Skewed Bridges and Girder Movements
Due to Rotations and Differential Deflections

by

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INTRODUCTION

This paper discusses rotation and deflection issues that must be addressed to properly design and construct highly skewed steel bridges. The degree of skew, the differential deflections of the adjacent steel members at intermediate crossframe locations and the displacement of the top flange relative to the bottom flange at the bearings may significantly impact the final bridge geometry. The owner, designer, detailer, fabricator, erector and contractor must each understand the impact of their decisions regarding deflection issues on the overall project.

Some information contained herein is excerpted direct from the document AASHTO/NSBA Steel Bridge Collaboration document G 12.1-2003 "Guidelines for Design for Constructibility" hereinafter the "AASHTO/NSBA Constructibility Guide" and this information is shown in italics.

DEFINITIONS

- No-load fit: – members detailed for field assembly as though no dead load, including self weight, acts on the structure, with the girder webs vertical when the crossframes are installed. The steel's self weight and the deck weight may both subsequently distort the webs.
- Steel dead load fit or steel-load fit: – members detailed for field assembly with the girder webs vertical when the crossframes are installed and the steel self-weight, but not the deck load, is acting on the girders. The deck weight may subsequently distort the webs
- Full dead load fit: - members detailed for field assembly so the webs will become vertical after the full non-composite dead load of steel and concrete is applied to the girders. Crossframes are installed with the steel positioned to anticipate subsequent deflections, so girder webs will not be vertical at that time.
- Differential deflection – the difference in relative displacement between either end of a member (e.g., crossframe) or adjacent members (e.g., girders) at a common location in a structure (e.g., midspan). This usually refers to vertical movement but could also include lateral or angular motion.
- End crossframes: – the crossframes or diaphragms at the supports of either simple span or continuous span bridges. The application for continuous spans applies if the crossframes at the supports are skewed parallel to the piers.
- Intermediate crossframes: - the crossframes or diaphragms at locations other than at the supports.

ISSUES

The principle issues involve the design, detailing, and erection of the intermediate and end crossframes on skewed bridges with differential deflections within the spans and girder rotations at supports. As various dead loads are applied, rotations may result in the girder flanges moving transversely and longitudinally. Fundamentally, the designer must decide: should the members be detailed for the 1) no-load fit condition, such that the girder webs are theoretically vertical as though no dead load has been applied, 2) steel dead-load fit, such that the girder webs are theoretically vertical when the crossframes are installed, or 3) full dead-load fit, such that the girder webs will become essentially vertical in their final condition after the non-composite dead load is applied?

GIRDER MOVEMENT AT SKEWED PIERS AND ABUTMENTS

General Considerations

Appendix A describes a model bridge that was constructed and tested to confirm the assumptions and concepts relating to girder movements associated with end crossframes at skewed supports.

The anticipated movement of the top and bottom girder flanges at skewed supports must be addressed by the designer, fabricator, erector, and contractor. End crossframe may significantly effect differential deflections of the girders at the intermediate crossframes.

Per the AASHTO/NSBA Constructibility Guide: *The problem for crossframes at skewed piers or abutments is the rotation of the girders at those locations. In a square bridge, rotation of the girders at the bearings is in the same plane as the girder web. If supports are skewed, girder rotation due to non-composite loads will be normal to the piers or abutments. This rotation displaces the top flange transversely from the bottom flange and causes the web to be out of plumb.*

The source for the above movement is the end crossframe trying to maintain its original shape. If the end of each girder rotates equally in the plane of its web, the end crossframe must change shape i.e - a rectangle must become a parallelogram, but would remain planar. However, unless the end crossframes permit this distortion due to their design details or unforeseen events, they will retain their initial geometry except for possible out-of-plane (weak axis) twisting.

As noted in Appendix A, the model behavior confirms the assumption in the AASHTO/NSBA Constructibility Guide that the *rotation displaces the top flange transversely from the bottom flange and causes the web to be out of plumb.* Though it is not stated in the Guide, this is true for the general case where the end crossframes are connected and bolts tightened prior to applying the dead load. This issue will be addressed later in this document.

Additionally, the Guide also states *If supports are skewed, girder rotation due to non-composite loads will be normal to the piers or abutments*. "Normal to the piers" does not exactly describe the rotation. This and concerns relating to bearings will also be covered in this document.

The discussion is applicable to both simple span and continuous span bridges where the end crossframes (or pier crossframes) are skewed parallel to the pier.

Girder Rotation Due to Dead-load Deflections

Note – Figures 1A, 1B, and 1C show a simple span girder with top and bottom flanges that are the same size, and the neutral axis is mid depth of the web. Where the top and bottom flanges are different sizes, corrections to the lengthening and shortening of the flanges as well as the transverse movements shown in Figures 1B and 1C should be calculated based on the actual flange dimensions. Also consider that girders continuous over two or more spans would probably not have the same rotations at each support.

The movements of parallel girders at supports on a straight, non skewed bridge are predictably uniform. Girders are usually fabricated with a camber such that after the total predicted dead-load deflection has occurred, the bridge will assume its intended profile. Figure 1A shows this condition for a simple span bridge. After the girders have deflected, the bottom flange will have lengthened by an amount based on the size of the bottom flange and the top flange will have shortened by an amount based on the size of the top flange. The ends of the girders (or the bearing locations on continuous bridges) will rotate to accommodate these length changes. Calculations herein are based on the assumption that the bottom flange at the fixed bearings will remain in its initial position while the bottom flange at the expansion bearings will move longitudinally by an amount R (based on same size top and bottom flanges.) The top flange at the fixed bearing will move by amount R while the top flange at the expansion bearing will remain in its initial condition. If the bearings are floating, meaning that there is no fixed or expansion bearing, the assumed longitudinal movements of the bottom flanges at each of bearings are be outward by an amount equal to 1/2 R and the assumed longitudinal

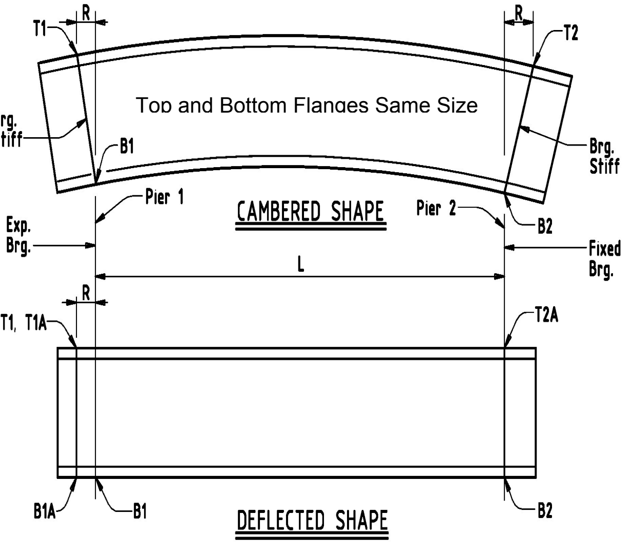


Figure 1A

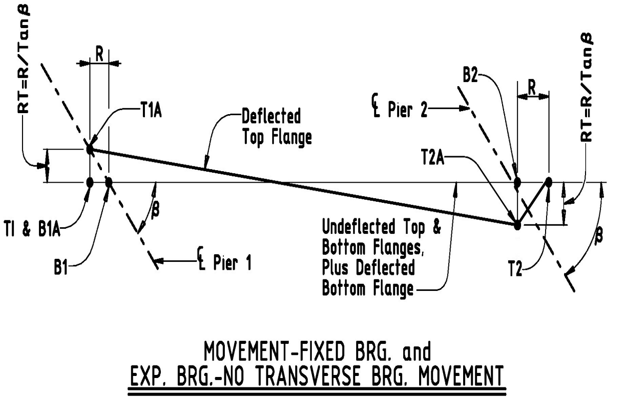


Figure 1B

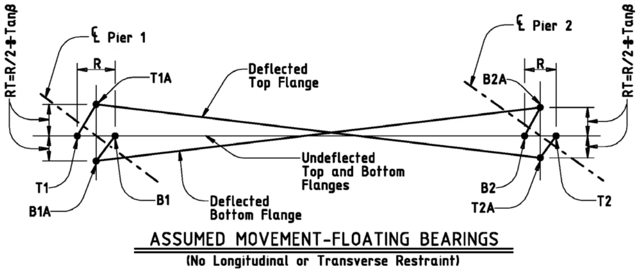


Figure 1C

movement of the top flanges at each of the bearings will be inward by an amount 1/2 R. These are assumed possible movements to show potential problems and may vary depending on restraints provided by the bearings.

For girders on skewed supports the movement becomes more complex. Refer to Figures 1A, 1B, and 1C. In this paper, R is the to computed longitudinal movement of the top flange relative to the bottom flange due to dead-load deflections; RT is the transverse movement due to movement R; β is the compliment of the skew angle; B1, B2, T1, and T2 are the undeflected locations of the top and bottom flanges; B1A, B2A, T1A and T2A are the rotated or deflected positions of the top and bottom flanges.

The actual movement of the girder top flange and bottom flange due to the girder rotation from its dead-load deflection becomes somewhat complicated. As noted above the AASHTO/NSBA Constructibility Guide states that the girder rotation will be normal to the piers. This generalization is true for certain conditions and incorrect for others.

As previously stated, the end crossframes will maintain their axes of rotation along the actual centerline of bearings (intersecting each bearing's center of rotation in the full dead load condition). If the bearings at a given support are at the same elevation, the axis of rotation will be horizontal and the rotation of the end crossframes will be normal to the pier. The transverse movement of the top flange (RT) with respect to the bottom flange is RT = R ÷ Tan β.

If the girders are not at the same elevation, the axis of rotation will be in the plane including the actual centerline or bearing, but slope to intersect the centers of rotation at adjacent bearings. For that situation, theoretically the Tan β term in the above equation would need to be modified by adding or subtracting the slope angle to the angle β depending on the direction of the slope [RT = R ÷ Tan (β ± θ) where θ is the slope of the bearing points]. In many cases this correction will not appreciably effect the actual movement and the correction may be ignored. The worst case should however be checked to determine the potential for error.

If the slope between bearings is 2% (1.15°), for an angle β between 60° and 20°, the RT dimension will be in error of 4% to 6.5% if the modification to the angle is not made. If the slope between bearings is 4% (2.3%), for an angle β between 60° to 20°, the RT dimension will be in error of 7.5% to 12.5%.

Additionally, if the expansion bearing is restrained against transverse movements, the rotational axis will also move longitudinally. Also, when relative elevation differences between adjacent bearings vary across the structure due to changing deck cross slope, the adjustment will differ and effects may compound.

For a fixed bearing (no longitudinal or transverse movement), the bottom flange does not move and the top flange moves normal to the centerline of the pier (See Figure 1B, Pier 2.) For a floating bearing (longitudinal and transverse movement allowed), both flanges move normal to the pier (see Figure 1C, Piers 1 and 2). The relative transverse movement of the top flange relative to the bottom flange in both cases is theoretically RT = R ÷ Tan β.

For an expansion bearing where transverse movement is prohibited, the bottom flange moves longitudinally while the top flange moves transversely (see Figure 1B, Pier 1). The transverse movement of the top flange relative to the bottom flange again is RT = R ÷ Tan β.

Note that in the two preceding paragraphs, no correction was made in the Tan β term to account for differences in elevation. Also note that the movements described above reflect how the members will try to move within the bridge system; actual movements will vary since the members are framed together and some distortions will result. Other factors such as the restraint provided by the deck forming materials, bearing design and restraint, and other unknown factors likely cause a variance in any or all of the assumptions made herein.

Addressing the Issues

The transverse movement of the top flange with respect to the bottom flange can significantly affect construction and the out-of–plumb condition at the bearings needs to be addressed by the designer. This out-of-plumb condition may complicate the situation at intermediate crossframes with differential deflections that also to be considered.

If a 5' deep girder's top flange moves 1" due to end rotation and the skew angle is 60° (β = 30°), the transverse movement of the top flange would be RT = 1 ÷ Tan 30° or 1.73" or 1 3/4". The designer needs to determine whether this out-of–plumb is acceptable and if not, how to deal with it. Additionally consider that the situation at the bearings will affect the intermediate crossframes.

There are several potential approaches to deal with the issues. One would be to verify that the out-of-plumb of the girders at the supports is acceptable and do permit it. This would entail detailing the end crossframes for the No-load fit or the Steel dead-load fit, and allowing the girders at the bearings to be out-of-plumb after final dead load is applied. The bearings must be able to accommodate the final transverse and longitudinal slope of the bottom flange.

A second method would be to detail the girders and crossframes (end and intermediate) so that after the steel and deck dead load is applied, the girders will be plumb. This requires the designer to accurately compute the deflections and movements, including girder and end crossframe rotations, and internal stresses caused by the temporary and final conditions, and show those on the design drawings so the contractor can detail the member's configurations and connections and erect them accordingly. Intentionally fabricating a girder with a specified twist is difficult and erecting a distorted structure may be expensive.

A third possibility is to not use end crossframes at such skewed piers. The stability of the bridge at all stages of construction and loading needs to be investigated. One recently constructed bridge with a simple span of

242' and a 64° skew was designed and constructed without end crossframes along the piers. The first crossframe was normal to the girder at the bearing of the first interior girder connecting to the adjacent girder 20'+ into the span.

A fourth option would be to design the end and intermediate crossframes and their connections so that the girders can rotate in the original plane of the web.

Other Issues

The movements described above need to be considered in the design and detailing of the bearings. The transverse rotations at the bearings will tilt the flanges and the bearings must accommodate this. There also may be transverse movement permitted at the bearings and the design details must accommodate it. Additionally, if bearings restrain girders against longitudinal and/or transverse movements, the flange tilt may cause problems with the bearing mechanism, especially for steel-on-steel rockers.

Another question for the designer: Will there be problems with deck joint expansion devices, particularly where adjacent spans bear on a common pier and girder motion may be in opposite directions?

One former state highway official indicated that skewed bridges tend to "walk", i.e. permanently change position on the substructure. This suggests the magnitude of forces associated with live and dead load deflections in this situation, and the potential for damaging transverse movements after the bridge is complete. The designer must consider the potential problems and incorporate features to resist them.

INTERMEDIATE CROSSFRAMES

Intermediate crossframes on skewed structures are thoroughly discussed AASHTO/NSBA Constructibility Guide so this report will briefly summarize the recommendations in that document.

Without restraint, there will be natural differences in dead load deflections at opposite ends of crossframes placed normal to girders on skewed structures. As the skew angle increases, those potential (unrestrained) differences in relative deflections (differential deflections) increase and must be addressed by the designer, the fabrication detailer and the erector. The magnitude and possible effects of differential deflection between girders at crossframe locations needs to be quantified and decisions made as to whether the intermediate crossframes are to be detailed and erected to meet the no-load fit, steel dead-load fit, or the full dead-load fit. (See Figure 1.6.1.B)

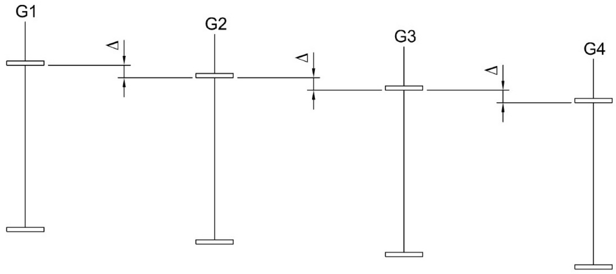
The performance of thousands of steel bridges has demonstrated that differential deflections typically do not cause problems (although out-of-plane bending on webs can cause fatigue problems if diaphragms are attached to webs instead of flanges). Differential movement between adjacent members becomes a significant concern in certain types of structures (small radius curves, high skews, cantilevers, etc.), and greater deflections may occur with the use of smaller members in conjunction with new design code criteria.

In design, evaluate the effects of differential deflections and girder rotations (transverse and longitudinal) that may result for skewed bridges, curved bridges, or staged construction. Consider such effects in bearing design

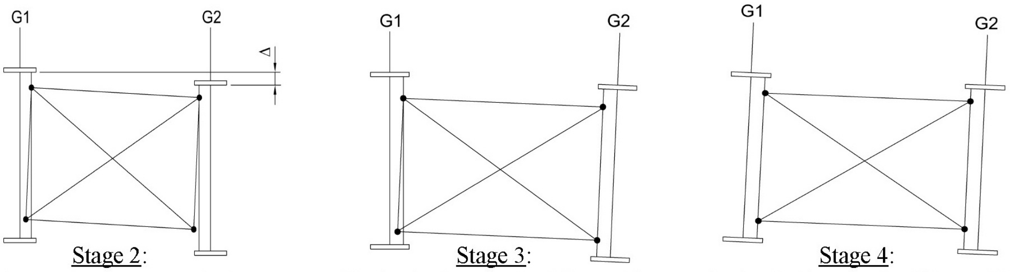
Consider the need to show on the plans how members are to be detailed and fabricated, including the condition under which the diaphragms should fit (for no-load fit, full dead-load fit, or some condition in between, such as under the steel dead load but without the deck).

If the girders are required to be plumb under full dead load or steel dead load, address the expected rotations anticipated under the applied dead load. Recognize, however, that the anticipated rotations are only a prediction and that actual rotations will likely be different, and therefore girders will be somewhat out-of-plumb.

If the full dead-load fit is specified, address in the erection framing plans or erection procedures, the magnitude of the rotations anticipated at crossframe installation and the temporary and final condition at the bearings.



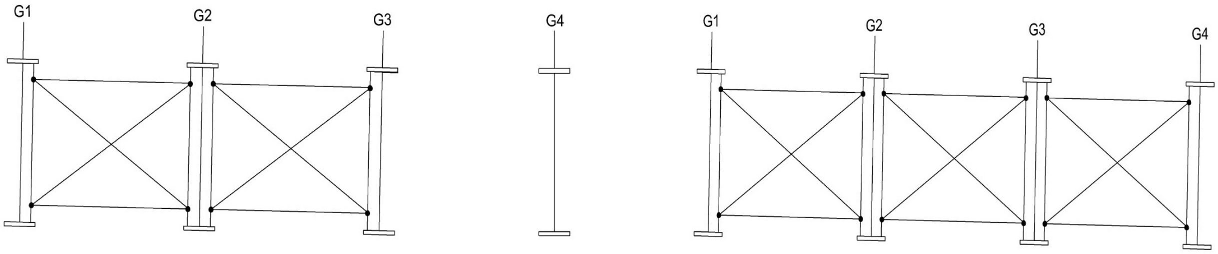
Stage 1:
Erected position prior to attaching crossframes



Stage 2:
Erect crossframes and pin top hole on each girder. Girders will remain in vertical position.

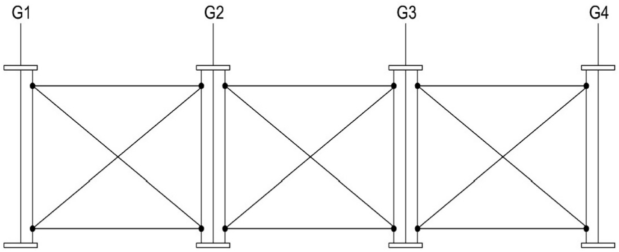
Stage 3:
Push bottom of G2 until stiffener hole lines up with crossframe hole.

Stage 4:
Push bottom of G1 until stiffener hole lines up with crossframe hole.



Stage 5:
Erect crossframe and pin top and bottom holes on G2. Pin top hole on G3, push bottom of G3 until bottom hole lines up.

Stage 6:
Erect crossframe and pin top and bottom holes on G3. Pin top hole on G4, push bottom of G4 until bottom hole lines up.



Stage 7:
Final position after full dead load is applied.

Figure 1.6.1.B

Crossframes normal to girders may be placed in-line for girders that have similar differential deflections between each pair of girders at the crossframe location, provided none of the crossframes with significant differential deflections connect close to a bearing location

For straight bridges, place crossframes either parallel to the skew or normal to the girders

if the deflection between girders is constant at crossframe connections and the skew angle is equal to or less than 20°. Otherwise place crossframes normal to the girders.

Cooperate with the fabricator, detailer, and erector to ensure proper geometry is achieved, especially if members are to be detailed in a condition other than "no-load" or if the girders are required to be plumb after erection.

ADDITIONAL COMMENT

AASHTO Specifications require that curved bridges have diaphragms or crossframes at the bearings. Eliminating end crossframes for that condition would be in violation of the specification.

CONCLUSIONS

The results confirm the assumption made in the AASHTO/NSBA Constructibility Guide that the ends of the girders on skewed supports do not rotate in a vertical plane parallel to the girder web. Though not stated in the document, the statement is true for the general case where the end crossframes are connected and bolts tightened prior to applying the dead load.

The ends of the girders will essentially rotate about an axis that runs through the centerlines of rotation at the bearings. When the girders are at the same elevation, the axis of rotation will be horizontal and the movement of the top flange with respect to the bottom flange will be in a vertical plane normal to the vertical plane containing the axis of rotation. If the calculated movement of the top flange relative to the bottom flange due to end rotation of the girder is R and the skew angle (the angle between the axis of rotation and a line normal to the girders) is α then the compliment of that angle is β, and the transverse movement of the top flange (RT) with respect to the bottom flange is $RT = R \div \tan \beta$ when the bearings are at the same elevation. See Figures 1A, 1B, and 1C. When the bearings are not at the same elevation, the axis of rotation becomes a sloping line and the rotation is in a plane normal to that axis. In that case $RT = R \div \tan (\beta \pm \theta)$ where θ is the slope, but small values of θ may be ignored without significant error.

The transverse movement of the top flange relative to the bottom flange results in the ends of the girders being out-of-plumb. This condition has a direct effect on the position (deflection, twist, etc.) of the girder webs at intermediate crossframes where there is also differential deflection between adjacent girders due to their relative locations in the span.

The designer must consider the issues relating to the movements caused by end crossframe rotations and differential deflections during the design phase. The designer, detailer, fabricator, erector and contractor need to understand the issues involved, and any action that may be required to address those issues.

Appendix A

End Crossframe Testing, Rotations and Movements

TESTING

A model bridge was constructed using poster board for the girder and end diaphragm elements. The purpose of the testing was to confirm concepts on how the ends of the girders move (translate and rotate) as a result of deflections due to dead load, thus intermediate crossframes were not included. Photos 1,2 and 3 show the model in various stages of girder end rotation.

To obtain measurable rotations by deflecting a beam of almost any size and/or material was very impractical and not an option for this test. The solution to the problem was to build the girders out of poster board and provide the girder end rotation by lowering one end of the bridge and keeping the other end at its original elevation.

The AASHTO/NSBA Steel Bridge Collaboration G 12.1 – 2003 Guidelines for Design for Constructibility reads - *The problem for crossframes at skewed piers or abutments is the rotation of the girders at those locations. In a square bridge, rotation of the girders at the bearings is in the same plane as the girder web. If supports are skewed, girder rotation due to non-composite loads will be normal to the piers or abutments. This rotation displaces the top flange transversely from the bottom flange and causes the web to be out of plumb.*

Justification for the above movement is based on the fact that the end crossframe will maintain its original shape. If the end of the girder were to rotate in the plane of the web, the end crossframe would need to change shape i.e. - a rectangle would need to become a parallelogram.

Testing Comments

1. Initially the girders at Pier 1(skewed pier) were at the same elevation as were the girders at Pier 2 (square pier).
2. The bearings at Pier 1 are expansion bearings with only longitudinal movement allowed. The bearings at Pier 2 are fixed with rotation possible, but not translation.
3. Several trials were necessary before the final three separate tests were conducted. The fragility of the measuring stations was an issue on one test. Uplift on line 1 at Pier 1 and line 3 at Pier 2 initiated unexpected results. The three sets of results shown in Tables 1, 2, and 3 are after the above problems were corrected.

MODEL

Photos 1, 2, and 3 show the details of the model. Essentially, the model is a simple span skewed bridge with the following characteristics:

- Pier 1 Skew Angle 45°; Pier 2 Skew Angle 90°
- Line 1 Girder 30" c/c bearings, Line 2 Girder 27" c/c bearings, Line 3 Girder 24" c/c bearings
- Girder spacing 3", Web depth 1 1/2 ", Top & Bottom Flanges 1/8" thick
- Total Depth of Girder 1 3/4", Distance from center line of rotation about the bearing to top of top flange 2 5/16"

TESTING PROCEDURES

The girders at Pier 1 and Pier 2 were initially at the same elevation. The girders at Pier 2 were subsequently lowered in 3/4" increments at elevations of -3/4", -1 1/2", -2 1/4", and -3". Readings of the longitudinal and transverse movements of the top and bottom flanges at Pier 1 were taken at each of the different elevations.

Each test was conducted 3 times and the measurements are reported as Test Numbers I, II, and III in the Tables.

RESULTS

See Tables 1, 2, and 3 for a tabulation of the results.

Thirty-six readings or the longitudinal and transverse movements were taken. The calculated longitudinal movements ranged from 1/16" through 9/32". Of 36 measured longitudinal movements, 26 were within 1/64" of calculated; 9 within 1/32" of calculated, and 1 at 3/64" of calculated.

The calculated transverse movements are the same as the calculated longitudinal movements; they ranged from 1/16" through 9/32". Of 36 measured transverse movements, 28 were within 1/64" of calculated, 6 within 1/32" of calculated, and 2 within 3/64" of calculated.

Photo 1

Photo 2

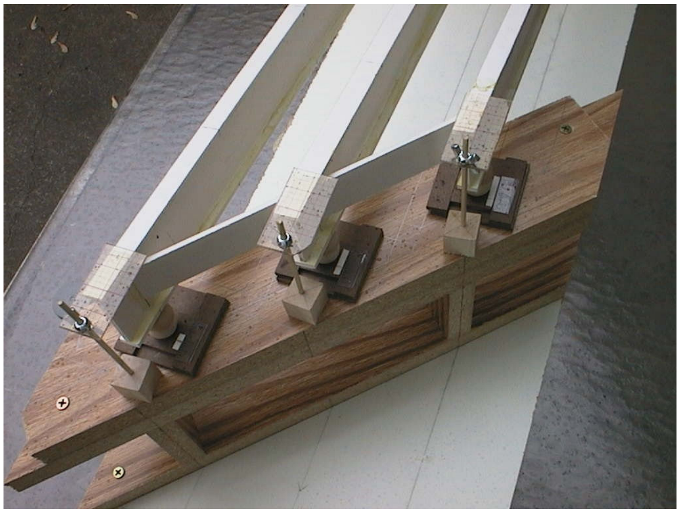


Photo 3

Table 1

		Change in Length											
	Δ, Brg Elev.	3/4"	3/4"	0 3/4"	1 1/2"	1 1/2"	1 1/2"	2 1/4"	2 1/4"	2 1/4"	3"	3"	3"
	Test Number	I	II	III	I	II	III	I	II	III	I	II	III
Line #	Calc/Act												
1	Calculated	0.0094			0.0375			0.0845			0.1504		
1	Actual	0.0156	0	0.0156	0.0312	0.047	0.0312	0.065	0.109	0.0781	0.1406	0.156	0.1562
1	Diff (Act-Calc)	0.0062	-0.0094	0.0062	-0.0063	0.0095	-0.0063	-0.0195	0.0245	-0.0064	-0.0098	0.0056	0.0058
1	Diff; Fractional	0	- 1/64	0	0	1/64	0	- 1/64	- 1/32	0	- 1/64	0	0
2	Calculated	0.0104			0.0417			0.0939			0.1672		
2	Actual	0.0156	0	0	0.0312	0.0312	0.0312	0.0469	0.0781	0.0625	0.1562	0.1562	0.1562
2	Diff (Act-Calc)	0.0052	-0.0104	-0.0104	-0.0105	-0.0105	-0.0105	-0.047	-0.0158	-0.0314	-0.011	-0.011	-0.011
2	Diff, Fractional	0	- 1/64	- 1/64	- 1/64	- 1/64	- 1/64	- 3/64	- 1/64	- 1/32	- 1/64	- 1/64	- 1/64
3	Calculated	0.0117			0.0469			0.1057			0.1882		
3	Actual	0.0156	0	0	0.0156	0.0156	0.0156	0.0156	0.0625	0.0625	0.1094	0.125	0.125
3	Diff (Act-Calc)	0.0039	-0.0117	-0.0117	-0.0313	-0.0313	-0.0313	-0.0901	-0.0432	-0.0432	-0.0788	-0.0632	-0.0632
3	Diff, Fractional	0	- 1/64	- 1/64	- 1/32	- 1/32	- 1/32	- 3/32	- 3/64	- 3/64	- 5/64	- 1/16	- 1/16

Table 2

		Transverse Movement of Top Flange at Center Line of Bearing											
	Δ, Elev. Of Brg.	3/4"	3/4"	3/4"	1 1/2"	1 1/2"	1 1/2"	2 1/4"	2 1/4"	2 1/4"	3"	3"	3"
	Test Number	I	II	III	I	II	III	I	II	III	I	II	III
Line #	Calc/Act												
1	Calc Movement	0.0578			0.1156			0.1734			0.2312		
1	Calc Fract Mvmnt	1/16			7/64			11/64			15/64		
1	Act Movement	0.0469	0.0781	0.0312	0.125	0.1406	0.1094	0.1875	0.1719	0.1719	0.25	0.2344	0.2344
1	Act Fract Mvmnt	3/64	5/64	1/32	1/8	9/64	7/64	3/16	11/64	11/64	1/4	15/64	15/64
1	Δ, Calc-Act Mvmnt	1/64	1/64	1/32	1/64	1/32	0	1/64	0	0	1/64	0	0
2	Calc Movement	0.0642			0.1285			0.1927			0.2569		
2	Calc Fract Mvmnt	1/16			1/8			3/16			1/4		
2	Act Movement	0.0625	0.0625	0.0469	0.0781	0.0469	0.125	0.2031	0.1875	0.2031	0.2344	0.25	0.2656
2	Act Fract Mvmnt	1/16	1/16	3/64	5/64	7/64	1/8	13/64	3/16	13/64	15/64	1/4	17/64
2	Δ, Calc-Act Mvmnt	0	0	1/64	1/64	1/64	0	1/64	0	1/64	1/64	0	1/64
3	Calc Movement	0.0723			0.1445			0.2168			0.2891		
3	Calc Fract Mvmnt	5/64			9/64			7/32			9/32		
3	Act Movement	0.0625	0.0625	0.0625	0.1094	0.125	0.125	0.1719	0.2031	0.1719	0.25	0.25	0.3125
3	Act Fract Mvmnt	1/16	1/16	1/16	7/64	1/8	1/8	11/64	13/64	11/64	1/4	1/4	5/16

3	Δ, Calc-Act Mvmnt	1/64	1/64	1/64	1/32	1/64	1/64	3/64	1/64	3/64	1/32	1/32	1/32

Table 3

Longitudinal Movement of Top Flange at Center Line of Bearing													
	Δ, Elev. Of Brg.	**3/4"**	**3/4"**	**3/4"**	**1 1/2"**	**1 1/2"**	**1 1/2"**	**2 1/4"**	**2 1/4"**	**2 1/4"**	**3"**	**3"**	**3"**
	Test Number	I	II	III	I	II	III	I	II	III	I	II	III
Line #	Calc/Act												
1	Calc Movement	0.0578			0.1156			0.1734			0.2312		
1	Calc Fract Mvmnt	1/16			7/64			11/64			15/64		
1	Act Movement	0.0625	0.0781	0.0469	0.1562	0.1875	0.1562	0.2812	0.2969	0.2656	0.3906	0.3594	0.4062
1	Act Chg Lgth	0.0156	0	0.0156	0.0312	0.047	0.0312	0.065	0.109	0.0781	0.1406	0.156	0.1562
1	Act Net Mvmnt	0.0469	0.0781	0.0313	0.125	0.1405	0.125	0.2162	0.1879	0.1875	0.25	0.2034	0.25
1	Act Fract Mvmnt	3/64	5/64	1/32	1/8	9/64	1/8	7/32	3/16	3/16	1/4	13/64	1/4
1	Δ, Calc-Net Mov	1/64	1/64	1/32	1/64	1/32	1/64	3/64	1/64	1/64	1/64	1/32	1/64
2	Calc Movement	0.0642			0.1285			0.1927			0.2569		
2	Calc Fract Mvmnt	1/16			1/8			3/16			1/4		
2	Act Movement	0.0625	0.0625	0.0781	0.1719	0.1562	0.1562	0.2344	0.2812	0.2656	0.4062	0.4062	0.4219
2	Act Chg Lgth	0.0156	0	0	0.0312	0.0312	0.0312	0.0469	0.0781	0.0625	0.1562	0.1562	0.1562
2	Act Net Mvmnt	0.0469	0.0625	0.0781	0.1407	0.125	0.125	0.1875	0.2031	0.2031	0.25	0.25	0.2657
2	Act Fract Mvmnt	3/64	1/16	5/64	9/64	1/8	1/8	3/16	13/64	13/64	1/4	1/4	17/64
2	Δ, Calc-Net Mov	1/64	0	1/64	1/64	0	0	0	1/64	1/64	0	0	1/64
3	Calc Movement	0.0723			0.1445			0.2168			0.2891 9/32		
3	Calc Fract Mvmnt	5/64			9/64			7/32					
3	Act Movement	0.0625	0.0938	0.0781	0.1562	0.1875	0.1562	0.25	0.3125	0.2969	0.4219	0.4375	0.4375
3	Act Chg Lgth	0.0156	0	0	0.0156	0.0156	0.0156	0.0156	0.0625	0.0625	0.1094	0.125	0.125
3	Act Net Mvmnt	0.0469	0.0938	0.0781	0.1406	0.1719	0.1406	0.2344	0.25	0.2344	0.3125	0.3125	0.3125
3	Act Fract Mvmnt	3/64	3/32	5/64	9/64	11/64	9/64	15/64	1/4	15/64	5/16	5/16	5/16
3	Δ, Calc-Net Mov	1/32	1/64	0	0	1/32	0	1/64	1/32	1/64	1/32	1/32	1/32

Notes:

1 - Items noted as Calc Movement are the computed rotational movement of the top flange relative to the bearing.

2 - Items noted as Calc Fract Mvmnt are the fractional value of the Calc Movement

3 - Items noted as Act Movement are the actual measurement recorded.

4 - Items noted as Act Chg Lgth reflect the actual change in length due to change in elevation of end of girders.

5 - Items noted as Act Net Mvmnt are the actual measured movement minus movement due to the change in length

6 - Items noted as Act Fract Mvmnt are the fractional equivalent of the item directly above it.

7 - Items noted as Δ, Calc-NetMov are the differences between the measured values and the computed values for the movement of the top flange.