EXPERIMENTAL DETERMINATION OF REQUIRED LATERAL RESTRAINT FORCES FOR Z-PURLIN SUPPORTED, SLOPED METAL ROOF SYSTEMS

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Thesis submitted to the faculty of
Virginia Polytechnic Institute and State University
In partial fulfillment of the requirements for the degree of

Master of Science

In

Civil Engineering

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July, 2001
Blacksburg, Virginia 24061

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(ABSTRACT)

Supplement No. 1 to Section D3.1 of the 1999 AISI Cold-Form Specification contains the current provisions for predicting required lateral restraint forces in Z-purlin supported, sloped metal roof systems under gravity loads. A proposed prediction equation, relying heavily on engineering principles, has been developed because the current provisions in the specification are empirical and based on statistical analysis. The provisions treat roof slope and system effects incorrectly, which necessitates refinement. Also, an assumed roof panel stiffness value was used for the development of the current design provisions, ignoring the effect that varying stiffness values have on the required restraint forces.

To determine the validity of the new restraint force prediction equation, experimental testing was conducted on single span and multiple span metal roof systems. Z-purlins were used extensively with through-fastened and standing seam roof panel. Two, four, and six purlin lines were used for the single span tests while only four purlin lines were used for the multiple span tests. Restraint forces were measured at five restraint locations in each span: support, third-point, midpoint, quarter-point, and third-point plus support. Each restraint configuration was tested at six roof slopes: 0:12, 0.5:12, 1:12, 2:12, 3:12, and 4:12. For each restraint configuration and roof slope, the restraint forces were measured and compared to predicted forces using the proposed design equation.

The proposed equation contains the term "δ" which is the resultant eccentricity of the applied gravity load acting on the top flange of a purlin. A value of 1/3 was assumed for δ in the development of the proposed equation and many of the test results were in

agreement with this value. However, other results were in better agreement with a value of 0 for δ and some of the measured forces were between the predicted forces with $\delta = 0$ and $\delta = 1/3$. No consistent correlation between the results and the proposed prediction equation was found.

ACKNOWLEDGEMENTS

I would like to express my appreciation to my committee chairman, Dr. Thomas M. Murray for his guidance, assistance, and friendship throughout my graduate studies. Also, I would like to thank Dr. Samuel Easterling and Dr. Carin Roberts-Wollman for their willingness to serve as thesis committee members.

I want to especially thank those fellow graduate students who assisted me at the Structures and Materials Laboratory. These people I will always remember; Matt Rowe, Emmett Sumner, James Warmouth, Rasheen Jackson, Ronald Fink, Scott Cortese, and Ben Mason. My gratitude goes out to the other those graduate students who spent their time and effort during my stay here. A special thanks goes to the laboratory technicians, Brett Farmer and Dennis Huffman, for their daily help, friendship, and tolerance of my sense of humor. Also, I would like to specially thank Ann Crate for her clerical assistance.

Finally, I would like to thank those family members, especially my mother and father and my in-laws, for the endless hours spent on the telephone in support of my education. I especially extend my love and devotion to my wife, Emily, for her patience and undying support through this time of our life.

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CHAPTER 1

INTRODUCTION

1.1 OBJECTIVE

This research is an experimental study to validate newly formulated design equations for the estimation of required lateral restraint forces in Z-purlin supported, sloped roofs under gravity loads developed by the work of Neubert and Murray (1998). Supplement No. 1 for Section D3.2.1 of the American Iron and Steel Institute's *Specification for the Design of Cold-formed Steel Members* (1999) contains the current design equations for these restraint forces. The proposed design equations were developed to more accurately predict lateral forces acting on Z-purlin supported and sloped roof systems. New provisions were proposed because the equations provided in the specification have several deficiencies, such as the incorrect treatment of roof slope and the absence of roof panel stiffness, which can have a critical effect on the required restraint force. Also, there is a range of roof slopes for which lateral bracing is not necessary, which Section D.3.2.1 does not address.

Thus, the goal of this research is to verify that the proposed design equations more accurately predict required restraint forces at discrete bracing locations and at varying roof slopes.

1.2 BACKGROUND

Thousands of metal building systems are completed each year, commonly constructed for low-rise, industrial use. A typical metal roof system consists of corrugated roof panels attached to cold-formed purlins (C or Z-sections). The roof panels are usually fastened in one of two ways. In a through-fastened system the panels are attached directly to the purlin flange using self-tapping fasteners, typically spaced at 12 in. along

each purlin. The other is a standing seam system in which one roof panel is overlapped on another with vertical side laps. The panels are attached to the purlins with clips typically spaced at 18-24 in. along each purlin. The clips are hidden and attached directly to the purlin flange using self-tapping fasteners. The roof panels are seamed using a mechanical seaming device, making the system more watertight than the through-fastened system.

Cold-formed Z-purlins range in size from 3 to 12 in. in depth, 1.75 to 3.25 in. in flange width, and 0.036 to 0.135 in. in thickness. These purlins are fabricated from steel sheets, by either press braking or roll-forming, to obtain the Z-shaped cross-section. In order to increase local bucking strength, the outer edges of the flanges are edge stiffened or lipped. The use of Z-purlins is advantageous in metal building construction because they are lightweight, they can be nested and lapped due to their cross-section, and they are easily erected and fabricated. These advantages lead to a more economical building.

The asymmetric cross-section of a Z-purlin causes it to twist and deflect laterally when loaded obliquely to its principal axes as defined by the angle θ in Figure 1.1.

An example would be a snow load acting on a flat roof. The presence of roof panels helps prevent relative movement of the purlins, but does not restrict the lateral translation of the entire roof system. This lateral movement and twisting significantly decreases the flexural strength of a roof system. This behavior warrants the need for a lateral restraint system usually seen in the form of lateral bracing. Bracing is typically used along each purlin span at discrete locations. The most common bracing configurations are support (torsional) restraints, third-point restraints, and midpoint restraint. The restraints are generally attached to the purlin web between the top flange and the mid-depth.

1.3 LITERATURE SURVEY

Experimental research to determine restraint forces has been conducted using full and partial scale tests of laterally braced Z-purlin roof systems. These tests have been performed on flat, single and multiple span roof systems with various restraint locations. Literature on the development and experimental verification of laterally braced Z-purlin roof systems, as well as a recently proposed theoretical design procedure, is reviewed in this section.

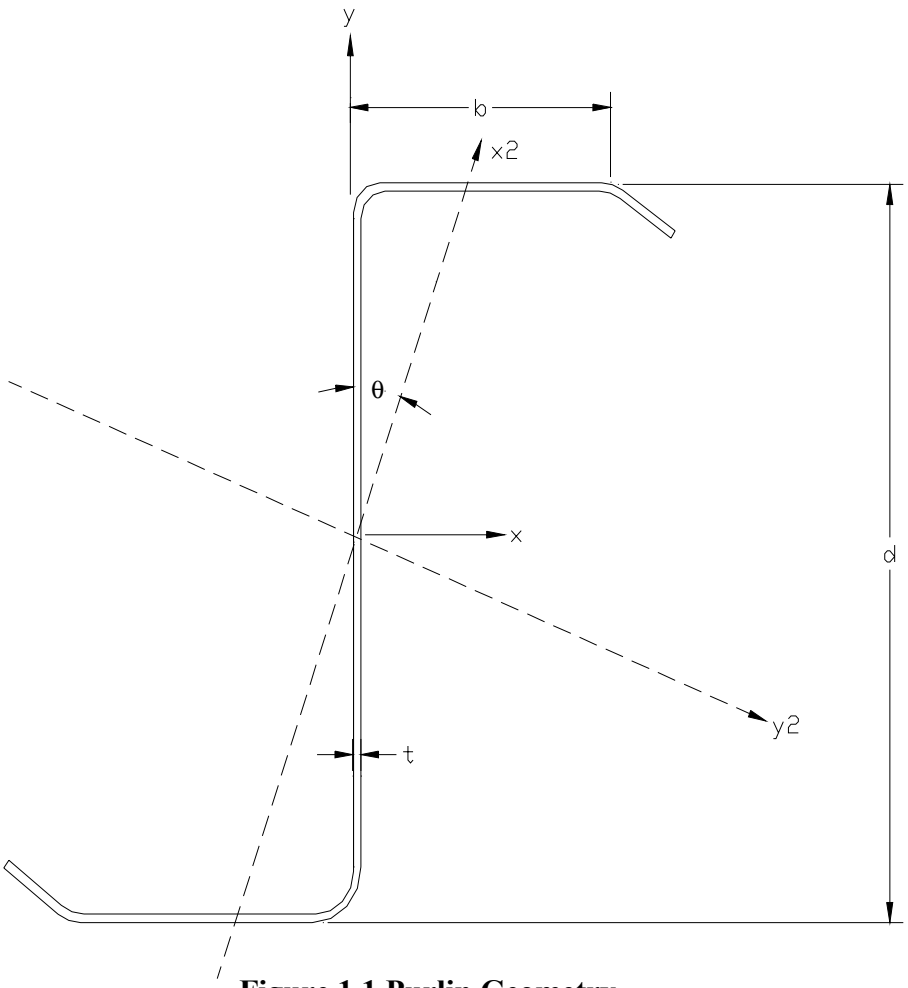


Figure 1.1 Purlin Geometry

Theoretical Studies. Zetlin and Winter (1955) studied single span, simply supported, Z-purins, with loading applied in the plane of the web. Lateral bracing at both flanges at locations of applied load was assumed. The following equation was developed from basic mechanics principles for determining the required restraint force:

$$P_L = (I_{xy}/I_x)W \tag{1.1}$$

where P_L is the restraint force, I_{xy} is the product of inertia, I_x is the moment of inertia with respect to the axis perpendicular to the web, and W is the applied load. This equation shows a linear response of lateral restraint forces due to applied loading. Also, the lateral restraint force is specifically dependent upon the cross-sectional properties of the purlin. This equation does not take into account eccentric loading acting on the top flange of the purlin, which could significantly change the restraint force.

Also Equation 1.1 only considers one purlin acting as the load-carrying member. In actual roof systems, the torsional and shear stiffness of the roof panel provides significant restraint to the purlins. A mathematical model developed by Needham (1981) allows for these panel forces to be accounted for. Assumptions made in the model are: 1) simply supported purlins, 2) no lateral bracing, 3) the panel behaves as an infinitely rigid diaphragm, and 4) the panel cannot move laterally with respect to the purlins. The top flange of the purlin was acted upon by a distributed load approximated as a point load by Needham, at a distance b/6 from the web, where b is the flange width. The net torque acting on the purlin cross-section equaled the sum of the torques caused by the applied loads and by the restraint induced from the roof panels. The primary force in the panel was taken to be $(I_{xy}/I_x)W$, as stated in the work of Zetlin and Winter. Another force, W_{ps}, was given to the panel to provide equilibrium. This secondary force acts at a distance of $d/2$ from the shear center of the purlin, which yields $W_{ps} = T/(d/2)$, where d is the depth of the purlin and T is the torque. From the previous assumptions and equations, an equation for total lateral bracing force was derived by Needham. The equation was extended to account for varying roof slopes:

$$P_0 = \left[\left(\frac{I_{xy}}{I_x}\right)(\cos\theta - 1) - \sin\theta + \frac{b}{3d}\right]W \tag{1.2}$$

where θ is the roof slope with respect to the horizontal. Needham found this expression to be in agreement with laboratory test results. However the accuracy of the test results with respect to Equation 1.2 depended on the value of eccentricity. The eccentricity is the location where the resultant of the applied load acts on the top flange of the purlin. The results from the tests performed by Needham showed a better correlation with the eccentricity *b/3* rather than *b/6.* Hence *b/3* was used in Equation 1.2.

Another method of predicting lateral restraint forces for simply supported Z-purlin attached to conventional roof panels was provided by the work of Ghazanfari and Murray (1983). A variety of bracing configurations were examined, all acted upon by uniform gravity load. There were various assumptions made in their model: 1) no panel rotational restraint, 2) no lateral movement of the purlins with respect to the panel, 3) the eccentricity of the vertical load acting on the top flange of a purlin is $b/3$, 4) a lateral panel force, W_h, is uniformly distributed in a horizontal plane at the top flange, and 5) all

brace forces are infinitely rigid and connected to fixed, immovable supports. In the model presented, Ghazanfari and Murray accounted for the effects of panel deformations on restraint forces. This deformation can only be determined if the lateral force acting on the panel is known. However, this lateral force is determined from the torque loading, which is dependent upon the panel deformation. To calculate these second order effects, an iterative computer program was developed. Several parameters affected the restraint force. Panel stiffness, span, load eccentricity, and principal axes location were determined to be the most critical.

The research performed by Ghazanfari and Murray did not examined the effects of multiple span and multiple restrained purlin lines. Elhouar and Murray (1985) developed a design procedure for lateral restraint requirements in through fastened, corrugated steel panel, roof systems with sufficiently braced systems incorporating multiple spans and multiple restrained purlin lines. A computer-generated stiffness model (see Figure 1.2) was built and adjusted to match full-scale (Curtis and Murray, 1983) and quarter-scale (Seshappa and Murray, 1985) experimental test results. The model was constructed utilizing STRUDL (Structural Design Language) and represented with Z-purlins as space frame line elements and roof panels with plane trusses. Braces were connected to the top line elements of purlins. The eccentricity of the applied loading was assumed to be $b/3$.

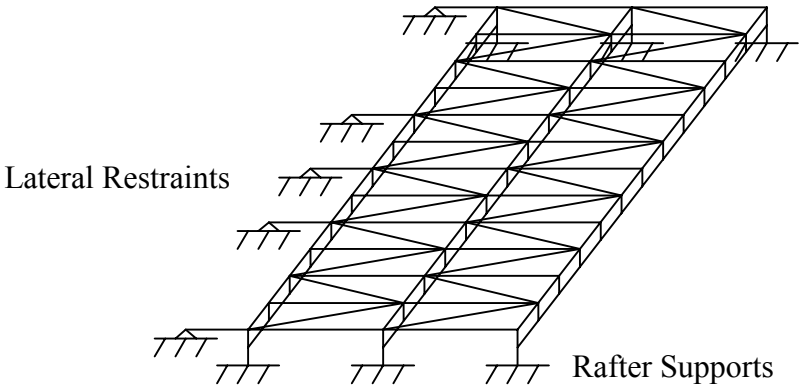


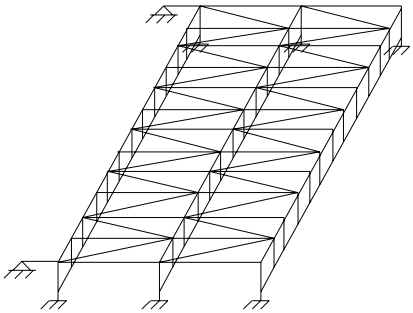
Figure 1.2 Elhouar and Murray's Stiffness Model

Assumptions made were that the braces and purlins were attached to rigid, immovable supports that prevent all translation, and that purlins could not move relative to the deck.

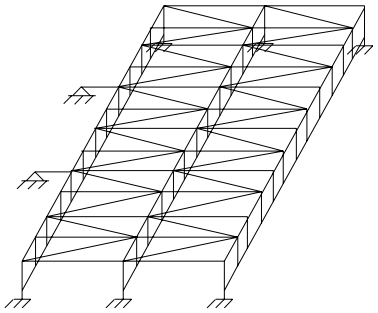
Three bracing configurations (see Figure 1.3) were examined: end restraints, third-point restraints, and midpoint restraints. Determined by data developed from the stiffness model, a parametric study was performed to determine how the restraint force is affected by cross-sectional properties, number of restrained purlin lines, span length, number of spans, and bracing configuration. Roof slope was not included in the study, but was corrected based on quarter-scale tests by Seshappa and Murray (1985) and Elhouar and Murray (1985). The correction for roof slope is shown in the following relationship:

$$P_L = P_{Lo} - W \tan \theta \tag{1.3}$$

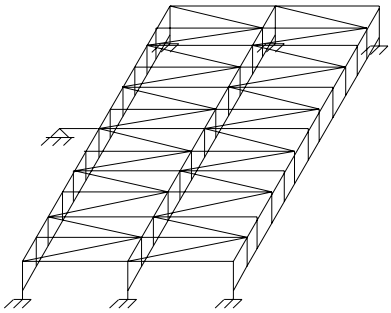
where P_{Lo} is the restraint force on a flat roof. A roof stiffness of 2500 lb/in was assumed for all cases, hence varying roof panel stiffness was not examined in the studies. It was believed that the increase in required restaint force was insignificant for roof panels exhibiting stiffness greater than 2500 lb/in, based on results by Ghazanfari and Murray (1983). Prediction equations were derived from regression analysis on the data.



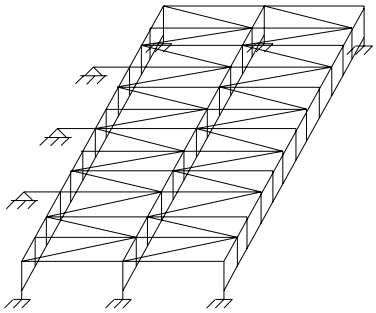
(a) Support Restraints



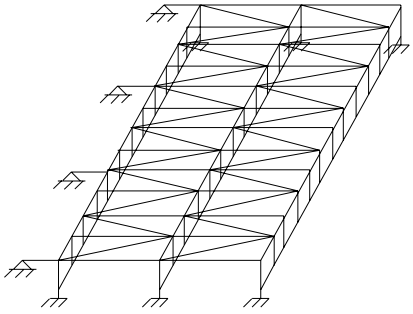
(b) Third-Point Restraints



(c) Midpoint Restraint



(d) Quarter-Point Restraints



(e) Third-Point Plus Support Restraints

Figure 1.3 Elhouar and Murray Bracing Configurations

These equations account for varying spans and bracing conditions. For example, Elhourar and Murray's equation for the force in each brace of a single span system with end support restraints is:

$$P_L = 0.5\left(\frac{0.220 \cdot b^{1.500}}{n_p^{0.716} d^{0.901} t^{0.600}} - \tan\theta \right) W \tag{1.4}$$

where n_p is the number of restrained purlin lines and t is the thickness of the purlin. Experimental results previously studied indicated a "system effect" which was caused by increasing the number of restrained purlin lines. As this number is increased the ratio of lateral restraint force to applied gravity load is decreased. The cause of this system effect is believed to be the torsional resistance of the purlins. The regression terms in Elhouar and Murray's equations take this system effect into account.

The work conducted by Elhouar and Murray was extended to include two new bracing configurations: quarter-point restraints and third-point plus end support restraints, and was performed by Danza and Murray (1998). A series of computer tests was run using elastic stiffness models, similar to those used by Elhouar, but with minor modifications. The parameters studied included purlin cross-section, number of spans, number of restrained purlin lines, and span length. The study did not include roof slope and a panel stiffness of 2500 lb/in. was assumed. As before in the work of Elhouar and Murray, regression analysis performed on the stiffness model results was used to obtain empirically derived design equations. The form of equations was modified from that used by Elhouar and Murray with span length included in the regression. An example of Danza and Murray's design equation for single span system with quarter-point restraints is shown on the following page:

$$P_L = C\left[\left(\frac{t}{L} \right)^{0.16} - \frac{0.407 t^{0.75} d^{0.50} n^{0.39}}{b^{1.25}} \right] W \tag{1.5}$$

where $C = 0.25$ for braces near supports, $C = 0.50$ for brace at midspan and W is the total applied gravity load (lb).

The most recent study performed for determining lateral restraint forces in single span or multiple span roof systems containing multiple restrained purlin lines is that of Neubert and Murray (1998). The current design equations developed from work

performed by Elhouar and Murray (1985) have several deficiencies. These include: 1) incorrect treatment of roof slope, 2) heavy reliance upon statistical regression, 3) assumed value for roof panel stiffness of 2500 lb/in., which can significantly alter required restraint force, and 4) lower bound limits on required restraint forces due to a range of roof slopes for which no lateral restraint is necessary. New design equations were developed for multiple span and multiple restrained purlin lines for five bracing configurations. These configurations include: support restraints, third-point restraints, quarter-point restraints, midspan restraints, and third-point plus support restraints. A space frame stiffness model was developed to test the restraint force behavior of different roof system conditions. Parameters included in the research were purlin cross-section, span length, roof panel stiffness, roof slope, and number of restrained purlin lines. The difference between the study conducted by Neubert and Murray and previous work is the correct treatment of roof slope and panel stiffness in the design model. A new treatment of Z-purlin statics relying more heavily on engineering principles is the basis for Neubert and Murray's theoretical design equations. Design coefficients were determined and are used in the equations to determine restraint forces for specific bracing configurations. The regression coefficients were determined by a regression analysis of the stiffness model results. For example, the following is Neubert and Murray's design equation for multiple span systems with support restraint forces is:

$$P_L = P_o C_1(\alpha + \gamma) \tag{1.6}$$

Where:

$$P_0 = \left[\left(\frac{I_{xy}}{2I_x} + \frac{b}{3d}\right)\cos\theta - \sin\theta\right] W_t \tag{1.7}$$

$$W_t = \textit{total applied load} \tag{1.8}$$

$$\alpha = \textit{the system factor} = 1 - C_2\left(\frac{t}{d}\right)\left(n_p{}^* - 1\right) \tag{1.9}$$

$$\mathrm{n_p}^* = \textit{effective number of purlin lines} = min\ \{n_p, n_{p(max)}\} \tag{1.10}$$

$$n_{p(\max)} = 0.5 + \frac{d}{2C_2 t} \tag{1.11}$$

$$\gamma = \textit{the shear stiffness factor} = C_3 \log\left(\frac{G'}{2500}\right) \tag{1.12}$$

If the only difference for a given test set-up is the location of bracing, unique regression coefficients are used for the predicted force calculations. Table 3.1 shows Nuebert and Murray's final design regression coefficient values used to determine the predicted values. C_1 is the brace location factor. It is a constant factor which represents the percentage of total restraint that is allocated to each brace in the system. C_2 is a constant factor depending on the bracing configuration. C_3 is another constant factor for a given bracing scheme determined by regression analysis of stiffness model results (Nuebert and Murray, 1998).

Table 1.1 Design Equation Coefficient Values

Configuration	C_1	C_2	C_3
Support Restraints:			
SS	0.50	5.9	0.35
MS, exterior	0.50	5.9	0.35
MS, interior	1.00	9.2	0.45
Third-Point Restraints:			
SS	0.50	4.2	0.25
MS, exterior	0.50	4.2	0.25
MS, interior	0.45	4.2	0.35
Midpoint Restraints:			
SS	0.85	5.6	0.35
MS, exterior	0.80	5.6	0.35
MS, interior	0.75	5.6	0.45
Quarter-Point Restraints:			
SS, exterior	0.25	5.0	0.35
SS, interior	0.45	3.6	0.15
MS, exterior 1/4 span	0.25	5.0	0.40
MS, interior 1/4 span	0.22	5.0	0.40
MS, 1/2 span	0.45	3.6	0.25
Third-Point Plus Support Restraints:			
SS, exterior	0.17	3.5	0.35
SS, interior	0.35	3.0	0.05
MS, exterior support	0.17	3.5	0.35
MS, interior support	0.30	5.0	0.45
MS, third-point	0.35	3.0	0.10

Experimental Studies. A number of full-scale tests on flat roofs were conducted by Needham (1981) to validate his analysis. The test apparatus consisted of two purlins, 9.5 in. deep, spaced at 5 ft apart. Roof panels were fastened to each purlin. Support restraints were the only bracing configuration used on the test. Simulated gravity load was applied. Lateral loads were measured with load cells and were between 9.1% and 9.7% of the total applied load.

Ghazanfari and Murray (1982) also conducted full-scale tests to confirm their work. Nine tests on flat, single span systems were performed. Two purlins were used for each test with four different bracing schemes. The results showed a negligible increase in the lateral restraint forces for two purlin systems, when the deck stiffness was increased above 1500 lb/in. The restraint force varied between 14% and 29% of the total applied load, depending on the span and bracing configuration.

Under gravity load, twenty full-scale tests were conducted by Curtis and Murray (1983) on flat, single span systems utilizing two, six, and seven restrained purlin lines. The results from these tests substantiated the existence of the system effect previously mentioned. They also found that increasing the number of restrained purlin lines decreased the lateral restraint force by 5% to 10% of the total load.

Sesheppa and Murray (1985) performed 28 tests on quarter-scale models of multiple span, multiple purlin line systems. These tests included end restraint, third-point restraint, and midpoint restraint bracing schemes. One series of tests was conducted on systems with flat roof slope varying from 0:12 to 1.5:12. It was concluded that by subtracting off the lateral component of the applied load from the flat roof prediction (Equation 1.3), the bracing force for sloped roofs could be predicted. System effects and roof slope interaction was not considered in these tests.

Six single span and six three span continuous tests for lateral restraint forces in Z-purlin supported, standing seam roof systems were conducted by Rivard and Murray (1986). The bracing configurations investigated were end restraints, third-point restraints, and midpoint restraints. Two-piece clips were used for both rib type and pan type roof panels. One single span test was conducted on a through-fastened system for comparison. From the results it was found that the equations Elhouar and Murray (1985) developed were applicable to both through-fastened and standing seam roof systems.

A comparison of results between experimental data and newly proposed theoretical data (Nuebert and Murray, 1998) is contained in Chapter 5. Restraint forces from various bracing schemes, determined by Ghazanfari and Murray, and Rivard and Murray will be compared to predicted solutions using the Nuebert and Murray's proposed design equation.

1.4 SCOPE OF RESEARCH

The intent of this reseach is to verify the proposed design equations developed by Neubert and Murray for five lateral bracing configurations. Parameters varied in the study include: roof slope, roof panel stiffness, purlin thickness, number of spans, and number of restrained purlin lines. Details of the test parameters are in Chapter 2. Experimental test results, analysis of previous research, and comparisons of results are located in Chapters 3 and 4. Chapter 5 contains a discussion of results. A brief summary and conclusion follows in Chapter 6.

CHAPER 2

TEST DETAILS

2.1 EXPERIMENTAL TEST PROGRAM

An experimental program was developed to test the validity of Nuebert and Murray's proposed design equation. The program consisted of eight series of tests (1 through 8). The first six series of tests contained five bracing configurations: supports, third-points, third-points plus supports, quarter-points, and midpoint. The final two series contained only support bracing. For each bracing configuration restraint forces were measured at six roof slopes: 0:12, 0.5:12, 1:12, 2:12, 3:12, and 4:12. Therefore, 30 tests were performed in each test series except for Series 7 and 8. These series included one test for each roof slope using support restraints.

Series 1 was tested on a frame spanning 20 ft with two purlin lines and through-fastened roof panel. Series 2 was tested on a frame spanning 20 ft with two purlin lines and standing seam roof panel. Series 3 was tested on a frame spanning 20 ft with four purlin lines and through-fastened roof panel. Series 4 was tested on a frame spanning 20 ft with four purlin lines and standing seam roof panel. Series 5 was tested on a three span frame, each span being 20 ft with four purlin lines and through-fastened roof panel. Series 6 was tested on a three span frame, each span being 20 ft with four purlin lines and standing seam roof panel. Series 7 was tested on a frame spanning 16 ft with six purlin lines and through-fastened roof panel. Series 8 was tested on a frame spanning 16 ft with six purlin lines and standing seam roof panel.

For Series 1 through 8 the top purlin flanges faced toward the ridge side, that being the side nearest the centerline of a roof plan, parallel to the purlin lines. The eave side is that which is closest to the edge of a roof plan, parallel to the purlin lines. Z-purlins with a thickness of 0.06 in. and a depth of 8 in. were used for all tests with through-fastened

roof panels. Z-purlins with a thickness of 0.075 in. and a depth of 8.5 in. were used for all tests with standing seam roof panels. The orientation of the test frame for Series 7 and 8 was perpendicular to that of Series 1 through 6. Hence, the ridge side for these series was that side toward the unpinned end of the test set-up. The eave side was that toward the pinned end of the set-up.

Table 2.1 is the test matrix. The series notation is as follows:

- The first number, 8 or 8.5, denotes the depth of the purlins used.
- The following letter denotes a Z-purlin.
- The decimal number, 0.060, indicates the thickness of the purlin being used.
- The next number, 2 or 4, indicates how many purlin lines are being used.
- The lower case letters indicate the span(s), *ss* for single span or *ms* multiple span.
- The upper case letter denotes the roof panel being used, TF for through-fastened and S for standing seam.
-

For example, 8Z0.060-2-ss-TF designates a 2-Z purlin test with a purlin thickness of 0.060 in., single-span, and through-fastened deck. Note that the series identification provides no information regarding restraint bracing location or roof slope.

The test matrix identifies the span lengths and roof panel types used. Support bracing was placed at the support or rafter locations along the length of a purlin. Third-point bracing was located at the third points (the span length divided into thirds) along the length of a purlin. Midpoint bracing was placed halfway along the length of a purlin. The quarter-point location is similar to that of third-point bracing, except at the quarter-points along the length of a purlin. Third-point plus support bracing included the schemes described above for third-point and support bracing. In each series, restraint forces were determined for each bracing configuration at six roof slopes: 0:12, 0.5:12, 1:12, 2:12, 3:12, and 4:12.

Table 2.1 Test Matrix of Experiments

Series	Series Identification	Tests Included	Span Length	Panel Type
1	8Z0.060-2-ss-TF	1 through 30	20'	Through-Fastened
2	8.5Z0.075-2-ss-S	31 through 60	20'	Standing Seam
3	8Z0.060-4-ss-TF	61 through 90	20'	Through-Fastened
4	8.5Z0.075-4-ss-S	91 through 120	20'	Standing Seam
5	8Z0.060-4-ms-TF	121 through 150	3@20'	Through-Fastened
6	8.5Z0.075-4-ms-S	151 through 180	3@20'	Standing Seam
7	8.5Z0.075-6-ss-TF	181 through 186	16'	Through-Fastened
8	8.5Z0.075-6-ss-S	187 through 192	16'	Standing Seam

2.2 COMPONENTS OF THE TEST ASSEMBLIES

Purlins. Z-purlins were used in the experimental program: 8Z0.060 and 8.5Z0.075. Cross-sectional dimensions and properties, and material properties are found in Appendix A.

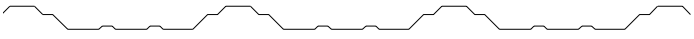
The purlin spacing for systems using two and four purlin lines (Series 1 through 6) was 4 ft 10 in. on center. A spacing of 5 ft on center was used for Series 7 and 8. For the tests using two Z-purlins the deck overhang was 13 in. on each side. The tests using four Z-purlins the deck overhang was 9 in. on each side. The tests using six Z-purlins had an overhang of 3 in. for through-fastened panel and 18 in. for standing seam panel. The overhang dimension for both test systems was measured from the purlin web.

Panels and Fasteners. Both rib and pan type panel profiles were used in the experimental program. Figure 2.1 shows cross-sections of the three panel types. The rib type was used for both the seamed roof panel tests and the through-fastened roof panel tests with the exception of Series 1, which was conducted using through-fastened pan type roof panel. The rib type panel used for the standing seam series was seamed using a mechanical seaming device. The through-fastened panel stiffness, as reported by the manufacturer, is 27,500 lb/in the standing seam panel stiffness, as reported by the manufacturer, is 1,000 lb/in.

The pan type roof panel had a nominal width of 24 in. and was 24 gage. The seamed rib type roof panel had a nominal width of 24 in. and was 25 gage. The through-fastened rib type roof panel had a nominal width of 36 in. and was 24 gage. The panel lengths were determined by the number of purlin lines. If two purlin lines were used the panel length was 7 ft. If four purlin lines were used the panel length was 15 ft 8 in. If six purlin lines were used the panel length was 25-30 ft.

Pan Type

Rib Type-Standing Seam



Rib Type-Through-Fastened

Figure 2.1 Typical Cross-Section of Roof Panels Used in Tests

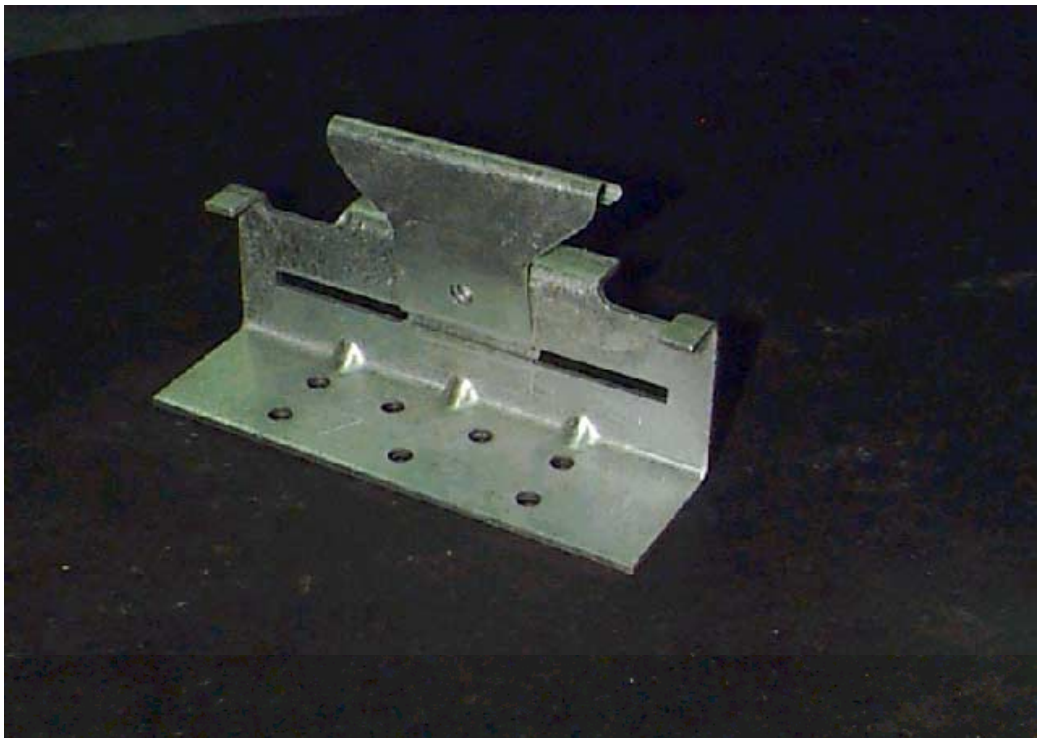


Figure 2.2 Typical Low-Profile Clip Used for Standing Seam Tests

Self-drilling fasteners were attached at 12 in. on center through the through-fastened roof panel to the top purlin flange. One fastener was used at each fastening location. The same type of fastener was used to attach clips to the top purlin flange for the standing seam panels. Two fasteners were used to attach a clip. Lap fasteners were attached along the rib, 12 in. on center, for the through-fastened system.

Clips. A low profile, two-piece sliding clip was used for the tests utilizing the standing seam roof system. Figure 2.2 shows a clip used for the standing seam tests.

Bracing. The bracing configurations used in the testing program are: supports, third-points, third-points plus supports, quarter-points, and midpoint. Figure 2.3 shows the location of the bracing for the single span test set-ups. Figures 2.4 shows the locations for the multiple span tests. All of the braces in Figure 2.3 and 2.4 are shown on the eave side. Bracing locations and identifiers on the ridge side were identical to the notation on the eave side.

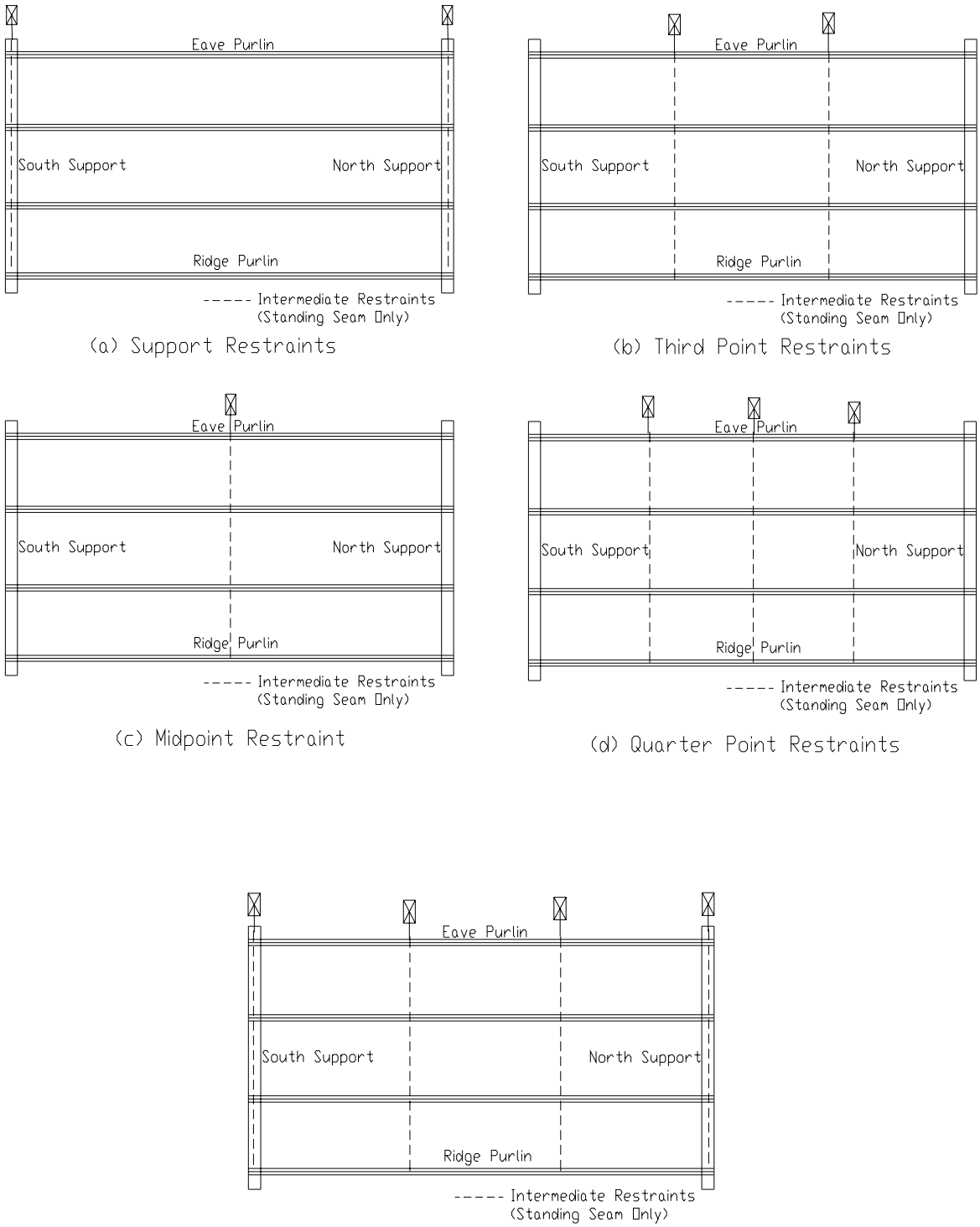


Figure 2.3 Bracing Configurations

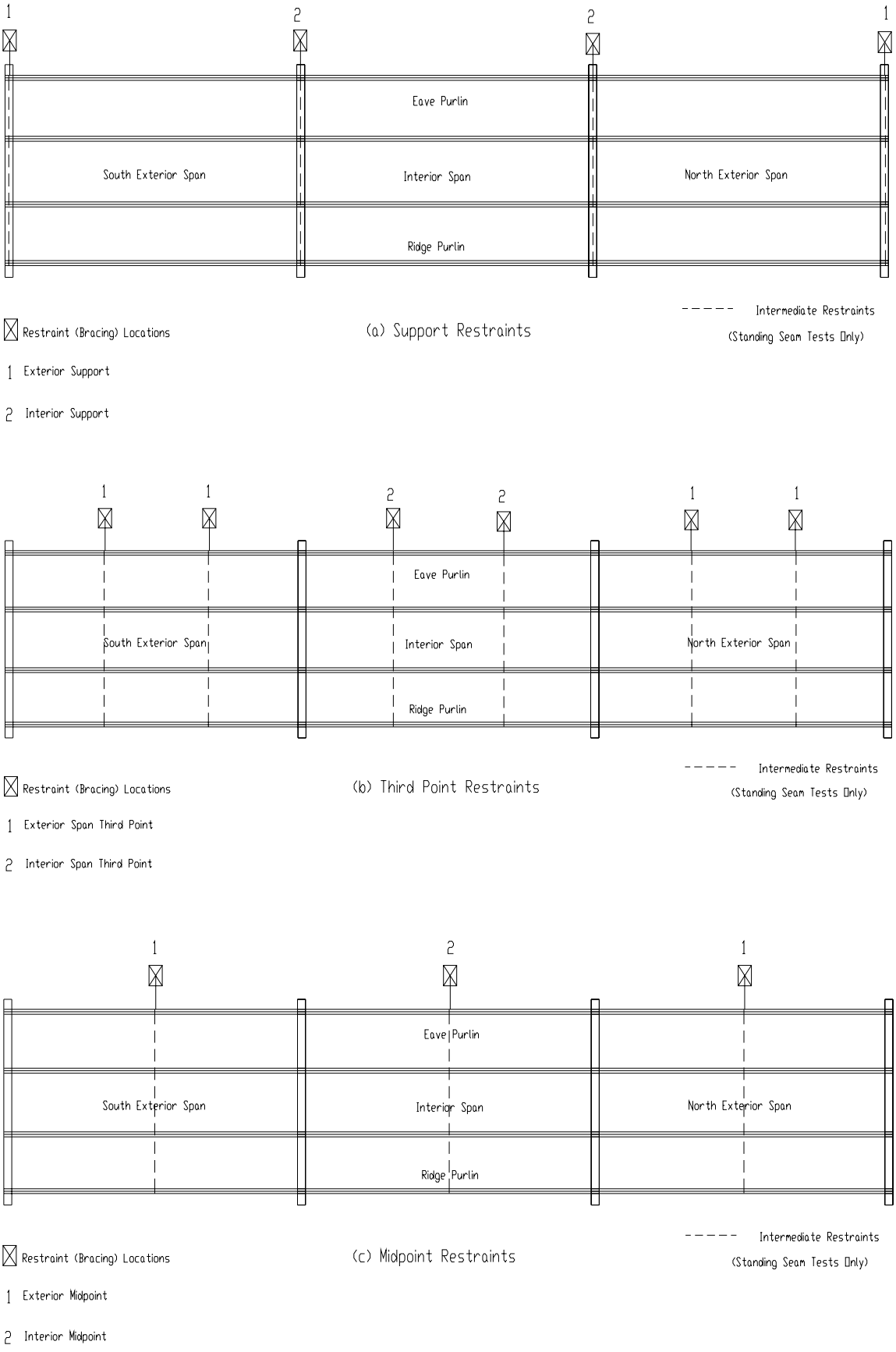


Figure 2.4 Multiple Span Bracing Configurations

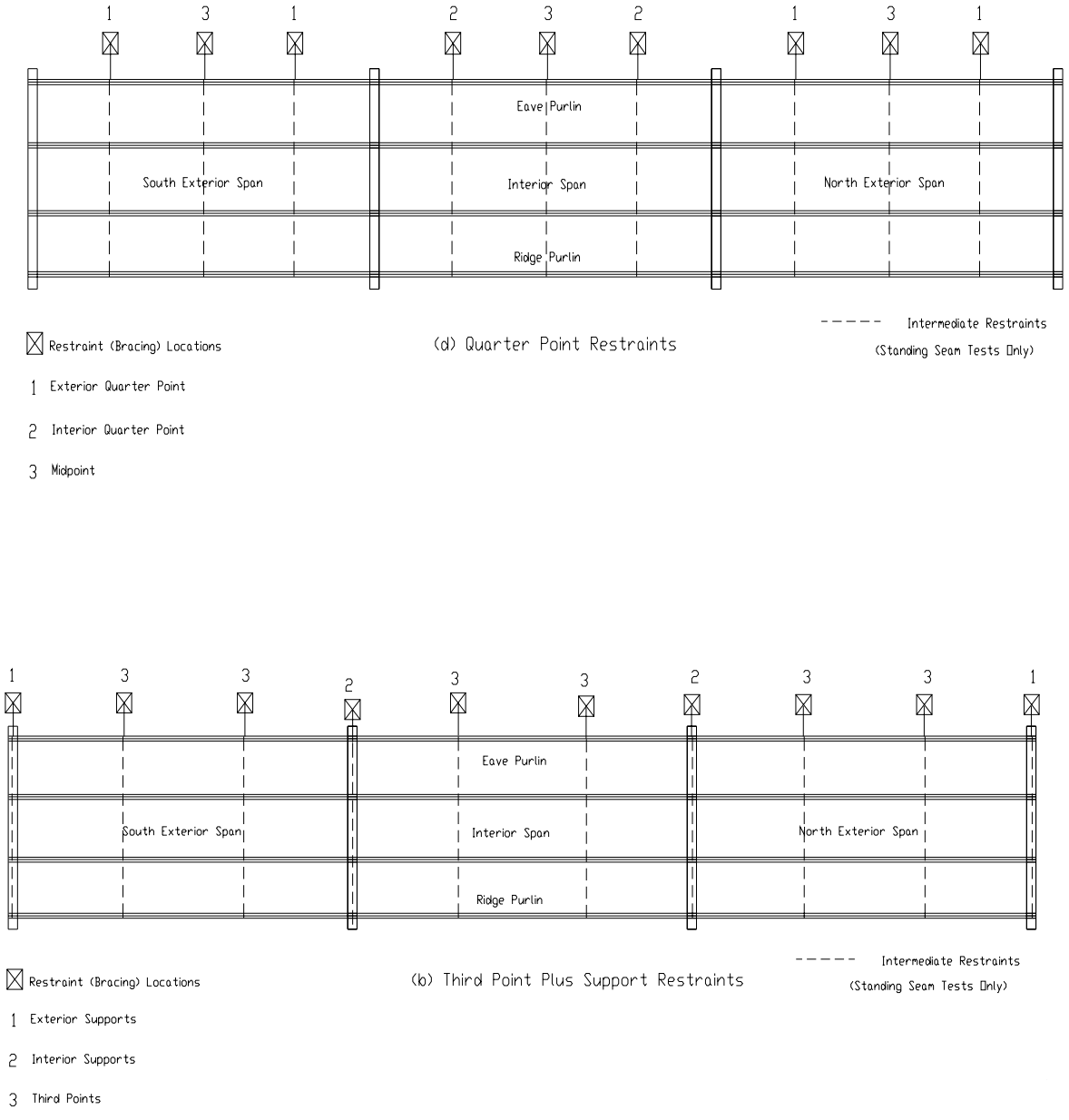


Figure 2.4 Multiple Span Bracing Configurations (continued)

Half-inch diameter rod was used for the bracing. The rods used in the tests with 4 purlin lines were 9 in. long. The rods used in the test with two purlin lines were 5 ft 5 in. long. The rods were attached to the purlin web approximately 2 in. from the top purlin flange. Holes were drilled into the purlin web approximately 2 in. from the top flange and into a W8x48 on the eave and a W6x25 on the ridge side of the test set-up. The holes were placed at every discrete bracing location. The holes were oversized to allow for rotation when the purlins deflected under gravity load. Every rod was threaded on each end so that nuts could be used to anchor the rod on one end to a rigid beam and to the purlin web on the other end. Each rod was instrumented with four strain gages located at each quarter point around the rod. Four gages were used to account for bending in any direction with respect to the cross-section of the rod.

Figure 2.5 shows a typical rod-to-purlin connectiom. Figure 2.6 is a typical instrumented rod and a two purlin line support condition.

Intermediate bracing between purlins was used for the standing seam tests (see Figure 2.7). The rods used for this purpose were not instrumented. Intermediate braces were used to prevent relative movement between the purlins lines.

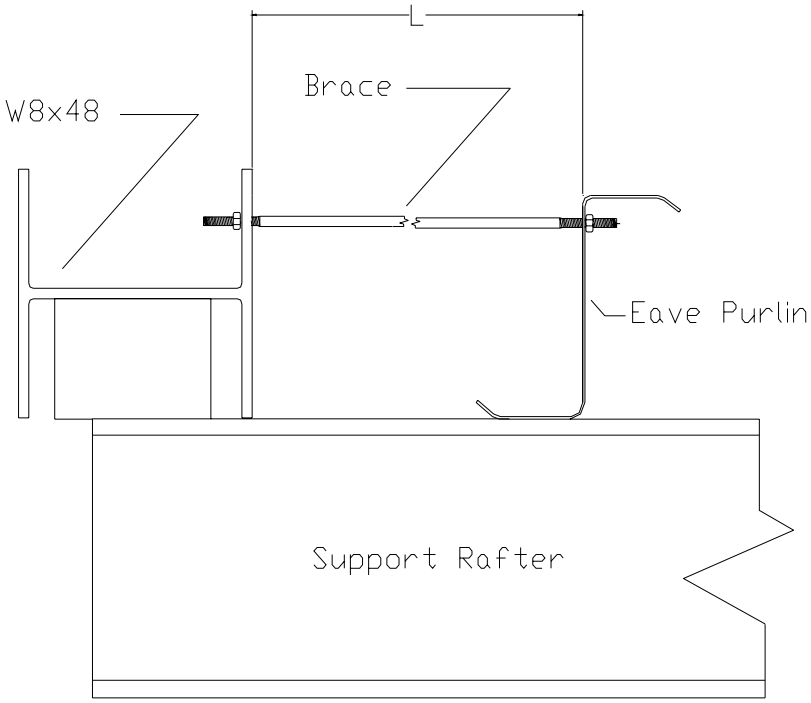


Figure 2.5 Typical Instrumented Rod-to-Purlin Connection

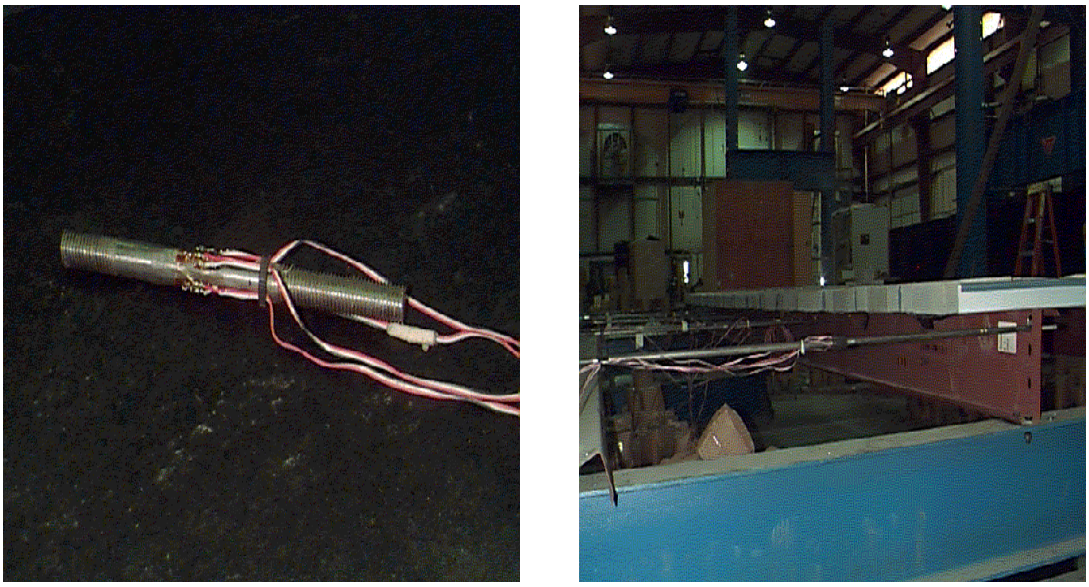


Figure 2.6 Instrumented Rods Used as Load Cells

Simulated Gravity Loading. Two types of simulated gravity loading were used. Test Series 1,3, and 4 were conducted using concrete bricks weighing 5 lbs each. The bricks were evenly spaced across the roof system to act as gravity load. Load increments were by 5 psf and increased to 20 psf.

Test series 2, 5, 6, 7, and 8 were carried out using boxes filled with purlin fabrication chads as the gravity load. The boxes weighed 20 lbs each and were evenly distributed across the roof system to simulate a gravity load of 20 psf.

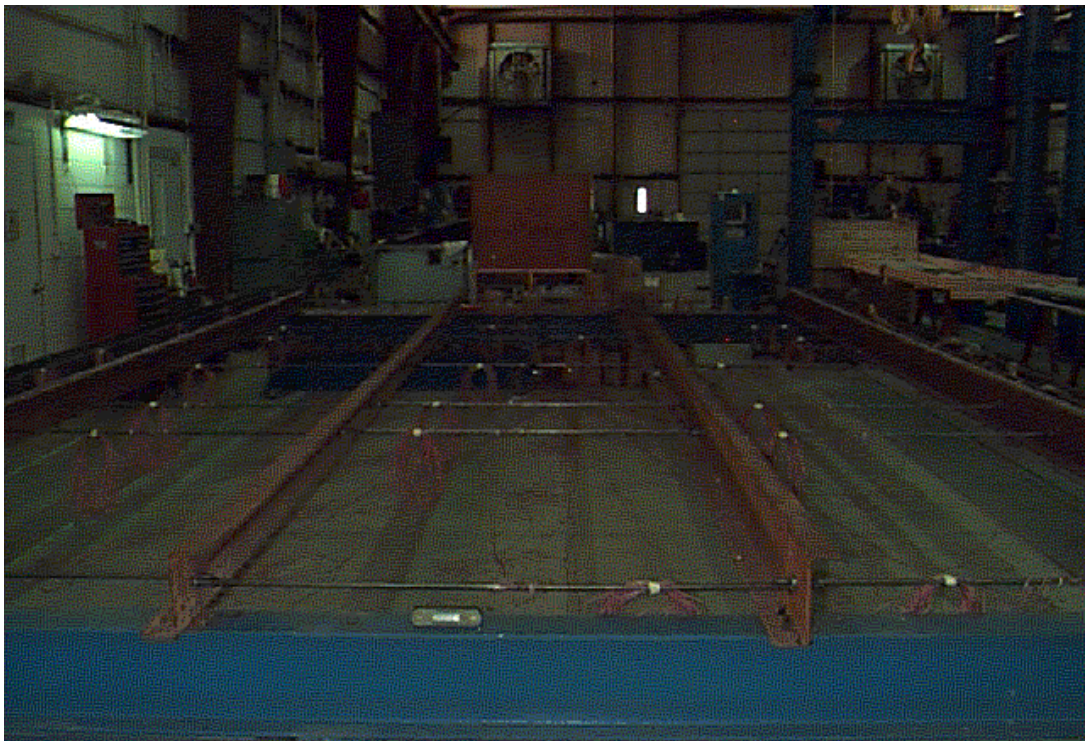


Figure 2.7 Intermediate Bracing Used for Standing Seam Series

2.3 TEST PROCEDURES AND SET-UPS

2.3.1 General Test Procedure

The instrumented rods used as bracing were placed for the scheme to be tested. If the test being conducted was a standing seam panel test, intermediate bracing between the purlins was also placed and tightened on each side of the purlin web. The eave side of the test frame was always to be in tension first, so using ½-inch nuts, the rods on the eave side were slightly tensioned between 5-10 lbs by tightening the nut on the inside flange of the support beam (see Figure 2.5). Once the rods were tensioned the output the computer acquisition system was zeroed, and the loading procedure began. The system was then loaded to the amount at which it was to be tested, usually from 5 psf to 20 psf. The bricks or boxes used as load were evenly spaced to simulate an evenly distributed load. Once the system was loaded to the designated amount, readings of the restraint forces for the given bracing scheme were recorded at each slope: 0:12, 0.5:12, 1:12, 2:12, 3:12, 4:12. The system was lifted using overhead laboratory cranes. At each slope the system was given time to settle so that the restraint forces would converge to a steady value. If the series being tested was loaded with increments of 5 psf, readings were taken after each load increment.

As a roof system is lifted the restraint forces are initially in tension on the eave side. As the slope increased, the eave side restraint forces approach zero. When the eave side bracing reached between 10-60 lbs (tension), the ridge side bracing was tensioned and zeroed so that it would then be effective. After the ridge side restraint bracing was set, the test continued until the maximum designated slope was reached.

2.3.2 Test Set-Ups

Test Series 1 through 6 were conducted using the same basic set-up. Two rafter supports were used for the single span test series and four rafter supports were used for the multiple span test series. W10x26 beams were used as the rafter supports. Each rafter was 16 ft long and cantilevered over another W10x26, which was 7 ft in length and fixed to the laboratory floor with anchor bolts. Pin connections were located on the eave side of each rafter support to allow the entire system to rotate when lifted by overhead cranes. Two beams were used as rigid anchors for the lateral braces. A W6x25 was used

on the ridge side and a W8x48 was used on the eave side. Figure 2.8 is an elevation view of a typical rafter support for tests using two Z-purlins

Figure 2.9 is an elevation view of a typical rafter support for the tests using 4 purlin lines. The test frame for Series 7 and 8 was modified because six purlins were being used. Figure 2.10 is an elevation view of the test frame used for Series 7 and 8.

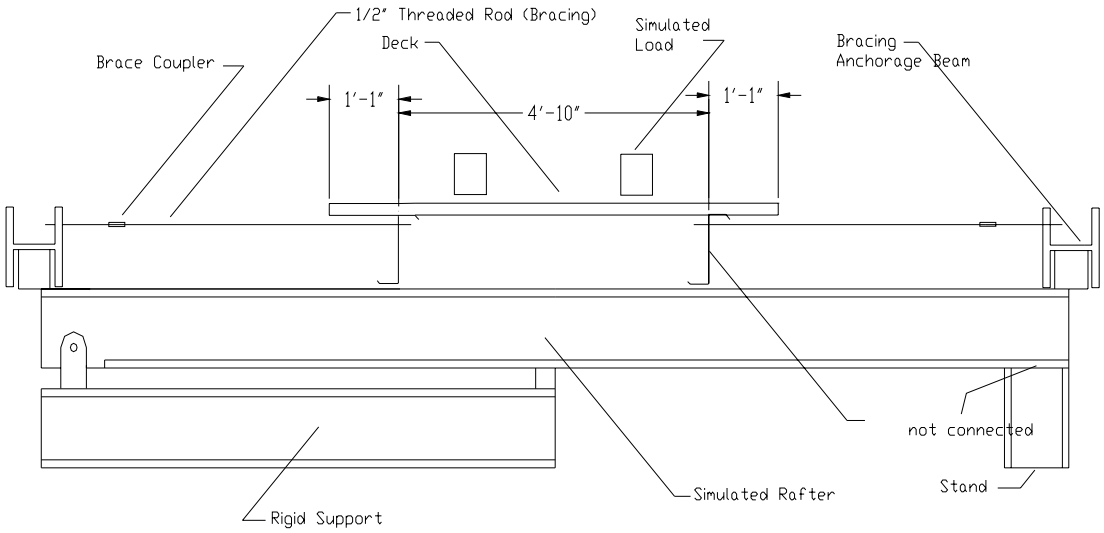


Figure 2.8 Typical Rafter Support Used for 2 Purlin Line Tests

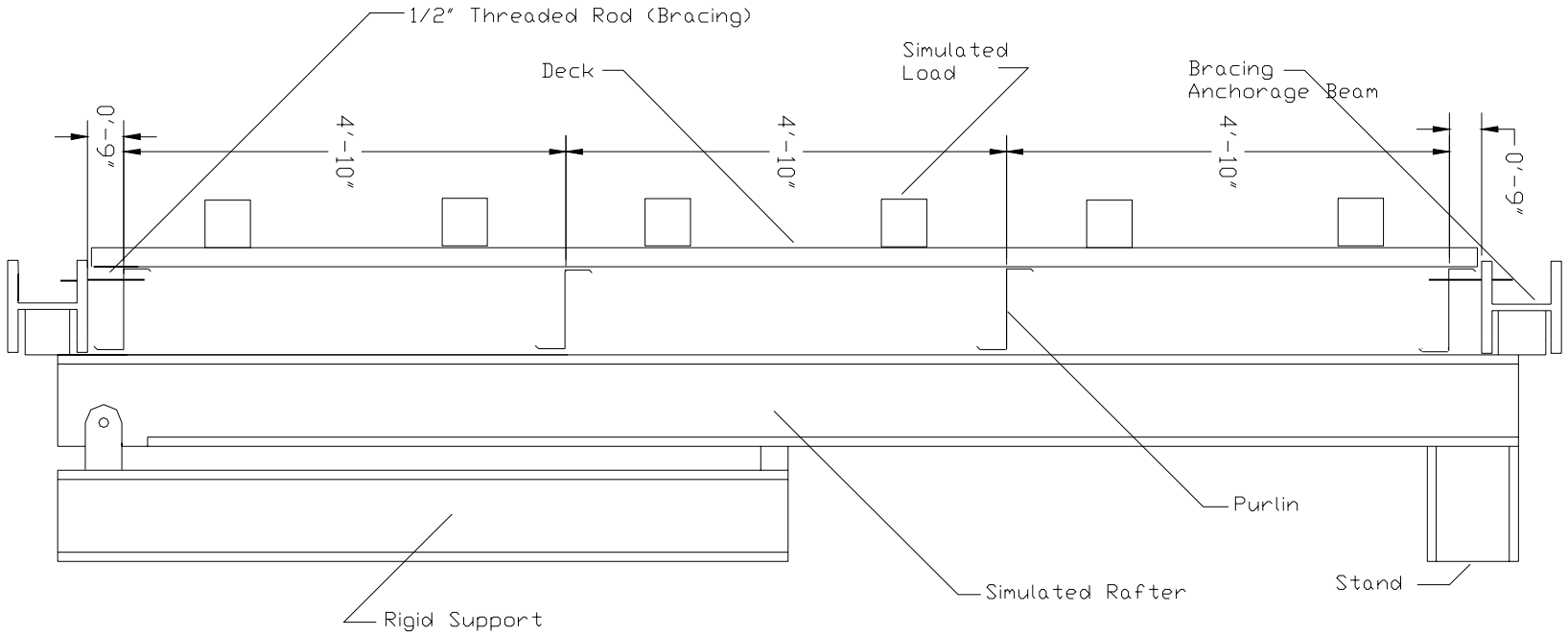


Figure 2.9 Typical Rafter Support Used for 4 Purlin Line Tests.

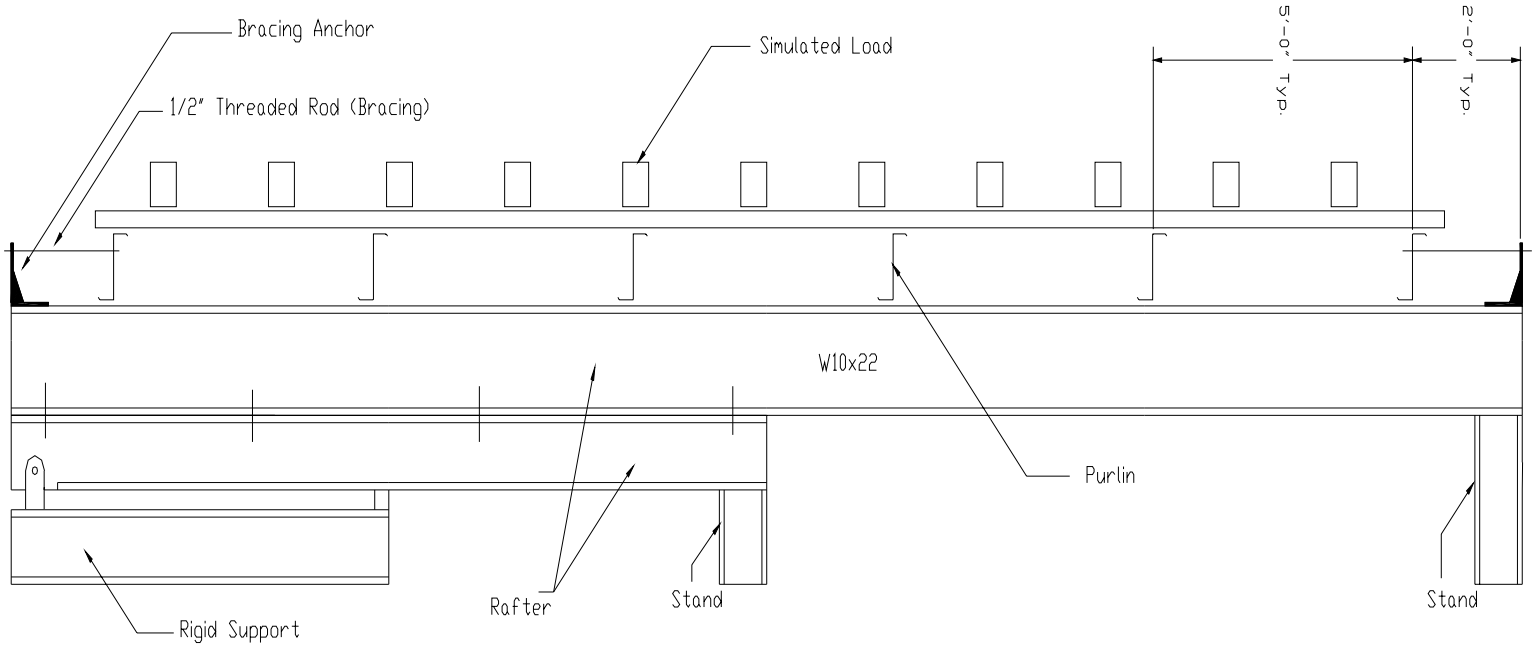


Figure 2.10 Typical Rafter Support Used for 6 Purlin Line Tests

2.3.3 Series 1: Single Span, Two Purlin, Through-Fastened

Test Series 1 was tested using bricks as simulated load. Each specific test within the series was incrementally loaded from 5 psf to 20 psf. Figure 2.11 shows the test apparatus used for Series 1.

Figure 2.11 Series 1 Test Apparatus

2.3.4 Series 2: Single Span, Two Purlin, Standing Seam

The load boxes described in Section 2.3 were used as the load component for Series 2. This test series was loaded to 20 psf for each bracing scheme and then raised to each slope. The test set-up for Series 2 is identical to that shown in Figure 2.11 except for the difference in deck type. Also, intermediate bracing was placed for each respective bracing scheme.

2.3.5 Series 3: Single Span, Four Purlin, Through-Fastened

Bricks were used to load Series 3. The set-up was loaded incrementally from 5 psf to 20 psf for each bracing configuration, however, the set-up was only raised through each test slope for the 20 psf load. The test apparatus used for this test series is shown in Figure 2.12(a). The underside of the test setup is shown in Figure 2.12(b).

2.3.6 Series 4: Single Span, Four Purlin, Standing Seam

The testing procedure for Series 4 was identical to that of Series 3. The only exception was the placement of intermediate bracing for each configuration. Figure 2.12 is also representative of the apparatus used for Series 4. Standing seam roof panel was used as compared to the through-fastened panel shown.

2.3.7 Series 5: Muliple Span, Four Purlin, Through-Fastened

Test Series 5 was loaded using boxes. The setup was loaded directly to 20 psf for each bracing configuration and then raised for each test slope. The test setup used for Series 5 is shown in a lifted position in Figure 2.13.

2.3.8 Series 6: Multiple Span, Four Purlin, Standing Seam

The testing procedure for Series 6 was identical to that of Series 5. The only exception was the placement of intermediate bracing for each configuration. Figure 2.14 shows the test set-up used for Series 6.

2.3.9 Series 7: Single Span, Six Purlin, Through-Fastened

Test Series 7 was conducted only measuring the restraint forces for support bracing with through fastened roof panel. Each test was loaded to 20 psf directly and then raised at each slope. Figure 2.15 is a picture of the test set-up for Series 7.

2.3.10 Series 8: Single Span, Six Purlin, Standing Seam

Test Series 8 was conducted measuring the restraint forces for support bracing with standing seam roof panel. The set-up was loaded to 20 psf directly and then raised at each slope. Figure 2.15 is a representative of the test set-up used for Series 8.

(a)

(b)

Figure 2.12 (a) Series 3 Test Apparatus (b) Underside of Test Apparatus

Figure 2.13 Series 5 Test Apparatus

Figure 2.14 Series 6 Test Apparatus

Figure 2.15 Series 7 Test Apparatus

CHAPTER 3

EXPERIMENTAL RESULTS

3.1 GENERAL COMMENTS

Data sheets with cross-sectional dimensions and properties of the purlins used are included in Appendix A. Complete information for each test series conducted is given in Appendices B-I. Appendix B contains data sheets for Series 1, consisting of load versus restraint force data and slope versus restraint force data. Data sheets were completed for each bracing locations. For example, for support restraints, six load versus restraint force plots are shown, one for each roof slope tested: 0:12, 0.5:12, 1:12, 2:12, 3:12, and 4:12. In addition, four slope versus restraint force plots are shown for each load increment: 5 psf, 10 psf, 15, psf, and 20 psf. Appendices D and E contain load versus restraint force plots for each bracing scheme for the horizontal (0:12) condition. In addition, slope versus restraint force plots were completed for the 20 psf loading condition. Appendices C, F, G, H, and I contain only slope versus restraint force plots for a 20 psf loading condition. There are no load versus restraint force plots in these appendices. Again, each bracing scheme within a series has its own set of data sheets for the plots described.

Each data sheet also contains a table above each graph. The table lists the theoretical restraint forces and the experimental restraint force at each bracing location used for the given test. The theoretical restraint forces were calculated using the proposed theoretical equations (Nuebert and Murray, 1998). The values shown in each table are with reference to the eave side. That is, a negative number is compression on the eave side and a positive number is tension on the eave side. Every graph in the appendices is plotted with respect to the eave side of the test setup. This means that any tension force on the ridge side was plotted as a compression, or negative force, on the eave side.

The "zero-slope" is the slope at which no lateral restraint force is required to restrain the system. The following equation shows the zero-slope angle as a function of the cross-section properties and the eccentricity of the load location acting on the top purlin flange as shown in Figure 3.1:

$$\theta_o = \tan^{-1}\left(\frac{I_{xy}}{2I_x} + \delta\frac{b}{d}\right) \tag{3.1}$$

The zero-slope of any system is dependent upon the assumed eccentrity, δ. Nuebert and Murray assumed the eccentricity, δ, equal to 1/3 times the width of the flange, b measured from the web of the purlin**.** Preliminary testing showed that δ varied between 0 and 1/3. As a result all of the load versus restraint force plots and the slope versus restraint force plots show theoretical lines for δ = 0 and δ = 1/3 as shown in Figure 3.2.

Figure 3.3 shows how actual measured restraint forces can vary between the theoretical solutions with eccentricities of 0 and 1/3. Figure 3.3a shows actual results which agree with the predicted solution for which an eccentricity of 1/3 is used. Figure 3.3b shows actual results which agree with the predicted solution when an eccentricity of 0 is used.

An example calculation for the determination of theoretical restraint forces is found in the following section. In Sections 3.3 through 3.7, experimental and theoretical results for each bracing configuration are discussed.

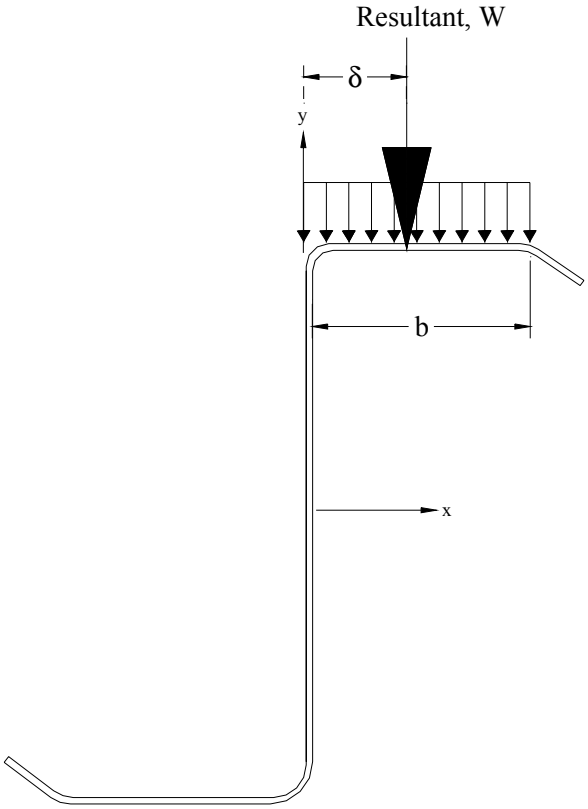


Figure 3.1 Location of Resultant Eccentricity, δ

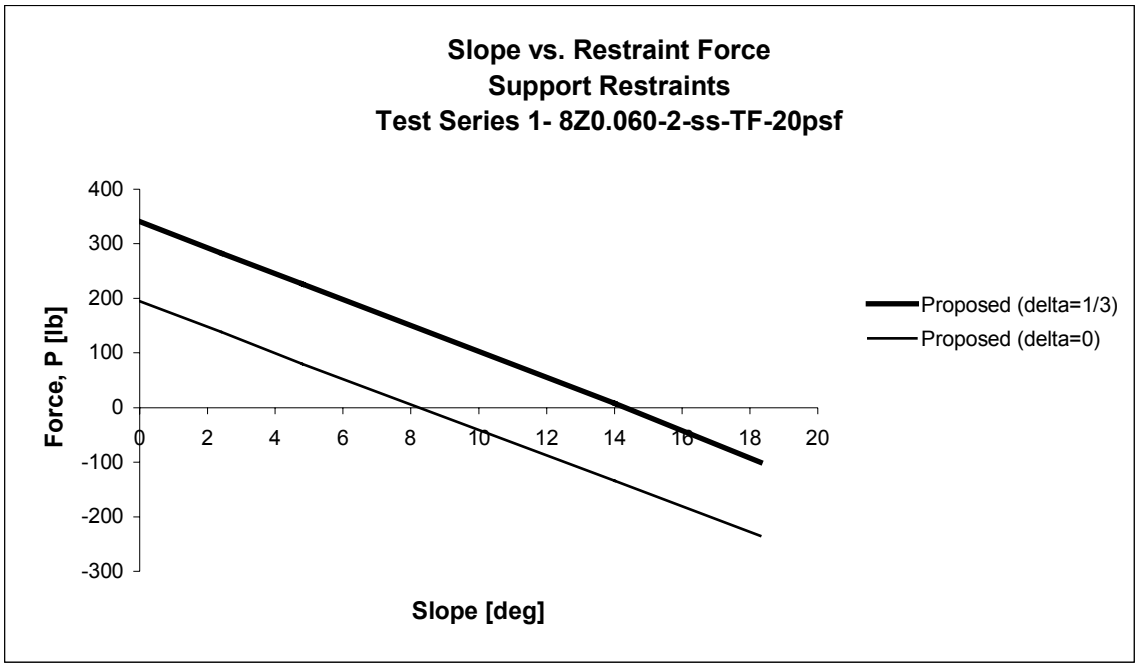
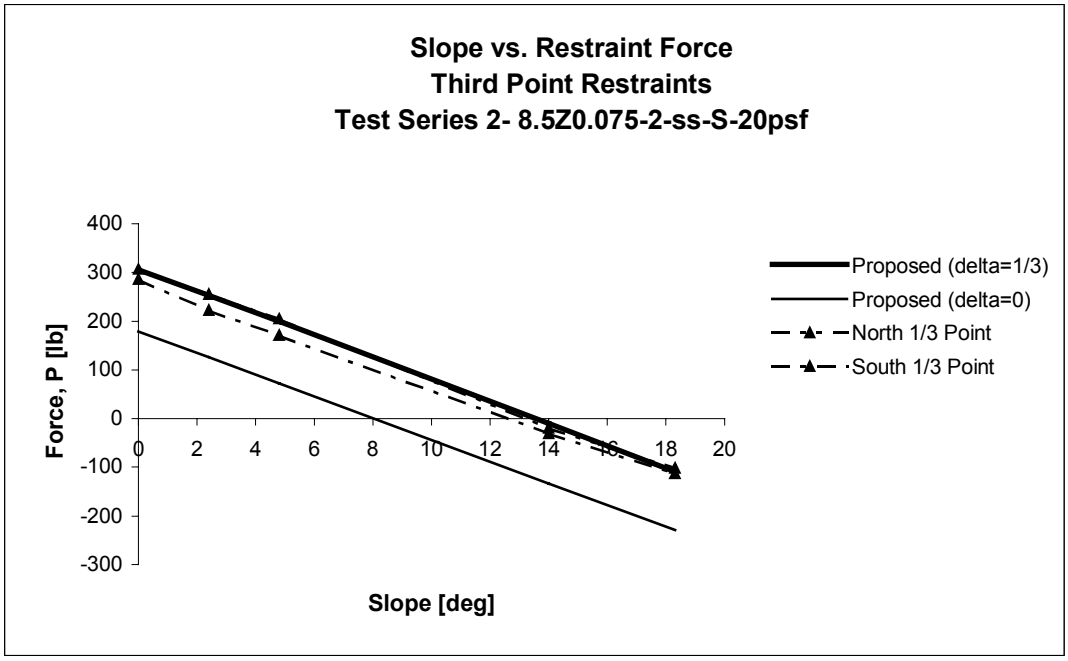
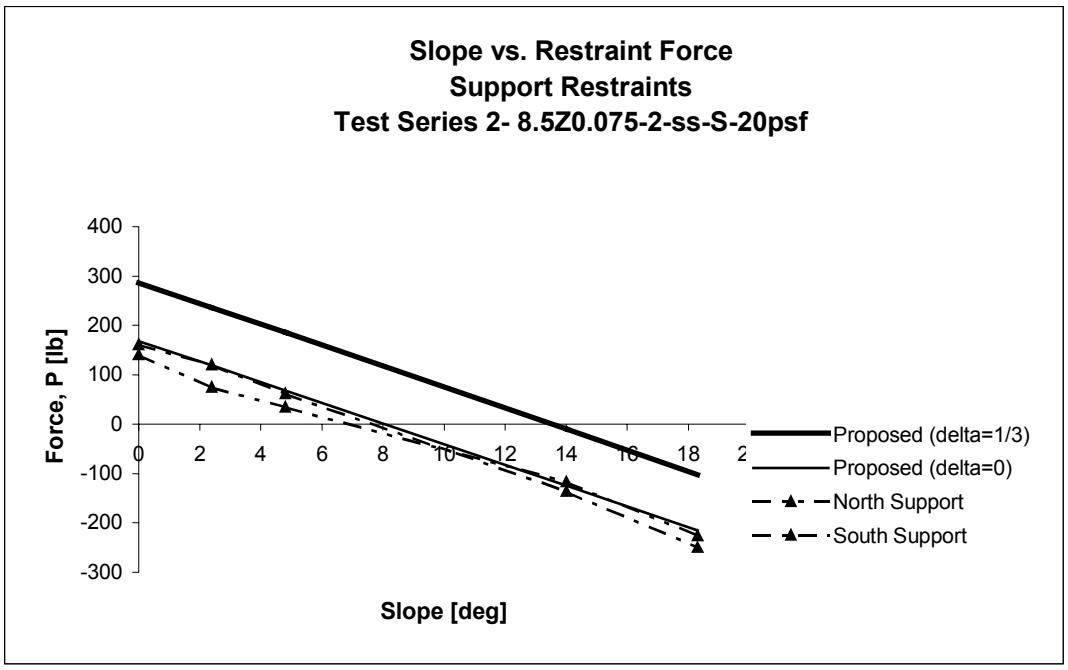


Figure 3.2 Slope vs. Restraint Force Graph Showing Theoretical Solutions for Eccentricities of 0 and 1/3 Times the Flange Width



(a)



(b)

Figure 3.3 Slope vs. Restraint Force Graphs Showing Differences in Eccentricity, δ

3.2 PREDICTED RESTRAINT FORCES

The following procedure illustrates how the predicted support restraint forces were calculated for the 1:12 roof slope test in Series 1. The predicted forces for each series are based on a diaphragm stiffness of 27,500 lb/in. for through-fastened panel and 1,000 lb/in. for standing seam panel as reported by the deck manufacturers.

A single span roof system consisting of four purlin lines, spanning 20 ft, with through-fastened roof panel having a shear stiffness of 27,500 lb/in. is analyzed. The spacing between purlins is 5 ft and the design load is 20 psf. The roof has a slope of 1:12 (4.8°) with support restraints. Figure 3.4 shows the system with the desired restraint forces, P_L.

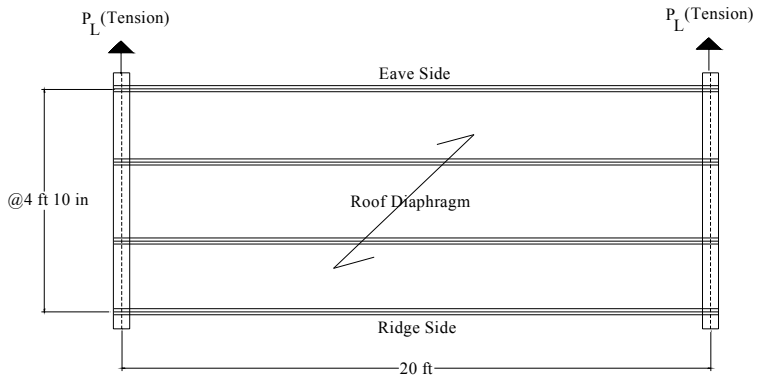


Figure 3.4 Restraint Forces for Proposed Roof System

The general procedure for determining restraint forces is as follows:

The prediction equation is:

$$P_L = P_o C_1(\alpha + \gamma) \tag{1.6}$$

From Table 1.1, for single span systems with support restraints:

$C_1 = 0.50$ $C_2 = 5.9$ $C_3 = 0.35$

For the purlin section 8Z0.060, the following section properties were determined:

$d = 8$ in., $b = 2.62$ in., $t = 0.060$ in., $I_{xy} = 2.53$ in.^{4}, $I_x = 10.10$ in.^{4}

with

$$P_0 = \left[\left(\frac{I_{xy}}{2I_x} + \frac{b}{3d}\right)\cos\theta - \sin\theta\right]W_T \tag{1.7}$$

and

W_t = *total applied load = (distributed design load)(surface area)* (1.8)

= *(*20 psf)(15 ft x 20 ft) = 6000 lb

Thus

$$P_0 = \left[\left(\frac{2.53in^4}{2(10.10in^4)} + \frac{2.62in.}{3(8in.)}\right)\cos 4.8^\circ - \sin 4.8^\circ\right](6000lb) = 900 \text{ lb}$$

With

$$\alpha = 1 - C_2\left(\frac{t}{d}\right)\left(n_p{}^* - 1\right) \tag{1.9}$$

and

$$\mathrm{n_p}^* = min\ \{n_p, n_{p(max)}\},\ n_{p(\max)} = 0.5 + \frac{d}{2C_2 t} \tag{1.10}$$

Forsupport restraints:

$$n_{p(max)} = 0.5 + \frac{8in.}{2(5.9)(0.060in)} = 11.29 > \mathrm{n_p} = 4, \text{ therefore } \mathrm{n_p}^* = 4$$

$$\alpha = 1 - 5.9\left(\frac{0.060in.}{8in.}\right)(4-1) = 0.8673$$

The roof panel shear stiffness modifier is:

$$\gamma = C_3 \log\left(\frac{G'}{2500}\right) \tag{1.11}$$

Thus,

$$\gamma = 0.35\log\left(\frac{27{,}500lb/in.}{2500}\right) = 0.3644$$

Finally, the design restraint forces are:

P_L = (900 lb)(0.50)(.8673 + 0.3644) = 554 lb (Tension)

Check $|P_L| \le |P_o C_1|$ **:** = 554 lb ≥ (900)(0.50) = 450 lb, Therefore use 450 lb (Tension)

3.3 TESTS WITH SUPPORT RESTRAINTS

Figures 3.5 through 3.7 show support restraint results. Figure 3.5 includes the results for all of the single span tests. Figure 3.5a shows the results for a two purlin line, single span system with through-fastened roof panel. Figure 3.5b shows the results for a two purlin line, single span system with standing seam roof panel. Figure 3.5c shows the results for a four purlin line, single span system with through-fastened roof panel. Figure 3.5d shows the results for a four purlin line, single span system with standing seam roof panel.

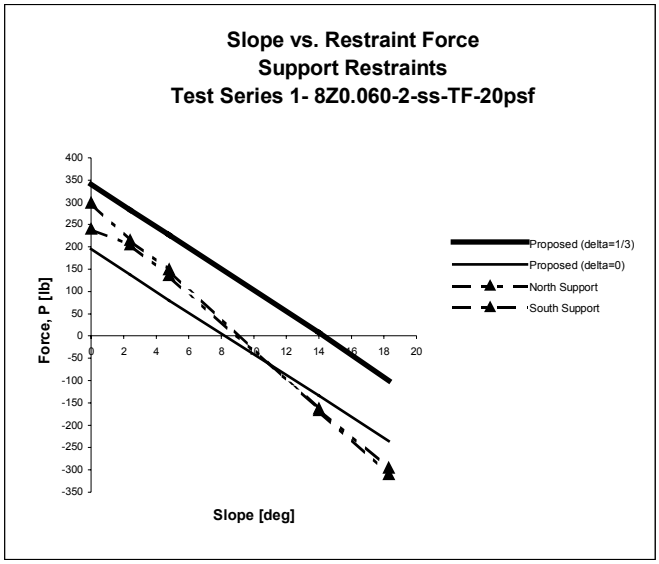
Figure 3.6 includes the results for all of the multiple span tests with support restraints. Figure 3.6a shows the exterior support restraint results for a four purlin line, multiple span system with through-fastened roof panel. Figure 3.6b shows the exterior support restraint results for a four purlin line, multiple span system with standing seam roof panel. Figure 3.6c shows the interior support restraint results for a four purlin line, multiple span system with through-fastened roof panel. Figure 3.6d shows the interior support restraint results for a four purlin line, multiple span system with standing seam roof panel.

Figure 3.7 includes the results for all of the single span tests with support restraints and six purlin lines. Figure 3.7a shows the results for a six purlin line, single span system with through-fastened roof panel. Figure 3.7b shows the results for a six purlin line, single span system with standing seam roof panel.

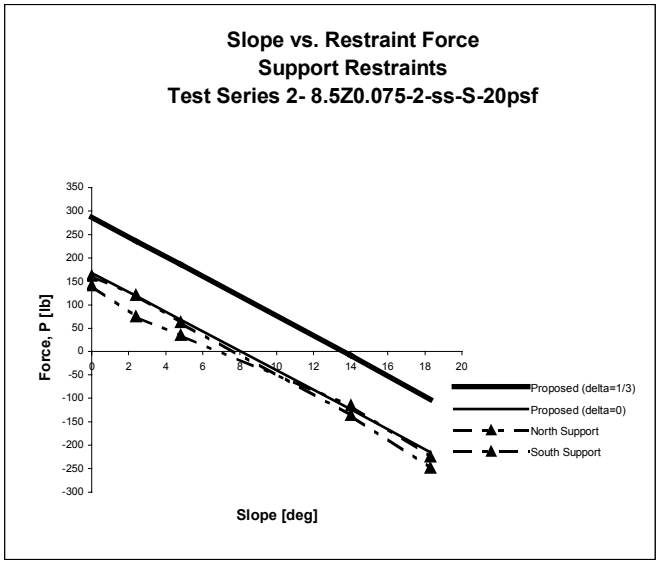
Predicted forces assuming $\delta = 0$ and $\delta = 1/3$ are shown on each plot along with the measured data. The results were not consistent with each other and were very poor relative to the proposed forces for the multiple span test. The exception being the exterior support restraints for the multiple span system using standing seam panel (see Figure 3.6b).

The results tend to be closer to the prediction with $\delta = 0$. However, to assume such a value for the eccentricity would be unconversative in some cases especially for low roof slopes, that is, less than the zero-slope value. For example, if a roof system with support restraints, similar to the exterior supports of Series 6, was designed with □ = 0, the actual restraint forces would be greater than the predicted forces if the roof slope was less than 8º (see Figure 3.6b).

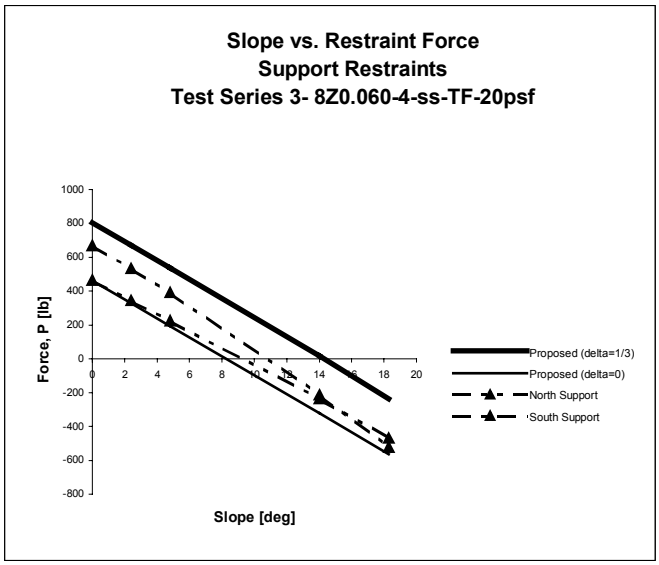
Table 3.1 shows the representative values for eccentricity, □, for the support bracing condition. These values were determined by observing each plot and which value of eccentricity it was closest to. These values are not intended to be design values for the proposed equation, but rather they are those values that the measured results were closest to. Any value that is less than zero (< 0) means that the measured restraint forces were far below the predicted forces for □ = 0.



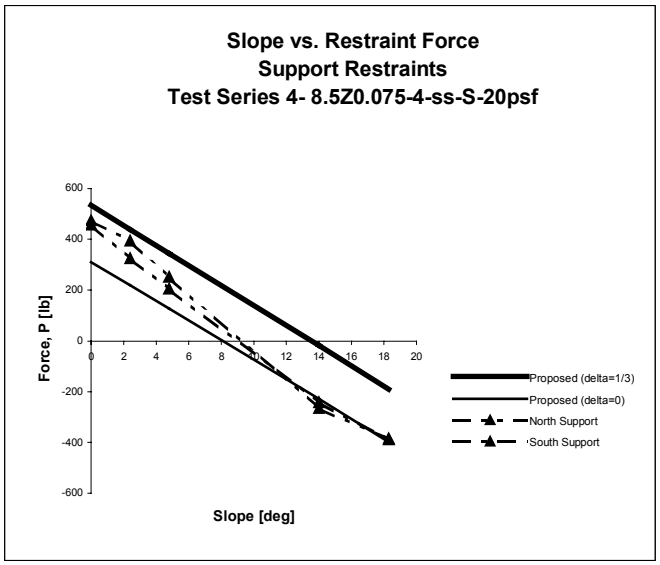
(a)



(b)

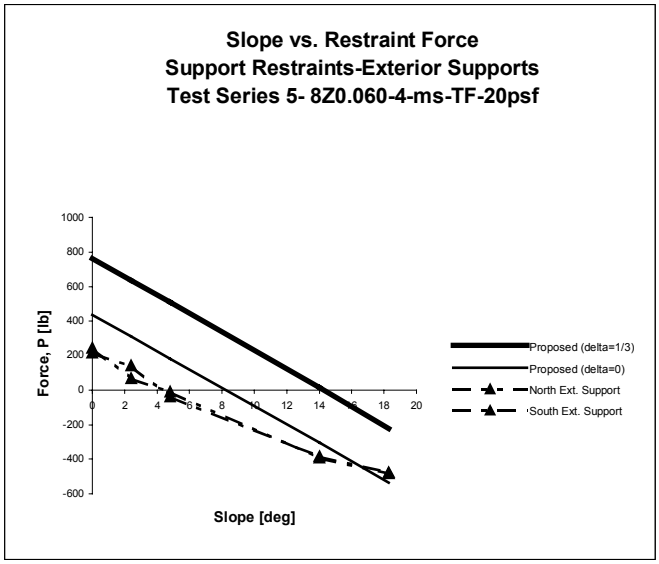


(c)

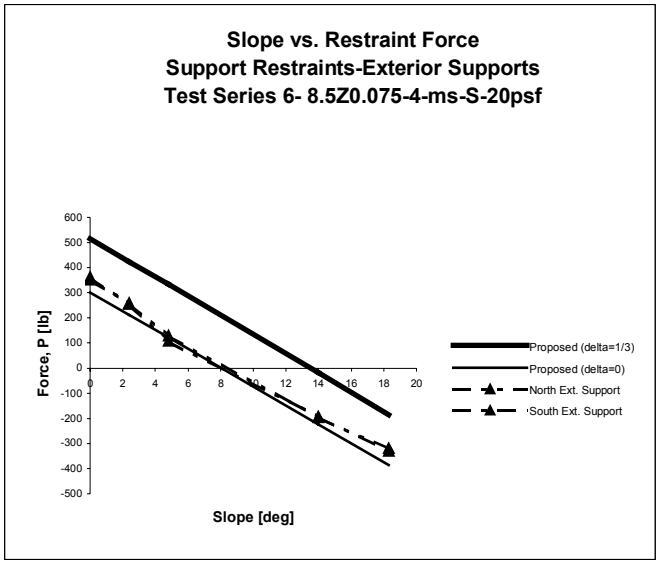


(d)

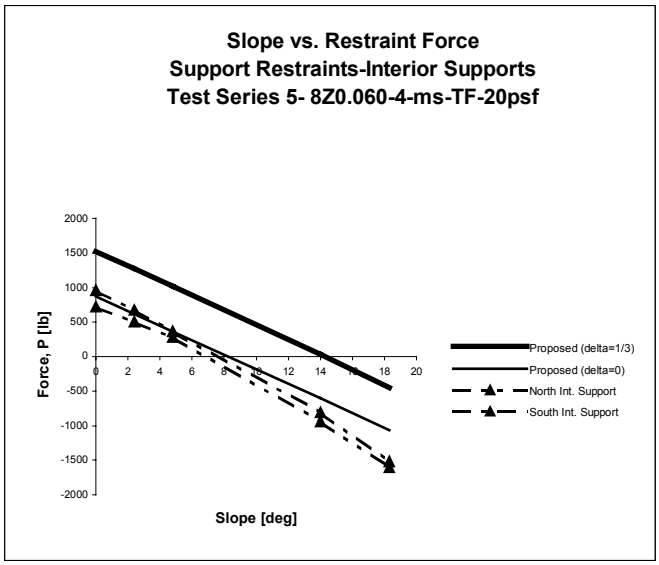
Figure 3.5 Slope vs. Restraint Force Results for Support Restraints-Series 1 to 4



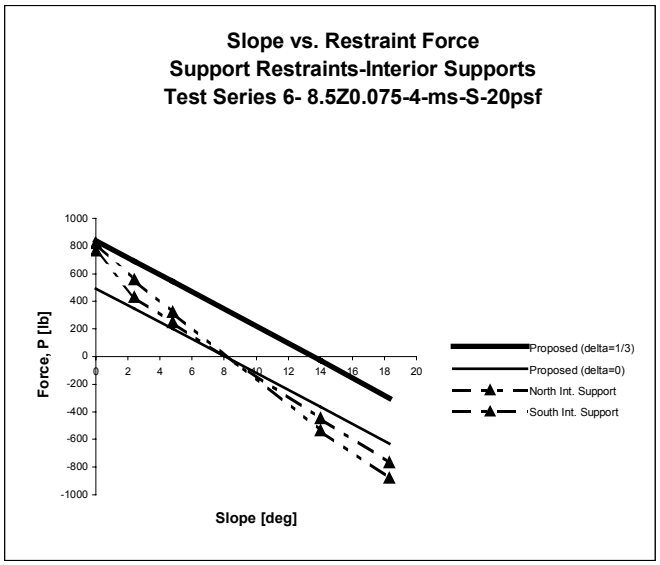
(a)



(b)

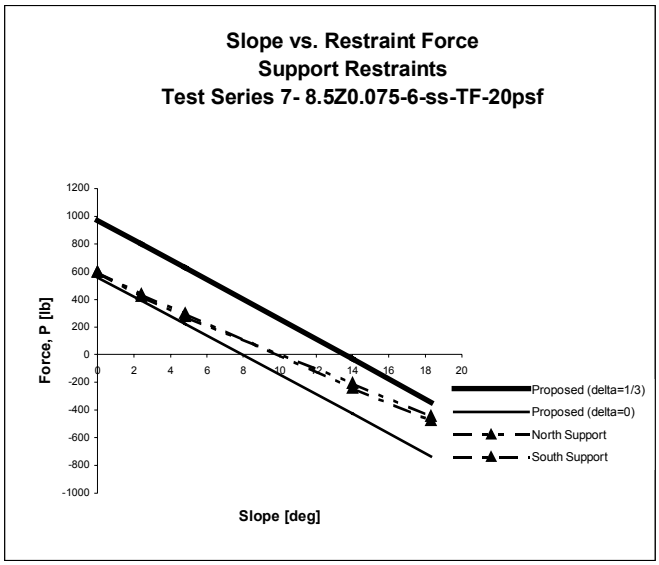


(c)



(d)

Figure 3.6 Slope vs. Restraint Force Results for Support Restraints-Series 5 and 6



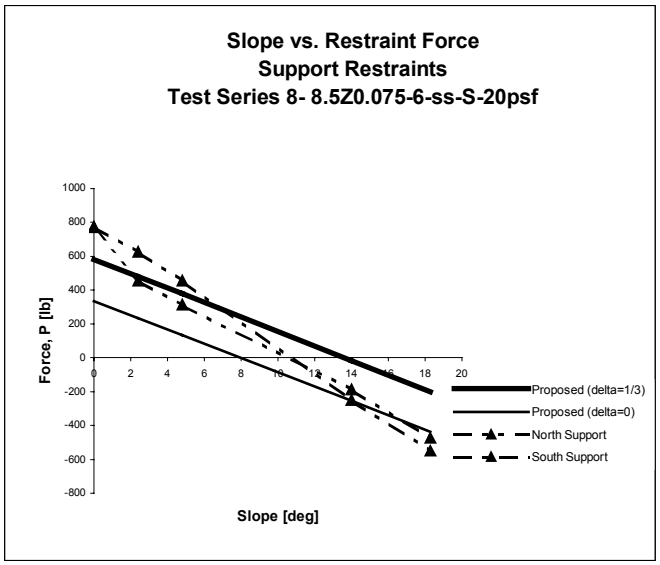


Figure 3.7 Slope vs. Restraint Force Results for Support Restraints-Series 7 and 8

Table 3.1 Representative Eccentricity Values for Support Restraint Test Series

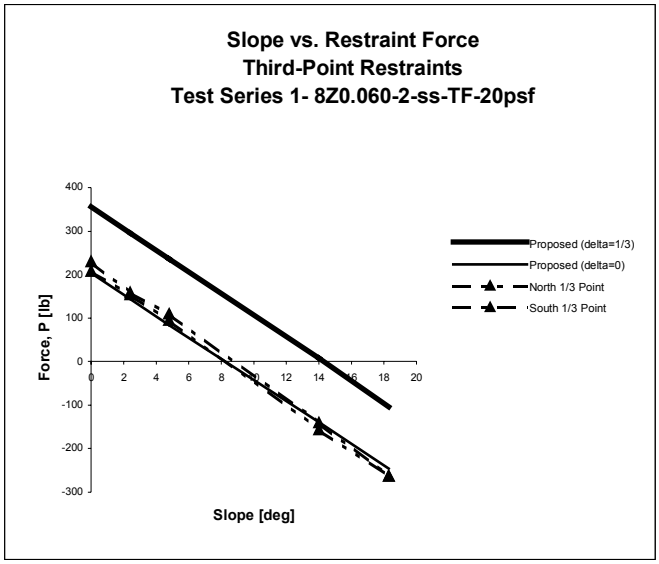
Series Identification	**Representative Eccenticity, δ Support Bracing**			
Series 1 *2 Purlins, Single Span, TF*	0	0	N/A	
Series 2 *2 Purlins, Single Span, S* Seam	0	0		
Series 3 *4 Purlins, Single Span, TF*	0	0 to 1/6		
Series 4 *4 Purlins, Single Span, S*	0	0		
Series 5 *4 Purlins, Multiple Span, TF*	< 0	0	0	< 0
Series 6 4 *Purlins, Multiple Span, S*	0	0	0	0
Series 7 *6 Purlins, Single Span, TF*	1/6	1/6	N/A	
Series 8 *6 Purlins, Single Span, S*	0 to 1/3	0 to 1/3		

3.4 TESTS WITH THIRD-POINT RESTRAINTS

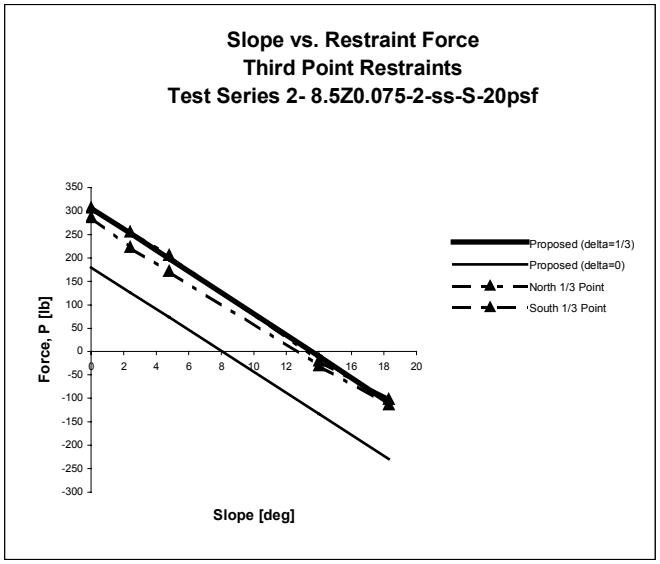
Third-point restraint results are found in Figures 3.8 and 3.9. Figure 3.8 includes the results for all of the single span tests. Figure 3.8a shows the results for a two purlin line, single span system with through-fastened roof panel. Figure 3.8b shows the results for a two purlin line, single span system with standing seam roof panel. Figure 3.8c shows the results for a four purlin line, single span system with through-fastened roof panel. Figure 3.8d shows the results for a four purlin line, single span system with standing seam roof panel.

The results for all of the multiple span tests with third-point restraints are contained in Figure 3.9. Figure 3.9a shows the exterior third-point restraint results for a four purlin line, multiple span system with through-fastened roof panel. Figure 3.9b shows the exterior third-point restraint results for a four purlin line, multiple span system with standing seam roof panel. Figure 3.9c shows the interior third-point restraint results for a four purlin line, multiple span system with through-fastened roof panel. Figure 3.9d shows the interior third-point restraint results for a four purlin line, multiple span system with standing seam roof panel.

Predicted forces assuming $\delta = 0$ and $\delta = 1/3$ are shown on each plot along with the measured data. Overall the results were not consistent with each other. However, the tests in which through-fastened roof panel was used tend to be closer to the prediction with $\delta = 0$. The tests in which standing seam roof panel was used tend to be closer to $\delta = 1/3$ except for the Series 6 (see Figure 3.9b). The north exterior restraint results for this series were very poor with respect to the predicted forces, but the others were in agreement with the predicted forces with $\delta = 0$.



(a)



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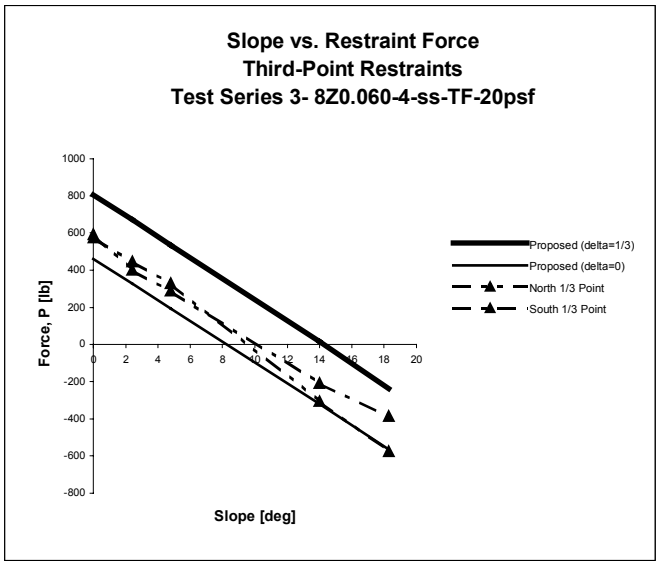

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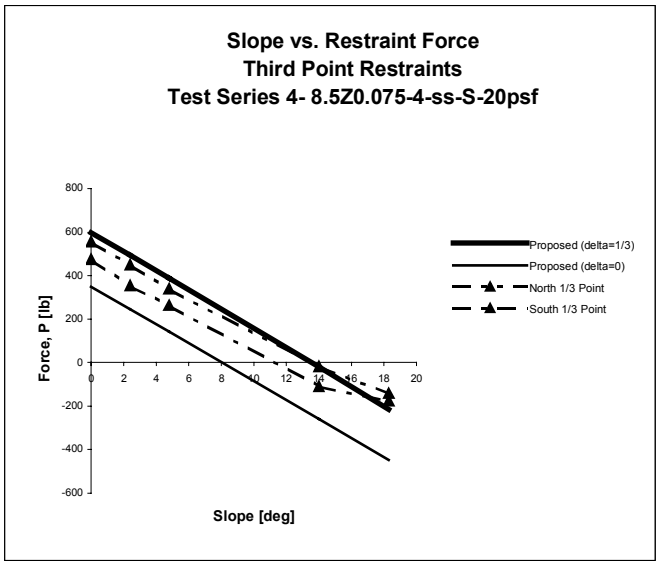


(d)

Figure 3.8 Slope vs. Restraint Force Results for Third-Point Restraints-Series 1 to 4

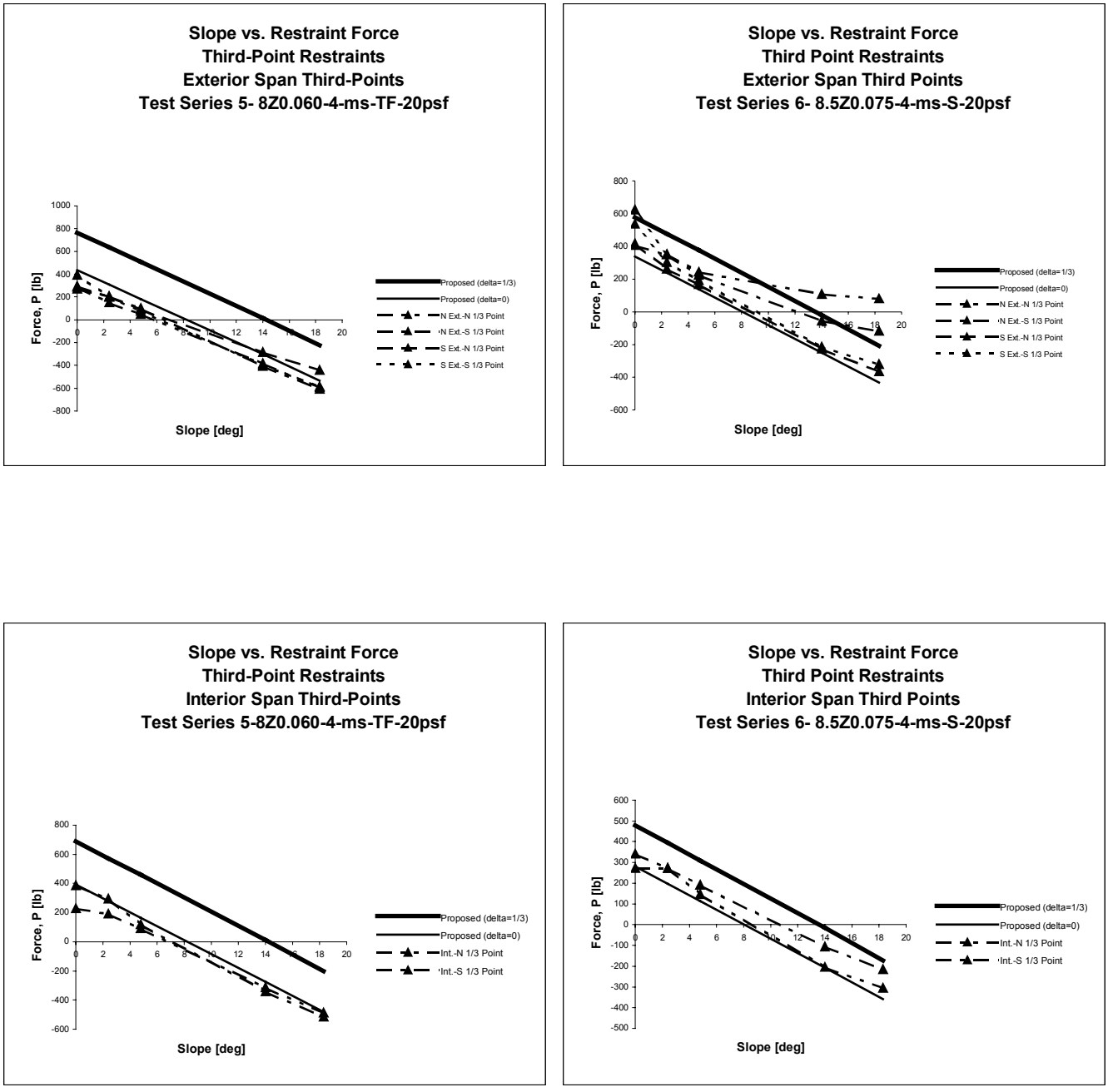


Figure 3.9 Slope vs. Restraint Force Results for Third-Point Restraints-Series 5 and 6

Many of the third-point restraint results were in good agreement with the theoretical forces. To assume the eccentricity values for which the series were closest to would be reasonable. The exception would be when the measured restraint forces were lower than the predicted forces if □ = 0 was used (see Figure 3.10c) or when the measured restraint forces were greater than the predicted forces if □ = 1/3 was used.

Table 3.2 shows the representative values for eccentricity, □, for the third-point bracing condition. These values are not intended to be design values for the proposed equation, but rather they are those values that the measured results were closest to. Any value labeled "NG" indicates that the measured results were of no use and that a representative value of eccentricity could not be determined.

Table 3.2 Representative Eccentricity Values for Third-Point Restraint Test Series

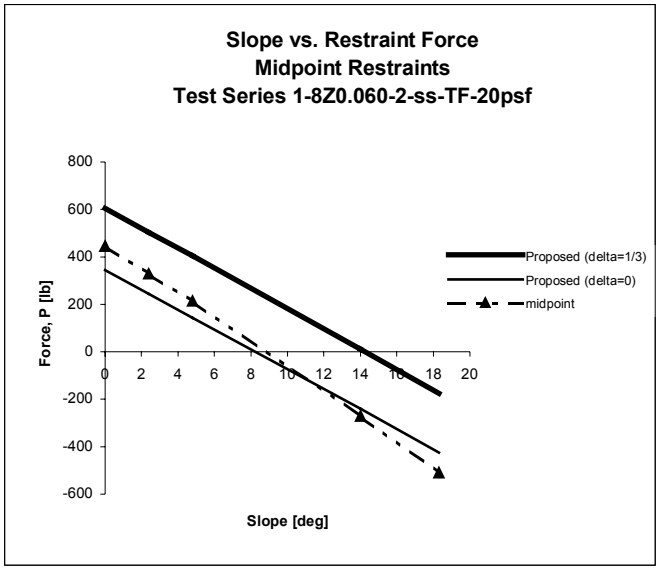
Series Identification	**Representative Eccenticity, δ Third-Point Bracing**					
Series 1 *2 Purlins, Single Span, TF*	0	0	N/A			
Series 2 *2 Purlins, Single Span, S* Seam	1/3	1/3				
Series 3 *4 Purlins, Single Span, TF*	0 to 1/6	0 to 1/6				
Series 4 *4 Purlins, Single Span, S*	1/3	1/3				
Series 5 *4 Purlins, Multiple Span, TF*	0	0	0	0	0	0
Series 6 4 *Purlins, Multiple Span, S*	0	0	0 to 1/6	0 to 1/6	NG	NG

3.5 TESTS WITH MIDPOINT RESTRAINTS

Figures 3.10 and 3.11 show midpoint restraint results. Figure 3.10 includes the results for all of the single span tests. Figure 3.10a shows the results for a two purlin line, single span system with through-fastened roof panel. Figure 3.10b shows the results for a two purlin line, single span system with standing seam roof panel. Figure 3.10c shows the results for a four purlin line, single span system with through-fastened roof panel. Figure 3.10d shows the results for a four purlin line, single span system with standing seam roof panel.

Figure 3.11 includes the results for all of the multiple span tests with midpoint restraints. Figure 3.11a shows the exterior midpoint restraint results for a four purlin line, multiple span system with through-fastened roof panel. Figure 3.11b shows the exterior midpoint restraint results for a four purlin line, multiple span system with standing seam roof panel. Figure 3.11c shows the interior midpoint restraint results for a four purlin line, multiple span system with through-fastened roof panel. Figure 3.11d shows the interior midpoint restraint results for a four purlin line, multiple span system with standing seam roof panel.

Predicted forces assuming $\delta = 0$ and $\delta = 1/3$ are shown on each plot along with the measured data. The results for midpoint bracing were similar to the third-point bracing results in that the tests using through-fastened roof panel had a tendency to be closer to the prediction with $\delta = 0$. The restraint forces for Series 3, however, were in agreement with $\delta = 1/3$ until the roof slope reached 7° after which the forces moved closer to the predicted values where $\delta = 0$ (see Figure 3.10c). The tests in which standing seam roof panel was used tend to be closer to = 1/3. The results from Series 6 were the exception. They tended to agree more with the predicted forces where $\delta = 0$ (see Figures 3.11b and 3.11d).



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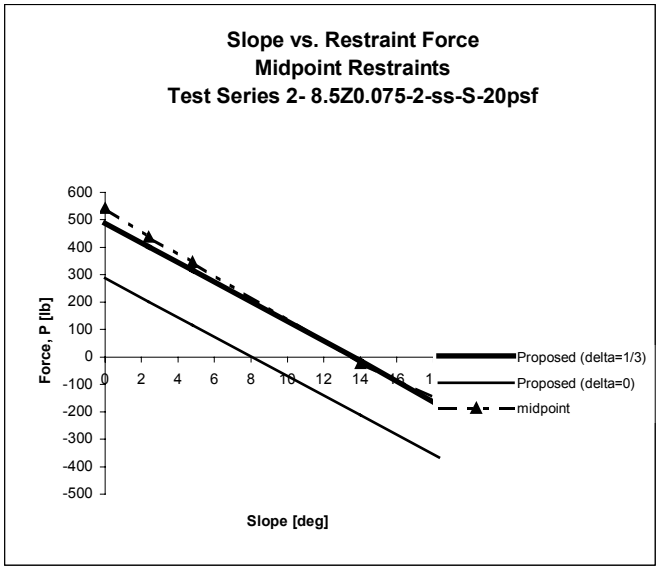

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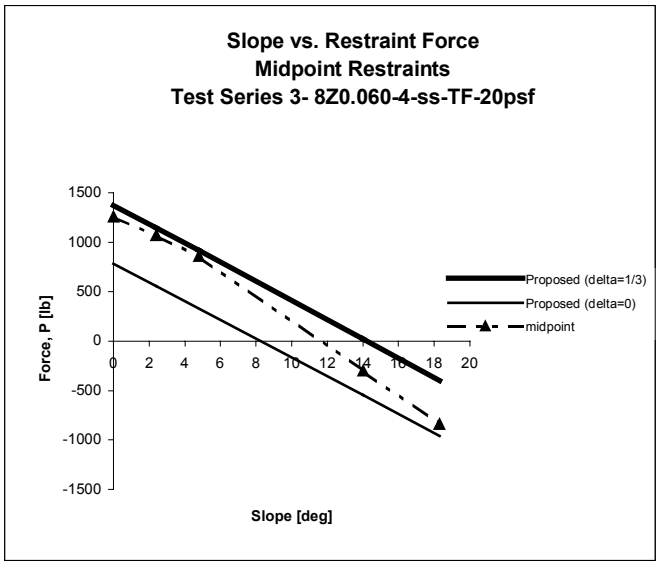

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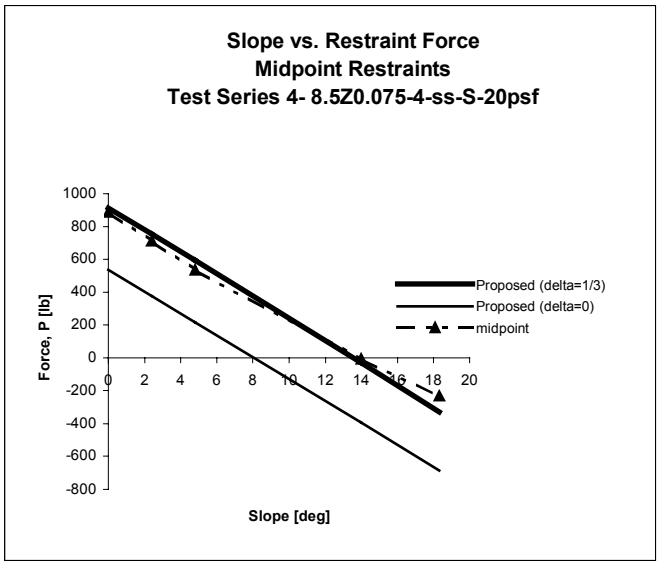
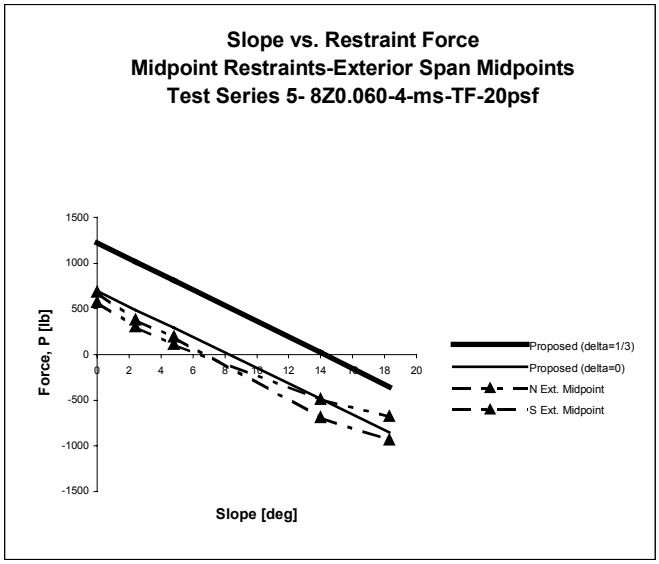
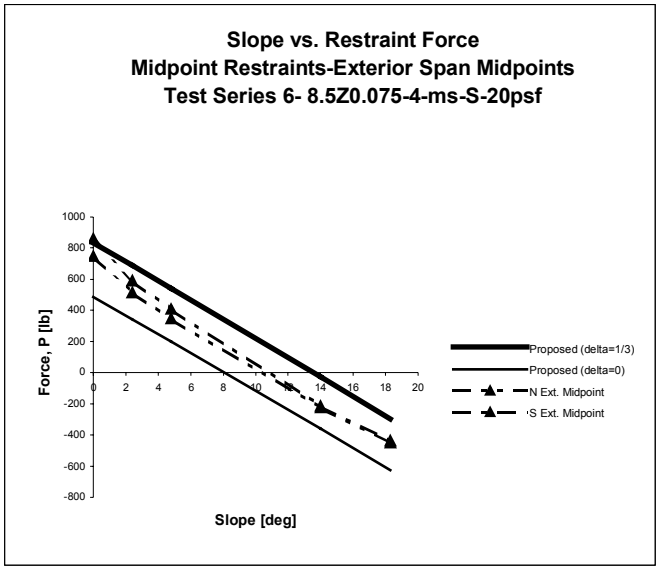


(d)

Figure 3.10 Slope vs. Restraint Force Results for Midpoint Restraints-Series 1 to 4

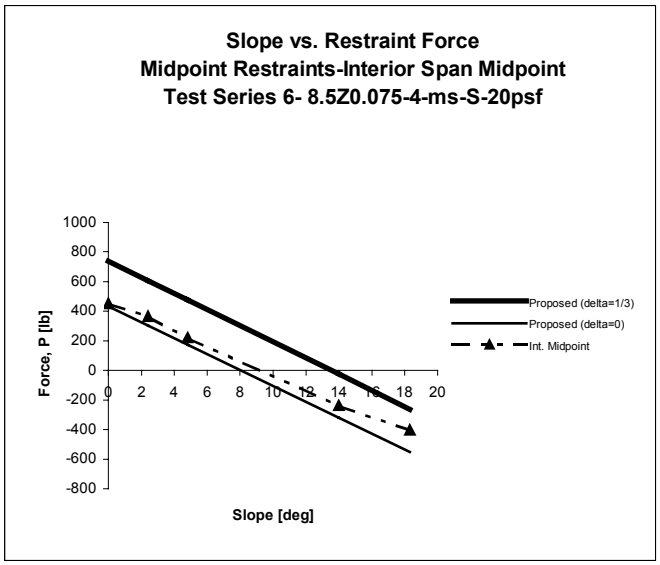


(a)



(b)

(c)



(d)

Figure 3.11 Slope vs. Restraint Force Results for Midpoint Restraints-Series 5 and 6

Table 3.3 shows the representative values for eccentricity, □, for the midpoint bracing condition. Again, these values are not intended to be design values for the proposed equation, but rather they are those values that the measured results were closest to. However, in some cases in which the data was in good agreement with the predicted solution it would be conservative to use the eccentricity value to determine restraint forces. For example, Figure 3.10d shows good a good correlation between the measured and the predicted results, as does Figure 3.10b.

Midpoint bracing results existed where the measured values were lower than the predicted forces. This occurred for the multiple span, through-fastened roof panel tests included in Series 5. Both the exterior and interior midpoint bracing resulted in forces lower than the proposed restraint forces (see Figures 3.11a and 3.11c).

Table 3.3 Representative Eccentricity Values for Midpoint Restraint Test Series

Series Identification	**Representative Eccenticity, δ Midpoint Bracing**		
Series 1 *2 Purlins, Single Span, TF*	0	N/A	
Series 2 *2 Purlins, Single Span, S* Seam	1/3		
Series 3 *4 Purlins, Single Span, TF*	0 to 1/3		
Series 4 *4 Purlins, Single Span, S*	1/3		
Series 5 *4 Purlins, Multiple Span, TF*	0	< 0	0
Series 6 4 *Purlins, Multiple Span, S*	1/6	0	1/6

3.6 TESTS WITH QUARTER-POINT RESTRAINTS

The quarter-point restraint results are shown in Figures 3.12 through 3.15. Figure 3.12 contains the results for the single span tests of Series 1 and 2. Figure 3.12a shows the quarter-point restraint results for a two purlin line, single span system with through-fastened roof panel. Figure 3.12b shows the quarter-point restraint results for a two purlin line, single span system with standing seam roof panel. Figure 3.12c shows the midpoint restraint results for a two purlin line, single span system with through-fastened roof panel. Figure 3.12d shows the midpoint restraint results for a two purlin line, single span system with standing seam roof panel.

The results for the single span tests of Series 3 and 4 are contained in Figure 3.13. Figure 3.13a shows the quarter-point restraint results for a four purlin line, single span system with through-fastened roof panel. Figure 3.13b shows the quarter-point restraint results for a four purlin line, single span system with standing seam roof panel. Figure 3.13c shows the midpoint restraint results for a four purlin line, single span system with through-fastened roof panel. The midpoint restraint results for a four purlin line, single span system with standing seam roof panel are displayed in Figure 3.13d.

Figure 3.14 contains the exterior and interior span, quarter-point results for the multiple span tests of Series 5 and 6. Figure 3.14a shows the exterior span quarter-point restraint results for a four purlin line, multiple span system with through-fastened roof panel. Figure 3.14b shows the exterior span quarter-point restraint results for a four purlin line, multiple span system with standing seam roof panel. Figure 3.14c shows the interior span quarter-point restraint results for a four purlin line, multiple span system with through-fastened roof panel. Figure 3.14d shows the interior span quarter-point restraint results for a four purlin line, multiple span system with standing seam roof panel.

Figure 3.15 includes the exterior and interior span, midpoint results for the multiple span tests of Series 5 and 6. Figure 3.15a shows the midpoint restraint results for a four purlin line, multiple span system with through-fastened roof panel. Figure 3.15b shows the midpoint restraint results for a four purlin line, multiple span system with standing seam roof panel.

Each plot shows the predicted forces assuming $\delta = 0$ and $\delta = 1/3$ along with the measured data. The results were inconsistent with each other and were very poor with respect to the proposed forces for most of the single span and multiple span tests. Figure 3.13d was the only test in which a good correlation between measured forces and predicted values was shown. The other results for quarter-point bracing were inconclusive as to what value for δ might be assumed for the determination of predicted results. To assume any $\delta = 0$ or $\delta = 1/3$ would be unconversative in all cases.

Table 3.4 shows the representative values for eccentricity, □, for the quarter-point bracing condition. These values are those that the measured restraint forces were closest to and are not intended to be design values for the proposed equation.

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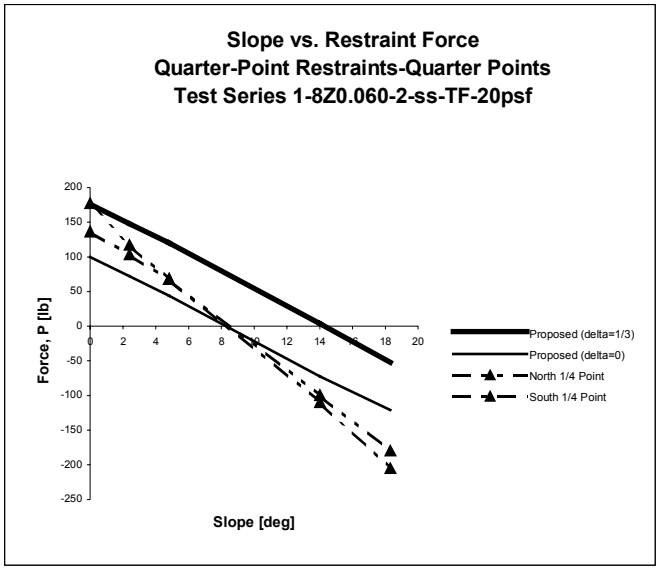
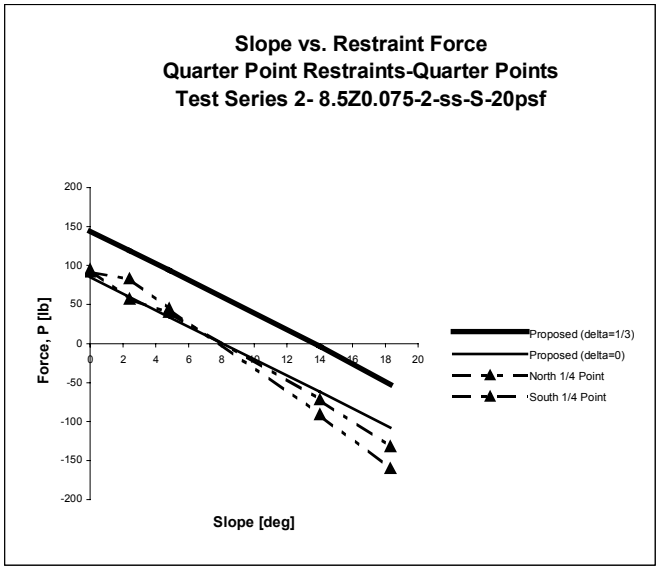


(a)



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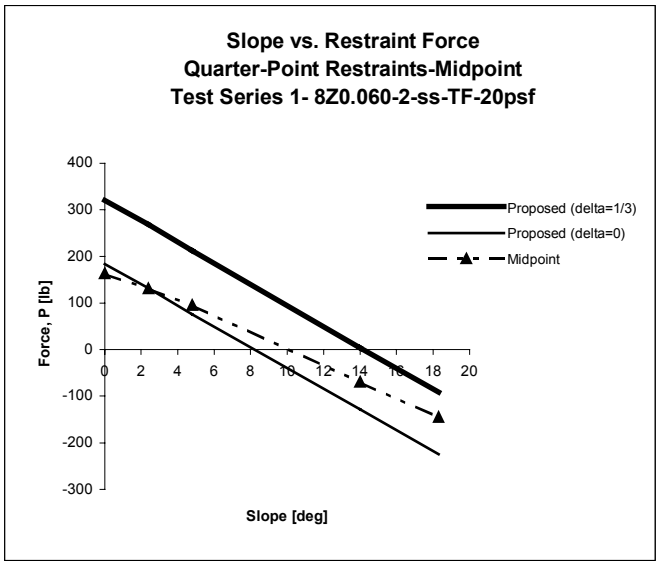
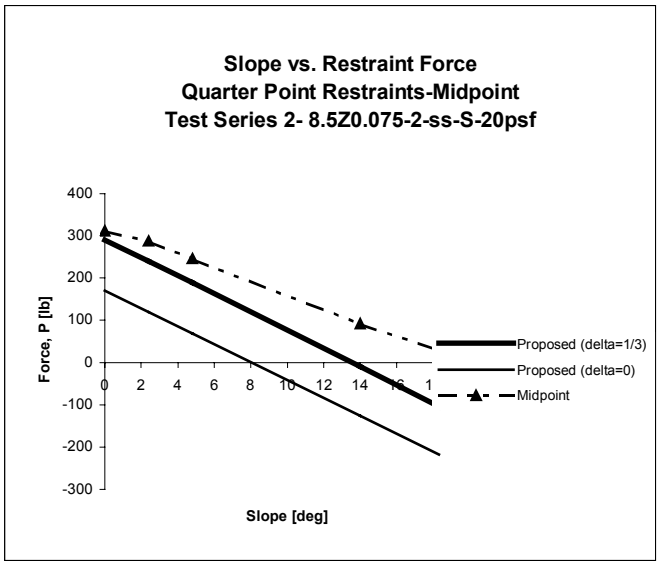
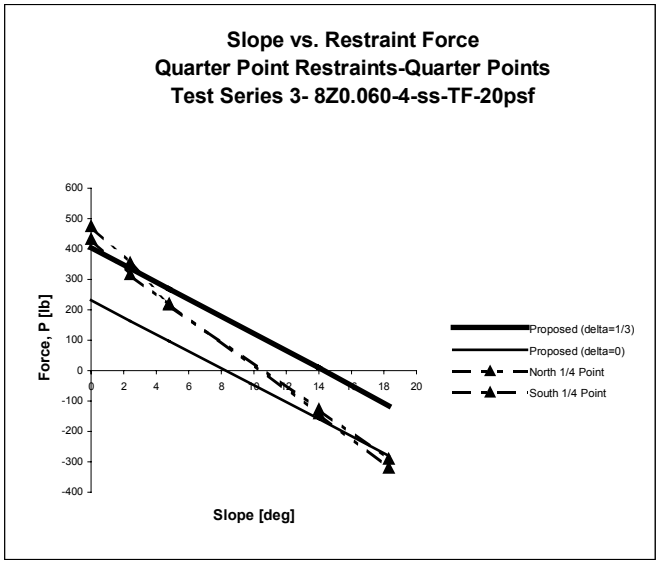


(c)

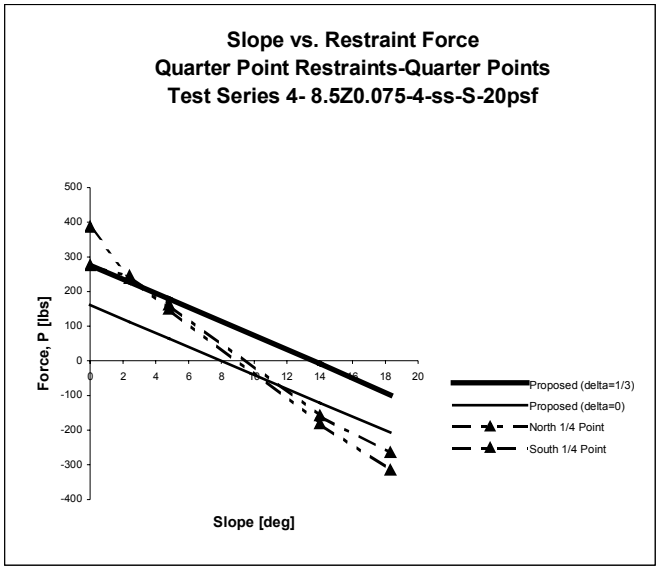


(d)

Figure 3.12 Slope vs. Restraint Force Results for Quarter-Point Bracing-Series 1 and 2



(a)



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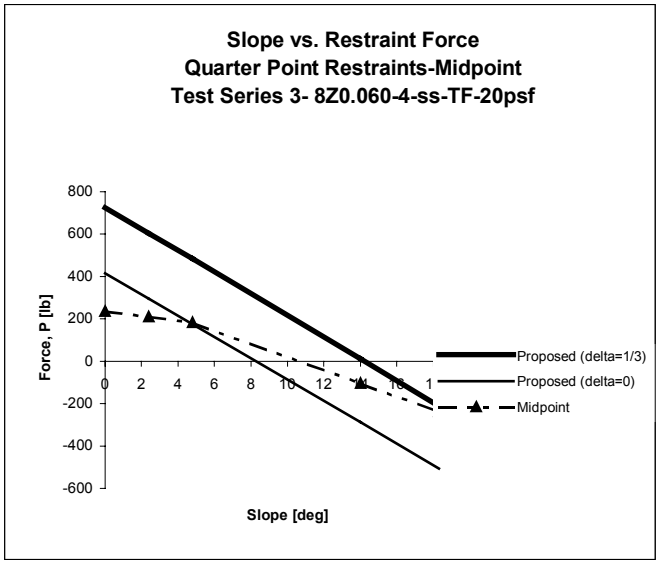

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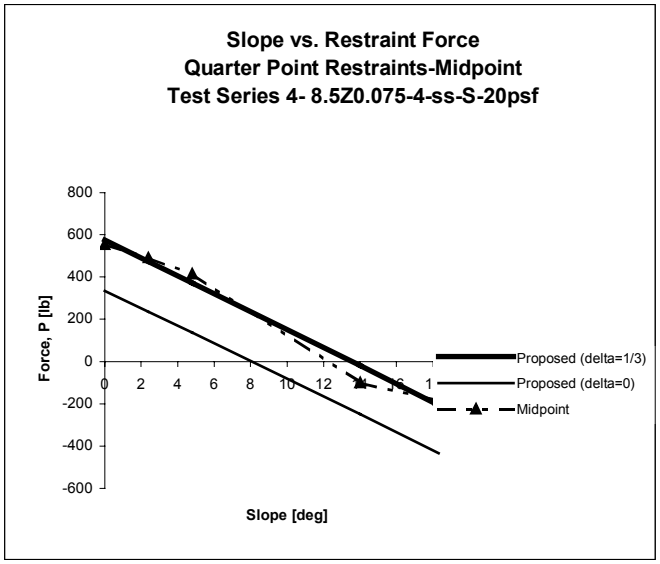
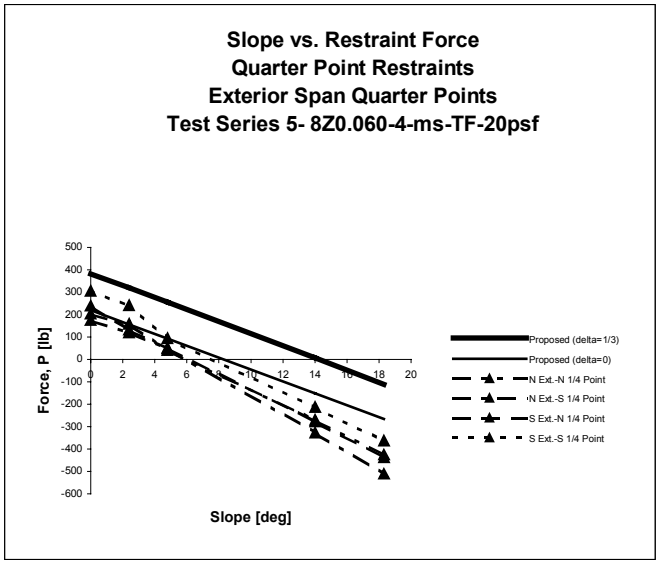


(d)

Figure 3.13 Slope vs. Restraint Force Results for Quarter-Point Restraints Series 3 and 4



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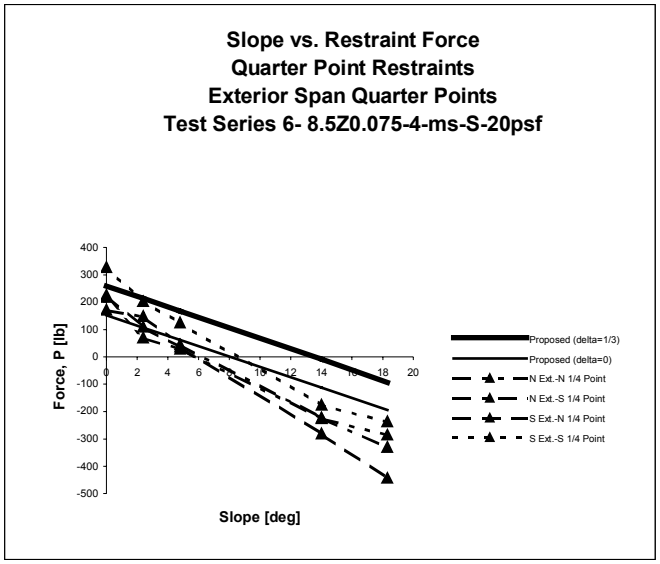

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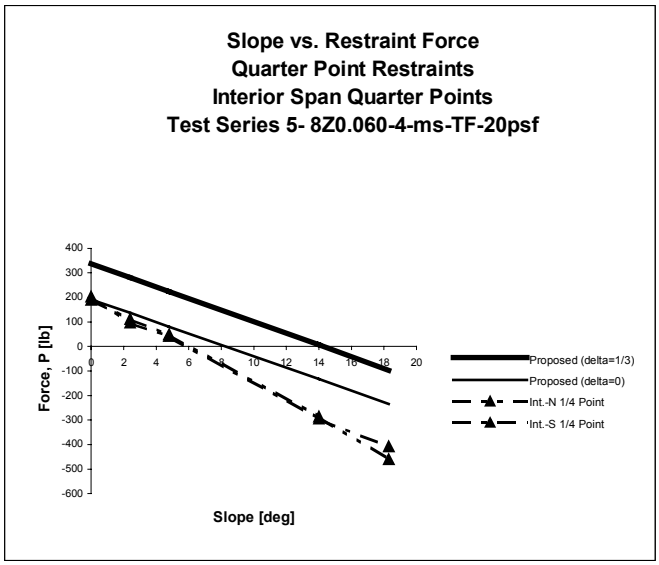

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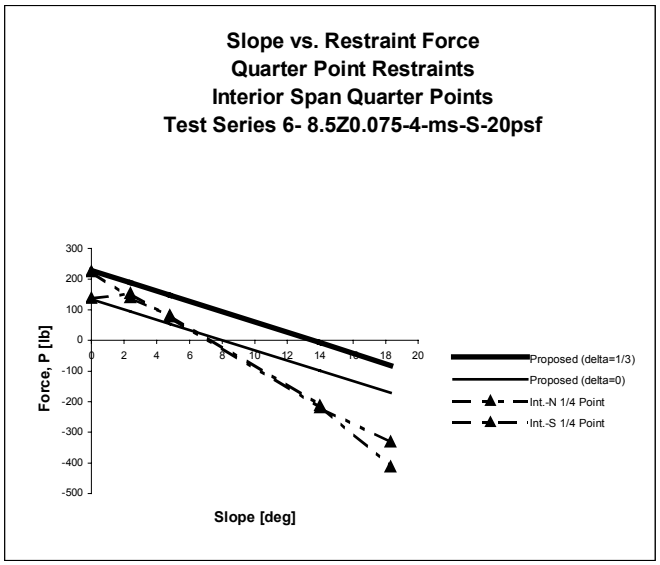
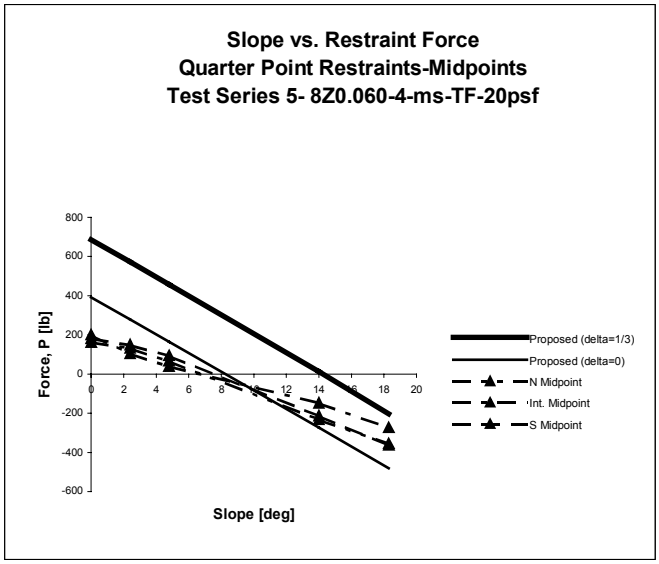


(d)

Figure 3.14 Slope vs. Restraint Force Results for Quarter-Point Restraints (Quarter-Points)-Series 5 and 6



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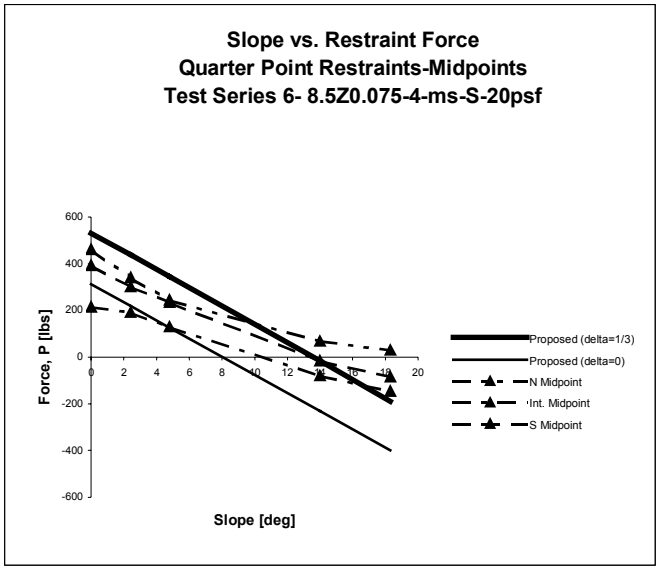


(b)

Figure 3.15 Slope vs. Restraint Force Results For Quarter-Point Restraints-(Midpoints) Series 5 and 6

Table 3.4 Representative Eccentricity Values for Quarter-Point Restraint Test Series

Series Identification	**Representative Eccenticity, δ Quarter-Point Bracing**								
Series 1 *2 Purlins, Single Span, TF*	0	0 to 1/6	0	N/A					
Series 2 *2 Purlins, Single Span, S* Seam	1/3	NG	1/3						
Series 3 *4 Purlins, Single Span, TF*	NG	0 to 1/3	NG						
Series 4 *4 Purlins, Single Span, S*	NG	1/3	NG						
Series 5 *4 Purlins, Multiple Span, TF*	< 0	0	< 0	< 0	0	< 0	< 0	0	< 0
Series 6 4 *Purlins, Multiple Span, S*	< 0	NG	< 0	< 0	NG	< 0	< 0	NG	< 0

3.7 TESTS WITH THIRD-POINT PLUS SUPPORT RESTRAINTS

Figures 3.16 through 3.19 illustrate the third-point plus support restraint results. The results for the single span tests of Series 1 and 2 are included in Figure 3.16. Figure 3.16a shows the support restraint results for a two purlin line, single span system with through-fastened roof panel. The support restraint results for a two purlin line, single span system with standing seam roof panel are located in Figure 3.16b. Figure 3.16c shows the third-point restraint results for a two purlin line, single span system with through-fastened roof panel. The third-point restraint results for a two purlin line, single span system with standing seam roof panel can be seen in Figure 3.16d.

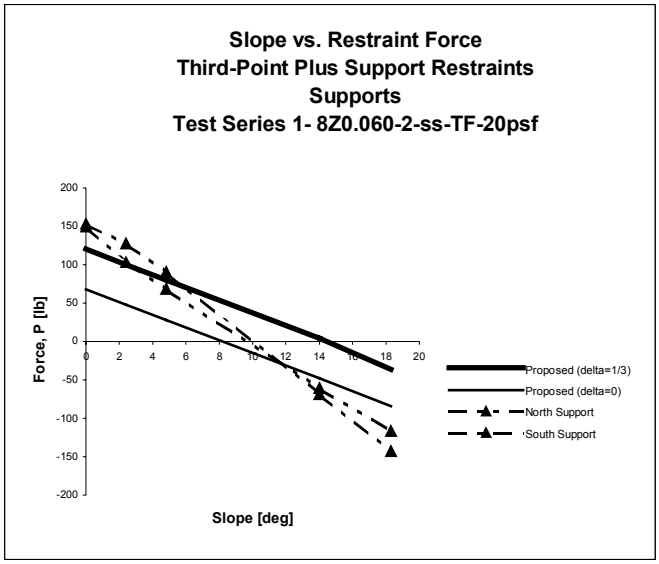
The results for the single span tests of Series 3 and 4 are included in Figure 3.17. Figure 3.17a contains the support restraint results for a four purlin line, single span system with through-fastened roof panel. The support restraint results for a four purlin line, single span system with standing seam roof panel are located in Figure 3.17b. Figure 3.17c shows the third-point restraint results for a four purlin line, single span system with through-fastened roof panel. The results for third-point restraints for a four purlin line, single span system with standing seam roof panel are displayed in Figure 3.17d.

The exterior and interior span, support restraint results for the multiple span tests of Series 5 and 6 are located in Figure 3.18. Figure 3.18a shows the exterior support restraint results for a four purlin line, multiple span system with through-fastened roof panel. The exterior support restraint results for a four purlin line, multiple span system with standing seam roof panel are found in Figure 3.18b. Figure 3.18c shows the interior support restraint results for a four purlin line, multiple span system with through-fastened roof panel. Figure 3.18d shows the interior support restraint results for a four purlin line, multiple span system with standing seam roof panel.

Figure 3.19 includes the third-point restraint results for exterior and interior spans for the multiple span tests of Series 5 and 6. Figure 3.19a shows the third-point restraint results for a four purlin line, multiple span system with through-fastened roof panel. The third-point restraint results for a four purlin line, multiple span system with standing seam roof panel are shown in Figure 3.19b.

The predicted forces assuming $\delta = 0$ and $\delta = 1/3$, along with the measured data, were shown on each plot. Just as with the quarter-point restraint results, the test data for the third-point plus support restraint was inconsistent and insufficient for most of the tests. The only tests which showed a good correlation between measured and predicted forces were the four purlin, single span tests (see Figures 3.16c and 3.16d). The remaining results for third-point plus support bracing were inconclusive. To assume any $\delta = 0$ or $\delta = 1/3$ would be unconversative in all cases.

The representative values for eccentricity, □, for the third-point plus support bracing condition are shown in Table 3.5. In no way should these values be used for the prediction of lateral restraint forces for such a bracing system. They were merely the values closest to the measured results.



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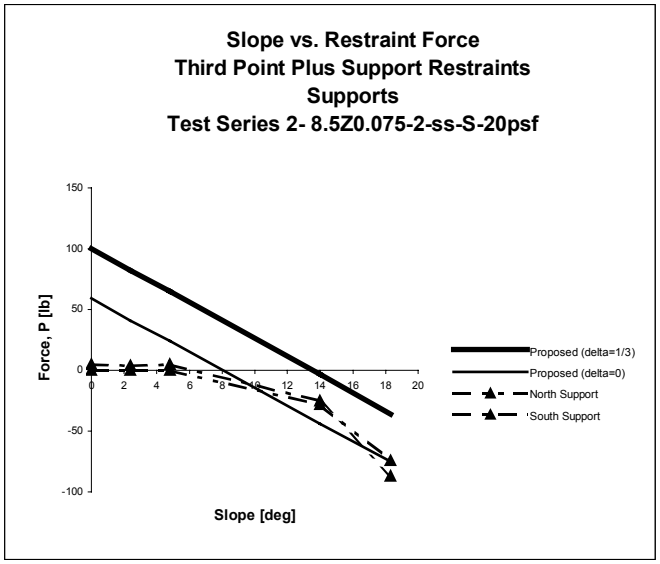

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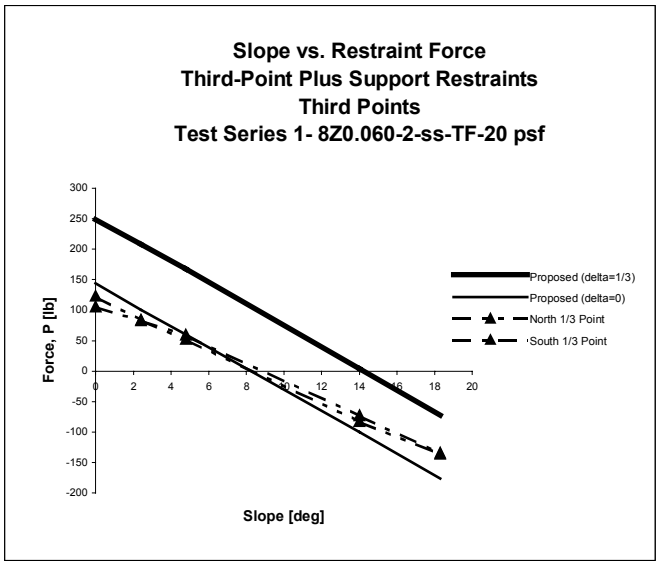

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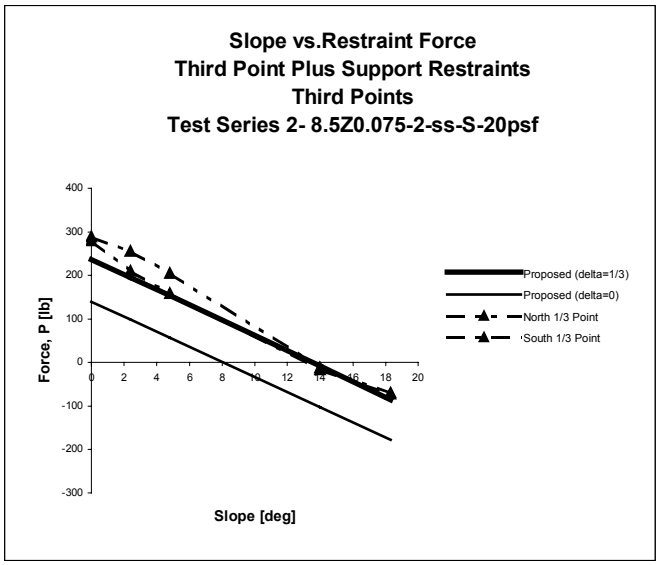
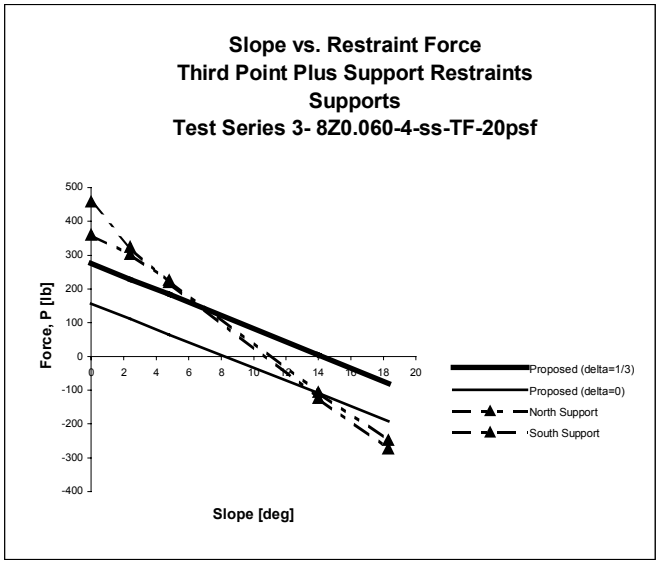
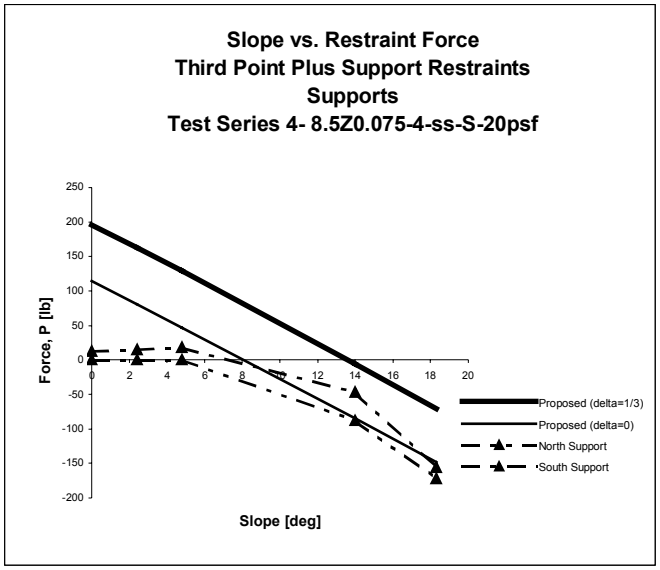


(d)

Figure 3.16 Slope vs. Restraint Force Results for Third-Point Plus Support Restraints Series 1 and 2



(a)



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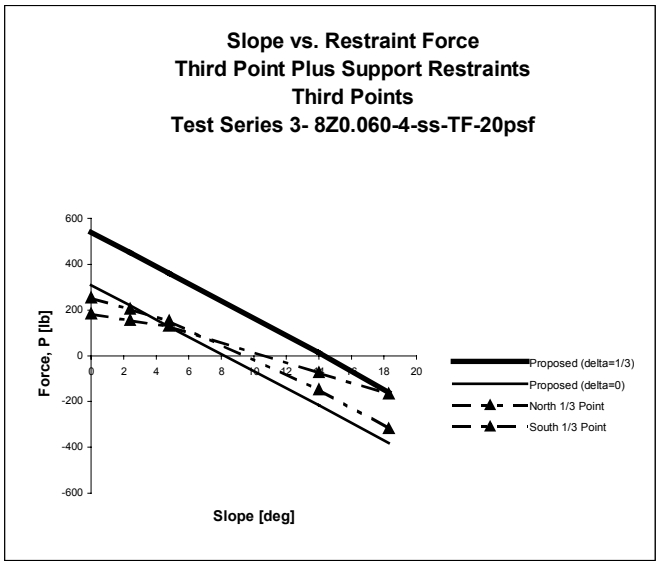

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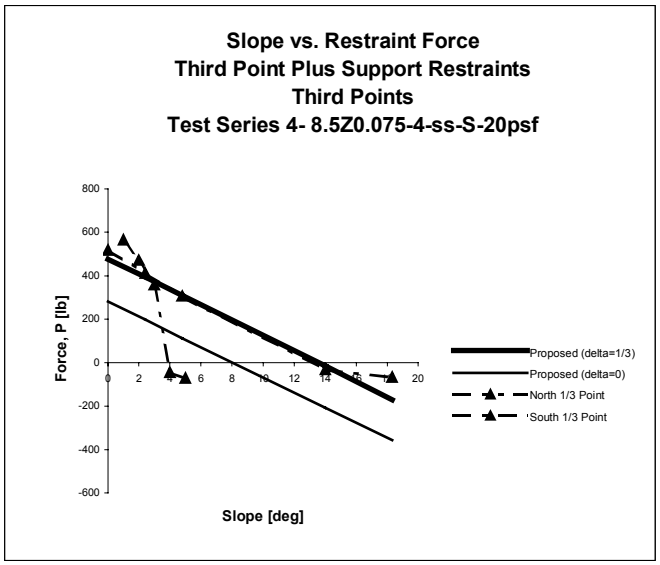
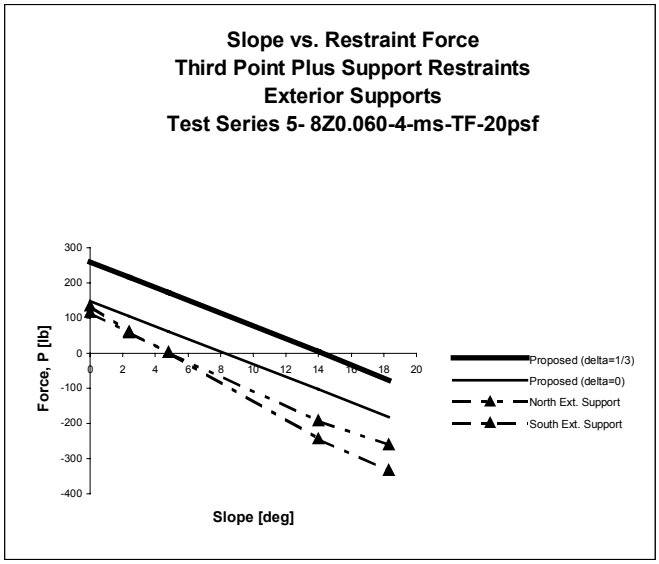


(d)

Figure 3.17 Slope vs. Restraint Force Results for Third-Point Plus Support Restraints Series 3 and 4



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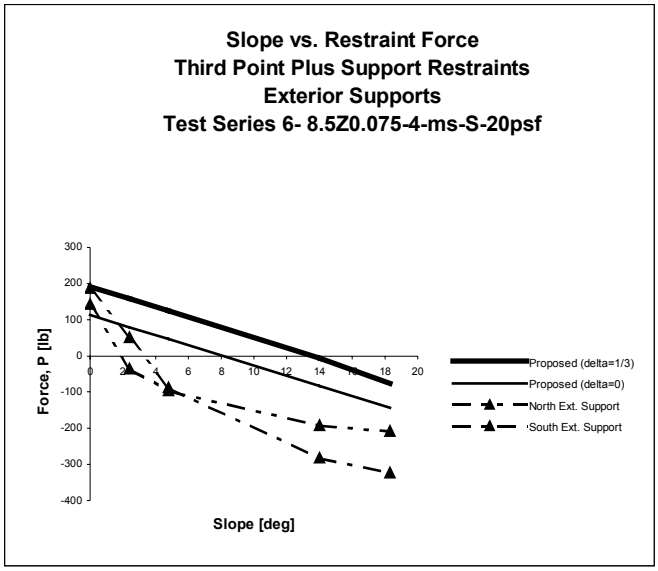

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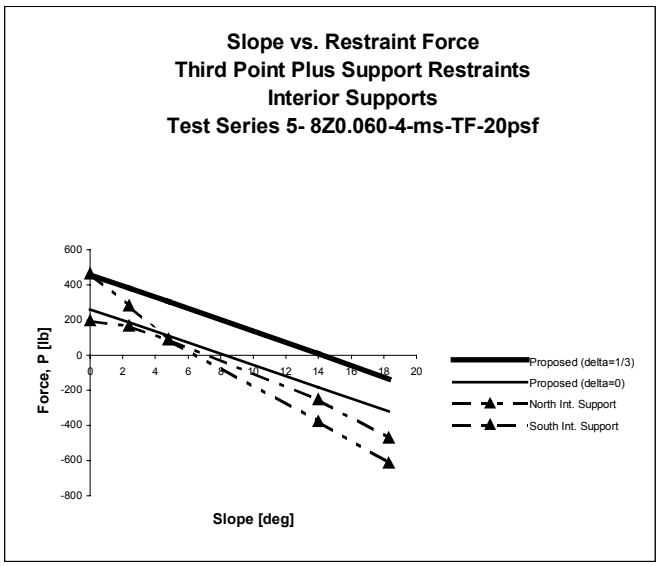

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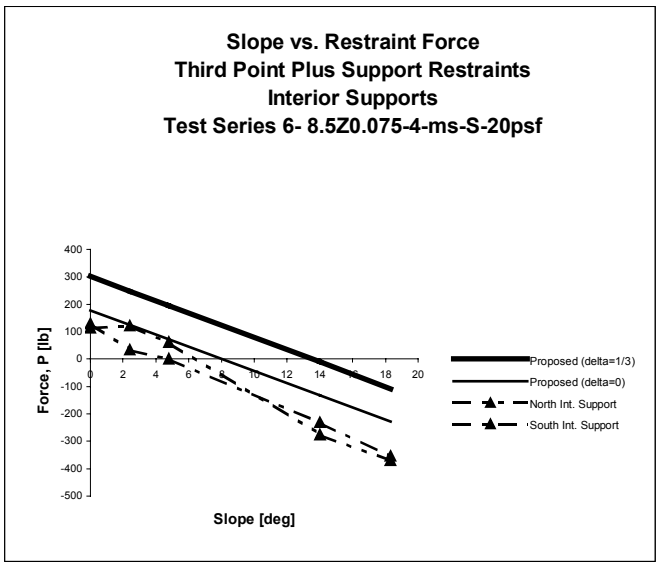
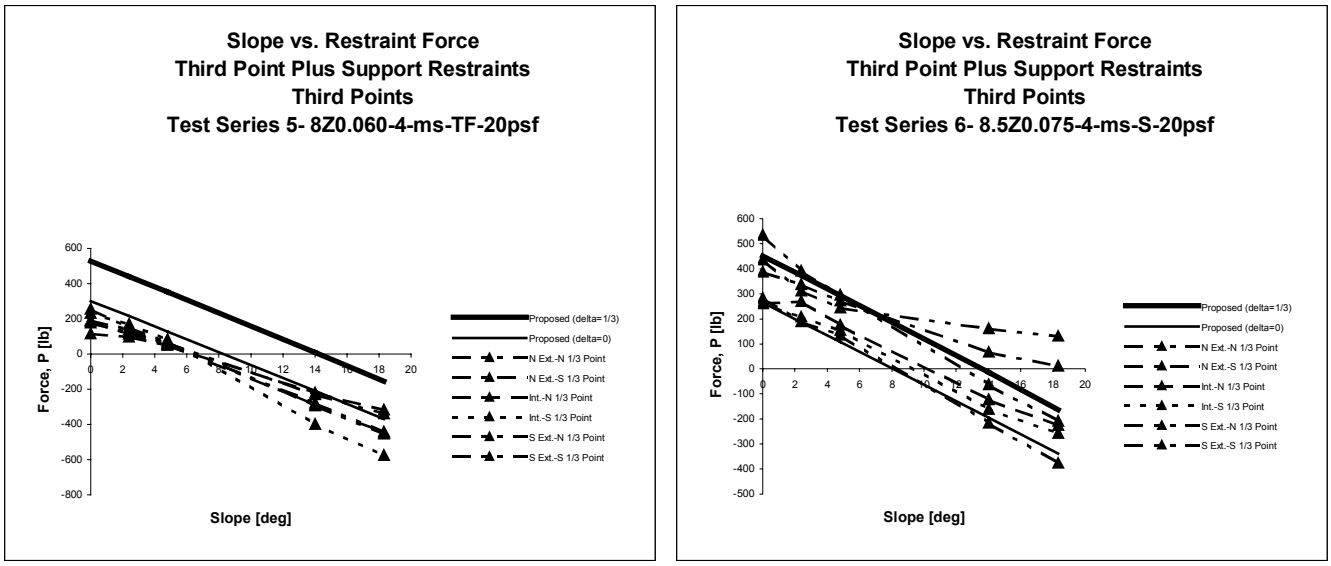


(d)

Figure 3.18 Slope vs. Restraint Force Results for Third-Point Plus Support Restraints (Supports)-Series 5 and 6



(a) (b)

Figure 3.19 Slope vs. Restraint Force Results for Third-Point Plus Support Restraints (Third-Points)-Series 5 and 6

Table 3.5 Representative Eccentricity Values for Third-Point Plus Support Restraint Test Series

Series Identification	**Representative Eccenticity, δ Third-Point Plus Support Bracing**									
Series 1 *2 Purlins, Single Span, TF*	NG	0	0	NG	N/A					
Series 2 *2 Purlins, Single Span, S* Seam	0	1/3	1/3	0						
Series 3 *4 Purlins, Single Span, TF*	NG	0 to 1/6	0 to 1/6	NG						
Series 4 *4 Purlins, Single Span, S*	0	1/3	1/3	0						
Series 5 *4 Purlins, Multiple Span, TF*	< 0	< 0	< 0	NG	< 0	< 0	< 0	< 0	< 0	< 0
Series 6 4 *Purlins, Multiple Span, S*	< 0	1/3	0	< 0	0	1/6	< 0	NG	NG	< 0

3.8 ANALYSIS OF PREVIOUS RESEARCH RESULTS

3.8.1 General Comments

Previous research performed by Ghazanfari and Murray, (1982) and Rivard and Murray, (1986) was similar to the experimental work performed to validate Nuebert and Murray's proposed design equations. Because of this, the required restraint forces for various bracing schemes and test set-ups from the previous work are now compared to predicted solutions determined from Nuebert and Murray's proposed prediction equation. All comparisons are made using a distributed load of 20 psf.

Ghazanfari and Murray (1982) tested two Z-purlin, single span roof systems with through fastened roof panel and 0:12 slope. Restraint forces were determined for lateral bracing at two locations: support and quarter-point.

Rivard and Murray (1986) tested two Z-purlin, single span and multiple span roof systems with standing seam roof panel. Each test was conducted on a horizontal roof system (0:12 slope). Restraint forces were determined for lateral bracing at three locations: support, third-point and midpoint.

3.8.2 Ghazanfari and Murray's Results

The Z-purlins used for these tests were 8 in. in depth and had a thickness of 0.090 in. The span length was 20 ft and the spacing between purlins was 5 ft on center. The tests were performed with through-fastened roof panel and are comparable to those performed in Series 1 of this study with respect to the purlin depth, span length, and purlin spacing. The exception is the purlin thickness. Table 3.6 shows the measured and predicted restraint forces for each bracing configuration at 20 psf. The predicted forces are based on a diaphragm stiffness of 10,000 lb/in.

For the support condition, the difference between the average measured restraint force and the predicted force with □ = 1/3 is 9%. For the quarter-point exterior restraints, the average restraint force is within 20% of the predicted force with $\delta = 0$. The quarter-point interior (midpoint) restraint differs from the predicted value with $\delta = 0$ by 4%.

The equivalent to these tests are those of Series 1 at the same bracing locations: support and quarter-point. For the support condition, the Series 1 results were closer to the predicted solution with $\delta = 1/3$, but the percent difference was 24% from the predicted.

the Series 1 quarter-point exterior forces were closer to the theoretical solution with δ = 1/3 with a difference of 11%. The same forces had a difference of 57% with respect to the predicted force with δ = 0. The quarter-point interior force was closer to the predicted force with δ = 0 and differed by 11%.

Table 3.6 Comparison Between Ghazanfari and Murray's Results and Predicted Forces

Bracing Location	Restraint Forces			
	Brace1 (lbs)	*Brace 2 (lbs)*	*Predicted δ =1/3(lbs)*	*Predicted δ =0 (lbs)*
Support	225	230	250	146
Quarter-Point-Exterior	75	100	125	73
Quarter-Point-Interior	125		225	131

3.8.3 Rivard and Murray's Results – Single Span

The Z-purlins used for these tests were 8 in. in depth and had a thickness of 0.060 in. The span length was 20 ft and the spacing between purlins was 5 ft on center. The tests were performed with standing seam roof panel and are comparable to those performed in Series 2 in this study. Table 3.7 shows the measured and predicted restraint forces for each bracing configuration at 20 psf. The predicted forces are based on a diaphragm stiffness of 1,500 lb/in.

For the support condition, the average measured restraint force was within 12% of the predicted force with δ = 1/3. For third-point restraints, the average measured restraint force was within 34% of the predicted force if δ = 0. The midpoint restraint force was in fair agreement with the proposed force if δ = 1/3, the difference between the forces being 15%.

Table 3.7 Comparison Between Rivard and Murray's Single Span Results and Predicted Forces

Bracing Location	Restraint Forces-Single Span			
	Brace 1 (lbs)	*Brace 2 (lbs)*	*Predicted δ=1/3 (lbs)*	*Predicted δ=0 (lbs)*
Support	180	200	216	122
Third-Point	150	200	230	130
Midpoint	310		368	209

The equivalent to these tests are those of Series 2 at the same bracing locations: support, third-point, and midpoint. The Series 2 results for the support restraints were closer to the predicted solution with □ = 0, the difference being 24% from the predicted force with □ = 0 and 55% from the predicted force with □ = 1/3. The third-point restraint forces were closer to the theoretical force with δ = 1/3. The difference was 13% from the predicted force with δ = 1/3 and 98% from the predicted force with δ = 0. The midpoint restraint force was nearer to the predicted force with δ = 1/3. The difference was 5% with respect to the predicted force with δ = 1/3 and 61% with respect to the predicted force with δ =0.

3.8.4 Rivard and Murray's Results – Multiple Span

The Z-purlins used for these tests were 8 in. in depth and had a thickness of 0.075 in. Three spans of 23 ft were used for the tests and the spacing between purlins was 5 ft on center. Standing seam roof panel was used for these tests. Table 3.8 shows the measured and predicted restraint forces for each bracing configuration at 20 psf. The predicted forces were calculated using a diaphragm stiffness of 1,500 lb/in. The notation used for restraints in Table 3.8 lists braces 1 through 4. If the bracing condition being considered used two restraints then "Brace 1" and "Brace 2" show results and the other locations are labeled "N/A". For example, the support restraint condition for the multiple span tests used four restraints, one at each support. The interior support restraints are listed

separately because the predicted forces are different than those for the exterior support restraints. Hence, only two restraint forces are shown for the interior support restraints. The only restraint condition in which all four restraints were used was third-point exterior bracing. This means that two restraints were located at the third-points in each exterior span.

Table 3.8 Comparison Between Rivard and Murray's Single Span Results and Predicted Forces

Bracing Location	**Restraint Forces-Multiple Span**					
	Brace 1 (lbs)	*Brace 2 (lbs)*	*Brace 3 (lbs)*	*Brace 4 (lbs)*	*Predicted δ =1/3 (lbs)*	*Predicted δ = 0 (lbs)*
Supports-Interior	475	525	N/A	N/A	454	260
Support-Exterior	190	190	N/A	N/A	249	142
Third-Points-Interior	125	175	N/A	N/A	228	131
Third-Points-Exterior	220	125	220	150	266	152
Midpoint-Interior	280	N/A	N/A	N/A	356	204
Midpoint-Exterior	330	330	N/A	N/A	400	230

For each restraint condition, the measured forces were in between the predicted forces with $\delta = 0$ and $\delta = 1/3$. The only case in which this was not true was for the interior support restraints (see Table 3.8). In that case, the average measured force of 500 lbs was 46 lbs greater than the predicted force with $\delta = 1/3$. The percent difference is 10% for this eccentricity and 98% for $\delta = 0$. The interior support restraint showed a difference of 23% from the predicted result with an eccentricity value of $\delta = 1/3$ and 33% with $\delta = 0$.

The third-point restraint results, both exterior and interior, were closer to the predicted force with $\delta = 0$. A difference of 18% was shown between the exterior results and the predicted forces. The percent difference for the interior restraints when compared to the proposed forces was 15%.

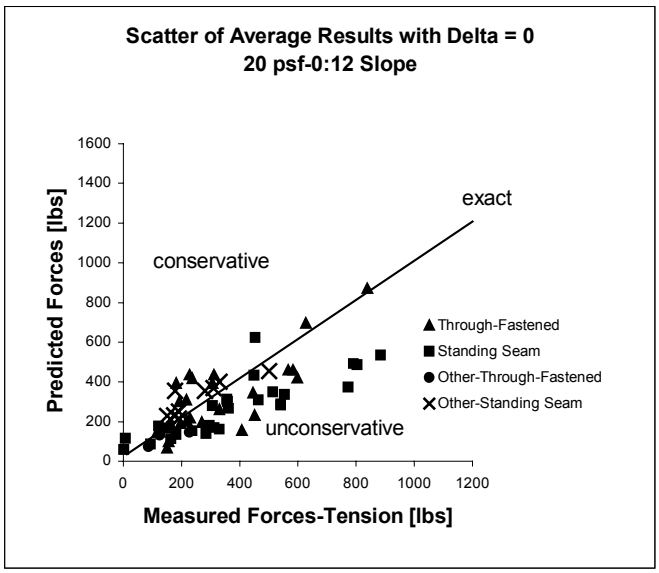
The difference between the interior midpoint restraint and the predicted $\delta = 1/3$ and $\delta = 0$ forces are equal, whereas the measured forces for the exterior midpoint restraints were closer to the predicted with an eccentricity value of 1/3.

No comparisons can be made between Rivard and Murray's multiple span results and this study. Series 6 was tested with four purlins, all of which were 8.5 in. deep. The span lengths for Series 6 were 20 ft as compared to 23 ft used for Rivard and Murray's multiple span tests.

3.8.5 Summary of Previous and Current Research

The previous research results discussed in this chapter are similar to the equivalent tests performed in the current study. The measured forces are near one of the theoretical predictions (= 0 or = 1/3), but no definitive trends were identified.

Figure 3.20 shows the scatter of the average measured forces for = 0 and = 1/3 at each roof slope except for 2:12. Many of the tests reached the zero-slope near this slope and the forces were very small and difficult to measure. On each graph, data points for each type of roof panel are shown for the current research. The data points represent the average measured forces for every restraint condition at a load of 20 psf. Any measured force that is the same as the predicted force is represented by the solid line labeled "exact". Data points located above this show that the measured forces are smaller than the predicted forces. Those points that are below this line represent measured forces that are greater than the predicted forces.



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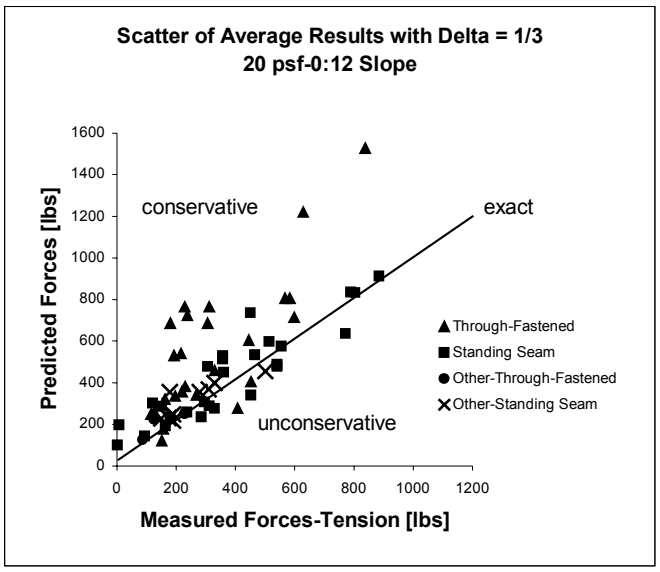

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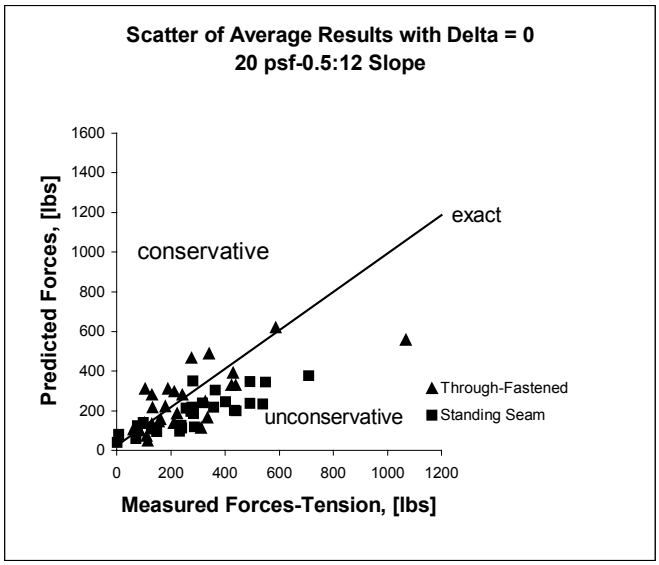

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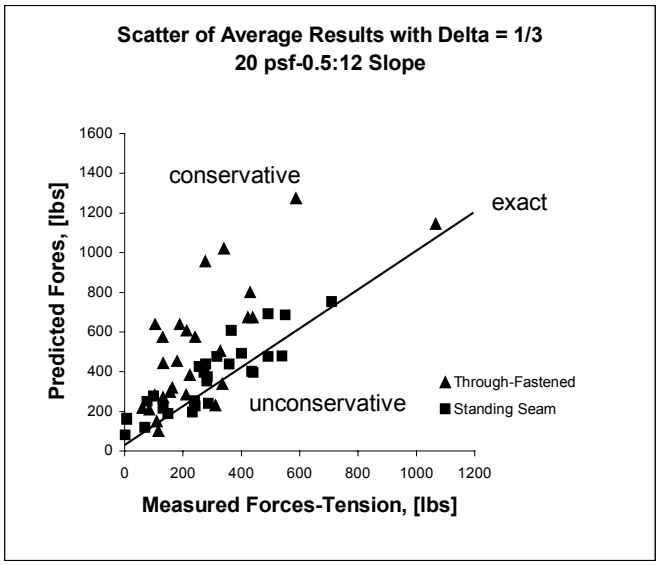

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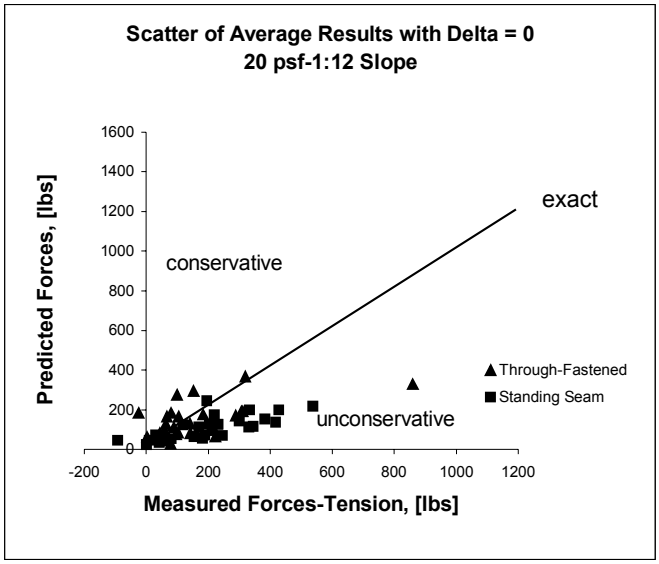
Figure 3.20 Scatter Graphs of Results with Proposed Predictions



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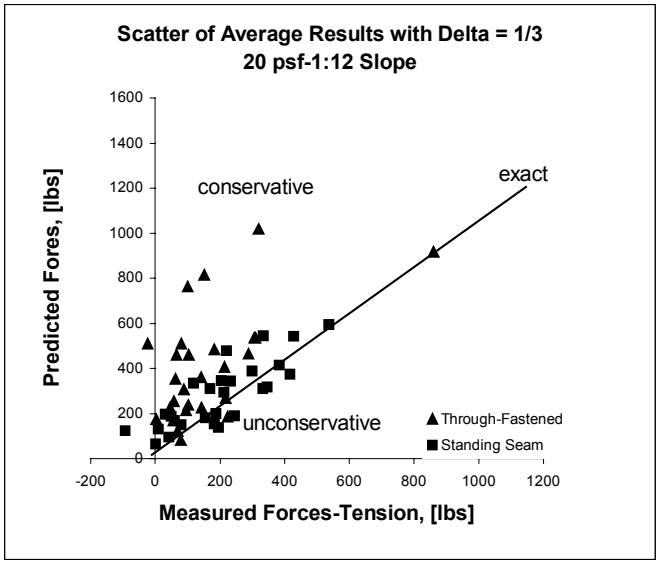

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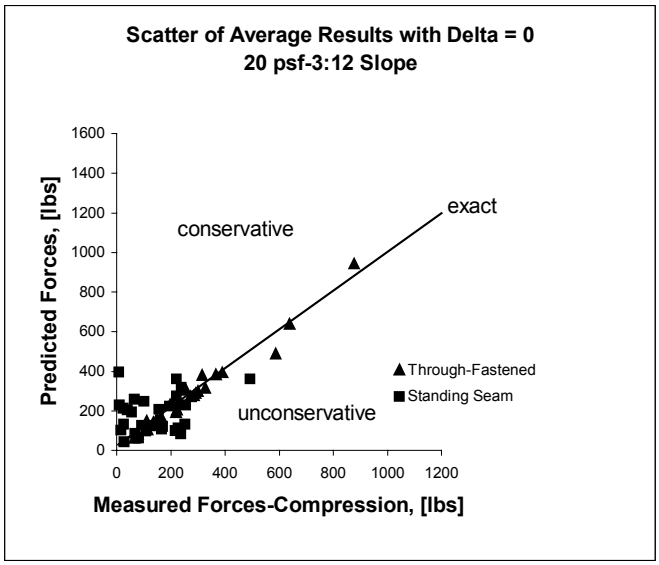

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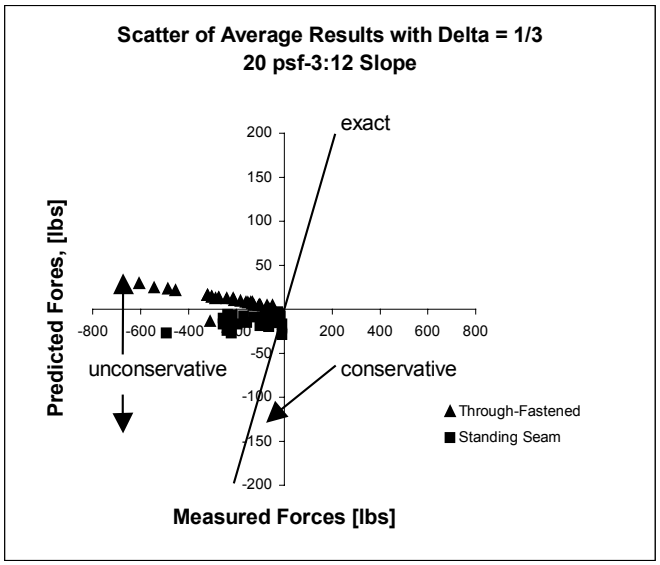

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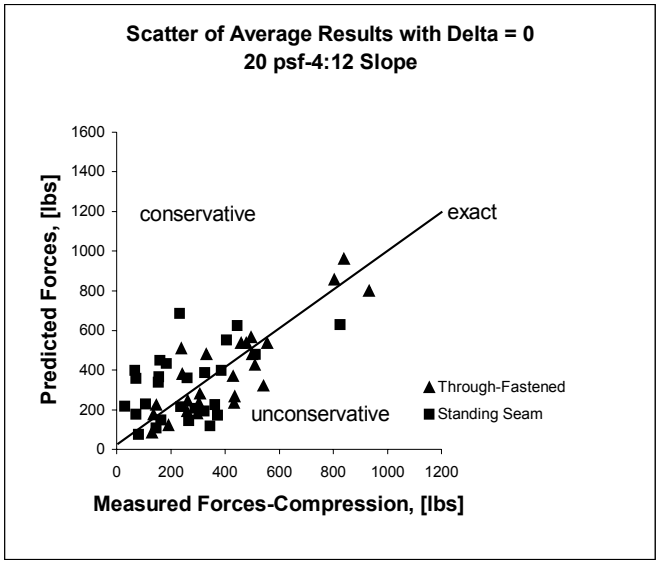
Figure 3.20 Scatter Graphs of Results with Proposed Predictions (continued)



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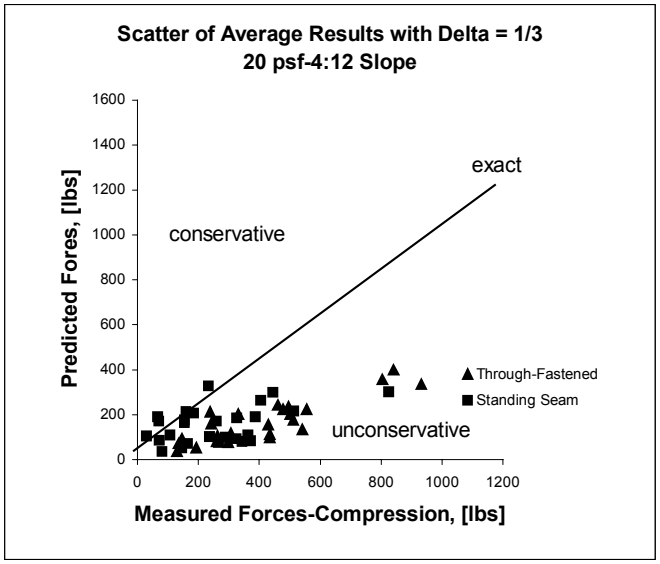


(j)

Figure 3.20 Scatter Graphs of Results with Proposed Predictions (continued)

Figures 3.20a and 3.20b show the scatter of results from tests performed with a 0:12 roof slope for □ = 0 and □ = 1/3. Also, the results from previous research are shown in these figures. Using □ = 0 is unconservative because the majority of the measured forces in Figure 3.20a are below the exact solution line. The measured forces in Figure 3.20b are mostly above the line. This shows that a majority of the measured forces were smaller than the predicted forces, hence using □ = 1/3 is conservative. The same trend is shown for the figures representing slopes of 0.5:12 and 1:12.

Figure 3.20g shows the scatter of results for tests conducted with a roof slope of 3:12. This graph shows an equal amount data points on both sides of the line representing the exact solution.

Figure 3.20h shows the scatter of results when □ = 1/3. It is shown that using □ = 1/3 is unconservative for this roof slope because many of the measured forces are in compression while the predicted forces are in tension.

Figures 3.20i and 3.20j show the scatter or results for the tests conducted at a roof slope of 4:12. Figure 3.20j illustrates that using □ = 1/3 is unconservative for this roof slope. It is fairly conservative to use □ = 0 for this slope, however a substantial number of the measured forces were located in the unconservative region for □ = 0.

The figures discussed above show general trends that occurr throughout the testing program. At low roof slopes (below 5º) an eccentricity of □ = 1/3 is more conservative. At high roof slopes (above 14º) an eccentricity of □ = 0 is more conservative. The results at roof slopes between 5º and 14º show characteristics of both trends, but are mostly unconservative, whether □ = 0 or □ = 1/3 is used, because the predicted forces are in the opposite sense as the measured forces in many cases.

CHAPTER 4

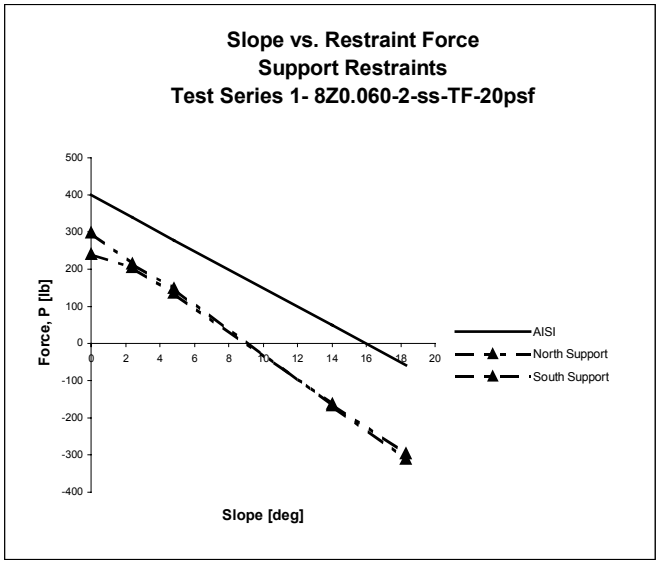
COMPARISON OF RESULTS WITH AISI SPECIFICATION PROVISIONS AND DANZA AND MURRAY'S PREDICTION EQUATIONS

4.1 GENERAL COMMENTS

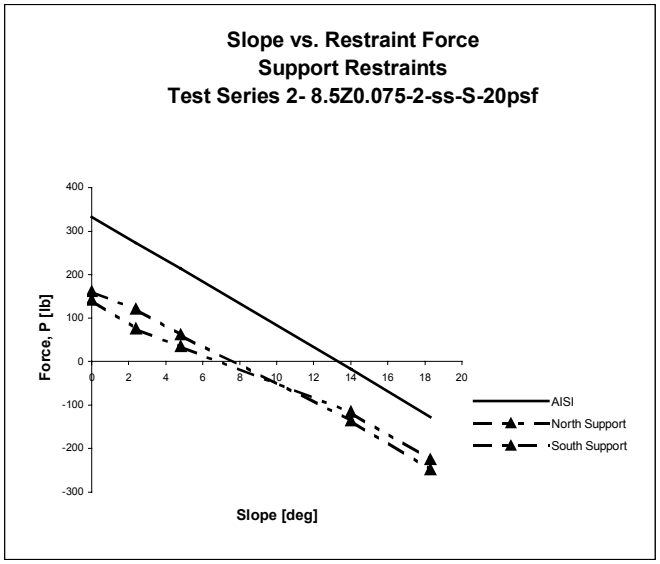
This chapter contains comparisons between the results from each test series with the AISI Specification provisions (1999) and prediction equations developed by Danza and Murray (1998). The AISI provisions contain regression based prediction equations for support, third-point, and midpoint restraint condtions. Danza and Murray's research provides similar prediction equations for quarter-point and third-point plus support restraint conditions.

4.2 TESTS WITH SUPPORT RESTRAINTS

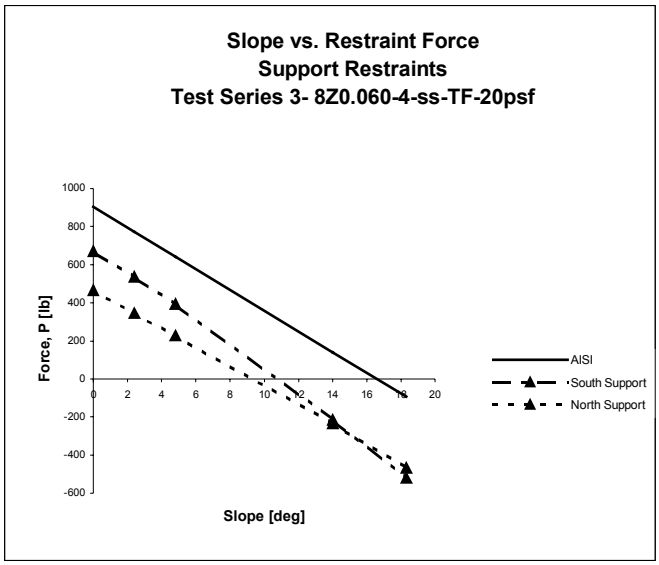
Figure 4.1 shows support restraint results compared to forces predicted from the AISI Specification provisions (Equations D3.2.1-2 through D3.2.1-7) for every test series. This figure is analogous to Figures 3.5 through 3.7. The restraint forces predicted using the AISI provisions are not in good agreement with the measured forces for Series 1 through 6. The measured forces from Series 7 and 8 (Figures 4.1i and 4.1j) are in much better agreement with the AISI provisions than Nuebert and Murray's predicted forces with □ = 1/3.



(a)



(b)



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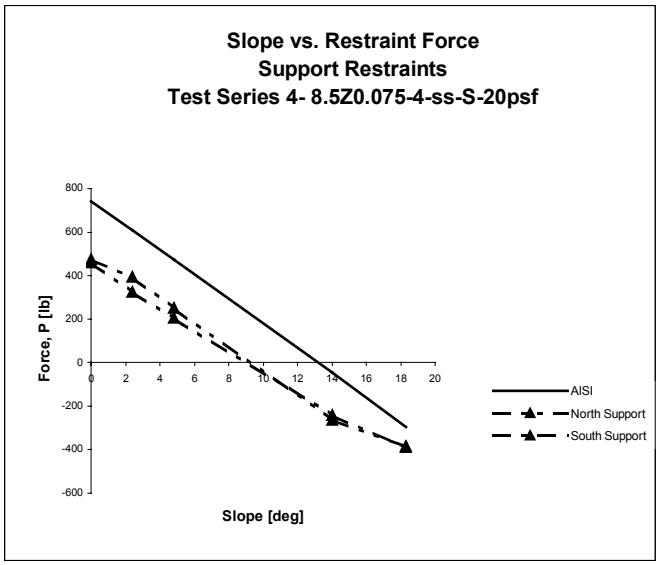
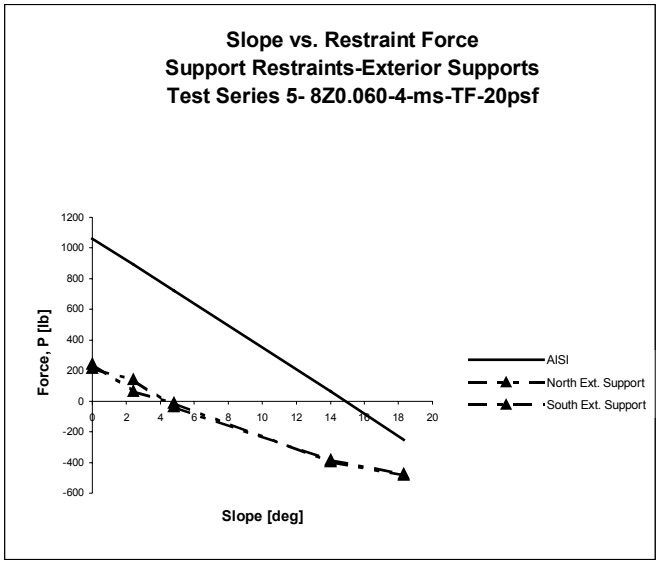


(d)

Figure 4.1 Slope vs. Restraint Force Results Showing Comparisons with AISI Specification Provisions for Support Restraints



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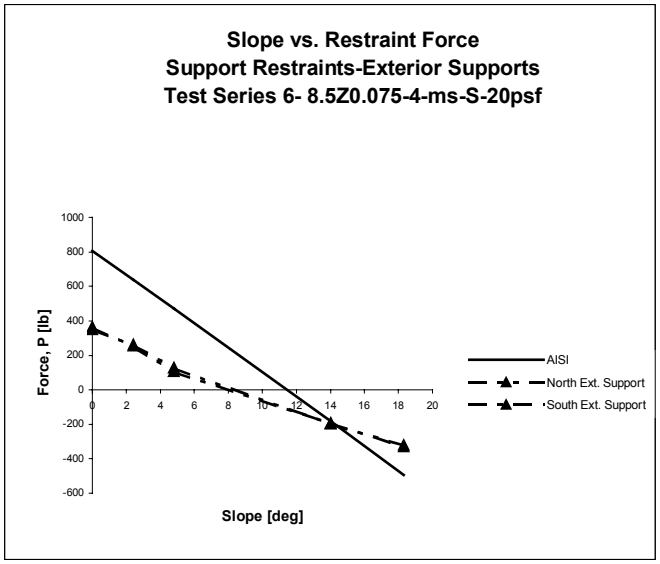

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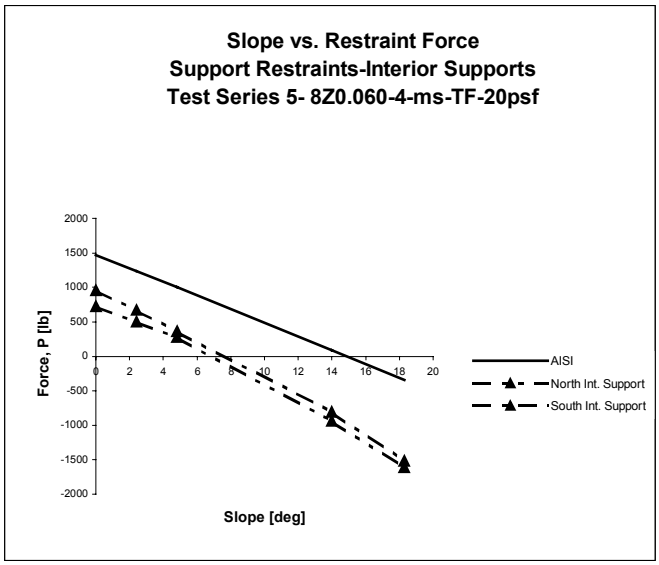

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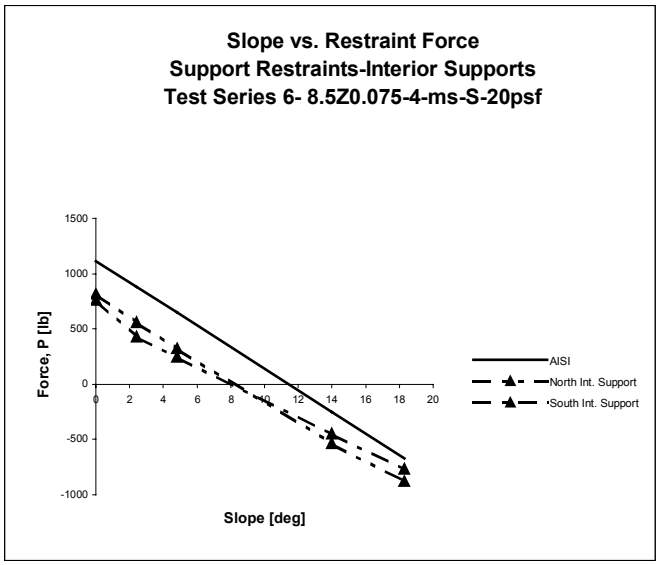
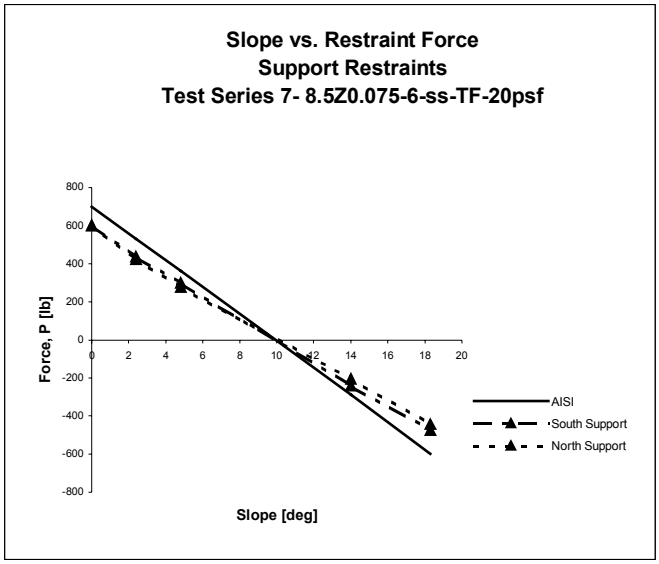
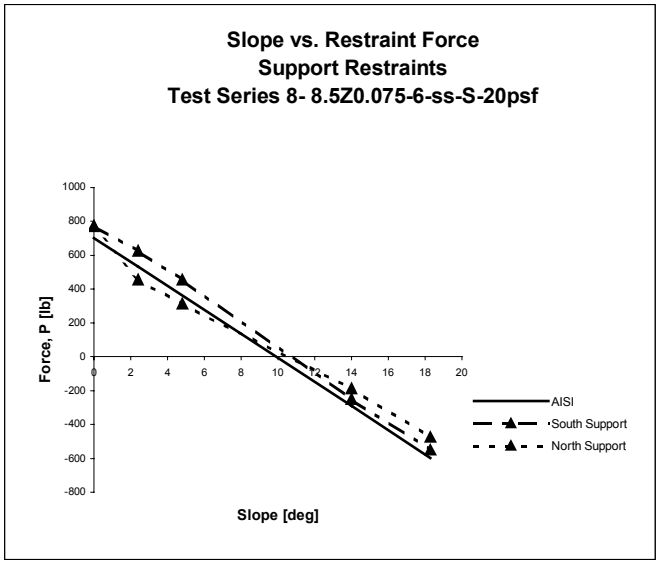


(h)

Figure 4.1 Slope vs. Restraint Force Results Showing Comparisons with AISI Specification Provisions for Support Restraints (continued)



(i)

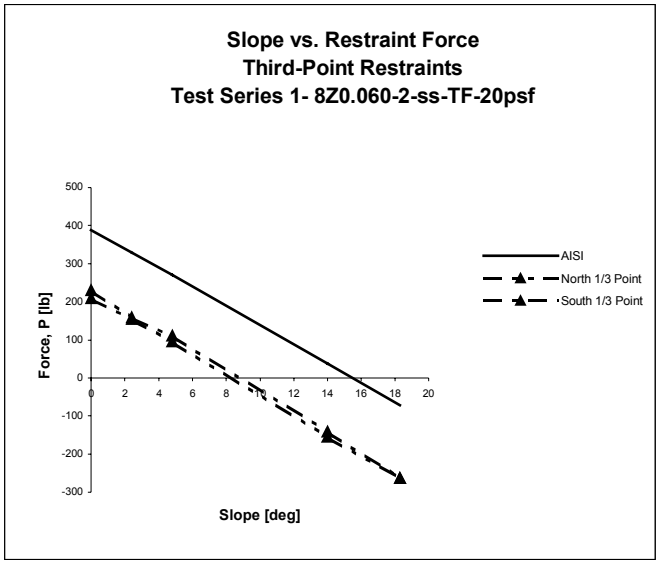


(j)

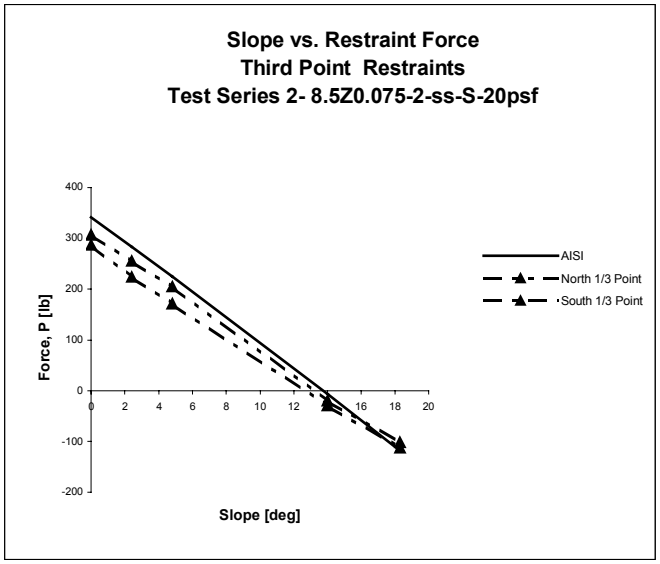
Figure 4.1 Slope vs. Restraint Force Results Showing Comparisons with AISI Specification Provisions for Support Restraints (continued)

4.3 TESTS WITH THIRD-POINT RESTRAINTS

The third-point restraint results compared with forces predicted from the AISI Specification provisions for each test series are shown in Figure 4.2. This figure is analogous to Figures 3.8 and 3.9. The measured forces from Series 2 show fair correlation with the AISI provisions, while the rest are in agreement with the proposed forces. In some cases, the measured results and the AISI design forces show better correlation at higher roof slopes. For instance, Figure 4.2f shows the restraint forces from third-point restraints for Series 4. In this case, the measured restraint forces are much larger than the design forces at low roof slopes. However, with increasing slope, the restraint forces are closer to the AISI design forces.



(a)



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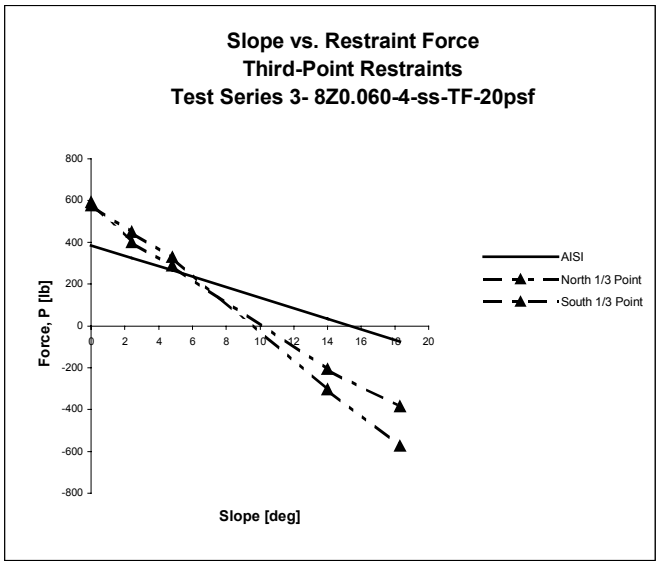

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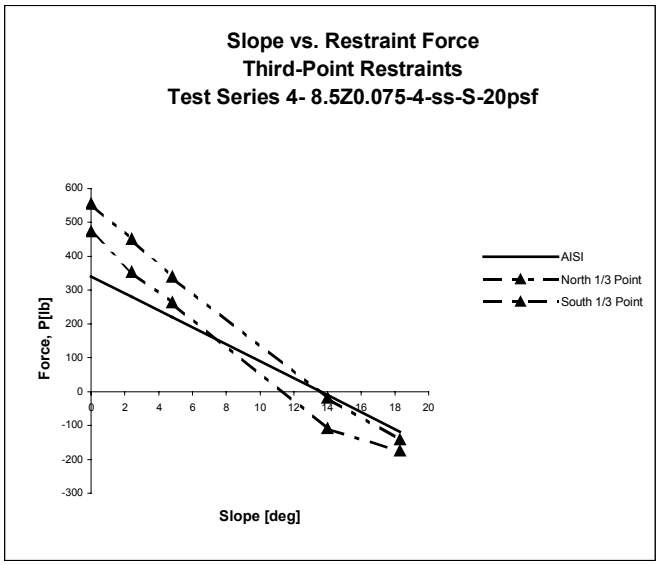
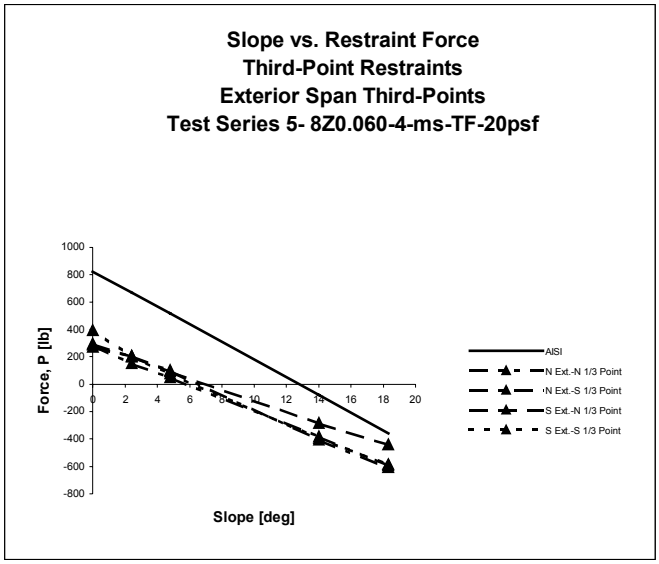


(d)

Figure 4.2 Slope vs. Restraint Force Results Showing Comparisons with AISI Specification Provisions for Third-Point Restraints



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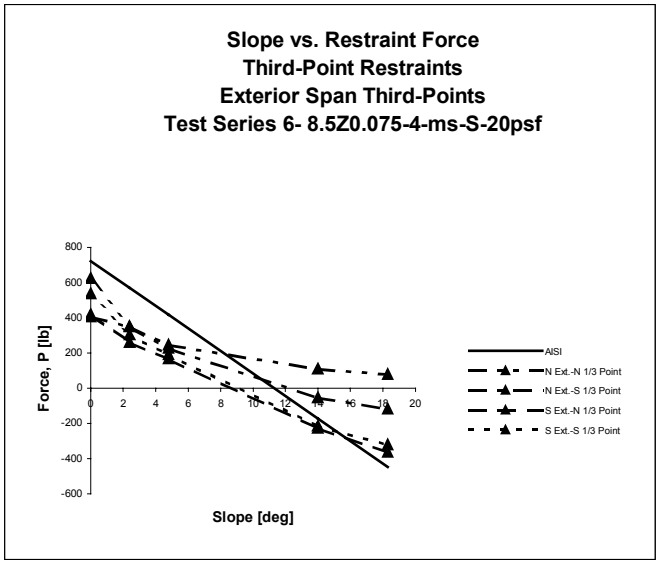

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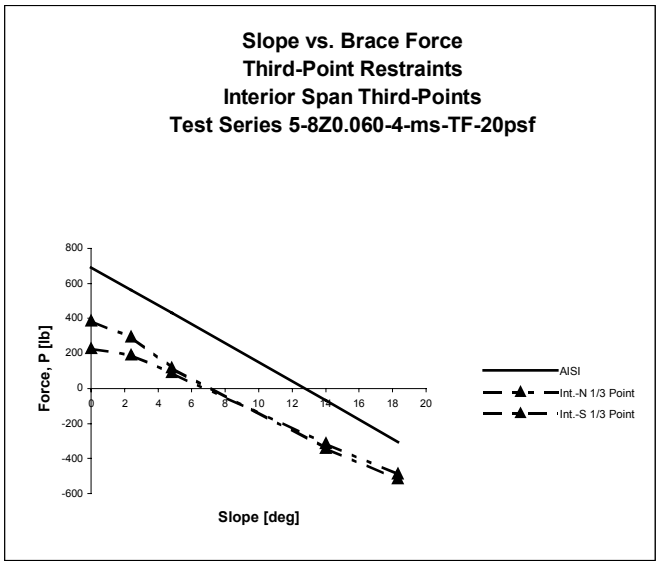

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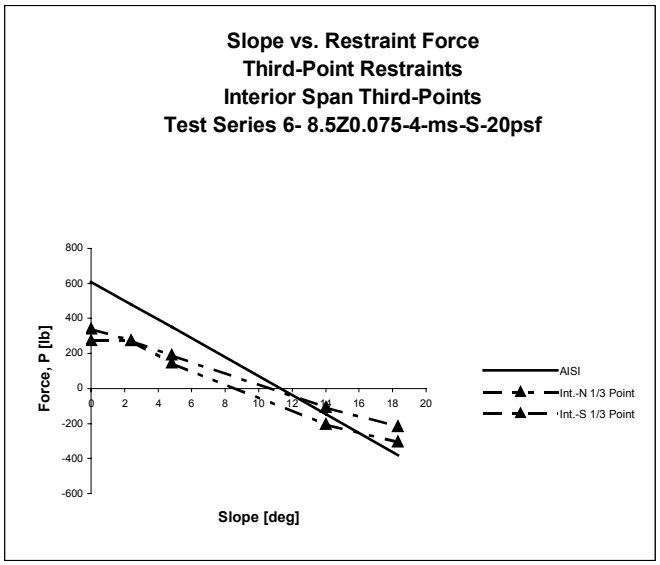


(h)

Figure 4.2 Slope vs. Restraint Force Results Showing Comparisons with AISI Specification Provisions for Third-Point Restraints (continued)

4.4 TESTS WITH MID-POINT RESTRAINTS

Figure 4.3 shows measured restraint forces compared with design forces from the AISI provisions for every test series in which midpoint restraints were used. This figure is akin to Figures 3.10 and 3.11. Fair correlation is shown for each series. The predicted forces using □ = 1/3 and □ =0 were in better agreement with measured forces for the midpoint bracing condition. A greater differential exists between the measured results and AISI design forces, as compared to the difference between the proposed prediction forces and the measured forces.

(a) (b)

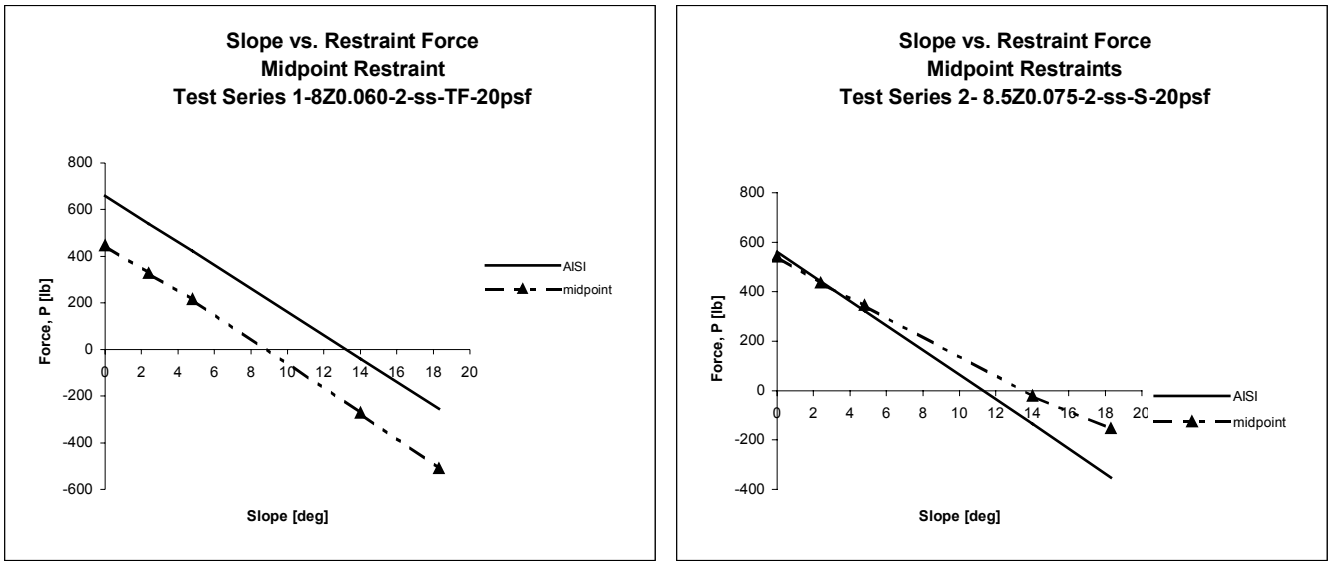
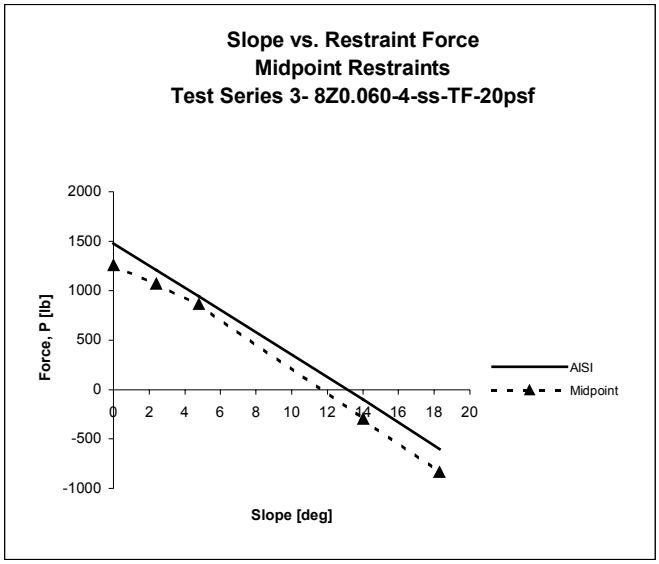
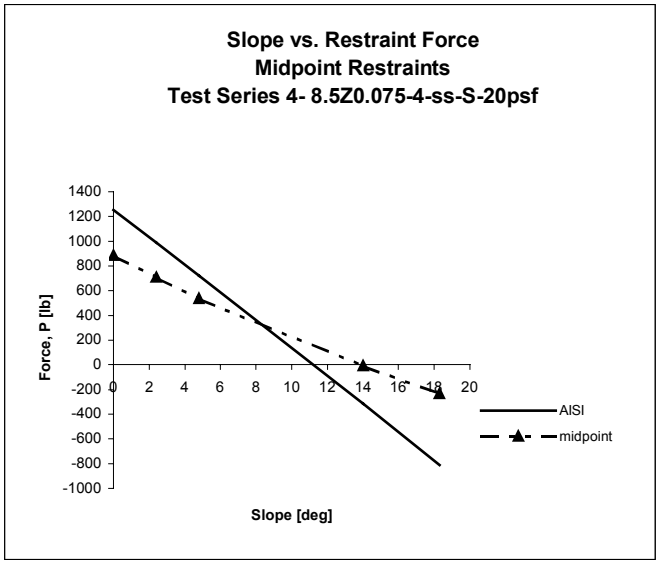


Figure 4.3 Slope vs. Restraint Force Results Showing Comparisons with AISI Specification Provisions for Midpoint Restraints

(c)



(d)



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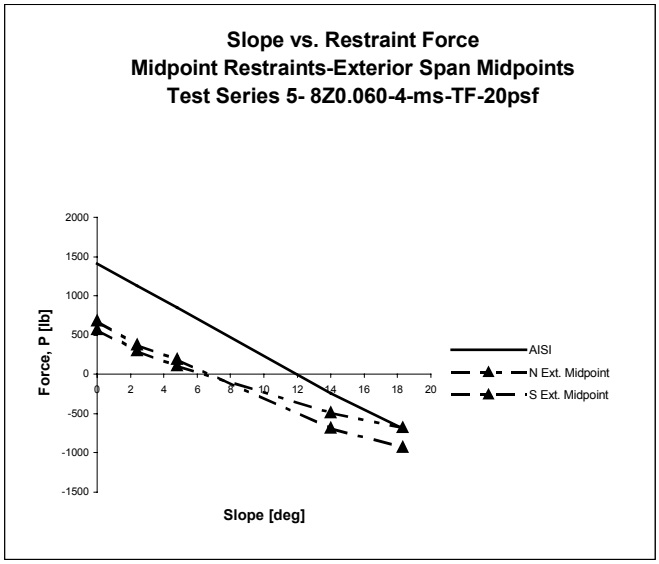

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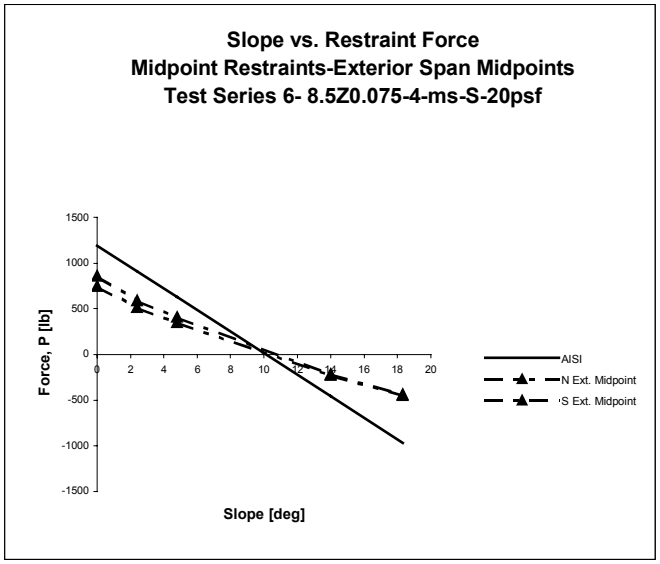
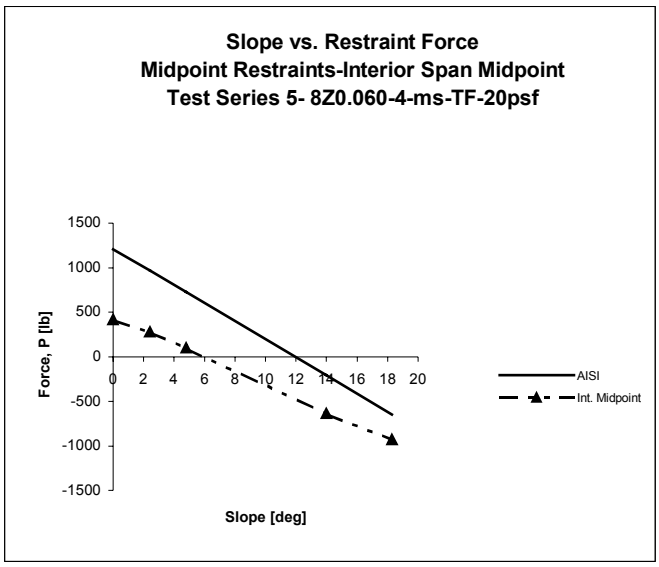


Figure 4.3 Slope vs. Restraint Force Results Showing Comparisons with AISI Specification Provisions for Midpoint Restraints (continued)



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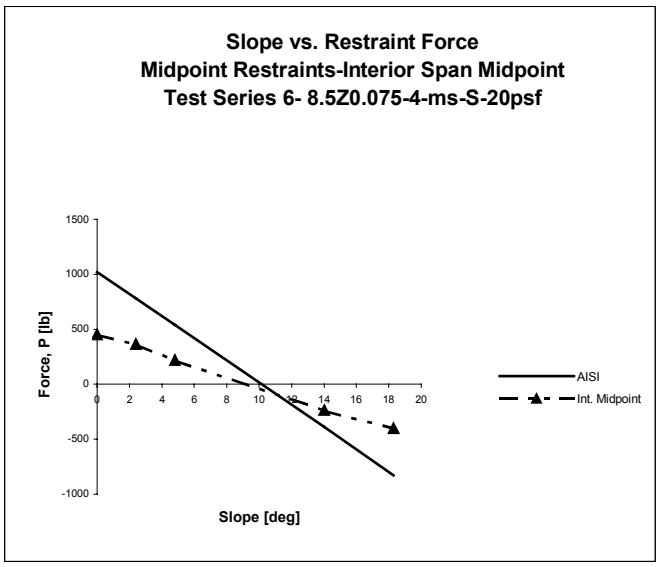
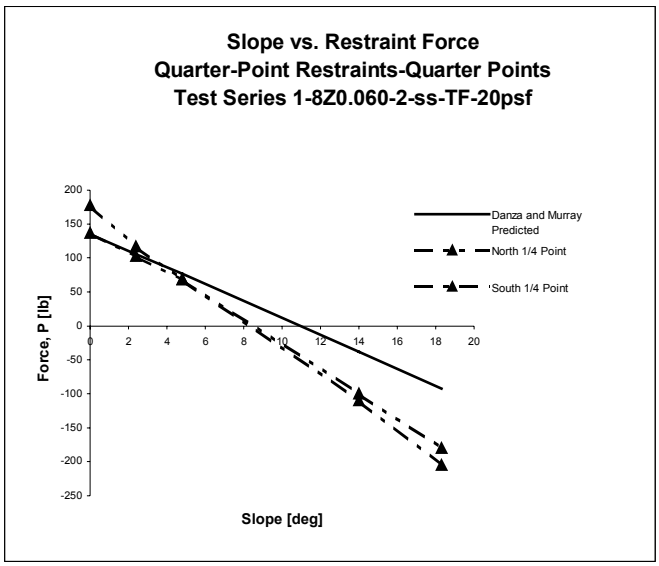


(h)

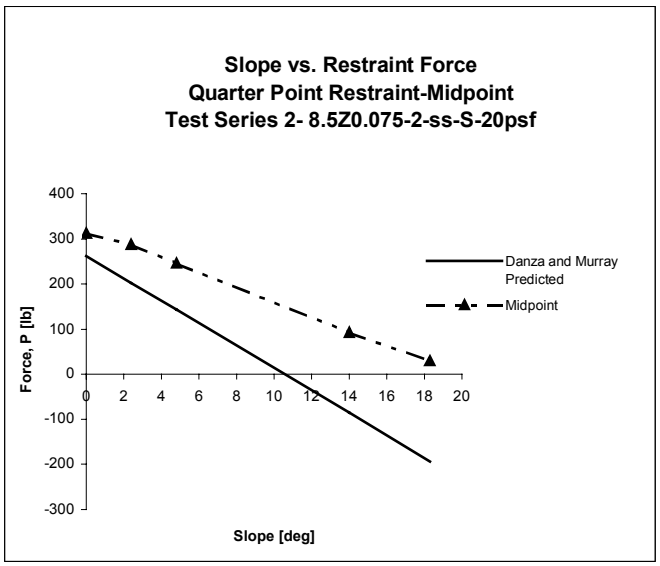
Figure 4.3 Slope vs. Restraint Force Results Showing Comparisons with AISI Specification Provisions for Midpoint Restraints (continued)

4.5 TESTS WITH QUARTER-POINT RESTRAINTS

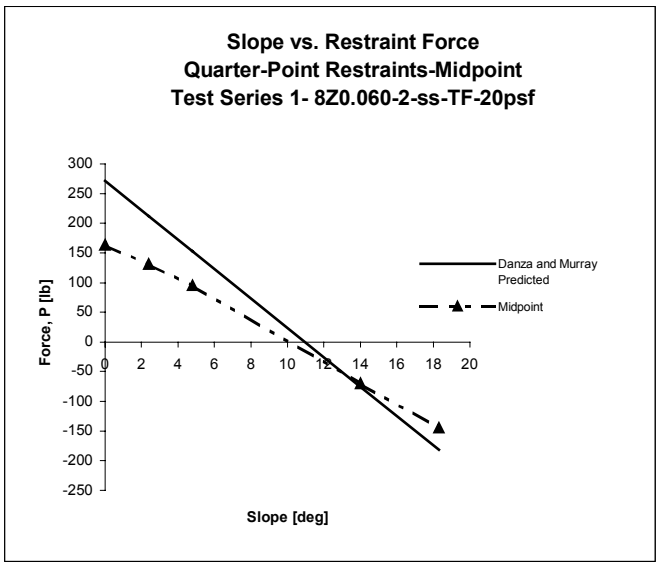
Figure 4.4 shows measured restraint forces compared with predicted forces determined from equations developed by Danza and Murray (1998) for the quarter-point restraint conditon. This figure is similar to Figures 3.12 through 3.15. Fair correlation is shown between the predicted forces and the measured forces for Series 1 through 4. The predicted forces from Danza and Murray's equations are slightly different than the proposed forces with □ = 1/3. In most cases Danza and Murray's predicted forces are in better correlation than the proposed forces with □ = 1/3. Poor correlation is shown between the predicted forces and measured forces for the multiple span results in Series 7 and 8. Danza and Murray's predicted forces are much larger than the proposed forces with □ = 1/3 and the measured forces.



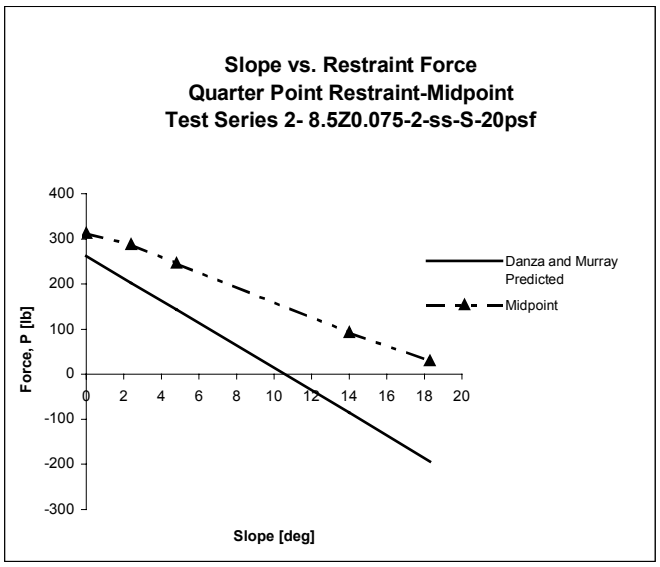
(a)



(b)



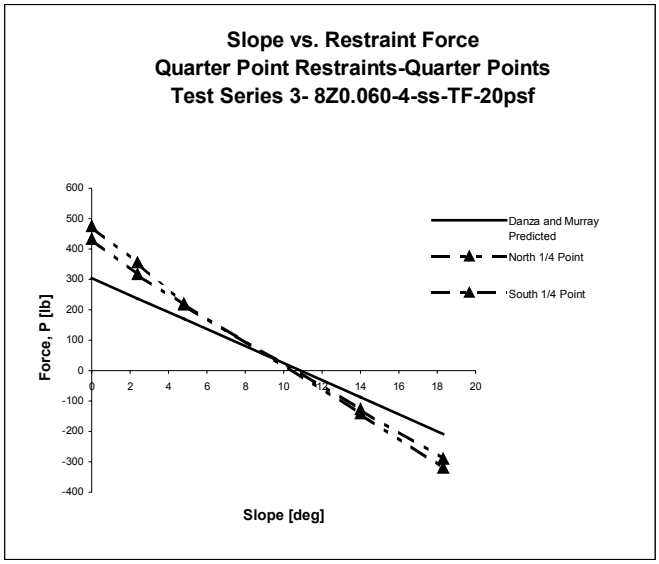
(c)



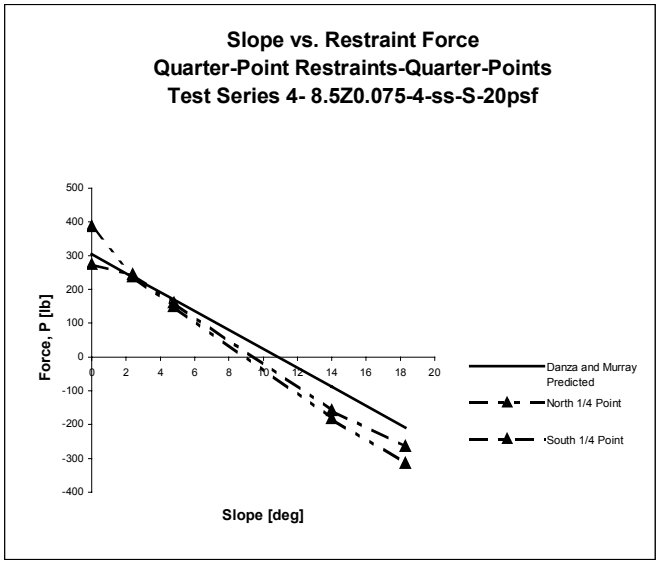
(d)

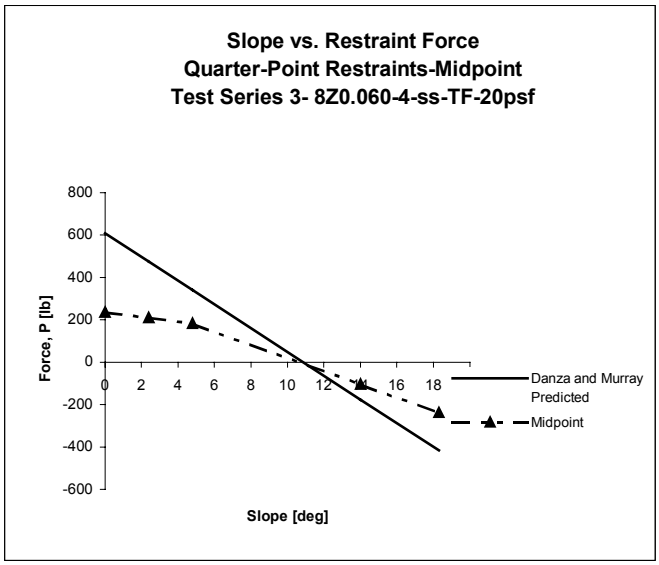
Figure 4.4 Slope vs. Restraint Force Results Showing Comparisons with Danza and Murray's Prediction Equation for Quarter-Point Restraints

(e)



(f)





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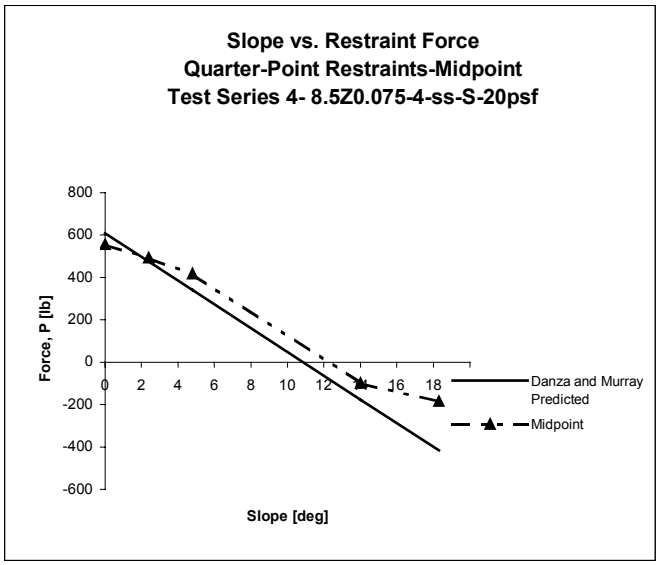
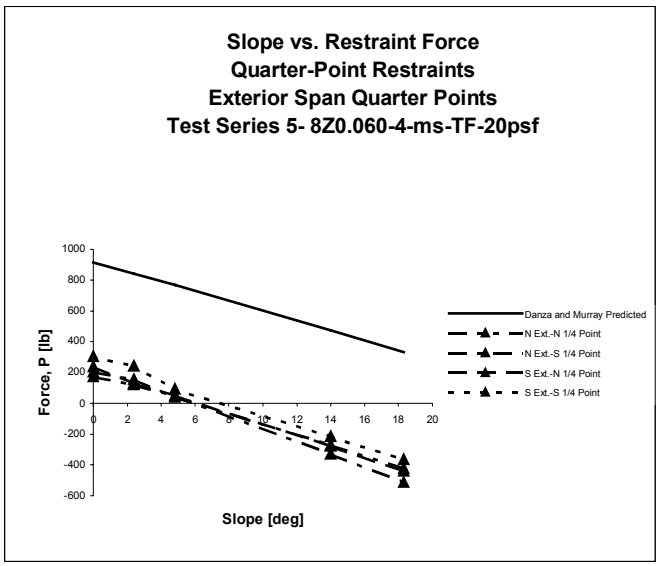
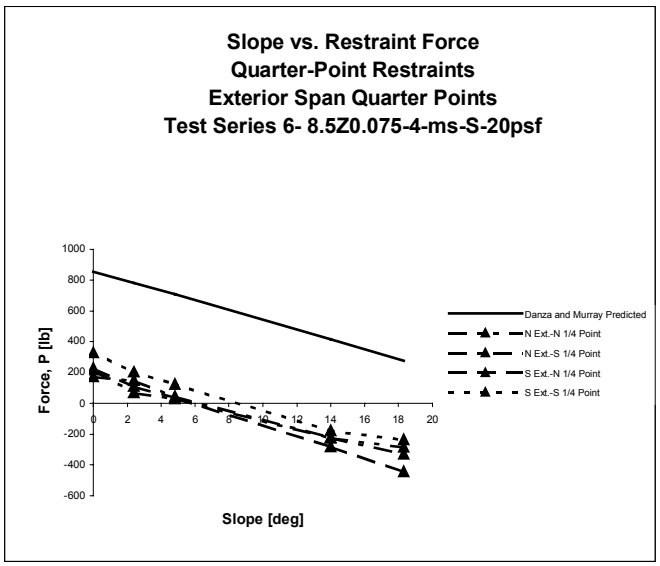


(h)

Figure 4.4 Slope vs. Restraint Force Results Showing Comparisons with Danza and Murray's Prediction Equation for Quarter-Point Restraints (continued)



(i)



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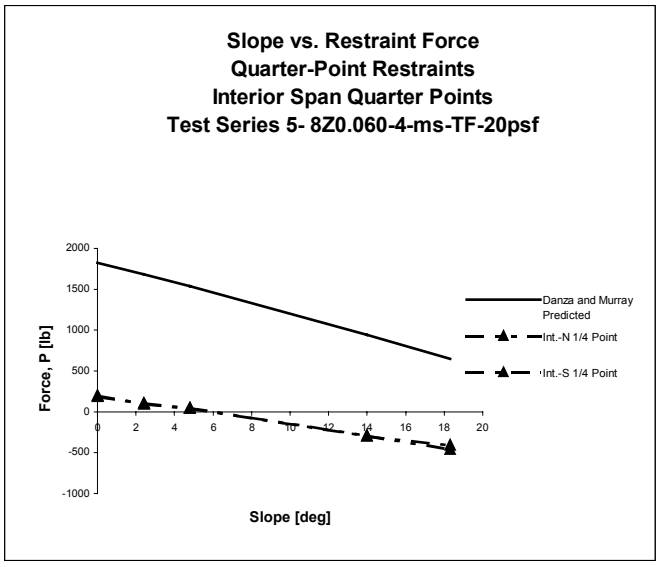

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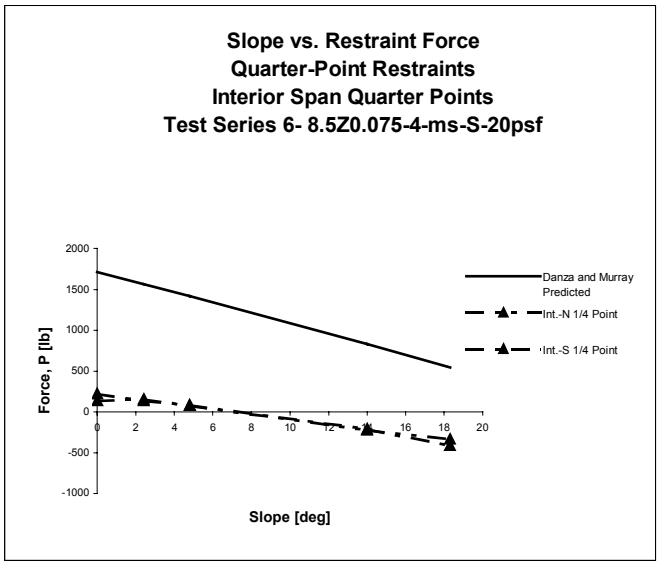
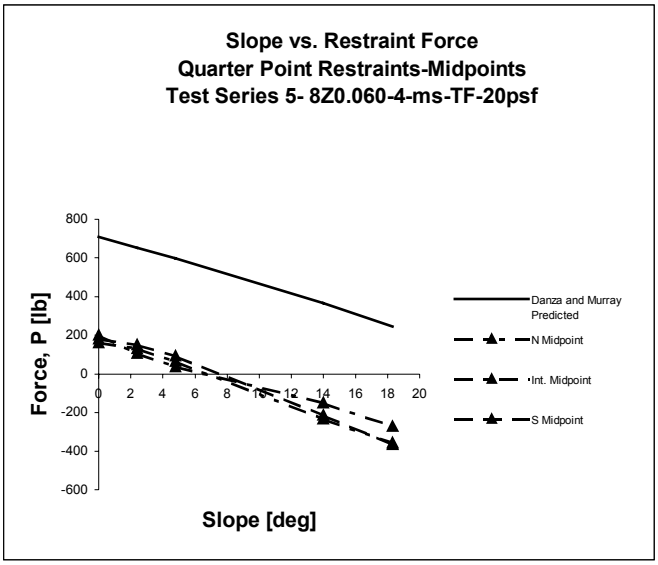


(l)

Figure 4.4 Slope vs. Restraint Force Results Showing Comparisons with Danza and Murray's Prediction Equation for Quarter-Point Restraints (continued)



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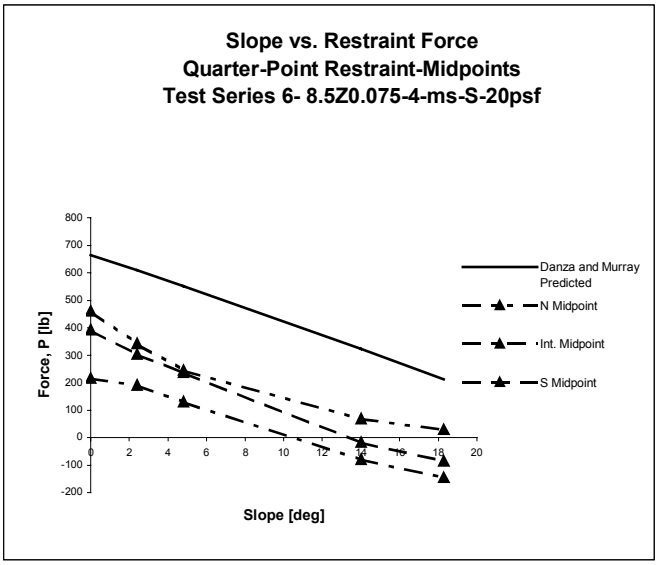
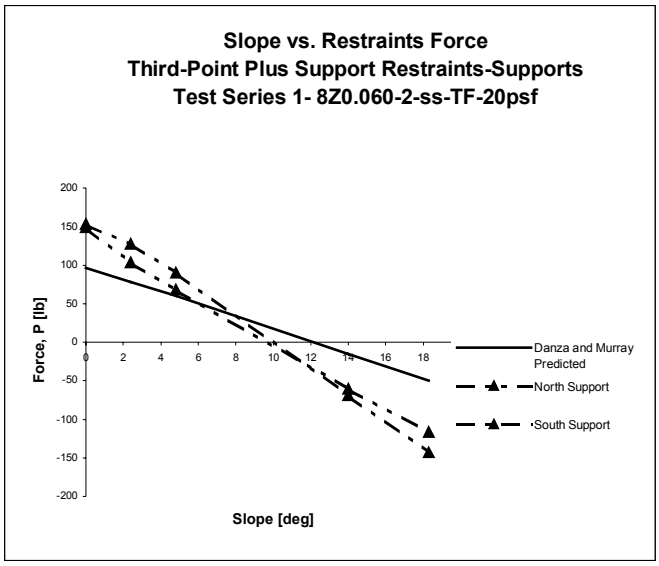


(n)

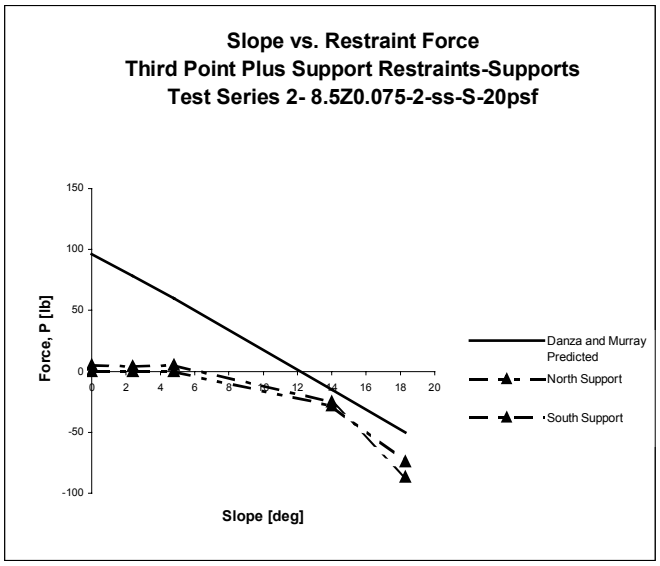
Figure 4.4 Slope vs. Restraint Force Results Showing Comparisons with Danza and Murray's Prediction Equation for Quarter-Point Restraints (continued)

4.6 TESTS WITH THIRD-POINT PLUS SUPPORT RESTRAINTS

Figure 4.5 shows measured restraint forces compared with predicted forces determined from equations developed by Danza and Murray (1998) for the third-point plus support restraint condition. This figure is similar to Figures 3.16 through 3.19. For Series 1 through 4, very few of the measured forces correlate well with the predicted forces. The measured forces from Series 7 and 8 disagree strongly with the predicted forces.



(a)



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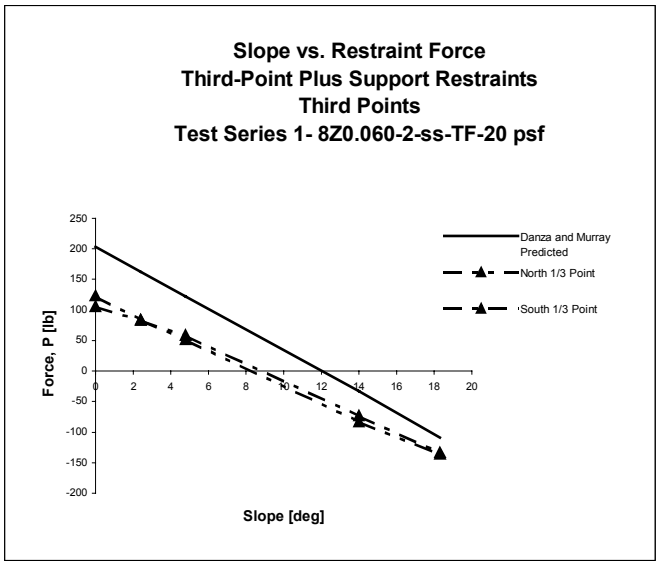
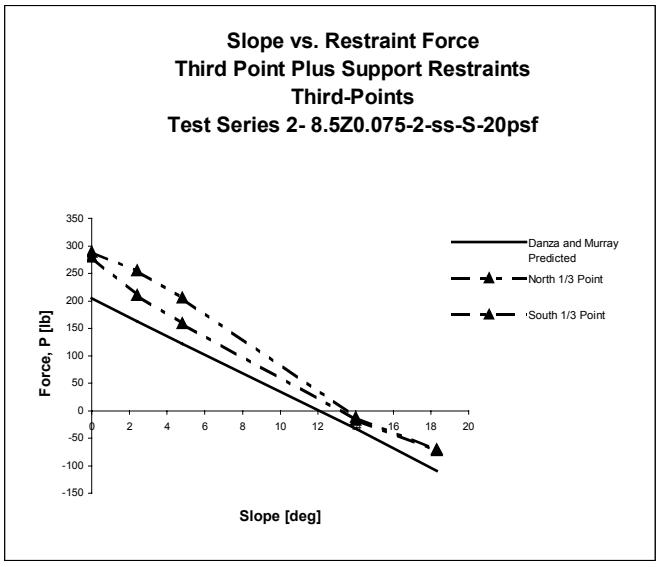
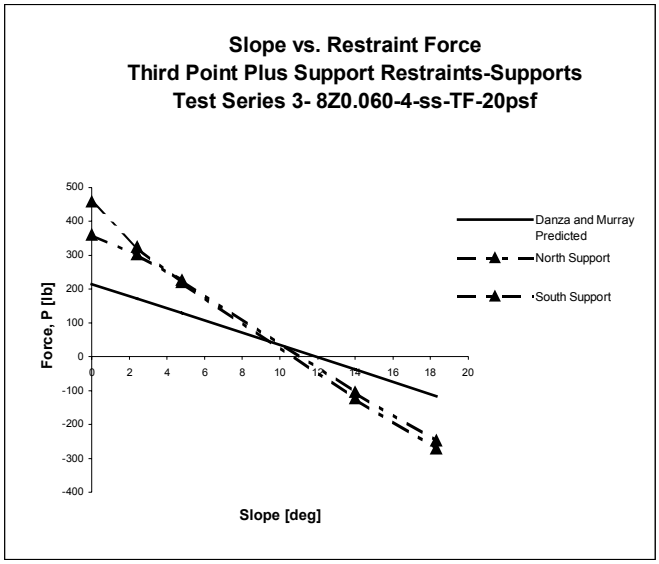


(c)



(d)

Figure 4.5 Slope vs. Restraint Force Results Showing Comparisons with Danza and Murray's Prediction Equation for Third-Point Plus Support Restraints



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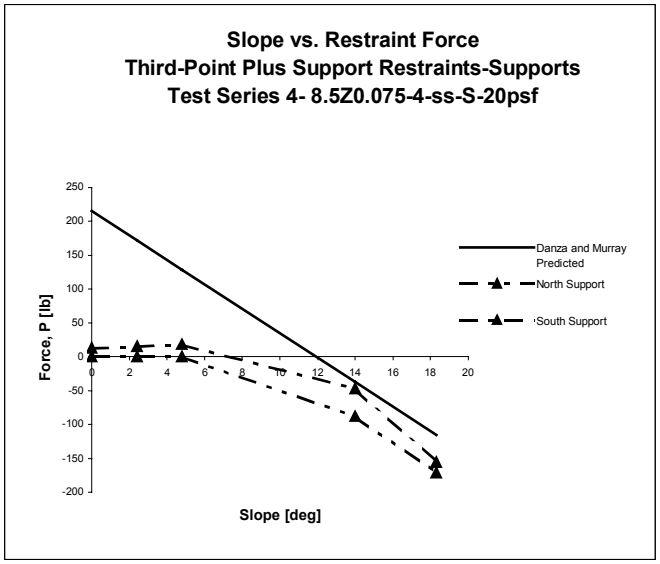

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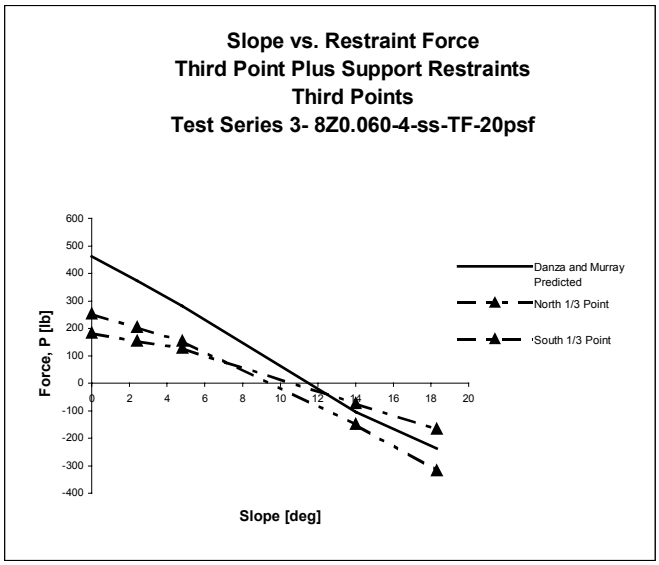
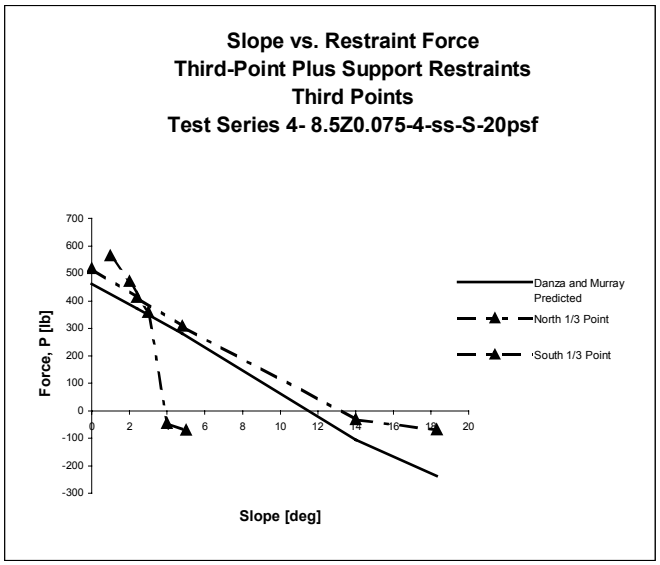
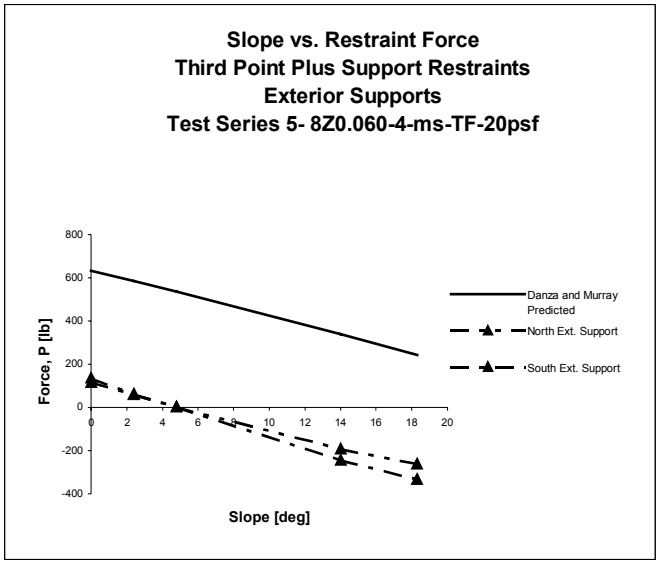


(g)

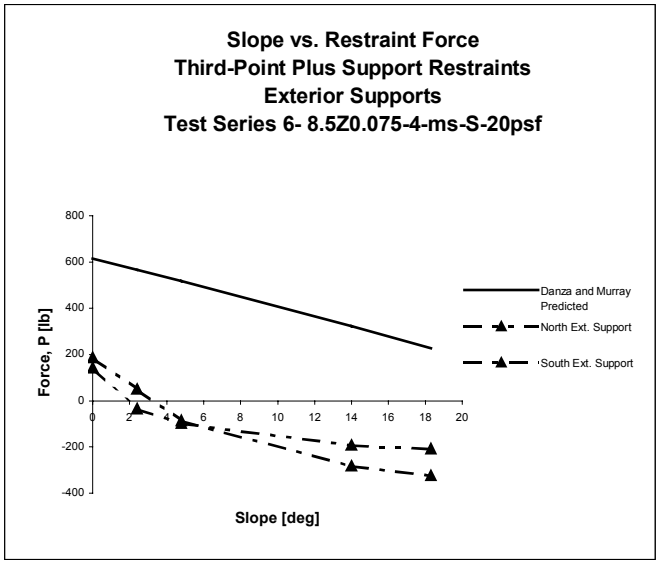


(h)

Figure 4.5 Slope vs. Restraint Force Results Showing Comparisons with Danza and Murray's Prediction Equation for Third-Point Plus Support Restraints (continued)



(i)



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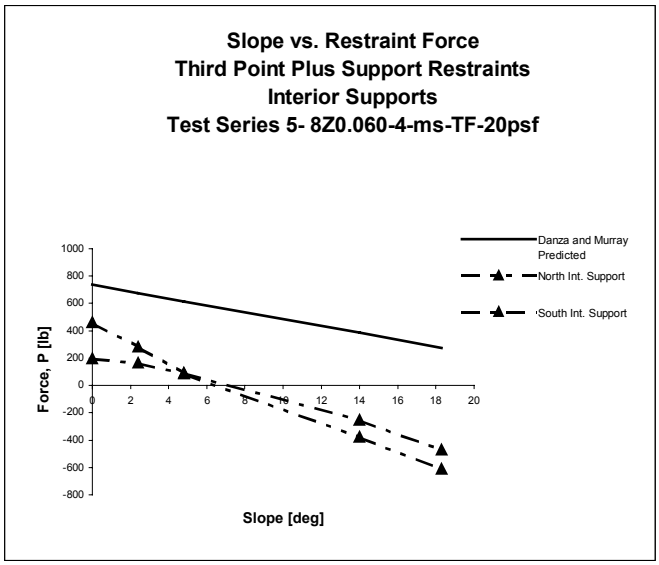

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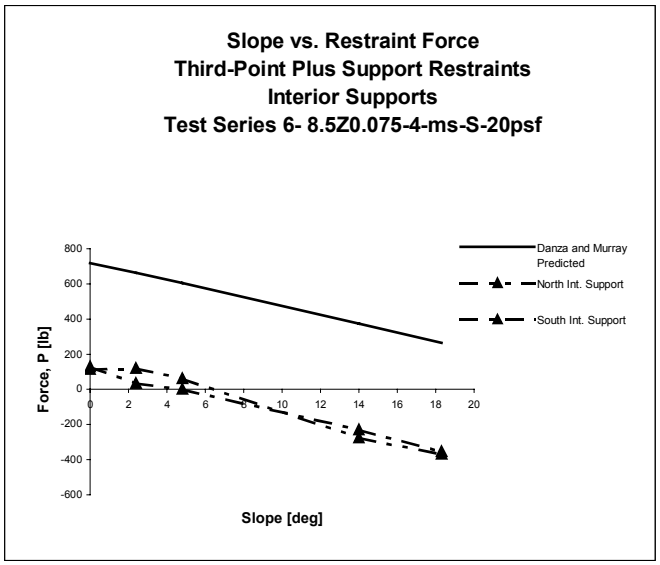
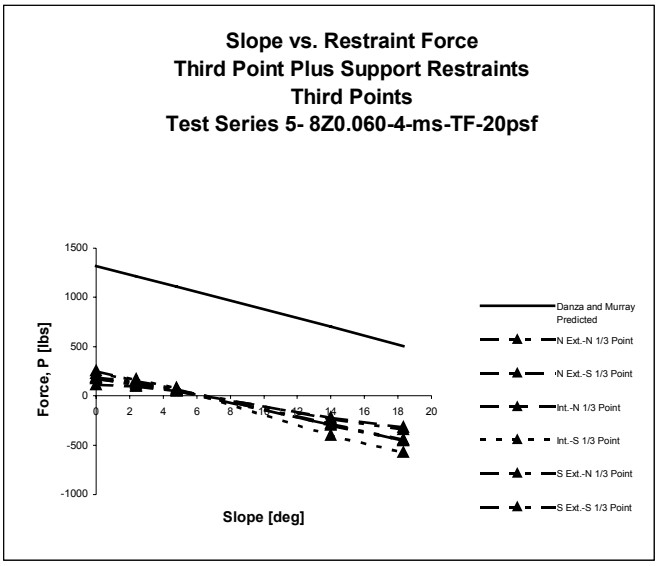
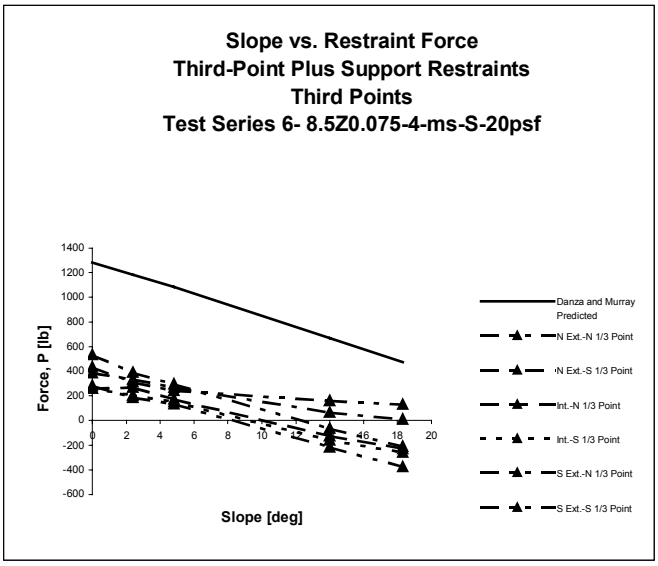


(l)

Figure 4.5 Slope vs. Restraint Force Results Showing Comparisons with Danza and Murray's Prediction Equation for Third-Point Plus Support Restraints (continued)



(m)



(n)

Figure 4.5 Slope vs. Restraint Force Results Showing Comparisons with Danza and Murray's Prediction Equation for Third-Point Plus Support Restraints (continued)

4.7 SUMMARY OF COMPARISONS

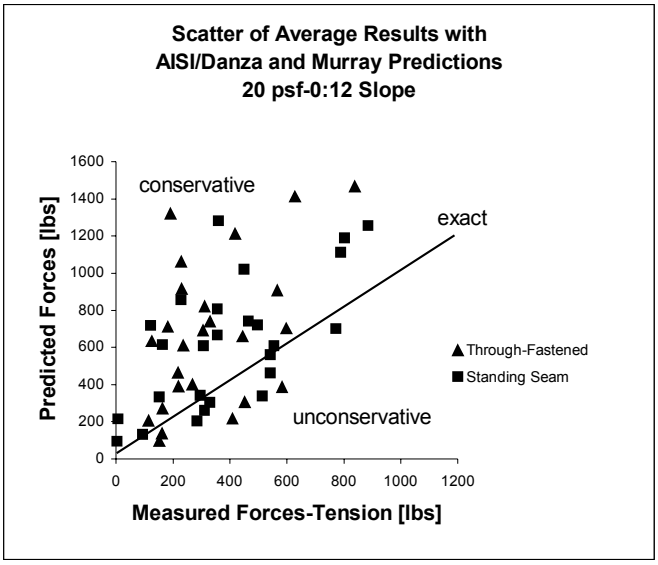
Overall the measured results were in poor agreement with the AISI Specification provisions (1999) and the prediction equations developed by Danza and Murray (1998). However, the support restraint results for Series 7 and 8 and the quarter-point restraint results for Series 1 through 4 were in good agreement with these predicted forces.

Figure 4.6 shows the scatter of the average measured forces for the AISI and Danza and Murray predicted forces at each roof slope except 2:12. Many of the tests reached the zero-slope near this slope and the forces were very small and difficult to measure. The graphs in Figure 4.7 are comparable to those in Figure 3.20.

Figure 4.6a shows the scatter of results from tests performed with a roof slope of 0:12. Using the AISI and Danza and Murray equations predicting restraint forces at this

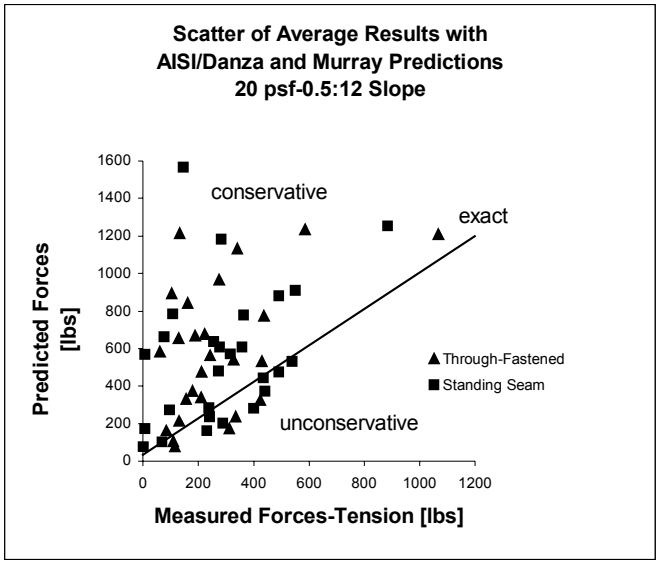
roof slope is generally conservative. There are some measured forces shown in Figure 4.6a that are greater than the predicted forces, but the majority of measured forces are smaller than the predicted design forces. Figures 4.6b and 4.6c show the same correlation at roof slopes of 0.5:12 and 1:12.

The scatter of results from tests conducted with roof slopes of 3:12 and 4:12 are shown in Figures 4.6d and 4.6e. Many of the data points show that when the predicted forces are in tension, the measured forces are in compression. In general, the predicted forces determined to be in compression are smaller than the measured forces in compression.

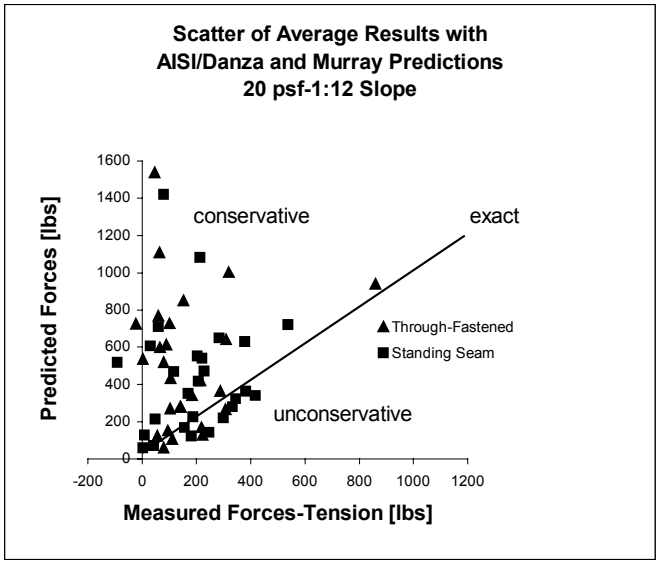


(a)

Figure 4.6 Scatter Graphs of Results with AISI and Danza and Murray Predictions



(b)



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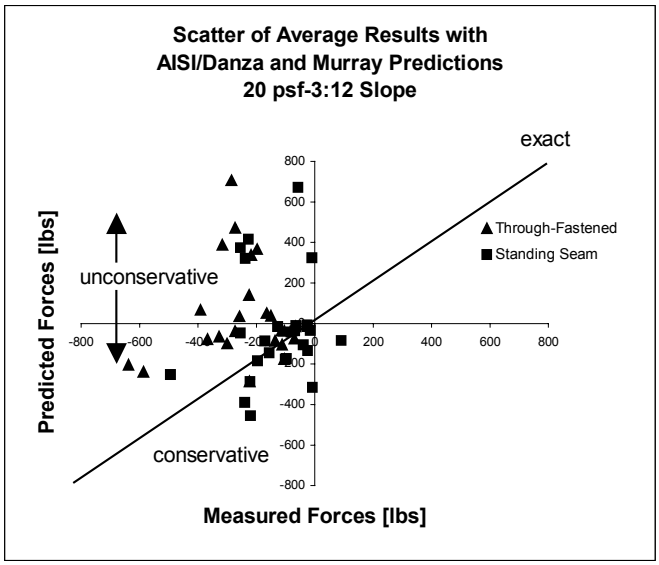
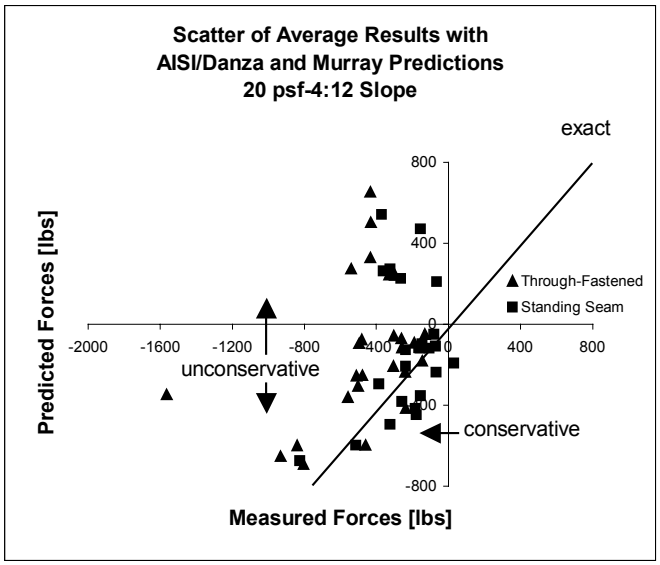


(d)



(e)

Figure 4.6 Scatter Graphs of Results with AISI and Danza and Murray Predictions (continued)

CHAPTER 5

DISCUSSION OF RESULTS

5.1 EVALUATION OF TEST METHOD

The test method used to experimentally verify the required restraint forces employed instrumented rods at each restraint location. At the beginning of each test, the rods were zeroed and then an initial load of 5 psf (Series 1) or 20 psf (Series 2 through 7) was placed on the roof panel. Once the roof system was loaded, the forces in the restraints were recorded. The system was then raised incrementally to the prescribed roof slopes and the restraint forces were measured at each slope. In the majority of the tests performed, the measured restraint forces at the initial 0:12 slope were substantially different from each other. For instance, in Series 1 the restraint forces for the support only bracing condition were 240 lbs and 298 lbs (see Appendix B). Obviously, the restraint forces should be the same at similar locations for a system that is symmetrical.

To overcome the difference between restraint forces after a roof system has been loaded initially, the average restraint force for a specific restraint condition could be physically imposed by adjusting the tension in the instrumented restraint rods to the average value.

The results from some tests showed that the restraint forces at similar locations were nearly identical. For example, the support restraint forces for Series 7 were 597 lbs and 600 lbs at 20 psf (see Appendix G). When this was the case, the results were in better agreement with the theoretical forces, whether it be with $\delta = 0$ or $\delta = 1/3$.

Overall, the testing procedure provided results in which not enough consistent data was gathered to confidently recommend the proposed design equation. This observation is with respect to the experimental results from these tests and not the formulation of the proposed design equation.

5.2 ECCENTRICITY OF RESULTANT LOADING, δ

The term □ refers to the eccentricity of the resultant due to the applied gravity load acting on the top flange of a purlin and measured from the web. The original proposed prediction equation was developed using a value of 1/3 for □. However, many of the results were in better agreement with theoretical forces if δ = 0. Nearly all of the measured restraint forces for the support restraint condition were in better agreement with the predicted forces if δ = 0. As a system with support restraints is loaded, the purlins deflect toward the ridge, with the largest deflection occurring at the midpoint of the span. As deflection occurs, the eccentricity, □, begins to reach zero. More of the lateral force is resisted by the purlins bending, therefore decreasing the restraint forces. An inherent decrease in system stiffness and restraint force is caused by this behavior. Hence, the tests with the support restraint condition were in better agreement with δ = 0.

When restraints are located away from the supports, such as quarter-point restraints, the system has more stiffness and the restraint forces will increase. Also, the purlin deflection is less and the eccentricity remains near 1/3.

The restraint configurations besides support restraints, like mid-point, were in better agreement with predicted forces if δ = 1/3. However, too many results exist in which the system behavior previously described is not found. For example, Figure 3.12b shows quarter-point restraint results for Series 2. From the dicussion above it would seem reasonable for these results to agree with δ = 1/3 but the actual results follow the plot representing δ = 0.

For design purposes it would be unconservative to use the larger value of eccentricity, δ = 1/3, for all cases (those cases in which the results were very near to the proposed forces with δ = 1/3, as shown in Figure 3.10d, would be the exception). Consider a case in which the experimental results showed agreement with δ = 0. If δ = 1/3 was used in this case, the predicted restraint forces would be too low, or could possibly be in tension while the actual forces are in compression, for steep roof slopes. The actual results show that the zero-slope for δ = 0 is reached before the predicted forces for δ = 1/3 have reached the zero-slope. Thus if a design is done with □ = 1/3 at a

specific range of roof slopes, the restraints are in compression even though they were designed for tension.

An example case is that of third-point restraints for Series 5. Figure 3.9a shows that the actual measured restraints followed the predicted forces if $\delta = 0$. Assume a roof system was to be designed at a roof slope of 2:12 (9.5°). If the third-point restraints were designed assuming an eccentricity of 1/3, the actual restraint forces would be in compression rather than tension, for which the system was designed.

Test results suggest that the only conservative method of predicting lateral restraint forces is to use $\delta = 1/3$ for designing roof slopes less than the zero-slope calculated with $\delta = 0$. The other case is to use a value of $\delta = 0$ for designing roof slopes greater than the zero-slope calculated using $\delta = 1/3$. Figure 5.1 shows these recommendations.

Results are inconclusive for systems with roof slopes in the region bounded by the zero-slopes calculated using $\delta = 1/3$ and $\delta = 0$. The reason for this can be seen from experimental results. This is the region where many of the measured restraint forces were in the opposite sense as the predicted forces, making it difficult to suggest a feasable value for eccentricity.

The recommendations for δ are invalid for cases in which measured forces are greater than the proposed forces for either δ value. For example, Figure 3.7b shows actual forces that are greater than predicted forces at low roof slopes. An eccentricity of $\delta = 1/3$ is used for design purposes at a low roof slope, according to the recommendations given. However, the predicted forces would be lower than the measured forces for a roof slope of 0.5:12 (2.4º). The other case would be that of greater roof slopes. Figure 3.6d shows actual forces which are greater than the predicted values when the roof slope is greater than 12°. This is the region where $\delta = 0$ is used to predict the restraint forces, but in this case, the actual forces show that the design forces are lower than the actual forces.

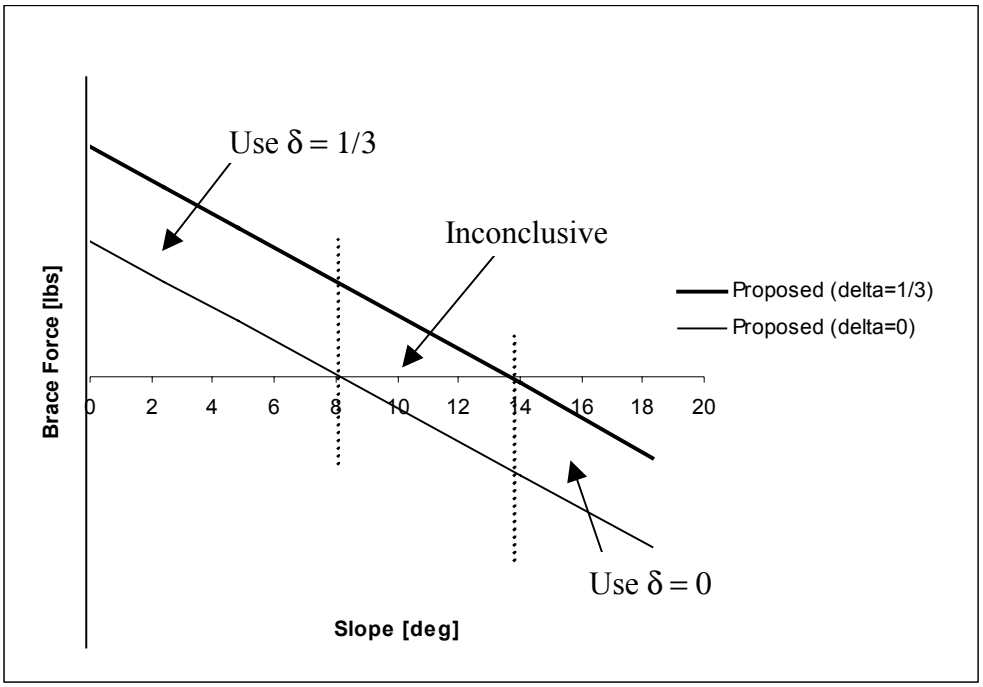


Figure 5.1 Slope vs. Restraint Force Showing Recommended Eccentricity Values for Varying Roof Slopes

CHAPTER 6

SUMMARY AND CONCLUSION

6.1 SUMMARY

The objective of this research was to experimentally validate proposed design equations developed to predict lateral restraint forces in Z-purlin supported, sloped metal roof systems (Nuebert and Murray, 1998).

To do this, eight series of tests were conducted: (1) two purlin lines, single span with through-fastened roof panel, (2) two purlin lines, single span with standing seam roof panel, (3) four purlin lines, single span with through-fastened roof panel, (4) four purlin lines, single span with standing seam roof panel, (5) four purlin lines, three span with through-fastened roof panel, (6) four purlin lines, three span with standing seam roof panel, (7) six purlin lines, single span with through-fastened roof panel, and (8) six purlin lines, single span with standing seam roof panel. For each series, restraint forces were measured at five locations in each span: support, third-point, midpoint, quarter-point, and third-point plus support. For each restraint condition, restraint forces were measured at six roof slopes: 0:12, 0.5:12, 1:12, 2:12, 3:12, and 4:12. Each test, except for those in test Series 1,was loaded to 20 psf and the measured restraint forces were compared to predicted values determined from the proposed prediction equation. The tests conducted for Series 1 were loaded incrementally from 5 psf to 20 psf and the measured restraint forces were compared to the predicted values at each load increment.

6.2 CONCLUSIONS

The measured restraint forces determined from the experimental test program were inconsistent with the predicted restraint forces. Therefore the use of the proposed design equation in design applications is not recommended. It was found that some of the

results were in better correlation with the predicted forces when a load eccentricity of $\delta = 0$ was used in the proposed equation. However, other restraint forces agreed with the eccentricity value, $\delta = 1/3$, which is the initial value used in the development of the proposed equation. The general trend observed from the experimentation is that the actual restraint forces were in between the proposed forces using $\delta = 1/3$ and $\delta = 0$.

The measured forces from the current research are in poor correlation with the forces calculated using the current design provisions located in Supplement No. 1 of the AISI Specification (1999) and the prediction equations developed by Danza and Murray (1998). Overall, the results from the current research are in better correlation with the prediction equations developed by Nuebert and Murray.

It is recommended that additional testing be performed for single span and multiple span systems with roof slopes between 1:12 and 3:12. This is the range of roof slopes in which the results were most inconclusive. The recommendations for eccentricity values in Chapter 5 are not intended to be used for design, but rather they are the best observations made from the experimental results. Additional tests at roof slopes below 1:12 should be performed to validate these observations. The majority of the tests were performed with four or less purlin lines. Two series were conducted with six purlin lines with support restraints only. Therefore it is recommended that tests with more than four purlin lines be conducted and compared with the proposed equation.

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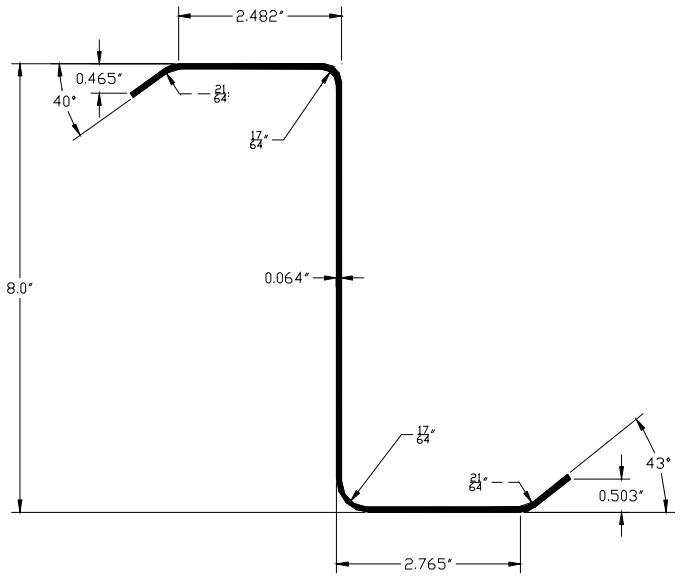
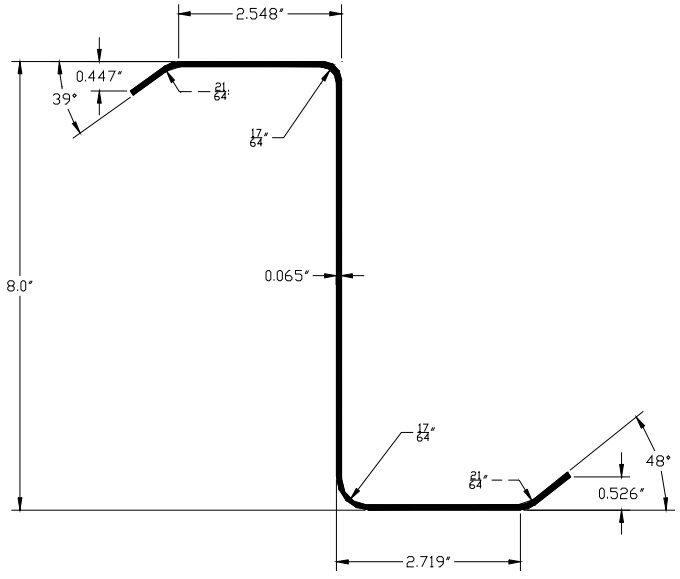
APPENDIX A: Purlin Geometry and Properties

Purlin 1-Eave-Through-Fastened Series



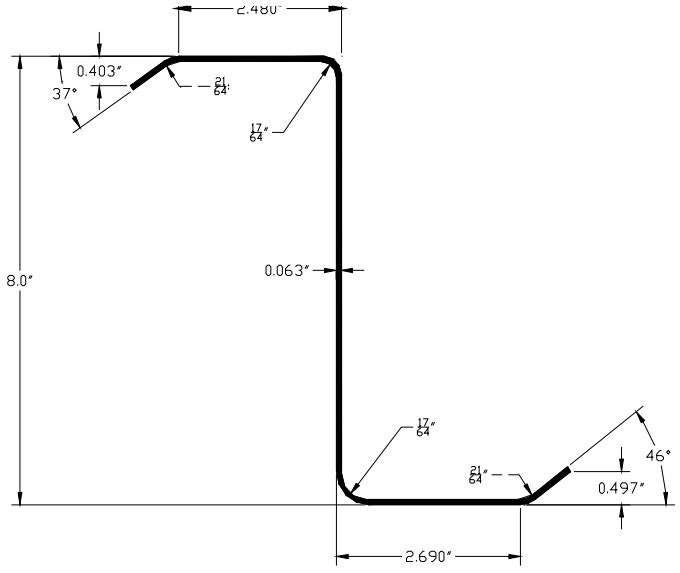
Purlin Properties	
A_g [in^2]	0.91
I_x [in^4]	8.86
I_y [in^4]	1.47
I_{xy} [in^4]	2.65
F_y [ksi]	55
E [ksi]	29500

Purlin 2-Ridge-Through-Fastened Series



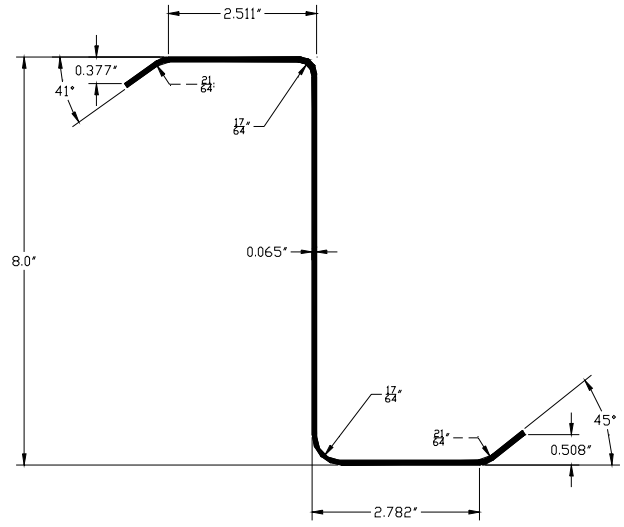
Purlin Properties	
A_g [in^2]	0.93
I_x [in^4]	9.02
I_y [in^4]	1.48
I_{xy} [in^4]	2.68
F_y [ksi]	55
E [ksi]	29500

Purlin 3 MidEave-Through-Fastened Series



Purlin Properties	
A_g [in^2]	0.89
I_x [in^4]	8.57
I_y [in^4]	1.34
I_{xy}[in^4]	2.48
F_y [ksi]	55
E [ksi]	29500

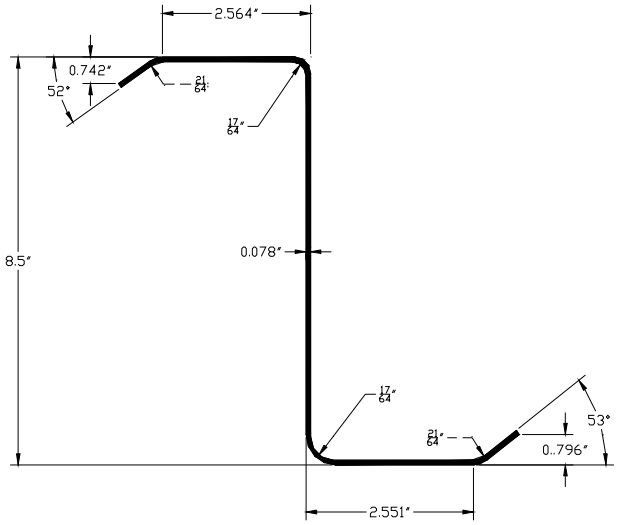
Purlin 4-MidRidge-Through-Fastened Series



Purlin Properties	
A_g [in^2]	0.92
I_x [in^4]	8.85
I_y [in^4]	1.4
I_{xy}[in^4]	2.57
F_y [ksi]	55
E [ksi]	29500

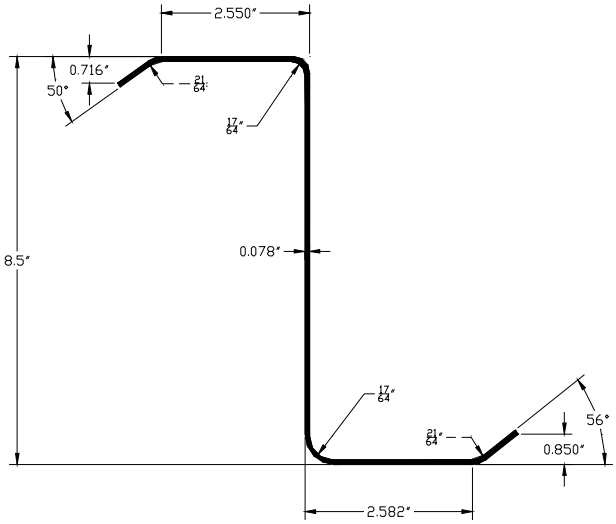
NOTE: Averages of all dimensions and properities for purlins 1 through 4 were used for calculation purposes. For two purlin line tests, the eave and ridge purlins were used. For four purlin line tests, including multiple span, the dimensions and properties of purlins 1 through 4 were used.

Purlin 5-Eave-Standing Seam Series



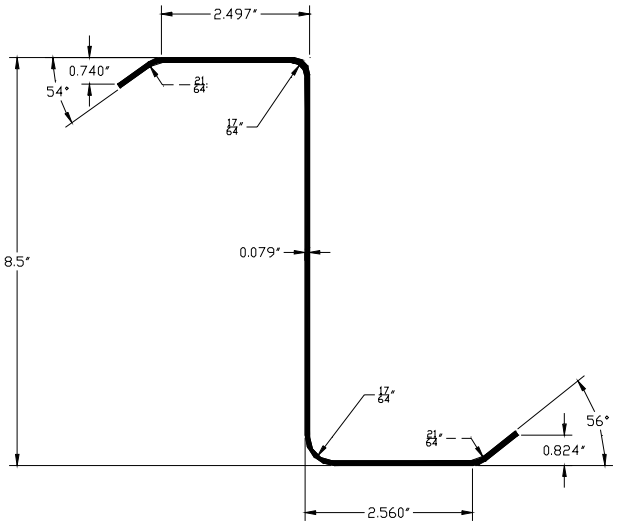
Purlin Properties	
A_g [in^2]	1.17
I_x [in^4]	12.55
I_y [in^4]	1.94
I_{xy}[in^4]	3.59
F_y [ksi]	55
E [ksi]	29500

Purlin 6-Ridge-Standing Seam Series



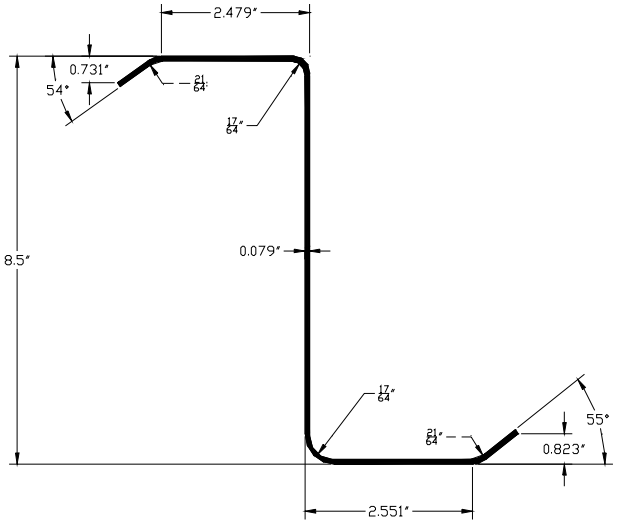
Purlin Properties	
A_g [in^2]	1.17
I_x [in^4]	12.58
I_y [in^4]	1.97
I_{xy}[in^4]	3.62
F_y [ksi]	55
E [ksi]	29500

Purlin 7-MidEave-Standing Seam Series



Purlin Properties	
A_g [in^2]	1.18
I_x [in^4]	12.56
I_y [in^4]	1.87
I_{xy}[in^4]	3.52
F_y [ksi]	55
E [ksi]	29500

Purlin 8-MidRidge-Standing Seam Series



Purlin Properties	
A_g [in^2]	1.18
I_x [in^4]	12.53
I_y [in^4]	1.85
I_{xy}[in^4]	3.5
F_y [ksi]	55
E [ksi]	29500

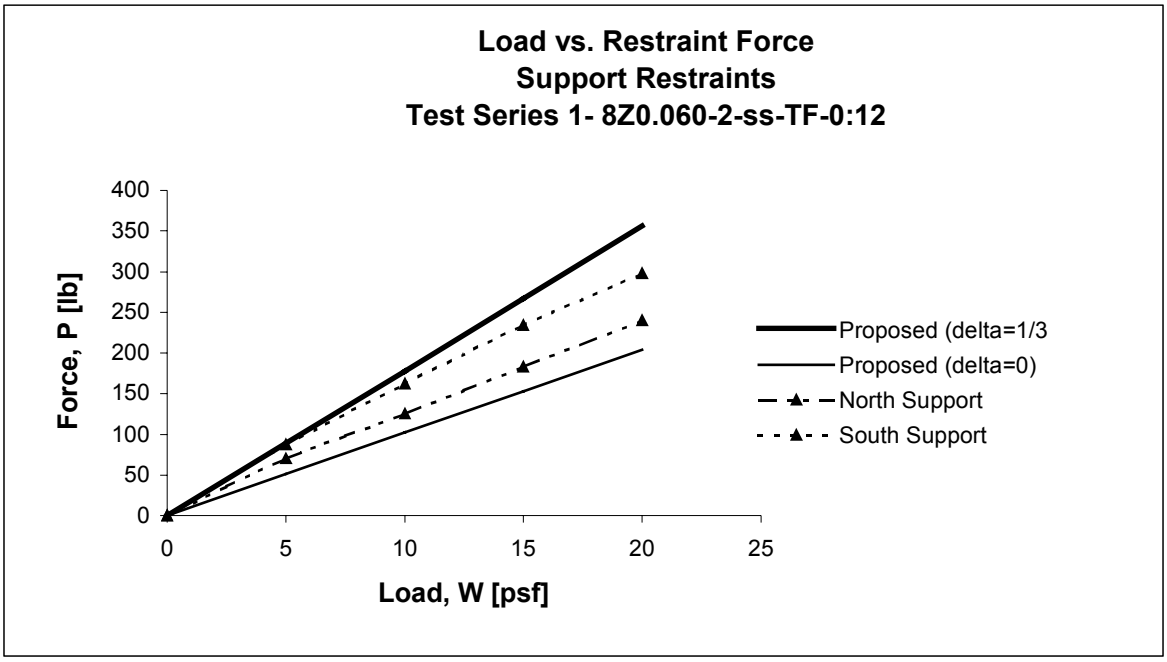
NOTE: Averages of all dimensions and properities for purlins 5 through 8 were used for calculation purposes. For two purlin line tests, the eave and ridge purlins were used. For four purlin line tests, including multiple span, the dimensions and properties of purlins 5 through 8 were used.

APPENDIX B-Series 1: 8Z0.060-2-ss-TF Results

Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 1
Test Date: 12-11-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Support

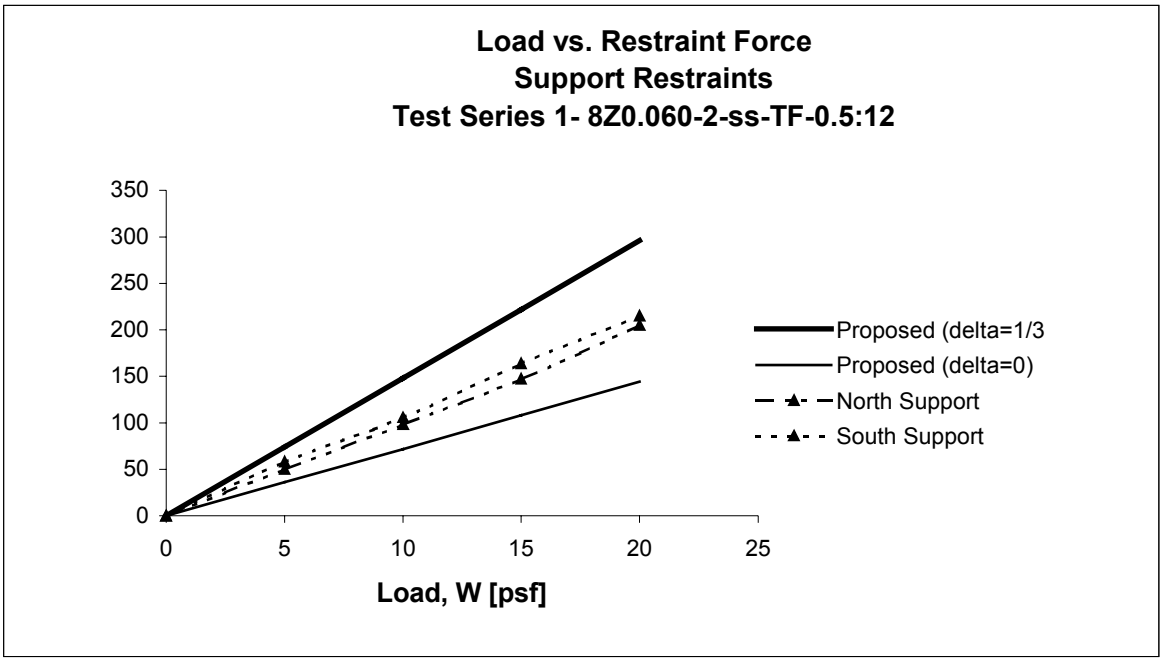
Test Series 1- 8Z0.060-2-ss-TF-0:12 Support Restraints				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0	0	0	0	0
5	89	51	70	87
10	178	102	125	162
15	267	153	183	234
20	356	204	240	298



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 2
Test Date: 12-11-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Support

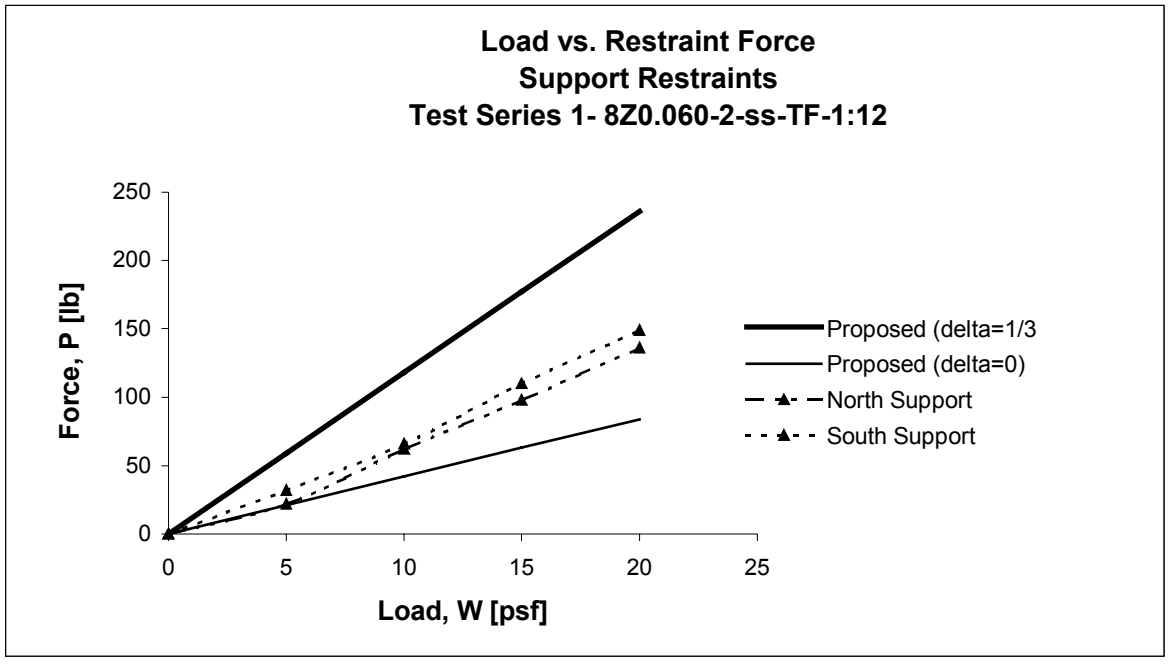
Test Series 1- 8Z0.060-2-ss-TF-0.5:12 Support Restraints				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0	0	0	0	0
5	74	36	50	58
10	148	72	98	106
15	222	108	147	164
20	296	144	205	215



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 3
Test Date: 12-11-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Support

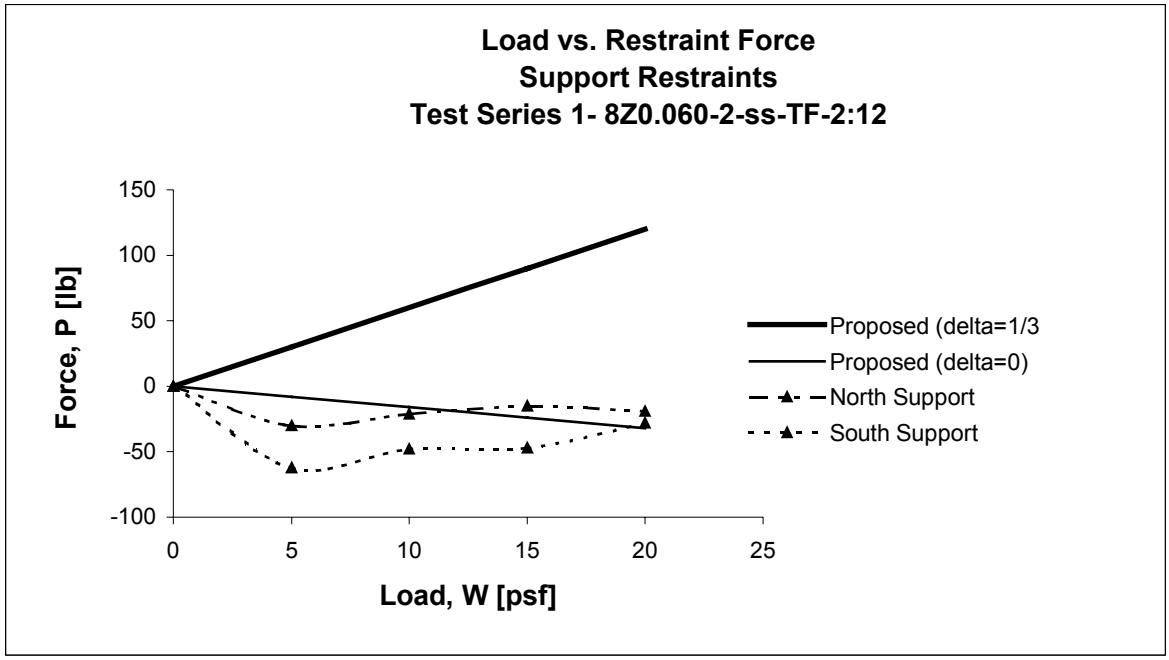
Test Series 1- 8Z0.060-2-ss-TF-1:12 Support Restraints				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0	0	0	0	0
5	59	21	22	32
10	118	42	62	66
15	177	63	98	110
20	236	84	136	149



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 4
Test Date: 12-11-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Support

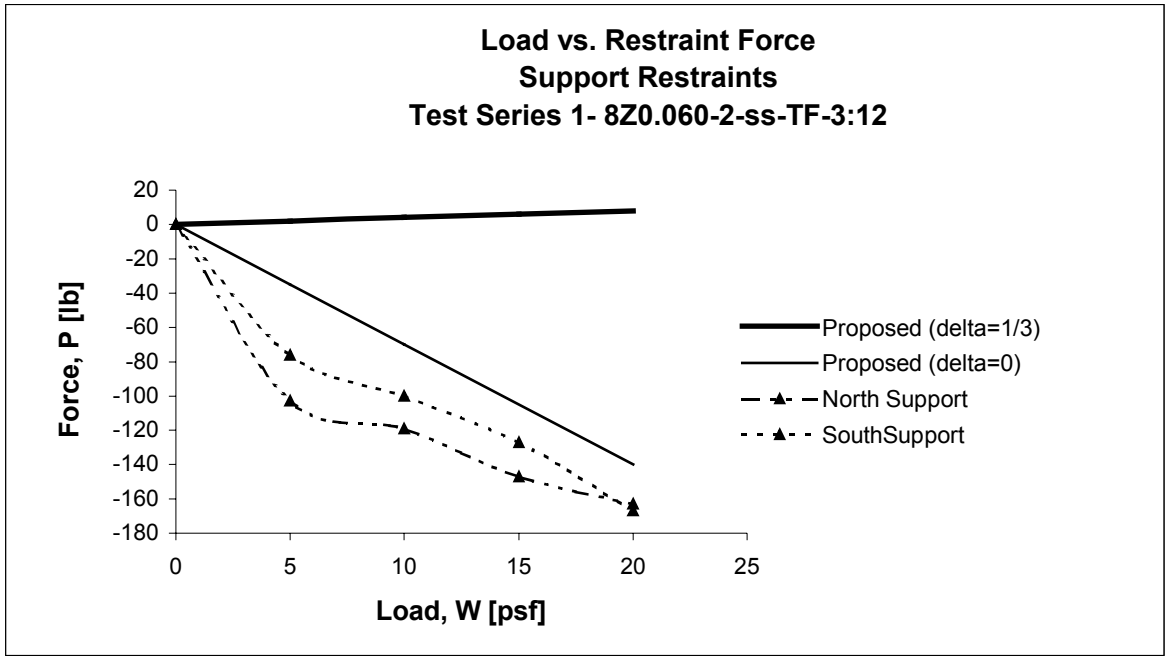
Test Series 1- 8Z0.060-2-ss-TF-2:12 Support Restraints				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0	0	0	0	0
5	30	-8	-30	-62
10	60	-16	-21	-48
15	90	-24	-15	-47
20	120	-32	-19	-28



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 5
Test Date: 12-11-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Support

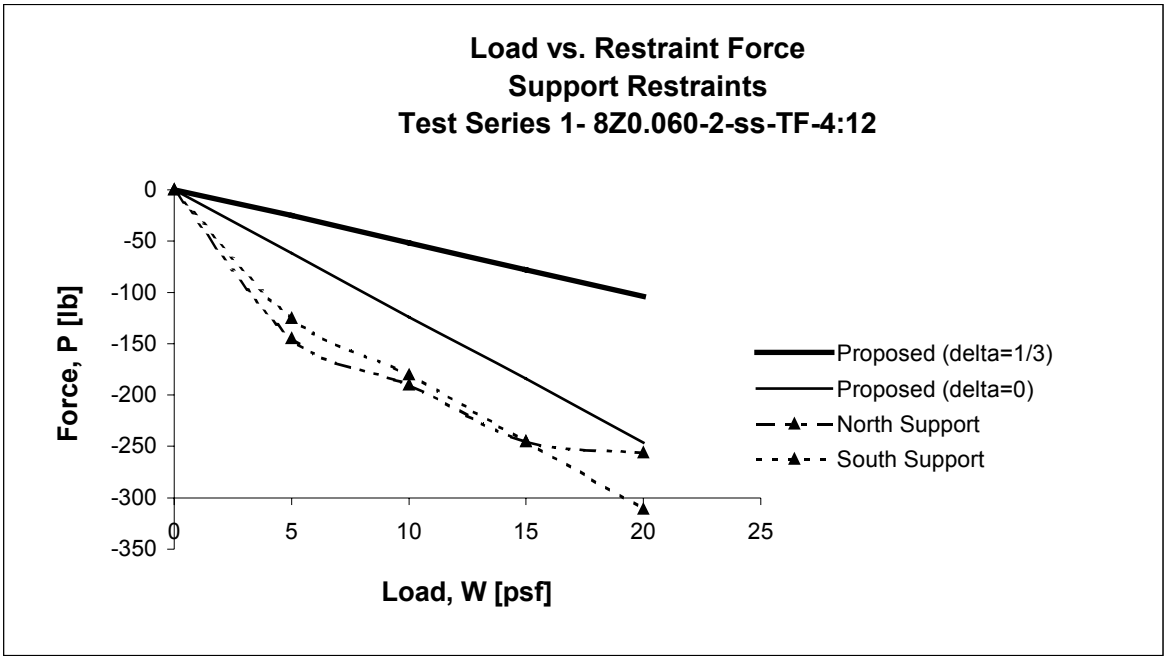
Test Series 1- 8Z0.060-2-ss-TF-3:12 Support Restraints				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0	0	0	0	0
5	2	-35	-103	-76
10	4	-70	-119	-100
15	6	-105	-147	-127
20	8	-140	-163	-167



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 6
Test Date: 12-11-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Support

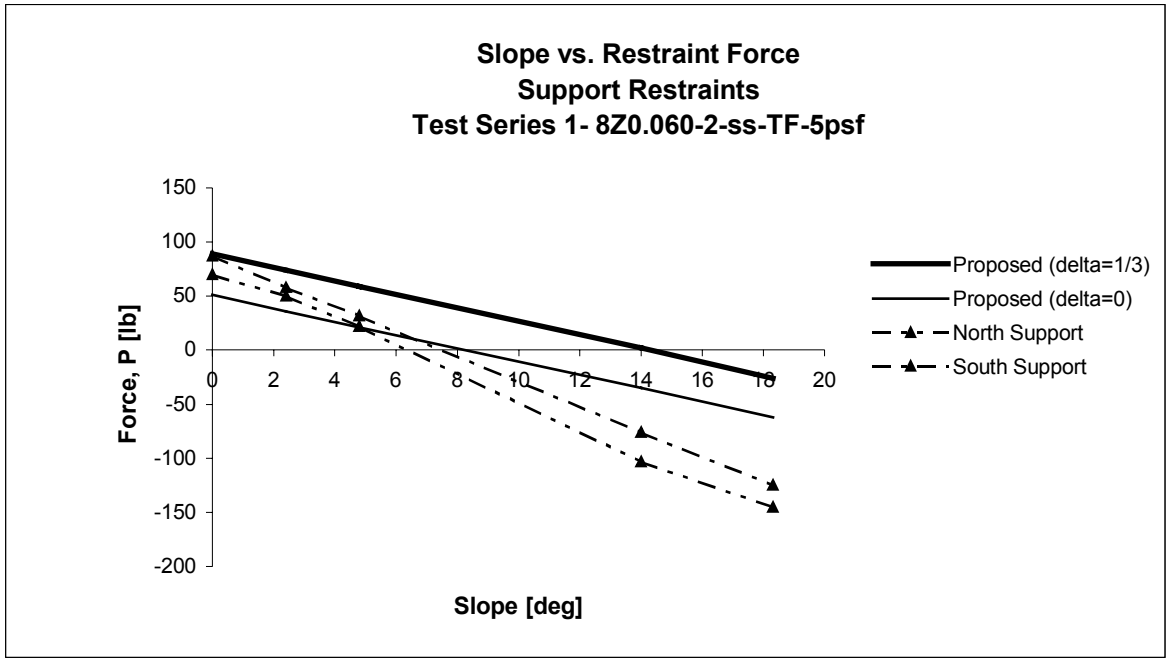
Test Series 1- 8Z0.060-2-ss-TF-4:12 Support Restraints				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0	0	0	0	0
5	-25	-62	-145	-125
10	-52	-124	-190	-180
15	-78	-184	-245	-245
20	-104	-246	-256	-311



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 7
Test Date: 12-11-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Support

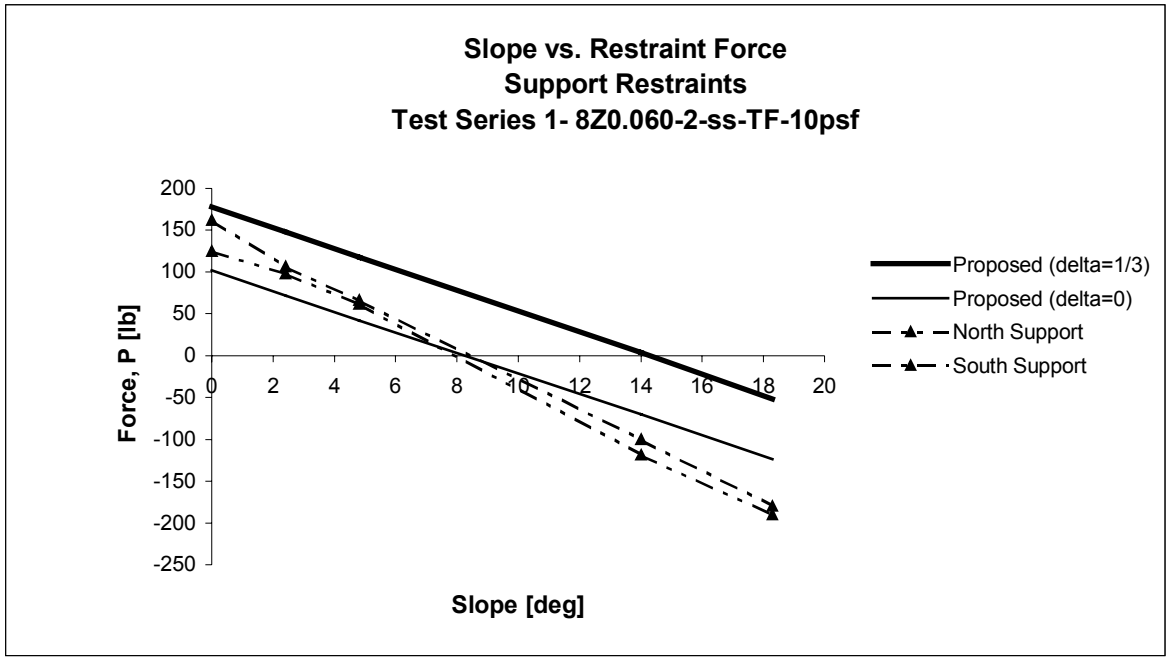
Test Series 1- 8Z0.060-2-ss-TF-5psf			Support Restraints	
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0.0	89	51	70	87
2.4	74	36	50	58
4.8	59	21	22	32
14.0	2	-35	-103	-76
18.3	-26	-62	-145	-125



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 8
Test Date: 12-11-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Support

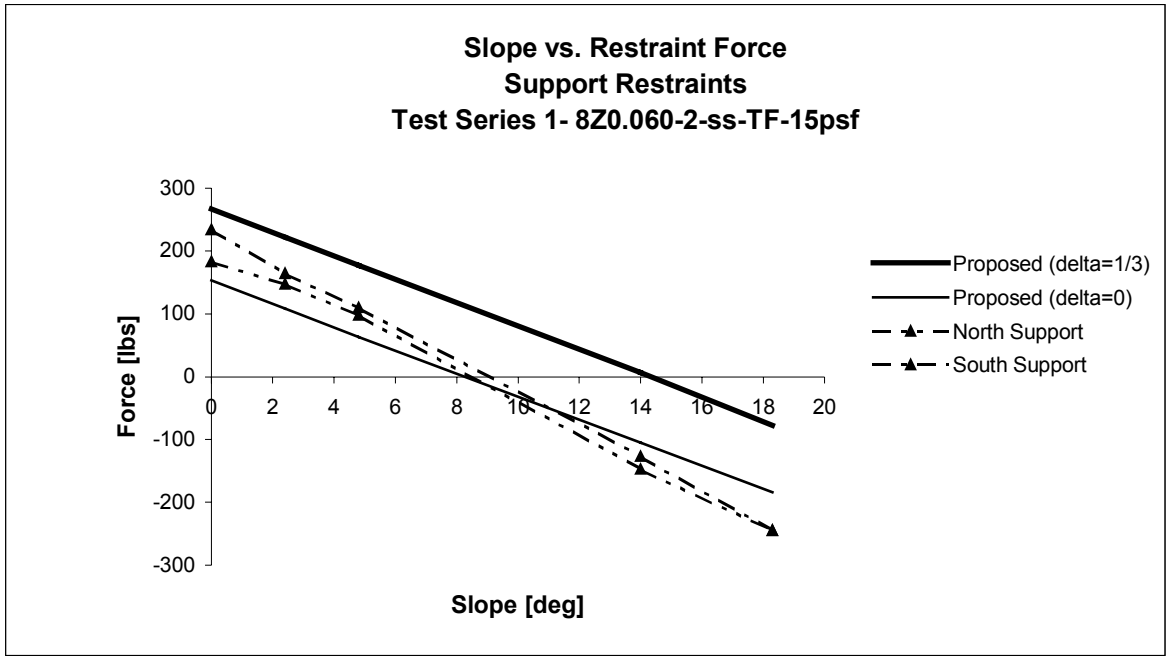
Test Series 1- 8Z0.060-2-ss-TF-10psf Support Restraints				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0.0	178	102	125	162
2.4	148	72	98	106
4.8	118	42	62	66
14.0	4	-70	-119	-100
18.3	-52	-124	-190	-180



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 9
Test Date: 12-11-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Support

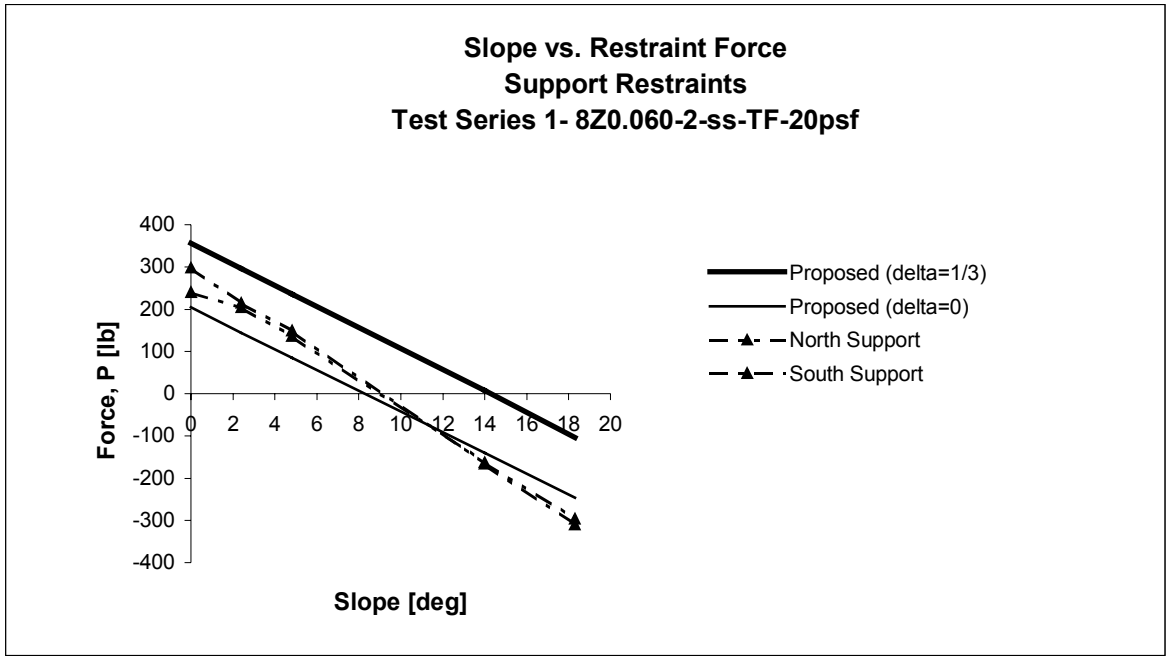
Test Series 1- 8Z0.060-2-ss-TF-15psf Support Restraints				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0.0	267	153	183	234
2.4	222	108	147	164
4.8	177	63	98	110
14.0	6	-105	-147	-127
18.3	-78	-184	-245	-245



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 10
Test Date: 12-11-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Support

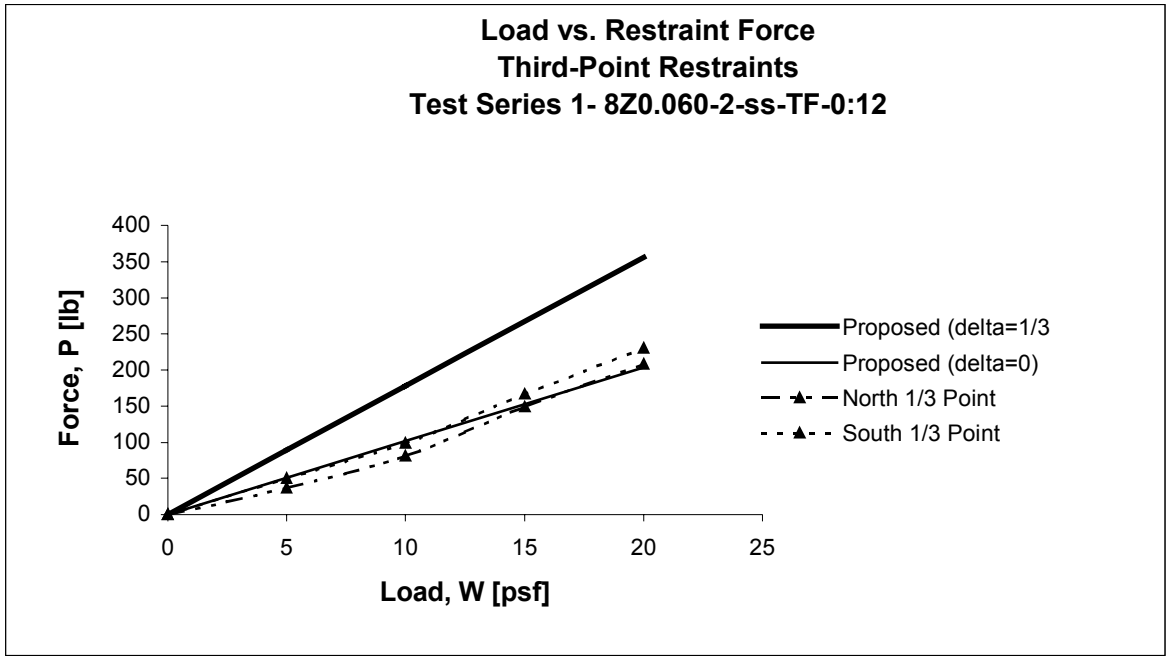
Test Series 1- 8Z0.060-2-ss-TF-20psf Support Restraints				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0.0	356	204	240	298
2.4	296	144	205	215
4.8	236	84	136	149
14.0	8	-140	-163	-167
18.3	-104	-246	-296	-311



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 11
Test Date: 12-12-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point

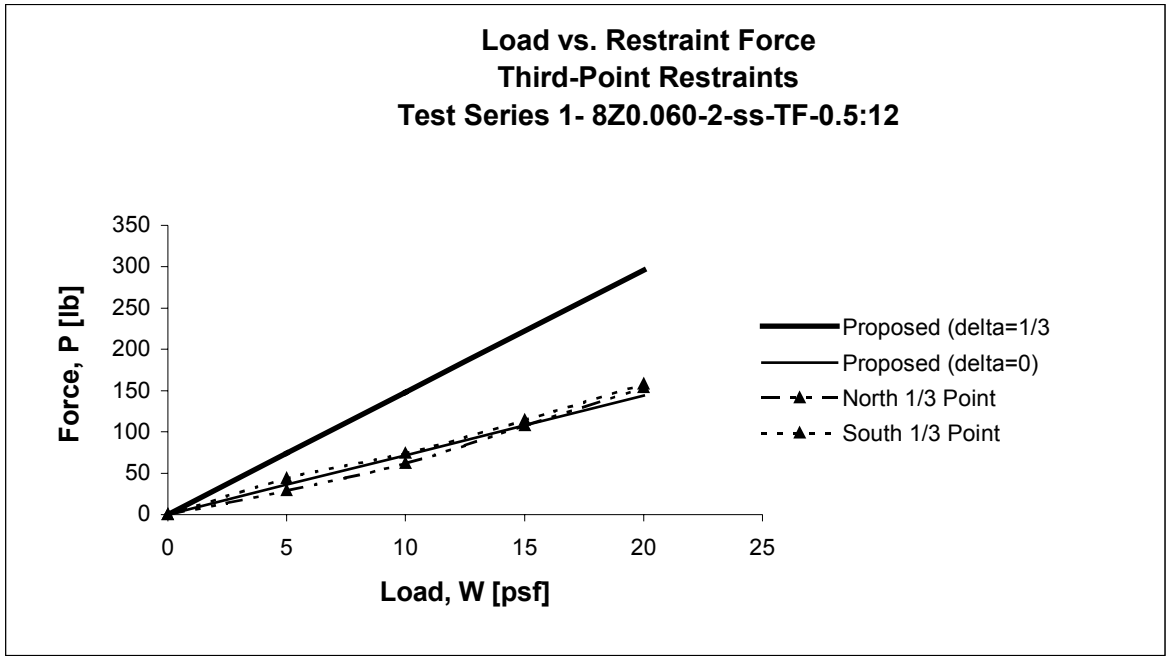
Test Series 1- 8Z0.060-2-ss-TF-0:12 Third-Point Restraints				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0	0	0	0	0
5	89	51	37	50
10	178	102	81	99
15	267	153	149	167
20	356	204	208	230



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 12
Test Date: 12-12-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point

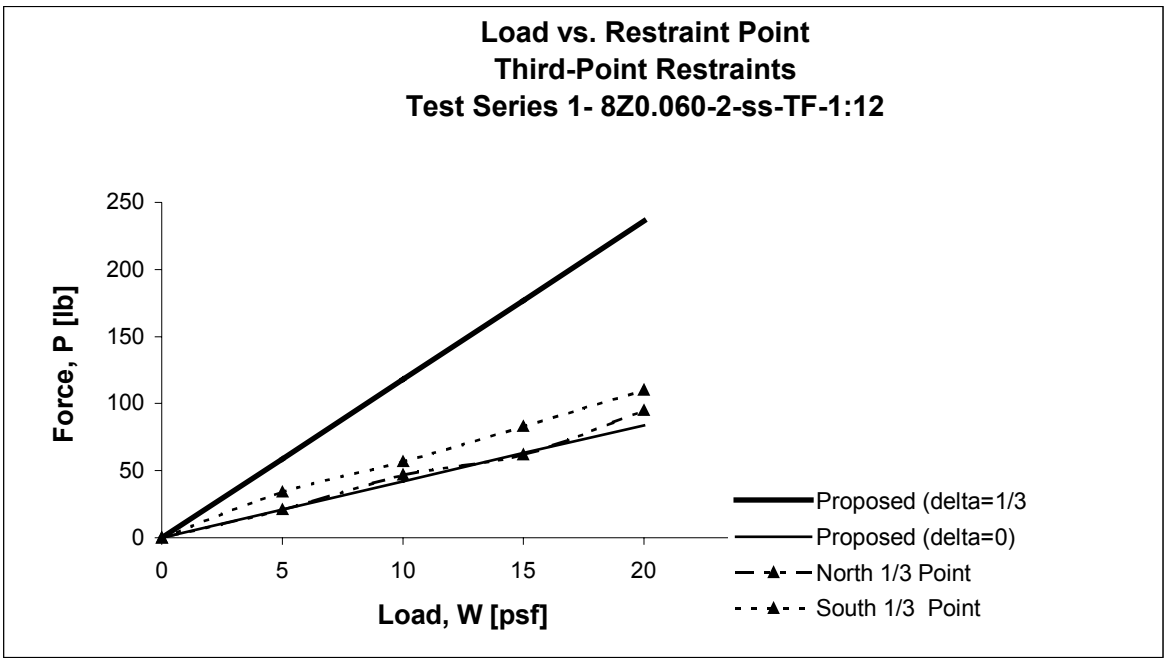
Test Series 1- 8Z0.060-2-ss-TF-0.5:12 Third-Point Restraints				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0	0	0	0	0
5	74	36	29	44
10	148	72	62	74
15	222	108	108	114
20	296	144	154	158



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 13
Test Date: 12-12-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point

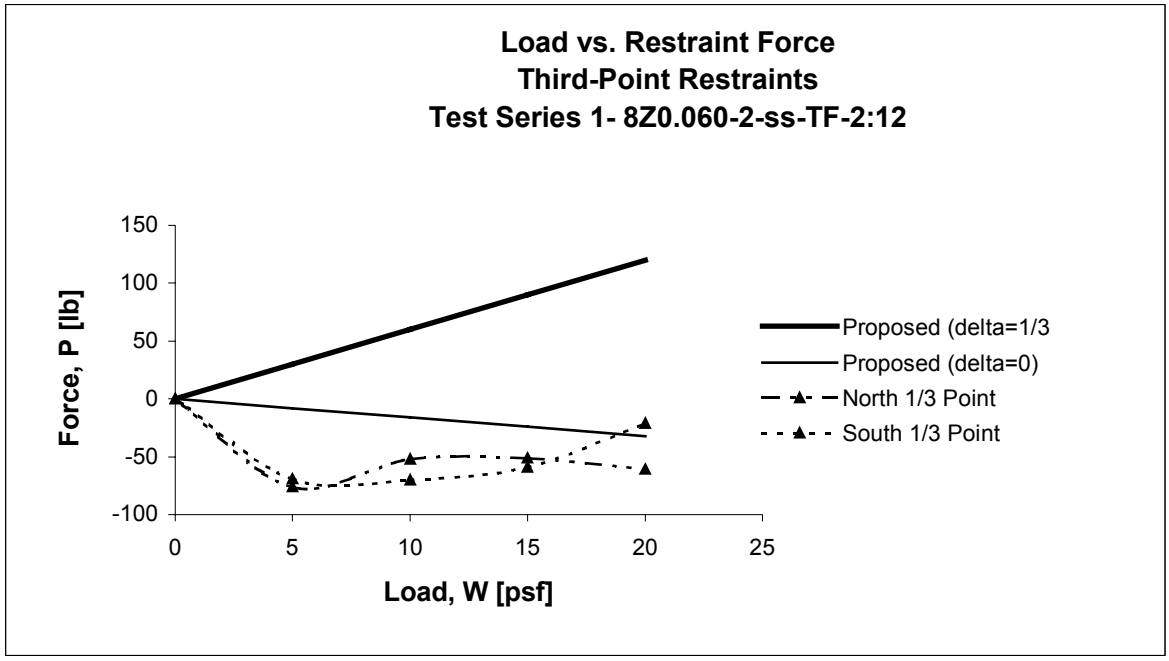
Test Series 1- 8Z0.060-2-ss-TF-1:12 Third-Point Restraints				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0	0	0	0	0
5	59	21	21	34
10	118	42	47	57
15	177	63	62	83
20	236	84	95	110



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 14
Test Date: 12-12-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point

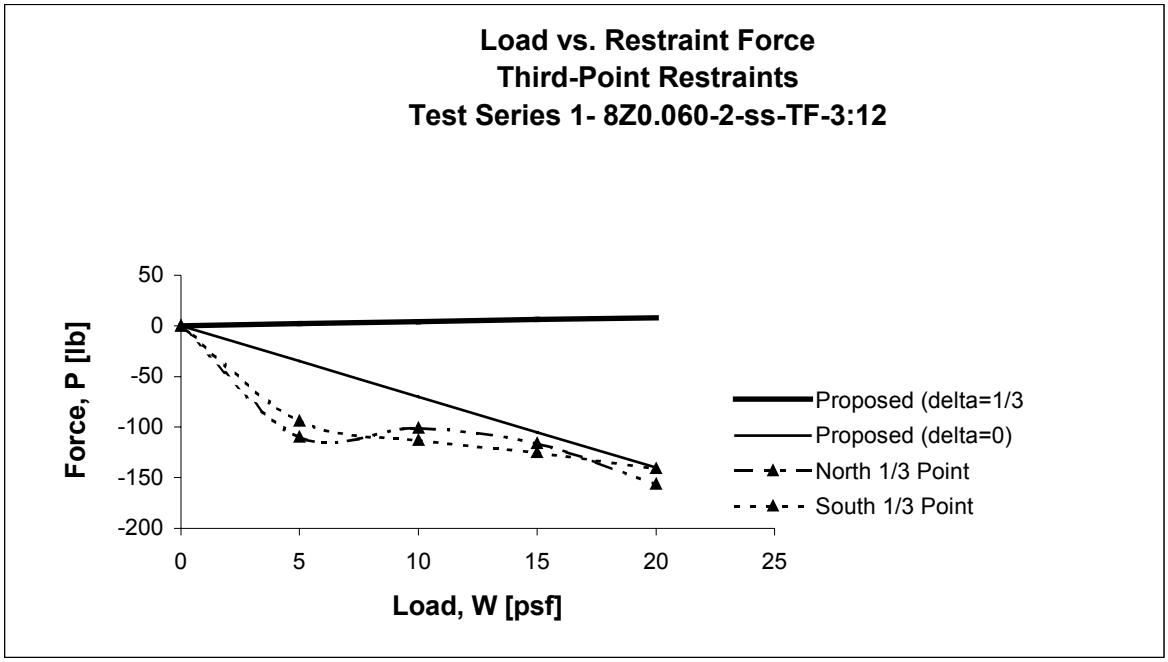
Test Series 1- 8Z0.060-2-ss-TF-2:12 Third-Point Restraints				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0	0	0	0	0
5	30	-8	-76	-69
10	60	-16	-52	-70
15	90	-24	-51	-59
20	120	-32	-61	-21



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 15
Test Date: 12-12-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point

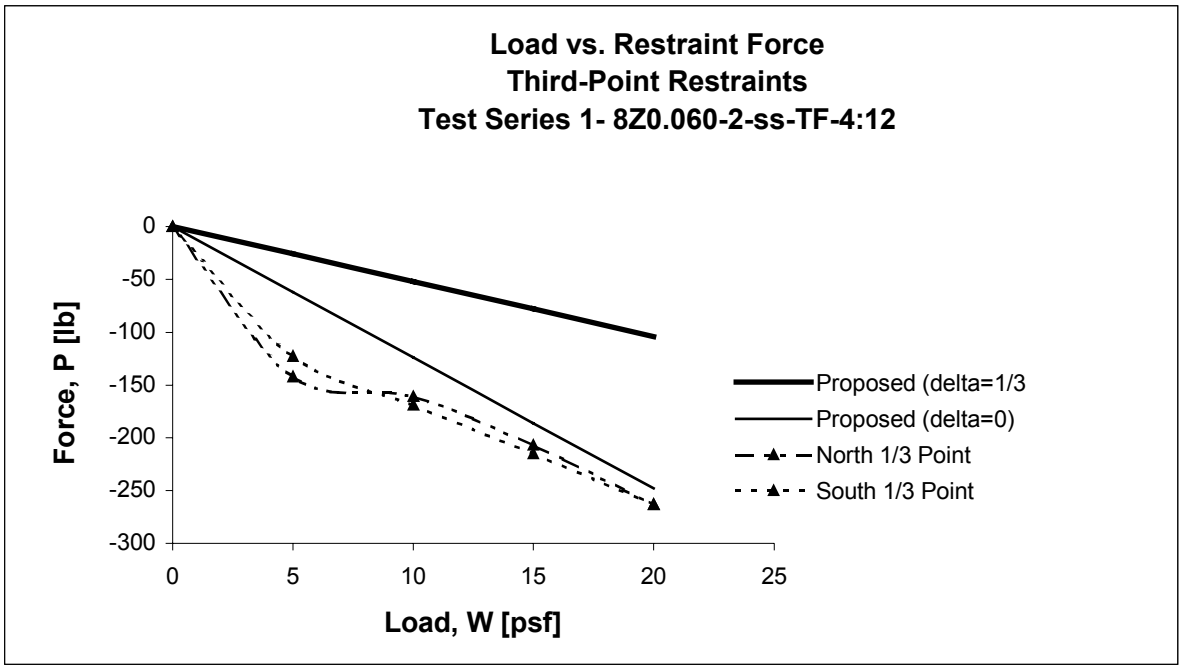
Test Series 1- 8Z0.060-2-ss-TF-3:12 Third-Point Restraints				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0	0	0	0	0
5	2	-35	-110	-94
10	4	-70	-101	-113
15	6	-105	-116	-125
20	8	-140	-156	-141



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 16
Test Date: 12-12-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point

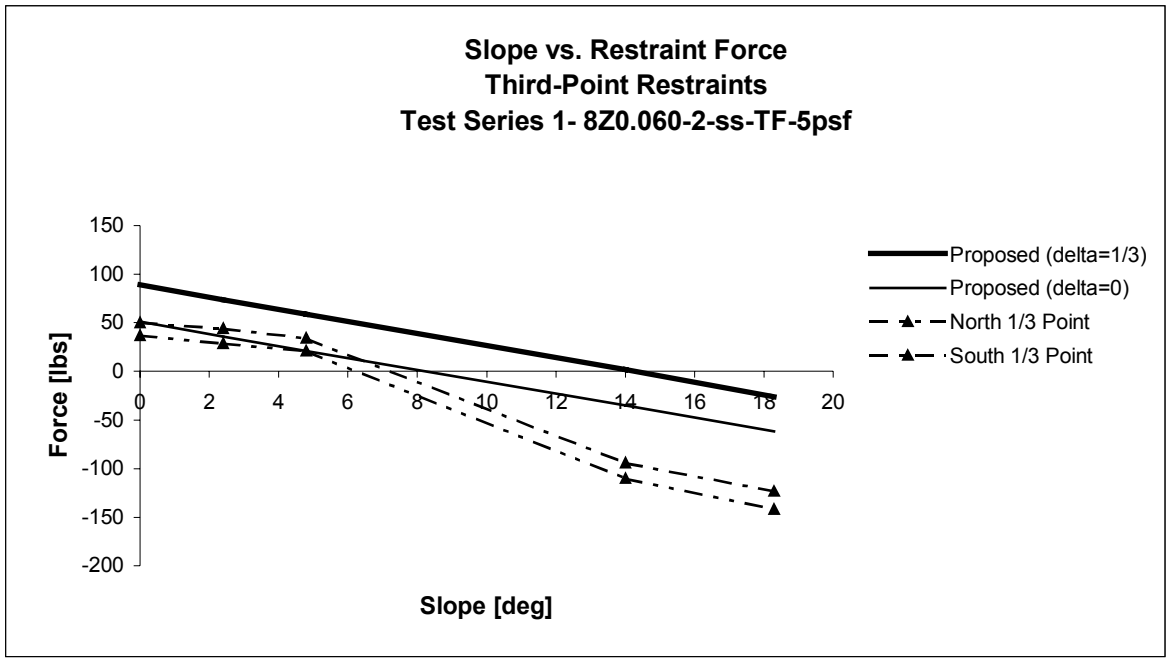
Test Series 1- 8Z0.060-2-ss-TF-4:12 Third-Point Restraints				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0	0	0	0	0
5	-26	-62	-142	-123
10	-52	-124	-161	-169
15	-78	-186	-207	-215
20	-104	-248	-263	-263



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 17
Test Date: 12-12-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point

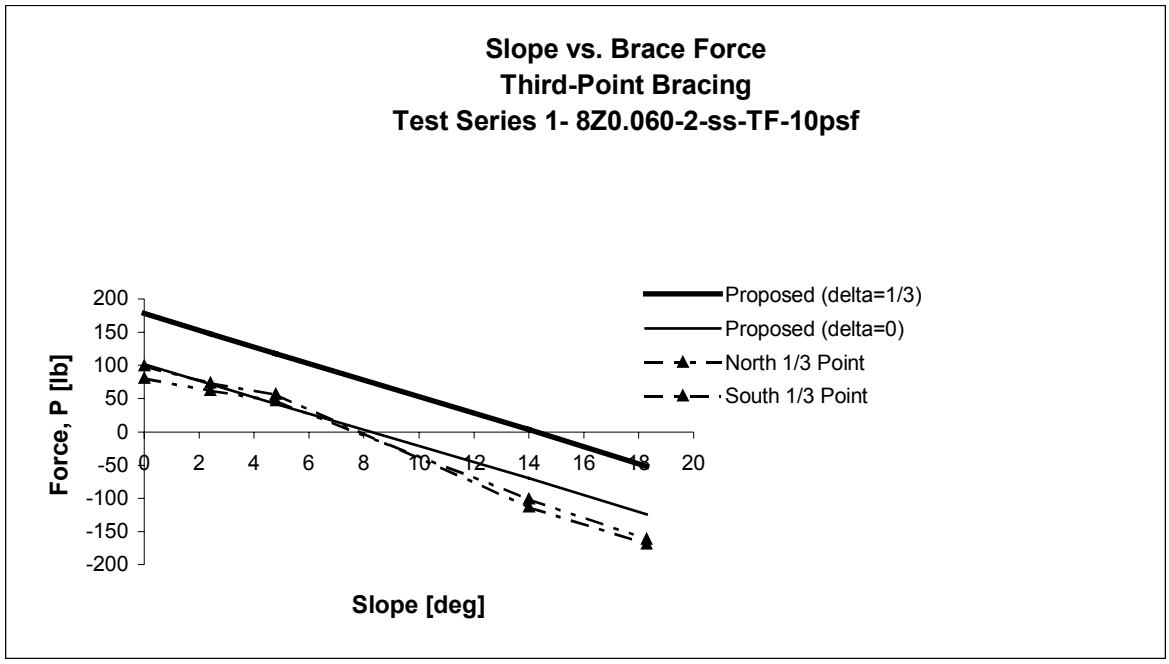
Test Series 1- 8Z0.060-2-ss-TF-5psf Third-Point Restraints				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0.0	89	51	37	50
2.4	74	36	29	44
4.8	59	21	21	34
14.0	2	-35	-110	-94
18.3	-26	-62	-142	-123



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 18
Test Date: 12-12-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point

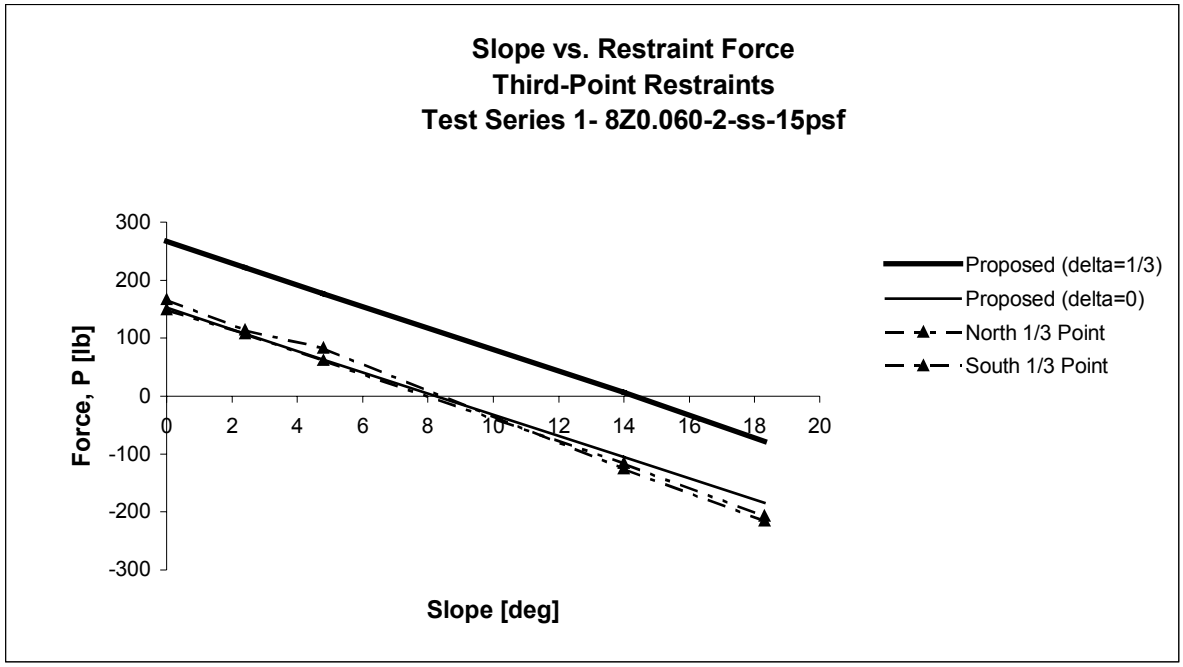
Test Series 1- 8Z0.060-2-ss-TF-10psf Third-Point Restraints				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0.0	178	102	81	99
2.4	148	72	62	74
4.8	118	42	47	57
14.0	4	-70	-101	-113
18.3	-52	-124	-161	-169



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 19
Test Date: 12-12-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point

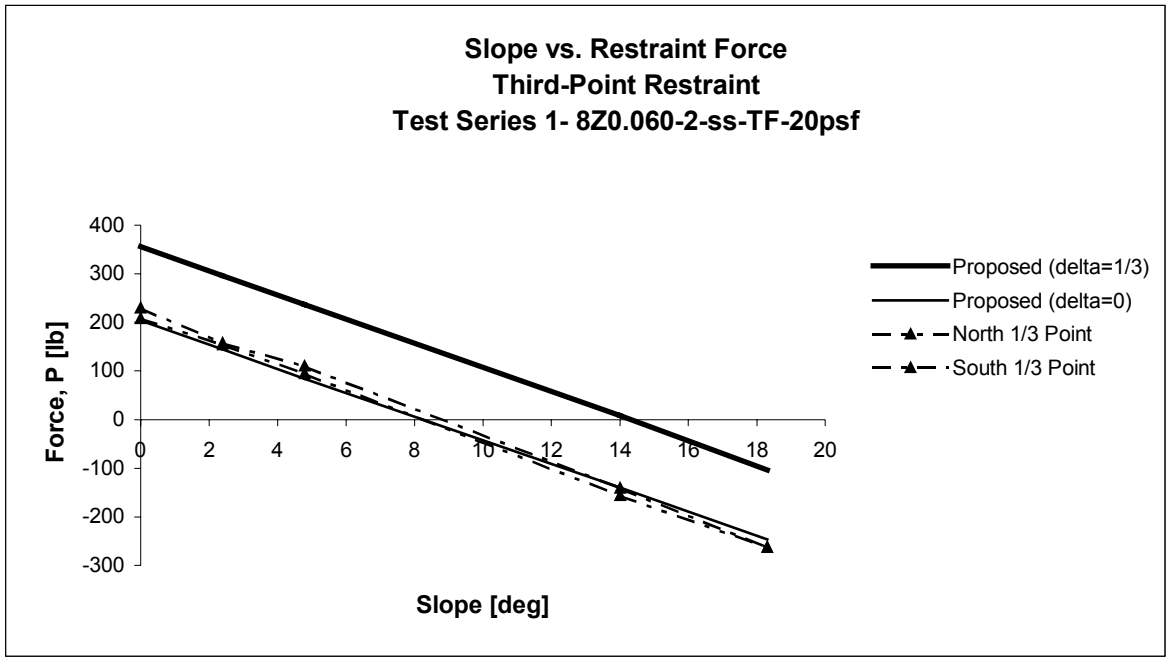
Test Series 1- 8Z0.060-2-ss-TF-15psf Third-Point Restraints				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0.0	267	153	149	167
2.4	222	108	108	114
4.8	177	63	62	83
14.0	6	-105	-116	-125
18.3	-78	-184	-207	-215



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 20
Test Date: 12-12-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point

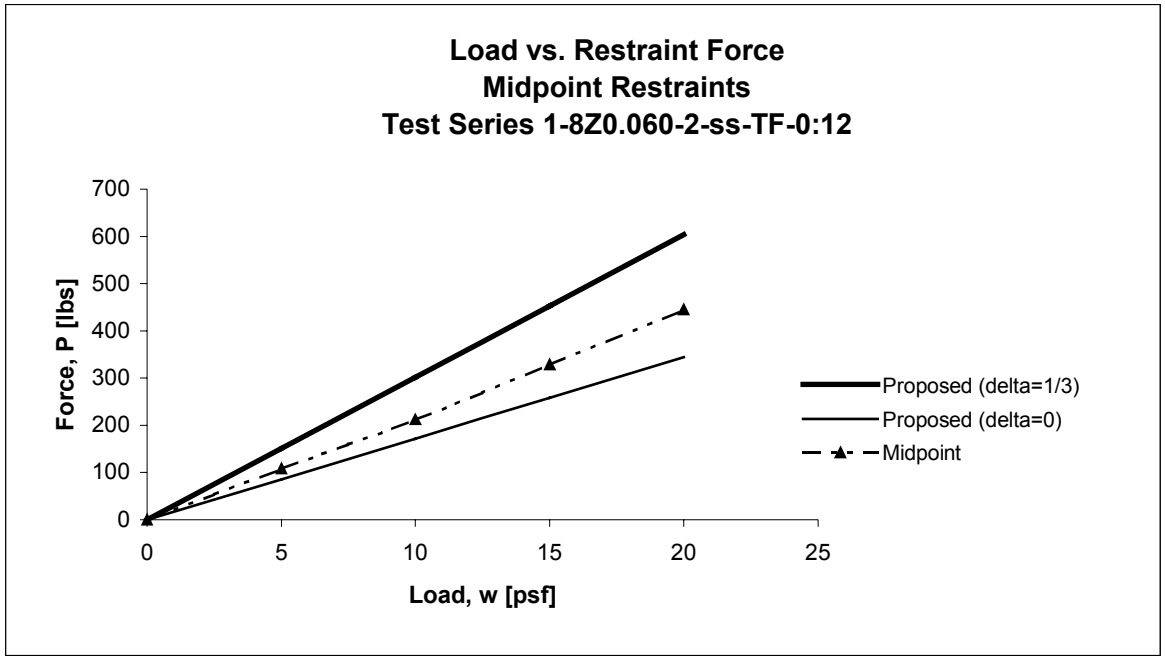
Test Series 1- 8Z0.060-2-ss-TF-20psf Third-Point Restraints				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0.0	356	204	208	230
2.4	296	144	154	158
4.8	236	84	95	110
14.0	8	-140	-156	-141
18.3	-104	-246	-263	-263



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 21
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Midpoint

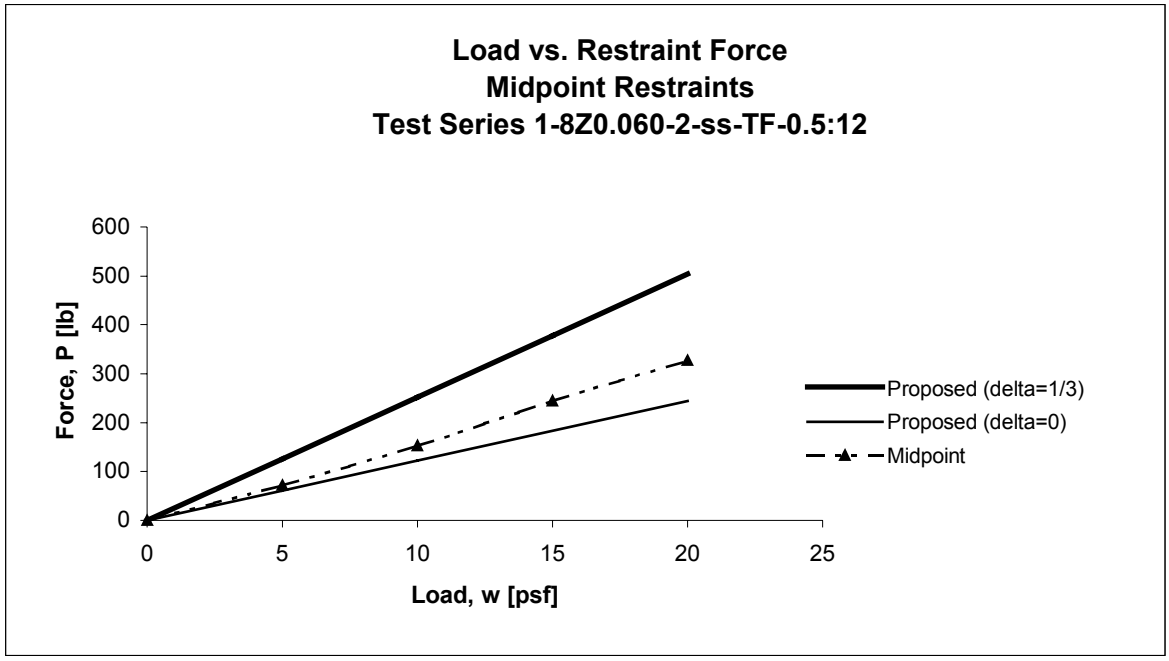
Test Series 1-8Z0.060-2-ss-TF-0:12 Midpoint Restraints			
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0	0	0	0
5	151	86	108
10	302	172	212
15	453	258	328
20	604	344	445



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 22
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Midpoint

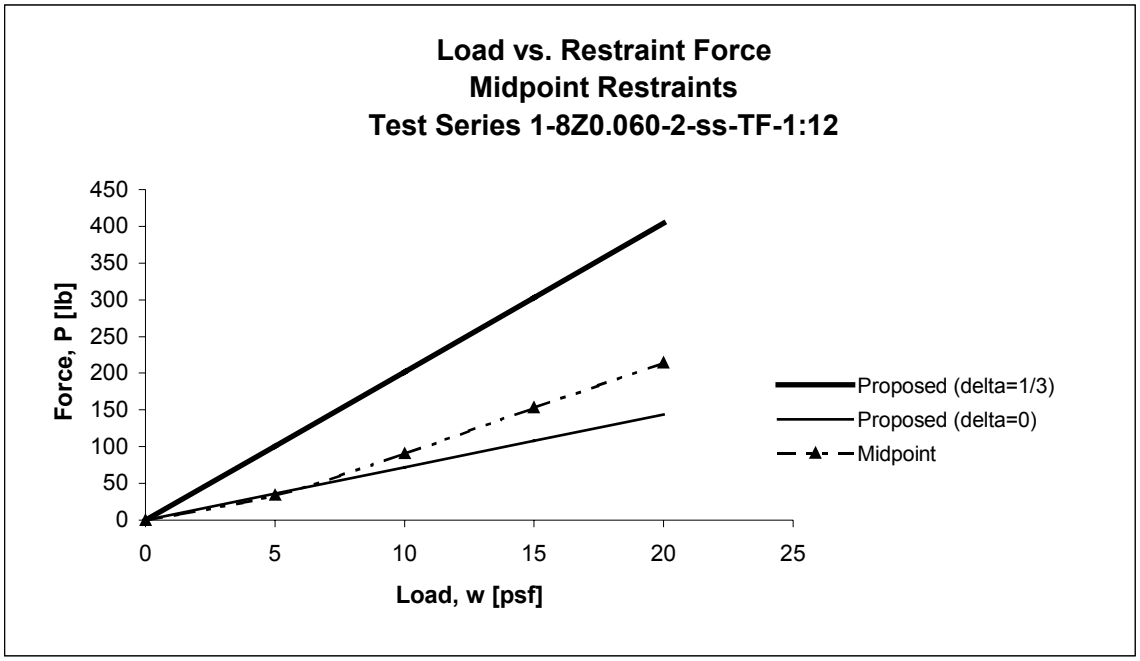
Test Series 1- 8Z0.060-2-ss-TF-0.5:12 Midpoint Restraints			
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midspoint**
0	0	0	0
5	126	61	72
10	252	122	153
15	378	183	244
20	504	244	327



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 23
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Midpoint

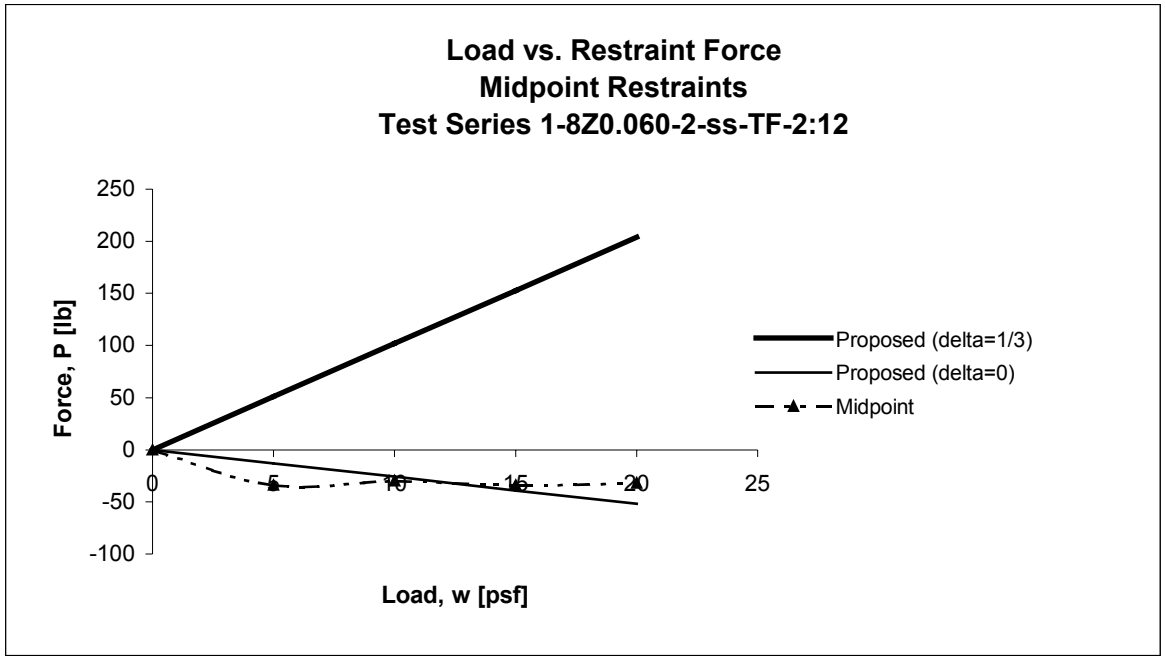
Test Series 1-8Z0.060-2-ss-TF-1:12 Midpoint Restraints			
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0	0	0	0
5	101	36	34
10	202	72	91
15	303	108	153
20	404	144	214



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 24
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Midpoint

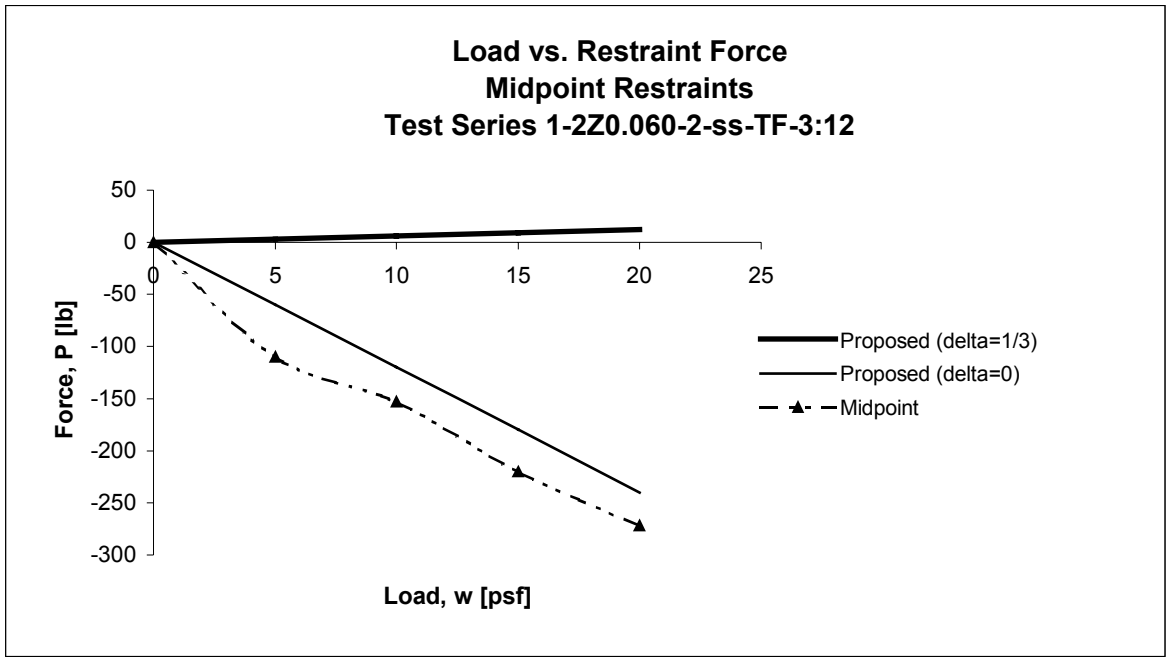
Test Series 1-8Z0.060-2-ss-TF-2:12 Midpoint Restraints			
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0	0	0	0
5	51	-13	-34
10	102	-26	-30
15	153	-39	-34
20	204	-52	-32



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 25
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Midpoint

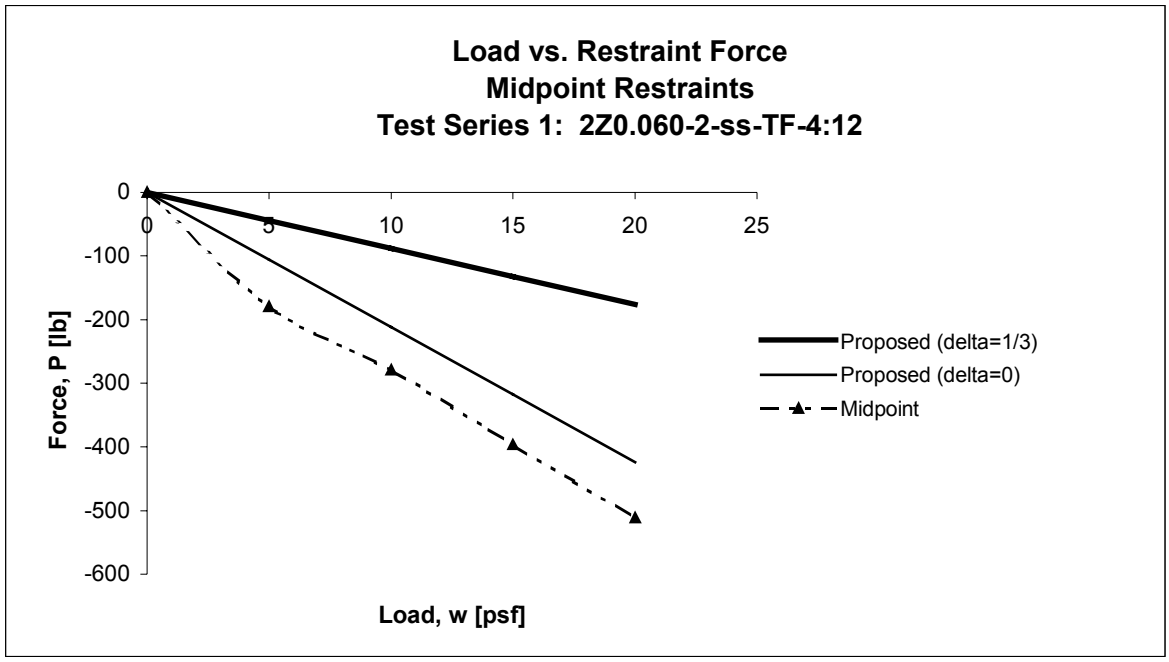
Test Series 1-2Z0.060-2-ss-TF-3:12 Midpoint Restraints			
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0	0	0	0
5	3	-60	-110
10	6	-120	-153
15	9	-180	-220
20	12	-240	-272



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 26
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Midpoint

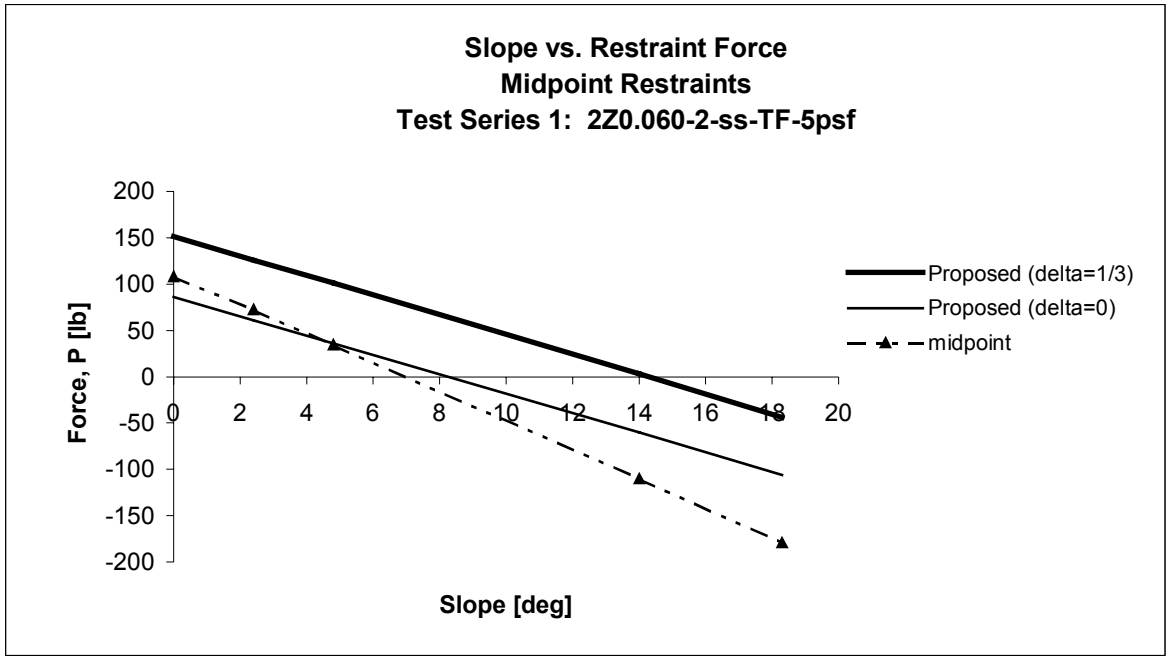
Test Series 1- 2Z0.060-2-ss-TF-4:12 Midpoint Restraints			
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0	0	0	0
5	-44	-106	-179
10	-88	-212	-279
15	-132	-318	-396
20	-176	-424	-511



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 27
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Midpoint

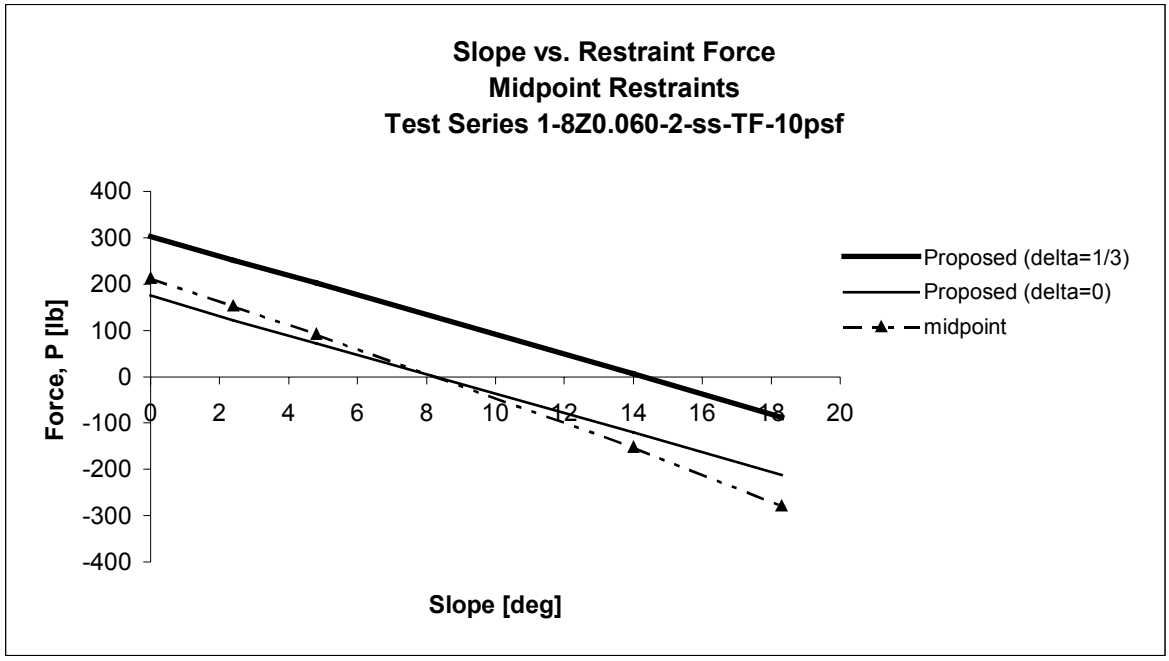
Test Series 1: 2Z0.060-2-ss-TF-5psf Midpoint Restraints			
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0.0	151	86	108
2.4	126	61	72
4.8	101	36	34
14.0	3	-60	-110
18.3	-44	-106	-179



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 28
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Midpoint

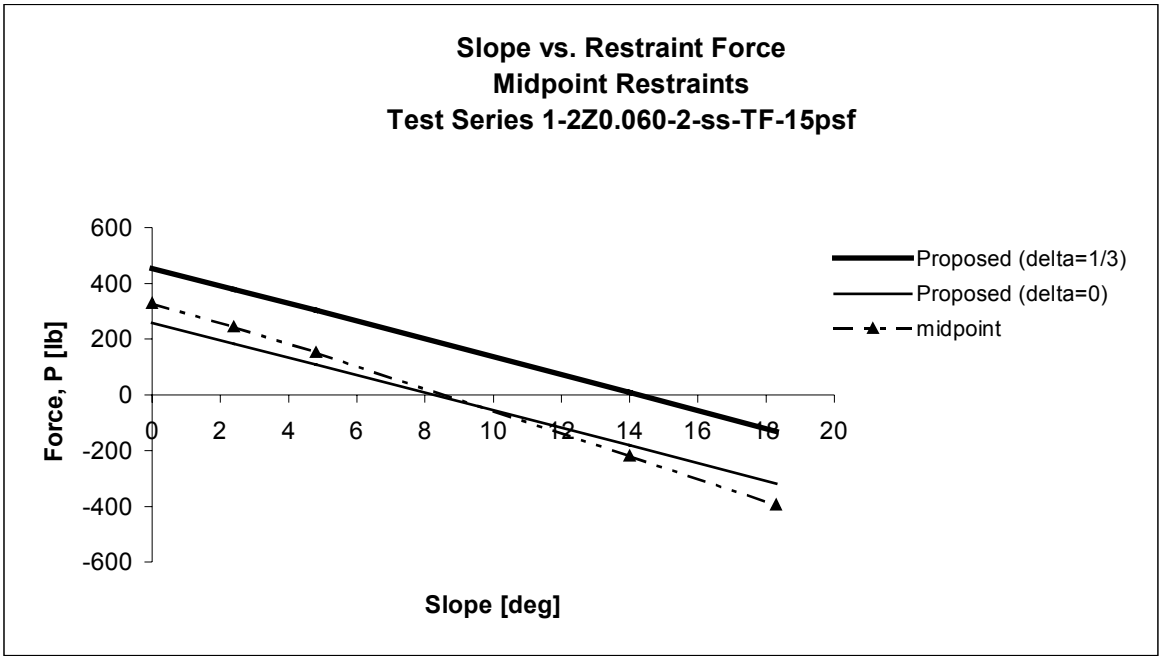
Test Series 1-8Z0.060-2-ss-TF-10psf Midpoint Restraints			
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0.0	302	176	212
2.4	252	122	153
4.8	202	72	91
14.0	6	-120	-153
18.3	-88	-212	-279



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 29
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Midpoint

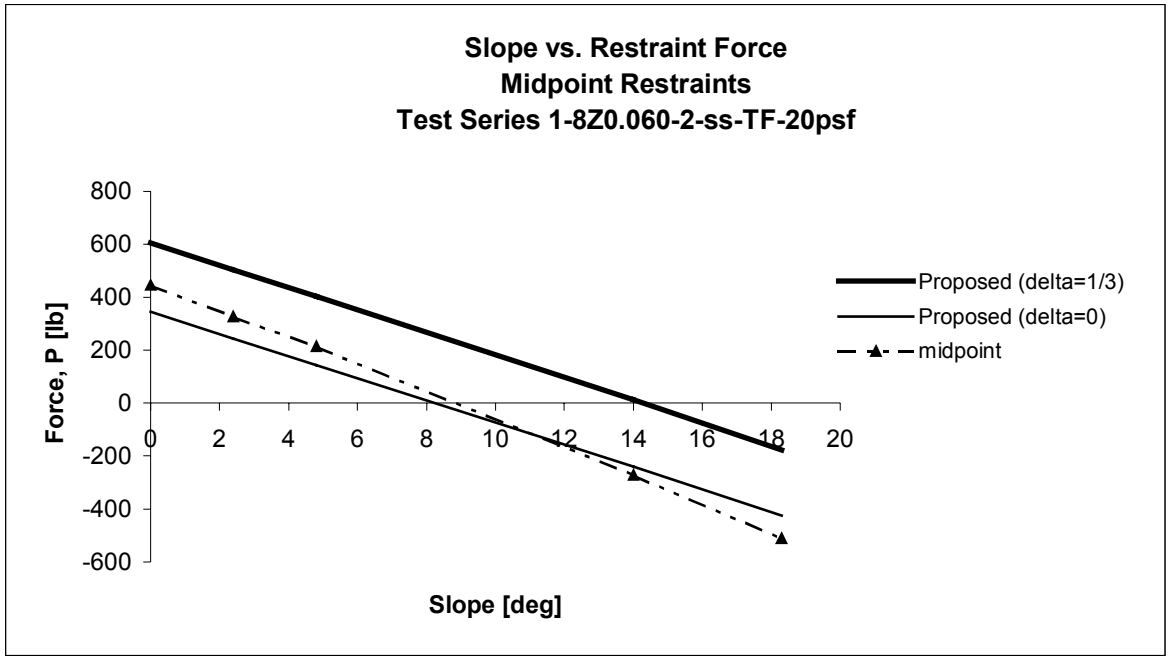
Test Series 1-8Z0.060-2-ss-TF-15psf Midpoint Restraints			
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0.0	453	258	328
2.4	378	183	244
4.8	303	108	153
14.0	9	-180	-220
18.3	-132	-318	-396



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 30
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Midpoint

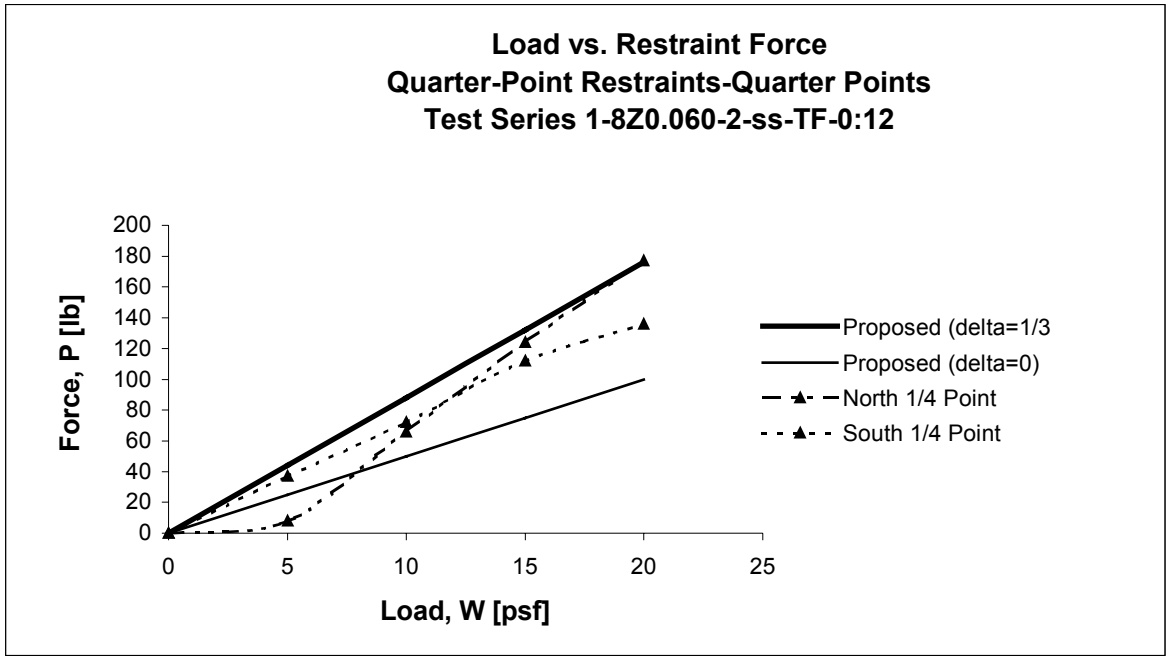
Test Series 1-8Z0.060-2-ss-TF-20psf Midpoint Restraints			
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0.0	604	344	445
2.4	504	244	327
4.8	404	144	214
14.0	12	-240	-272
18.3	-176	-424	-511



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 31
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

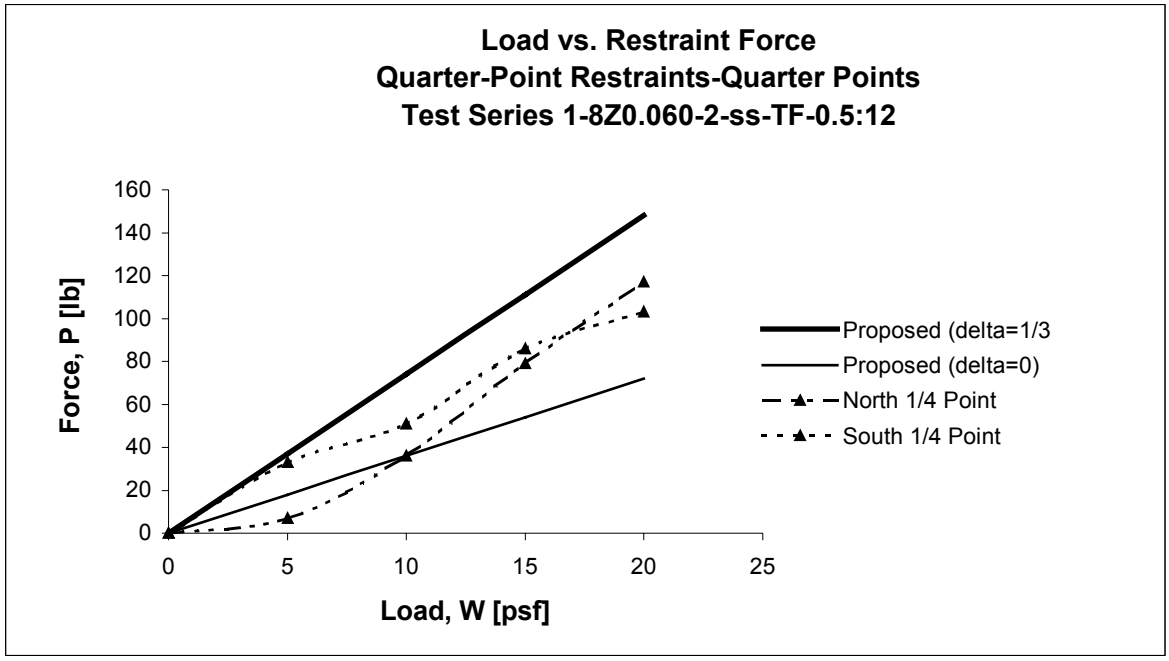
Test Series 1-8Z0.060-2-ss-TF-0:12 Quarter-Point Restraints-Quarter Points				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/4 Point**	**South 1/4 Point**
0	0	0	0	0
5	44	25	8	37
10	88	50	66	72
15	132	75	124	112
20	176	100	177	136



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 32
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

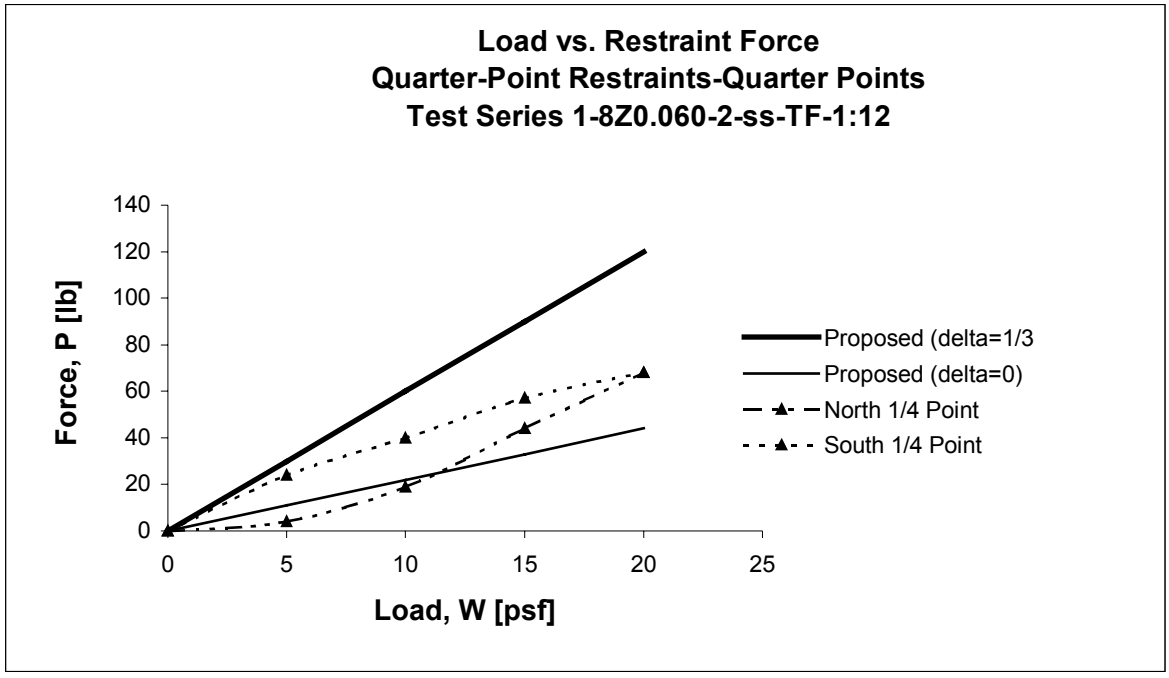
Test Series 1-8Z0.060-2-ss-TF-0.5:12 Quarter-Point Restraints-Quarter Points				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**South 1/4 Point**	**North 1/4 Point**
0	0	0	0	0
5	37	18	7	33
10	74	36	36	51
15	111	54	79	86
20	148	72	117	103



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 33
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

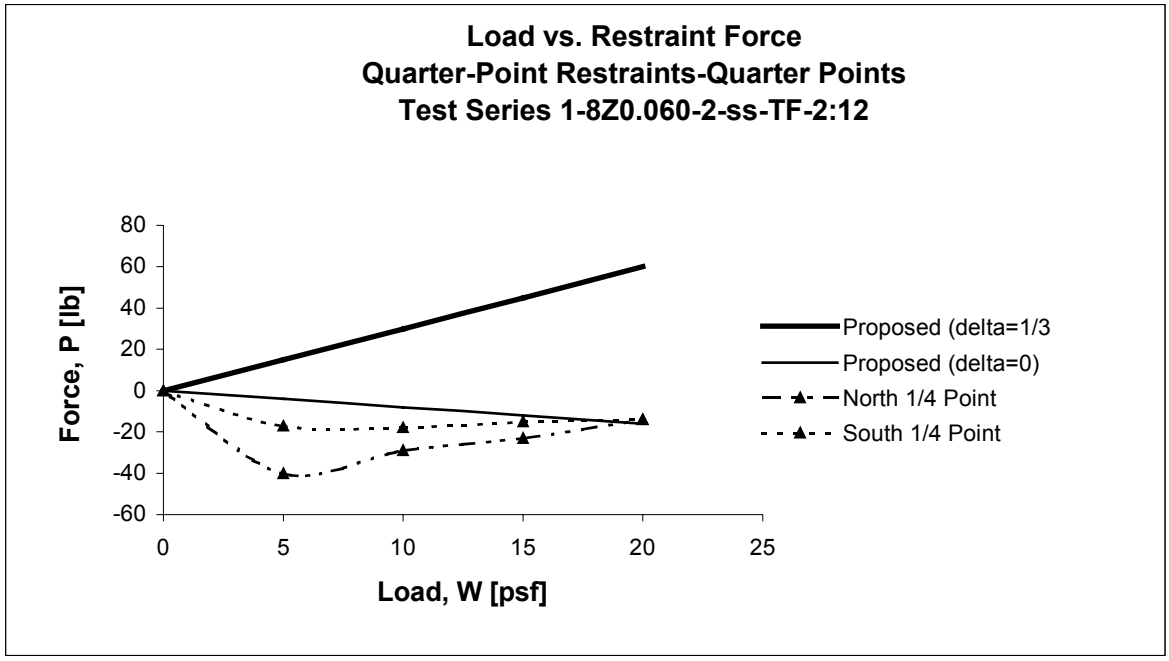
Test Series 1-8Z0.060-2-ss-TF-1:12 Quarter-Point Restraints-Quarter Points				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/4 Point**	**South 1/4 Point**
0	0	0	0	0
5	30	11	4	24
10	60	22	19	40
15	90	33	44	57
20	120	44	68	68



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 34
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

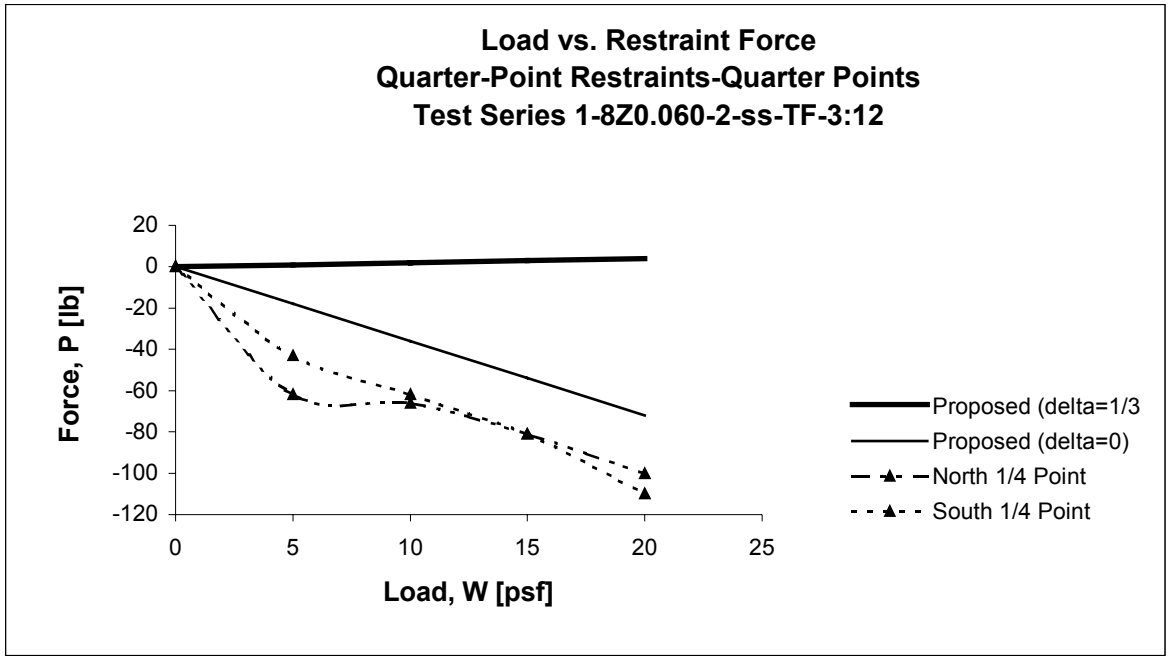
Test Series 1-8Z0.060-2-ss-TF-2:12 Quarter-Point Restraints-Quarter Points				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/4 Point**	**South 1/4 Point**
0	0	0	0	0
5	15	-4	-40	-17
10	30	-8	-29	-18
15	45	-12	-23	-15
20	60	-16	-14	-14



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 35
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

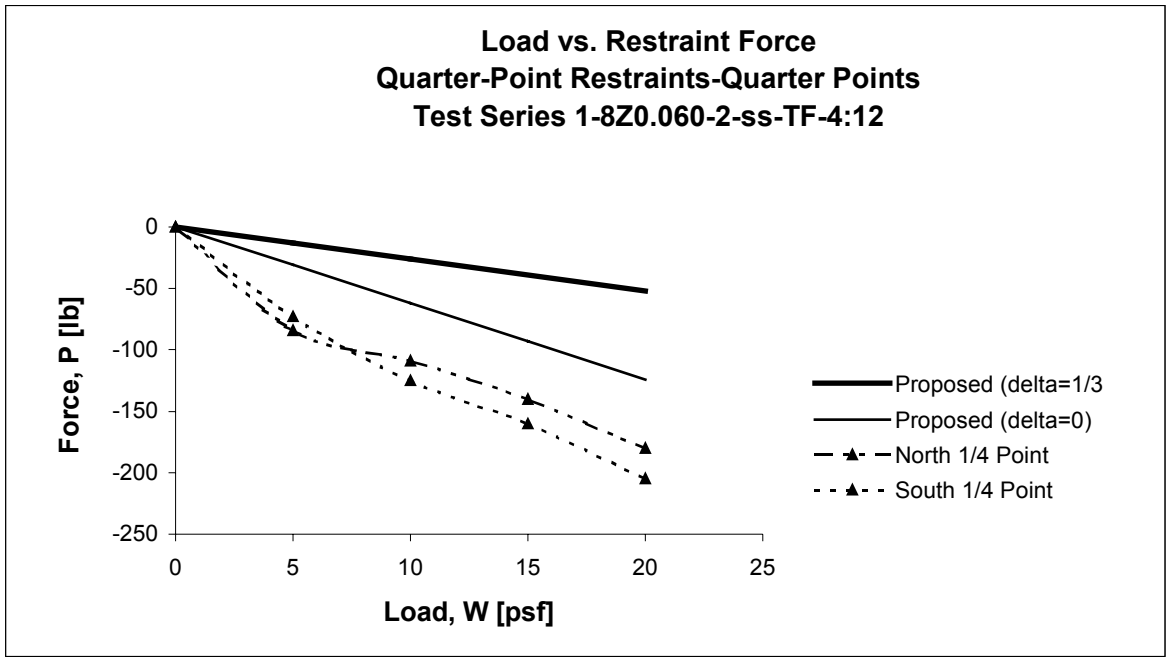
Test Series 1-8Z0.060-2-ss-TF-3:12 Quarter-Point Restraints-Quarter Points				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/4 Point**	**South 1/4 Point**
0	0	0	0	0
5	1	-18	-62	-43
10	2	-36	-66	-62
15	3	-54	-81	-81
20	4	-72	-100	-110



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 36
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

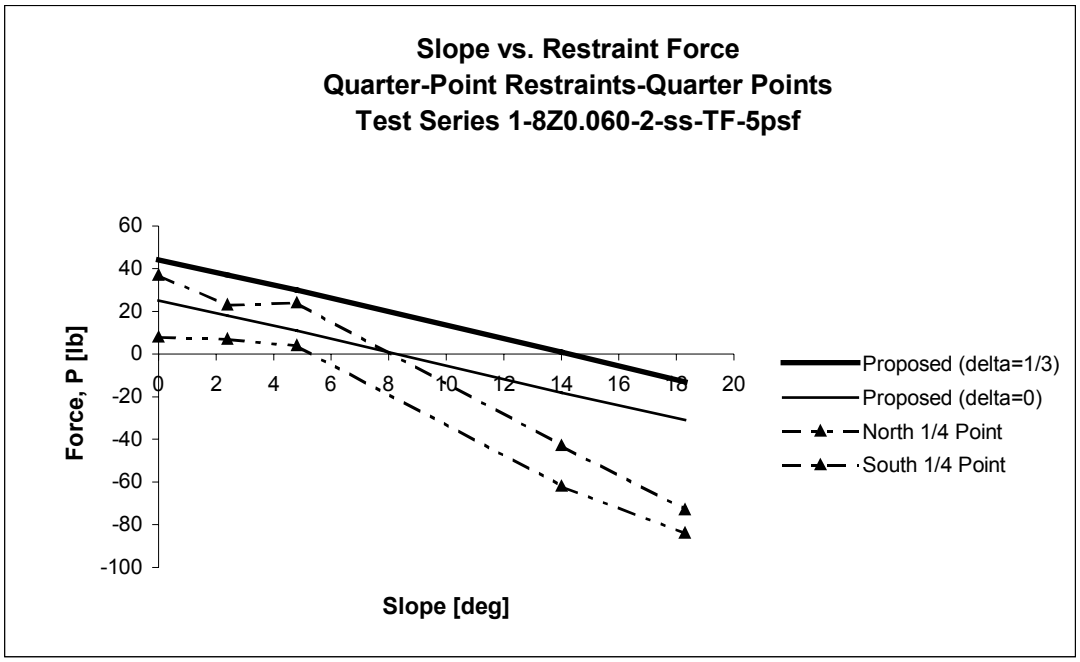
Test Series 1-8Z0.060-2-ss-TF-4:12 Quarter-Point Restraints-Quarter Points				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/4 Point**	**South 1/4 Point**
0	0	0	0	0
5	-13	-31	-84	-73
10	-26	-62	-109	-125
15	-39	-93	-140	-160
20	-52	-124	-180	-205



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 37
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

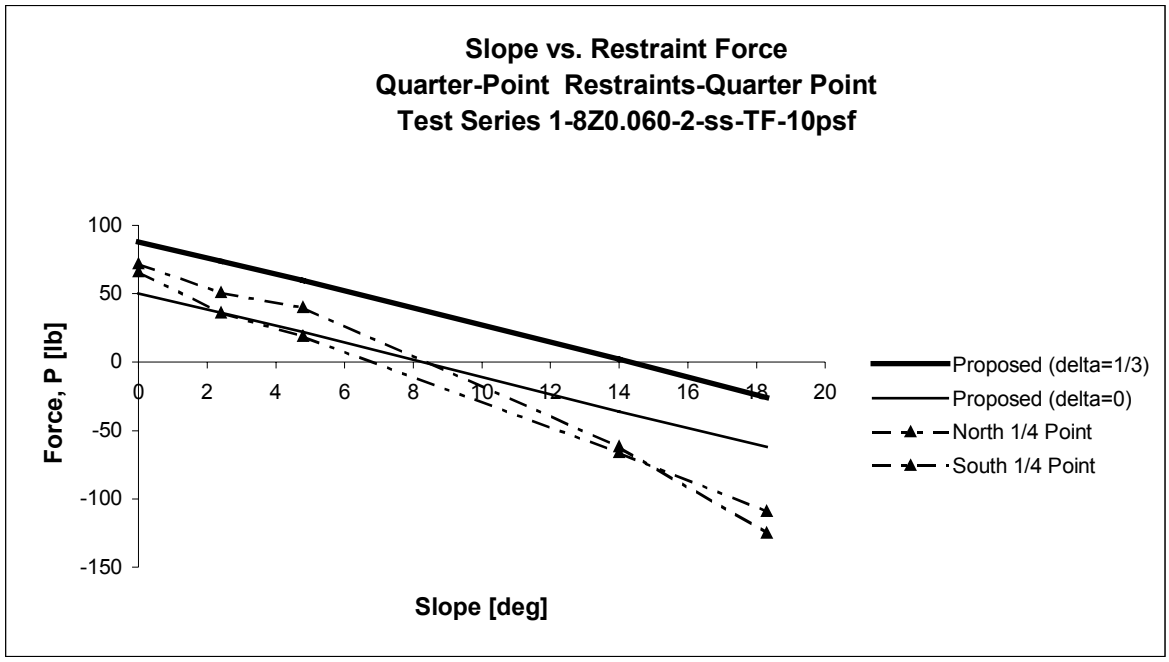
Test Series 1-8Z0.060-2-ss-TF-5psf Quarter-Point Restraints-Quarter Points				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/4 Point**	**South 1/4 Point**
0.0	44	25	8	37
2.4	37	18	7	23
4.8	30	11	4	24
14.0	1	-18	-62	-43
18.3	-13	-31	-84	-73



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 38
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

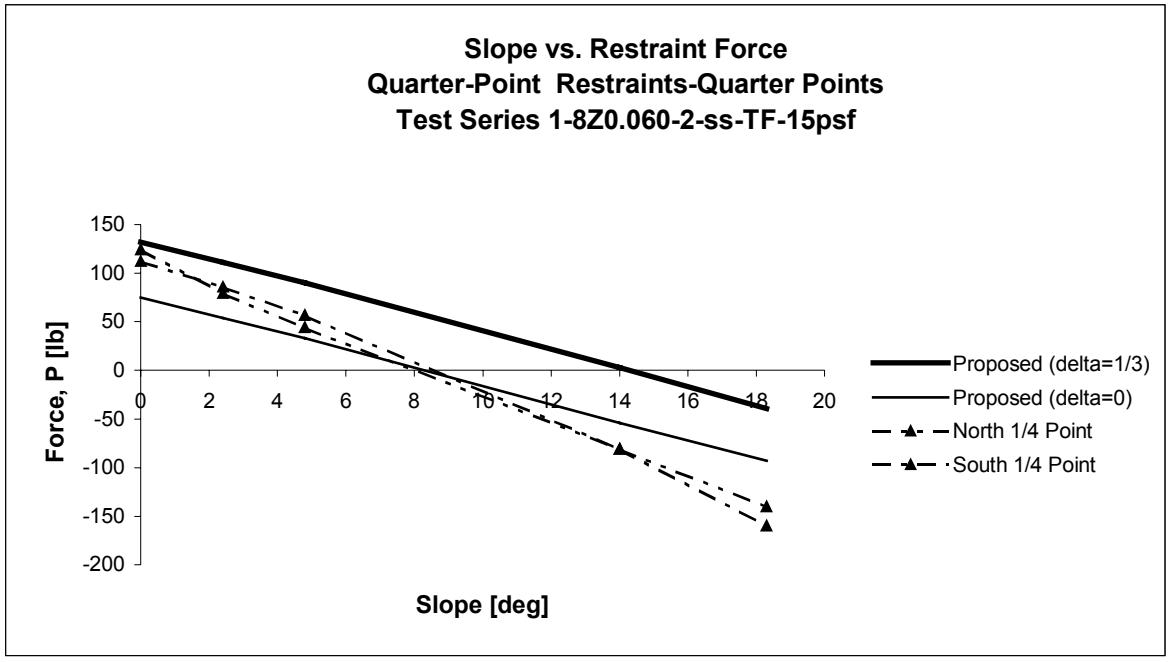
Test Series 1-8Z0.060-2-ss-TF-10psf Quarter-Point Restraints-Quarter Points				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/4 Point**	**South 1/4 Point**
0.0	88	50	66	72
2.4	74	36	36	51
4.8	60	22	19	40
14.0	2	-36	-66	-62
18.3	-26	-62	-109	-125



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 39
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

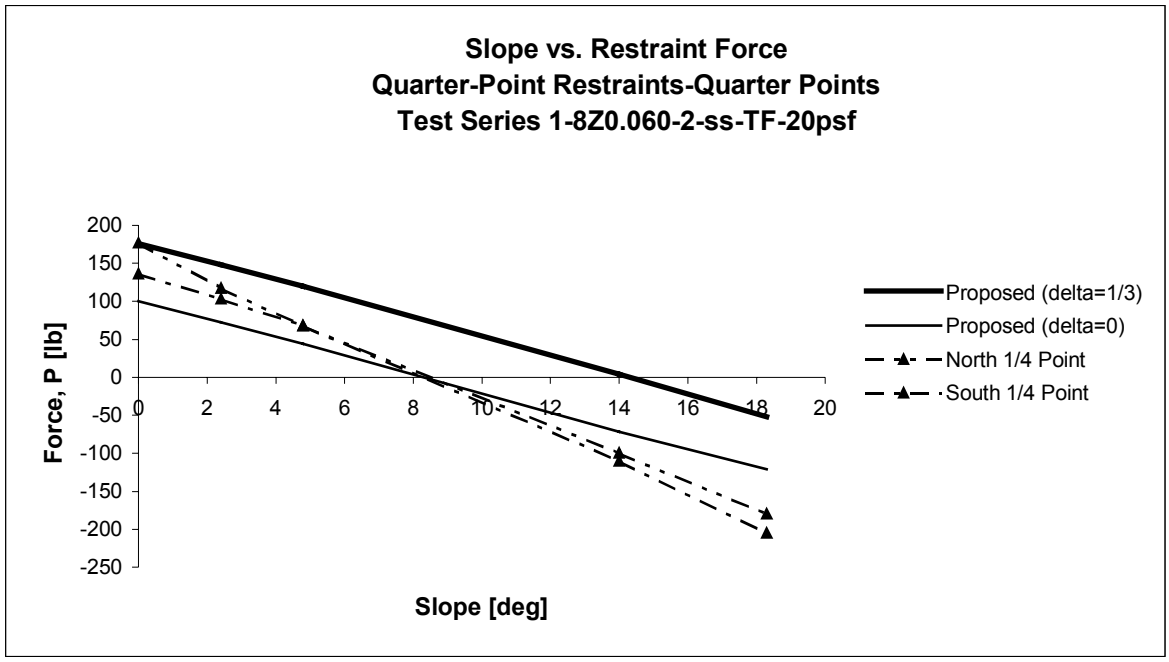
Test Series 1-8Z0.060-2-ss-TF-15psf Quarter-Point Restraints-Quarter Points				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/4 Point**	**South 1/4 Point**
0.0	132	75	124	112
2.4	111	54	79	86
4.8	90	33	44	57
14.0	3	-54	-81	-81
18.3	-39	-93	-140	-160



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 40
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

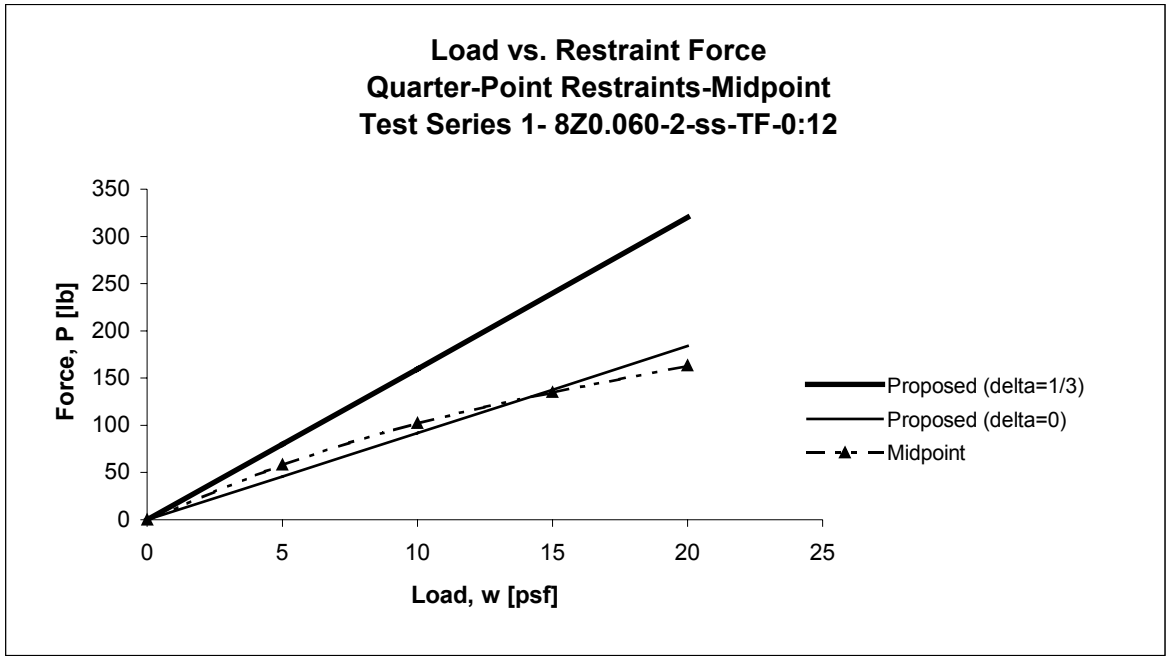
Test Series 1-8Z0.060-2-ss-TF-20psf Quarter-Point Restraints-Quarter Points				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/4 Point**	**South 1/4 Point**
0.0	176	100	177	136
2.4	148	72	117	103
4.8	120	44	68	68
14.0	4	-72	-100	-110
18.3	-52	-121	-180	-205



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 41
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

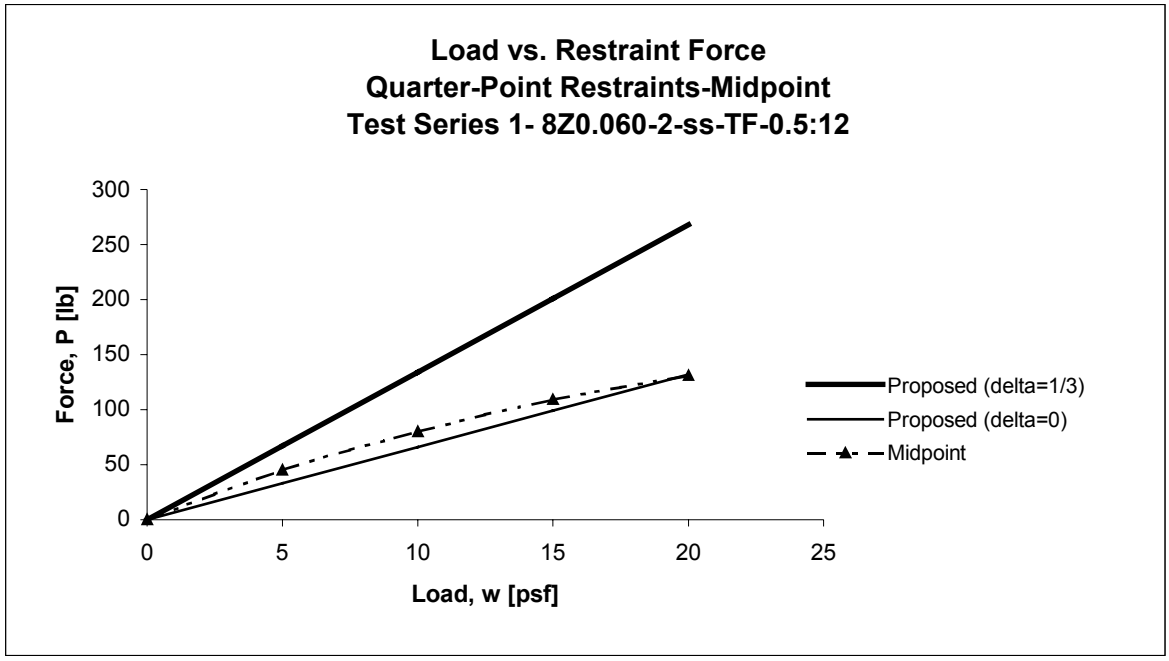
Test Series 1- 8Z0.060-2-ss-TF-0:12 Quarter-Point Restraints-Midpoint			
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0	0	0	0
5	80	46	58
10	160	92	102
15	240	138	135
20	320	184	163



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 42
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

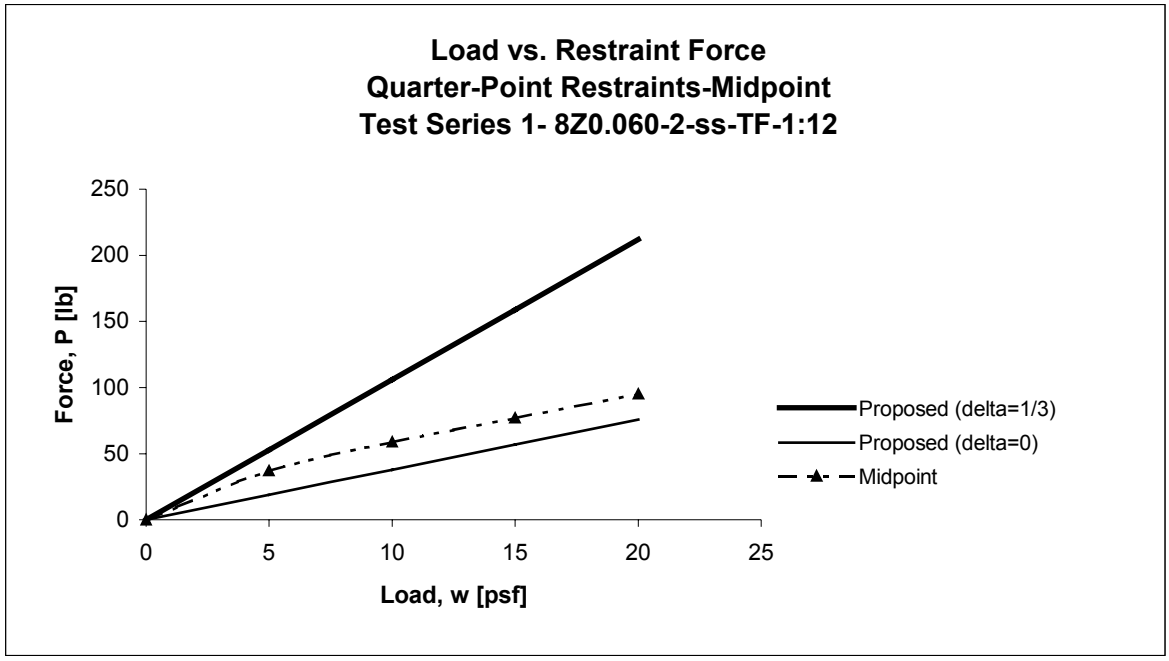
Test Series 1- 8Z0.060-2-ss-TF-0.5:12 Quarter-Point Restraints-Midpoint			
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0	0	0	0
5	67	33	45
10	134	66	80
15	201	99	109
20	268	132	131



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 43
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

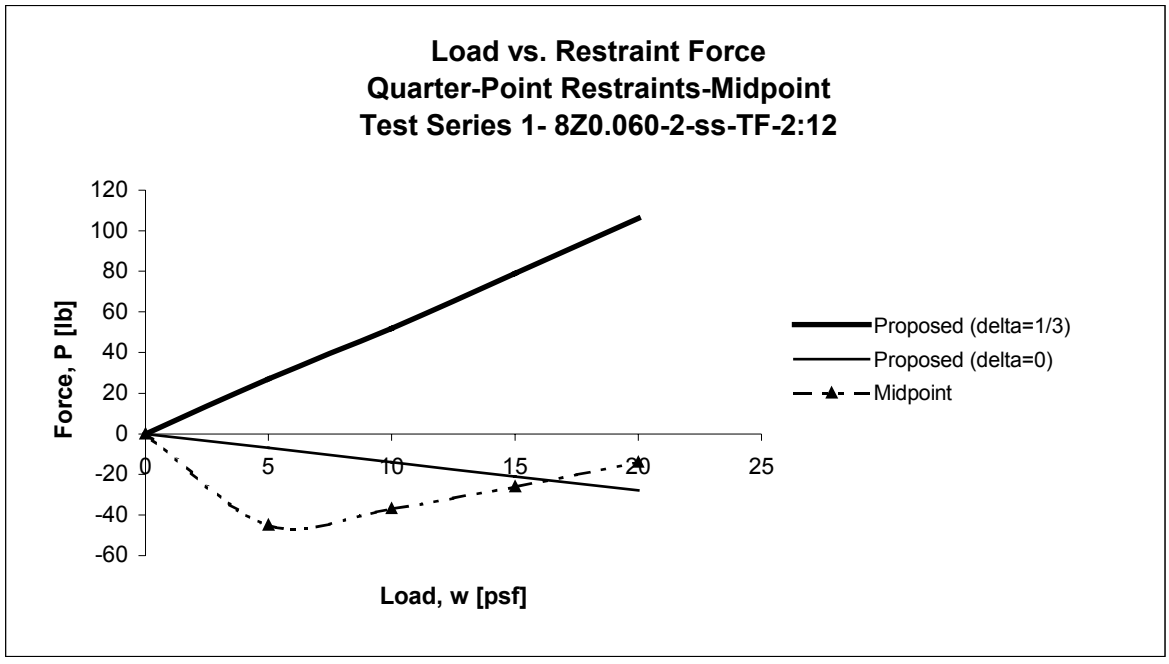
Test Series 1- 8Z0.060-2-ss-TF-1:12 Quarter-Point Bracing-Restraint			
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0	0	0	0
5	53	19	37
10	106	38	59
15	159	57	77
20	212	76	95



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 44
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

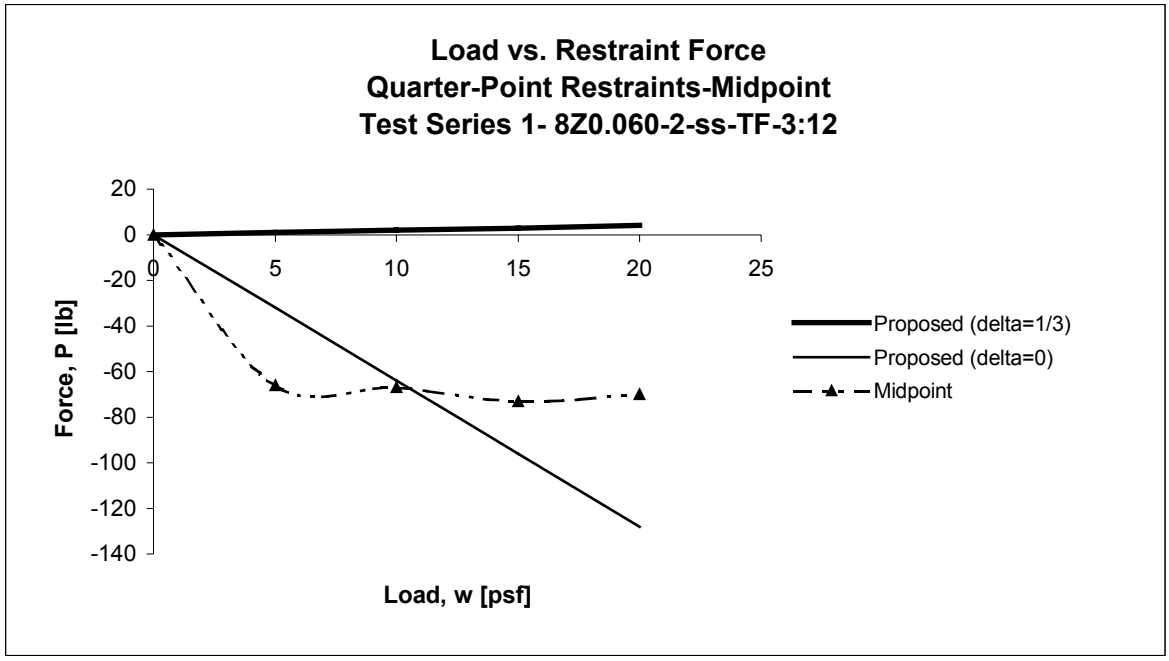
Test Series 1- 8Z0.060-2-ss-TF-2:12 Quarter-Point Restraints-Midpoint			
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0	0	0	0
5	27	-7	-45
10	52	-14	-37
15	79	-21	-26
20	106	-28	-14



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 45
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

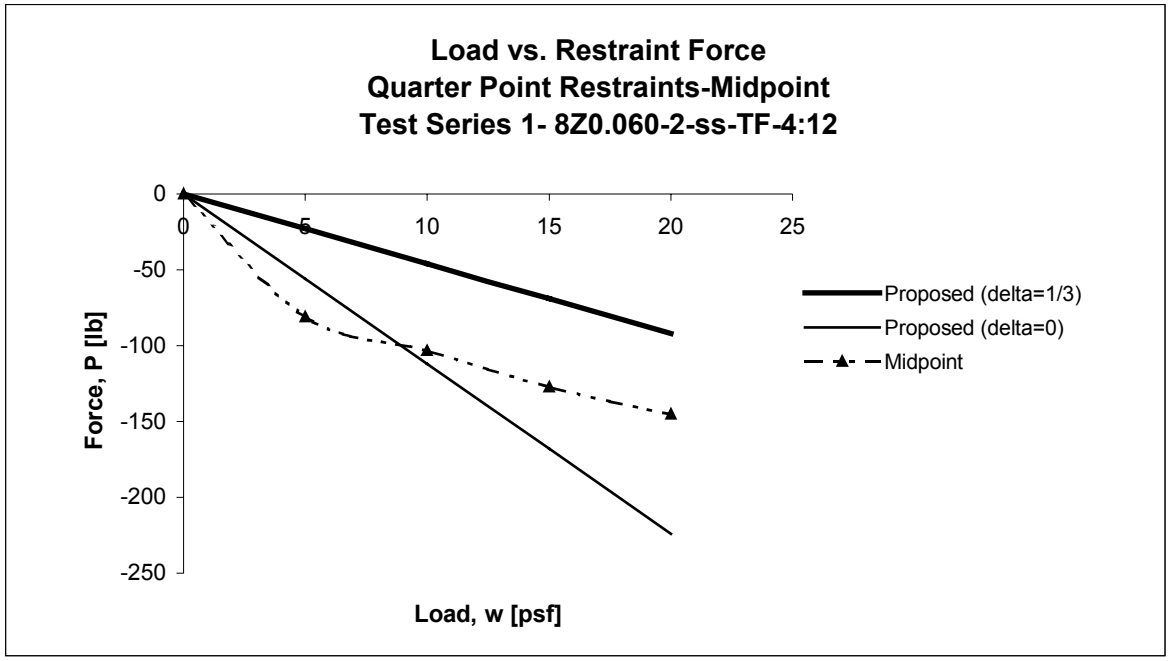
Test Series 1- 8Z0.060-2-ss-TF-3:12 Quarter-Point Restraints-Midpoint			
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0	0	0	0
5	1	-32	-66
10	2	-64	-67
15	3	-96	-73
20	4	-128	-70



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 46
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

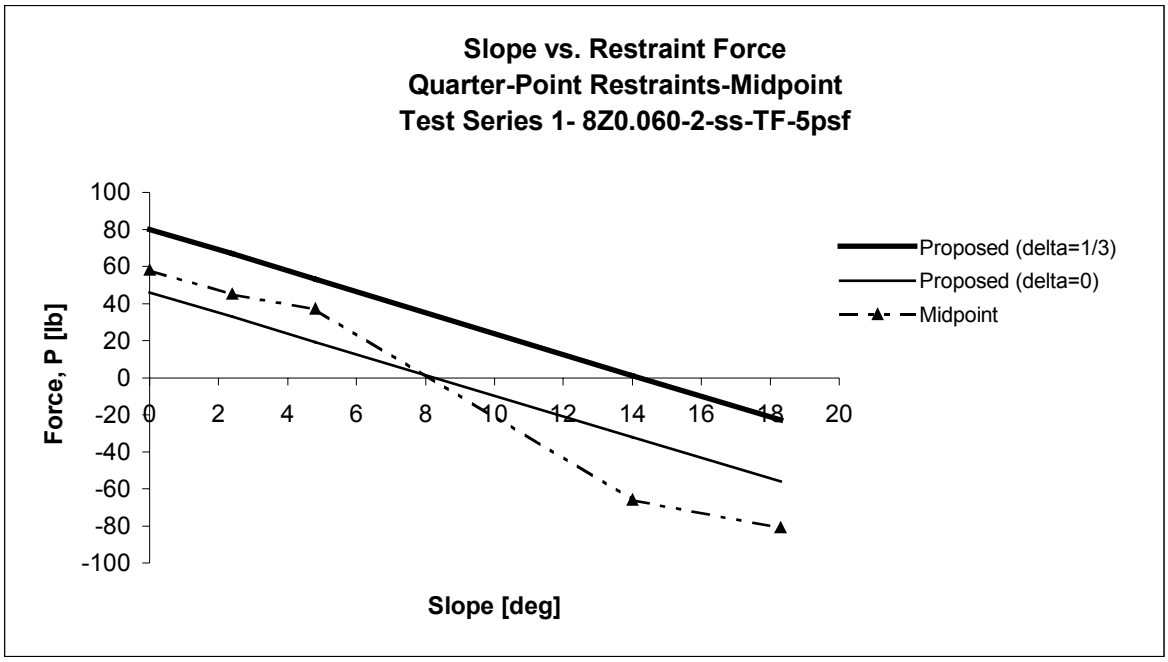
Test Series 1- 8Z0.060-2-ss-TF-4:12 Quarter-Point Restraints-Midpoint			
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0	0	0	0
5	-23	-56	-81
10	-46	-112	-103
15	-69	-168	-127
20	-92	-224	-145



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 47
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

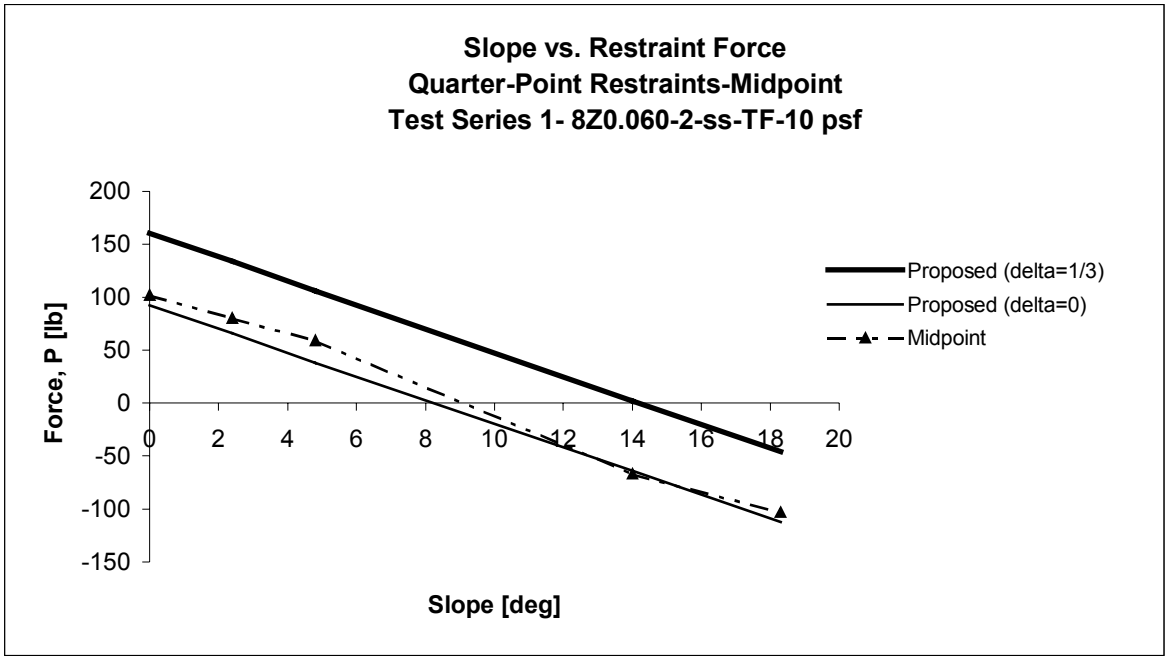
Test Series 1- 8Z0.060-2-ss-TF-5psf Quarter-Point Restraints-Midpoint			
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0.0	80	46	58
2.4	67	33	45
4.8	53	19	37
14.0	1	-32	-66
18.3	-23	-56	-81



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 48
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

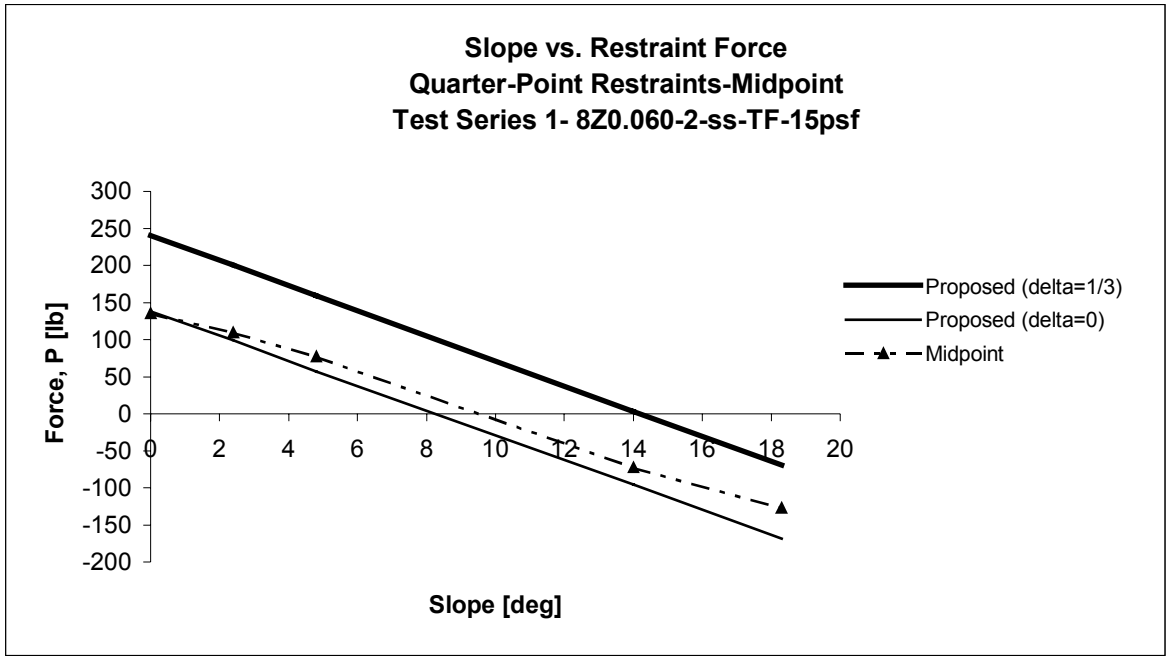
Test Series 1- 8Z0.060-2-ss-TF-10psf Quarter-Point Restraints-Midpoint			
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0.0	160	92	102
2.4	134	66	80
4.8	106	38	59
14.0	2	-64	-67
18.3	-46	-112	-103



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 49
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

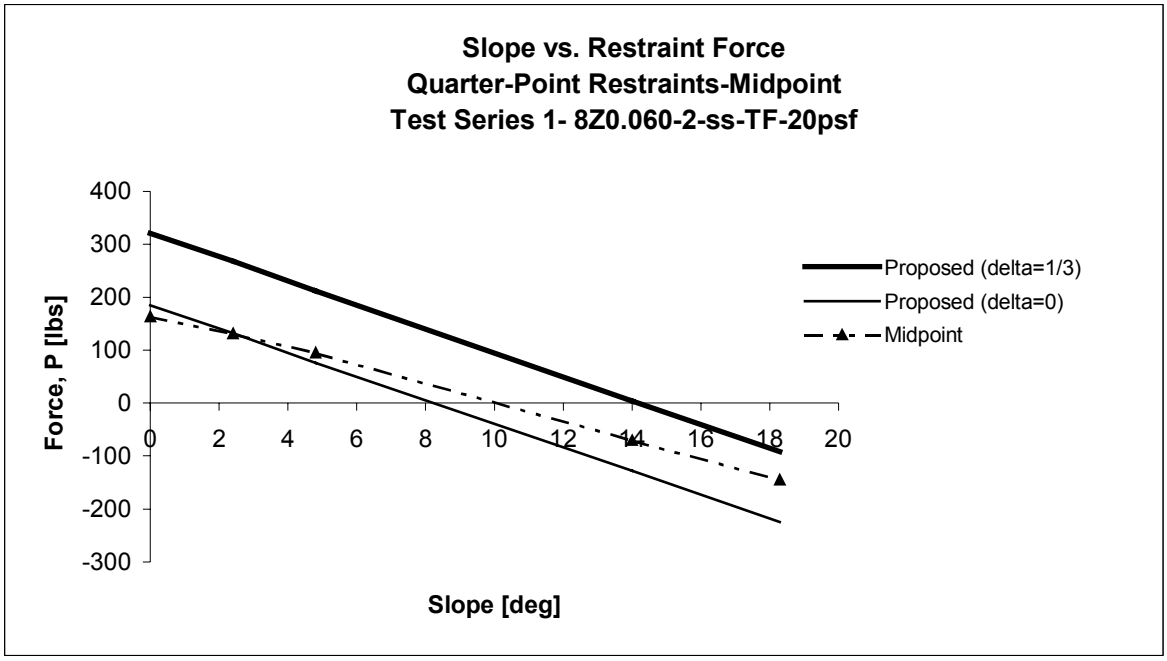
Test Series 1- 8Z0.060-2-ss-TF-15psf Quarter-Point Restraints-Midpoint			
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0.0	240	138	135
2.4	201	99	109
4.8	159	57	77
14.0	3	-96	-73
18.3	-69	-168	-127



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 50
Test Date: 12-13-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

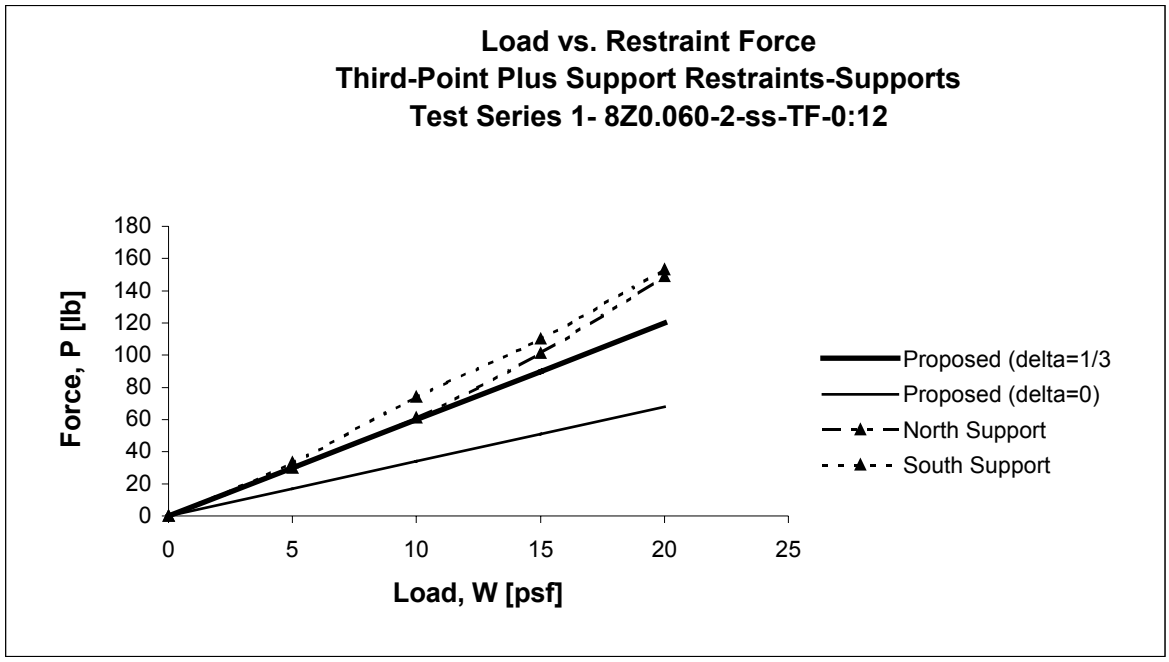
Test Series 1- 8Z0.060-2-ss-TF-20psf Quarter-Point Restraints-Midpoint			
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0.0	320	184	163
2.4	268	132	131
4.8	212	76	95
14.0	4	-128	-70
18.3	-92	-224	-145



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 51
Test Date: 12-15-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

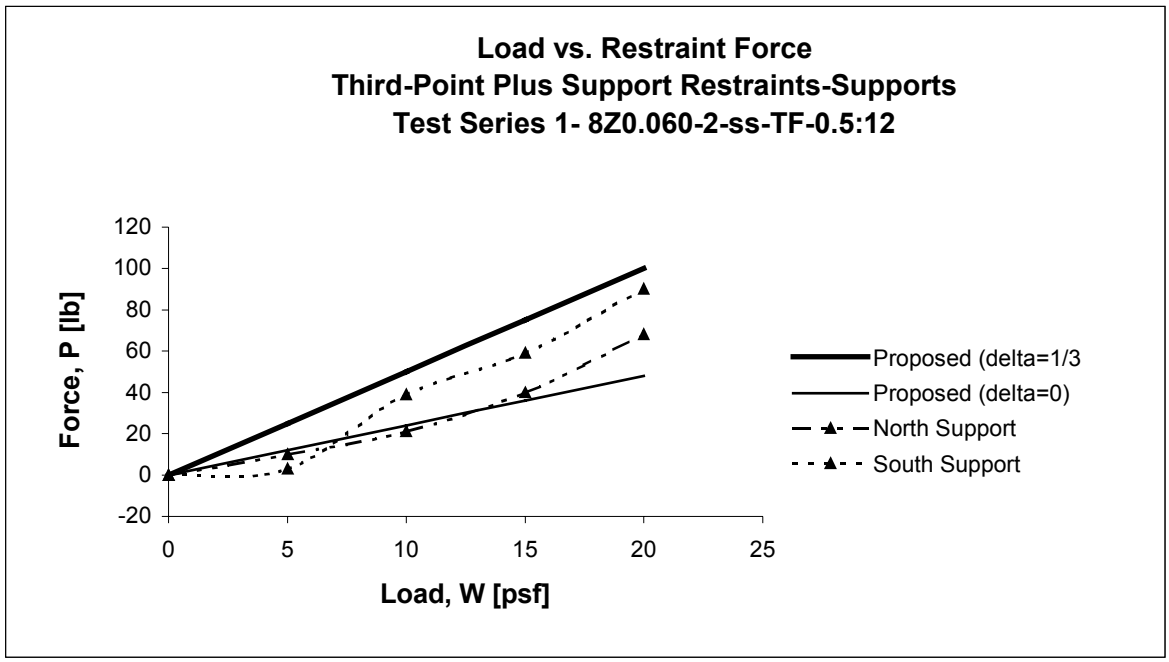
Test Series 1- 8Z0.060-2-ss-TF-0:12 Third-Point Bracing Plus Support Restraints-Supports				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Ext. Eave**	**South Ext. Eave**
0	0	0	0	0
5	30	17	30	33
10	60	34	61	74
15	90	51	101	110
20	120	68	149	153



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 52
Test Date: 12-15-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

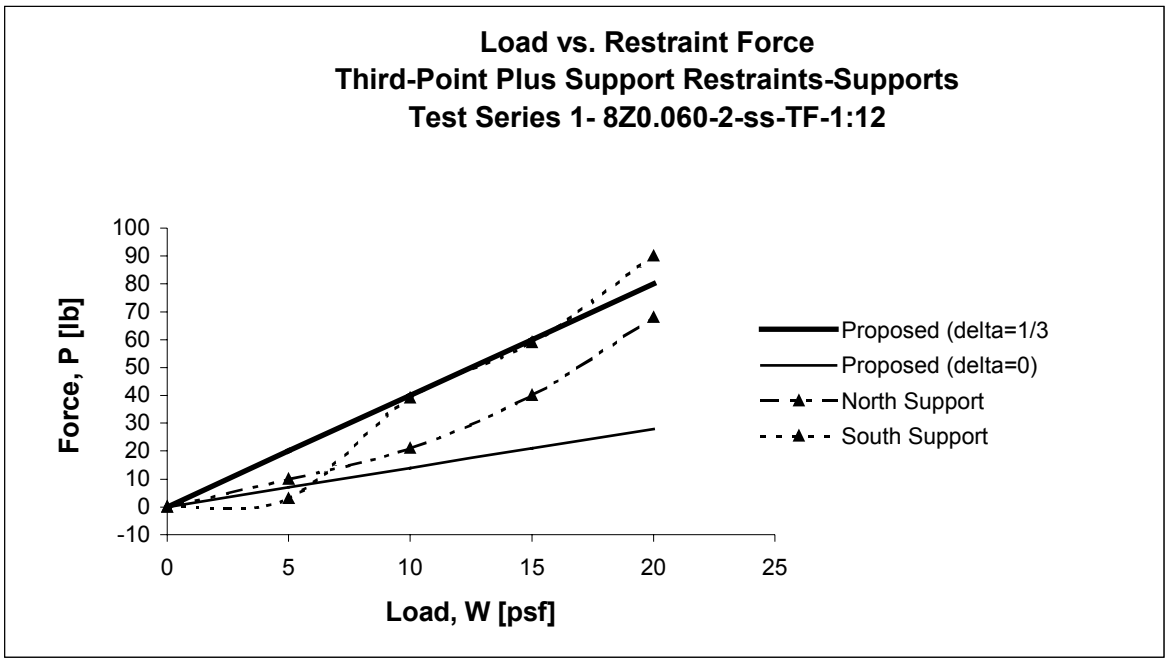
Test Series 1- 8Z0.060-2-ss-TF-0.5:12 Third-Point Plus Support Restraints-Supports				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0	0	0	0	0
5	25	12	10	3
10	50	24	21	39
15	75	36	40	59
20	100	48	68	90



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 53
Test Date: 12-15-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

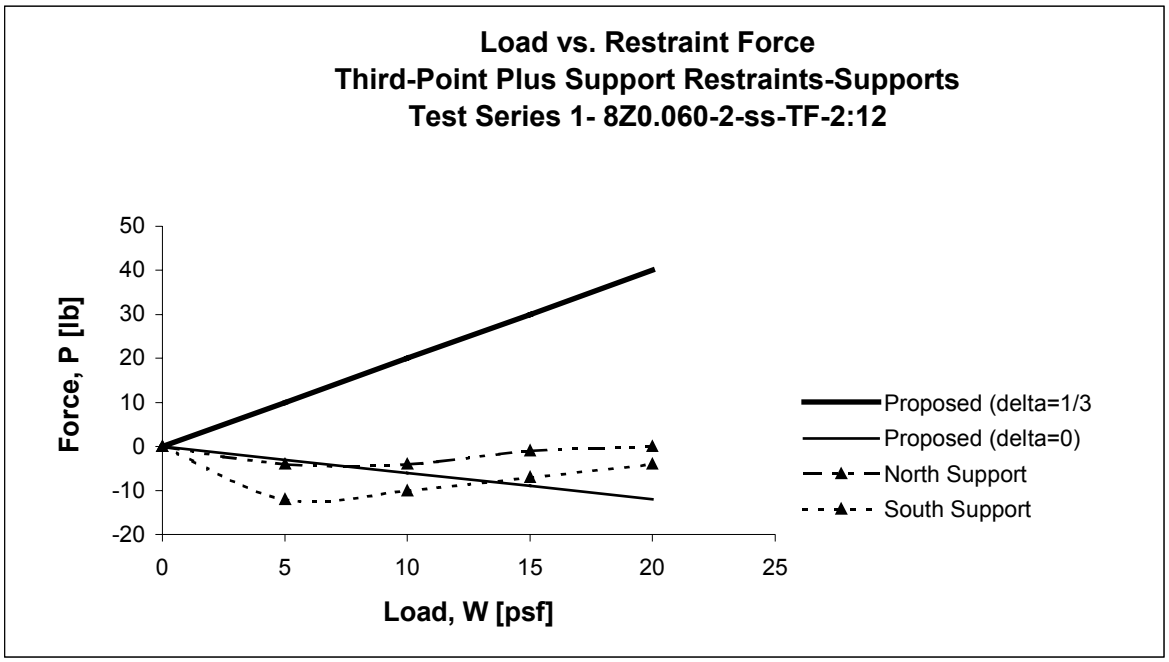
Test Series 1- 8Z0.060-2-ss-TF-1:12 Third-Point Plus Support Restraints-Supports				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0	0	0	0	0
5	20	7	10	3
10	40	14	21	39
15	60	21	40	59
20	80	28	68	90



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 54
Test Date: 12-15-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

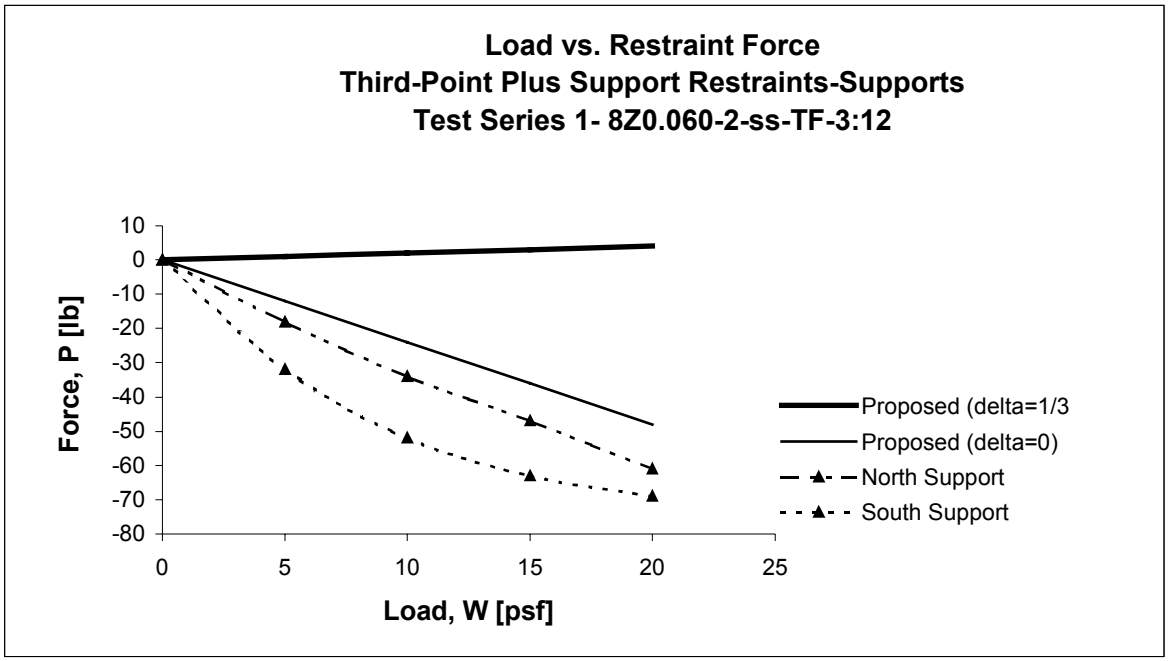
Test Series 1- 8Z0.060-2-ss-TF-2:12 Third-Point Plus Support Restraints-Supports				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0	0	0	0	0
5	10	-3	-4	-12
10	20	-6	-4	-10
15	30	-9	-1	-7
20	40	-12	0	-4



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 55
Test Date: 12-15-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

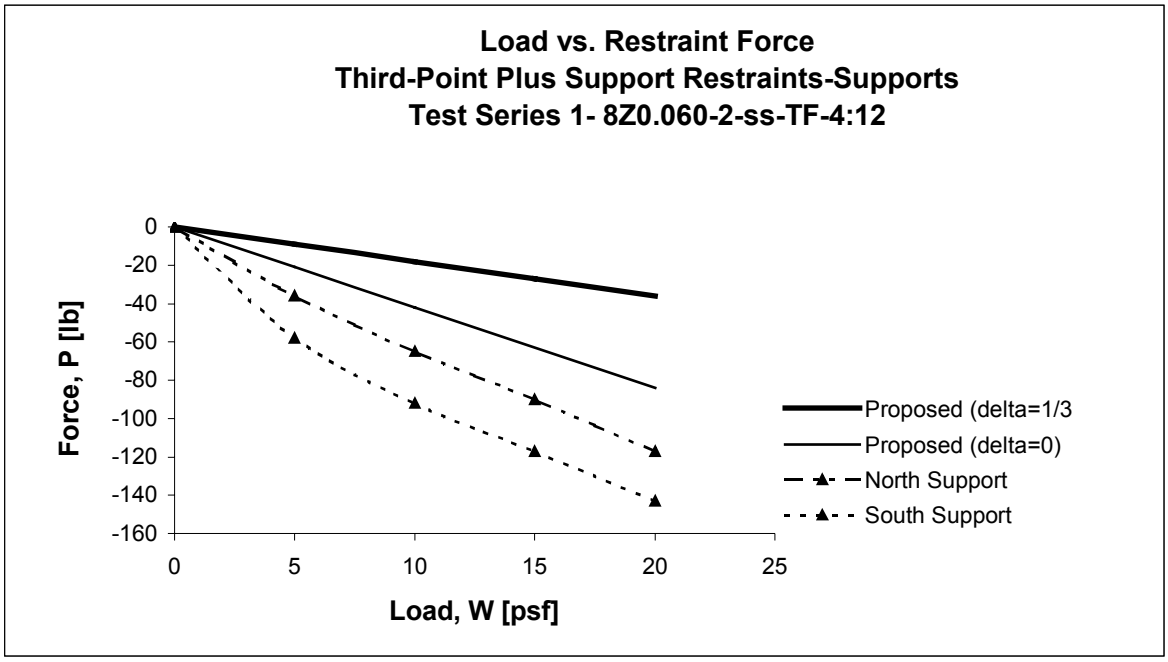
Test Series 1- 8Z0.060-2-ss-TF-3:12 Third-Point Plus Support Restraints-Supports				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0	0	0	0	0
5	1	-12	-18	-32
10	2	-24	-34	-52
15	3	-36	-47	-63
20	4	-48	-61	-69



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 56
Test Date: 12-15-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

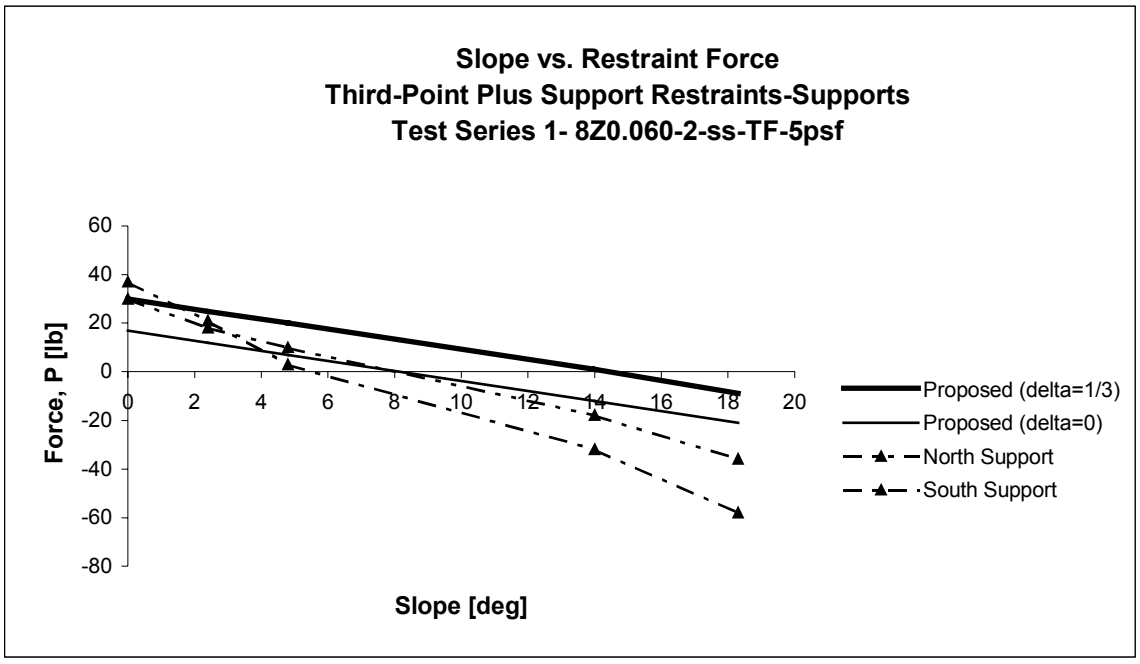
Test Series 1- 8Z0.060-2-ss-TF-4:12 Third-Point Plus Support Restraints-Supports				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0	0	0	0	0
5	-9	-21	-36	-58
10	-18	-42	-65	-92
15	-27	-63	-90	-117
20	-36	-84	-117	-143



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 57
Test Date: 12-15-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

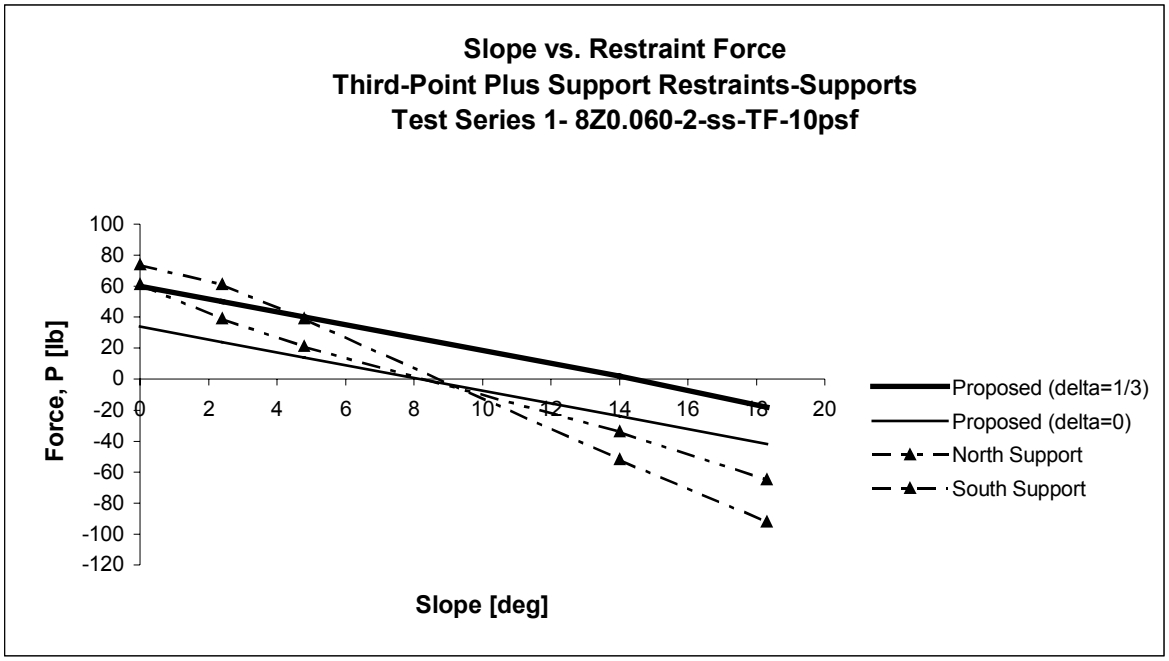
Test Series 1- 8Z0.060-2-ss-TF-5psf Third-Point Plus Support Restraints-Supports				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0.0	30	17	30	37
2.4	25	12	18	21
4.8	20	7	10	3
14.0	1	-12	-18	-32
18.3	-9	-21	-36	-58



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 58
Test Date: 12-15-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

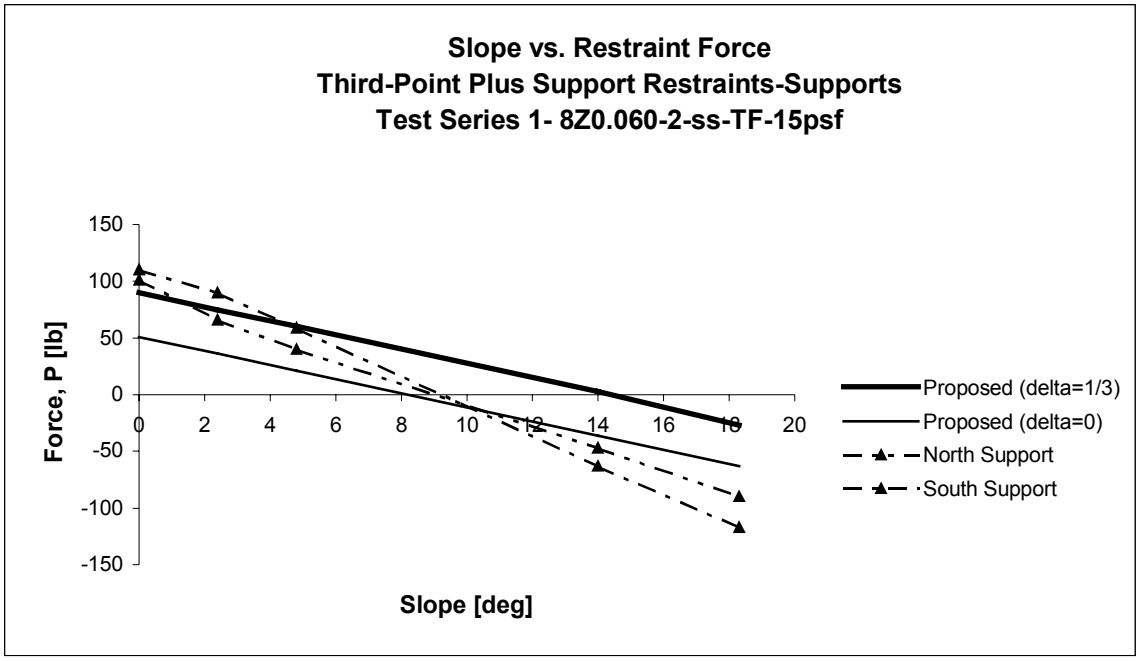
Test Series 1- 8Z0.060-2-ss-TF-10psf Third-Point Plus Support Restraints-Supports				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0.0	60	34	61	74
2.4	50	24	39	61
4.8	40	14	21	39
14.0	2	-24	-34	-52
18.3	-18	-42	-65	-92



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 59
Test Date: 12-15-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

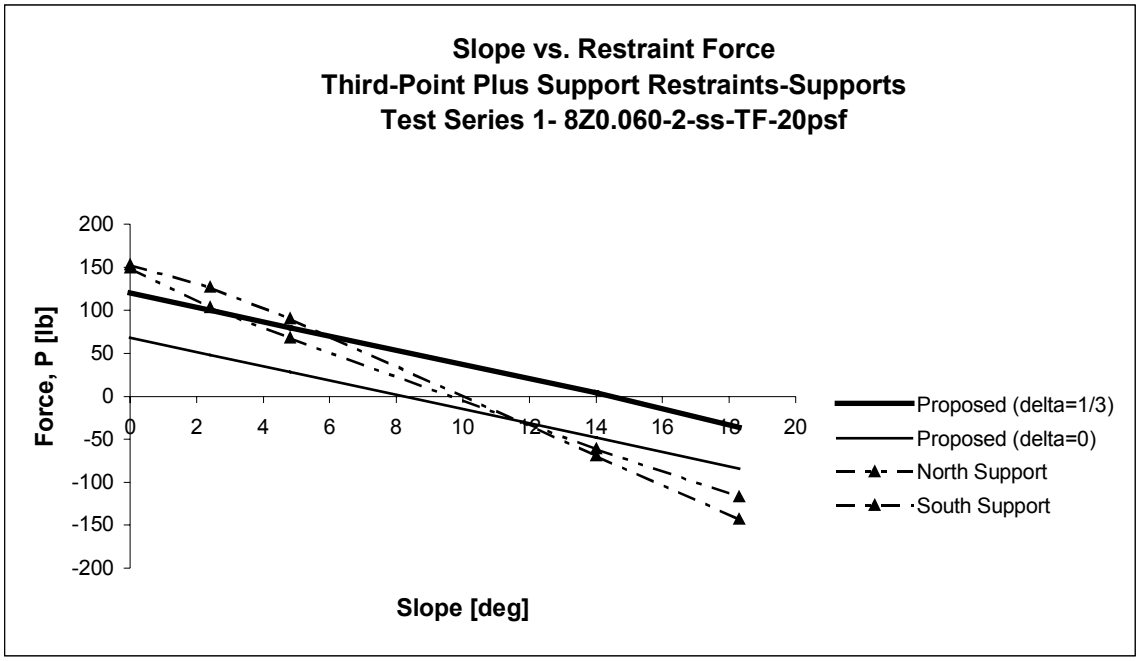
Test Series 1- 8Z0.060-2-ss-TF-15psf Third-Point Plus Support Restraints-Supports				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0.0	90	51	101	110
2.4	75	36	66	90
4.8	60	21	40	59
14.0	3	-36	-47	-63
18.3	-27	-63	-90	-117



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 60
Test Date: 12-15-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

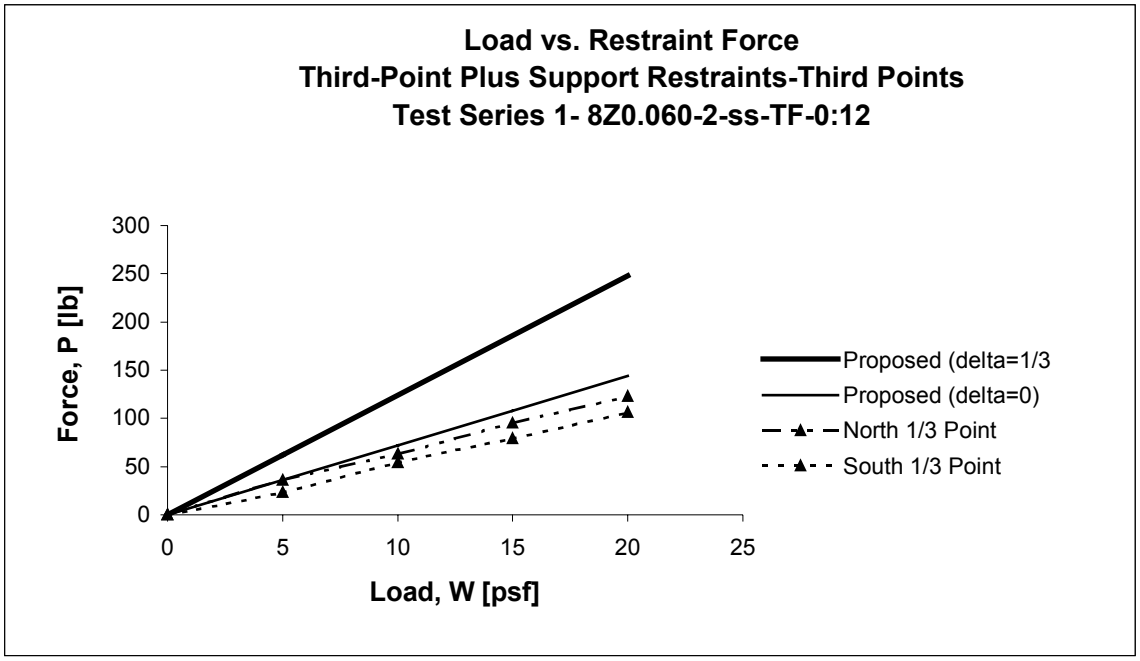
Test Series 1- 8Z0.060-2-ss-TF-20psf Third-Point Plus Support Restraints-Supports				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0.0	120	68	149	153
2.4	100	48	103	127
4.8	80	28	68	90
14.0	4	-48	-61	-69
18.3	-36	-84	-117	-143



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 61
Test Date: 12-15-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

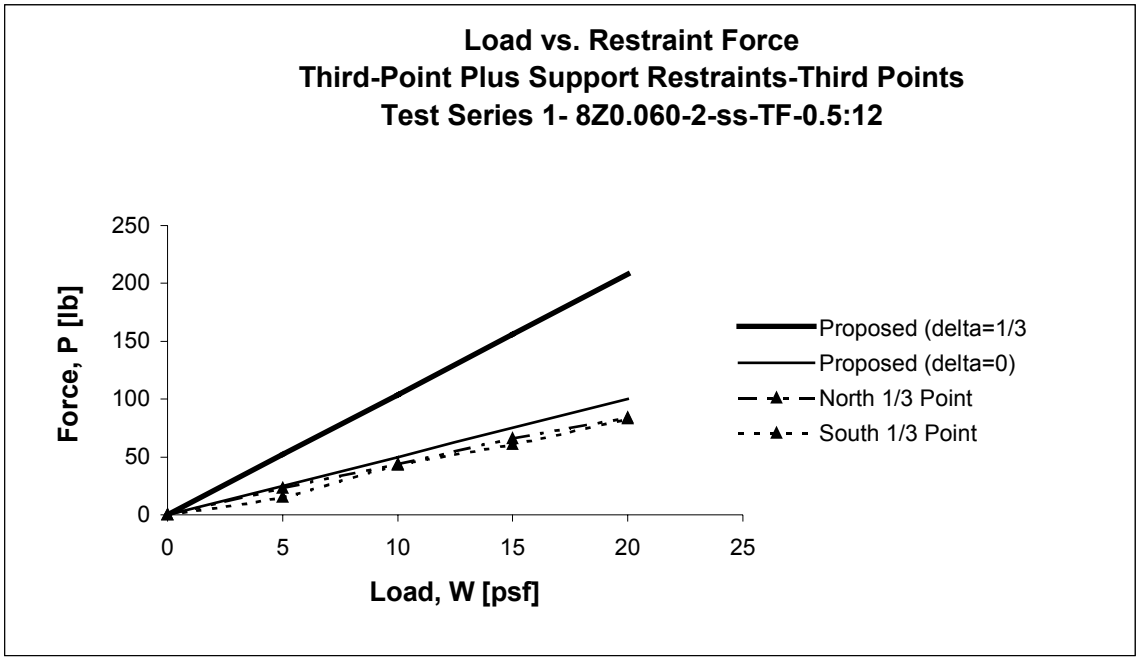
Test Series 1- 8Z0.060-2-ss-TF-0:12 Third-Point Plus Support Restraints-Third Points				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0	0	0	0	0
5	62	36	36	23
10	124	72	63	54
15	186	108	95	79
20	248	144	123	106



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 62
Test Date: 12-15-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

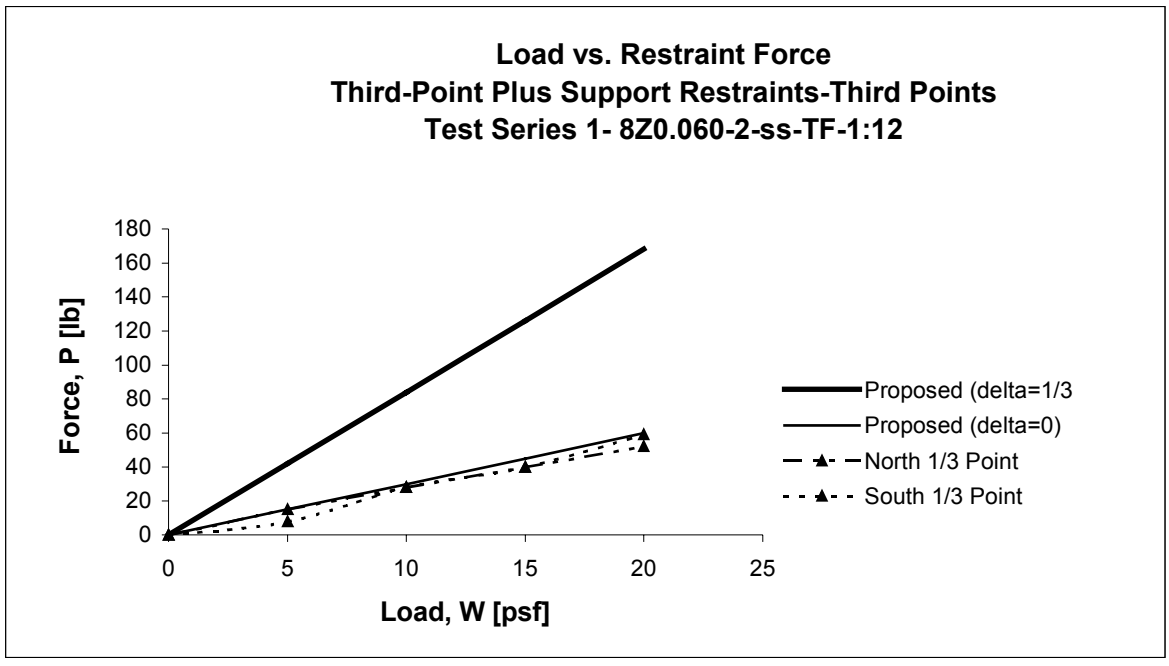
Test Series 1- 8Z0.060-2-ss-TF-0.5:12 Third-Point Plus Support Restraints-Third Points				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0	0	0	0	0
5	52	25	23	15
10	104	50	44	43
15	156	75	66	61
20	208	100	84	83



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 63
Test Date: 12-15-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

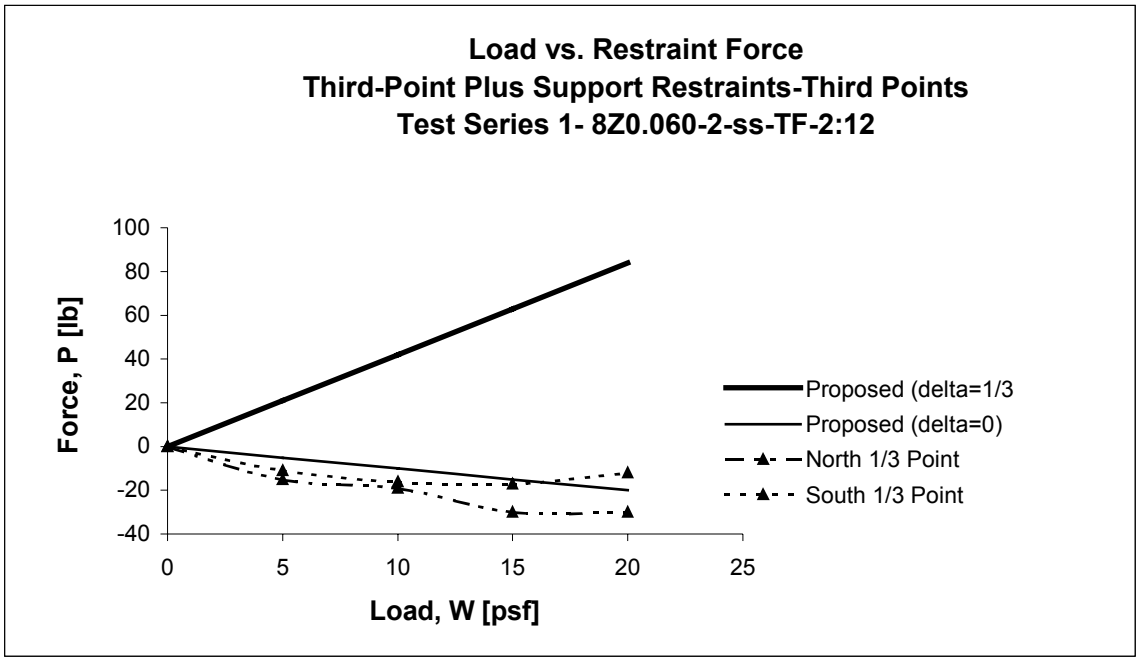
Test Series 1- 8Z0.060-2-ss-TF-1:12 Third-Point Plus Support Restraints-Third Points				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0	0	0	0	0
5	42	15	15	8
10	84	30	28	28
15	126	45	40	40
20	168	60	52	59



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 64
Test Date: 12-15-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

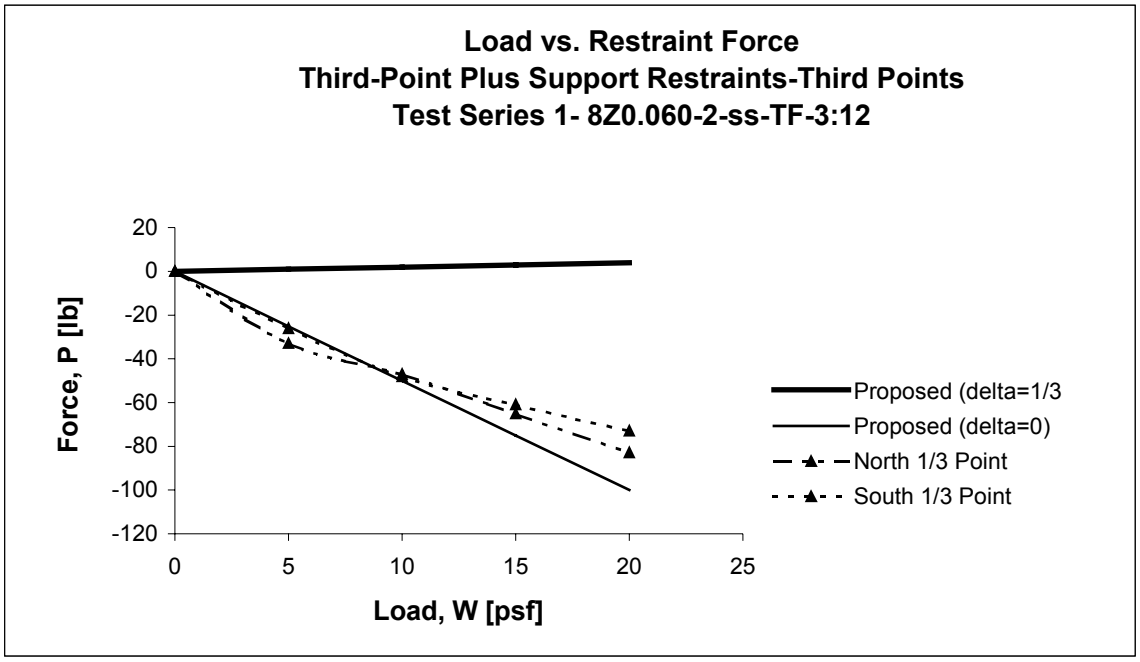
Test Series 1- 8Z0.060-2-ss-TF-2:12 Third-Point Plus Support Restraints-Third Points				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0	0	0	0	0
5	21	-5	-15	-11
10	42	-10	-19	-16
15	63	-15	-30	-17
20	84	-20	-30	-12



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 65
Test Date: 12-15-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

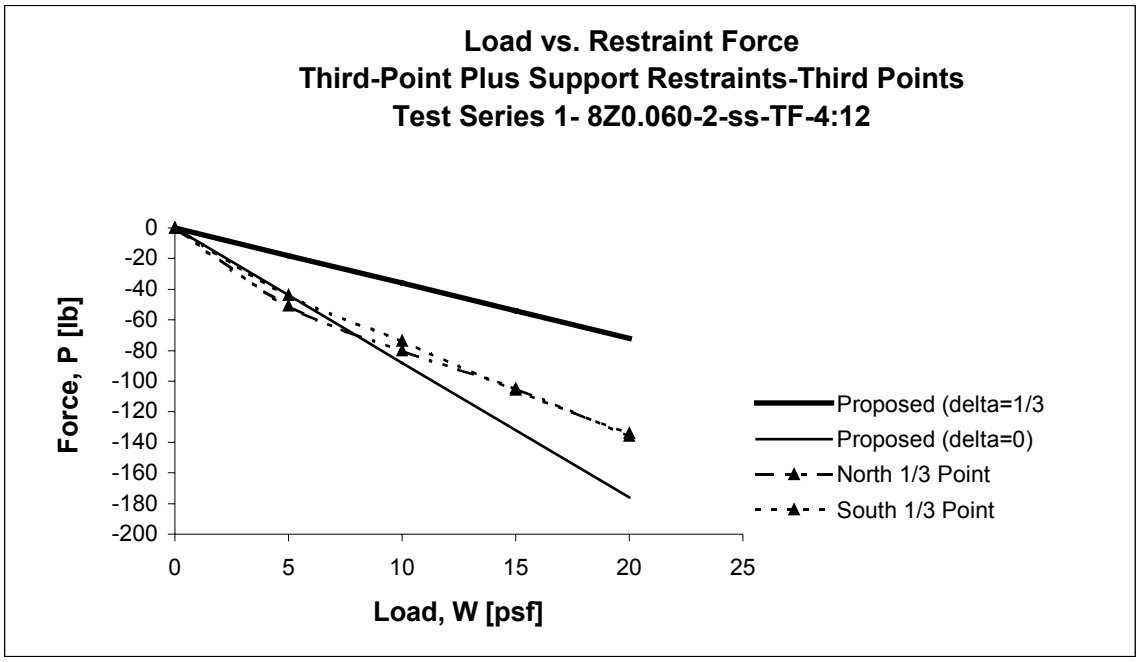
Test Series 1- 8Z0.060-2-ss-TF-3:12 Third-Point Plus Support Restraints-Third Points				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0	0	0	0	0
5	1	-25	-33	-26
10	2	-50	-47	-48
15	3	-75	-65	-61
20	4	-100	-83	-73



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 66
Test Date: 12-15-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

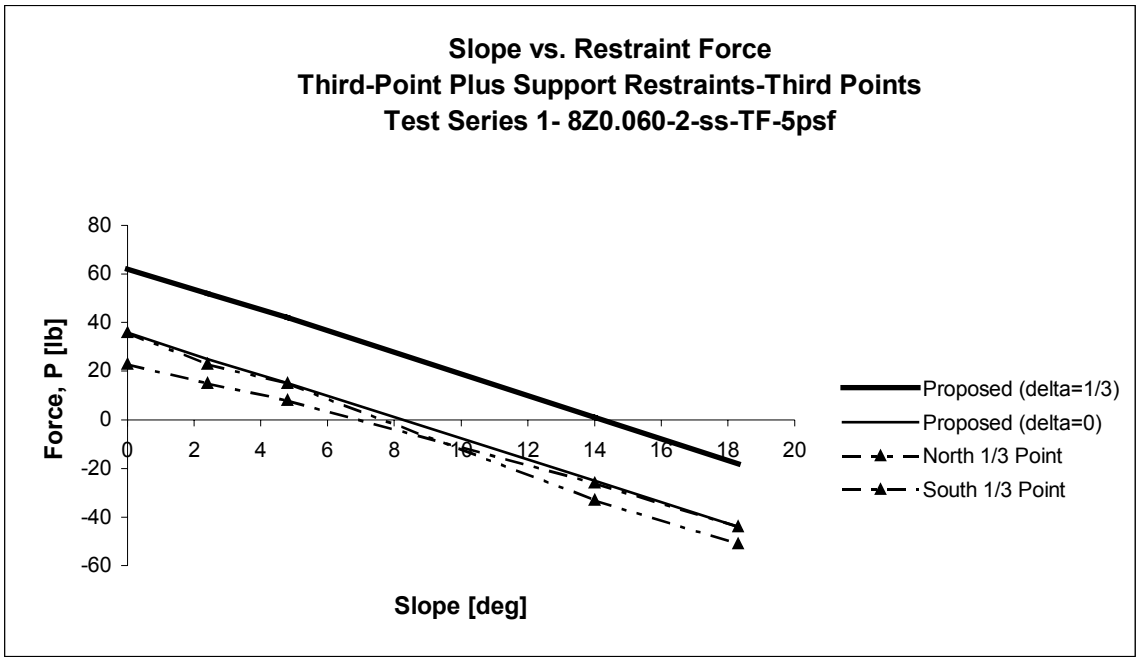
Test Series 1- 8Z0.060-2-ss-TF-4:12 Third-Point Plus Support Restraints-Third Points				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0	0	0	0	0
5	-18	-44	-51	-44
10	-36	-88	-80	-74
15	-54	-132	-105	-106
20	-72	-176	-136	-134



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 67
Test Date: 12-15-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

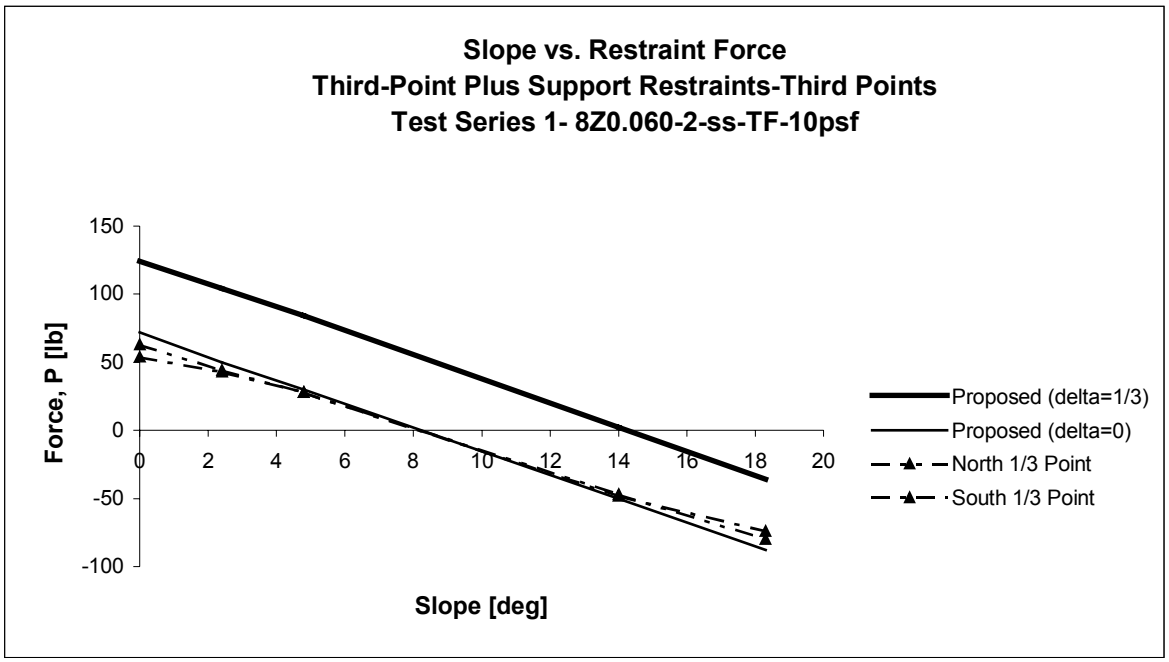
Test Series 1- 8Z0.060-2-ss-TF-5psf Third-Point Plus Support Restraints-Third Points				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0.0	62	36	36	23
2.4	52	25	23	15
4.8	42	15	15	8
14.0	1	-25	-33	-26
18.3	-18	-44	-51	-44



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 68
Test Date: 12-15-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

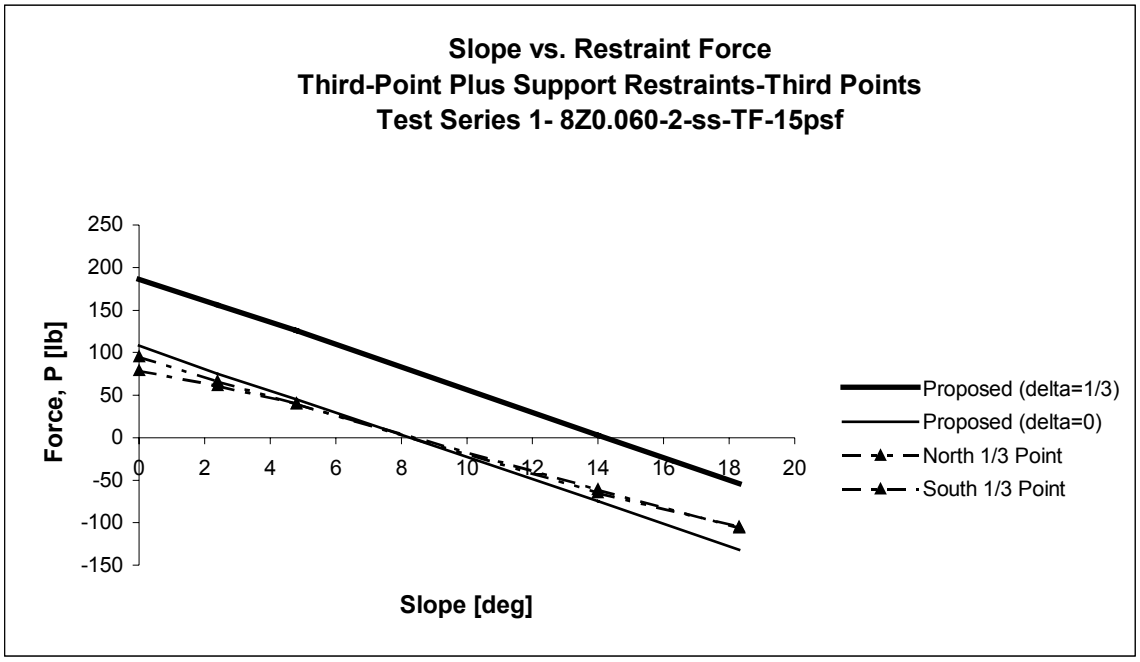
Test Series 1- 8Z0.060-2-ss-TF-10psf Third-Point Plus Support Restraints-Third Points				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0.0	124	72	63	54
2.4	104	50	44	43
4.8	84	30	28	28
14.0	2	-50	-47	-48
18.3	-36	-88	-80	-74



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 69
Test Date: 12-15-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

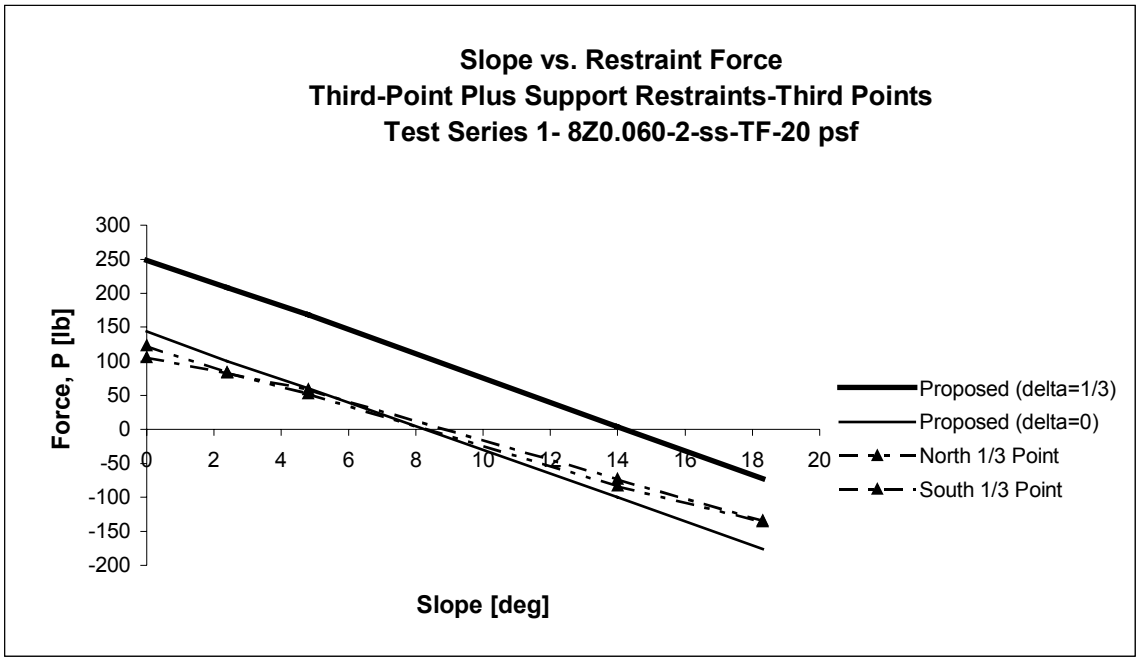
Test Series 1- 8Z0.060-2-ss-TF-15psf Third-Point Plus Support Restraints-Third Points				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0.0	186	108	95	79
2.4	156	75	66	61
4.8	126	45	40	40
14.0	3	-75	-65	-61
18.3	-54	-132	-105	-106



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 70
Test Date: 12-15-00
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

Test Series 1- 8Z0.060-2-ss-TF-20psf Third-Point Plus Support Restraints-Third Points				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0.0	248	144	123	106
2.4	208	100	84	83
4.8	168	60	52	59
14.0	4	-100	-83	-73
18.3	-72	-176	-136	-134

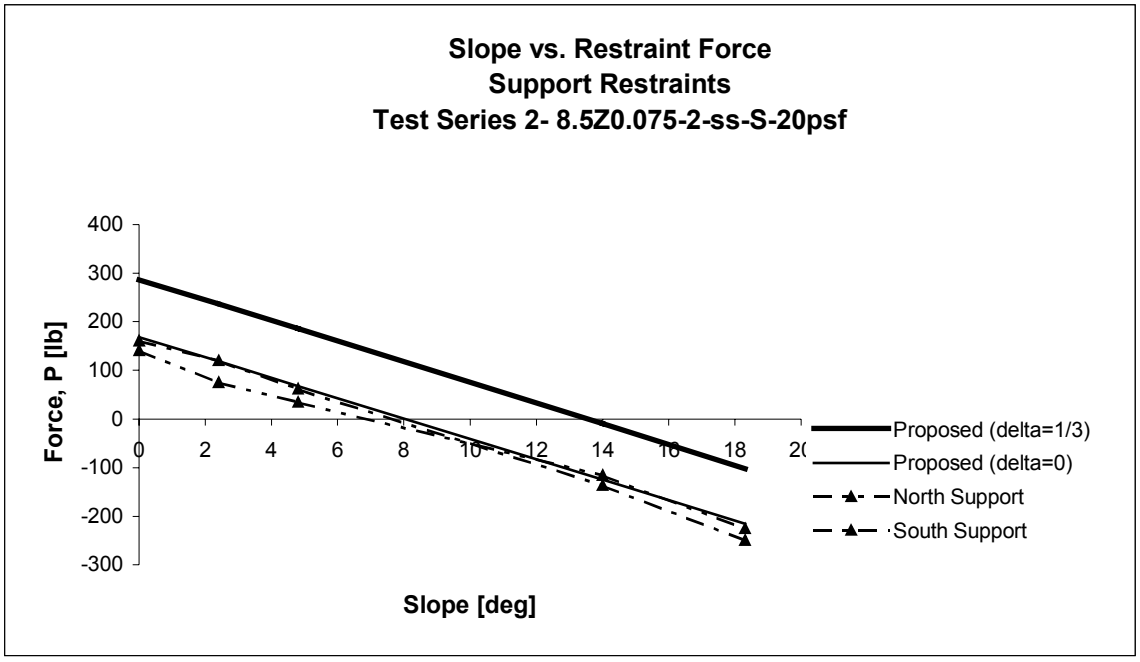


APPENDIX C-Series 2: 8.5Z0.075-2-ss-S Results

Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 71
Test Date: 2-5-01
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Support

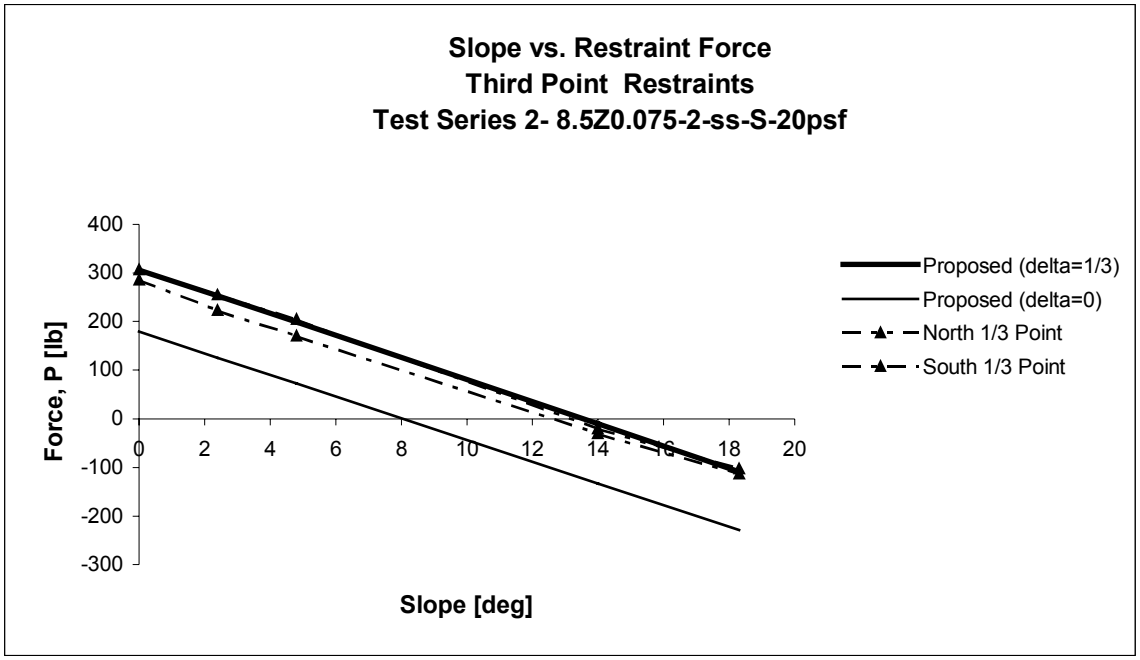
Test Series 2- 8.5Z0.075-2-ss-S-20psf Support Restraints				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0.0	286	168	141	161
2.4	236	119	75	120
4.8	186	68	35	62
14.0	-9	-124	-116	-136
18.3	-102	-215	-225	-249



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 72
Test Date: 2-7-01
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Third-Point

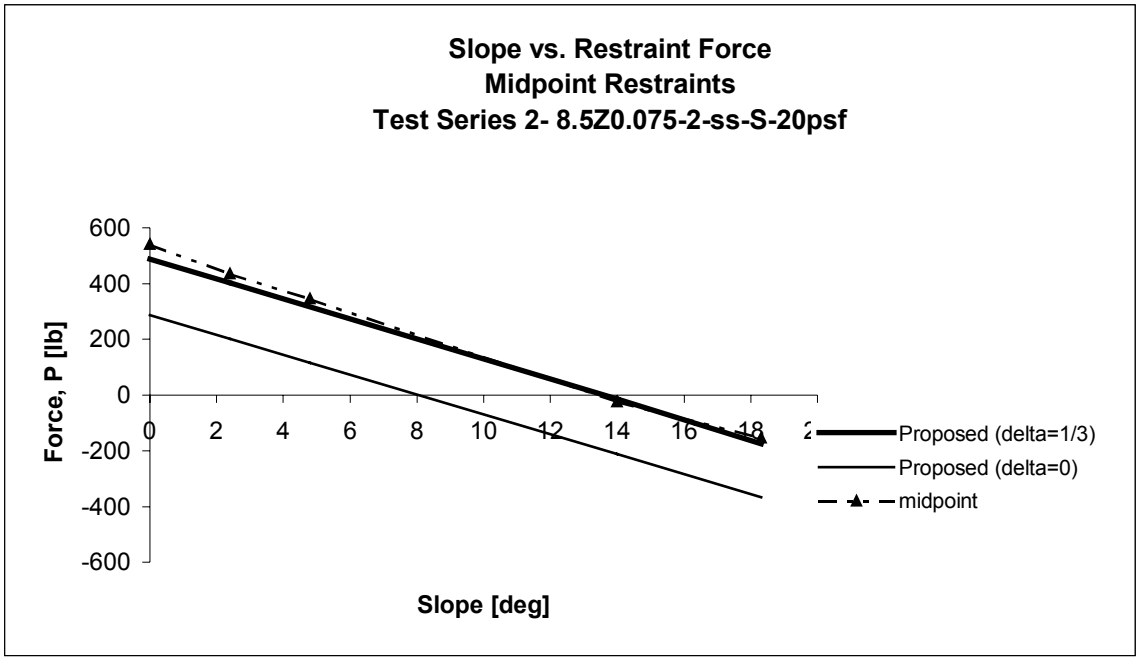
Test Series 2- 8.5Z0.075-2-ss-S-20psf Third Point Restraints				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0.0	306	179	307	286
2.4	253	126	255	223
4.8	199	73	205	171
14.0	-10	-133	-20	-30
18.3	-109	-229	-102	-113



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 73
Test Date: 2-9-01
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Midpoint

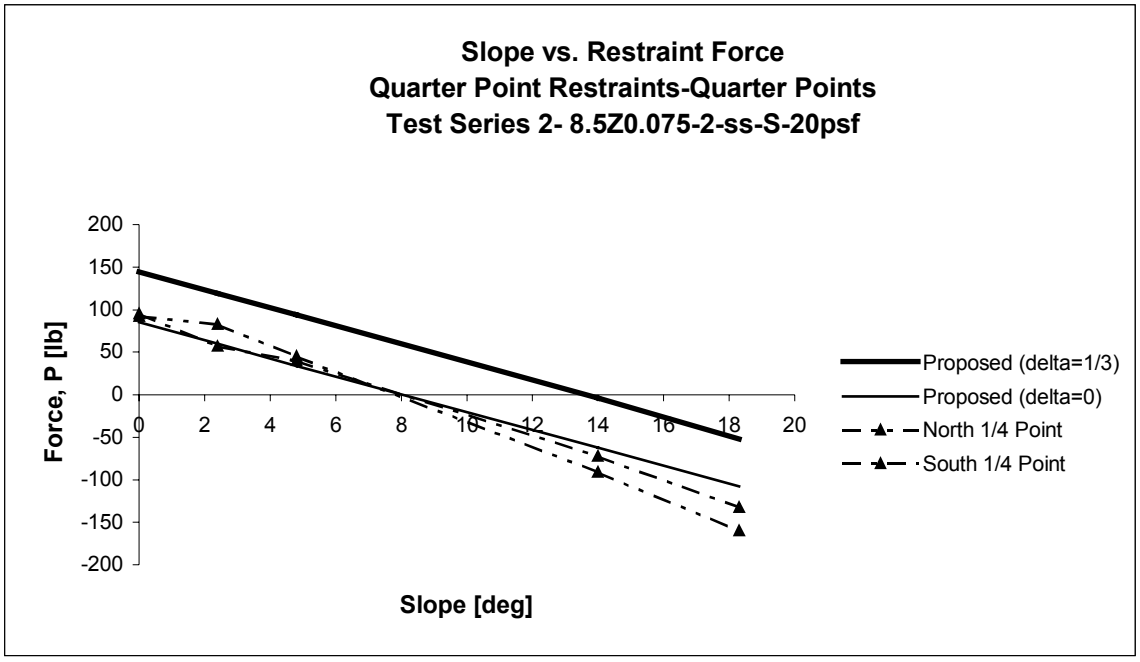
Test Series 2- 8.5Z0.075-2-ss-S-20psf Midpoint Restraints			
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0.0	488	287	541
2.4	402	201	436
4.8	317	116	345
14.0	-15	-212	-23
18.3	-175	-366	-155



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 74
Test Date: 2-12-01
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Quarter-Point

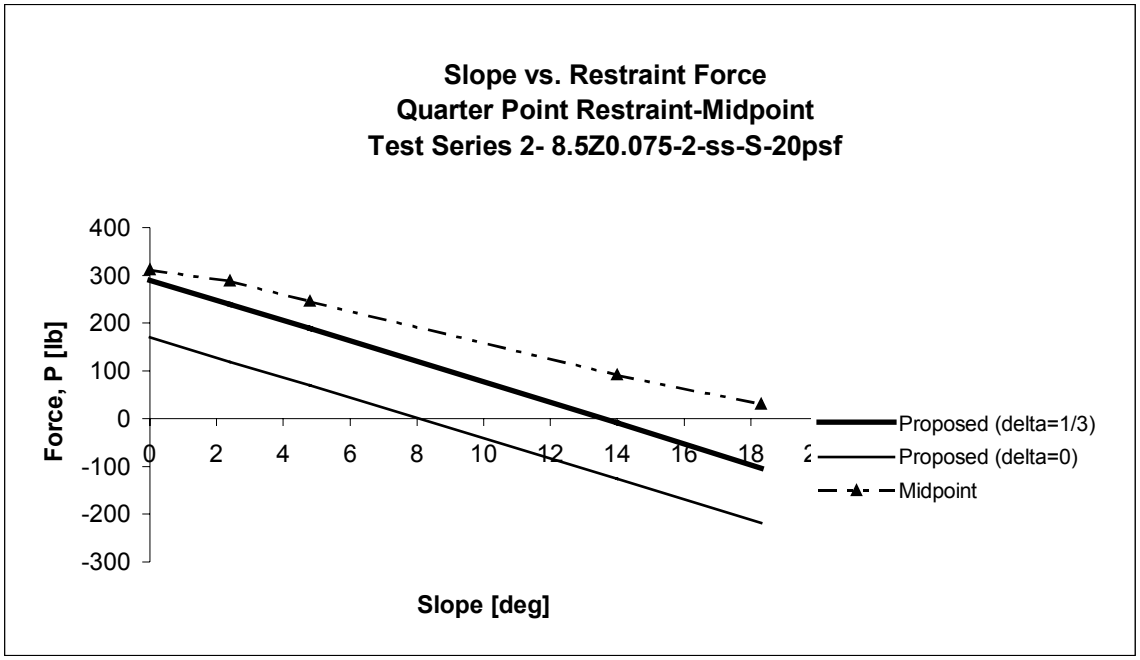
Test Series 2- 8.5Z0.075-2-ss-S-20psf Quarter Point Restraints-Quarter Points				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/4 Point**	**South 1/4 Point**
0.0	144	85	92	95
2.4	119	60	83	57
4.8	94	34	45	40
14.0	-4	-62	-91	-72
18.3	-52	-108	-160	-132



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 75
Test Date: 2-14-01
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Quarter-Point

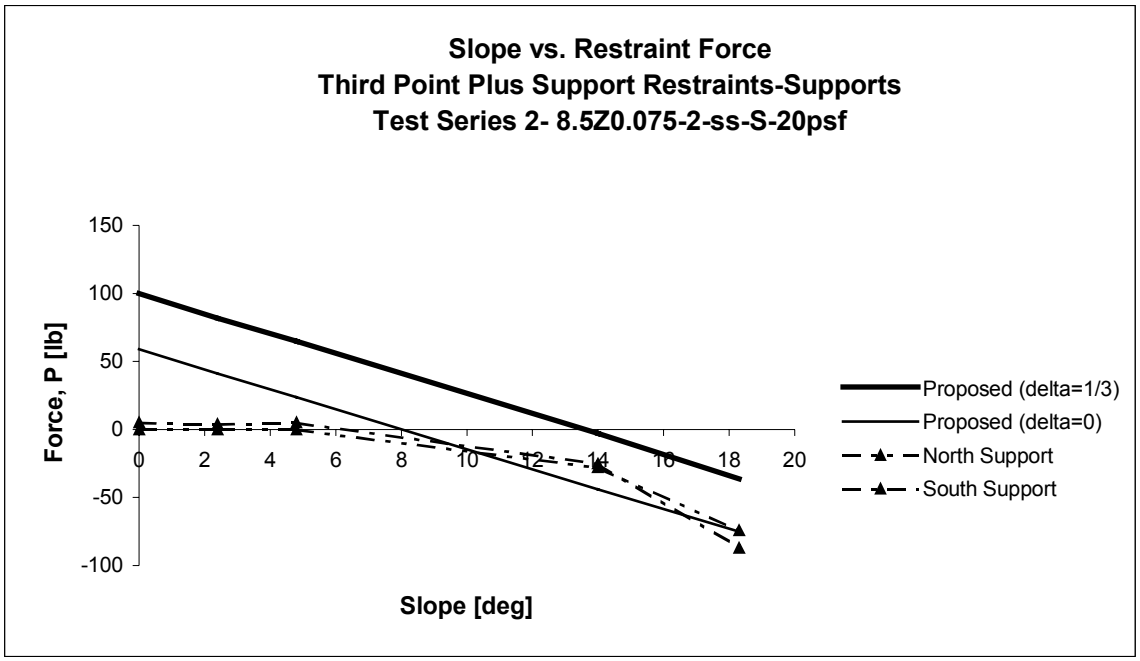
Test Series 2- 8.5Z0.075-2-ss-S-20psf Quarter Point Restraints-Midpoint			
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0.0	290	170	312
2.4	239	119	288
4.8	189	69	246
14.0	-9	-126	92
18.3	-104	-218	30



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 76
Test Date: 2-16-01
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Third-Point Plus Support

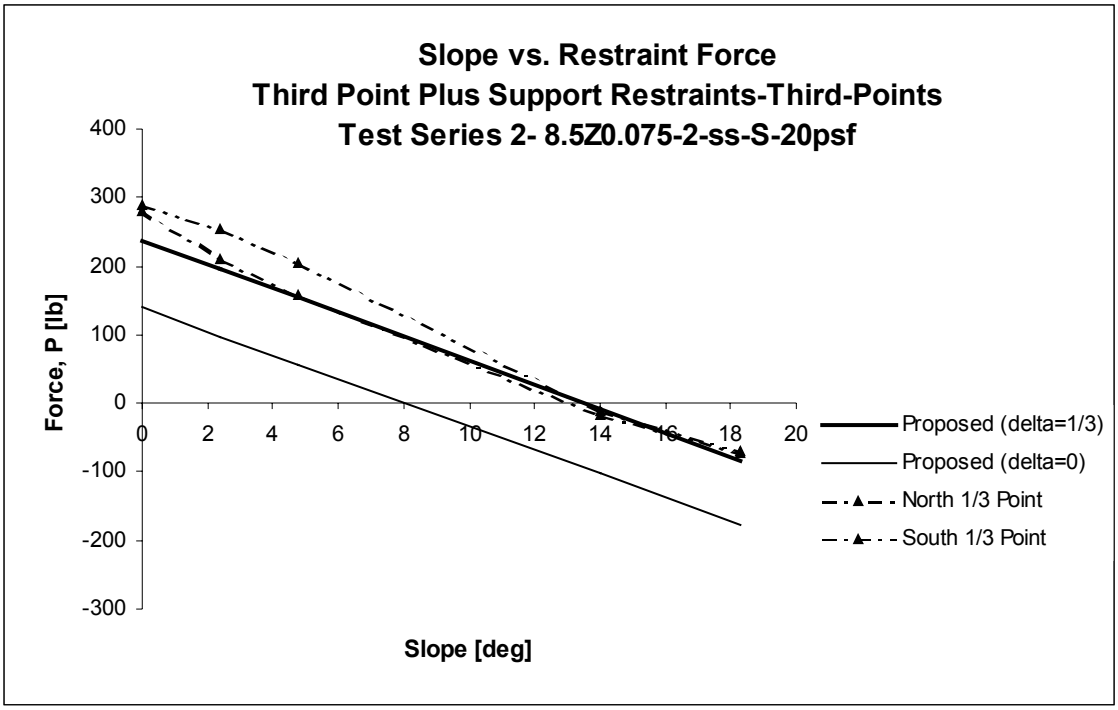
Test Series 2- 8.5Z0.075-2-ss-S-20psf Third Point Plus Support Restraints-Supports				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0.0	100	59	0	5
2.4	82	41	0	4
4.8	65	24	0	5
14.0	-3	-44	-28	-25
18.3	-36	-75	-74	-87



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 77
Test Date: 2-19-01
Span Length: 20 ft.
Number of Purlins: 2 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Third-Point Plus Support

Test Series 2- 8.5Z0.075-2-ss-S-20psf Third Point Plus Support Restraints-Third-Points				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0.0	236	139	289	280
2.4	195	98	255	210
4.8	154	57	205	159
14.0	-8	-103	-12	-17
18.3	-85	-177	-70	-72

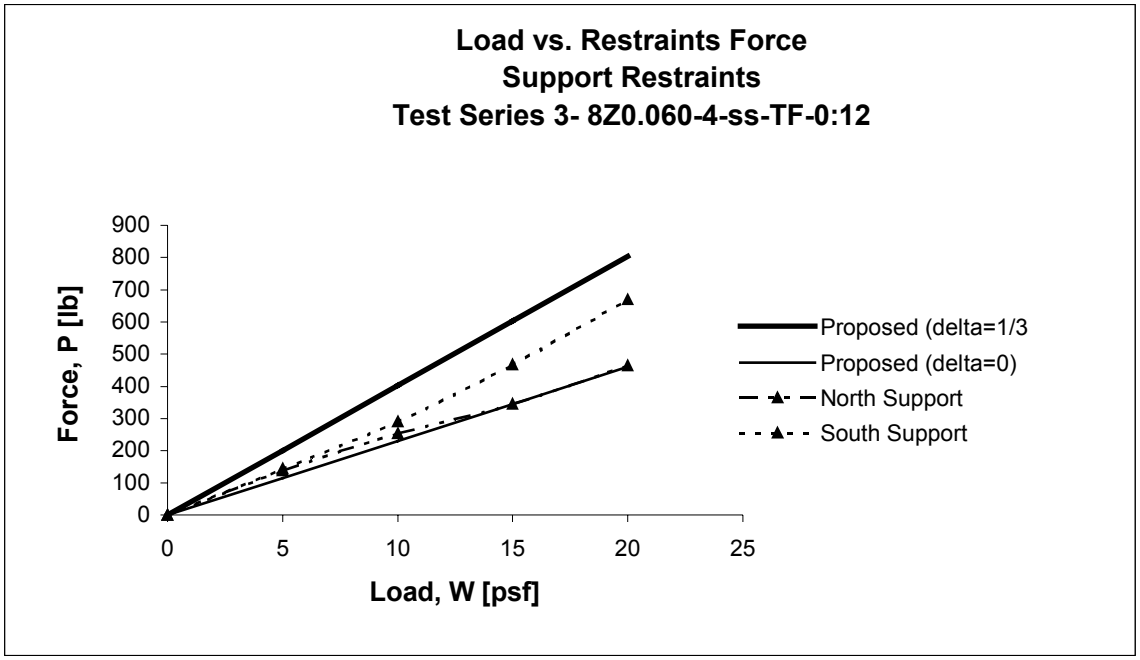


APPENDIX D-Series 3: 8Z0.060-4-ss-TF Results

Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 76
Test Date: 1-8-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Support

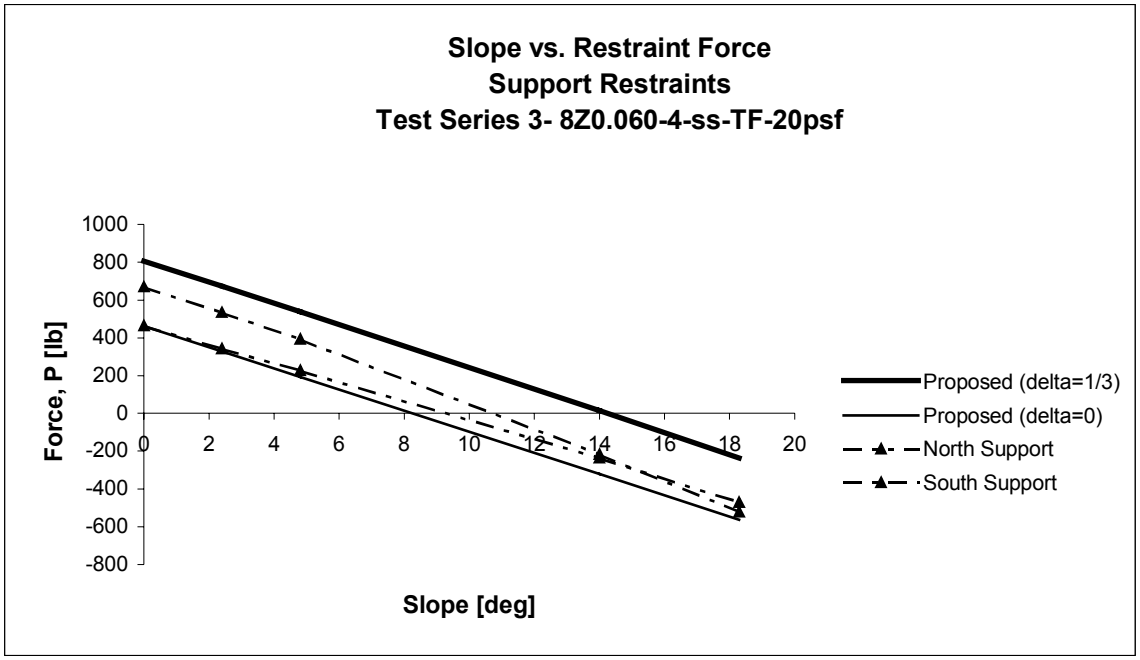
Test Series 3- 8Z0.060-4-ss-TF-0:12 Support Restraints				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0	0	0	0	0
5	201	115	137	144
10	402	230	253	290
15	603	345	344	467
20	804	460	464	669



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 77
Test Date: 1-8-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Support

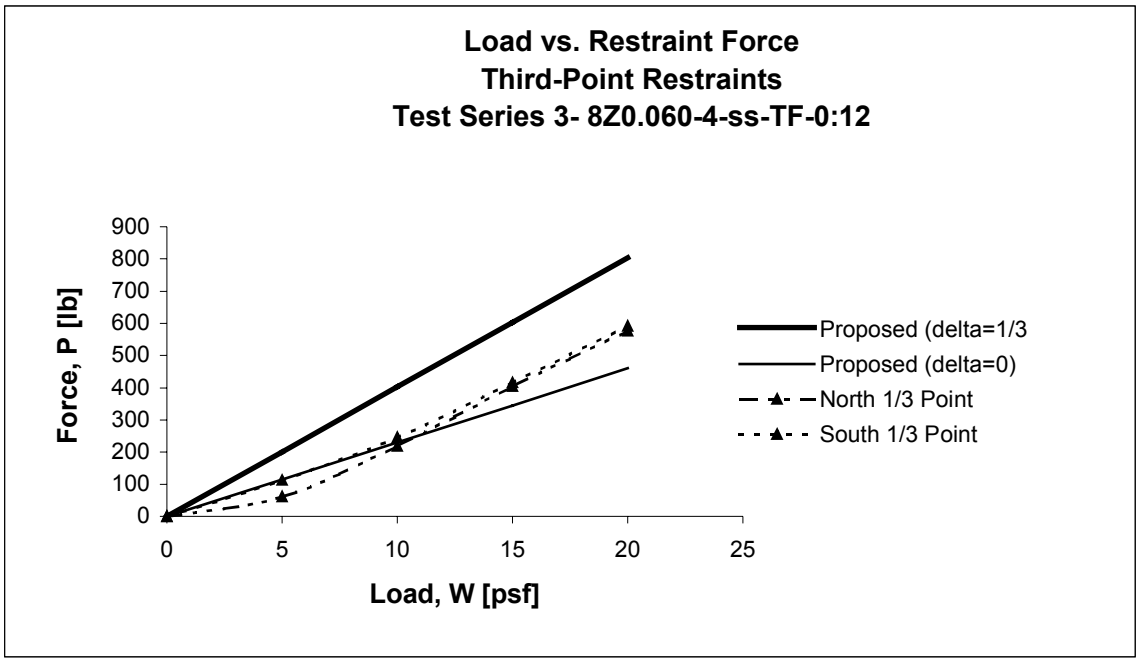
Test Series 3- 8Z0.060-4-ss-TF-20psf Support Restraints				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0.0	804	460	464	669
2.4	672	328	343	534
4.8	536	192	226	393
14.0	16	-320	-235	-215
18.3	-236	-564	-469	-522



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 78
Test Date: 1-9-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point

Test Series 3- 8Z0.060-4-ss-TF-0:12 Third-Point Restraints				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0	0	0	0	0
5	201	115	61	113
10	402	230	219	246
15	603	345	404	416
20	804	460	576	591



Test Summary

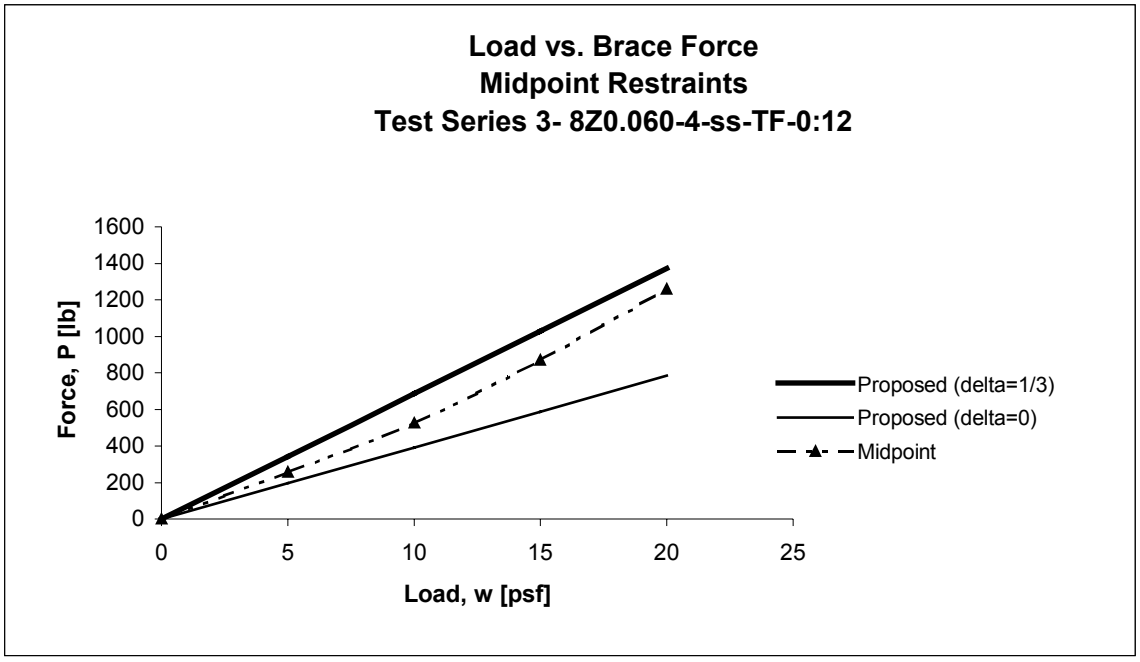
Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 79
Test Date: 1-9-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point

Test Series 3- 8Z0.060-4-ss-TF-20psf Third-Point Restraints				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0.0	804	460	576	592
2.4	672	328	447	400
4.8	536	192	327	287
14.0	16	-320	-305	-209
18.3	-236	-564	-575	-387

Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 79
Test Date: 1-9-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Midpoint

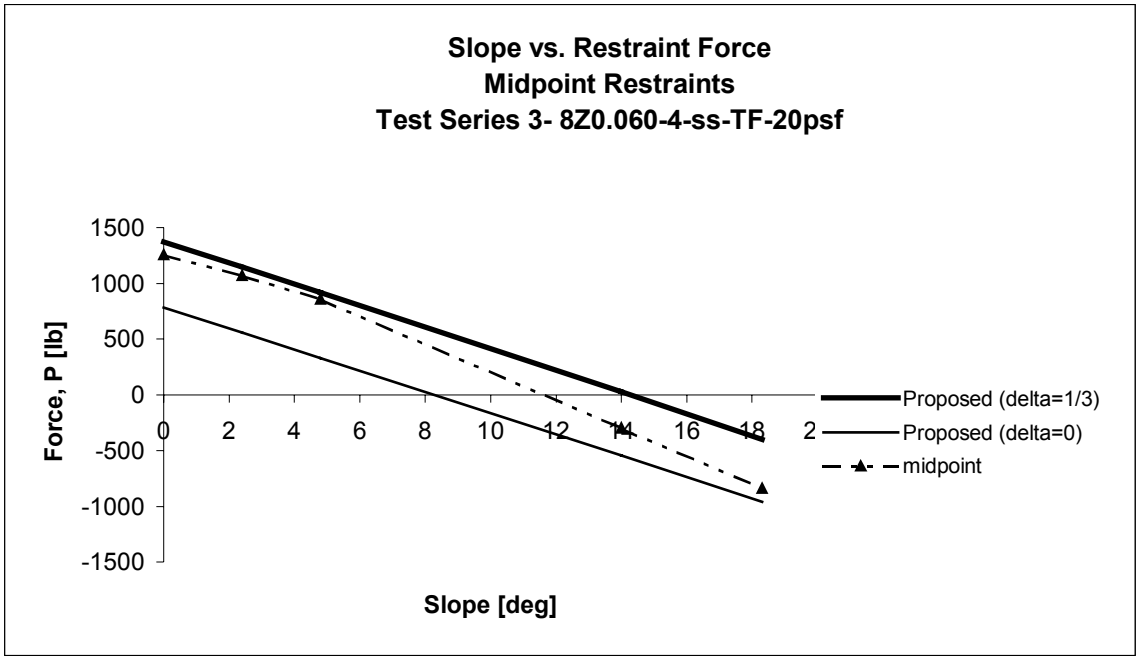
Test Series 3- 8Z0.060-4-ss-TF-0:12 Midpoint Restraints			
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0	0	0	0
5	343	196	256
10	686	392	526
15	1029	588	869
20	1372	784	1258



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 80
Test Date: 1-9-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Midpoint

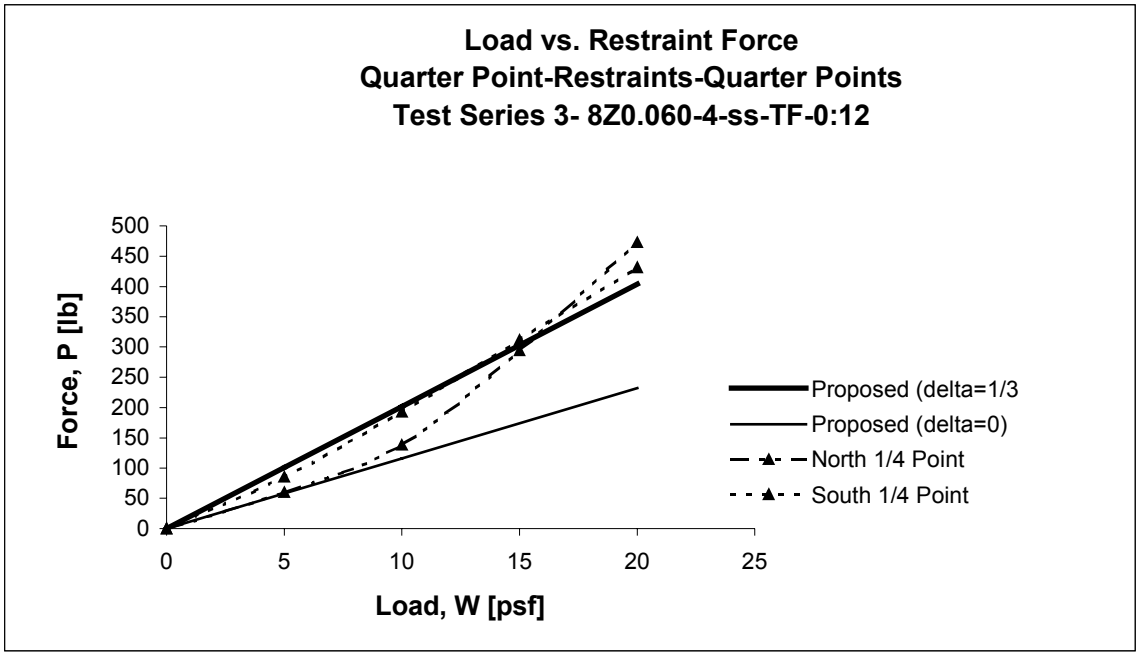
Test Series 3- 8Z0.060-4-ss-TF-20psf Midpoint Restraints			
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0.0	1372	784	1258
2.4	1144	556	1067
4.8	916	328	860
14.0	24	-544	-300
18.3	-400	-960	-840



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 81
Test Date: 1-11-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

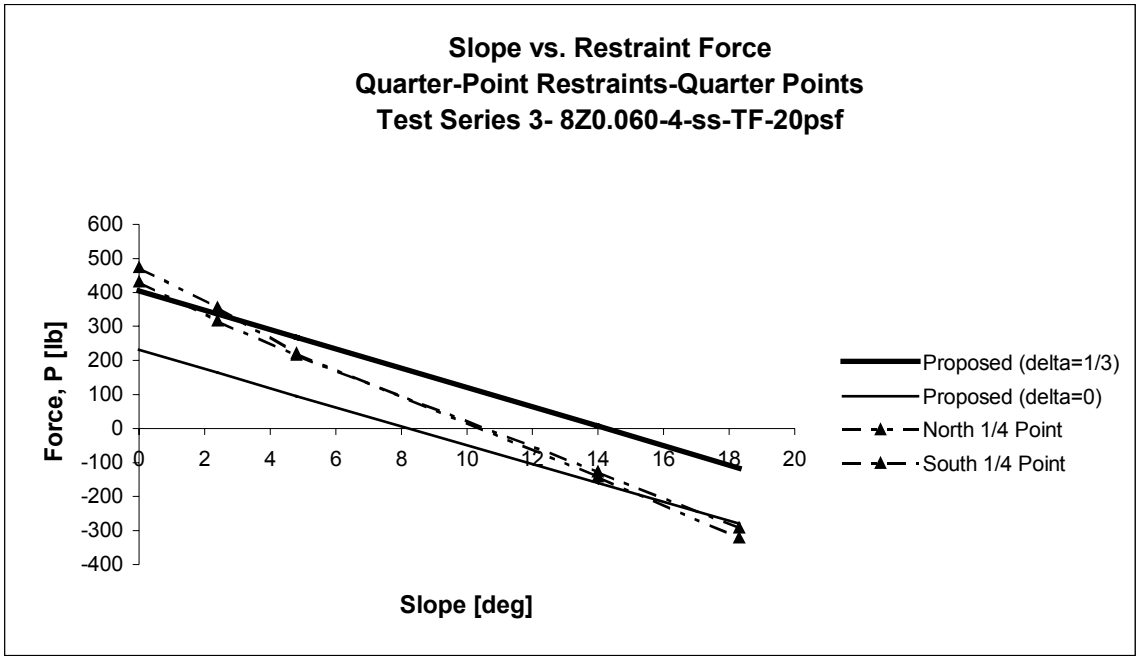
Test Series 3- 8Z0.060-4-ss-TF-0:12 Quarter-Point Restraints-Quarter Points				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/4 Point**	**South 1/4 Point**
0	0	0	0	0
5	101	58	60	85
10	202	116	138	193
15	303	174	294	312
20	404	232	473	431



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 82
Test Date: 1-11-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

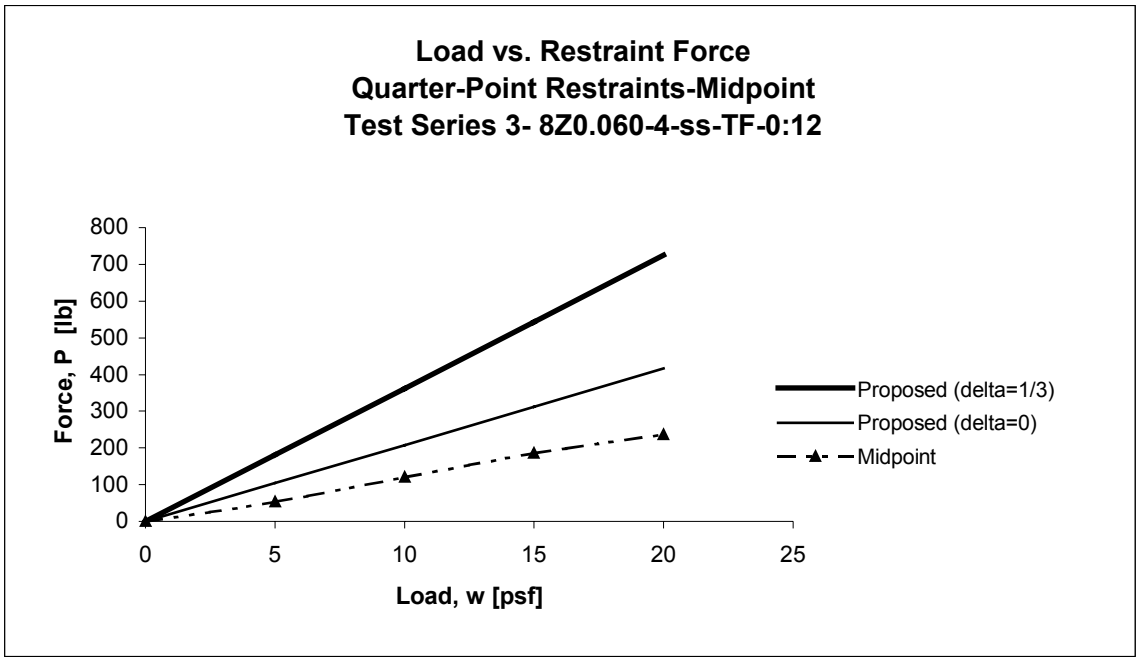
Test Series 3- 8Z0.060-4-ss-TF-20psf Quarter-Point Restraints-Quarter Points				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/4 Point**	**South 1/4 Point**
0.0	404	232	473	431
2.4	336	164	355	316
4.8	268	96	220	216
14.0	8	-160	-142	-128
18.3	-116	-280	-321	-292



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 83
Test Date: 1-11-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

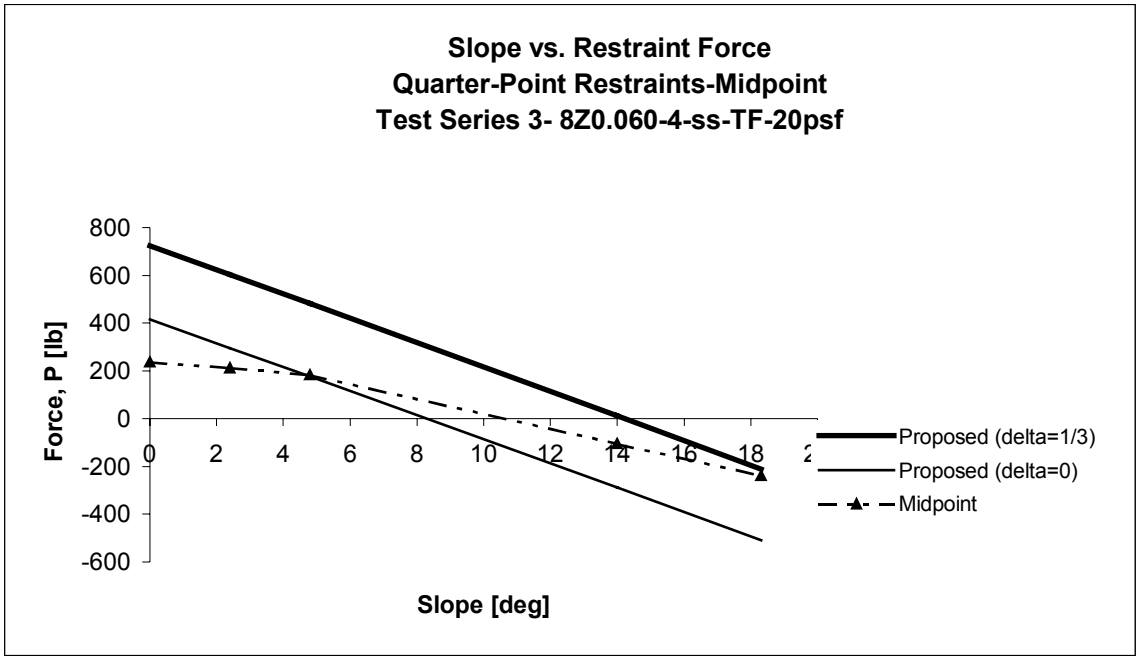
Test Series 3- 8Z0.060-4-ss-TF-0:12 Quarter-Point Restraints-Midpoint			
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0	0	0	0
5	181	104	54
10	362	208	121
15	543	312	186
20	724	416	237



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 84
Test Date: 1-11-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

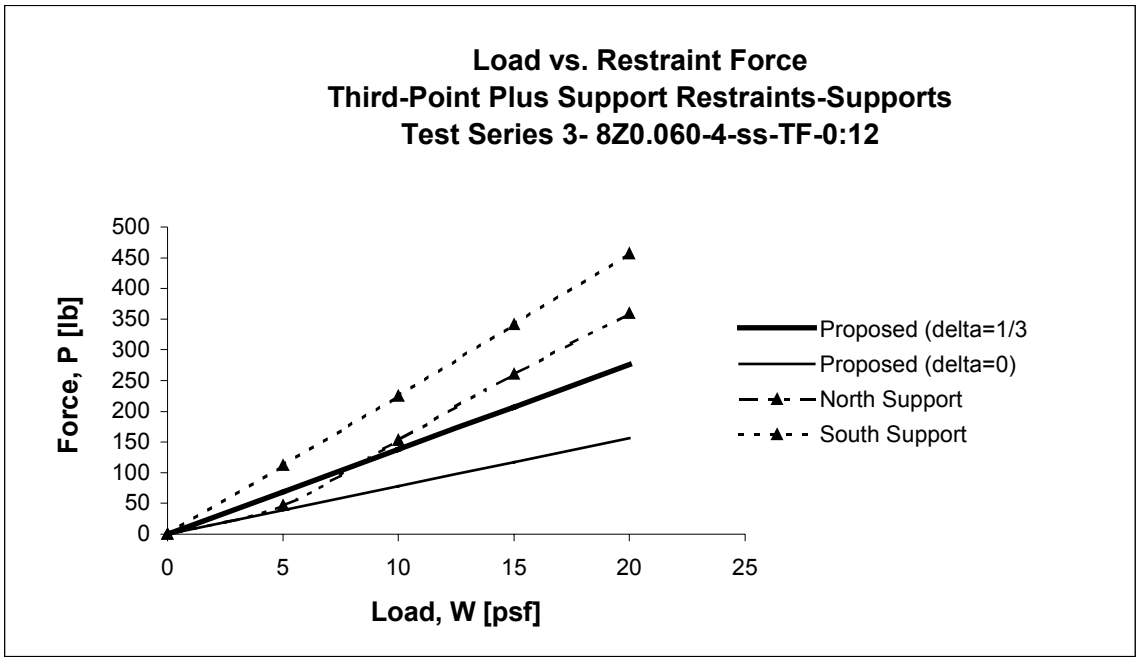
Test Series 3- 8Z0.060-4-ss-TF-20psf Quarter-Point Restraints-Midpoint			
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0.0	724	416	237
2.4	604	296	212
4.8	484	176	183
14.0	12	-288	-105
18.3	-212	-508	-238



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 85
Test Date: 1-12-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

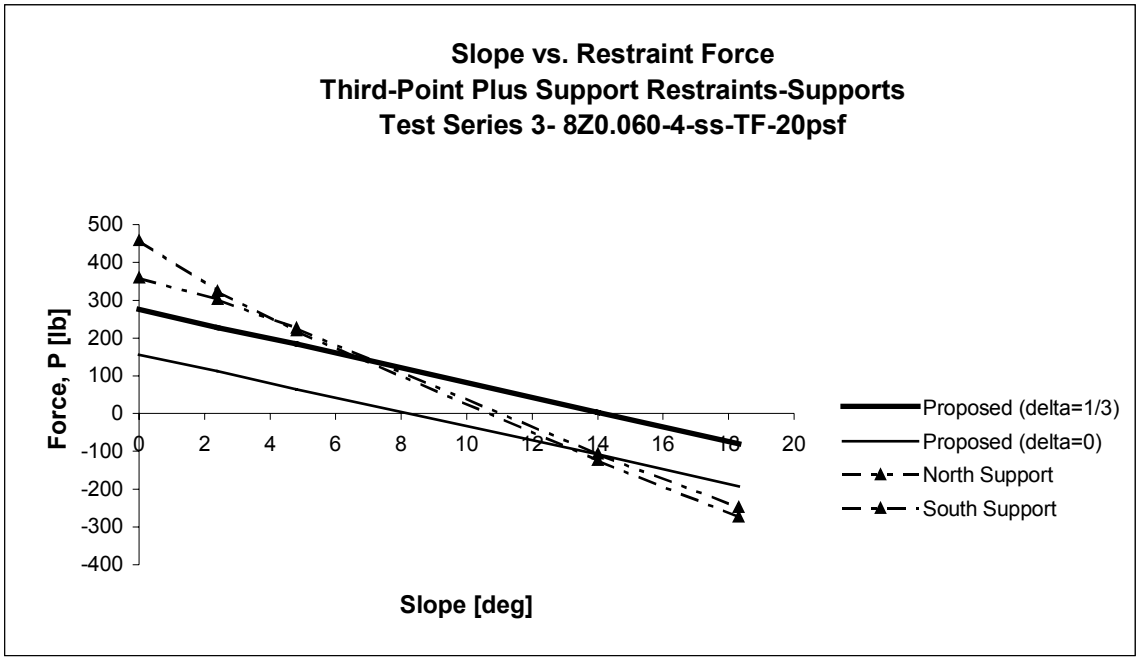
Test Series 3- 8Z0.060-4-ss-TF-0:12 Third-Point Plus Support Restraints-Supports				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**North Support**
0	0	0	0	0
5	69	39	47	112
10	138	78	153	225
15	207	117	260	341
20	276	156	359	457



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 86
Test Date: 1-12-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

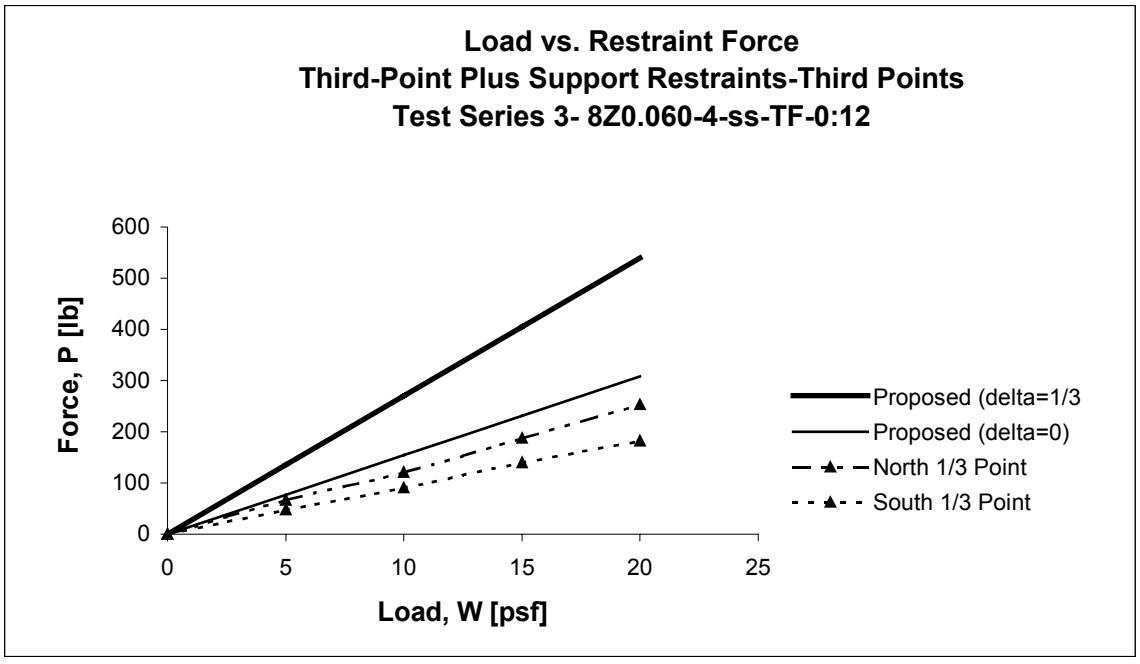
Test Series 3- 8Z0.060-4-ss-TF-20psf Third-Point Plus Support Restraints-Supports				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0.0	276	156	359	457
2.4	228	112	302	323
4.8	184	64	226	219
14.0	4	-108	-106	-124
18.3	-80	-192	-248	-273



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 87
Test Date: 1-12-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

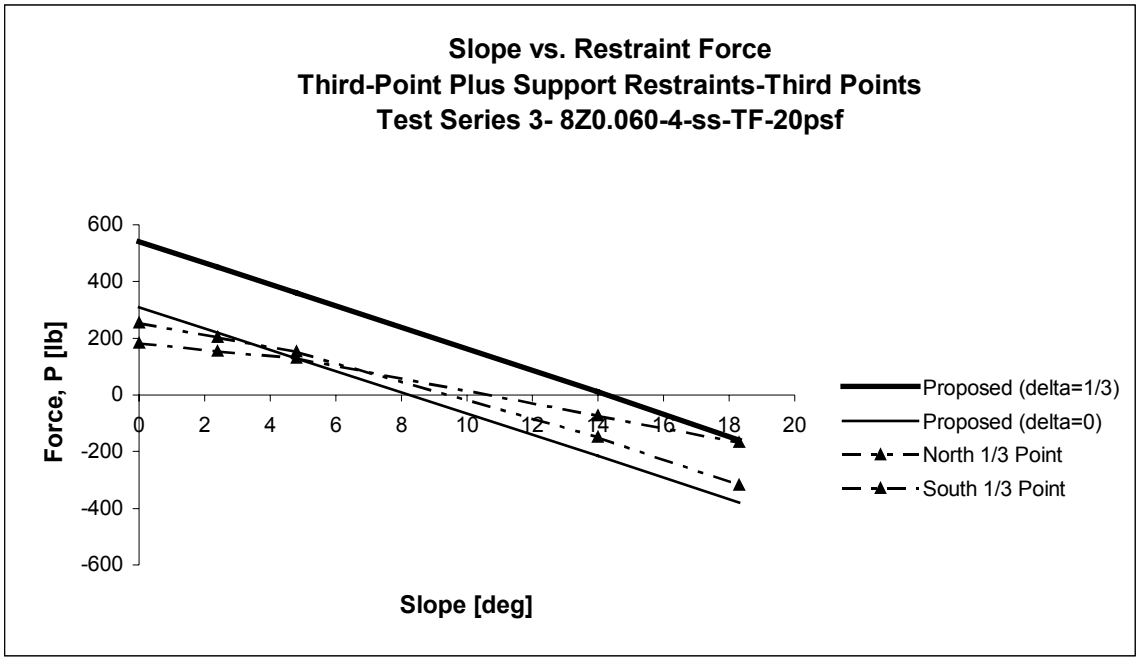
Test Series 3- 8Z0.060-4-ss-TF-0:12 Third-Point Plus Support Restraints-Third Points				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0	0	0	0	0
5	135	77	67	48
10	270	154	121	91
15	405	231	187	140
20	540	308	253	182



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 88
Test Date: 1-12-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

Test Series 3- 8Z0.060-4-ss-TF-20psf Third-Point Plus Support Restraints-Third Points				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0.0	540	308	253	182
2.4	452	220	204	154
4.8	360	128	153	129
14.0	12	-215	-149	-74
18.3	-160	-380	-318	-167

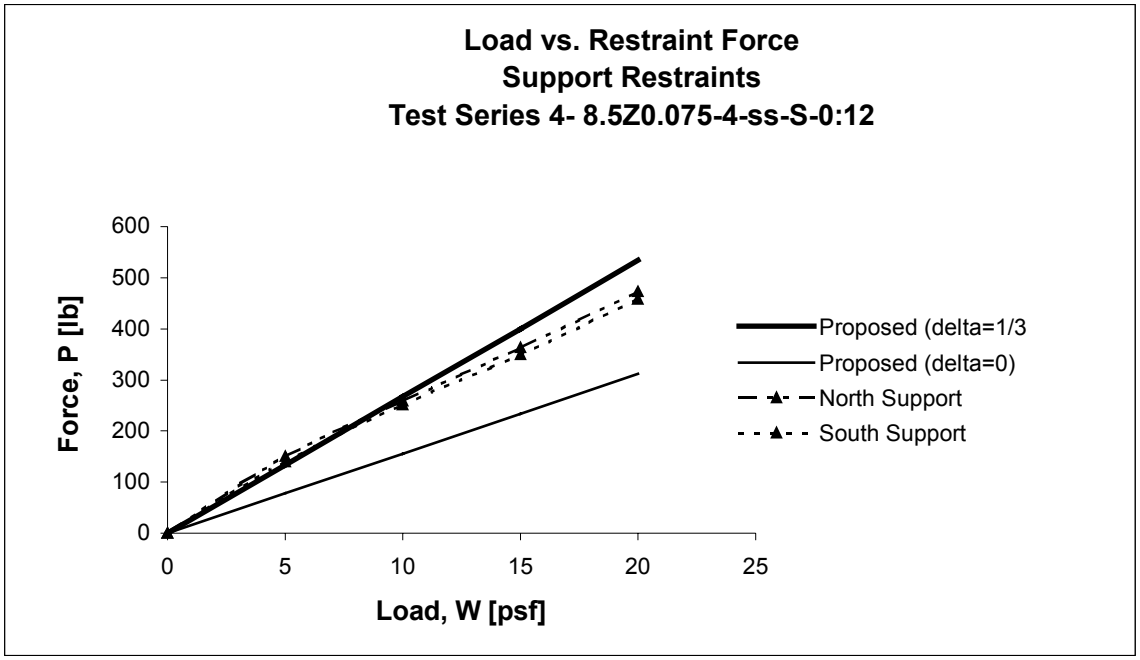


APPENDIX E-Series 4: 8.5Z0.075-4-ss-S Results

Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 89
Test Date: 1-22-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Support

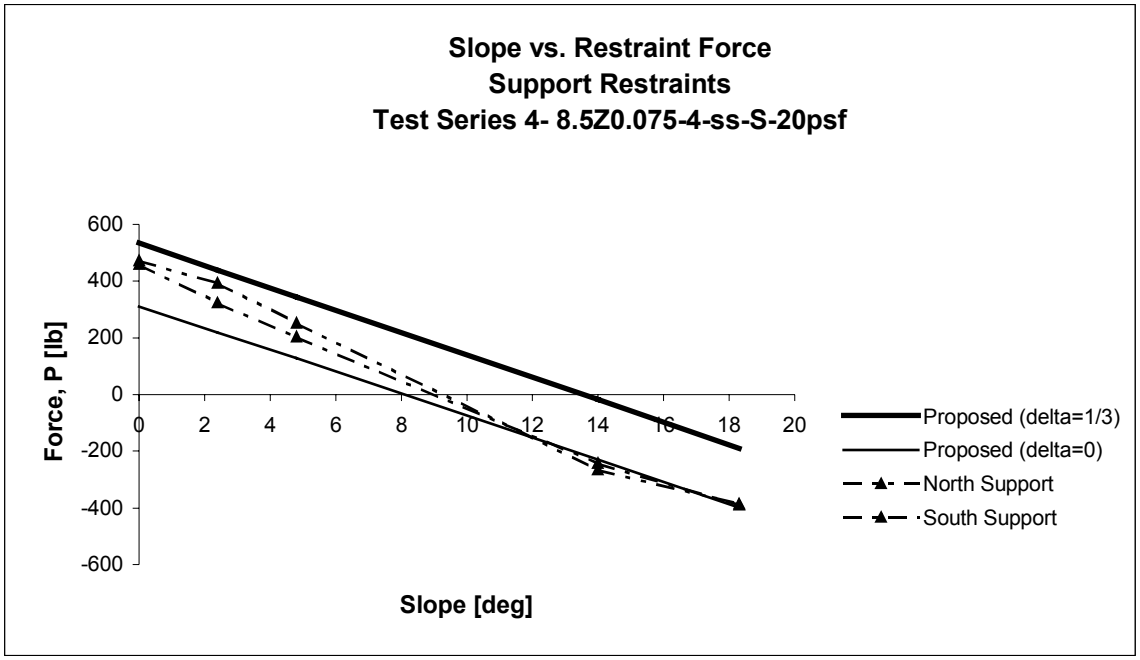
Test Series 4- 8.5Z0.075-4-ss-S-0:12 Support Restraints				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0	0	0	0	0
5	134	78	150	140
10	267	156	259	252
15	400	234	363	350
20	534	312	473	458



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 90
Test Date: 1-22-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Support

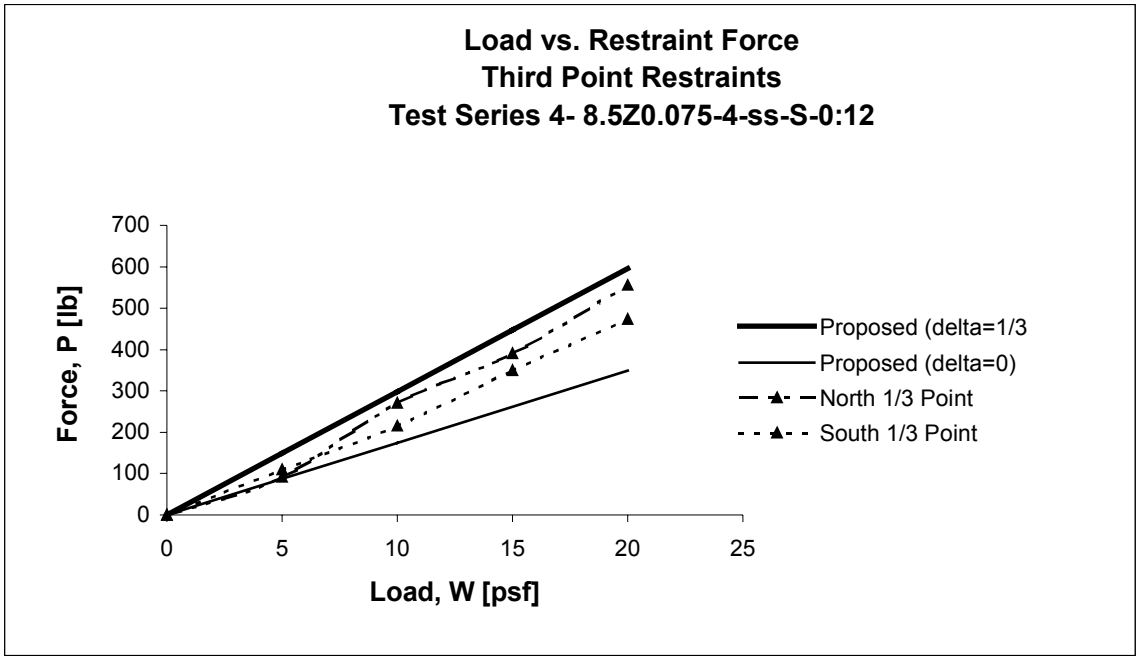
Test Series 4- 8.5Z0.075-4-ss-S-20psf Support Restraints				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0.0	534	310	473	458
2.4	438	219	394	324
4.8	344	127	252	204
14.0	-17	-229	-265	-243
18.3	-190	-399	-385	-389



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 91
Test Date: 1-24-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Third-Point

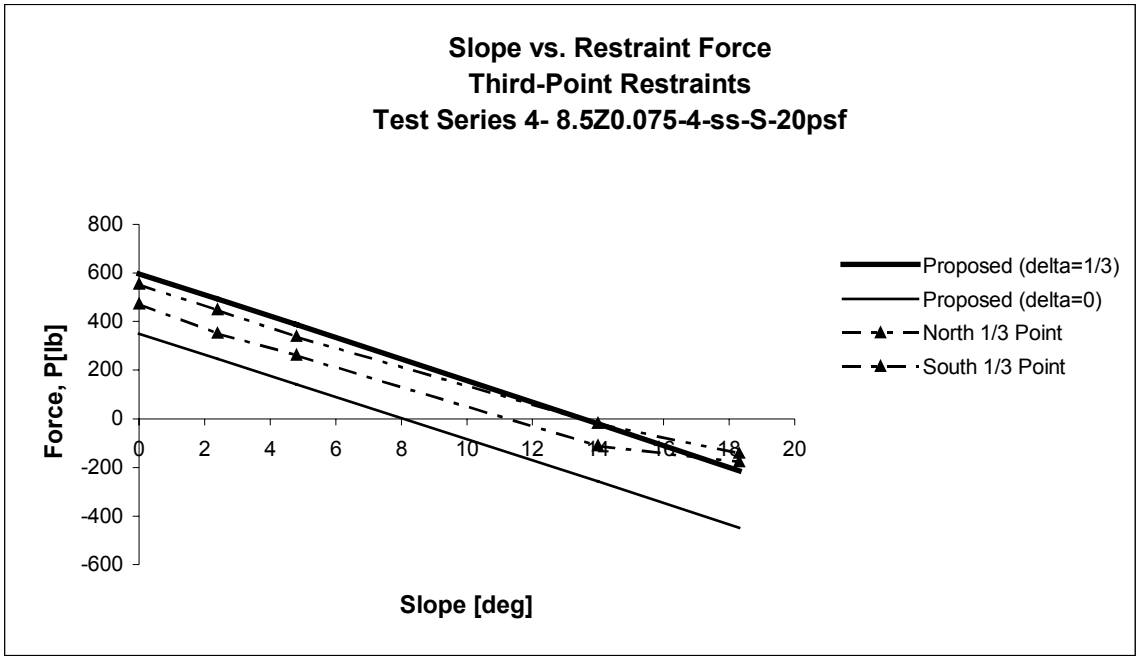
Test Series 4- 8.5Z0.075-4-ss-S-0:12 Third-Point Restraints				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0	0	0	0	0
5	149	88	92	109
10	298	174	271	215
15	447	262	390	350
20	596	349	555	473



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 92
Test Date: 1-24-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Third-Point

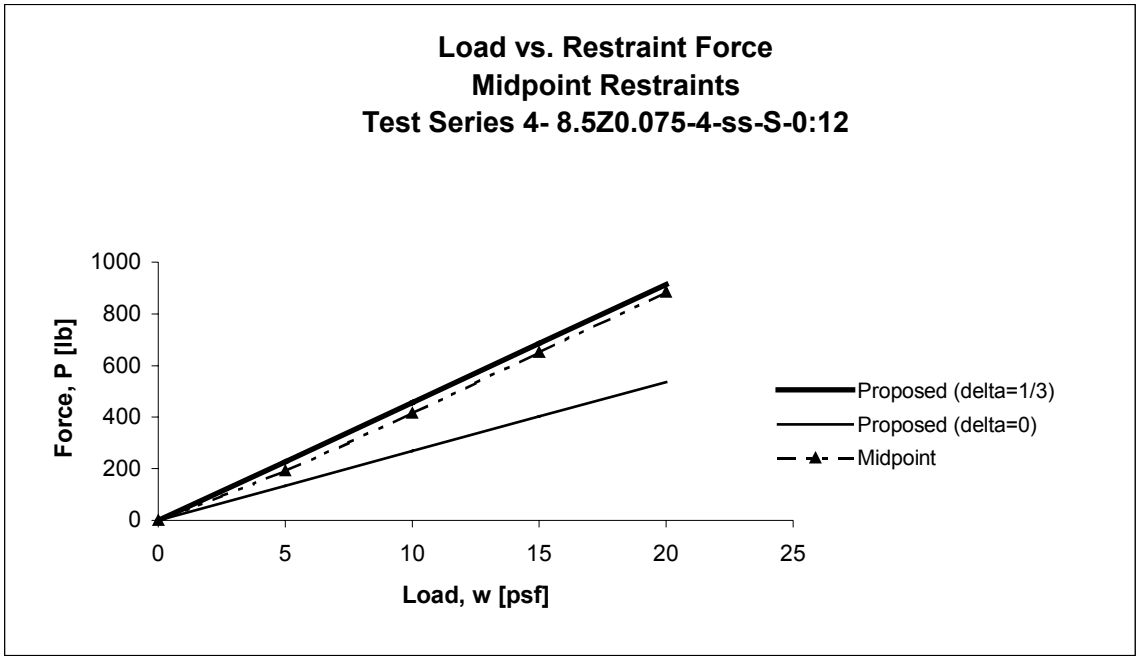
Test Series 4- 8.5Z0.075-4-ss-S-20psf Third-Point Restraints				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0.0	597	350	555	473
2.4	493	246	450	353
4.8	388	142	339	262
14.0	-20	-258	-19	-110
18.3	-214	-448	-142	-176



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 93
Test Date: 1-29-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Midpoint

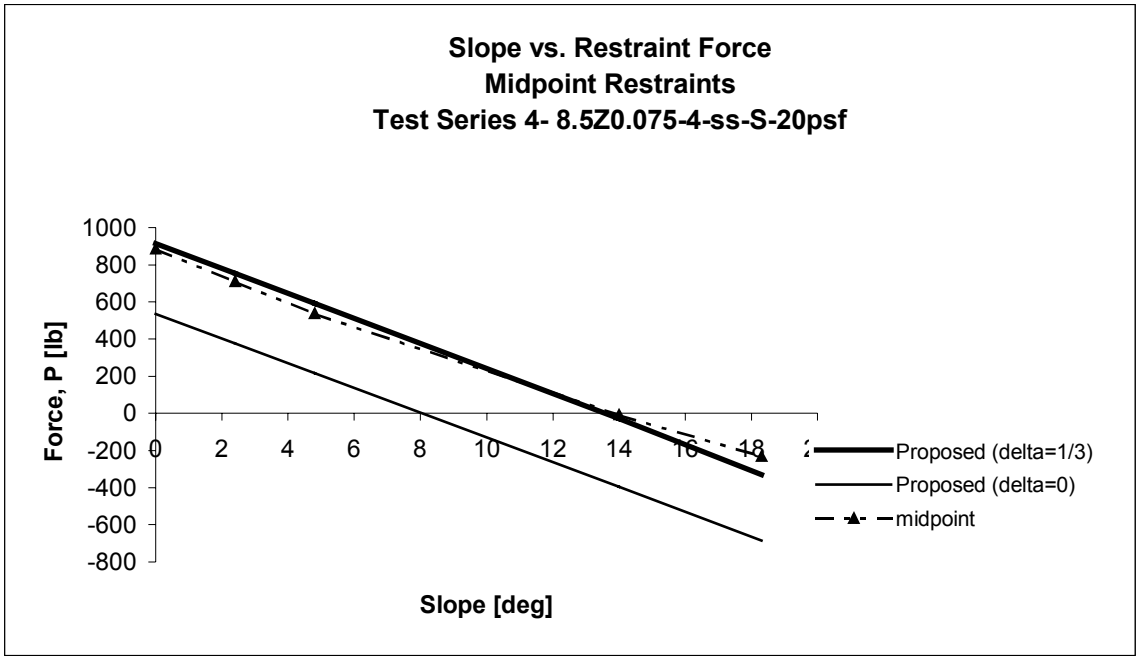
Test Series 4- 8.5Z0.075-4-ss-S-0:12 Midpoint Restraints			
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0	0	0	0
5	228	134	193
10	456	268	416
15	685	402	651
20	913	536	885



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 94
Test Date: 1-29-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Midpoint

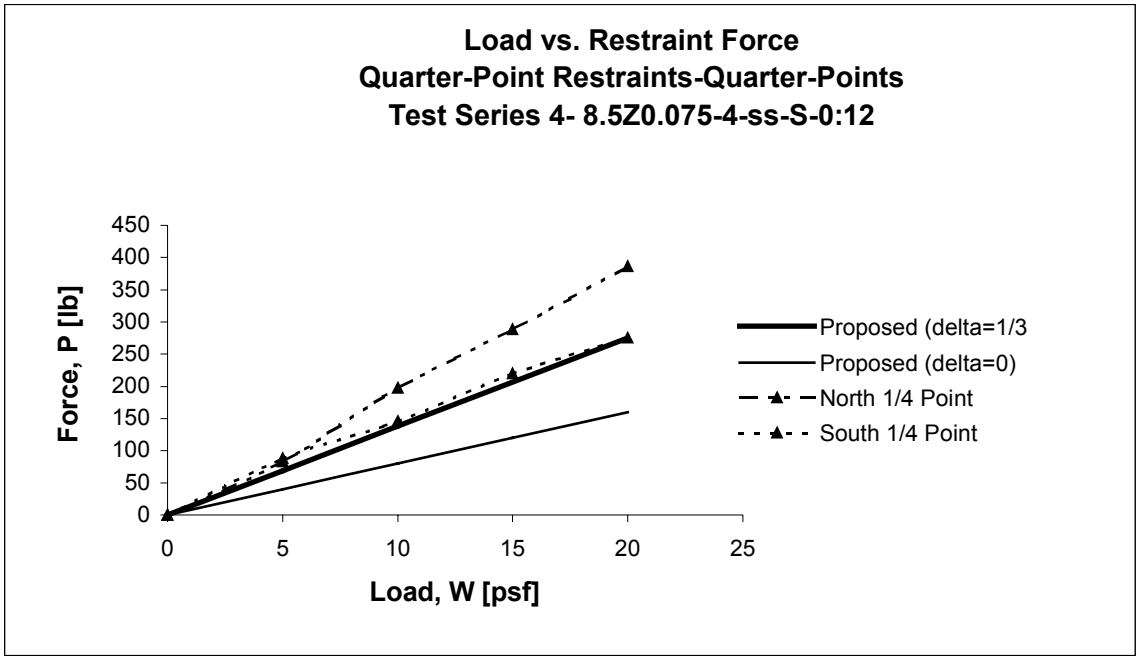
Test Series 4- 8.5Z0.075-4-ss-S-20psf Midpoint Restraints			
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0.0	913	536	885
2.4	754	377	710
4.8	593	217	537
14.0	-29	-395	-8
18.3	-328	-686	-233



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 95
Test Date: 1-30-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Quarter-Point

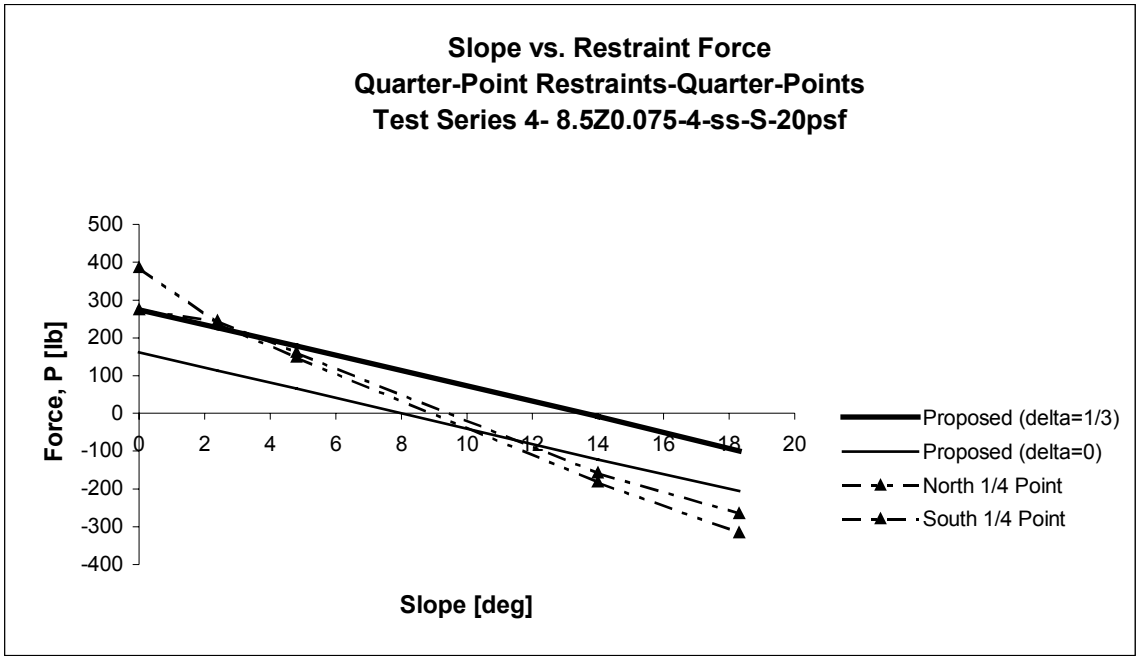
Test Series 4- 8.5Z0.075-4-ss-S-0:12 Quarter-Point Restraints-Quarter-Points				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/4 Point**	**South 1/4 Point**
0	0	0	0	0
5	69	40	83	88
10	138	80	197	146
15	206	120	288	220
20	275	160	386	275



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 96
Test Date: 1-30-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Quarter-Point

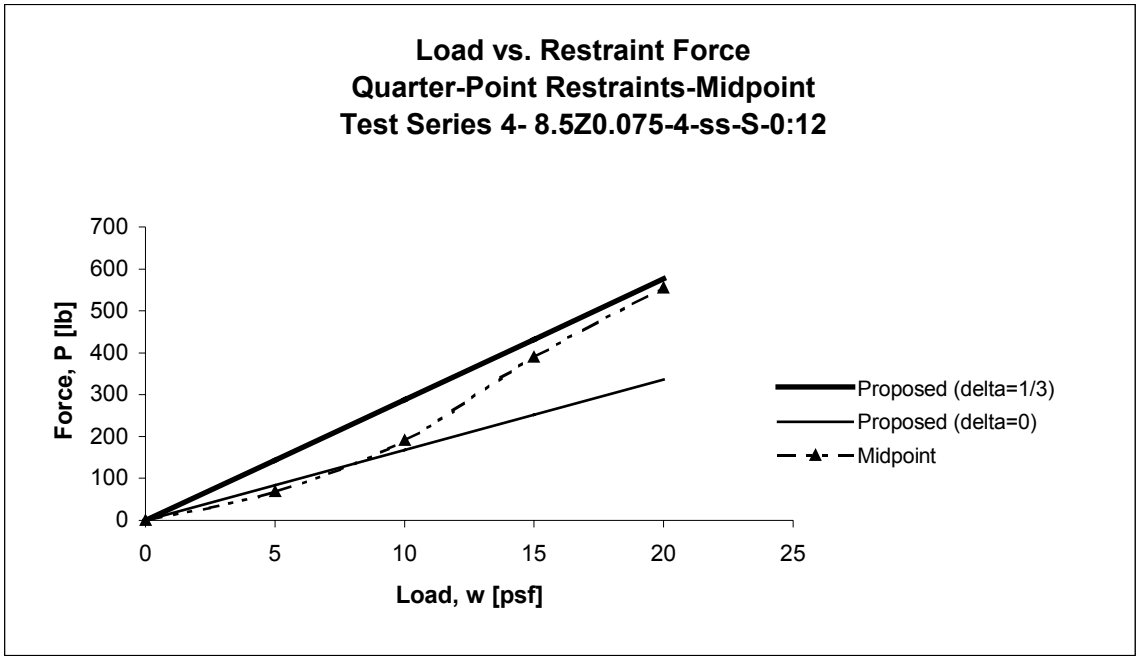
Test Series 4- 8.5Z0.075-4-ss-S-20psf Quarter-Point Restraints-Quarter-Points				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/4 Point**	**South 1/4 Point**
0.0	275	161	386	275
2.4	227	113	238	244
4.8	179	65	149	161
14.0	-8	-122	-182	-158
18.3	-99	-206	-315	-264



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 97
Test Date: 1-30-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Quarter-Point

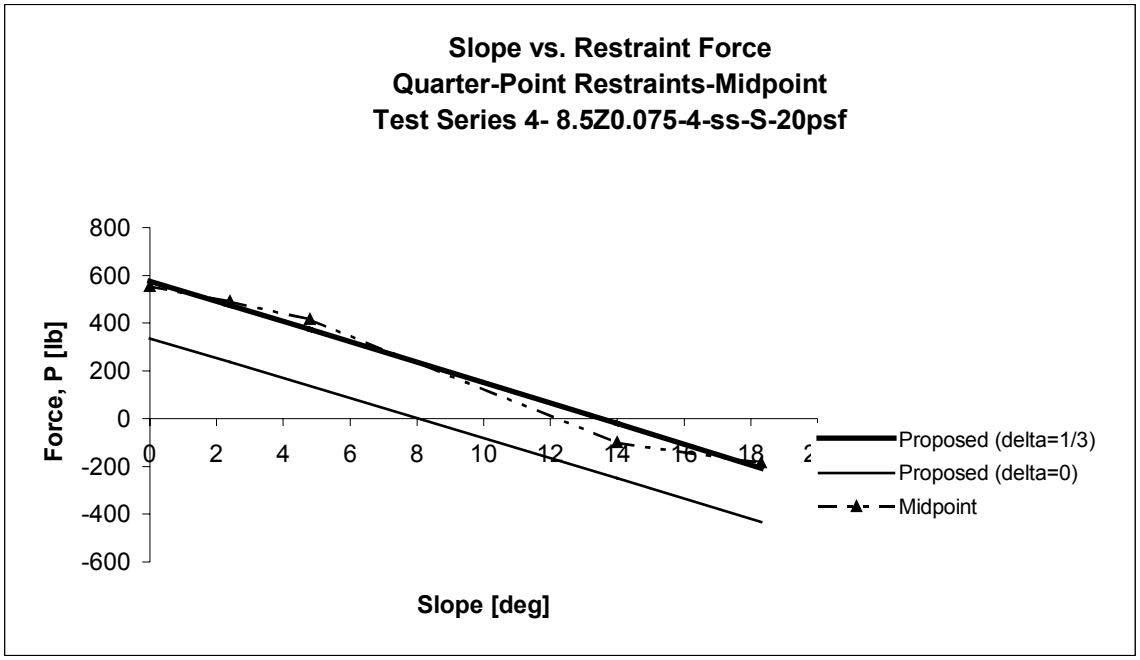
Test Series 4- 8.5Z0.075-4-ss-S-0:12 Quarter-Point Restraints-Midpoint			
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0	0	0	0
5	144	84	69
10	288	168	191
15	432	252	390
20	576	336	555



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 98
Test Date: 1-30-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Quarter-Point

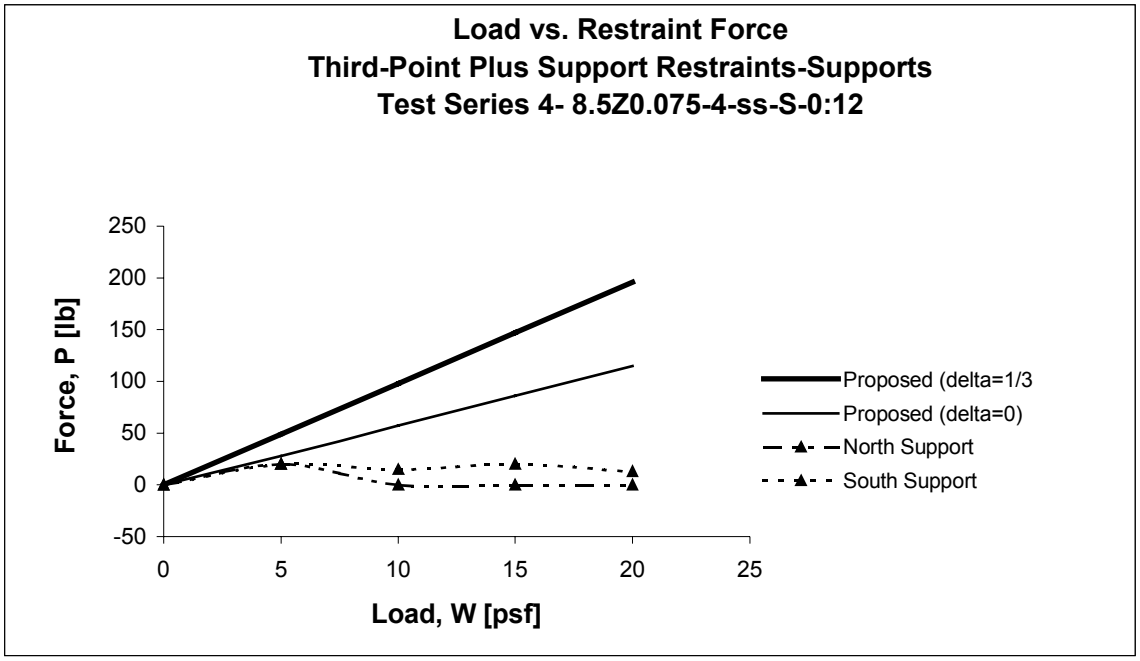
Test Series 4- 8.5Z0.075-4-ss-S-20psf Quarter-Point Restraints-Midpoint			
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Midpoint**
0.0	575	336	555
2.4	475	237	492
4.8	374	137	417
14.0	-19	-249	-100
18.3	-206	-432	-184



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 99
Test Date: 2-1-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Third-Point Plus Support

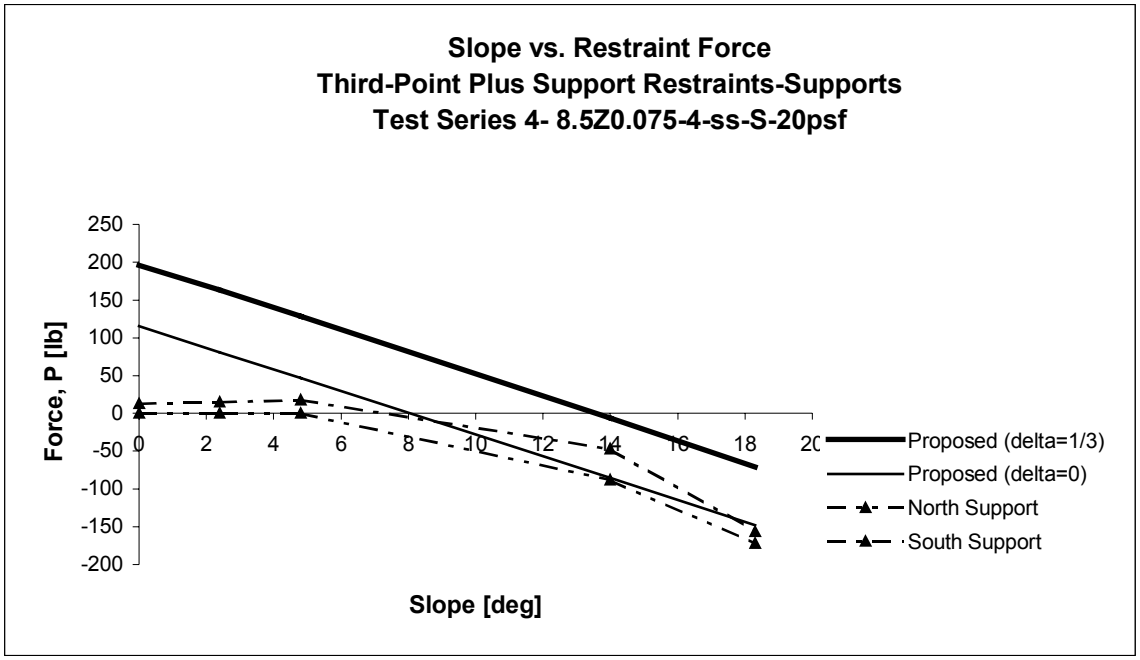
Test Series 4- 8.5Z0.075-4-ss-S-0:12 Third-Point Plus Support Restraints-Supports				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0	0	0	0	0
5	49	28	20	20
10	98	57	0	15
15	147	86	0	20
20	196	115	0	13



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 100
Test Date: 2-1-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Third-Point Plus Support

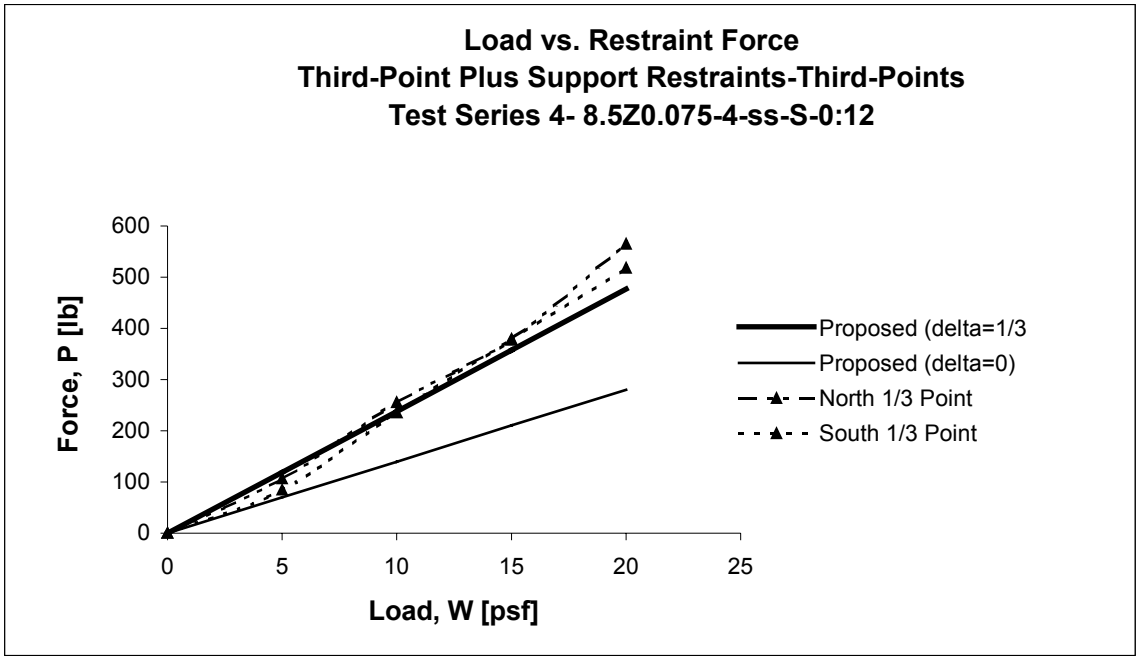
Test Series 4- 8.5Z0.075-4-ss-S-20psf Third-Point Plus Support Restraints-Supports				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0.0	196	115	0	13
2.4	163	81	0	15
4.8	129	47	0	18
14.0	-6	-85	-88	-47
18.3	-71	-148	-172	-156



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 101
Test Date: 2-1-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Third-Point Plus Support

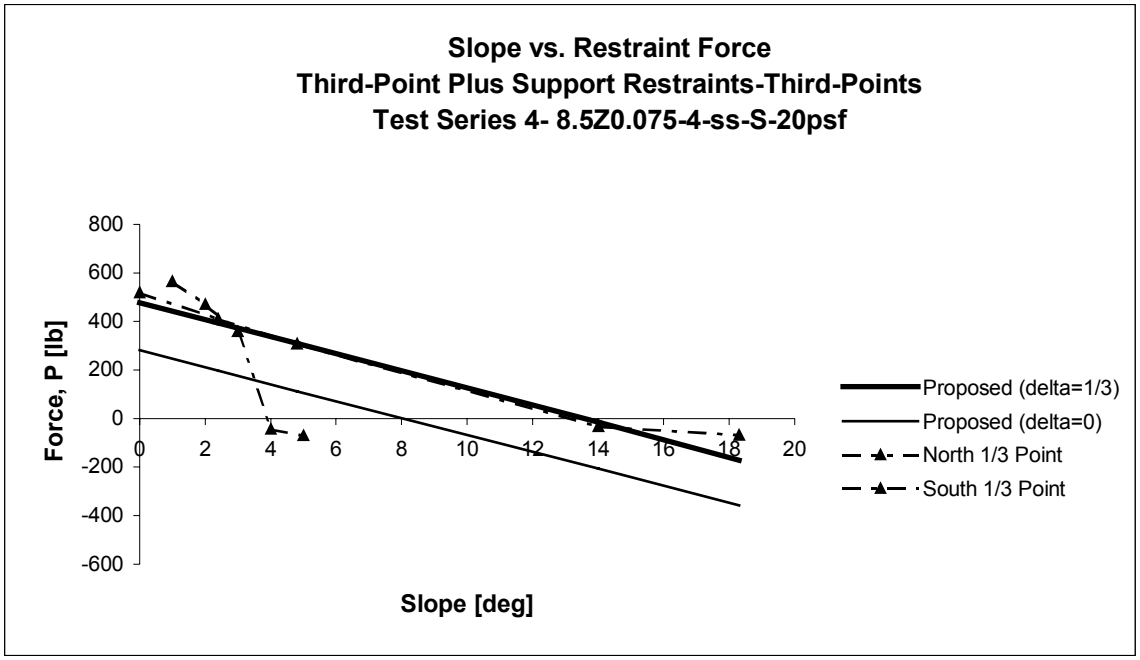
Test Series 4- 8.5Z0.075-4-ss-S-0:12 Third-Point Plus Support Restraints-Third-Points				
Load, [psf]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0	0	0	0	0
5	119	70	106	84
10	238	140	255	235
15	357	210	379	377
20	477	280	565	518



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 102
Test Date: 2-1-01
Span Length: 20 ft.
Number of Purlins: 4 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Third-Point Plus Support

Test Series 4- 8.5Z0.075-4-ss-S-20psf Third-Point Plus Support Restraints-Third-Points				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North 1/3 Point**	**South 1/3 Point**
0.0	477	282	565	518
2.4	394	198	471	412
4.8	309	113	358	307
14.0	-16	-206	-45	-33
18.3	-171	-358	-71	-68

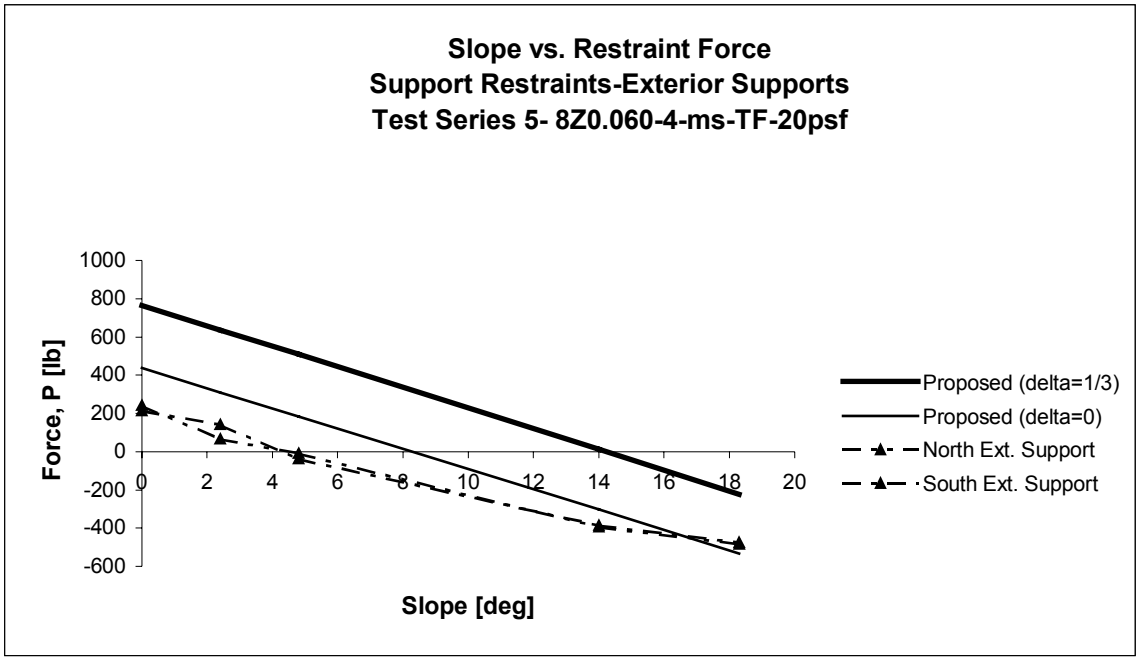


APPENDIX F-Series 5: 8Z0.060-4-ms-TF Results

Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 103
Test Date: 3-6-01
Span Length: 3 @ 20 ft.
Number of Purlins: 4 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Support

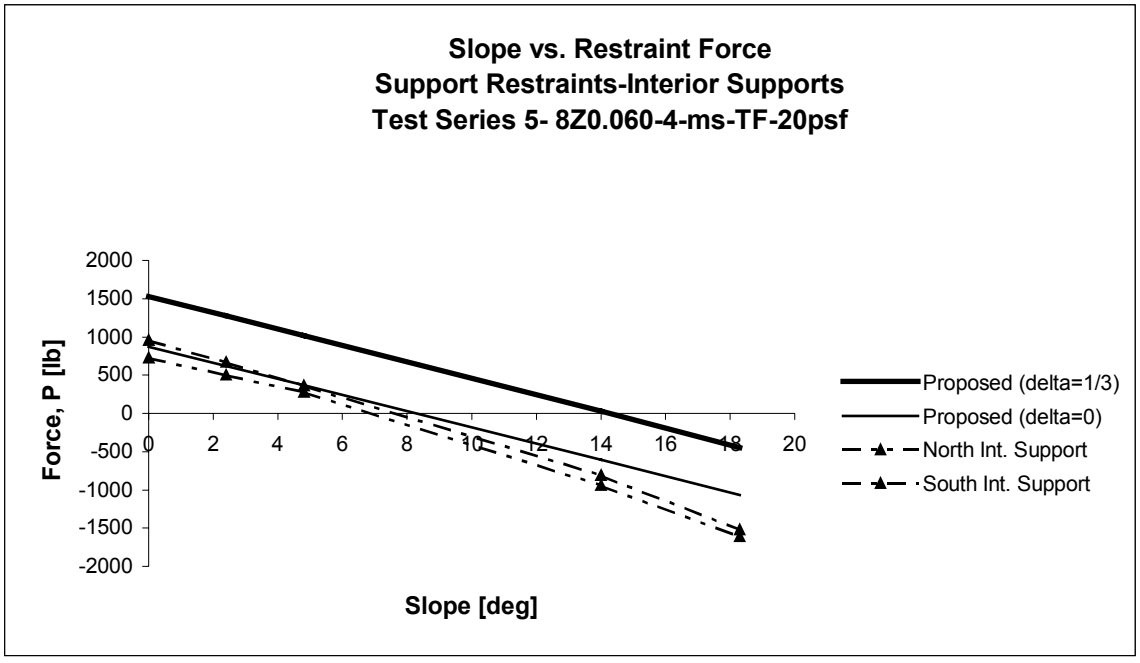
Test Series 5- 8Z0.060-4-ms-TF-20psf Support Restraints-Exterior Supports				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Ext. Support**	**South Ext. Support**
0.0	763	436	242	215
2.4	636	310	66	142
4.8	509	183	-10	-37
14.0	14	-303	-394	-385
18.3	-223	-534	-483	-475



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 104
Test Date: 3-6-01
Span Length: 3 @ 20 ft.
Number of Purlins: 4 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Support

Test Series 5- 8Z0.060-4-ms-TF-20psf Support Restraints-Interior Supports				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Int. Support**	**South Int. Support**
0.0	1525	871	722	955
2.4	1273	619	502	671
4.8	1018	366	278	362
14.0	29	-606	-942	-810
18.3	-446	-1067	-1610	-1519

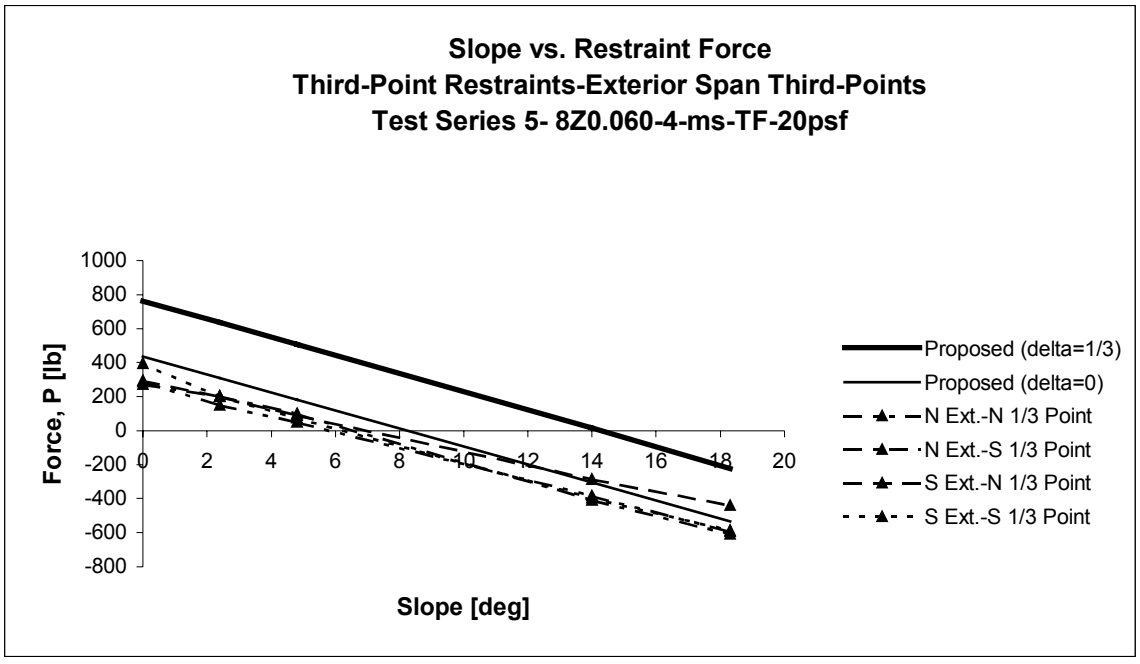


Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 105
Test Date: 3-8-01
Span Length: 3 @ 20 ft.
Number of Purlins: 4 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point

Test Series 5- 8Z0.060-4-ms-TF-20psf Third-Point Restraints-Exterior Span Third Points		
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**
0.0	763	436
2.4	636	310
4.8	509	182
14.0	14	-303
18.3	-223	-534

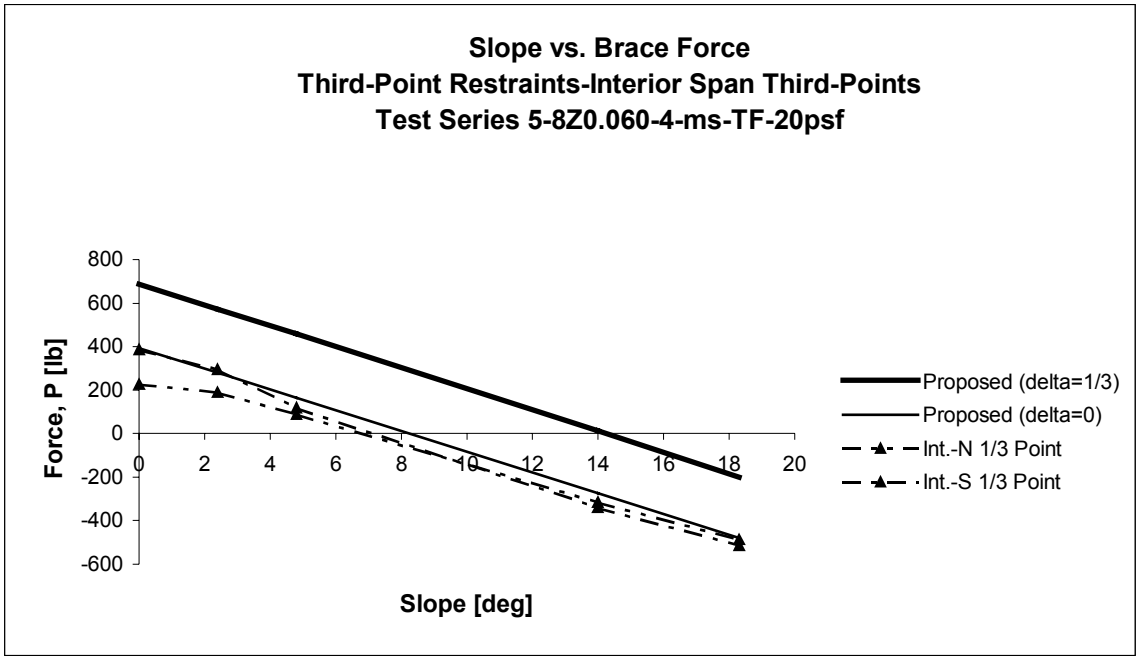
N Ext.-N 1/3 Point	N Ext.-S 1/3 Point	S Ext.-N 1/3 Point	S Ext.-S 1/3 Point
288	272	295	394
150	204	200	200
51	99	92	76
-382	-408	-285	-395
-592	-608	-440	-587



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 106
Test Date: 3-8-01
Span Length: 3 @ 20 ft.
Number of Purlins: 4 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point

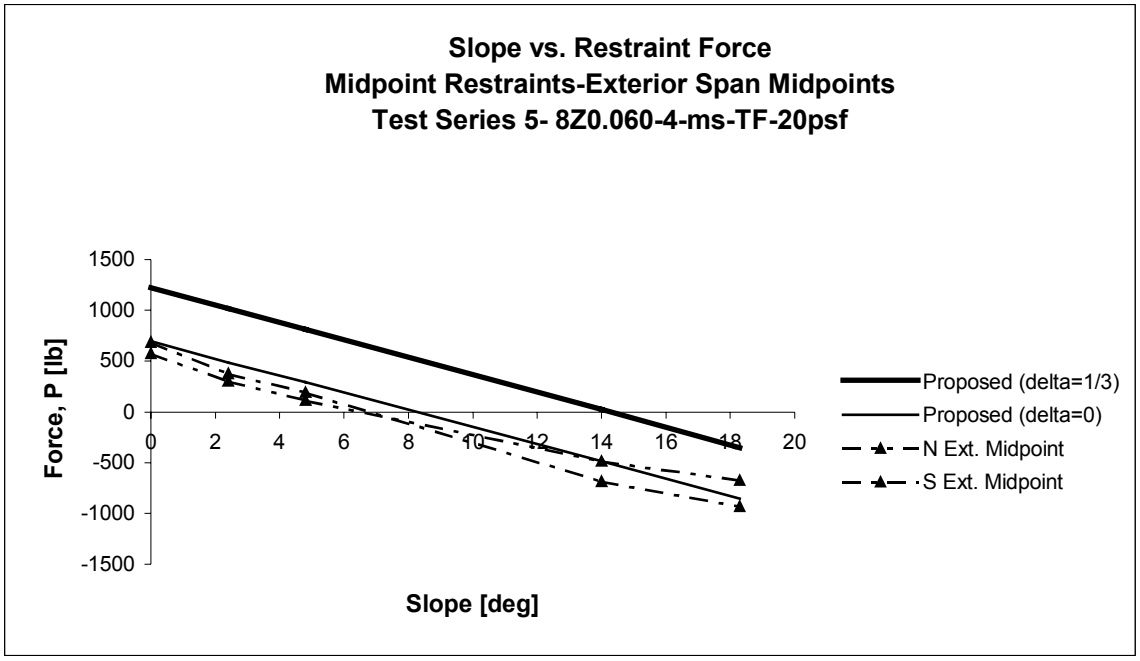
Test Series 5- 8Z0.060-4-ms-TF-20psf Third-Point Restraints-Interior Span Third Points				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Int.-N 1/3 Point**	**Int.-S 1/3 Point**
0.0	686	392	227	386
2.4	573	279	190	295
4.8	458	165	90	118
14.0	13	-273	-315	-340
18.3	-201	-480	-487	-515



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 107
Test Date: 3-12-01
Span Length: 3 @ 20 ft.
Number of Purlins: 4 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Midpoint

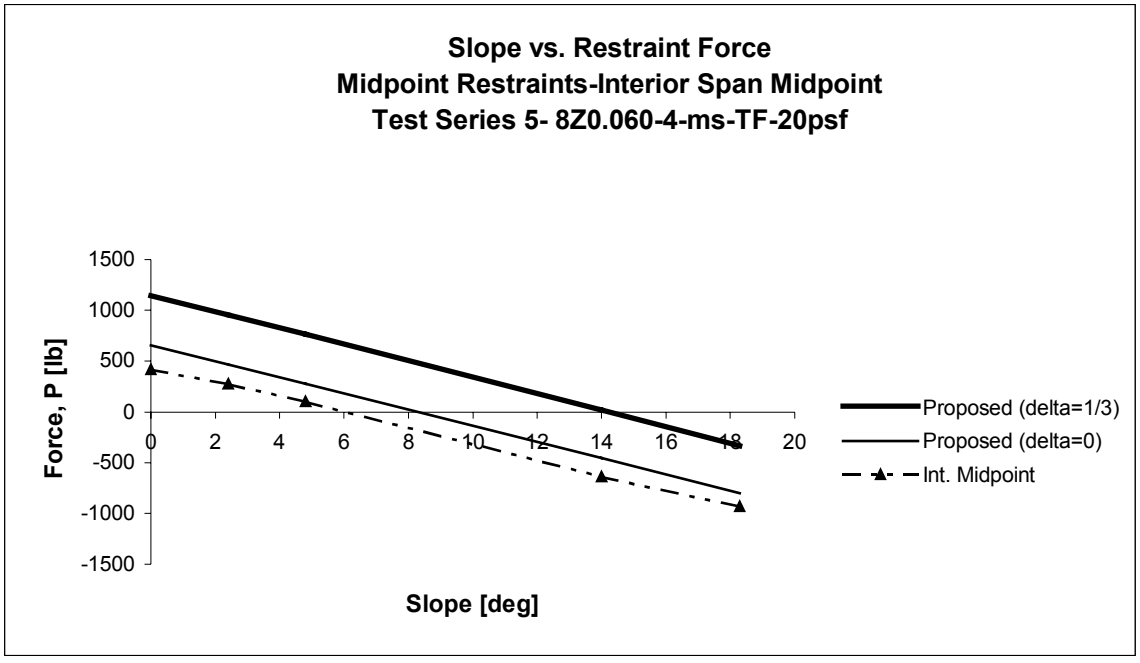
Test Series 5- 8Z0.060-4-ms-TF-20psf Midpoint Restraints-Exterior Span Midpoints				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**N Ext. Midpoint**	**S Ext. Midpoint**
0.0	1220	697	573	684
2.4	1018	486	303	377
4.8	814	293	112	192
14.0	23	-485	-488	-686
18.3	-357	-854	-676	-932



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 108
Test Date: 3-12-01
Span Length: 3 @ 20 ft.
Number of Purlins: 4 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Midpoint

Test Series 5- 8Z0.060-4-ms-TF-20psf Midpoint Restraints-Interior Span Midpoint			
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Int. Midpoint**
0.0	1144	654	418
2.4	955	465	276
4.8	763	275	100
14.0	21	-455	-638
18.3	-335	-800	-932

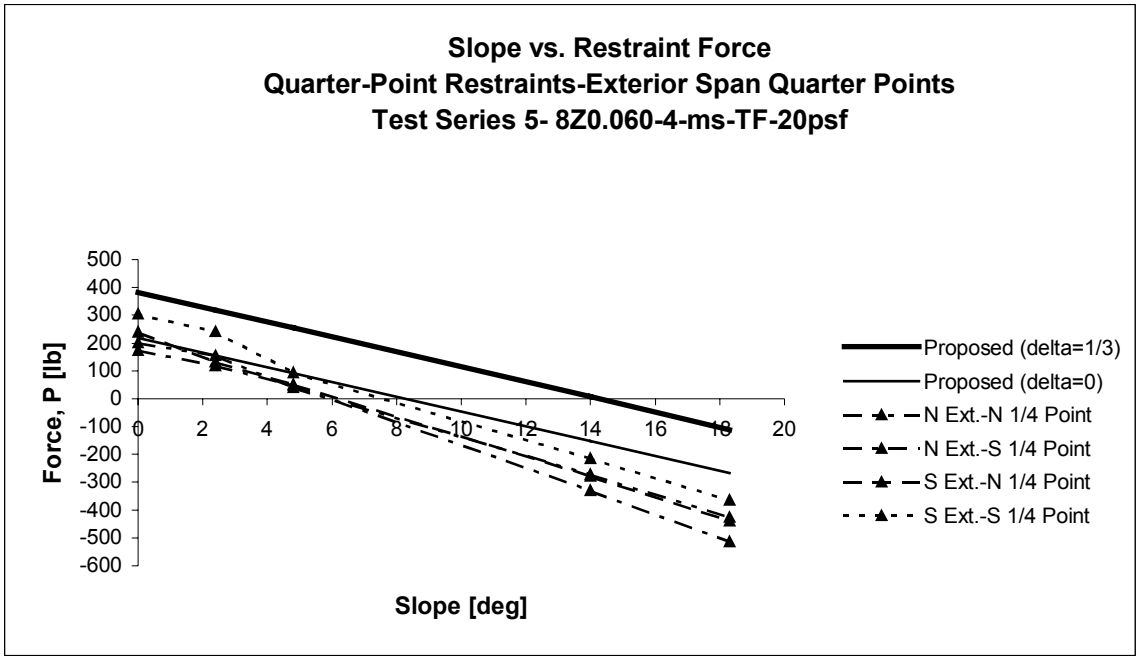


Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 109
Test Date: 3-14-01
Span Length: 3 @ 20 ft.
Number of Purlins: 4 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

Test Series 5- 8Z0.060-4-ms-TF-20psf Quarter-Point Restraints-Exterior Span Quarter Points		
Slope [deg]	Proposed (delta=1/3)	Proposed (delta=0)
0.0	381	218
2.4	318	155
4.8	254	92
14.0	7	-152
18.3	-112	-267

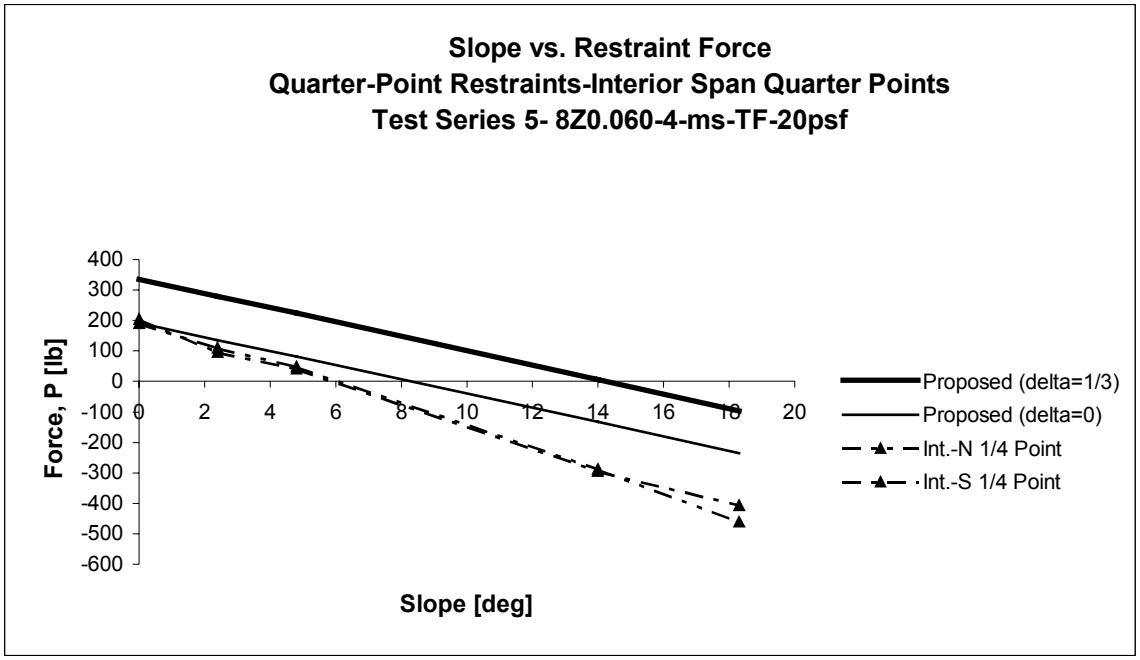
N Ext.-N 1/4 Point	N Ext.-S 1/4 Point	S Ext.-N 1/4 Point	S Ext.-S 1/4 Point
202	174	239	305
156	119	132	241
41	48	51	94
-272	-329	-279	-214
-425	-513	-439	-364



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 110
Test Date: 3-14-01
Span Length: 3 @ 20 ft.
Number of Purlins: 4 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

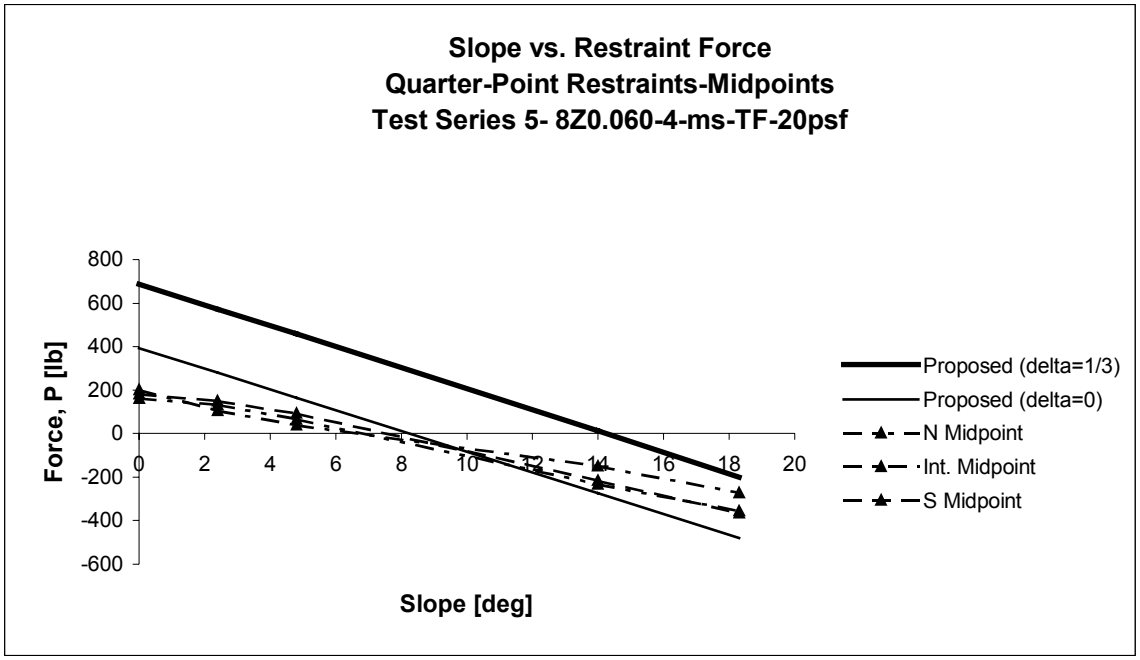
Test Series 5- 8Z0.060-4-ms-TF-20psf Quarter-Point Restraints-Interior Span Quarter Points				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Int.-N 1/4 Point**	**Int.-S 1/4 Point**
0.0	336	192	189	203
2.4	280	136	110	95
4.8	224	81	48	41
14.0	6	-133	-288	-296
18.3	-98	-235	-461	-408



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 111
Test Date: 3-14-01
Span Length: 3 @ 20 ft.
Number of Purlins: 4 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Quarter-Point

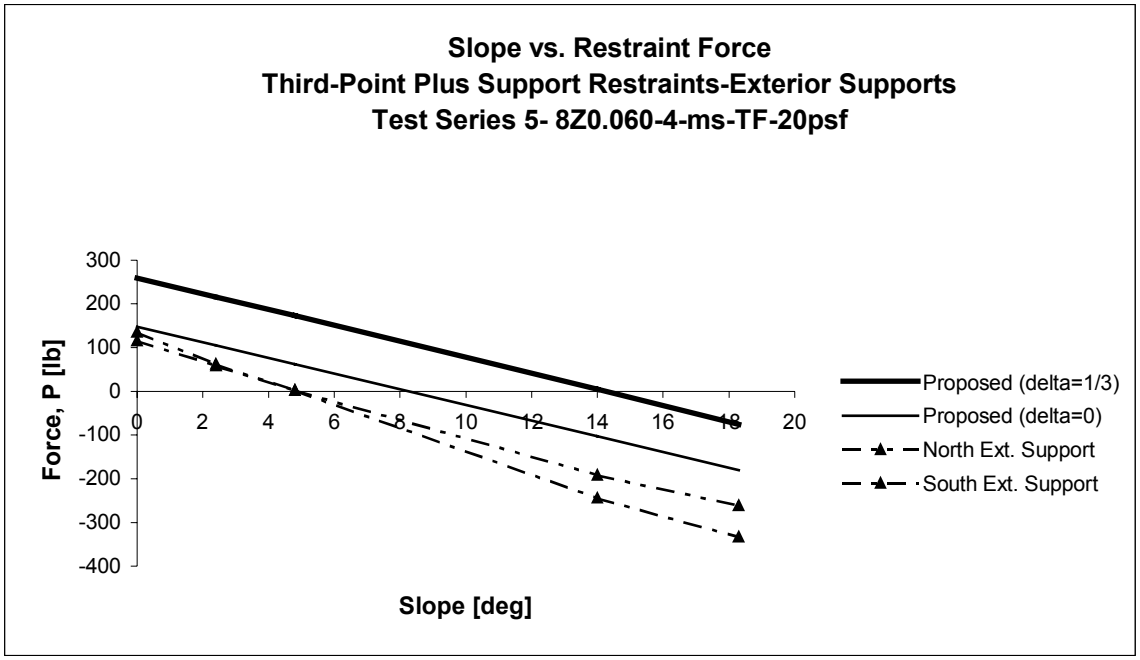
Test Series 5- 8Z0.060-4-ms-TF-20psf Quarter-Point Restraints-Midpoints					
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**N Midpoint**	**Int. Midpoint**	**S Midpoint**
0.0	686	392	163	201	181
2.4	573	279	132	106	150
4.8	458	165	66	39	94
14.0	13	-273	-232	-149	-214
18.3	-201	-480	-356	-272	-364



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 112
Test Date: 3-19-01
Span Length: 3 @ 20 ft.
Number of Purlins: 4 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

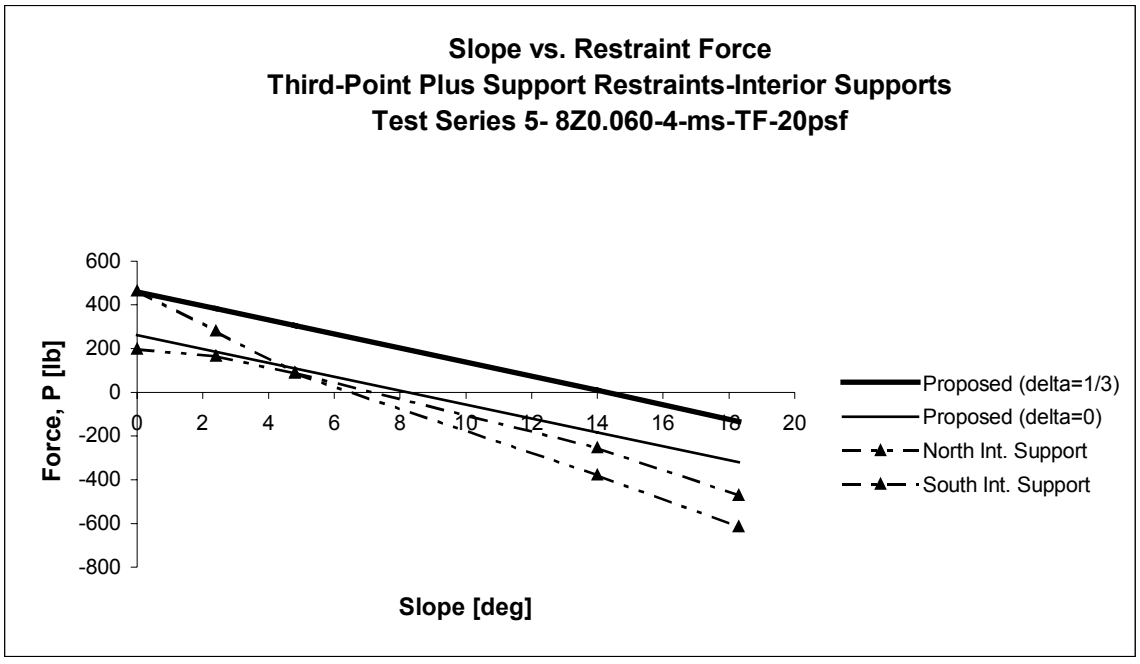
Test Series 5- 8Z0.060-4-ms-TF-20psf Third-Point Plus Support Restraints-Exterior Supports				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Ext. Support**	**South Ext. Support**
0.0	259	148	135	116
2.4	216	105	62	59
4.8	173	62	3	3
14.0	5	-103	-192	-244
18.3	-76	-181	-261	-333



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 113
Test Date: 3-19-01
Span Length: 3 @ 20 ft.
Number of Purlins: 4 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

Test Series 5- 8Z0.060-4-ms-TF-20psf Third-Point Plus Support Restraints-Interior Supports				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Int. Support**	**South Int. Support**
0.0	458	261	197	463
2.4	382	186	165	281
4.8	305	110	87	91
14.0	9	-182	-379	-253
18.3	-134	-320	-614	-471

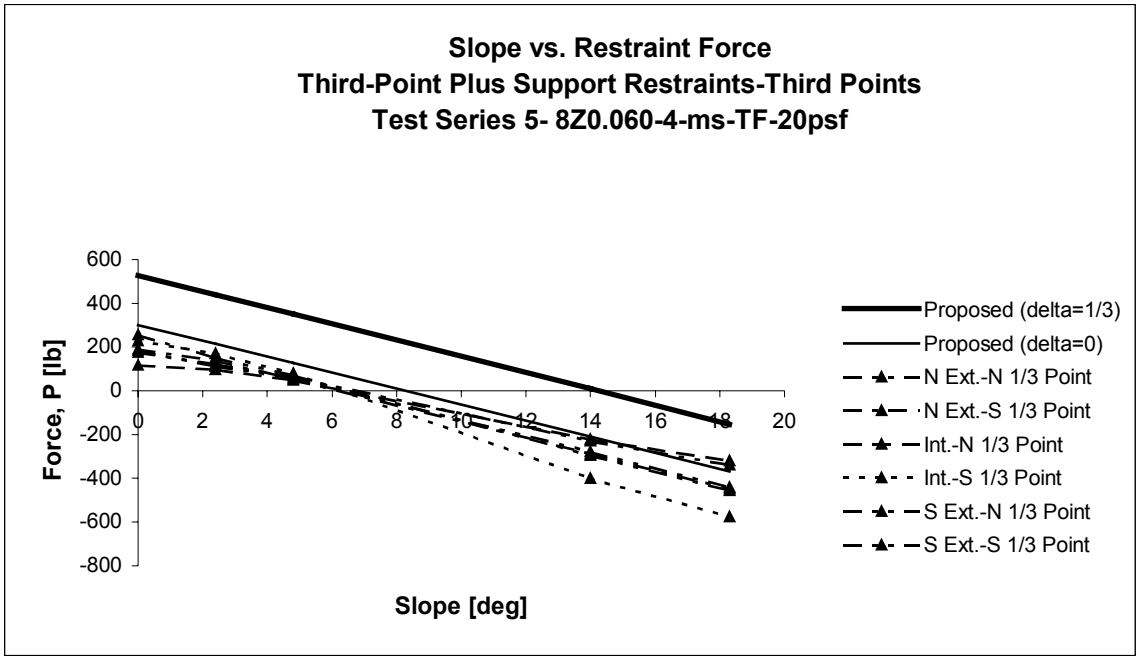


Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 114
Test Date: 3-19-01
Span Length: 3 @ 20 ft.
Number of Purlins: 4 Thickness: 0.060 in.
Deck Type: Through-Fastened Bracing Configuration: Third-Point Plus Support

Test Series 5- 8Z0.060-4-ms-TF-20psf Third-Point Plus Support Restraints-Third Points		
Slope [deg]	Proposed (delta=1/3)	Proposed (delta=0)
0.0	528	301
2.4	440	214
4.8	352	127
14.0	10	-210
18.3	-154	-369

N Ext.-N 1/3 Point	N Ext.-S 1/3 Point	Int.-N 1/3 Point	Int.-S 1/3 Point	S Ext.-N 1/3 Point	S Ext.-S 1/3 Point
185	191	116	230	176	256
112	140	98	170	123	152
58	54	50	81	63	70
-278	-289	-222	-400	-229	-295
-442	-448	-319	-575	-340	-456

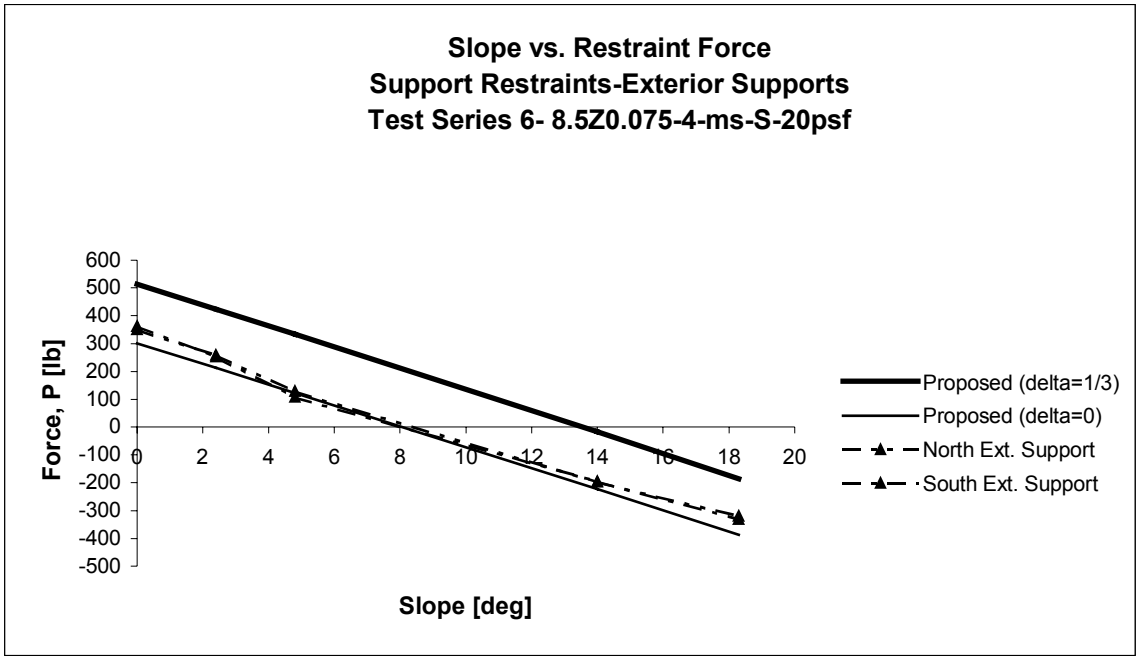


APPENDIX G-Series 6: 8.5Z0.075-4-ms-S Results

Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 115
Test Date: 3-27-01
Span Length: 3 @ 20 ft.
Number of Purlins: 4 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Support

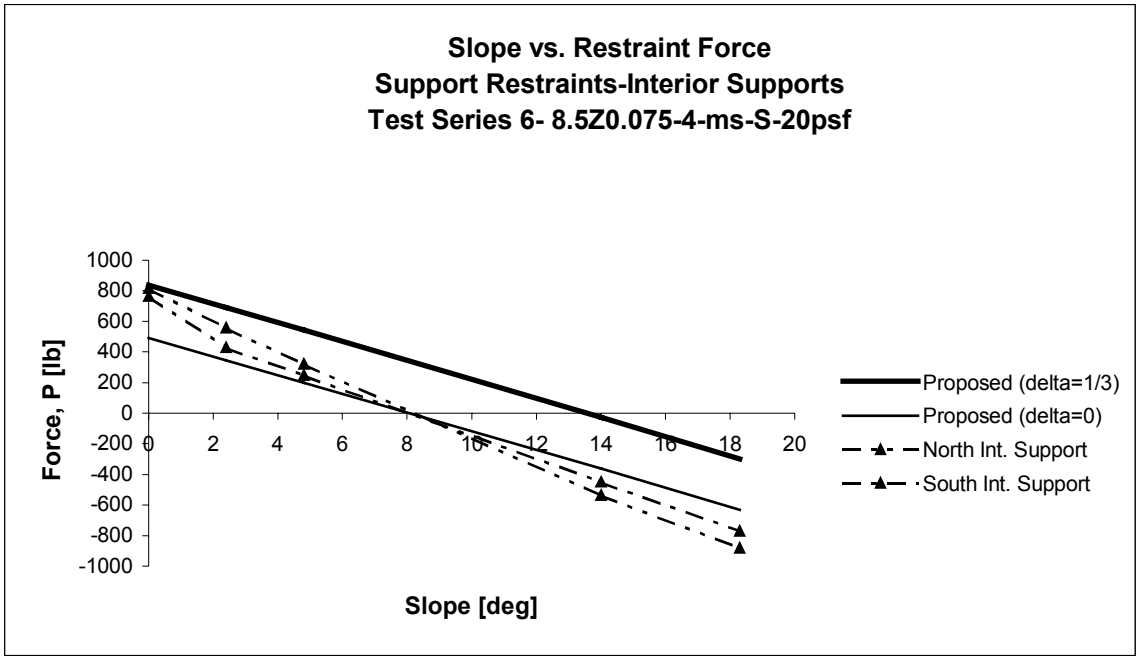
Test Series 6- 8.5Z0.075-4-ms-S-20psf Support Restraints-Exterior Supports				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Ext. Support**	**South Ext. Support**
0.0	514	301	351	363
2.4	424	212	259	254
4.8	334	123	128	107
14.0	-17	-223	-197	-195
18.3	-185	-386	-320	-331



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 116
Test Date: 3-27-01
Span Length: 3 @ 20 ft.
Number of Purlins: 4 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Support

Test Series 6- 8.5Z0.075-4-ms-S-20psf Support Restraints-Interior Supports				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Int. Support**	**South Int. Support**
0.0	837	491	817	763
2.4	691	346	557	427
4.8	544	199	322	246
14.0	-27	-362	-538	-448
18.3	-301	-629	-880	-770

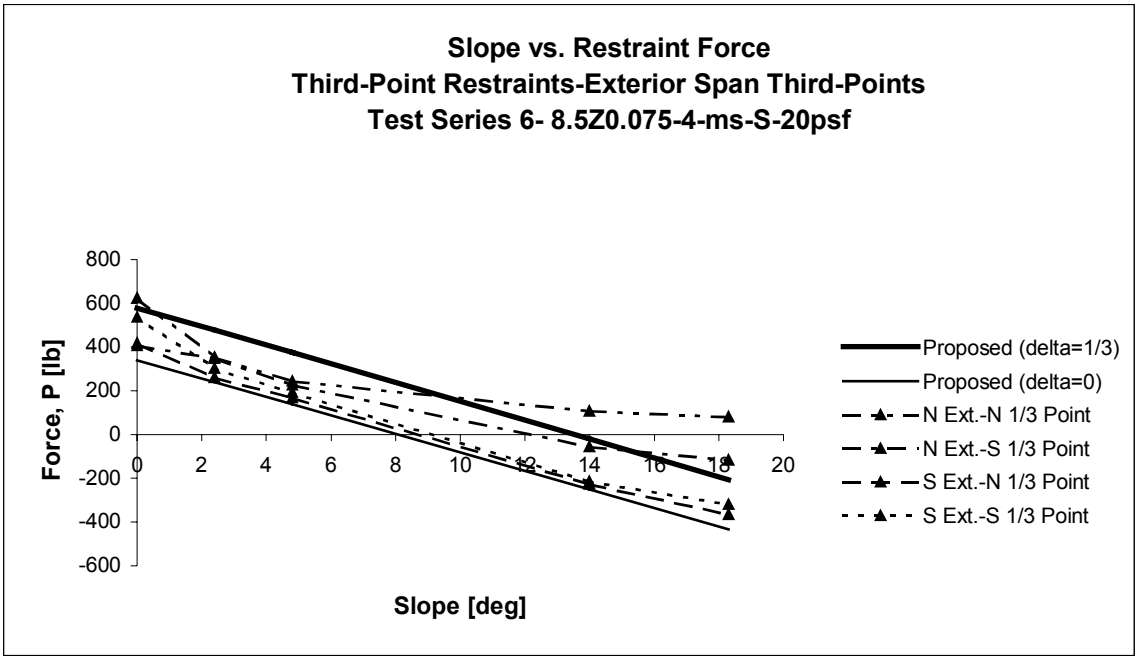


Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 117
Test Date: 3-29-01
Span Length: 3 @ 20 ft.
Number of Purlins: 4 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Third-Point

Test Series 6- 8.5Z0.075-4-ms-S-20psf Third-Point Restraints-Exterior Span Third-Points		
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**
0.0	577	339
2.4	477	239
4.8	376	138
14.0	-19	-250
18.3	-207	-433

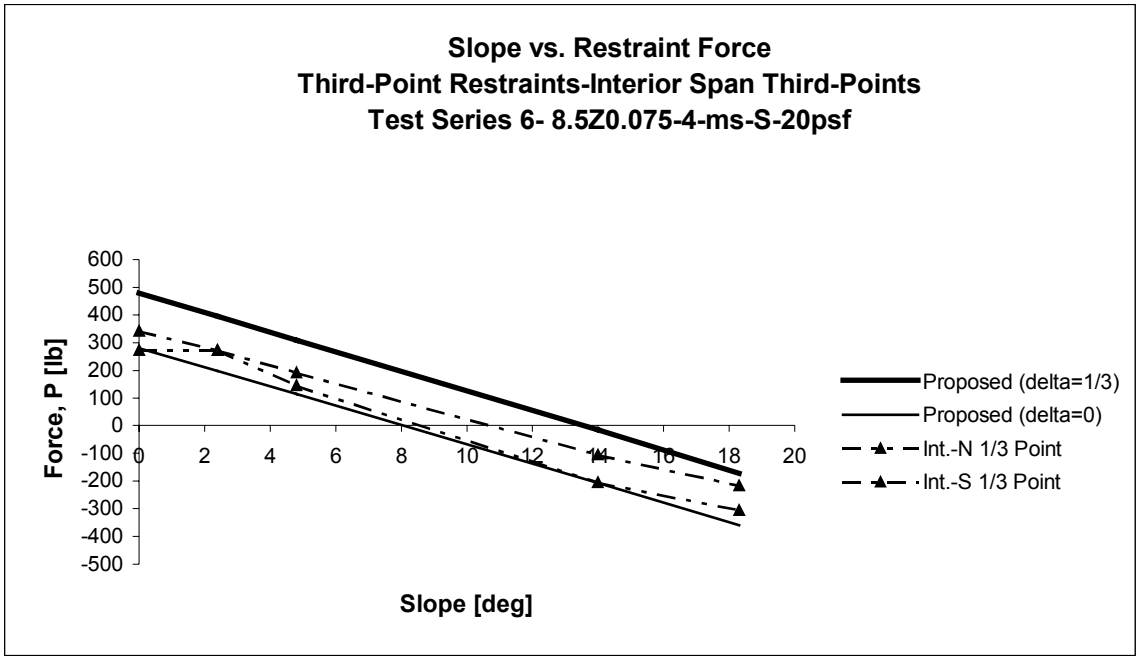
N Ext.-N 1/3 Point	N Ext.-S 1/3 Point	S Ext.-N 1/3 Point	S Ext.-S 1/3 Point
625	407	417	536
353	349	262	303
245	226	168	192
108	-55	-226	-215
80	-117	-365	-320



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 118
Test Date: 3-29-01
Span Length: 3 @ 20 ft.
Number of Purlins: 4 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Third-Point

Test Series 6- 8.5Z0.075-4-ms-S-20psf Third-Point Restraints-Interior Span Third-Points				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Int.-N 1/3 Point**	**Int.-S 1/3 Point**
0.0	478	281	273	341
2.4	395	197	273	272
4.8	310	114	146	192
14.0	-15	-207	-205	-106
18.3	-172	-359	-305	-216



Test Summary

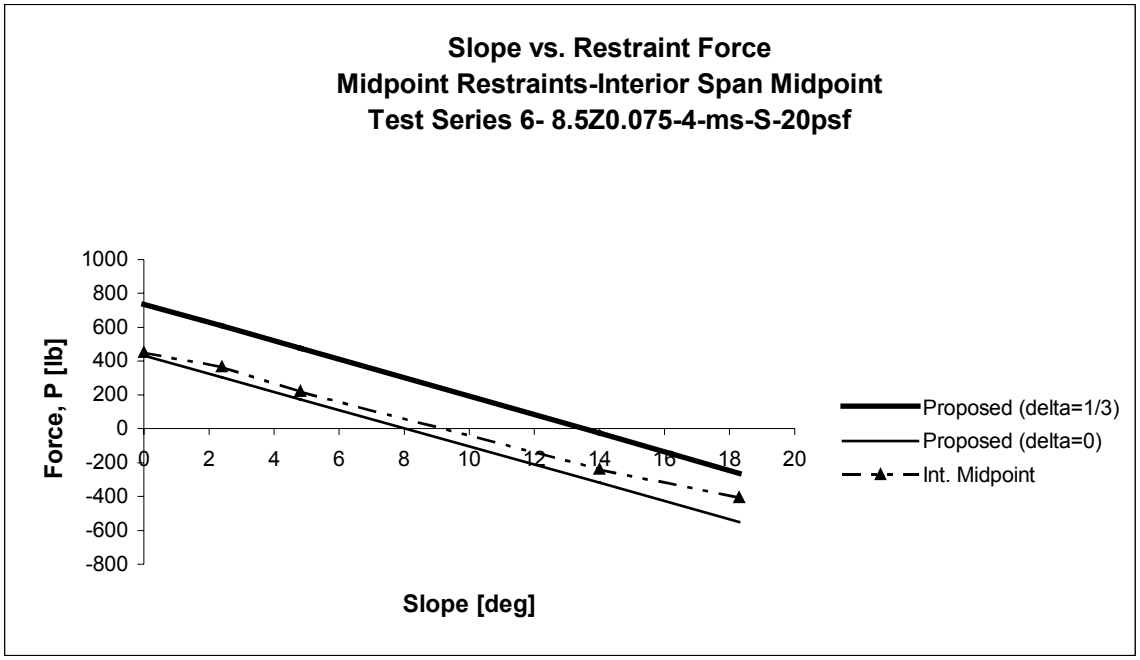
Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 119
Test Date: 4-2-01
Span Length: 3 @ 20 ft.
Number of Purlins: 4 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Midpoint

Test Series 6- 8.5Z0.075-4-ms-S-20psf Midpoint Restraints-Exterior Span Midpoints				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**N Ext. Midpoint**	**S Ext. Midpoint**
0.0	832	488	748	859
2.4	687	344	513	588
4.8	541	198	348	408
14.0	-27	-360	-225	-215
18.3	-298	-624	-452	-438

Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 120
Test Date: 4-2-01
Span Length: 3 @ 20 ft.
Number of Purlins: 4 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Midpoint

Test Series 6- 8.5Z0.075-4-ms-S-20psf Midpoint Restraints-Interior Span Midpoint			
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Int. Midpoint**
0.0	736	432	450
2.4	608	304	365
4.8	478	175	220
14.0	-24	-319	-239
18.3	-264	-552	-405

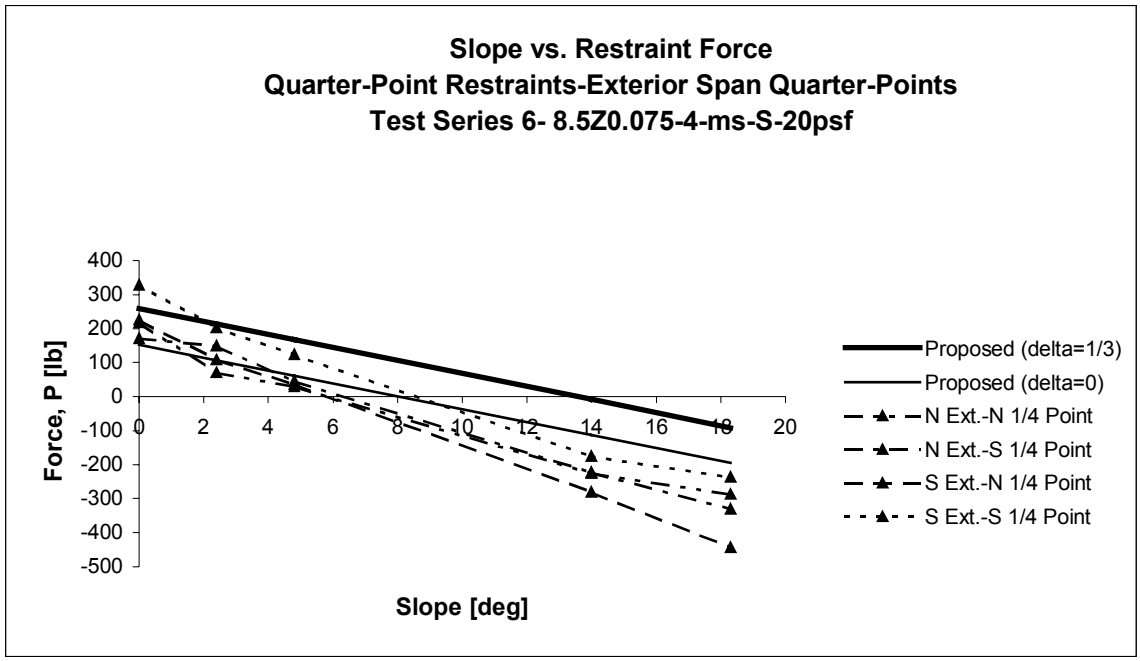


Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 121
Test Date: 4-3-01
Span Length: 3 @ 20 ft.
Number of Purlins: 4 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Quarter-Point

Test Series 6- 8.5Z0.075-4-ms-S-20psf Quarter-Point Restraints-Exterior Span Quarter-Points		
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**
0.0	259	152
2.4	214	107
4.8	168	62
14.0	-8	-112
18.3	-93	-194

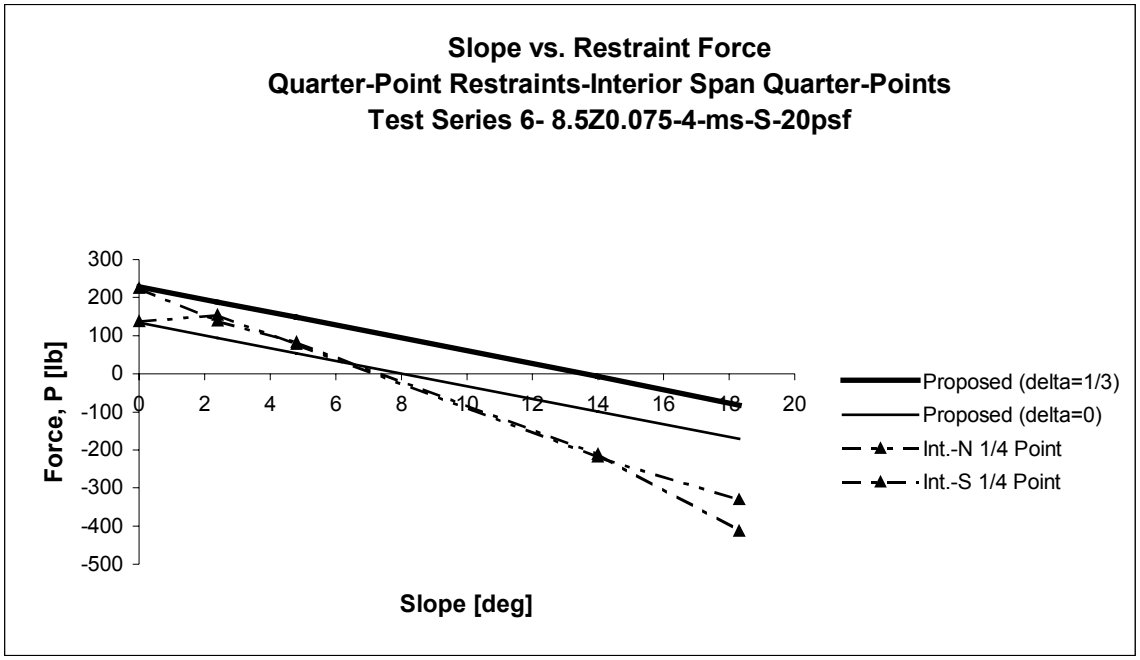
N Ext.-N 1/4 Point	N Ext.-S 1/4 Point	S Ext.-N 1/4 Point	S Ext.-S 1/4 Point
218	171	226	328
70	149	109	203
30	45	37	124
-225	-223	-281	-176
-286	-330	-443	-237



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 122
Test Date: 4-3-01
Span Length: 3 @ 20 ft.
Number of Purlins: 4 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Quarter-Point

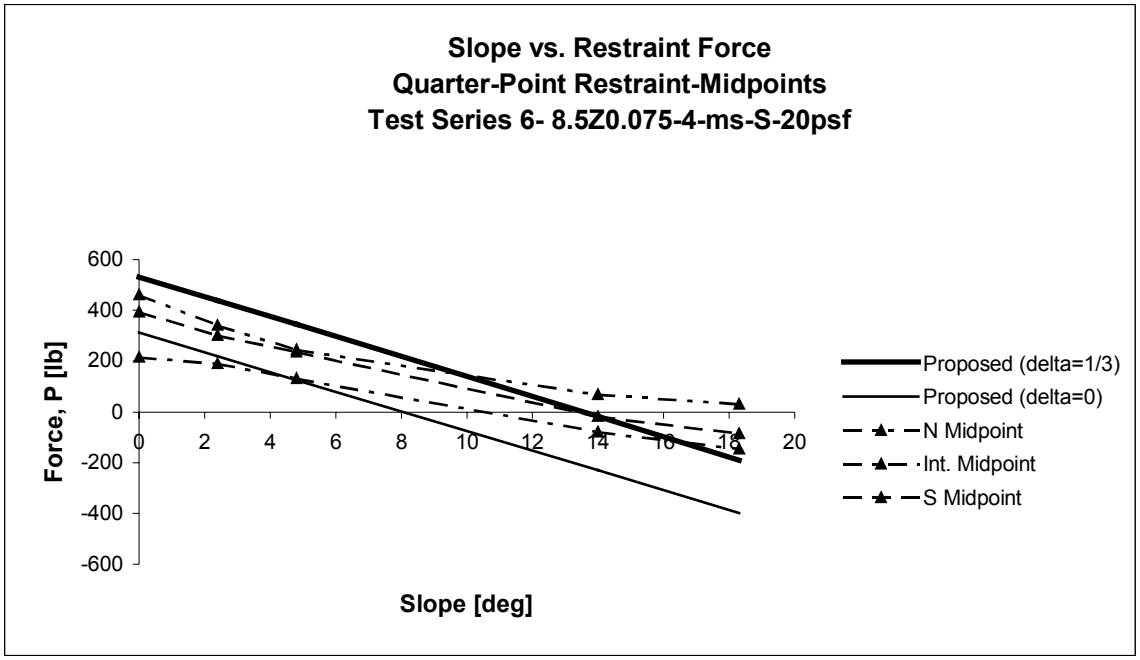
Test Series 6- 8.5Z0.075-4-ms-S-20psf Quarter-Point Restraints-Interior Span Quarter-Points				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**Int.-N 1/4 Point**	**Int.-S 1/4 Point**
0.0	228	134	138	225
2.4	188	94	154	139
4.8	148	54	77	83
14.0	-7	-99	-219	-212
18.3	-82	-171	-331	-413



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 123
Test Date: 4-3-01
Span Length: 3 @ 20 ft.
Number of Purlins: 4 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Quarter-Point

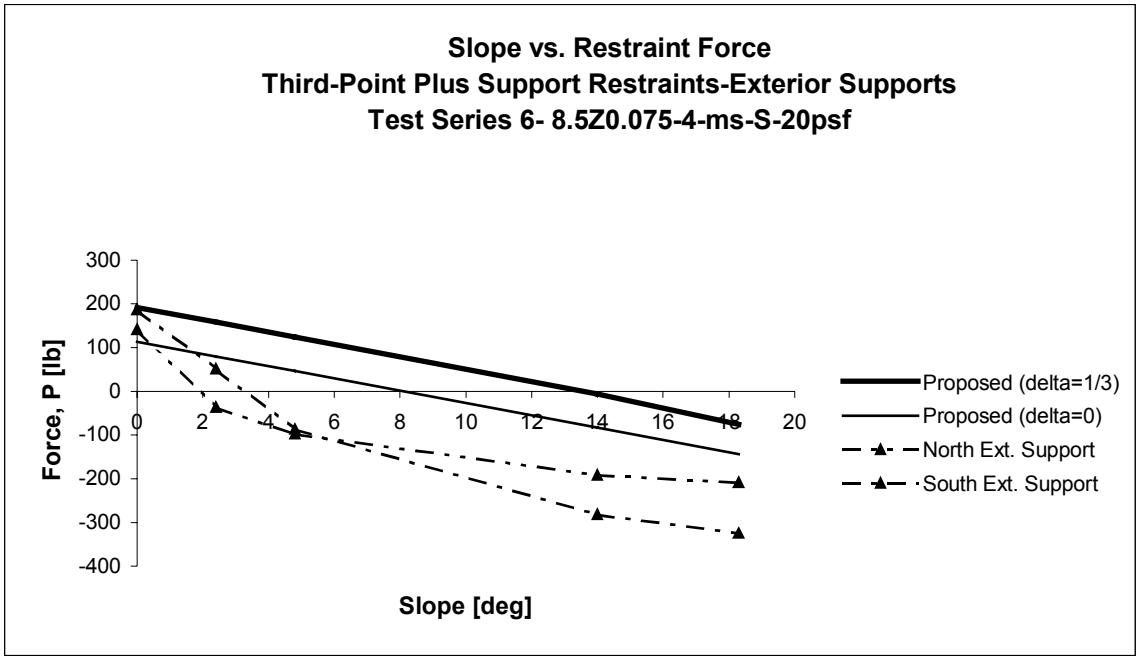
Test Series 6- 8.5Z0.075-4-ms-S-20psf Quarter-Point Restraints-Midpoints					
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**N Midpoint**	**Int. Midpoint**	**S Midpoint**
0.0	530	312	461	215	393
2.4	438	219	341	191	302
4.8	345	126	245	131	236
14.0	-17	-230	68	-79	-17
18.3	-190	-399	30	-146	-85



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 124
Test Date: 4-9-01
Span Length: 3 @ 20 ft.
Number of Purlins: 4 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Third-Point Plus Support

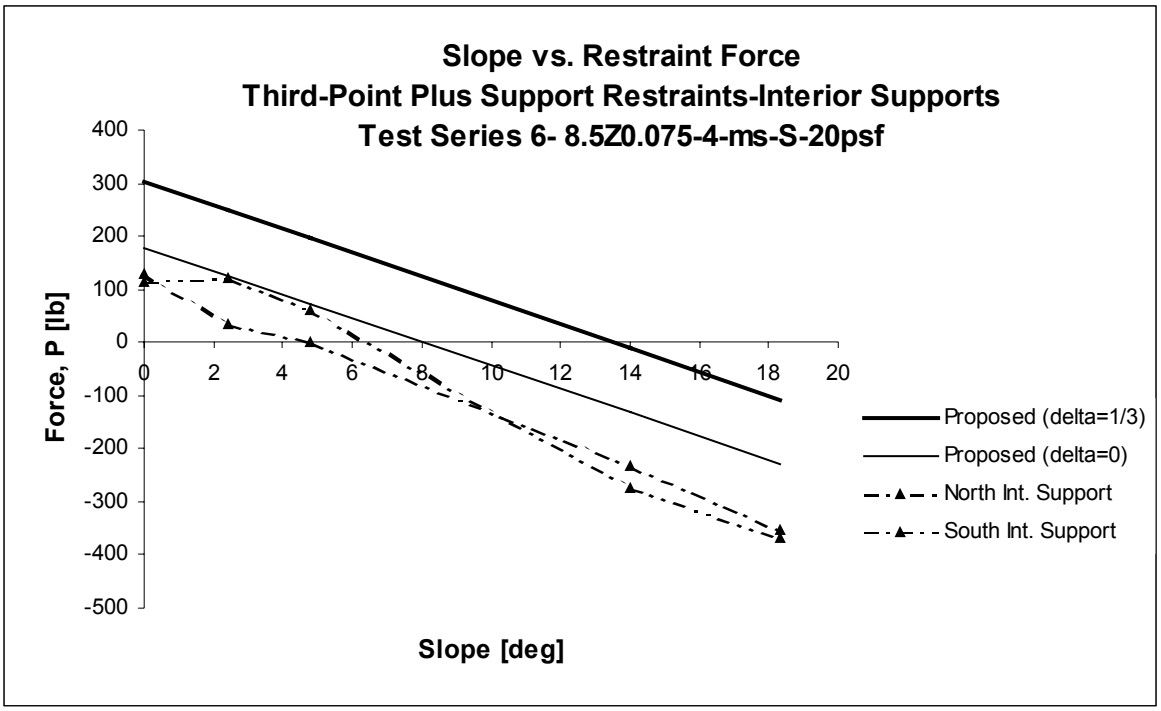
Test Series 6- 8.5Z0.075-4-ms-S-20psf Third-Point Plus Support Restraints-Exterior Supports				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Ext. Support**	**South Ext. Support**
0.0	191	113	142	186
2.4	158	79	-36	51
4.8	124	46	-97	-87
14.0	-6	-83	-192	-282
18.3	-76	-144	-208	-324



Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 125
Test Date: 4-9-01
Span Length: 3 @ 20 ft.
Number of Purlins: 4 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Third-Point Plus Support

Test Series 6- 8.5Z0.075-4-ms-S-20psf Third-Point Plus Support Restraints-Interior Supports				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Int. Support**	**South Int. Support**
0.0	302	177	114	129
2.4	249	125	121	34
4.8	196	72	62	0
14.0	-10	-131	-275	-231
18.3	-109	-227	-370	-354

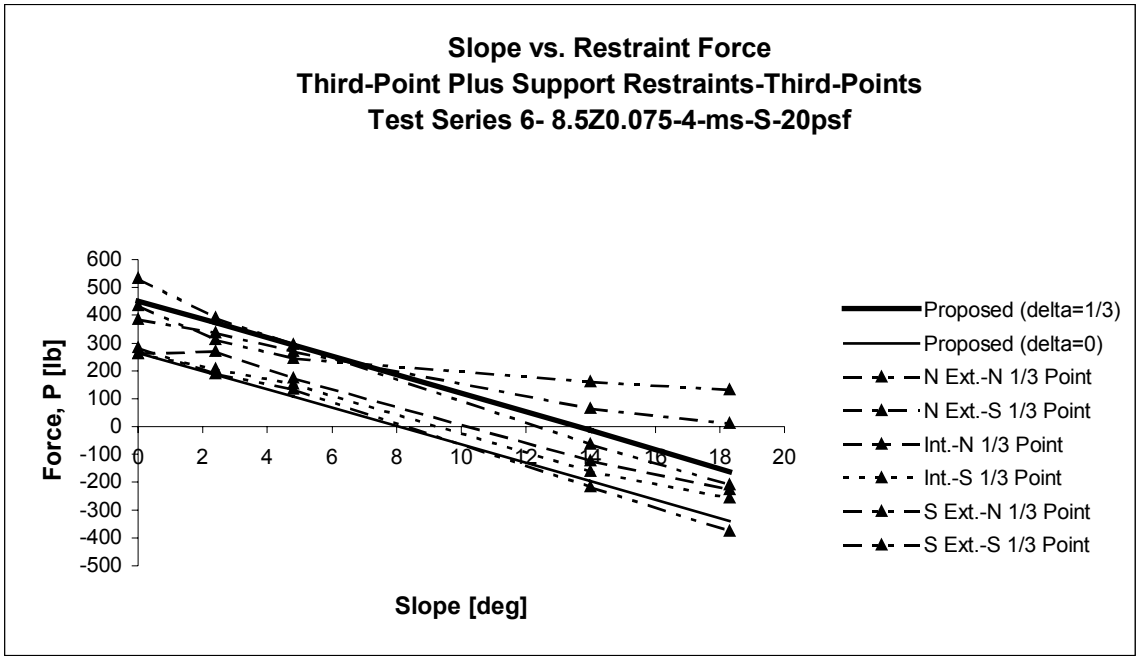


Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 126
Test Date: 4-9-01
Span Length: 3 @ 20 ft.
Number of Purlins: 4 Thickness: 0.075 in.
Deck Type: Standing Seam Bracing Configuration: Third-Point Plus Support

Test Series 6- 8.5Z0.075-4-ms-S-20psf Third-Point Plus Support Restraints-Third-Points		
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**
0.0	451	265
2.4	373	186
4.8	293	108
14.0	-14	-195
18.3	-163	-339

NExt.-N 1/3 Point	NExt.-S 1/3 Point	Int.-N 1/3 Point	Int.-S 1/3 Point	SExt.-N 1/3 Point	SExt.-S 1/3 Point
436	386	263	262	283	533
313	337	270	207	189	391
245	271	175	154	135	295
161	66	-123	-160	-216	-63
132	11	-226	-256	-376	-209

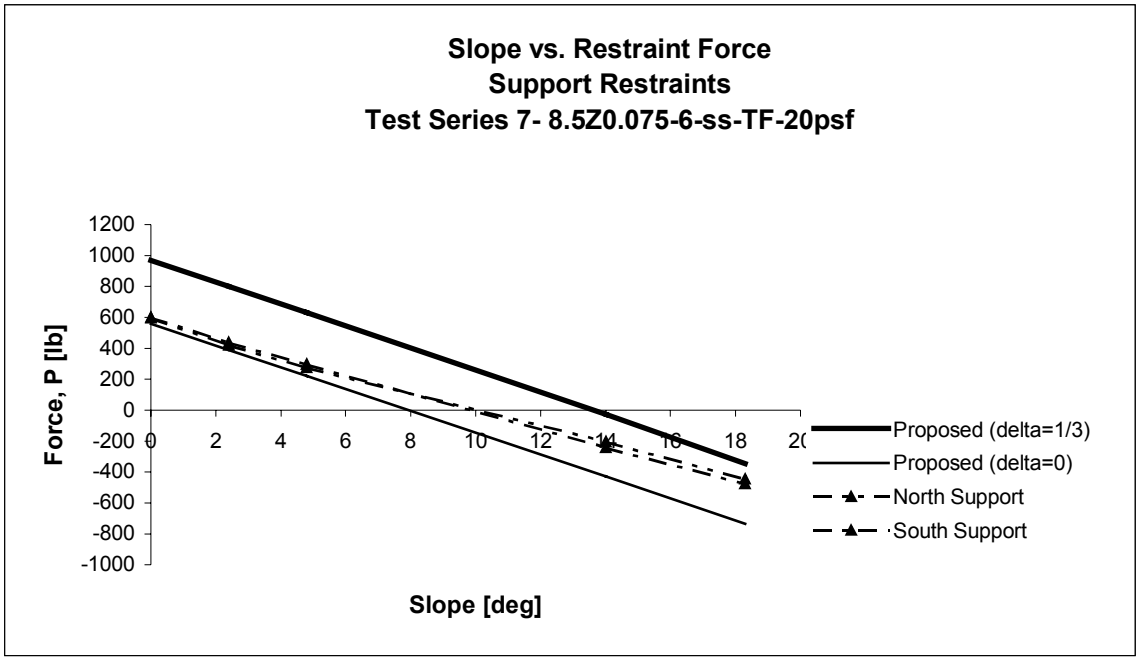


APPENDIX H-Series 7: 8.5Z0.075-6-ss-TF Results

Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 127
Test Date: 5-10-01
Span Length: 16 ft.
Number of Purlins: 6 Thickness: 0.075 in.
Deck Type: Through-Fastened Bracing Configuration: Support

Test Series 7- 8.5Z0.075-6-ss-TF-20psf Support Restraints				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0.0	968	558	597	600
2.4	800	390	421	437
4.8	630	221	277	298
14.0	-28	-426	-205	-242
18.3	-344	-733	-445	-476

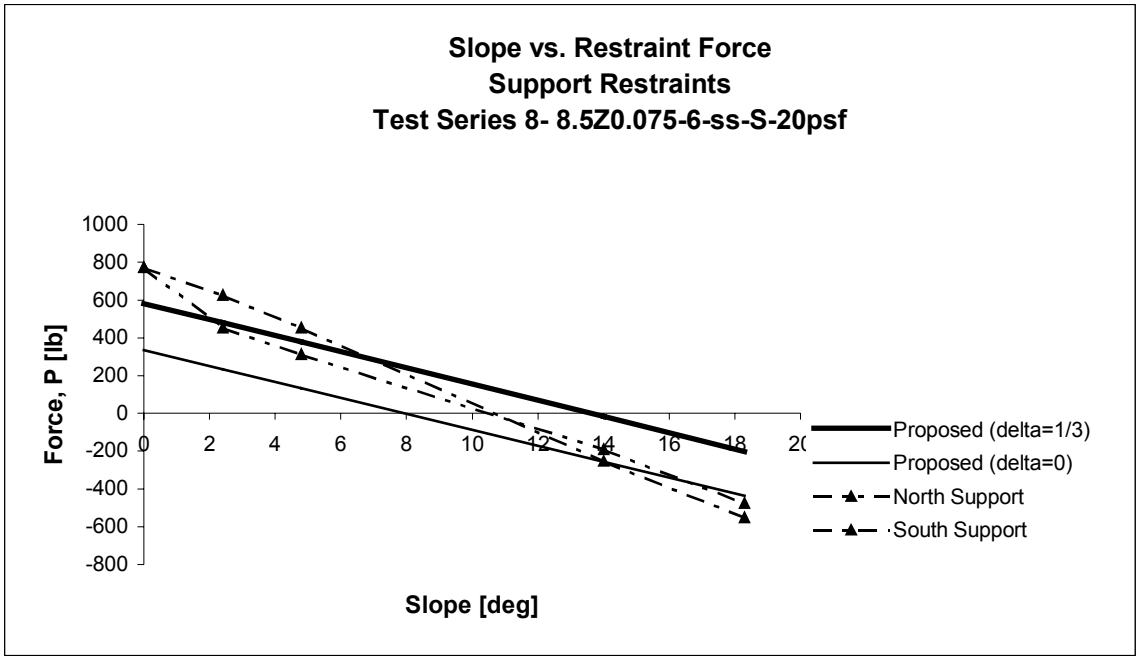


APPENDIX I-Series 8: 8.5Z0.075-6-ss-S Results

Test Summary

Project: Experimental Verification of Proposed Design Equation for Lateral Restraints
Data Sheet No.: 128
Test Date: 5-17-01
Span Length: 16 ft.
Number of Purlins: 6 Thickness: 0.075in.
Deck Type: Through-Fastened Bracing Configuration: Support

Test Series 8- 8.5Z0.075-6-ss-S-20psf Support Restraints				
Slope [deg]	**Proposed (delta=1/3)**	**Proposed (delta=0)**	**North Support**	**South Support**
0.0	581	335	771	772
2.4	480	234	454	626
4.8	378	133	313	454
14.0	-17	-256	-190	-252
18.3	-202	-436	-475	-552



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The author was born March 30, 1975 in Twin Falls, Idaho. He was raised and attended school in Jerome, Idaho. In 1999 he graduated from Brigham Young University with his Bachelors of Science Degree in Civil Engineering.

The author began his graduate studies in January of 2000 at Virginia Polytechnic Institute and State University. He was married to Emily Anderson on April 24, 1998. Upon graduation, he will continue his career at Walter P. Moore and Associates in Atlanta, Georgia.