b) for concrete structures? __________________________________________________________________________

What is the maximum overall expansive length used (without positive expansion devices)
   c) for steel structures
   d) for concrete structures?

When used for one, two, three, and four-span structures, what are typical span lengths
   e) for steel structures
   f) for concrete structures?

Are you using the method for both non-skewed and skewed structures, and, if using for skewed, are additional limitations imposed
   g) for steel structures
   h) for concrete structures?

In your design do you take induced stresses into consideration—e.g., due to thermal effects, creep, shrinkage, backfill movement and settlement, etc.,
   i) for steel structures
   j) for concrete structures?
In your design (non-integral construction) do you provide for (allow) girder end rotation

k) for steel structures Yes__ No__ If Yes, how? (e.g., curved steel plates)__________

l) for concrete structures? Yes__ No__ If Yes, how? (e.g., curved steel plates)__________

If girder end rotation—separate from joint rotation—is not allowed (integral or semi-integral
construction) do you assume and take into consideration joint rotation due to flexing of the abutment
piling and pier piling

m) for steel structures

n) for concrete structures?

4. What limitations do you impose with respect to flexibility and type of substructure—e.g., pile materials,
L/r ratios, cast in place substructures on spread footing, backfilling techniques, preboring, etc., for
integral or semi-integral type of construction

a) for steel structures

b) for concrete structures?

5. What objections, if any, do you have to the above method referred to in questions 1 and 2.

a) for steel structures

b) for concrete structures?

6. What problems, if any, have you encountered when the method referred to in questions 1 and 2 was used

a) for steel structures

b) for concrete structures?

7. Additional comments and suggestions

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
Non-integral:
- Const. Jt. with 2"x4" Jt. Key
- Holes in Stringer Web (typ.)
- 3/4" Jt. Filler (typ.)
- 1-Layer of 55# Roofing Felt or 1-Heavy Coat of Emulsified Asphalt

Semi-integral:
- Const. Jt. with 2"x3" Jt. Key
- Angle Support for Stringer
- Channel Support for Stringer

Integral:
- Holes in Stringer Web (typ.)

Note: Slab reinforcement and shear connectors have been left off for clarity.
Summary of Replies to Questionnaire

1. Do you approve the use of flexible stub abutments and piers without expansion or rocker type supporting devices; i.e., tying the girders directly to the abutments and piers

   a) for steel structures?
      - yes - 23
      - no - 16
      - blank - 7

   b) for concrete structures?
      - yes - 30
      - no - 10
      - blank - 6

2. Are you using, or have you used, the above method

   a) for steel structures
      I. Non-Integral
      - yes - 28
      - no - 10
      - blank - 8
      II. Semi-Integral
      - yes - 17
      - no - 20
      - blank - 9
      III. Integral
      - yes - 13
      - no - 25
      - blank - 8

   b) for concrete structures
      I. Non-Integral
      - yes - 26
      - no - 13
      - blank - 7
      II. Semi-Integral
      - yes - 28
      - no - 10
      - blank - 8
      III. Integral
      - yes - 24
      - no - 16
      - blank - 6

3. If any of the answers to 2 above was Yes, what limitations, if any, are imposed (I, II, or III)

   a) for steel structures?
      12 For types II and III, limit structures to approximately 200 ft length.
      14 Type II limited to 200 ft bridge length, 0-20° skew; 160 ft bridge length, 20-30° skew.
      16 Type II must have provision for rotation.
      20 Limitations as to the length of structure, length of wings, height of end bent, and type of foundation.
      25 Spans not exceeding 40 ft for type II.
      26 The beam is free to rotate (use type II only).
      27 We use bearing plates to insure uniform bearing and rotation for dead load.
      35 250 ft total bridge length for types I and II.
      37 Pier bents must be flexible enough to deflect for continuous structures. Continuous span steel plate girders or WF beams with cantilevered end spans supported on fixed pier bents with non-integral connections to them are free to rotate on
the curved plate bearings. Piers are designed to deflect due to thermal and shrinkage stresses from the superstructure. Curtain walls at the ends of the cantilevered end spans are integral with the superstructure and are not supported by a foundation but are "free floating". Earth backfill pressure and concrete pouring sequence is considered. To date, no flexible abutment bents have been used, but they are being considered on a project under design.

41 Spans less than 45 ft.
42 Type I used for two adjacent piers fixed (part of a 3 to 7-span structure).
44 At present we are trying balanced 2-span continuous bridge ≤ 250 ft.
46 150 ft of expansion to abutment (300 ft maximum bridge length), 10° maximum skew.
47 Types I, II, and III limited to 300 ft with 30° skew.
48 Type III limited to a maximum structure length of 300 ft and a maximum skew of 30°.
51 Type III used only once for special application.
52 None for type I. Expansion device required at intermediate bents for type II.
53 No limitations on type I for short spans or one span of a series.
54 When this type (integral) abutment is used, care is taken to assure that temperature stresses are not excessive. For type I, the stiffness of the end abutment must be low enough so that temperature motions can occur at the abutment or else expansion motion must be accounted for in the adjacent piers. Type II is not generally used, but is subject to the same general limitations as type I. Type III has not been used for steel structures, largely because of problems associated with girder end rotations, and also because this State uses very few short span steel bridges.
55 Two rows of piles required for type I. Types II and III limited to 150 ft.
56 Types II and III not used at piers. Type I used on flexible piers only.
62 Used on short spans where deflections are small. Provide for elastic shortening due to post tensioning in the abutment design for spans approximately 115 ft and greater. Consider rotation when abutment span exceeds 160 ft. Assume a design longitudinal force of 15 to 25 kips per pile applied at the base of the diaphragm, depending upon pile type.
63 Types II and III used for short single spans only--50 ft maximum.
67 Type II limited to low skew bridges only.
Question 3 continued.

b) for concrete structures?

11 Type II limited to short spans (< 40 ft) and no shear key used.
12 Use type III on structures up to 500 ft length, then use type I.
14 For prestressed, use type I if over 30° skew; otherwise somewhat longer spans than for steel (limits given for steel were that type II is limited to 200 ft bridge length, 0-20° skew; 160 ft bridge length, 20-30° skew).
15 We use this type construction on rigid frame structures only.
16 Type II must have provision for rotation. Type III is used for slab spans only.
20 Limitations as to the length of structure, length of wings, height of end bent, and type of foundation.
24 Foundations bearing on piles for types II and III.
25 Spans not exceeding 40 ft for type II.
26 The beam is free to rotate (use type II only).
27 Structure length and foundation conditions.
41 Slab construction less than 100 ft.
42 Types II and III limited to thermal movement less than 1 in.
43 Used for prestressed concrete beam bridges and for slab bridges.
47 Types I, II, and III limited to 300 ft with 30° skew.
48 For type III, no limitations within practical length limits for type of bridge. Type II is no longer used.
49 Overall structure length and skew angle.
51 Types II and III used only where total bridge length is less than 300 ft.
52 Type II limited to 300 ft of structure without expansion devices.
54 When this type (integral) abutment is used, care is taken to assure that temperature stresses are not excessive. For type I, the stiffness of the end abutment must be low enough so that temperature motions can occur at the abutment or else expansion motion must be accounted for in the adjacent piers. Type II is not generally used, but is subject to the same general limitations as type I. Type III is largely restricted to flat slab or box girder construction of short to medium span. Care is taken to investigate the effect of the pile fixity on the structure.
55 Types II and III limited to structures less than 150 ft.
61 Types II and III not used with skew angles over 30°.
62 Provide for elastic shortening due to post tensioning in the abutment design for spans approximately 115 ft and greater. Consider rotation when abutment span exceeds 160 ft. Assume a design longitudinal force of 15 to 25 kips per pile applied at the base of the diaphragm, depending upon pile type.
63 Type III limited to 300 ft for 2 and 3-span structures; somewhat longer structures used with type II.
64 Length of structure and area in which structure is located.
65 Type III generally limited to short bridges (less than 100 ft).
66 Skews limited to 30°.
67 Type II limited to low skew bridges only.
68 For type III, superstructure length allowed is based upon flexibility of substructure.
Question 3 continued.

What is the maximum overall expansive length used (without positive expansion devices)

c) for steel structures?

<table>
<thead>
<tr>
<th>I. Non-Integral</th>
<th>II. Semi-Integral</th>
<th>III. Integral</th>
</tr>
</thead>
<tbody>
<tr>
<td>0- 40 - 0</td>
<td>0- 40 - 1</td>
<td>0- 40 - 0</td>
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<td>41-100 - 6</td>
<td>41-100 - 4</td>
<td>41-100 - 2</td>
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<td>101-200 - 5</td>
<td>101-200 - 3</td>
<td>101-200 - 7</td>
</tr>
<tr>
<td>201-300 - 1</td>
<td>201-300 - 2</td>
<td>201-300 - 2</td>
</tr>
<tr>
<td>&gt;200 - 1</td>
<td>&lt;200 - 1</td>
<td>&lt;200 - 1</td>
</tr>
<tr>
<td>250 &amp; 522 - 1</td>
<td>736 - 1</td>
<td>blank - 34</td>
</tr>
<tr>
<td>blank - 31</td>
<td></td>
<td></td>
</tr>
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</table>

d) for concrete structures?

<table>
<thead>
<tr>
<th>I. Non-Integral</th>
<th>II. Semi-Integral</th>
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</thead>
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<td>0- 40 - 0</td>
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<td>41-100 - 4</td>
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<td>101-200 - 4</td>
<td>101-200 - 3</td>
<td>101-200 - 6</td>
</tr>
<tr>
<td>201-300 - 3</td>
<td>201-300 - 8</td>
<td>201-300 - 7</td>
</tr>
<tr>
<td>&gt;500 - 1</td>
<td>325-350 - 2</td>
<td>350-400 - 2</td>
</tr>
<tr>
<td>blank - 34</td>
<td>450 - 1</td>
<td>450 - 2</td>
</tr>
<tr>
<td>&lt;500 - 1</td>
<td>blank - 25</td>
<td>blank - 24</td>
</tr>
</tbody>
</table>

When used for one, two, three, and four-span structures, what are typical span lengths

e) for steel structures?

<table>
<thead>
<tr>
<th>I. one</th>
<th>two</th>
<th>three</th>
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</thead>
<tbody>
<tr>
<td>15; 50</td>
<td>80, 80</td>
<td>100, 125, 100</td>
<td>100, 125, 125, 100</td>
</tr>
<tr>
<td>14</td>
<td>75, 75</td>
<td>35, 45, 35</td>
<td>35, 45, 45, 35a</td>
</tr>
<tr>
<td>20; 100;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>120, 120;</td>
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<tr>
<td>37</td>
<td></td>
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<td>155, 225, 165, 126</td>
</tr>
<tr>
<td>42; 100;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>125, 125;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>117, 117;</td>
<td>77, 100, 77;</td>
<td>37, 95, 95, 37</td>
</tr>
<tr>
<td>49</td>
<td>150;</td>
<td></td>
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<tr>
<td>51</td>
<td>137;</td>
<td>105, 105;</td>
<td>112, 127, 112;</td>
</tr>
<tr>
<td>53; 100;</td>
<td></td>
<td>Expansion device used.</td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>100, 100;</td>
<td>51, 66, 51;</td>
<td>91, 100, 100, 91</td>
</tr>
<tr>
<td>62</td>
<td>Various combinations--within allowable overall maximum.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>85; Use positive expansion devices for multiple spans.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>67</td>
<td>100;</td>
<td>100, 100;</td>
<td>75, 100, 75;</td>
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a For any skew.
Question 3(e) continued.

### II.

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<th>three</th>
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<tr>
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<td>100,</td>
<td>100;</td>
<td>60, 60,</td>
<td>44, 56, 56, 44^a</td>
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<td>80;</td>
<td>48, 64,</td>
<td>35, 45, 45, 35^b</td>
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<tr>
<td>16</td>
<td>Expansion provided—usually at first interior bent.</td>
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<td>57, 43;</td>
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<tr>
<td>55</td>
<td>&lt;90;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>62</td>
<td>Various combinations—within allowable overall maximum.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>63</td>
<td>50;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>Use positive expansion devices for multiple spans.</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>67</td>
<td>100; 100, 100; 75, 100, 75; 55, 70, 70, 55</td>
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</table>

^a0–20° skew (all values).

^b20–30° skew (all values).

^cConstructed as simple spans (all values).

### III.

<table>
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<td>16</td>
<td>Expansion provided—usually at first interior bent.</td>
<td>34, 132, 34;</td>
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</table>

^dHave used nine spans at 58 ft each.

f) for concrete structures?

### I.

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### II. one two three four

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</table>

*constructed as simple spans (all values).*

### III. one two three four

<p>| | | | | |</p>
<table>
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<tr>
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<td>150; 125, 125;</td>
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<td>62</td>
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<td>80, 100, 100, 80</td>
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<td>80; 120, 120;</td>
<td>60, 80, 80, 60</td>
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<tr>
<td>65</td>
<td>Use positive expansion devices for multiple spans.</td>
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<td>50; 60, 80, 60;</td>
<td>30, 35, 35, 30</td>
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</tbody>
</table>

*0–30° skew and prestressed.*

*Any skew and other than prestressed (all values).*

*Have used six spans--37, 48, 48, 48, 48, 37.*
Question 3 continued.

Are you using the method for both non-skewed and skewed structures, and, if using for skewed, are additional limitations imposed

g) for steel structures?

<table>
<thead>
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<th>Condition</th>
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<tr>
<td>Non-skewed only</td>
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<tr>
<td>Both, 0 to 15° skew</td>
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<tr>
<td>Both, 15 to 30° skew</td>
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Additional limitations (or comments)

<table>
<thead>
<tr>
<th>Limitation</th>
<th>Count</th>
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<tbody>
<tr>
<td>30° maximum skew</td>
<td>14</td>
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<tr>
<td>Lateral component of earth pressure considered</td>
<td>16</td>
</tr>
<tr>
<td>Slots in bearings for expansion</td>
<td>26</td>
</tr>
<tr>
<td>10° maximum skew</td>
<td>46</td>
</tr>
<tr>
<td>300 ft maximum length</td>
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</tr>
<tr>
<td>Bridge width vs. span ratio, number of piers, size, etc.</td>
<td>67</td>
</tr>
</tbody>
</table>

h) for concrete structures

<table>
<thead>
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<th>Count</th>
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<td>Both, 0 to 15° skew</td>
<td>6</td>
</tr>
<tr>
<td>Both, 15 to 30° skew</td>
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<tr>
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Additional limitations (or comments)

<table>
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<th>Limitation</th>
<th>Count</th>
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<tbody>
<tr>
<td>30° maximum skew for integral prestressed; otherwise no limitation.</td>
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<tr>
<td>Type III to about 15° only.</td>
<td>16</td>
</tr>
<tr>
<td>Matter of judgment</td>
<td>20</td>
</tr>
<tr>
<td>Slots in bearings for expansion.</td>
<td>26</td>
</tr>
<tr>
<td>Substructures limited to pile bents.</td>
<td>42</td>
</tr>
<tr>
<td>Skews to 45° on slab bridges; to 30° on prestressed.</td>
<td>46</td>
</tr>
<tr>
<td>Used only where skew is 20° or less.</td>
<td>48</td>
</tr>
<tr>
<td>Used only for skewed structures less than 80 ft.</td>
<td>49</td>
</tr>
<tr>
<td>In skewed structures having internal hinges, the piling is battered.</td>
<td>51</td>
</tr>
<tr>
<td>Bridge width vs. span ratio, number of piers, size, etc.</td>
<td>63</td>
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</tbody>
</table>

In your design do you take induced stresses into consideration—e.g., due to thermal effects, creep, shrinkage, backfill movement and settlement, etc.,

i) for steel structures?

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j) for concrete structures?

<table>
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<td>No</td>
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</table>
Questions 3(i) and (j) continued.

If Yes, what types of stresses—i.e., due to (a) How? (b)

11 a) Provide rockers.
12 a) Primarily thermal and fill movement; b) use additional reinforcing steel.
13 a) Temperature and shrinkage; b) column deflection.
14 a) Thermal movement; b) bearing design and possibly column design.
20 a) Passive earth pressure from expansion; pier deflection; b) reinforce accordingly.
27 a) Thermal effects; b) moments induced by thermal effects are accounted for based on \(E\) of concrete equal to one-thirtieth that of steel.
37 a) Thermal effects, shrinkage, and backfill pressures.
42 a) Thermal effects; b) assume pier takes full deflection.
44 a) Thermal effect; b) 12 in. C.I.P. piles are designed to take bending due to superstructure moment.
47 a) Thermal effects; b) using 1000 psf on abutments and wingwalls.
48 a) Temperature and backfill pressure; b) limit maximum stress in bottom flange to 90 percent of allowable.
52 a) Thermal effects; b) expansion devices.
53 a) Thermal; b) calculate forces involved.
54 a) Thermal, creep, live load, shrinkage (deck); b) assume pile depth for fixity.
55 a) Thermal effects; b) bearings and expansion devices, columns.
56 a) All, if applicable.
Questions 3(i) and (j) continued.

62 a) Use an assigned value for restraining force--up to 25 kips per pile.
64 a) Thermal effects, creep, backfill movement and settlement, etc.
66 a) Thermal effects, creep, backfill movement and settlement, etc.
67 a) Thermal effects, side creep, settlement; b) Earth fill strain vs. passive pressure build-up acting on bridge.
68 a) Thermal effects, side creep, settlement; b) Earth fill strain vs. passive pressure build-up acting on bridge.

In your design (non-integral construction) do you provide for (allow) girder end rotation

k) for steel structures?
   Yes - 26
   No - 0
   Blank - 20
   If Yes, how? (e.g., curved steel plates)

   11 Curved plates, rockers and elastomeric pads.
   12 Curved plates, rockers and elastomeric pads.
   13 Curved plates or neoprene pads.
   14 Bearings.
   16 Rocker shoes or curved steel plates or neoprene pads.
   20 Rocker plates, pins or elastomeric pads.
   24 Curved sole plates.
   26 Curved sole plates.
   27 Dead load only.
   35 Curved steel plates and rockers.
   37 Curved steel plates or rocker bearings.
   41 Curved plates or neoprene pads.
   42 Curved steel bearing plates.

1) for concrete structures?
   Yes - 26
   No - ?
   Blank - 17
   If Yes, how? (e.g., curved steel plates)

   11 Only on long spans (40 ft or greater).
   12 Curved plates, rockers and elastomeric pads.
   13 Curved plates or neoprene pads.
   14 Bearings.
   16 Neoprene pads. No for slab spans.
   20 Rocker plates, pins or elastomeric pads.
   24 Elastomeric bearing pads, curved steel plates.
   26 Curved sole plates.
   27 Dead load only.
   35 Curved steel plates and rockers.
   37 Curved steel plates or rocker bearings.
   41 Curved plates or neoprene pads.
   42 Curved steel bearing plates.
Questions 3(k) and (l) continued.

44 Curved steel plates and rudimentary hinge (crossed re-bars) in backwall.
46 Curved plates, rockers, rollers.
47 Curved steel plates.
48 Curved steel plates.
51 Elastomeric bearing pads or pinned bearings.
52 Curved plates and pinned type shoes.
53 Neoprene pads or suitable bearing devices.
54 Pin.
55 Curved rocker bearings.
56 Curved steel plates, when required by AASHO.
61 Curved steel plates.
63 Elastomeric pads.
64 Curved steel plates, neoprene pads.

65 Curved plates.
67 Elastomeric bearing pads; short spans--expansion felt or 90-lb paper.

If girder end rotation--separate from joint rotation--is not allowed (integral or semi-integral construction) do you assume and take into consideration joint rotation due to flexing of the abutment piling and pier piling

m) for steel structures?

| Yes | 7 |
| No  | 9 |
| Blank | 30 |

Comments

16 By judgment.
20 If end bent is too stiff, a hinge is provided; similar hinge top and bottom for very short end columns.
26 Bearings allow for rotation.

n) for concrete structures?

| Yes | 14 |
| No  | 7  |
| Blank | 25 |

Comments

For voided slab spans on occasion.
By judgment.
If end bent is too stiff, a hinge is provided; similar hinge top and bottom for very short end columns.
Bearings allow for rotation.
Questions 3(m) and (n) continued.

37 Pier or pile bents designed to deflect.
44 Used symmetrical span arrangement and elastomeric bearing at pier.
47 Assume flexing of the piling.
49 Assume flexing of the piling. Piling is assumed to rotate at abutments.
54 Moments and rotations are calculated based on an assumed pile fixity position.
59 Moments and rotations are calculated based on an assumed pile fixity position.
61 Girders end rotation is assumed to occur by flexing of piling.
62 Use on steel is very infrequent.
63 Neglect for the small spans used.
67 Generally not; we have with deep curtain walls.

4. What limitations do you impose with respect to flexibility and type of substructure—e.g., pile materials, L/r ratios, cast in place substructures on spread footing, backfilling techniques, preboring, etc., for integral or semi-integral type of construction

a) for steel structures?

11 Use limited number of pile bent piers.
12 Use limited number of pile bent piers.
13 Have not used them for abutments or short, stout columns.
14 Pile cap bents--15 ft maximum exposed pile length.
15 Pile cap bents--15 ft maximum exposed pile length; insure pin connection at bottom of interior bent (voided slab).
16 Use battered piling or drilled shafts for lateral stiffness for both steel and concrete structures (except slab spans).
20 For integral abutments, we would require piling, or flexible hinged columns--some flexibility.

b) for concrete structures?

L/D = 20 maximum.
Use limited number of pile bent piers.
Have not used them for abutments or short, stout columns.
Pile cap bents--15 ft maximum exposed pile length; insure pin connection at bottom of interior bent (voided slab).
Use battered piling or drilled shafts for lateral stiffness for both steel and concrete structures (except slab spans).
For integral abutments, we would require piling, or flexible hinged columns--some flexibility.
Questions 4(a) and (b) continued.

24

27 Limited to column bents and abutments on single row of piles.

42 When piers of sufficient height to cause minimal horizontal forces due to thermal movement.

44 Flexibility of pile material—we use 12 in. CIP, 40 ton capacity. Piles prebored to bottom of fill at abutment, granular material backfill (compacted in place); piers are either pile supported or on spread footing.

46 Keep down resistance to movement (earth pressure) by use of corrugated sheet metal and styrofoam on abutment backwall.

47 Steel and timber piling only; prebore through embankment; backfill after deck is in place.

48 Select granular backfill; pre-boring for 10 ft minimum and backfill with sand. We use steel piling oriented as shown in your detail, although we do allow timber piles also.

53 Integral and Semi-Integral types not used for steel structures.

54 Structural integrity must be maintained, taking into account all of the above factors.

55 Abutments on steel piling only.

56 Vertical piles, columns, and spread footings designed for movement.

Minimum of 20 ft piles for end bents.

Limited to column bents and abutments on single row of piles.

Cast in place substructure on spread footing limited to square structures where integral construction is used.

Use prebored holes for piling.

Flexibility of pile material—we use 12 in. CIP, 40 ton capacity. Piles prebored to bottom of fill at abutment, granular material backfill (compacted in place); piers are either pile supported or on spread footing.

Steel and timber piling only; prebore through embankment; backfill after deck is in place.

Select granular backfill; pre-boring for 10 ft minimum and backfill with sand. No restriction on pile type.

Single row of piling at abutments—column type piers.

Single row of piling used.

Structural integrity must be maintained, taking into account all of the above factors.

Abutments on steel piling only.

Vertical piles, columns, and spread footings designed for movement.
Questions 4(a) and (b) continued.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>61</td>
<td>Integral end bents to date have been pile supported for reasonable flexibility. Supporting data to justify the use of integral end bents for long spans are not extensive enough to formulate any definite standards for future construction.</td>
</tr>
</tbody>
</table>

| 62 | Infrequently used. |
| 63 | No limitations established. |
| 65 | If pile footing, use single row embedded 1 ft into concrete. Use concrete key if on spread footing. |
| 67 | **H** piles or 15-in. maximum piles; one row of piles or two rows with small torsion arm; piles 20 ft or longer; ordinary backfill (some yielding). |
| 68 | **H** piles or 15-in. maximum piles; one row of piles or two rows with small torsion arm; piles 20 ft or longer; ordinary backfill (some yielding). Substructure flexible enough to satisfy AASHO Group IV loading. |

5. What objections, if any, do you have to the above method referred to in questions 1 and 2.

<table>
<thead>
<tr>
<th></th>
<th>a) for steel structures?</th>
<th>b) for concrete structures?</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>None at this time when within skew limits.</td>
<td>None for appropriate cases; some judgment is required.</td>
</tr>
<tr>
<td>20</td>
<td>None for appropriate cases; some judgment is required.</td>
<td>We use expansion bearings at abutments to eliminate earth pressure stresses being induced into girders.</td>
</tr>
<tr>
<td>21</td>
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<td>Does not allow for expansion or rotation.</td>
</tr>
<tr>
<td>26</td>
<td>Does not allow for expansion or rotation.</td>
<td>None when used within limitations established by above answers.</td>
</tr>
<tr>
<td>27</td>
<td>None when used within limitations established by above answers.</td>
<td>Areas of structural distress may be more prevalent.</td>
</tr>
<tr>
<td>33</td>
<td>Areas of structural distress may be more prevalent.</td>
<td>Not enough freedom for structure to &quot;breathe&quot;.</td>
</tr>
<tr>
<td>36</td>
<td>Not enough freedom for structure to &quot;breathe&quot;.</td>
<td>Not enough freedom for structure to &quot;breathe&quot;.</td>
</tr>
</tbody>
</table>
Questions 5(a) and (b) continued.

42 Our present method of using rollers has not been a source of trouble.

44 None--except for the expense of approach slab currently used.

45 Induced stresses.

46

49 Actual movement of steel structures is normally much greater than movement of concrete structures.

51 Method not usually considered advantageous.

53 Suitable for short structures or one span of series only (Type I).

54 None, so long as stiffnesses are properly accounted for.

61

64 Thermal effects in most of the state are too great.

65 Uneconomical and approach surfacing problems.

67 On skew bridges, ends of bridge creep sideways; approach embankment settlement or movement; generally do not use approach slabs.

6. What problems, if any, have you encountered when the method referred to in questions 1 and 2 was used

a) for steel structures?

12 Non-Integral abutments tend to move. Also, maintenance of expansion device.

16 Fill settlement causes distress.

b) for concrete structures?

12 Non-Integral abutments tend to move. Also, maintenance of expansion device.

16 Fill settlement causes distress.
Questions 6(a) and (b) continued.

25 Concrete cracking around beams from live load deflection.

26 Joint between approach slab and end of bridge soon leaks and washes out fill under approach slabs.

37 Short piers present design problems due to their lack of flexibility for Semi-Integral or Integral connections to continuous superstructures, or for multiple simple spans using these connections at both ends.

42 No trouble since ends are allowed to rotate and/or expand. In a location which involved a 200 ft span and a very stiff pier, (low 1/r) the pier stem cracked badly. This involved both ends of the span becoming fixed. A conclusion would be to limit the 1/r not to maximum, but rather to a minimum value.

45 Spalled concrete in end-beam web.

47 When Semi-Integral, dowel bars should be placed in center of abutment wall. Dowel bars did crack the wall when placed only 3 in. from face.

48 None with steel piling. Some trouble in construction with timber piling (please see Item 7, Geographical Area 4).

49

51

53 Movement of end bent--forcing closure of expansion joints at other locations.

56 Cracking of wingwalls.

Joint between approach slab and end of bridge soon leaks and washes out fill under approach slabs.

None for moderately short spans.

When Semi-Integral, dowel bars should be placed in center of abutment wall. Dowel bars did crack the wall when placed only 3 in. from face.

Cracking of end diaphragms on structures skewed more than 20°.

Some cracking in endwalls; nothing serious.
Questions 6(a) and (b) continued.

62 Asphalt concrete approach fills appear to settle more than at conventional structures.

64 Some settlement of roadway embankment and continual cracking of roadway surfacing.

67 Skewed bridges have rotated, and are rotating; abutment movement; girder web vertical cracks or checks (reason uncertain at present).

68 Soil erosion where superstructure contracts away from backfill.

7. Additional comments and suggestions.

Geographical Area 1.

11 We have heard of the suggestion of using the Integral cap for long span steel structures. We wonder about the problem of movement of the earth fill. It seems that this would present a problem.

12 As indicated, it has been our practice to use monolithic construction on nearly all of our reinforced concrete structures until they get of such length we consider expansion too great. This includes monolithic construction between the superstructure and abutments, and the piers. We have used rocker type expansion devices when overall length gets beyond approximately 500 ft.

While we normally use some type of bearing devices in our steel construction, we are moving more and more to trying to cast the abutment in with the ends of the girders. This is an attempt to try to reduce maintenance costs resulting from abutment movement and backwall failures. However, structures much over 200 ft in length are normally placed on some type of bearing devices.

It is hoped your study will give us additional information relative to stresses created due to expansion and just how critical these are. We realize monolithic construction does carry sometimes relatively high moments; however, these do not seem to give us any structural failure problems.

Whenever possible we use Integral abutments on concrete structures. This gives us a maintenance saving. We have
Question 7 continued.

experienced no settlement problems, but occasionally a wing wall will crack.
Separated abutments means maintenance problems. Cracking of backwalls is common. Having to re-set bearing devices is common. De-icing agents leaking through expansion joint is always a trouble generator.

13 The fixed pier is new with us and as yet none have been built. We are building some at the present time and will know more about the problems involved in a couple of years.

14 Integral type of construction is not used for steel structures.
Use of Semi-Integral construction for concrete structures was discontinued in January, 1972. Non-Integral type of construction for concrete structures is not used currently.

15 We have not used this type of construction because of the unknowns as to restraint in the bridge. We do not believe the stresses predicted in the bridge are very reliable. We have used the Integral type construction on concrete rigid frames only.

16 Practically all of our abutments look like the "Non-Integral" section except piling are battered opposite directions 3:12 in pairs or 30-in. diameter straight drilled shafts are used. Continuous steel units are usually expansion with rocker shoes at abutments. Continuous concrete units are usually expansion with neoprene bearings at abutments. Simple spans are usually fixed but not Integral at abutments with expansion joint and bearing at the first interior bent. Concrete slab bridges usually rest directly on the cap, either fixed or expansion with roofing felt and graphite--some are even Integral. These abutments, being short of height, usually have vertical piling. Our abutments are designed for vertical superstructure loads and lateral soil pressure with no horizontal resistance counted for the superstructure--except for slab spans which are designed for vertical loads only. Fill settlement is not accounted for numerically in the abutment design, but does in fact cause distress in many of our abutments.

Geographical Area 2.

20 In general, we prefer Integral abutments and piers whenever feasible in continuous concrete or prestressed concrete structures, and this practice is now the rule rather than the exception. We have less experience with this type of construction in connection with steel superstructures, but we are considering this alternative in connection with various structures in the planning stages. We have
occasionally used Integral backwalls and wingwalls supported on steel girders where free cantilever end spans are used. This type of construction has to be used with good judgment. We have used fixed bearings (permitting rotation) for continuous steel girder bridges on tall piers, with spans up to 220 ft and units up to 780 ft between expansion bearings. We have used piers Integral with concrete box girders with spans up to 100-115 ft and in unit lengths up to about 400 ft between expansion joints. We would not use Integral abutments of low height founded on rock, without positive provision for expected movements. We give consideration, without attempting rational analysis, to such forces as friction between earth and wingwalls, inertia of long wings, etc. We need criteria for passive earth pressure against backwalls when the bridge expands. Need better criteria for effects of shortening of long post-tensioned bridges due to prestressing. Would find useful the publication of suggested details for Integral and Semi-Integral construction, including cantilever end spans.

21 It is our feeling that any deflection of the abutment due to earth pressures would induce additional stresses in the girders of the superstructure. This may be insignificant but this is the method we prefer.

22 We have used this on only a very limited number of structures. Not enough experience to answer this questionnaire. Basically they are built without considering any added stresses.

23 Our Bridge Design Division has never used this type of construction, so we are unable at this time to complete your questionnaire. We are studying the problems of induced stresses which result from this type of construction and plan to design three continuous steel superstructures with Semi-Integral or Integral abutments in the near future.

24 We have presently used all three conditions referred to on both poured-in-place concrete and prestressed, precast concrete bridges continuous over interior supports. We have designs under way with steel bridges with Semi-Integral end bents, but we have not constructed any at this date.

25 We primarily use the Semi-Integral type with a 40-ft simple span prestressed beam placed on a neoprene pad. The other end of the beam is placed on a neoprene pad which provides for expansion. On our continuous structures we provide a joint and bearing assembly to provide for rotation and translation on a Non-Integral type end abutments. Our normal end abutment for spans above 40 ft is Non-Integral with provision made for translation and rotation.
26 In recent years we have constructed both steel and concrete beam structures up to 300 ft in length with no provisions made for expansion in the bridge between superstructure and substructure. We have always provided for rotation of the beams with the curved sole plates as indicated on our sketch. We have also constructed structures up to 300 ft in length with expansion slots in the beams at the end bent bearings allowing the superstructure to expand against the approach fills. We are now trying to evaluate the effects of both of these types of construction after a few years of service under those conditions.

For continuous structures over 300 ft in length we have always used the Non-Integral condition similar to that indicated on your sketches. We are also presently using this type detail for most continuous structures regardless of length.

For simple span bridges our standard practice is to fix the beam or abutment and allow expansion at the opposite end of the beam.

27 We have been using this method of construction for some time and are well satisfied with the performance of the structure. Without question, our own design philosophy could be challenged; however, the structure meets the best test we've been able to come up with: it works.

28 I find it difficult to fill out the questionnaire itself because we have made very limited use of this procedure. We have occasionally used flexible piers with continuous spans but not flexible abutments except for a few concrete frames which are in a different category.

I see no objection to the use of either concrete or steel spans continuous being anchored to the abutments without provision for expansion provided the crossings are approximately square (no skew). We have actually built a few such bridges using continuous slab spans with initial expansion joints at abutments which, being small, quickly closed leaving no expansion provision within the structures.

With respect to steel expansion spans and especially those shown in your sketches as Semi-Integral or Integral, we do have serious objections. We have had too many cases of structural steel members projecting into and embedded in concrete walls and in such cases have had very considerable rusting of the steel at the point where it enters the concrete. If we were to use either of these designs, we feel we would have to provide for adequate protection against corrosion at this point and this detail we have not yet solved.

In general, I believe that the use of spans without interior provision for expansion can be successfully used with lengths up to several hundred feet provided they are not skewed. If the structures are skewed, provision would have to be made
Question 7 continued.

for preventing sidewise movement and related high stresses
due to the transverse component between bridge and approach
roadway slab.

Geographical Area 3.

31 In many instances, we have used flexible pile bent piers with
no expansion type devices. However, we have not, to date,
used abutments of this type.

32 We do not use any of the types noted in this Questionnaire.
At present we are dubious of their efficiency stress-wise
and in prevention or containment of water seepage at the fill
side of backwall.

Geographical Area 4.

41 In our state, we have used this type of construction very
sparingly--only on steel spans no longer than 45 ft and on
continuous concrete slab structures up to 100 ft over-all.
We therefore have limited applicable experience in their
design.

42 We have not constructed any steel beam structures with the
beam ends Integral or Semi-Integral with the abutments.
However, we have constructed continuous reinforced concrete
slab bridges with all pile bent caps Integral with the slab.

44 At each end of our structure we have incorporated a special
approach slab (13 ft long) which terminates at a reinforced
neoprene expansion joint. The road pavement also terminates
at this joint.
We have used Bituminous Pavement on the approaches for flexi-
bility because of settlement due to movement at abutment.
Some short structures have been constructed without special
approach slabs.

48 We had some trouble in construction with timber piling. In
this case we poured a sill similar to your Semi-Integral with
anchor bolts for the beams. Once the beams were set the
remainder of the abutment was poured and the abutment was
integral. One problem we had was that the anchor bolts were
set so that the beams would readily fit between temperatures
of 30° F and 100° F. The contractor tried to erect at -20° F
and needless to say the beams wouldn't fit. In another anchor
bolt type design by a consultant a temperature drop broke the
concrete in front of the anchor bolts as they had very little
concrete cover. We are working on new details for Integral
Question 7 continued.

Abutments for timber pile situations which we feel will eliminate the problems we have experienced.

49 Steel superstructures are rarely used in the span range where the fixed type of structures are used. The greater expansion and contraction of steel would restrict their use to overall length of approximately 150 ft, instead of the 300 ft we use with concrete. We use a temperature range of 150° for steel but only 85° for concrete.

Geographical Area 5.

51 In general, I am not opposed to the use of Type II or III abutment configurations for concrete bridges of moderate total length (say 300 ft). We seldom have occasion to use these abutment configurations for steel bridges because most of our steel bridges are of relatively long (100 ft or over) span and requirements for taking the expansion of steel bridges are more rigorous than for concrete bridges.

54 Many concrete slab structures are built in this state utilizing the Type III detail. A number of composite plate girder spans have used a detail similar to Type I. On many structures, however, we are using a back wall attached to the girders but an elastomeric pad between the girder and the supporting pile cap to allow some expansion motion.

56 The use of structures without specific provision for expansion is subject to considerable discussion and care is necessary in certain details such as wingwalls on abutments. The reduction in maintenance by elimination of expansion joints and bearings is welcome.

When designing locked-up superstructures every effort is made to keep substructures flexible. Backwalls are designed for passive earth pressure due to various movements. After the . . . earthquake in 1964 massive soil movements at abutments locked-up many of our bridges including some long span trusses. To date we have not noted distress in these structures. Wingwall cracking on wings parallel to roadway was experienced on first designs. Rotation soil friction and possibly freezing was more severe than expected. More reinforcement seems to have solved this problem.

Geographical Area 6.

62 We have not used the Non-Integral and Semi-Integral abutment types as detailed. Our use of these types has been limited to abutment footings with more than one row of piles to
provide rotational stability. On expansion end abutments some of the piles are battered.

65 We very seldom use this type of structure (Integral construction); we use positive expansion devices for multiple spans.

67 For short to moderate length bridges with no or moderate skews we have not seen any problems. On one bridge, approach has settled 3 in. \( \pm \) in 5-10 years after construction with resultant settlement of corners of bridge. Some low spots in approaches at end of bridge. Possibly worse on skewed bridges. Curb lines out of line from 1 in. on 125-ft 2-span skewed 4-year old bridge to 3 in. \( \pm \) on 400-ft long 5 to 6-span skewed bridge.