BASE TEST METHOD FOR GRAVITY LOADED STANDING SEAM ROOF SYSTEMS

By

Brian Lee Rayburn

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APPROVED:

T. M. Murray, Chairman

D. A. Garst

W. S. Easterling

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This thesis is dedicated to my parents. Without your help this could not have been possible.

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Brian Lee Rayburn

Committee Chairman: Thomas M. Murray
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(ABSTRACT)

The base test method provides a means of determining the load carrying capacity of multiple span, multiple purlin line standing seam roof systems. The method uses results from a single span, simply supported, two purlin line experimental test, the 1986 American Iron and Steel Institute Specifications, and a stiffness analysis of the actual design system. Currently, a base test must be conducted for each combination of purlins, deck panels, and clips which a manufacturer uses. The objective of this thesis is to investigate the possibility of eliminating size of purlins, orientation of purlins, length of span, and the presence or absence of insulation from a manufacturer's required base test matrix. The findings of the investigation are based on the results of four different series of gravity load base tests. It was found that a linear relationship exists between the percentage of through-fastened capacity obtained by the purlins and their effective section moduli. This relationship was found to exist regardless of the purlin type.

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

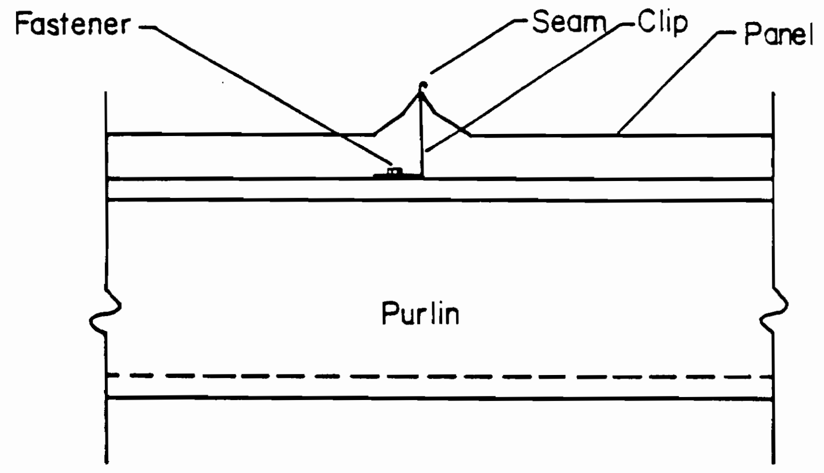
Metal buildings have become a common site in commercial and industrial surroundings. This popularity is a result of the cost effective alternative that metal buildings provide when compared to conventional construction of single story buildings. Recently, there have been many refinements in the components used in metal buildings; the most significant may be the implementation of standing seam roof systems. Standing seam roof systems provide an aesthically pleasing and functional alternative to conventional (through-fastened) roof systems.

One disadvantage to conventional roof systems is their susceptibility to leaks. The roof panels are directly attached to the purlin by a fastener which passes through the panel into the top flange of the purlin. When these roof systems are subjected to temperature expansion and contraction, the holes around the fasteners become elongated and allow moisture to pass into the building.

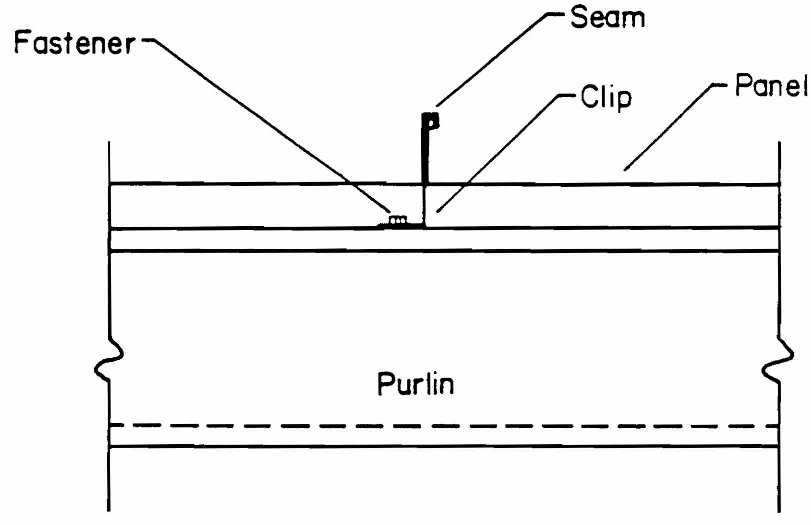
An advantage to through-fastened roofs is that the fasteners and deck panels provide full lateral support to the top flange of the purlin. By assuming constrained bending, the 1986 American Iron and Steel Institute (AISI) Specification provisions can be used to obtain design capacities for through-fastened roof systems. This provides a straightforward design method for through-fastened roof systems. By using standing seam roof systems, the problem of water leaks can be virtually eliminated. The panels used on standing seam roof systems are attached to the purlin in a different manner than panels used in through-fastened roof systems. The panel is attached to a clip which extends into the seam of adjoining panels which is above the water plane of the roof (see Figure 1.1). The clip is normally attached to the top flange of the purlin by self drilling fasteners. This type of system provides only partial lateral support to the top flange of the purlin, and thus, the analysis is much more complex.

Cold-formed Z- or C-sections are normally used to support roof panels used in metal buildings. When these sections are loaded in a plane other than that of a principle axis they will tend to rotate and deflect both vertically and laterally unless constrained from doing so (see Figure 1.2). The clips used in standing seam roof systems provide some lateral support to the top flange of the purlin, but not enough to assume full lateral support. To increase the amount of lateral bracing provided in standing seam roof systems another type of lateral support can be provided by cold-formed members known as "braces". These members are attached to a purlin at specified locations along its length to restrain it form moving out of plane. Lateral bracing is also provided to the purlin at the rafters in a building. Obviously, the function of bracing is to reduce the unbraced length of the purlin between braces.

Due to the complexity of the system, the design of a standing seam roof system is not as straight forward as that of a through-fastened roof system. If the purlins in a standing seam roof system are designed as fully laterally supported, the design would most likely be unconservative, and, if designed as laterally unsupported, the design would be too conservative to be cost effective. Currently, there is an accurate design procedure for predicting the capacity of

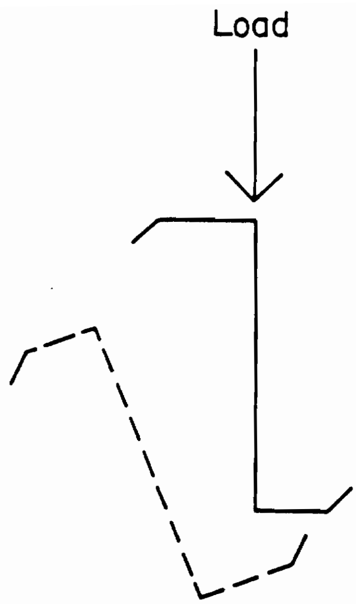


a) Rib Type Panel Seam Detail

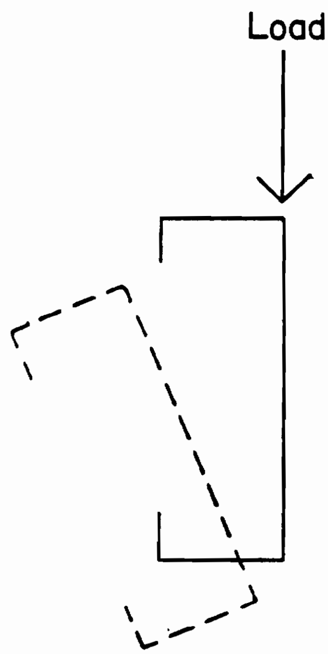


b) Pan Type Panel Seam Detail

Figure 1.1 Typical Standing Seam Roof Seam Details



a) Z-Purlin Deflection



b) C-Purlin Deflection

Figure 1.2 Deflection of Purlins

gravity loaded standing seam roof systems. This procedure is called the "base test method". The base test method requires that a two purlin line, simply supported, simple span experimental test be conducted using nominally identical components as those in the actual design system. Most manufacturers have many different sizes of purlins, deck panels, and clips. Conducting a base test for each combination of standing seam roof components which a manufacturer uses can obviously be quite expensive. The purpose of this study is to investigate the possibility of eliminating size of purlins, orientation of purlins, length of span, and the absence or presence of insulation from a manufacturer's required test matrix for the base test method.

1.2 Literature Review

Due to the relatively recent conception and development of standing seam roof systems very little research has been conducted on the subject.

Twelve experimental tests were conducted by Rivard and Murray (1986), six single span, and six continuous span tests. The single span tests were conducted at span lengths of 20 ft. The continuous span tests consisted of three spans, each at a length of 23 ft. The purlin lines were spaced at 5 ft. on center in all of the tests conducted. All of the tests consisted of gravity loaded Z-purlins, with the top flanges facing in the same direction. The experimental test program used different panel and clip types, and bracing configurations. Both rib and pan type decks were used. Bracing was provided at the rafters, third point, and midspan locations depending on the test.

Rivard (1986) examined design procedures for predicting anchorage forces in Z-purlin supported standing seam roof systems. Methods for predicting the ultimate failure loads of standing seam roof systems were also reported in his thesis. Three different procedures were used by Rivard to predict the ultimate failure loads of the systems (1) 1986 AISI Specification assuming full lateral restraint/constrained bending, (2) 1986 AISI Specification provisions for lateral buckling strength and, (3) a method proposed by the author which he termed the "Alternate Method".

In the Rivard's proposed method an allowable compressive stress was obtained from the Structural Stability Research Council (SSRC 1976) allowable stress equations. The 1986 AISI Specification procedures were then used in conjunction with the allowable compressive stresses calculated using the 1976 SSRC equations to predict the ultimate loads. Rivard found that some lateral support is provided to the purlin by the deck. The Rivard and Murray (1986) test results indicate that as the unbraced length is increased, the lateral support provided to the purlin by the deck increases. Unbraced length correction factors were developed by Rivard, based on this finding, to more accurately predict the ultimate failure load of standing seam roof systems.

Rivard's predictions of the ultimate failure loads using the 1986 AISI Specification full lateral restraint/constrained bending equations ranged from 32% to 248% unconservative. Rivard's results are expressed as percentage of error between the experimental load and the predicted loads. When the 1986 AISI lateral buckling strength provisions were used to predict the capacities, the results ranged from 32% unconservative to 76% conservative. The alternate method predicted the ultimate failure loads of the systems with results ranging from 12% unconservative to 58% conservative. Rivard concluded that more test data was needed to either refine the 1986 AISI Specification lateral buckling strength provisions or confirm the alternate method.

Four approaches were evaluated by Carballo (1989) to predict the strength of Z-purlin supported standing seam roof systems under gravity loading. The test results from Rivard and Murray (1986) were used to evaluate the predictions of the four methods. In the first approach, the 1986 AISI lateral buckling provisions were used to calculate a predicted failure load of the systems. This method provided a means of determining to what degree the standing seam roof systems behaved as fully lateral unsupported. The data from Rivard and Murray's six single span tests was compared to the predicted failure loads calculated from the 1986 AISI lateral buckling provisions. When the systems were compared assuming no lateral bracing, the results ranged from 18% to 86% conservative. Carballo expressed his results as a percentage of deviation from the actual failure loads. When the predicted loads were calculated for a fully lateral braced condition, the results were 22% to 35% unconservative. These results are from the tests with midspan and third point bracing.

Carballo's second method is based on a deflection correlation between the deflection of a standing seam roof system and that of a through-fastened (conventional) roof system. The hypothesis that the deflection of a standing seam roof system and the deflection of a through-fastened roof system are the same at the ultimate load is used in the correlation. A mathematical model was developed to predict the stiffness of a standing seam roof system. A method for calculating the deflection of a through-fastened roof system is provided in the 1986 AISI Specification. Using the stiffness for a standing seam roof system and the deflection obtained from the 1986 AISI Specification, a predicted failure load for the standing seam roof system is obtained. By knowing the deflection of the system at the ultimate failure load and the stiffness of the system, the load is calculated. When the test results from the single span test conducted by Rivard and Murray (1986) were compared to the loads predicted by this method, the results ranged from 3% to 28% unconservative.

Carballo's third method is a correlation between stresses in the cross section at the ultimate load and the allowable flexural stress calculated using the local buckling provisions in the 1986 AISI Specification. Using the flexural capacity obtained from the mathematical model developed in his second method, an ultimate load is predicted. The general flexure equation is used to obtain stresses based on the predicted ultimate load. The local buckling stresses were scaled by the general flexure stresses to obtain a predicted failure load. When this method was applied to the data from Rivard and Murray (1986), the results ranged from 0% to 22% conservative.

Carballo's fourth method is referred to as the "base test method". This method used results from a single span, two purlin line, gravity loaded, standing seam roof system to predict the capacity of a continuous span, multiple purlin line, gravity loaded standing seam roof system. The base test method consists of two parts. In the first part, a single span experimental test is conducted using nominally identical purlins, clips, and deck panels as used in the actual design system. From the experimental test, the maximum simple span moment is calculated from the failure load of the system. The second part of the base test method consists of a stiffness analysis conducted on one purlin line of the actual design system using a nominal uniform load. From this analysis, the maximum positive and negative moments are obtained. In this method, the maximum positive moment in the multiple span system is limited by the maximum positive moment obtained from the experimental single span test. Also, the maximum negative moment in the multiple span system was limited by the allowable flexural capacity of the cross section obtained from the 1986 AISI Specification. This limitation was imposed considering the purlins to be fully lateral braced at the lap splices in the multiple span system. The maximum compressive stress in the bottom flange of the purlin occurs at either one end of a lap splice or over one of the interior supports, depending on the moment of inertia. The maximum negative moment is calculated assuming the moment of inertia over the support to be the sum of the moment of inertia of the individual purlins. Using the moments obtained from the single span experimental test, stiffness analysis, and 1986 AISI lateral buckling provision a predicted failure load for the design system is calculated by scaling the moments obtained.

This method was evaluated by using the data from Rivard and Murray (1986), and the data from two single span and two confirming multiple span tests conducted by Carballo. The tests conducted by Carballo had the same span lengths as those conducted by Rivard and Murray (1986). The single span tests were conducted at span lengths of 20 ft., and the continuous span tests consisted of three spans at 23 ft. each. One of the limitations of the base test method is that the components used in the single span experimental test must be nominally identical to those used in the actual design system or confirming multiple span experimental test. The data used from Rivard and Murray (1986) was somewhat inconsistent with this limitation. The panels used by Rivard and Murray (1986) for their multiple span tests were of the same type, but not from the same manufacturer. Even with this inconsistency, the base test method predicted failure loads of the multiple span confirming test that ranged from 3% unconservative to 28% conservative. When the data from the two single and multiple span confirming tests conducted by Carballo was used, the base test method predictions were on the average, 98% accurate. This increase in accuracy was attributed to the use of nominally identical components in both the single span and multiple span confirming tests.

Of the four methods evaluated, the base test method was selected as the most practical and reasonable approach to predict the capacity of standing seam roof systems. The other methods were abandoned due to either their expense or lack of accuracy.

Nine sets of test were conducted by Brooks and Murray (1989, 1990) to verify the accuracy of the base test method. Each test set included a single span test and a multiple span confirming test. The span length of the single span tests was 25 ft. Each multiple span confirming test consisted of three spans at 23 ft. 6 in. The multiple span confirming tests consisted of three or four purlin lines, depending on the orientation of the purlin cross-section. Nominally identical components and bracing configurations were used in the confirming tests as were used in the single span tests. Four test sets used Z-purlins braced at the rafters. Three test sets used Z-purlins braced at the rafters and third point locations. One test set used Z-purlins facing the opposite direction, and one test set was conducted using C-purlins braced at the rafters. The type of deck and clips used varied from set to set. This was done to include as many different purlin, deck, and clip combinations as possible in the base test method verification. The results from the tests showed that the base test method predicted the capacity of the multiple span tests with an accuracy of 87% to

102%. These percentages are expressed as the actual failure loads of the base tests devided by the predicted failure loads of the confirming tests.

1.3 Scope of Research

Previous experimental and analytical research has verified the base test method as a reliable design procedure for predicting the capacity of gravity loaded standing seam roof systems. This study investigates the possibility of eliminating purlin size, length of span, and the presence or absence of insulation from the required test matrix for the base test method. The background, procedure, and previous restrictions and limitations of the base test method are discussed in Chapter II. The experimental program used in this study is discussed in Chapter III. The results of the base tests conducted in this study are presented in Chapter IV. Chapter V is a discussion of the effects that different parameters have on standing seam roof system strength. Chapter VI summarizes the findings of the study. Recommended design practice and example calculations are also presented in Chapter VI.

CHAPTER II

BASE TEST METHOD

2.1 Background

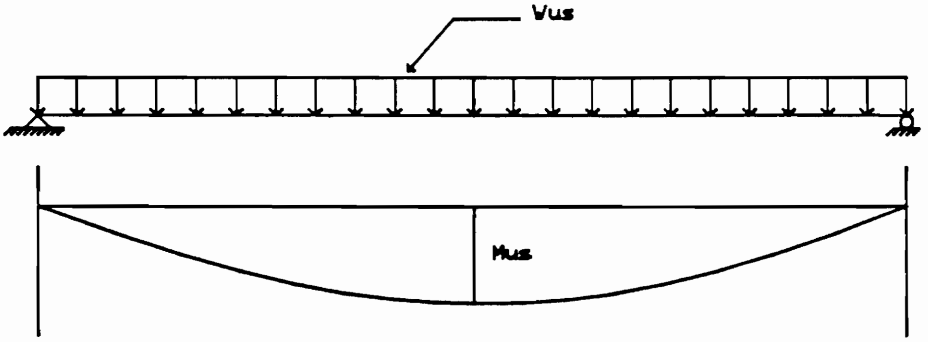
A variety of standing seam roof system components are available from manufacturers, all of which have different system variables (e.g., unbraced length, diaphragm shear stiffness, and flexural capacity of the cross section). Because of the variety of components used, and the complex structural behavior of standing seam roof systems, an analytical method to determine system capacities is complex. To alleviate the problem of examining the mechanics of each standing seam roof system, Carballo (1989) suggested an experimental procedure to determine standing seam roof system capacities. The procedure is referred to as the "base test method". The method uses results from two purlin line, single span tests conducted in the laboratory to obtain an allowable design load for multiple purlin line, multiple span continuous standing seam roof systems. The method was verified for gravity loaded systems by Brooks and Murray (1989, 1990). It was found to be, on average, 94% accurate.

2.2 Base Test Method For Gravity Loading

The base test method for gravity loading involves several steps before an allowable design load can be obtained for a multiple span continuous standing seam roof system.

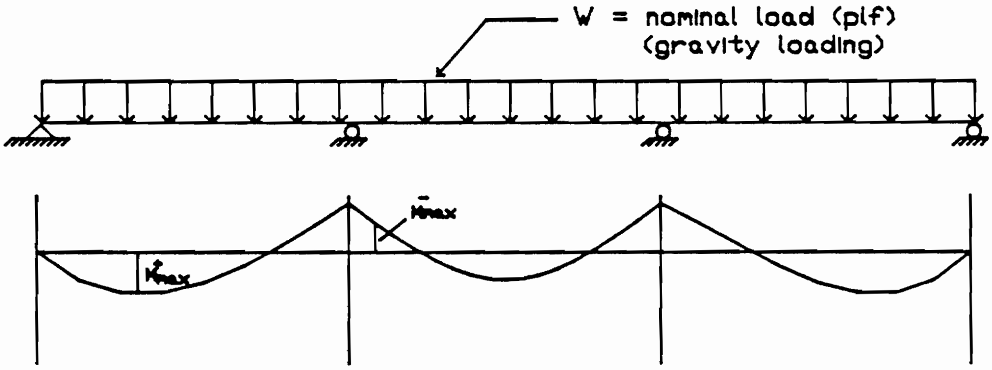
The first step requires that a base test be conducted. The base test is a two purlin line, single span, simply supported system using nominally identical components as in the actual standing seam roof system. A uniformly distributed gravity load is applied to the system, and an experimental failure load is obtained. The maximum positive moment corresponding to the experimental failure load is then calculated (see Figure 2.1). For gravity loading, a positive moment is defined as one which causes compression in the purlin flange attached to the clips and deck panels. This positive moment will limit the maximum allowable positive moment in the actual standing seam roof system. This limitation is imposed since the single span base test moment is the maximum positive moment which the system can resist. A factor of safety of 1.67 is applied to the base test moment since an allowable design load is desired.

The second step is a stiffness analysis of the actual continuous span system. The stiffness analysis is performed using a uniformly distributed nominal gravity load. Two moments are needed from the stiffness analysis, the maximum positive and negative moments. A negative moment is defined as one which causes tension in the purlin flange attached to the clips and deck panels. The maximum compressive stress in the bottom falange of the purlin will occur either over an interior support or at the end of a lap splice (see Figure 2.2). For analysis, the moment of inertia of the purlin line in the lap splice region is assumed to be the sum of the moments of inertia of the individual purlins. This is to be taken into consideration when calculating the maximum negative moment for the continuous system.



Vus = Failure Load of Single Span Base Test with Gravity Loading
Mus = Maximum Single Span Moment Corresponding to Vus

Figure 2.1 Single Span Base Test



$\overset{+}{M}max$ = Maximum positive moment corresponding to nominal load

$\overset{-}{M}max$ = Maximum negative moment corresponding to nominal load occuring at either the end of a lap splice or over an interior support

Figure 2.2 Multiple Span Stiffness Analysis

The third step is the calculation of the fully constrained flexural capacity of the purlin cross-section. This calculation is made using the 1986 AISI specification constrained bending equations. The maximum negative moment in the continuous system is limited by this flexural capacity. This limitation is imposed since the maximum negative moment in the continuous system will occur in a region where the lap splice is considered to provide sufficient lateral restraint to allow the purlin to develop its fully constrained flexural capacity.

The final step of the base test method is the calculation of the allowable design load of the multiple span continuous system. The allowable load is the minimum of two calculated loads based on the moments obtained in the first three steps. The first calculated load is the maximum load as limited by the single span base test moment. It is the ratio of the maximum single span base test moment to the maximum positive moment from the stiffness analysis multiplied by the nominal load used in the stiffness analysis. The second calculated load is the maximum load as limited by the fully constrained flexural capacity of the purlin cross-section calculated using the 1986 AISI constrained bending equations. The second calculated load is the ratio of the fully constrained flexural capacity of the cross-section to the maximum negative moment from the stiffness analysis multiplied by the nominal load used in the stiffness analysis. The allowable design load for the multiple span continuous system is the minimum of these two calculated loads. The final steps can be written in equation form as follows:

$$W_{allow} = \text{minimum of} \begin{cases} \dfrac{M_{us}}{M^{+}_{MAX}} \times \text{nominal load (plf)} \\ \\ \dfrac{M_{AISI}}{M^{-}_{max}} \times \text{nominal load (plf)} \end{cases}$$

where:

W_{allow} = Allowable design load of the multiple span continuous system.

M_{us} = Maximum moment corresponding to the experimental failure load obtained from the base test devided by a factor of safety of 1.67.

M_{AISI} = Flexural capacity of the purlin cross section calculated using the 1986 AISI Specification constrained bending equations.

M^{+}_{max} = Maximum positive moment from the multiple span continuous system stiffness analysis.

M^{-}_{max} = Maximum negative moment from the multiple span continuous system stiffness analysis.

2.3 Previous Restrictions and Limitations

The base test method provides a means of calculating allowable design loads based on experimental results. As with any method which involves experimental results, certain restrictions and limitations must be applied to insure that safety requirements are met. Brooks and Murray (1989, 1990), suggest the following restrictions and limitations when using the base test method:

1. The base test must be conducted using nominally identical panel, clip, insulation, and purlin components as are used in the actual standing seam roof system.
2. The failure moment determined from the base test can only be used to determine the capacity of roof systems using identical purlins, e.g. same cross-section dimensions and nominal yield stress.
3. The span of the base test must be greater than or equal to the largest span in the actual roof system.
4. The purlin line spacing in the base test must be greater than or equal to the purlin spacing in the actual roof system.
5. A factor of safety of 1.67 must be applied to the base test results.

CHAPTER III

EXPERIMENTAL PROGRAM

3.1 Test Components

Several combinations of standing seam roof components were used in the testing program of this study. Different combinations of components were used to investigate the possibility of eliminating some parameters from the current test matrix required for the base test method. The components used in the tests were supplied by different manufacturers that belong to the Metal Building Manufacturers Association (MBMA). The following paragraphs describe the test components used in the testing program.

Purlins. The purlins used in the tests were Z- and C-purlins. The purlins were spaced at 5 ft. on center and laterally braced at the rafters in all of the tests. Dimensions of the purlins varied with each test. The purlins had different thicknesses, heights, flange widths, and lip lengths.

Panels. Two types of deck panels are used in standing seam roof systems, "rib" and "pan" type (see Figure 3.1). Panel widths, seam details, and profiles vary with manufacturers but the basic shapes are somewhat standard. "Rib" type panels have several bends at the joint between panels. A "pan" type panel has a more defined shape, the bend at panel joints is a single 90° break. Some panels have interlocking mechanisms to prevent seam separation, others must be seamed by mechanical seamers to secure the joint. Both "rib" and "pan" type panels were used in the testing program.

a) Typical Rib Type Panel

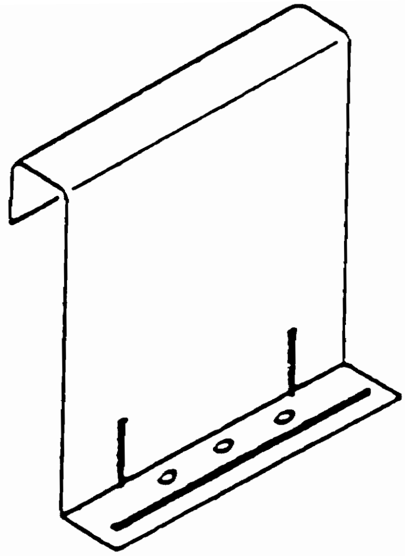
b) Typical Pan Type Panel

Figure 3.1 Typical Standing Seam Roof Panels

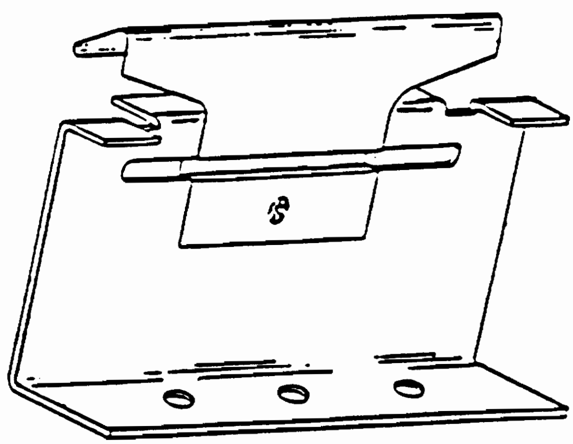
The panels used were 7 ft. 0 in. in length with an overhang of 1 ft. beyond the web of each purlin. This length was developed to produce the same curvature, when loaded, as that in a continuous system with multiple purlin lines. The curvature of the deck panels on a base test system will have a slope over the purlins equal to zero as in continuous systems. This slope will insure that the loading is applied to the purlins both equally and vertically. Effects of curvature of deck panels over the purlins is sometimes referred to as "sagging" or "hugging". Since the curvature is symmetric about the purlin, it is considered to provide some lateral restraint to the purlin flange connected to the deck components when a gravity load is applied.

Clips. Two different types of clips are used in standing seam roof systems, "fixed" and "sliding" types (see Figure 3.2). Both clip types were used in the tests. As with deck panels, the exact dimensions and configurations of clips vary with manufacturers. The clips are generally fastened to the purlin by self drilling self tapping screws through holes in the clip base. "Sliding" type clips allow relative movement between the purlin and deck panel. When a roof system is subjected to temperature expansion and contraction the "sliding" type clip facilitates movement. Both clip types were used in the testing program.

Insulation. Typical metal building insulation was used in the testing program. Metal building insulation is generally 4 in. thick. The insulation is placed between the top purlin flange and clip base.



a) Typical Fixed Type Clip



b) Typical Sliding Type Clip

Figure 3.2 Typical Standing Seam Roof Clip Types

3.2 Test Series

Four test series, Series I through IV, were conducted for the project. The first three series were used to examine the effect that size, type, and orientation of purlins, and the presence or absence of insulation had on the strength of standing seam roof systems. The fourth series was used to evaluate what effect length of span had on the strength of systems. The following paragraphs describe the combinations of components used in the test series.

Series I. Four tests were conducted in Series I. Three of the tests in the series were at a span length of 25 ft. 0 in. One test was conducted at a span length of 24 ft. 9 in. One set of purlins were cut 3 in. short by mistake and could not be used to construct a 25 ft. span test. Since the span length was only 3 in. short, the test results could be used with the 25 ft. test results without sacrificing accuracy. Z-purlins with the top flanges facing opposite directions (opposed) were used. The roof components consisted of "rib" type panels and "sliding" type clips. One test was conducted using insulation.

Series II. Series II also consisted of four tests, using Z-purlins. The span length was 25 ft. 0 in. and the purlins were oriented so the top flanges faced the same direction. "Rib" type deck panels and "sliding" clips were used. The panels and clips were the same type as those used in Series I but from different manufacturers. One test was conducted with insulation in place.

Series III. Five tests with 25 ft. 0 in. span lengths were conducted in Series III. C-purlins with the top flanges facing the same direction were used to support the deck components. "Pan" type deck and "fixed" clips were used, and one of the five tests was conducted using insulation.

Series IV. Four tests were conducted in Series IV, two using the same type of components as used in Series I, and two using components as used in Series III. Two of the tests were conducted at span lengths of 20 ft. 0 in., and two were conducted at 30 ft. 0 in. span lengths. A 20 ft. 0 in. test was conducted using Series I components, and another using Series III components. The 30 ft. 0 in. tests were conducted in the same manner.

3.3 Test Identification System

Table 3.1 shows the test matrix for the different series in the study. The following test identification system was used.

Example 1 R-S-10Z0.093-25-O

Example 2 P-F-9C0.075-20

- The first letter, R or P, indicates "rib" or "pan" type deck panels.
- The second letter, S or F, indicates "sliding" or "fixed" type clips.
- The third identifier is the size and type of purlin (e.g., 10 in. Z-purlin with a thickness of 0.093 in., or 9 in. C-purlin with a thickness of 0.075 in.).
- The fourth identifier is span length in feet, (e.g., 25 ft., or 20 ft.).
- The letter O at the end indicates that the top flanges of the purlins were facing opposite directions (opposed).

Table 3.1

Matrix of Test Configurations

Test Identification	Purlin Type	Purlin Orientation	Panel type	Clip Type	Insulation Used	Span Length
Series I						
R-S-8Z0.060-25-0	Z-	Opposed	Rib	Sliding	No	24'-9"
R-S-8.5Z0.06-25-0	Z-	Opposed	Rib	Sliding	Yes	25'
R-S-10Z0.073-25-0	Z-	Opposed	Rib	Sliding	No	25'
R-S-10Z0.092-25-0	Z-	Opposed	Rib	Sliding	No	25'
Series II						
R-S-8Z0.060-25	Z-	Facing	Rib	Sliding	Yes	25'
R-S-8Z0.10-25	Z-	Facing	Rib	Sliding	No	25'
R-S-10Z0.073-25	Z-	Facing	Rib	Sliding	No	25'
R-S-10Z0.094-25	Z-	Facing	Rib	Sliding	No	25'
Series III						
P-F-9C0.063-25	C-	Facing	Pan	Fixed	No	25'
P-F-9C0.064-25	C-	Facing	Pan	Fixed	Yes	25'
P-F-9C0.065-25	C-	Facing	Pan	Fixed	No	25'
P-F-9C0.074-25	C-	Facing	Pan	Fixed	No	25'
P-F-9C0.10-25	C-	Facing	Pan	Fixed	No	25'
Series IV						
R-S-10Z0.094-20-0	Z-	Opposed	Rib	Sliding	No	20'
R-S-10Z0.093-30-0	Z-	Opposed	Rib	Sliding	No	30'
P-F-9C0.075-20	C-	Facing	Pan	Fixed	No	20'
P-F-9C0.105-30	C-	Facing	Pan	Fixed	No	30'

3.4 Testing Setup and Procedures

The single span base tests were constructed and loaded to failure using a vacuum chamber. The chamber was made by connecting galvanized steel panels together to form a rectangular box. The panels were 3 ft. 6 in. high and were fastened to the laboratory floor. The chamber size used for the 20 ft., and 25 ft. span tests was 8 ft. wide by 26 ft. long. A 5 ft. "dummy" roof system was built to fill extra space when the 20 ft. tests were conducted. An eight feet wide by 31 ft. long chamber was used for the 30 ft. tests. A 6 mil sheet of polyethylene, large enough to accommodate the systems' configuration and deflections, was used to seal the top of the vacuum chamber. It was placed across the deck panels and secured by duct tape to the panel tops.

A uniform pressure was applied to the standing seam roof systems by evacuating the air inside the chamber. The air was evacuated by an electric motor driven vacuum pump which was connected to the chamber by a series of pipes. Valves were installed in the chamber panels. The valves allowed the air flow into the chamber to be regulated. The pressure differential between the air inside the chamber and the atmosphere was measured using a U-tube manometer and a pressure differential transducer.

The deflections of the standing seam roof systems were measured using linear displacement transducers. The vertical deflection at midspan of both purlins and the midspan horizontal deflection of the deck was measured by the transducers. Figure 3.3 shows typical load versus vertical deflection plots for Z-purlins facing, Z-purlins opposed, and C-purlins facing. The horizontal deck deflection was measured at the seam joint nearest to midspan. These deflections

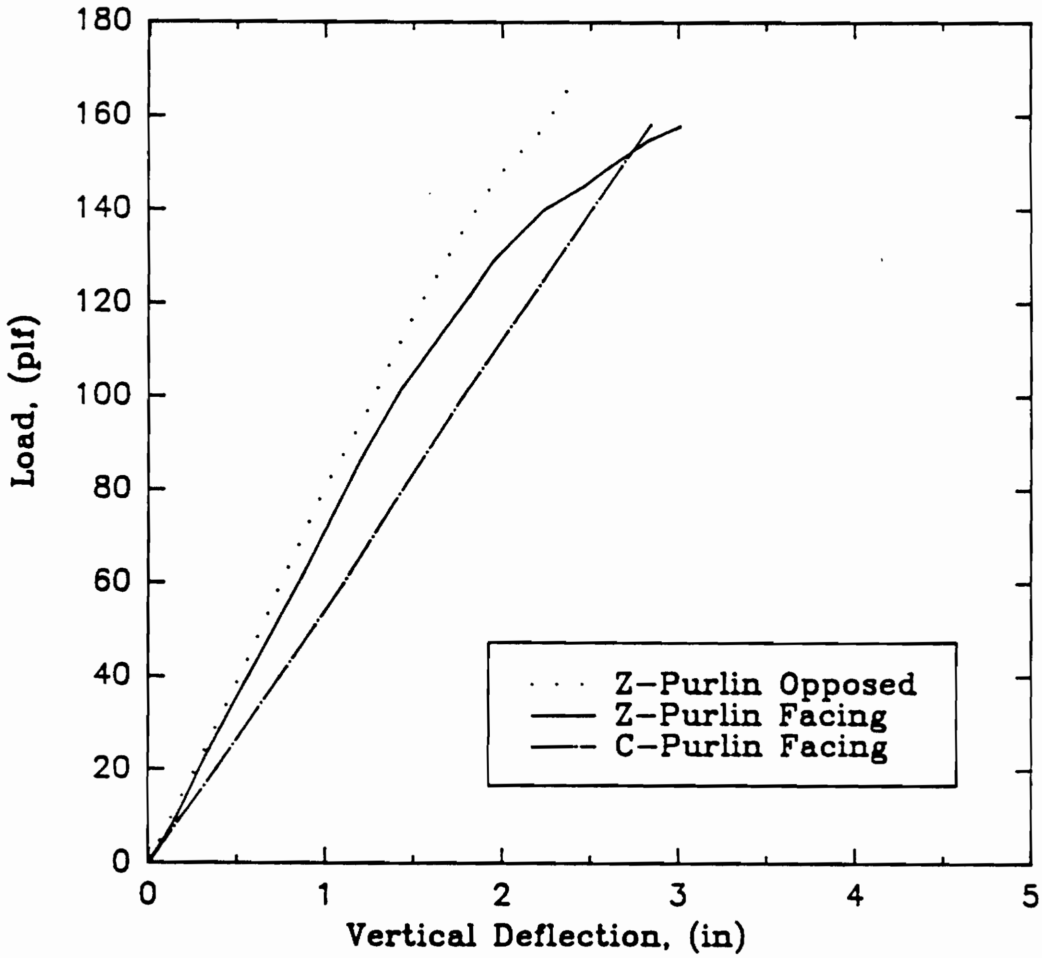


Figure 3.3 Typical Load versus Vertical Deflection Plots for Z- and C-Purlins

along with the pressure differential transducer measurements were read and recorded by a data acquisition system.

The purlins were supported at each end by a steel beam (see Figure 3.4). The beams were simply supported by 1/2 in. diameter steel rollers and short beam sections referred to as "stands". Lateral restraint for the purlins was provided at the rafters by 1/2 in. diameter rods. The rods were attached to a rigid support which was connected to the rafter beams. A cold formed angle was attached to one edge (eave side) of the deck panels to simulate the stiffness provided by eave strut purlins in metal buildings.

For each test, an initial load equal to 20% of the anticipated failure load was first applied. This load was removed and the transducer readings zeroed before beginning the actual loading of the system. Loads were gradually applied to the systems by constricting the flow of air through the valves installed in the chamber panel. Data were recorded at approximately every 1/2 in. of water pressure differential. The loading was continued until the systems failed. The pressure differential at which the system failed was then recorded as the ultimate capacity.

After the testing was complete, the systems were dismantled and a photographic record of the test was obtained. Photographs of clip movement, clip separation, failure region of the purlin, and final deflected shape of the entire system were taken for test records.

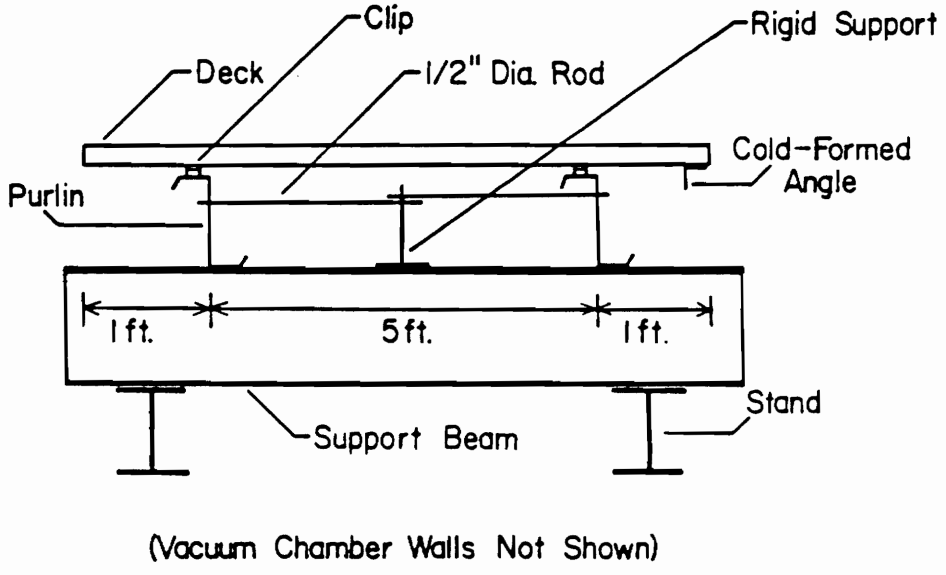


Figure 3.4 Test Setup Section at Support Beam

CHAPTER IV

EXPERIMENTAL TEST RESULTS

4.1 General

Complete results for the tests conducted in Series I through IV are found in Appendices A through D, respectively. Each set of results contains a test summary sheet, measured cross-section dimensions, measured yield stresses, 1986 AISI constrained bending strength calculations, and plots of load versus vertical deflection and load versus lateral panel deflection. The theoretical deflections shown were calculated assuming elastic material properties, full section properties, and constrained bending.

In the following sections, for the purpose of comparison, the experimental failure loads of the base tests are expressed as a percentage of the through-fastened capacity of the purlins. The 1986 AISI fully constrained bending provisions were used to calculate the through-fastened capacity for each purlin cross-section in the base tests. The experimental failure moment for each base test was divided by the fully constrained bending capacity of the purlin which failed and expressed as a percentage. That percentage is defined as R, the percentage of through-fastened capacity.

4.2 Series I Test Results

Four tests were conducted in Series I. Two lines of Z-purlins with the top flanges facing in opposite directions (opposed) were used. The span length for three of the tests was 25 ft. 0 in. As previously discussed, test R-S-8Z0.06-25-O was conducted at a span length of 24 ft. 9 in. The deck components used were "rib" type panels and "sliding" clips, and one test was conducted using insulation.

The failure mode for all of the tests in Series I, except test R-S-10Z0.092-25-O, was local buckling of the compression lip, flange, and web. Test R-S-10Z0.092-25-O failed by considerable lateral movement of the cross section. When a purlin fails by this mode, the cross section exhibits a considerable amount of lateral deflection with relatively little increase in load. If this failure mode occurs, the two pieces of the "sliding" clip separate from each other near mid span. When this happens, the deck panels are no longer attached to the purlin, and the purlin is unbraced in that region. The test results for Series I are shown in Table 4.1.

The purlins in Series I varied from relatively thin 8 in. sections to heavier 10 in. sections that were as thick as 0.092 in. The effective section modulus of the sections ranged from 1.63 in^3 to 4.26 in^3. The percentage of through-fastened capacities obtained by the systems ranged from 52.1% to 61.2%. The percentage of through-fastened capacity increased proportionally with the effective section modulus of the sections.

Table 4.1

Series I Test Results

Test	Insulation	S_{eff} (in^3)	F_y (ksi)	M_{AISI} (in-kips)	M_{us} (in-kips)	R (%)	Failure Mode
R-S-8Z0.06-25-0 *	No	1.85	56.8	105.0	54.7	52.1	LB
R-S-8.5Z0.06-25-0	Yes	1.63	64.3	104.7	54.6	52.2	LB
R-S-10Z0.073-25-0	No	3.22	59.7	191.8	115.7	60.3	LB
R-S-10Z0.092-25-0	No	4.26	61.5	261.9	160.2	61.2	LM

S_{eff} = Effective section modulus

F_y = Yield stress of material taken from purlin which failed

M_{AISI} = 1986 AISI fully constrained flexural strength, $S_{eff} \times F_y$

M_{us} = Experimental failure moment of base test

$R = \frac{M_{us}}{M_{AISI}} \times 100\%$

LB = Local buckling of lip, flange, and web

LM = Failure of cross section after considerable lateral movement

* Test conducted at a span length of 24'-9"

4.3 Series II Test Results

Series II consisted of four tests. The tests were conducted using two lines of Z-purlins with the top flanges facing the same direction. A span length of 25 ft. 0 in. was used. One test was conducted using insulation.

Three of the tests in Series II failed by local buckling of the compression lip, flange, and web. The other test, R-S-8Z0.10-25, had a failure mode of considerable lateral movement causing the "sliding" clip mechanisms to separate near midspan. The test results for Series II are shown in Table 4.2.

The purlin sizes used in Series II range from 8 in. deep, 0.060 in. thick, to 10 in. deep with a thickness of 0.094 in. Effective section moduli for the sections ranged form 1.76 in^3 to 4.30 in^3. The percentage of through-fastened capacity of the systems varied proportionally with effective section modulus of the sections and ranged from 54.7% to 60.1%.

4.4 Series III Test Results

Five tests were conducted in Series III, one with insulation in place. The supporting members were C-purlins with the top flanges facing the same direction. The span length of the C-purlins was 25 ft. 0 in.

The failure mode for all of the tests was local buckling of the compression lip, flange, and web. Table 4.3 shows the test results for the tests conducted in Series III.

Table 4.2

Series II Test Results

Test	Insulation	S_{eff} (in^3)	F_y (ksi)	M_{AISI} (in-kips)	M_{us} (in-kips)	R (%)	Failure Mode
R-S-8Z0.06-25	Yes	1.76	59.5	104.8	57.6	54.7	LB
R-S-8Z0.10-25	No	3.72	54.8	203.8	119.7	58.7	LM
R-S-10Z0.073-25	No	3.22	60.8	195.5	108.6	55.5	LB
R-S-10Z0.094-25	No	4.30	62.2	267.5	160.8	60.1	LB

S_{eff} = Effective section modules

F_y = Yield stress of material taken from purlin which failed

M_{AISI} = 1986 AISI fully constrained flexural strength, $S_{eff} \times F_y$

M_{us} = Experimental failure moment of base test

$$R = \frac{M_{us}}{M_{AISI}} \times 100\%$$

LB = Local buckling of lip, flange, and web

LM = Failure of cross section after considerable lateral movement

Table 4.3

Series III Test Results

Test	Insulation	S_{eff} (in^3)	F_y (ksi)	M_{AISI} (in-kips)	M_{us} (in-kips)	R (%)	Failure Mode
P-F-9C0.063-25	No	2.11	58.3	123.3	100.1	81.2	LB
P-F-9C0.064-25	Yes	2.14	51.5	110.3	87.5	79.3	LB
P-F-9C0.065-25	No	2.25	57.2	128.7	109.5	85.1	LB
P-F-9C0.075-25	No	2.55	59.2	151.2	138.5	91.6	LB
P-F-9C0.10-25	No	3.99	59.1	235.8	247.7	105.0	LB

S_{eff} = Effective section modules

F_y = Yield stress of material taken from purlin which failed

M_{AISI} = 1986 AISI fully constrained flexural strength, $S_{eff} \times F_y$

M_{us} = Experimental failure moment of base test

R = $\frac{M_{us}}{M_{AISI}} \times 100\%$

LB = Local buckling of lip, flange, and web

All of the C-purlins in Series III were 9 in. deep. Their thicknesses varied from 0.063 in to 0.10 in. The effective section modulus of the sections was from 2.11 in^3 to 3.99 in^3. The systems obtained 79.3% to 105.0% of through-fastened capacity of the purlin sections which failed. The percentage of through-fastened capacities obtained by the systems increased proportionally with the effective section modulus of the purlins. The strength of the system constructed using the heaviest C-purlin had an experimental failure load that exceeded the theoretical through-fastened capacity of the section by 5%.

4.5 Series IV Test Results

Four tests were conducted in Series IV. Two tests were conducted at a span length of 20 ft. 0 in. One of the 20 ft. 0 in. tests was conducted using Series I components, and the other using Series III components. A span length of 30 ft. 0 in. was used for the other two tests in the series. Series I components were used for one test, and the other test was conducted using components as from Series III.

Three of the tests failed by local buckling of the compression lip, flange, and web. The other test, R-S-10Z0.093-25-O, failed by considerable lateral movement of the cross-section. This mode of failure caused the two pieces of the "sliding" clip to separate along the entire span except near the support beams. The purlin cross-section could not distort enough to separate the clips near the support beam since bracing was provided at that location. Table 4.4 shows the test results for Series IV.

Table 4.4

Series IV Test Results

Test	Insulation	S_{eff} (in^3)	F_y (ksi)	M_{AISI} (in-kips)	M_{us} (in-kips)	R (%)	Failure Mode
R-S-10Z0.094-20-0	No	4.51	59.3	267.5	157.0	58.7	LB
R-S-10Z0.093-30-0	No	4.64	60.6	281.2	108.8	38.7	LM
R-F-9C0.075-20	No	2.56	57.7	147.7	147.4	99.8	LB
R-F-9C0.105-30	No	3.78	57.8	218.7	192.2	87.9	LB

S_{eff} = Effective section modules

F_y = Yield stress of material taken from purlin which failed

M_{AISI} = 1986 AISI fully constrained flexural strength, $S_{eff} \times F_y$

M_{us} = Experimental failure moment of base test

R = $\frac{M_{us}}{M_{AISI}} \times 100\%$

LB = Local buckling of lip, flange, and web

LM = Failure cross section after considerable lateral movement

The Z-purlins used in Series IV were 10 in. deep and relatively thick. The thicknesses were 0.093 in. and 0.094 in. The effective section modulus for the Z-purlins ranged from 4.51 in^3 to 4.64 in^3. The percentage of through-fastened capacity obtained by the 20 ft. system was 58.7% and the 30 ft. system obtained 38.7% of through-fastened capacity.

The height of the C-purlins used in Series IV was 9 in. The thicknesses were 0.075 in. and 0.105 in. The effective section modulus for the 0.075 in. thick purlin was 2.56 in^3 and the 0.105 in. thick purlin had an effective section modulus of 3.78 in^3. The 20 ft. system obtained 99.8% of through-fastened capacity and the 30 ft. system obtained 87.9%.

4.6 Tensile Coupon Test Results

Representative coupons were taken from the web area of the failed purlin in each base test. The coupons were machined, and tests were performed according to ASTM standard specifications. The yield stress of the coupons was determined using the 0.2% offset method on stress strain plots generated from the test data. Table 4.5 shows material thickness, yield stress, tensile strength, and percent elongation for each test.

Table 4.5

Tensile Coupon Test Results

Test	Thickness (in.)	Yield Stress (ksi)	Tensile Strength (ksi)	Elongation (%)
Series I				
R-S-8Z0.060-25-0 *	0.061	56.8	78.7	23.6
R-S-8.5Z0.06-25-0	0.060	64.3	84.2	21.1
R-S-10Z0.073-25-0	0.073	59.7	94.2	14.6
R-S-10Z0.092-25-0	0.093	61.5	71.8	17.5
Series II				
R-S-8Z0.060-25	0.060	59.5	79.9	28.5
R-S-8Z0.10-25	0.100	54.8	83.1	22.8
R-S-10Z0.073-25	0.073	60.8	82.3	23.8
R-S-10Z0.094-25	0.093	62.2	71.4	34.0
Series III				
P-F-9C0.063-25	0.064	58.3	80.6	20.7
P-F-9C0.064-25	0.064	51.5	74.2	28.3
P-F-9C0.065-25	0.065	57.2	78.6	25.2
P-F-9C0.074-25	0.074	59.2	78.2	22.3
P-F-9C0.10-25	0.107	59.1	78.8	34.1
Series IV				
R-S-10Z0.094-20-0	0.094	59.3	70.9	34.9
R-S-10Z0.093-30-0	0.093	60.6	72.6	36.5
P-F-9C0.075-20	0.074	57.7	79.5	17.6
P-F-9C0.105-30	0.105	57.8	79.7	16.6

* Test conducted at a span length of 24'-9"

CHAPTER V

EFFECTS OF TEST PARAMETERS ON SYSTEM STRENGTH

5.1 General

Figures 5.1, 5.2 and 5.3 are plots of the percentage of through-fastened capacity, R, versus fully constrained section strength for tests using Series I, II, and III components, respectively. The straight line on each plot is from a linear regression analysis, by the least squares method, using results of the 25 ft. 0 in. span tests in each series. This linear relationship is used in the following sections to access the effect that purlin size and type, purlin orientation, span length, and the presence or absence of insulation has on system strength. The results from Series IV are plotted on Figures 5.1 and 5.3 depending on the components used for the base test in the series.

5.2 Effect of Size and Type of Purlins

It is evident from Figures 5.1, 5.2 and 5.3 that, for a specific span, a linear relationship exists between percentage of through-fastened strength and nominal section strength. For both section types, Z-purlins (Figures 5.1 and 5.2) and C-purlins (Figure 5.3), the relative strength of the systems increases with increasing fully constrained section strength. That is, gravity loaded standing seam systems supported by stronger purlins exhibit relatively greater strength than systems supported by weaker purlins. This statement applies to all of the deck/clip configurations used in the experimental testing: rib deck/sliding clips, Figure 5.1; rib deck/sliding clips, Figure 5.2; and pan deck/fixed clips, Figure 5.3.

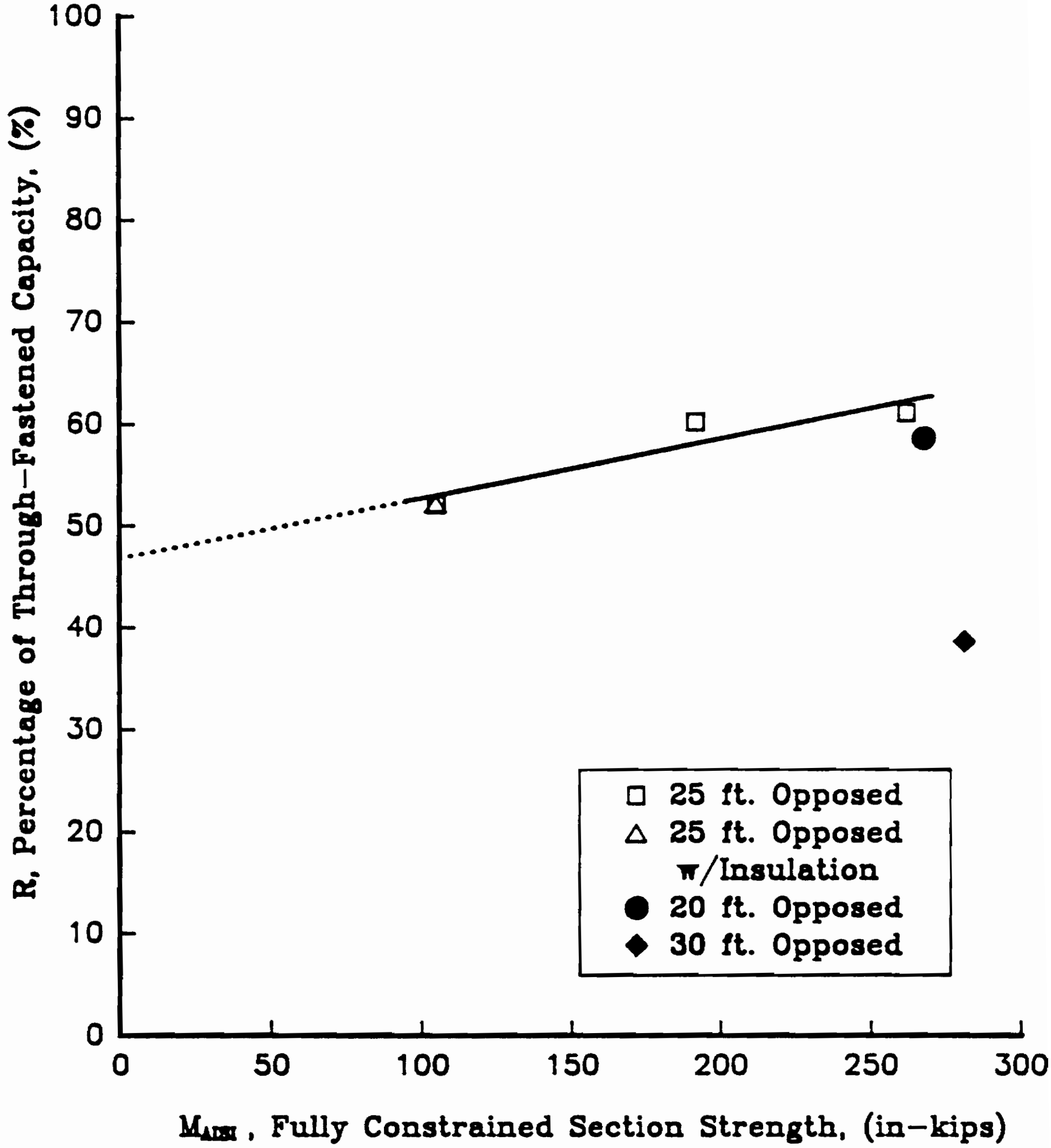
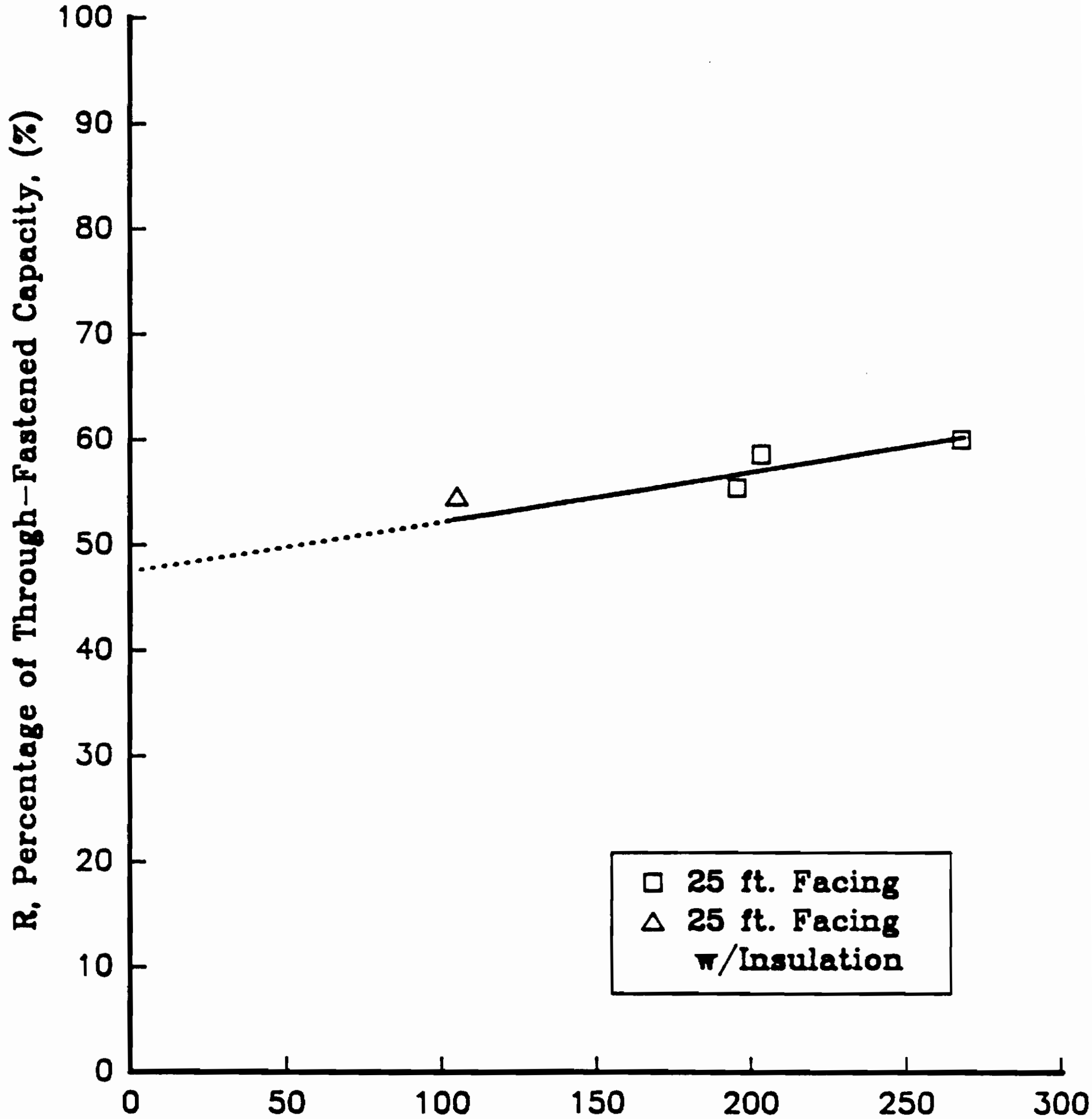


Figure 5.1 Percentage of Through-Fastened Capacity versus Fully Constrained Section Strength Plot for Series I Components



M_{AISI}, Fully Constrained Section Strength (in-kips)

Figure 5.2 Percentage of Through-Fastened Capacity versus Fully Constrained Section Strength Plot for Series II Components

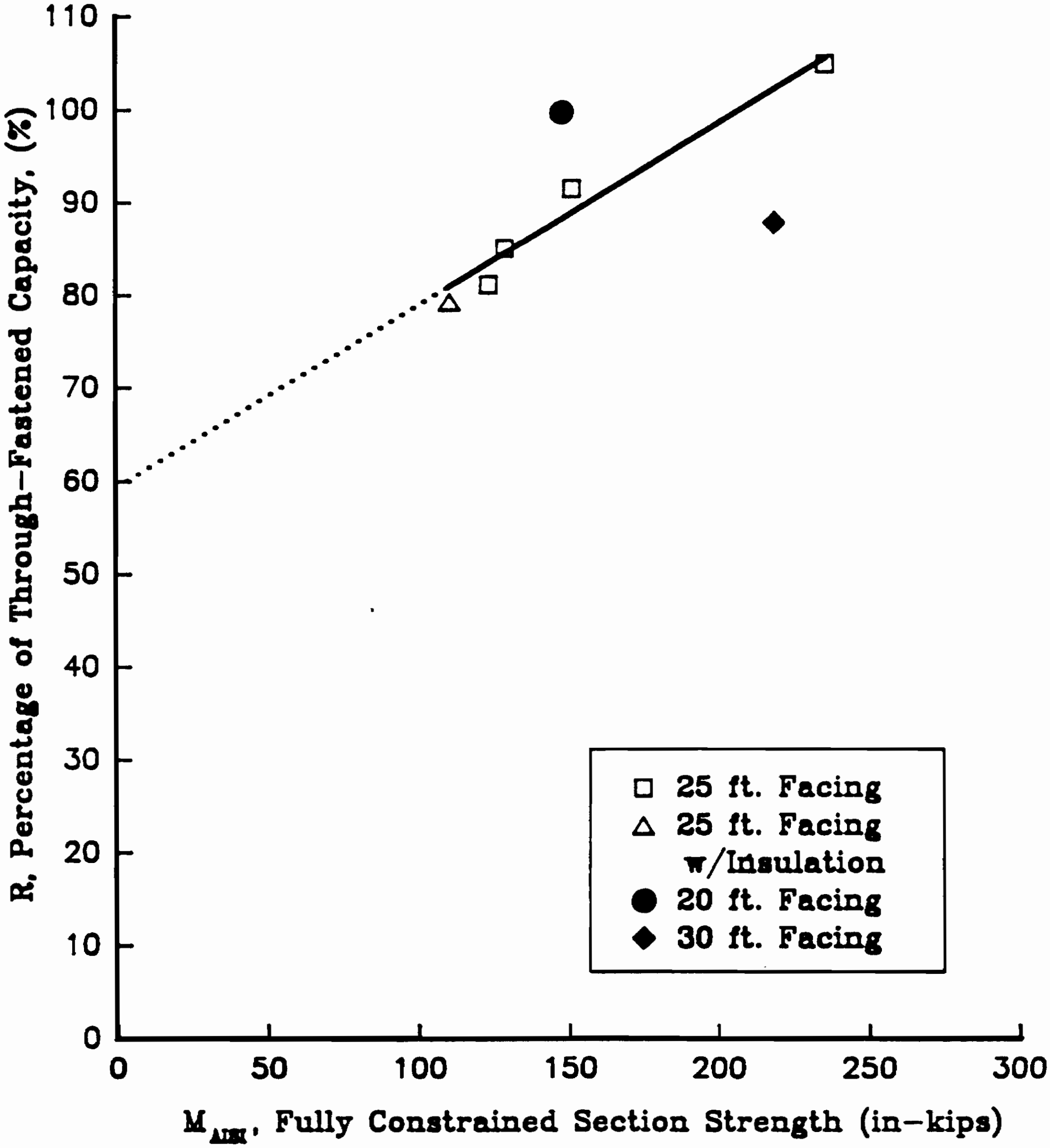


Figure 5.3 Percentage of Through-Fastened Capacity versus Fully Constrained Section Strength Plot for Series III Components

5.3 Effect of Orientation of Purlins

No direct comparison can be made concerning the effect of purlin orientation on system strength; however, a trend may have been identified. The clips and panels used in Series I and II were of the same type, but from different manufacturers. The Z-purlins used in Series I were oriented with the top flanges facing opposite directions (opposed), and those used in Series II were oriented such that the top flanges faced the same direction (facing).

When the linear regression lines in Figures 5.1 and 5.2 are compared, a slight difference in their slopes is apparent. The slope of the Series I line is greater than the slope of the line in Series II. The increase in slope of the Series I line over the slope of the line in Series II is attributed to the orientation of the Z-purlins. This trend was also observed by Brooks and Murray (1989, 1990) who found that base tests conducted with Z-purlins opposed had a strength increase of 7% over base tests conducted with Z-purlins facing.

5.4 Effect of Span Length

To evaluate the effect of span length on standing seam roof system strength applicable test results from Series IV were plotted with the results of Series I and III.

Figure 5.1 includes the results of the two tests in Series IV using Series I components but at different span lengths. Both the 20 ft. 0 in. test, R-S-10Z0.094-20-O, and 30 ft. 0 in. test, R-S-10Z0.093-30-O, show a decrease in system strength when compared to the regression line for the 25 ft. 0 in. tests.

The 30 ft. 0 in. test result is relatively much lower than the 20 ft. 0 in. test result and the linear regression line. The mode of failure of the 30 ft. 0 in. test, considerable lateral movement, is thought to be the reason for the difference. Bracing at the supports and the deck/clip system provided enough lateral bracing to allow the cross-section to develop only 38.7% of its through-fastened capacity.

The results for the two tests in Series IV using Series III components are included in Figure 5.3. The result for the 20 ft. 0 in. test, P-F-9C0.075-20, is above the linear regression line for the Series III test results; the result for the 30 ft. 0 in. test, P-F-9C0.105-30, is considerably below the same regression line. From the results of the 30 ft. span length tests in Series IV, it is apparent that span length has a definite effect on system strength.

5.5 Effect of Insulation

Three tests, with span lengths of 25 ft. 0 in., were conducted using insulation. The tests were conducted using components as in Series I, II and III.

Although no significant deviations of test results were shown for the tests conducted using insulation, a more accurate representation of system strength can be obtained if base tests are conducted with insulation in place. By conducting base tests using insulation when developing a relationship between percentage of through-fastened capacity and fully constrained section strength, the results would include any decrease in system strength due to the presence of the insulation.

CHAPTER VI

SUMMARY AND RECOMMENDATIONS

6.1 Summary

The primary objective of this study was to determine if some parameters could be eliminated from a manufacturer's required test matrix for the base test method. The effect that size and type of purlins, orientation of purlins, span length, and the presence or absence of insulation had on standing seam roof system strength were evaluated in this study. The results from four series of tests were used to evaluate effects of the parameters. To compare the results, a linear relationship between percentage of through-fastened capacity and fully constrained section strength was developed for the three standing seam roof systems.

When the data from the tests was compared, it was noticed that results from the base tests conducted at span lengths of 25 ft. 0 in. were following the same pattern. As the fully constrained section strength of the purlins increased, so did the percentage of through-fastened capacity of the systems. A linear regression analysis by the least squares method was performed with test results from the 25 ft. 0 in. base tests. Lines relating percentage of through-fastened capacity and fully constrained section strength were developed and plotted for each standing seam roof configuration. The lines fit the 25 ft. 0 in. base test data with little deviation, regardless of purlin type.

The orientation of the Z-purlins had an effect on the strength of the systems. The test results from Series I and II showed that an increase in system strength could be obtained by orienting the top flanges of the purlins in opposite directions.

If a relationship between percentage of through-fastened capacity and fully constrained section strength is developed with results from tests conducted with Z-purlins facing, the relationship would be conservative for systems with Z-purlins opposed using the same components. This would eliminate the need to test the same system using different purlin orientations. No comment can be made concerning orientation of C-purlins since only tests with the purlins facing were conducted in this study.

The 20 ft. and 30 ft. span test results showed span length to have a definite effect on system strength. As the span length was increased, the system strength decreased. No conclusion could be made concerning a decrease in span length since the results for one of the 20 ft. 0 in. tests was below the regression line and the other was above the regression line.

No significant change in system strength was apparent when base tests were conducted with insulation in place. It is suggested however, that base tests be conducted with insulation in place to obtain an accurate representation of a system's actual behavior if the test results are to be used in the design of systems using insulation.

In summary, a linear relationship exists between percentage of through-fastened capacity and fully constrained section strength of purlins used in standing seam roof systems. This relationship can be developed by conducting base tests using the lightest and heaviest purlins which a manufacturer has in inventory. This will eliminate the cost of conducting base tests for each purlin size used by a manufacturer for standing seam roof systems.

6.2 Recommended Design Practice

The following are recommendations for a safe design when using the base test method for standing seam roof systems.

1. The base test must be conducted using nominally identical panels, clips, as are used in the actual standing seam roof system.
2. The base test must be conducted with insulation in place if the results are to be used for the design of a standing seam roof system with insulation.
3. The span of the base test must be the same or greater than the span in the actual standing seam roof system.
4. The purlin line spacing in the base test must be greater than or equal to the purlin spacing in the actual standing seam roof system.
5. A factor of safety of 1.67 must be applied to the base test results.
6. The linear relationship between percentage of through-fastened capacity and fully constrained section strength cannot be extrapolated beyond the nominal section strength of the purlins used to develop the relationship.

The above reccommended design pracitce is implemented in the following example.

6.3 Example Calculations

A standing seam roof system is proposed for a metal building which has four bays with spans of 25 ft. each. The standing seam roof system is to be supported by 9 1/2 in.X1 5/8 in.X0.060 in., Fy = 50 ksi, Z-purlins oriented such that the top flanges face in the same direction. There are six purlin lines spaced at

5 ft. on center on each slope. Full moment continuity is considered at each rafter. Insulation is to be used with the system.

A simply supported, simple span base test was constructed using nominally identical Z-purlins, deck panel, clips, and insulation as the proposed standing seam roof system. The span length was 25 ft., and the purlin line spacing was 5 ft. on center. The Z-purlins were oriented with the top flanges facing the same direction. A cold-formed angle was attached to one (eave) side of the deck panels in the base test to simulate the stiffness provided by the eave strut purlin in the metal building. A uniformly distributed gravity load was applied to the base test system and an experimental failure load of 70 plf was obtained. The moment corresponding to the experimental failure load is $(70 \text{ plf})(25 \text{ ft.})^2/8 =$ 5,469 ft-lbs = 65.6 in-kips. After applying a factor of safety of 1.67, the base test moment is 39.3 in-kips.

The fully constrained section strength of the Z-purlin cross-section using the 1986 AISI Specification constrained bending equations is 60.6 in-kips.

A stiffness analysis of a purlin line with four spans of 25 ft. each was conducted. A uniformly distributed gravity load of 100 plf was used in the stiffness analysis. The maximum positive moment obtained from the stiffness analysis was 57.9 in-kips, and the controlling negative moment was 64.9 in-kips.

Using the base test method for the proposed standing seam roof system, the allowable design load is

$$W_{allow} = \text{minimum of} \left| \begin{array}{l} \dfrac{39.3 \text{ in-kips}}{57.9 \text{ in-kips}} \times 100 \text{ plf} = 67.9 \text{ plf} \\[2ex] \dfrac{60.6 \text{ in-kips}}{64.9 \text{ in-kips}} \times 100 \text{ plf} = 93.4 \text{ plf} \end{array} \right.$$

The positive moment region controls, W_{allow} = 67.9 plf.

REFERENCES

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APPENDIX A

SERIES I TEST SUMMARIES

MBMA PROJECT 502

Test Summary

Series I

R-S-8Z0.06-25-0

Test Date: May 8, 1990

Purpose: Single Span Base Test

Span: 24'-9"

Purlin:	Eave	Ridge
Thickness	0.060"	0.061"
Sweep	1/8"	1/8"

Parameters: Gravity Loading, Bracing @ Supports Only

Two Purlin Lines, 5'-0" O.C.; 1'-0" Deck Overhang

Purlins Facing Opposite Direction

Rib Type Deck with Two Piece Sliding Clip

Failure Load: 59.5 plf Failure Mode: Local Buckling

Yield Stress: 56.8 ksi

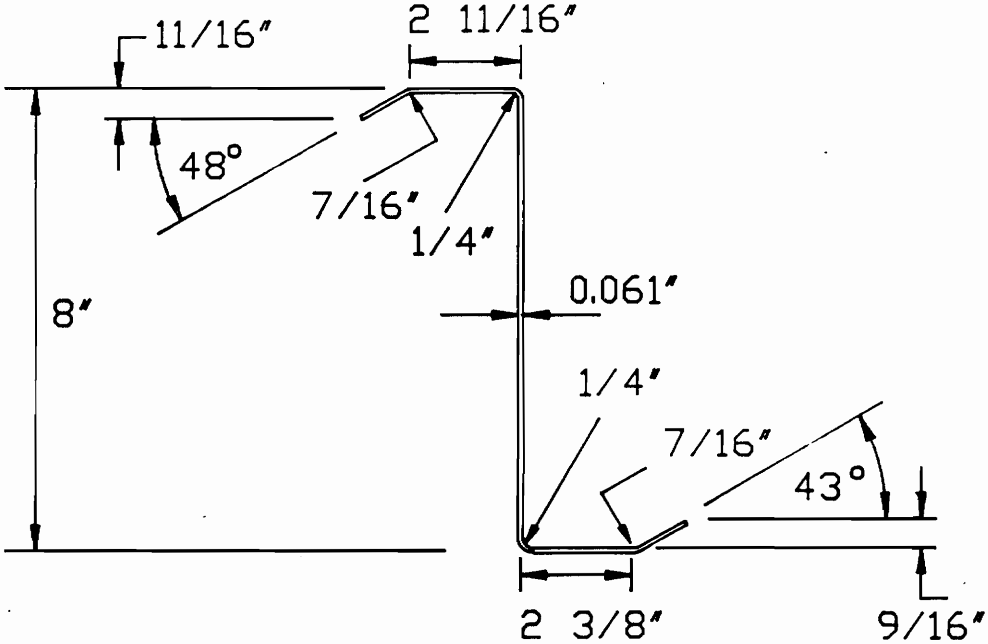
Predicted Constrained Bending Failure load: 114.3 plf

Actual Failure Load/Predicted Constrained Bending Failure Load: 52.1 %

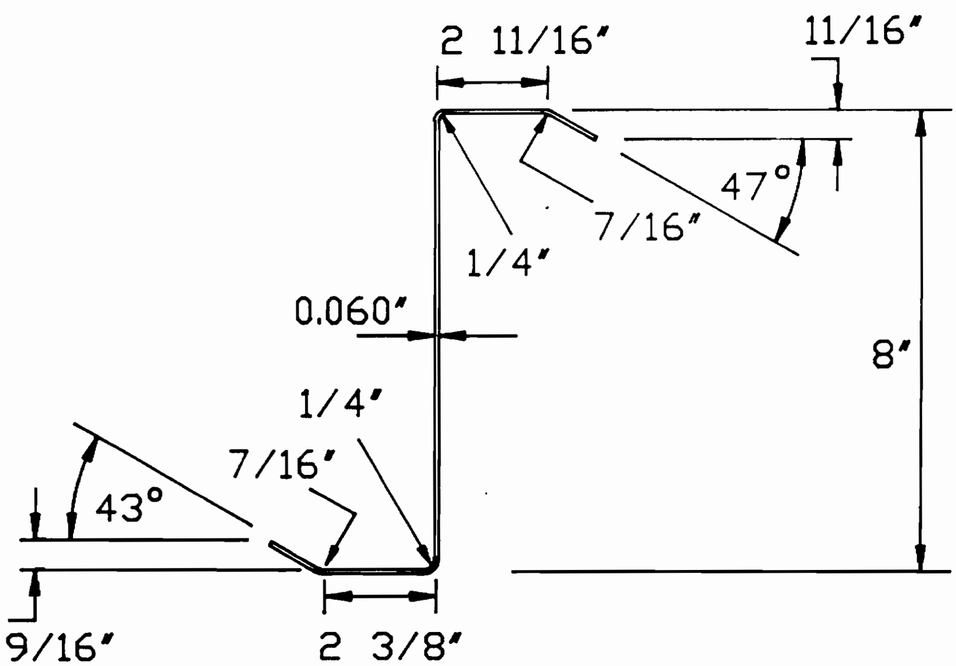
Discussion:

- Failure load includes 7.1 plf deadload.
- Vacuum chamber used to test system.
- Manometer used to measure load.
- Load deflection curve essentially linear.
- Failure occurred in ridge purlin by local buckling.
- No movement of clip W.R.T. deck.
- Maximum movement of two pieces of clips W.R.T. each other was approximately 1 1/4".

TEST R-S-8Z0.060-25-D
SERIES I



RIDGE PURLIN



EAVE PURLIN

Roof System Design Version 1.00

Date: 11/09/90 By: BLR

Job Id.: SERIES I R-S-8Z0.060-25-0
Roof Id.: RIDGE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Bay Information
Bay # 1:
Distance between supports: 24'-9"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 68.42 psf
Uplift Capacity: 34.21 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

Total System Weight: 78.9 Lbs.

Cross-Sections

Purlin Identification for Bay # 1: Z 8x0.061

	Top		Bottom	
Lip Length:	0.9251		0.8248	in.
Lip Angle:	48.000		43.000	Deg.
Radii:				
Lip to Flange:	0.4375		0.4375	in.
Flange to web:	0.2500		0.2500	in.
Flange Width:	2.6875		3.3750	in.
Total Depth:	8.000	in.		
Thickness:	0.0610	in.		
Yield Stress:	56.80	ksi		
Young's Modulus:	29500.0	ksi		

Roof System Design Version 1.00

Date: 11/09/90 By: BLR

Job Id.: SERIES I R-S-8Z0.060-25-O
Roof Id.: EAVE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Bay Information
Bay # 1:
Distance between supports: 24'-9"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 66.59 psf
Uplift Capacity: 33.30 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

Total System Weight: 77.6 Lbs.

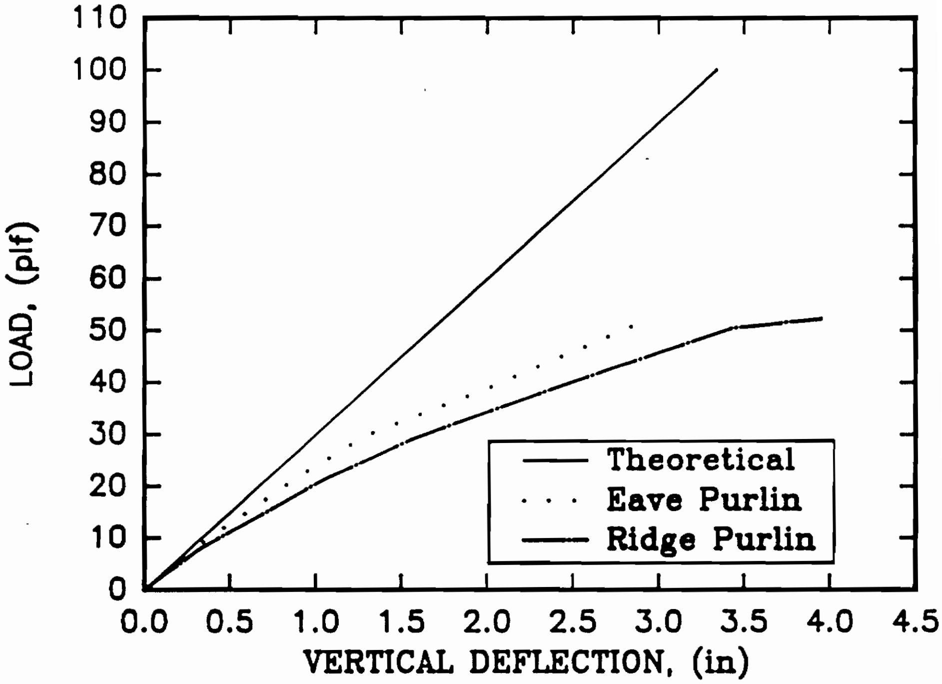
Cross-Sections

Purlin Identification for Bay # 1: Z 8x0.06

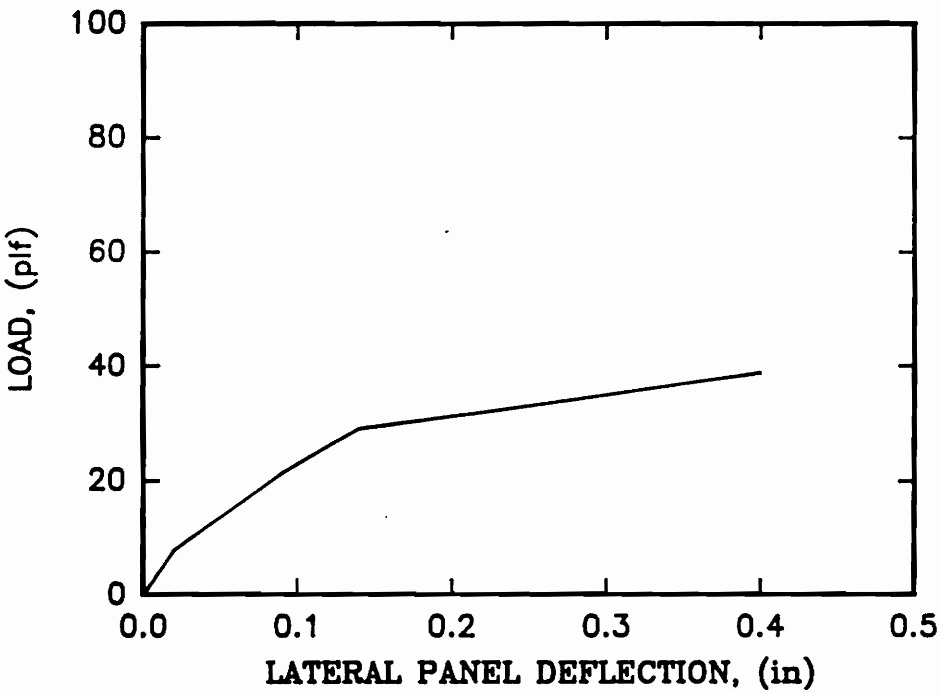
	Top		Bottom	
Lip Length:	0.9251		0.8248	in.
Lip Angle:	47.000		43.000	Deg.
Radii:				
Lip to Flange:	0.4375		0.4375	in.
Flange to web:	0.2500		0.2500	in.
Flange Width:	2.6875		3.3750	in.
Total Depth:	8.000	in.		
Thickness:	0.0600	in.		
Yield Stress:	56.80	ksi		
Young's Modulus:	29500.0	ksi		

SERIES I

TEST R-S-8Z0.060-25-0



a) Load vs. Vertical Deflection



b) Load vs. Lateral Panel Deflection

MBMA PROJECT 502

Test Summary

Series I

R-S-8.5Z0.06-25-0

Test Date: June 14, 1990

Purpose: Single Span Base Test

Span: 25'-0"

Purlin:	Eave	Ridge
Thickness	0.060"	0.060"
Sweep	1"	1/4"

Parameters: Gravity Loading, Bracing @ Supports Only

Two Purlin Lines, 5'-0" O.C.; 1'-0" Deck Overhang

Purlins Facing Opposite Direction

Rib Type Deck with Two Piece Sliding Clip

4 Inch Insulation

Failure Load: 58.2 plf Failure Mode: Local Buckling

Yield Stress: 64.3 ksi

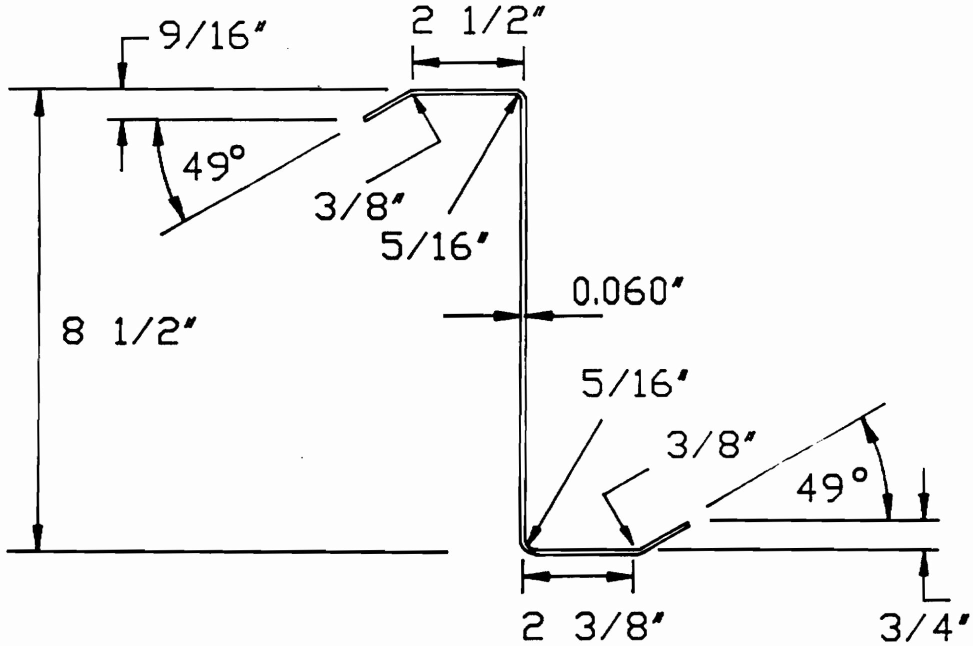
Predicted Constrained Bending Failure load: 111.7 plf

Actual Failure Load/Predicted Constrained Bending Failure Load: 52.1 %

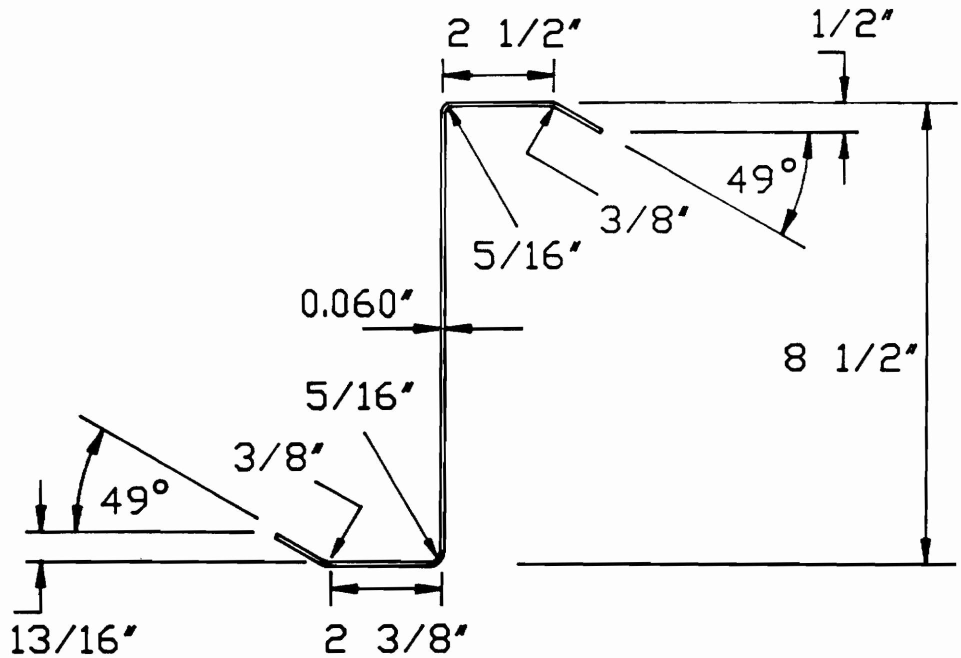
Discussion:

- Failure load includes 7.2 plf deadload.
- Vacuum chamber used to test system.
- Manometer used to measure load.
- Load deflection curve essentially linear.
- Failure occurred in ridge purlin by local buckling.
- 1" movement of clip W.R.T. deck midspan.
- Two piece sliding clips near mid-span moved the full extent of the sliding mechanism.

TEST R-S-8.5Z0.060-25-□
SERIES I



RIDGE PURLIN



EAVE PURLIN

Roof System Design Version 1.00

Date: 01/10/91 By: BLR

Job Id.: SERIES I R-S-8.5Z0.06-25-0 w/Insulation
Roof Id.: RIDGE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Applied Loads

Bay Information
Bay # 1:
Distance between supports: 25'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 70.14 psf
Uplift Capacity: 35.07 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

Total System Weight: 74.5 Lbs.

Cross-Sections

Purlin Identification for Bay # 1: Z 8.5x0.06

	Top		Bottom	
Lip Length:	0.7155		1.0136	in.
Lip Angle:	49.000		49.000	Deg.
Radii:				
Lip to Flange:	0.3750		0.3750	in.
Flange to web:	0.3125		0.3125	in.
Flange Width:	2.5200		2.3600	in.
Total Depth:	8.500	in.		
Thickness:	0.0600	in.		
Yield Stress:	64.30	ksi		
Young's Modulus:	29500.0	ksi		

Roof System Design Version 1.00

Date: 01/10/91 By: BLR

Job Id.: SERIES I R-S-8.5Z0.06-25-0 w/Insulation
Roof Id.: EAVE PURLINN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only
half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Applied Loads

Bay Information
Bay # 1:
Distance between supports: 25'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 66.89 psf
Uplift Capacity: 33.45 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

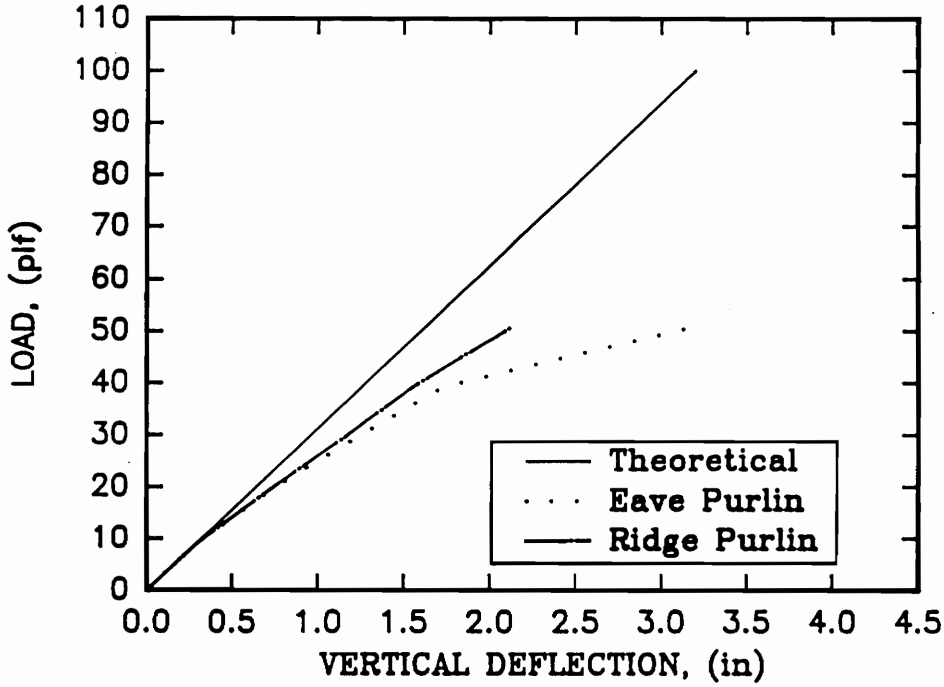
Total System Weight: 73.2 Lbs.

Cross-Sections

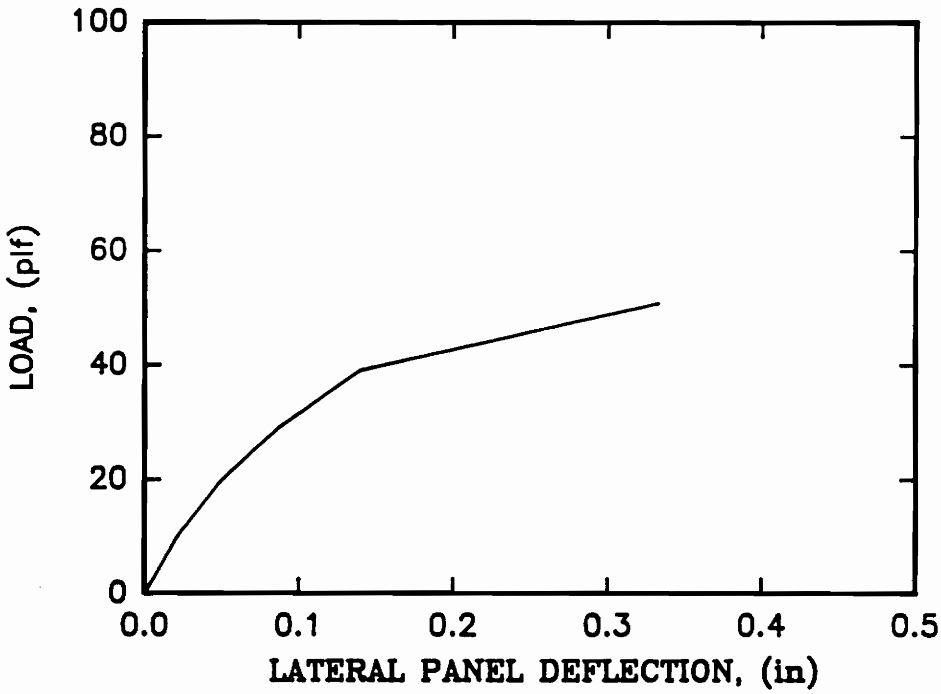
Purlin Identification for Bay # 1: Z 8.5x0.059

	Top		Bottom	
Lip Length:	0.6731		1.0812	in.
Lip Angle:	49.000		49.000	Deg.
Radii:				
Lip to Flange:	0.3750		0.3750	in.
Flange to web:	0.3125		0.3125	in.
Flange Width:	2.4480		2.3850	in.
Total Depth:	8.500	in.		
Thickness:	0.0590	in.		
Yield Stress:	64.30	ksi		
Young's Modulus:	29500.0	ksi		

SERIES I
TEST R–S–8.5Z0.060–25–0 w/Ins.



a) Load vs. Vertical Deflection



b) Load vs. Lateral Panel Deflection

MBMA PROJECT 502

Test Summary

Series I

R-S-10Z0.073-25-0

Test Date: May 17, 1990

Purpose: Single Span Base Test

Span: 25'-0"

Purlin:	Eave	Ridge
Thickness	0.073"	0.073"
Sweep	1/2"	3/4"

Parameters: Gravity Loading, Bracing @ Supports Only

Two Purlin Lines, 5'-0" O.C.; 1'-0" Deck Overhang

Purlins Facing Opposite Direction

Rib Type Deck with Two Piece Sliding Clip

Failure Load: 123.4 plf Failure Mode: Local Buckling

Yield Stress: 59.7 ksi

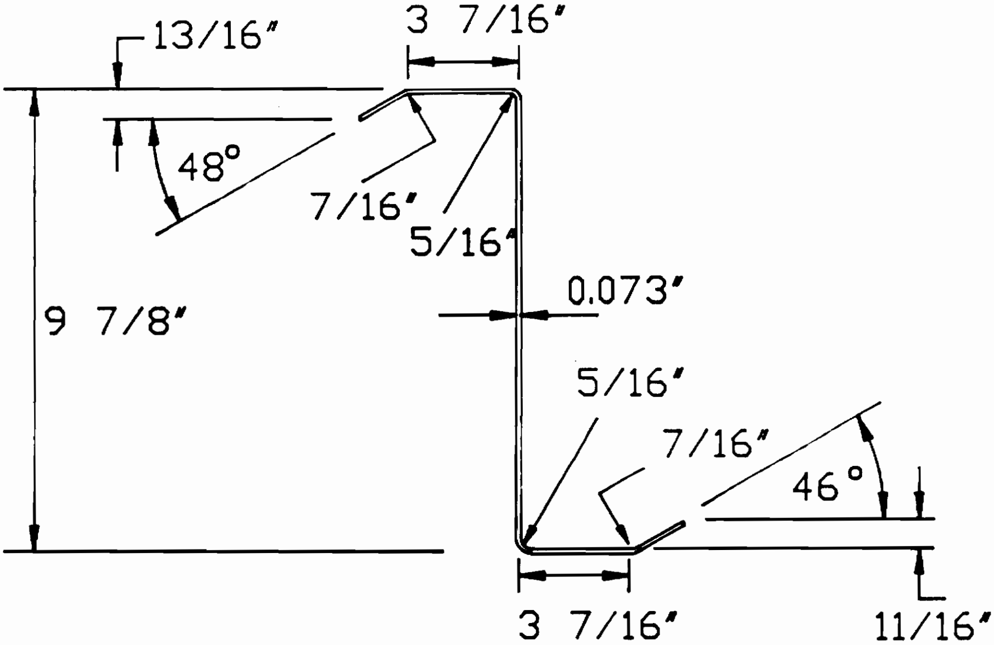
Predicted Constrained Bending Failure load: 204.6 plf

Actual Failure Load/Predicted Constrained Bending Failure Load: 60.3 %

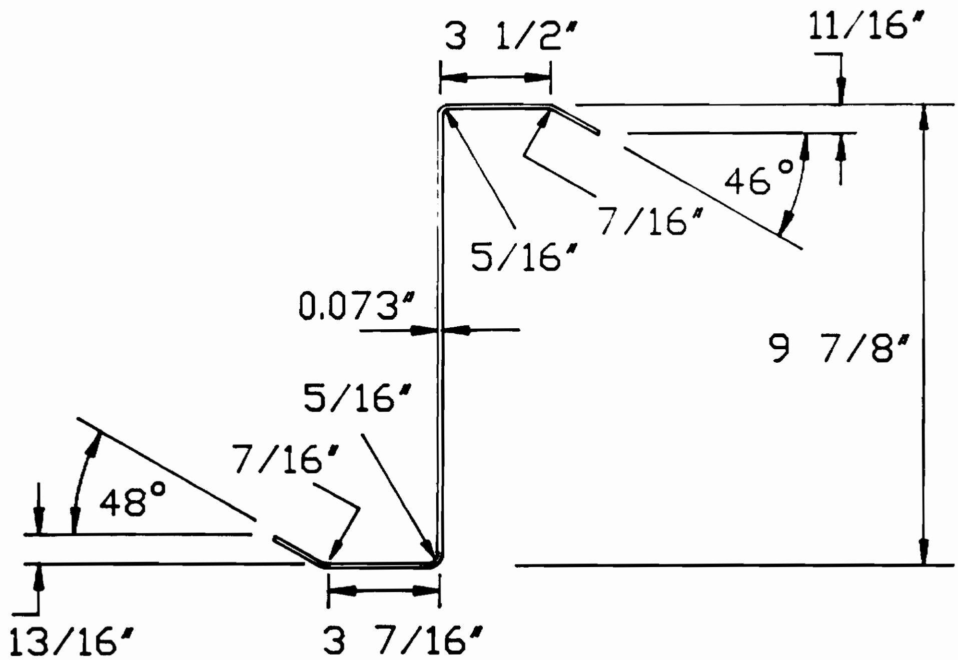
Discussion:

- Failure load includes 8.7 plf deadload.
- Vacuum chamber used to test system.
- Manometer used to measure load.
- Load deflection curve essentially linear.
- Failure occurred in ridge purlin by local buckling.
- 1" movement of clip W.R.T. deck midspan.
- Two piece sliding clips near mid-span moved the full extent of the sliding mechanism.

TEST R-S-10Z0.073-25-□
SERIES I



RIDGE PURLIN



EAVE PURLIN

Roof System Design Version 1.00

Date: 11/09/90 By: BLR

Job Id.: SERIES I R-S-10Z0.073-25-0
Roof Id.: RIDGE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Bay Information
Bay # 1:
Distance between supports: 25'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 122.53 psf
Uplift Capacity: 61.53 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

Total System Weight: 113.3 Lbs.

Cross-Sections

Purlin Identification for Bay # 1: Z 9.88x0.073

	Top		Bottom	
Lip Length:	1.0933		0.9557	in.
Lip Angle:	48.000		46.000	Deg.
Radii:				
Lip to Flange:	0.4375		0.4375	in.
Flange to web:	0.3125		0.3125	in.
Flange Width:	3.4375		3.4375	in.
Total Depth:	9.875	in.		
Thickness:	0.0730	in.		
Yield Stress:	59.70	ksi		
Young's Modulus:	29500.0	ksi		

Roof System Design Version 1.00

Date: 11/09/90 By: BLR

Job Id.: SERIES I R-S-10Z0.073-25-0
Roof Id.: EAVE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Bay Information
Bay # 1:
Distance between supports: 25'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 117.79 psf
Uplift Capacity: 58.90 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

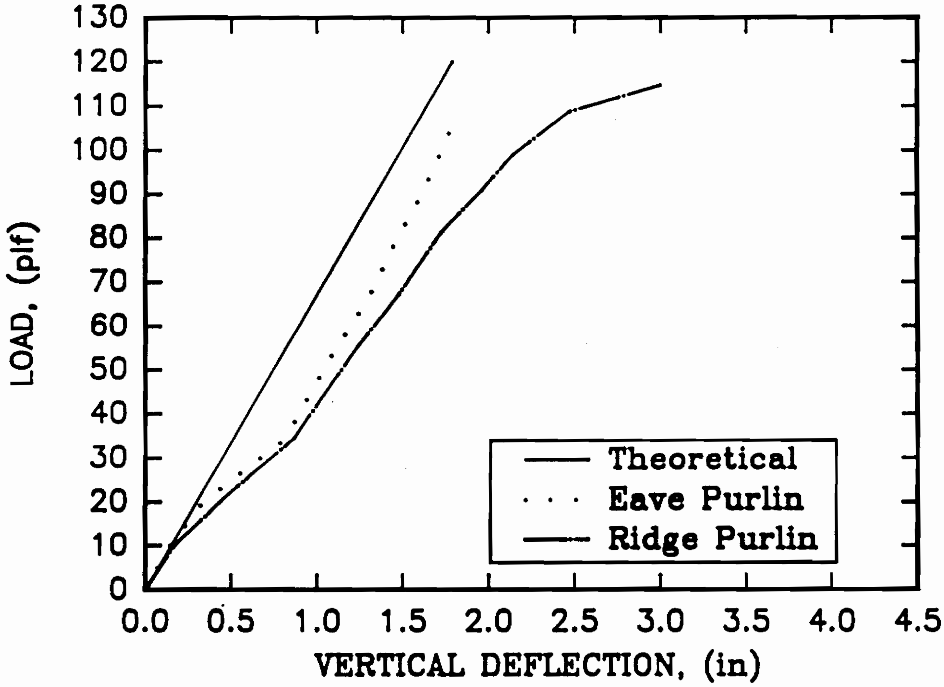
Total System Weight: 113.7 Lbs.

Cross-Sections

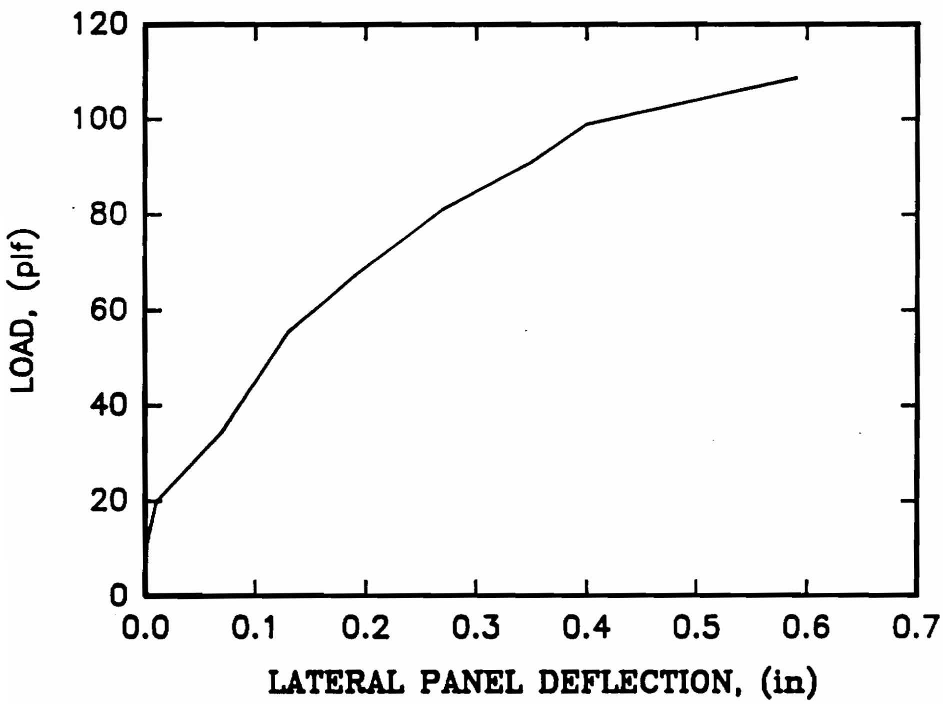
Purlin Identification for Bay # 1: Z 9.88x0.073

	Top		Bottom	
Lip Length:	0.9557		1.0933	in.
Lip Angle:	46.000		48.000	Deg.
Radii:				
Lip to Flange:	0.4375		0.4375	in.
Flange to web:	0.3125		0.3125	in.
Flange Width:	3.5000		3.4375	in.
Total Depth:	9.875	in.		
Thickness:	0.0730	in.		
Yield Stress:	59.70	ksi		
Young's Modulus:	29500.0	ksi		

SERIES I
TEST R-S-10Z0.073-25-0



a) Load vs. Vertical Deflection



b) Load vs. Lateral Panel Deflection

MBMA PROJECT 502

Test Summary

Series I

R-S-10Z0.092-25-0

Test Date: May 21, 1990

Purpose: Single Span Base Test

Span: 25'-0"

Purlin:	Eave	Ridge
Thickness	0.092"	0.092"
Sweep	1/2"	1/2"

Parameters: Gravity Loading, Bracing @ Supports Only

Two Purlin Lines, 5'-0" O.C.; 1'-0" Deck Overhang

Purlins Facing Opposite Direction

Rib Type Deck with Two Piece Sliding Clip

Failure Load: 170.9 plf   Failure Mode: Lateral Buckling

Yield Stress: 61.5 ksi

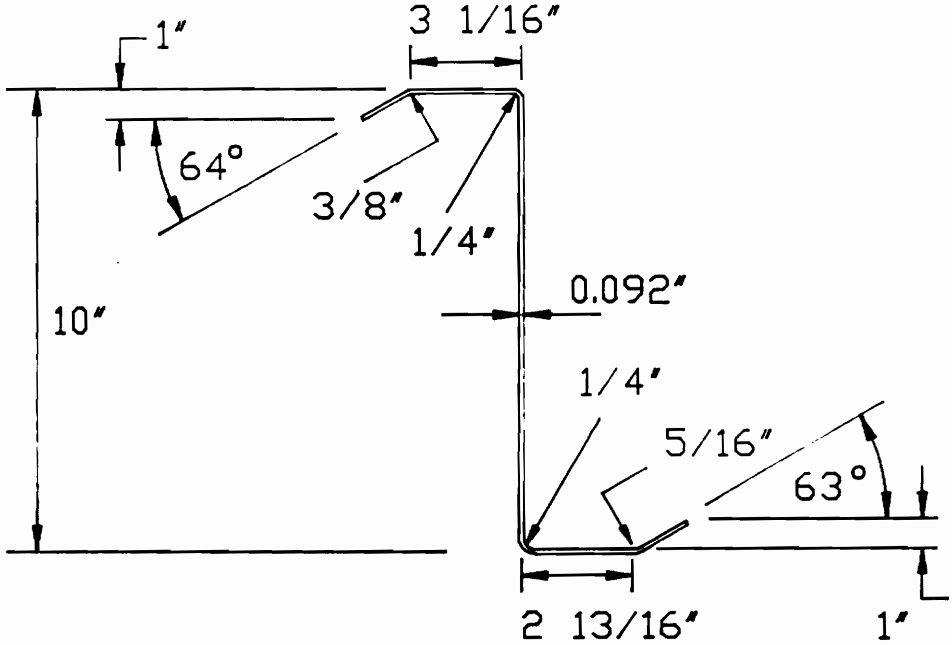
Predicted Constrained Bending Failure load: 279.4 plf

Actual Failure Load/Predicted Constrained Bending Failure Load: 61.2 %

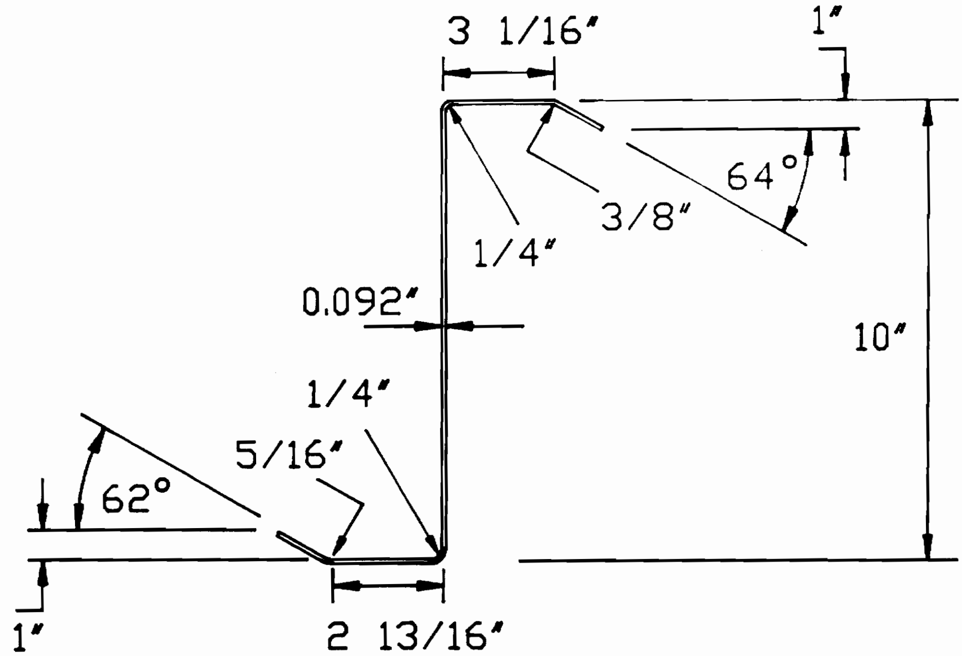
Discussion:

- Failure load includes 9.7 plf deadload.
- Vacuum chamber used to test system.
- Manometer used to measure load.
- Load deflection curve essentially linear.
- Failure occurred in ridge purlin by lateral buckling.
- Two piece sliding clips near mid-span moved the full extent of the sliding mechanism and separated.
- At 7.3 inches of H_2O, movement of a clip near mid-span caused a shift in the load-deflection curve for the eave purlin.

TEST R-S-10Z0.092-25-D
SERIES I



RIDGE PURLIN



EAVE PURLIN

Roof System Design Version 1.00

Date: 11/09/90 By: BLR

Job Id.: SERIES I R-S-10Z0.092-25-O
Roof Id.: RIDGE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Bay Information
Bay # 1:
Distance between supports: 25'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 167.29 psf
Uplift Capacity: 83.65 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

Total System Weight: 136.6 Lbs.

Cross-Sections

Purlin Identification for Bay # 1: Z 10x0.092

	Top		Bottom	
Lip Length:	1.1126		1.1223	in.
Lip Angle:	64.000		63.000	Deg.
Radii:				
Lip to Flange:	0.3750		0.3125	in.
Flange to web:	0.2500		0.2500	in.
Flange Width:	3.0625		2.8125	in.
Total Depth:	10.000	in.		
Thickness:	0.0920	in.		
Yield Stress:	61.50	ksi		
Young's Modulus:	29500.0	ksi		

Roof System Design Version 1.00

Date: 11/09/90 By: BLR

Job Id.: SERIES I R-S-10Z0.092-25-0
Roof Id.: EAVE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Bay Information
Bay # 1:
Distance between supports: 25'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 167.38 psf
Uplift Capacity: 83.69 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

Total System Weight: 136.7 Lbs.

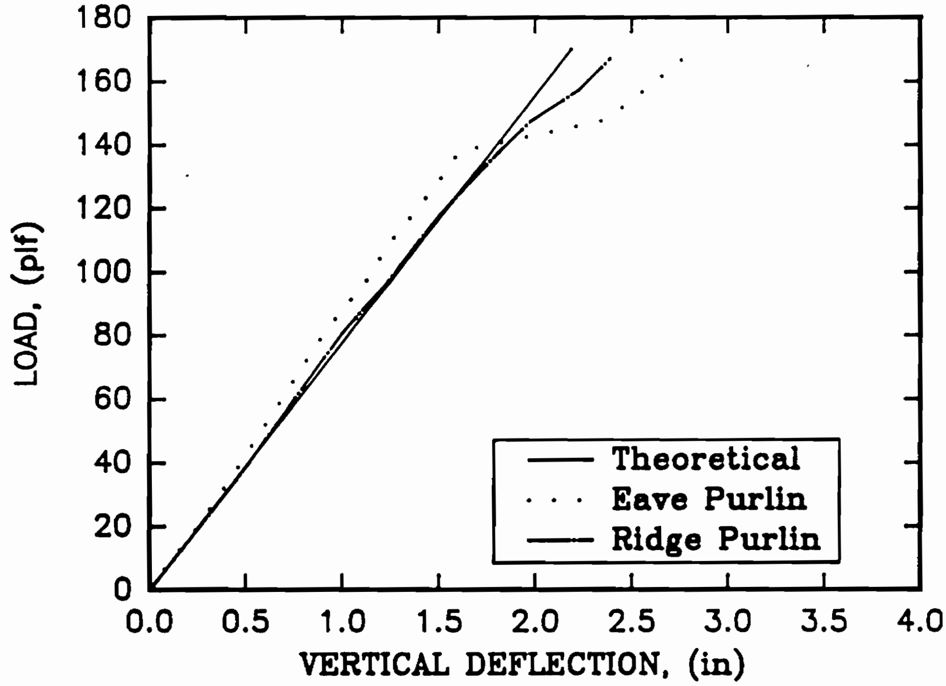
Cross-Sections

Purlin Identification for Bay # 1: Z 10x0.092

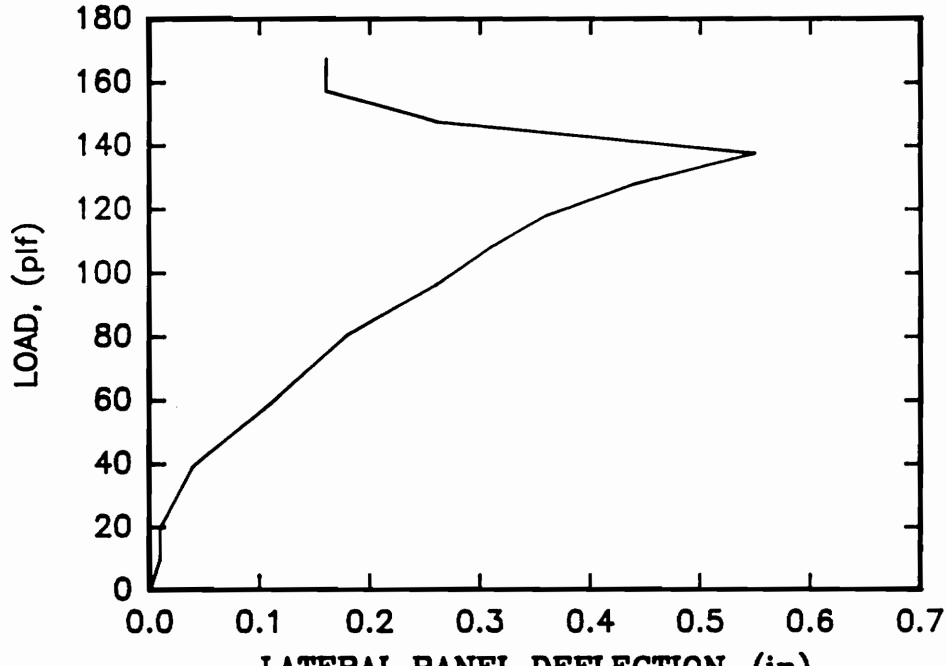
	Top		Bottom	
Lip Length:	1.1126		1.1326	in.
Lip Angle:	64.000		62.000	Deg.
Radii:				
Lip to Flange:	0.3750		0.3750	in.
Flange to web:	0.2500		0.2500	in.
Flange Width:	3.0625		2.8125	in.
Total Depth:	10.000	in.		
Thickness:	0.0920	in.		
Yield Stress:	61.50	ksi		
Young's Modulus:	29500.0	ksi		

SERIES I

TEST R-S-10Z0.092-25-0



a) Load vs. Vertical Deflection



b) Load vs. Lateral Panel Deflection

APPENDIX B

SERIES II TEST SUMMARIES

MBMA PROJECT 502

Test Summary

Series II

R-S-8Z0.06-25-0

Test Date: May 24, 1990

Purpose: Single Span Base Test

Span: 25'-0"

Purlin:	Eave	Ridge
Thickness	0.060"	0.060"
Sweep	1 1/4"	1 1/4"

Parameters: Gravity Loading, Bracing @ Supports Only

Two Purlin Lines, 5'-0" O.C.; 1'-0" Deck Overhang

Purlins Facing Same Direction

Rib Type Deck with Two Piece Sliding Clip

4 Inch Insulation

Failure Load: 61.4 plf Failure Mode: Local Buckling

Yield Stress: 59.5 ksi

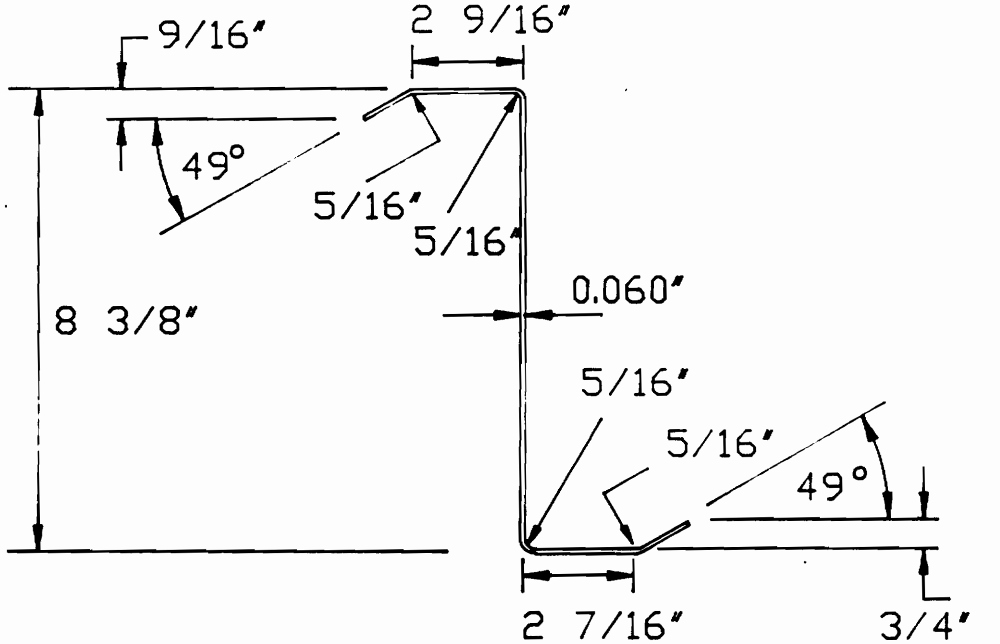
Predicted Constrained Bending Failure load: 111.8 plf

Actual Failure Load/Predicted Constrained Bending Failure Load: 54.9 %

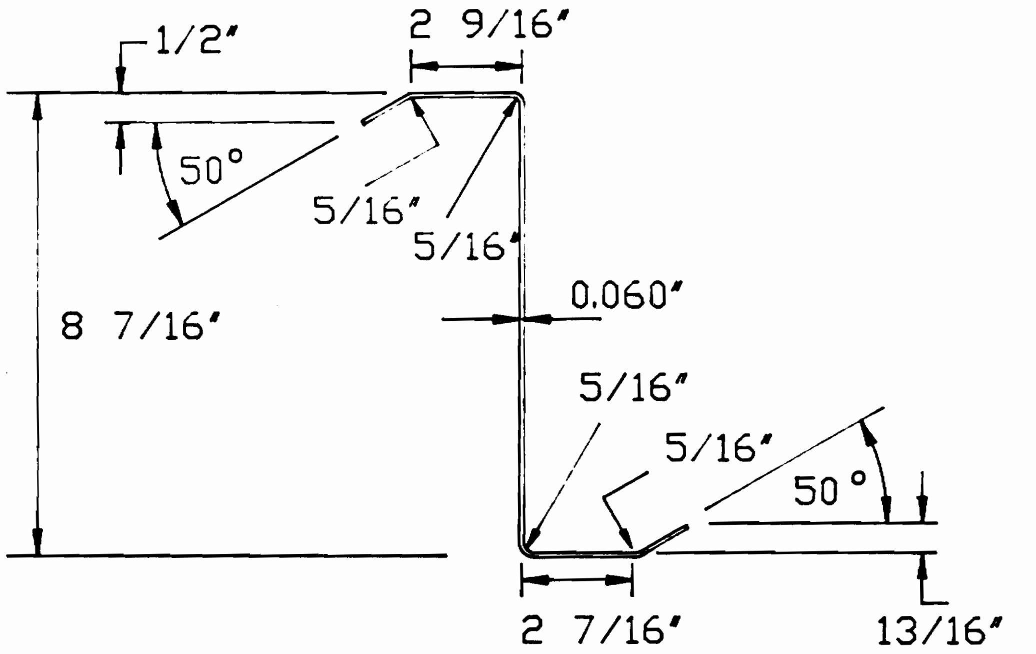
Discussion:

- Failure load includes 7.1 plf deadload.
- Vacuum chamber used to test system.
- Manometer used to measure load.
- Load deflection curve essentially linear.
- Failure occurred in ridge purlin by local buckling.
- 1 1/4" movement of clip W.R.T. deck at mid-span.
- Two piece sliding clips near mid-span moved the full extent of the sliding mechanism.

TEST R-S-8Z0.060-25
SERIES II



RIDGE PURLIN



EAVE PURLIN

Roof System Design Version 1.00

Date: 11/12/90 By: BLR

Job Id.: SERIES II R-S-8Z0.060-25
Roof Id.: RIDGE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Applied Loads

Bay Information
Bay # 1:
Distance between supports: 25'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 66.93 psf
Uplift Capacity: 33.46 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

Total System Weight: 74.6 Lbs.

Cross-Sections

Purlin Identification for Bay # 1: Z 8.38x0.06

	Top		Bottom	
Lip Length:	0.7453		0.9938	in.
Lip Angle:	49.000		49.000	Deg.
Radii:				
Lip to Flange:	0.3125		0.3125	in.
Flange to web:	0.3125		0.3125	in.
Flange Width:	2.5625		2.4375	in.
Total Depth:	8.375	in.		
Thickness:	0.0600	in.		
Yield Stress:	59.50	ksi		
Young's Modulus:	29500.0	ksi		

Roof System Design Version 1.00

Date: 11/12/90 By: BLR

Job Id.: SERIES II R-S-8Z0.060-25
Roof Id.: EAVE PURLINN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Applied Loads

Bay Information
Bay # 1:
Distance between supports: 25'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 65.07 psf
Uplift Capacity: 32.54 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

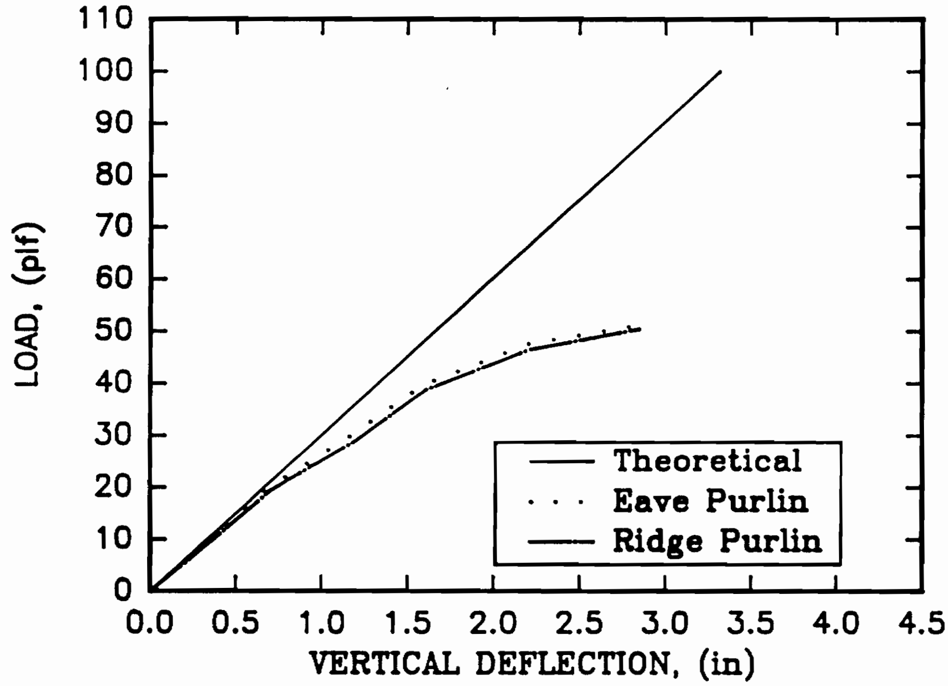
Total System Weight: 74.7 Lbs.

Cross-Sections

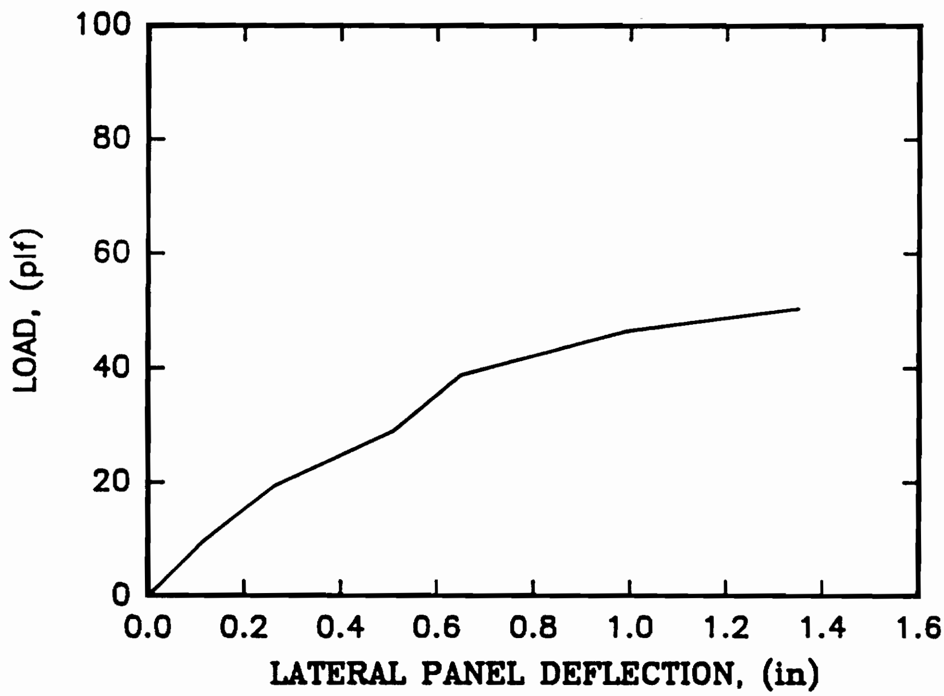
Purlin Identification for Bay # 1: Z 8.44x0.06

	Top		Bottom	
Lip Length:	0.6527		1.0606	in.
Lip Angle:	50.000		50.000	Deg.
Radii:				
Lip to Flange:	0.3125		0.3125	in.
Flange to web:	0.3125		0.3125	in.
Flange Width:	2.5625		2.4375	in.
Total Depth:	8.438	in.		
Thickness:	0.0600	in.		
Yield Stress:	59.50	ksi		
Young's Modulus:	29500.0	ksi		

SERIES II
TEST R-S-8Z0.060-25 w/Ins.



a) Load vs. Vertical Deflection



b) Load vs. Lateral Panel Deflection

MBMA PROJECT 502

Test Summary

Series II

R-S-8Z0.10-25

Test Date: May 31, 1990

Purpose: Single Span Base Test

Span: 25'-0"

Purlin:	Eave	Ridge
Thickness	0.101"	0.101"
Sweep	1 1/8"	neg.

Parameters: Gravity Loading, Bracing @ Supports Only

Two Purlin Lines, 5'-0" O.C.; 1'-0" Deck Overhang

Purlins Facing Same Direction

Rib Type Deck with Two Piece Sliding Clip

Failure Load: 127.7 plf Failure Mode: Lateral Buckling

Yield Stress: 54.8 ksi

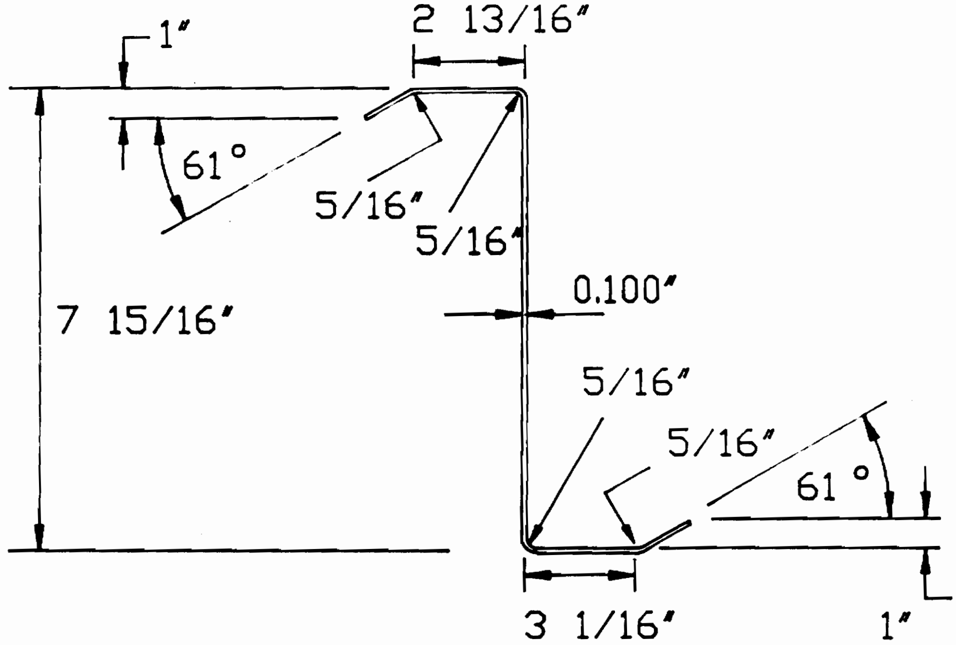
Predicted Constrained Bending Failure load: 217.4 plf

Actual Failure Load/Predicted Constrained Bending Failure Load: 58.7 %

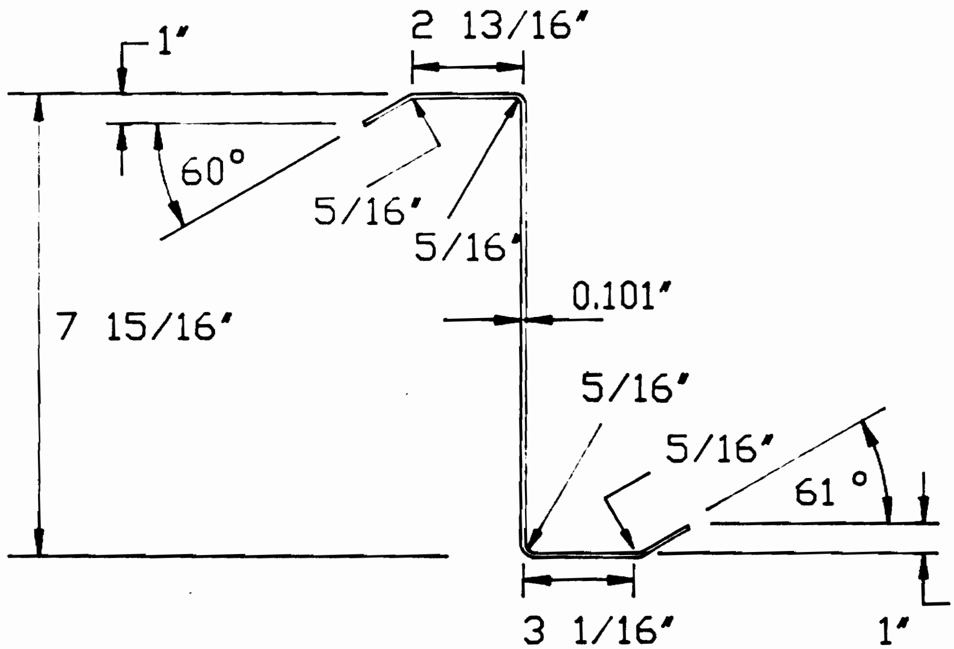
Discussion:

- Failure load includes 9.41 plf deadload.
- Vacuum chamber used to test system.
- Manometer used to measure load.
- Load deflection curve essentially linear.
- Failure occurred in eave purlin by lateral buckling.
- 1 1/4" movement of clip W.R.T. deck at mid-span.
- Two piece sliding clips near mid-span moved the full extent of the sliding mechanism and separated.

TEST R-S-8Z0.10-25
SERIES II



RIDGE PURLIN



EAVE PURLIN

Roof System Design Version 1.00

Date: 11/12/90 By: BLR

Job Id.: SERIES II R-S-8Z0.10-25
Roof Id.: RIDGE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Applied Loads

Bay Information
Bay # 1:
Distance between supports: 25'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 128.95 psf
Uplift Capacity: 64.48 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

Total System Weight: 130.9 Lbs.

Cross-Sections

Purlin Identification for Bay # 1: Z 7.94x0.1

	Top		Bottom	
Lip Length:	1.1434		1.1434	in.
Lip Angle:	61.000		61.000	Deg.
Radii:				
Lip to Flange:	0.3125		0.3125	in.
Flange to web:	0.3125		0.3125	in.
Flange Width:	2.8125		3.0625	in.
Total Depth:	7.938	in.		
Thickness:	0.1000	in.		
Yield Stress:	54.80	ksi		
Young's Modulus:	29500.0	ksi		

Roof System Design Version 1.00

Date: 11/12/90 By: BLR

Job Id.: SERIES II R-S-8Z0.10-25
Roof Id.: EAVE PURLINN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Applied Loads

Bay Information
Bay # 1:
Distance between supports: 25'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 130.17 psf
Uplift Capacity: 65.09 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

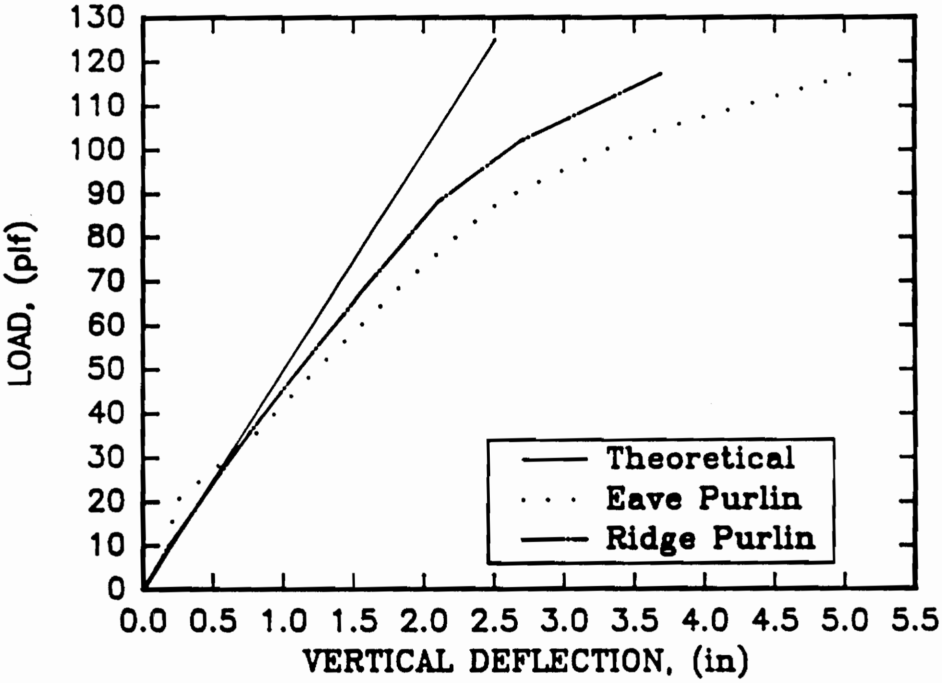
Total System Weight: 132.2 Lbs.

Cross-Sections

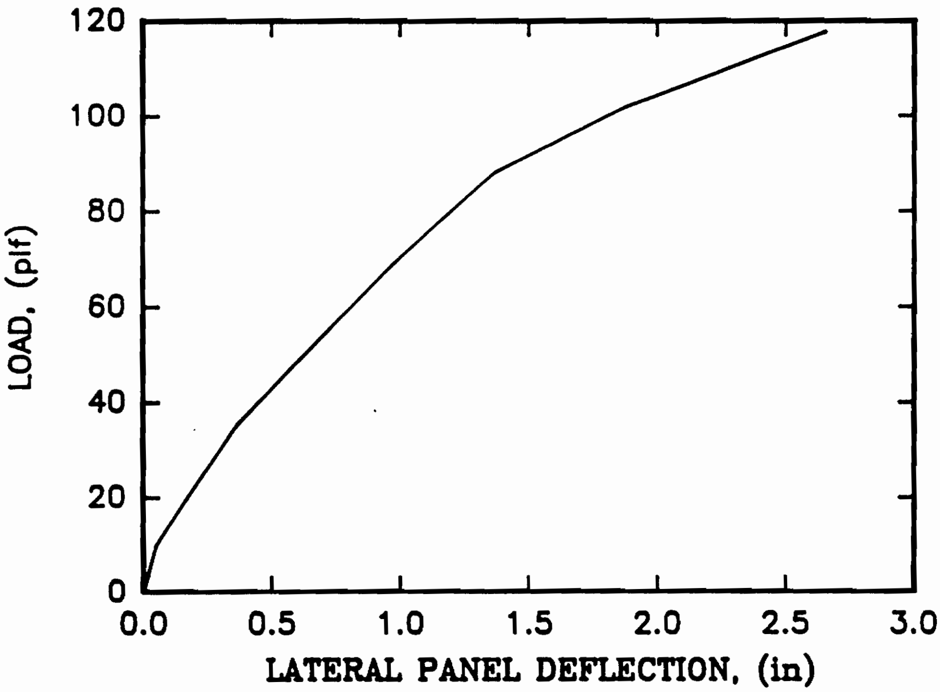
Purlin Identification for Bay # 1: Z 7.94x0.101

	Top		Bottom	
Lip Length:	1.1434		1.1434	in.
Lip Angle:	61.000		61.000	Deg.
Radii:				
Lip to Flange:	0.3125		0.3125	in.
Flange to web:	0.3125		0.3125	in.
Flange Width:	2.8125		3.0625	in.
Total Depth:	7.938	in.		
Thickness:	0.1010	in.		
Yield Stress:	54.80	ksi		
Young's Modulus:	29500.0	ksi		

SERIES II
TEST R-S-8Z0.10-25



a) Load vs. Vertical Deflection



b) Load vs. Lateral Panel Deflection

MBMA PROJECT 502

Test Summary

Series II

R-S-10Z0.073-25

Test Date: June 5, 1990

Purpose: Single Span Base Test

Span: 25'-0"

Purlin:	Eave	Ridge
Thickness	0.073"	0.074"
Sweep	5/8"	neg.

Parameters: Gravity Loading, Bracing @ Supports Only

Two Purlin Lines, 5'-0" O.C.; 1'-0" Deck Overhang

Purlins Facing Same Direction

Rib Type Deck with Two Piece Sliding Clip

Failure Load: 115.8 plf Failure Mode: Local Buckling

Yield Stress: 60.8 ksi

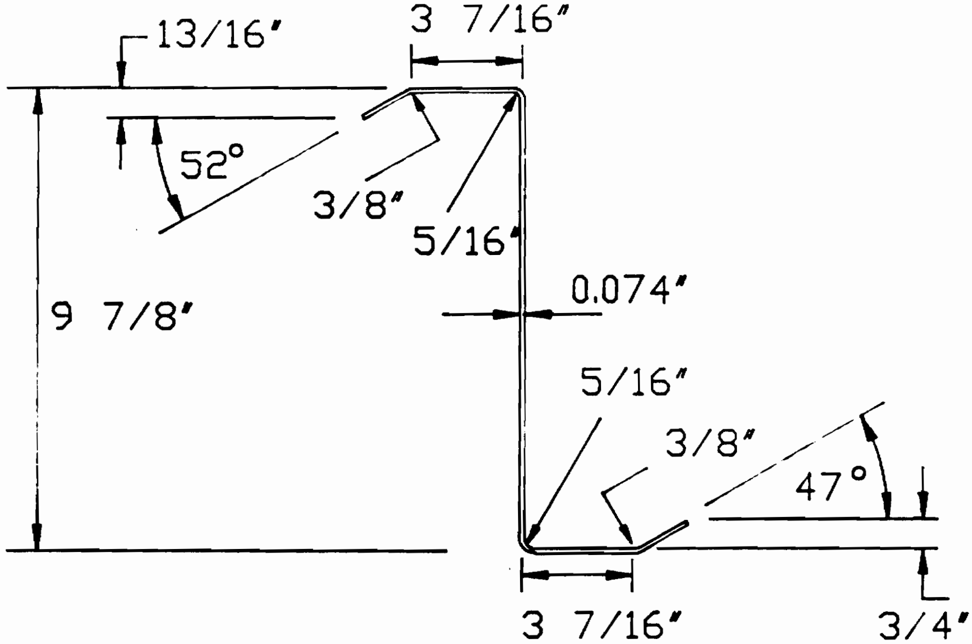
Predicted Constrained Bending Failure load: 208.5 plf

Actual Failure Load/Predicted Constrained Bending Failure Load: 55.5 %

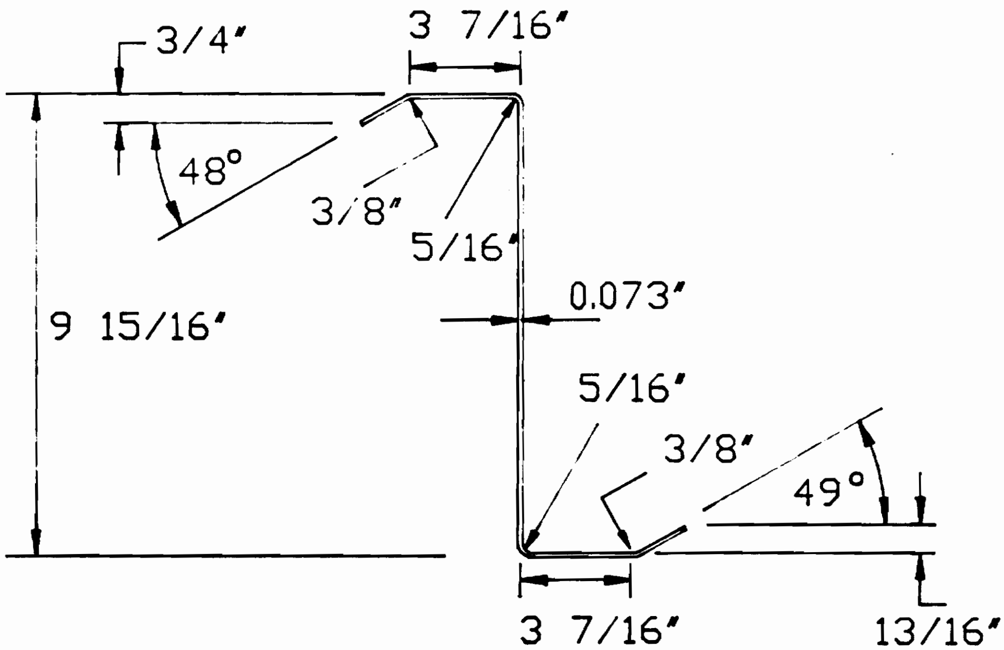
Discussion:

- Failure load includes 8.6 plf deadload.
- Vacuum chamber used to test system.
- Manometer used to measure load.
- Load deflection curve essentially linear.
- Failure occurred in eave purlin by local buckling.
- 1" movement of clip W.R.T. deck at mid-span.
- Two piece sliding clips near mid-span moved the full extent of the sliding mechanism.

TEST R-S-10Z0.073-25
SERIES II



RIDGE PURLIN



EAVE PURLIN

Roof System Design Version 1.00

Date: 11/12/90 By: BLR

Job Id.: SERIES II R-S-10Z0.073-25
Roof Id.: RIDGE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Applied Loads

Bay Information
Bay # 1:
Distance between supports: 25'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 126.36 psf
Uplift Capacity: 63.18 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

Total System Weight: 114.8 Lbs.

Cross-Sections

Purlin Identification for Bay # 1: Z 9.88x0.074

	Top		Bottom	
Lip Length:	1.0311		1.0255	in.
Lip Angle:	52.000		47.000	Deg.
Radii:				
Lip to Flange:	0.3750		0.3750	in.
Flange to web:	0.3125		0.3125	in.
Flange Width:	3.4375		3.4375	in.
Total Depth:	9.875	in.		
Thickness:	0.0740	in.		
Yield Stress:	60.81	ksi		
Young's Modulus:	29500.0	ksi		

Roof System Design Version 1.00

Date: 11/12/90 By: BLR

Job Id.: SERIES II R-S-10Z0.073-25
Roof Id.: EAVE PURLINN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Applied Loads

Bay Information
Bay # 1:
Distance between supports: 25'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 124.83 psf
Uplift Capacity: 62.41 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

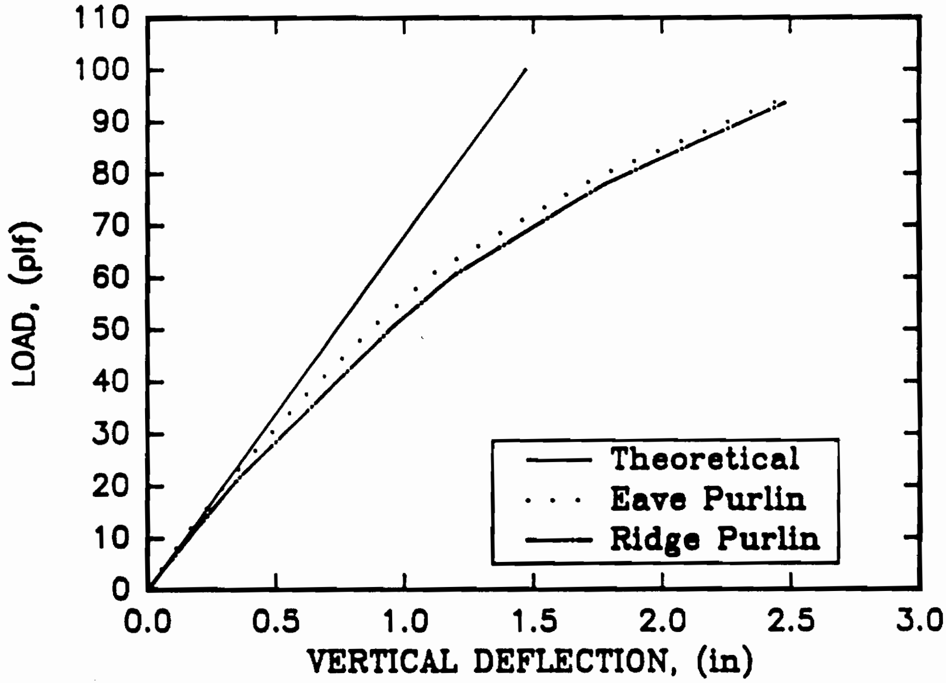
Total System Weight: 115.4 Lbs.

Cross-Sections

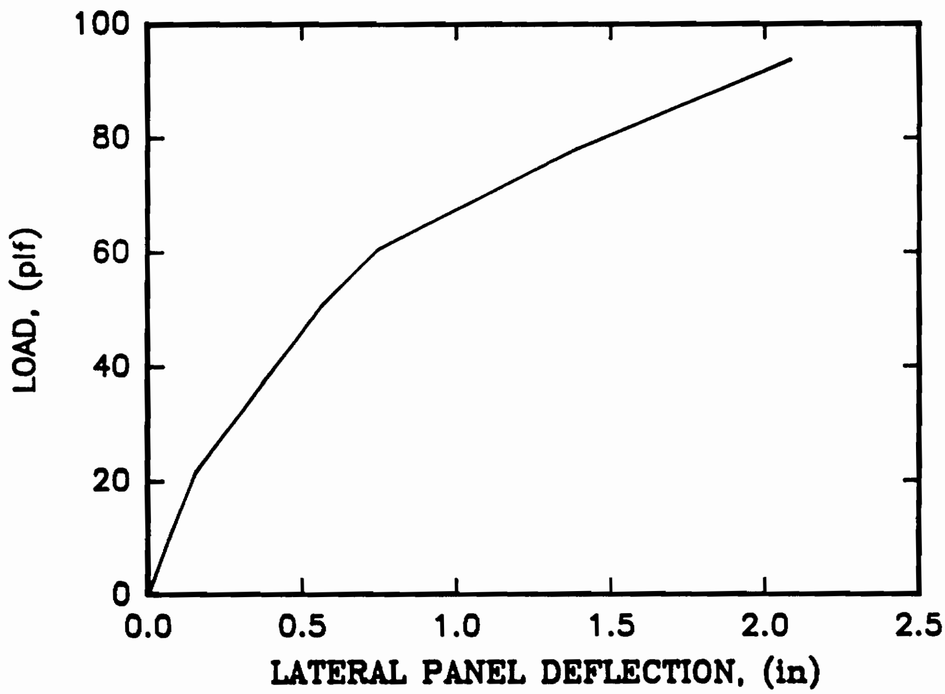
Purlin Identification for Bay # 1: Z 9.94x0.074

	Top		Bottom	
Lip Length:	1.0092		1.0766	in.
Lip Angle:	48.000		49.000	Deg.
Radii:				
Lip to Flange:	0.3750		0.3750	in.
Flange to web:	0.3125		0.3125	in.
Flange Width:	3.4375		3.4375	in.
Total Depth:	9.938	in.		
Thickness:	0.0740	in.		
Yield Stress:	60.81	ksi		
Young's Modulus:	29500.0	ksi		

SERIES II
TEST R-S-10Z0.073-25



a) Load vs. Vertical Deflection



b) Load vs. Lateral Panel Deflection

MBMA PROJECT 502

Test Summary

Series II

R-S-10Z0.094-25

Test Date: June 8, 1990

Purpose: Single Span Base Test

Span: 25'-0"

Purlin:	Eave	Ridge
Thickness	0.093"	0.094"
Sweep	1/4"	3/8"

Parameters: Gravity Loading, Bracing @ Supports Only

Two Purlin Lines, 5'-0" O.C.; 1'-0" Deck Overhang

Purlins Facing Same Direction

Rib Type Deck with Two Piece Sliding Clip

Failure Load: 171.5 plf Failure Mode: Local Buckling

Yield Stress: 62.2 ksi

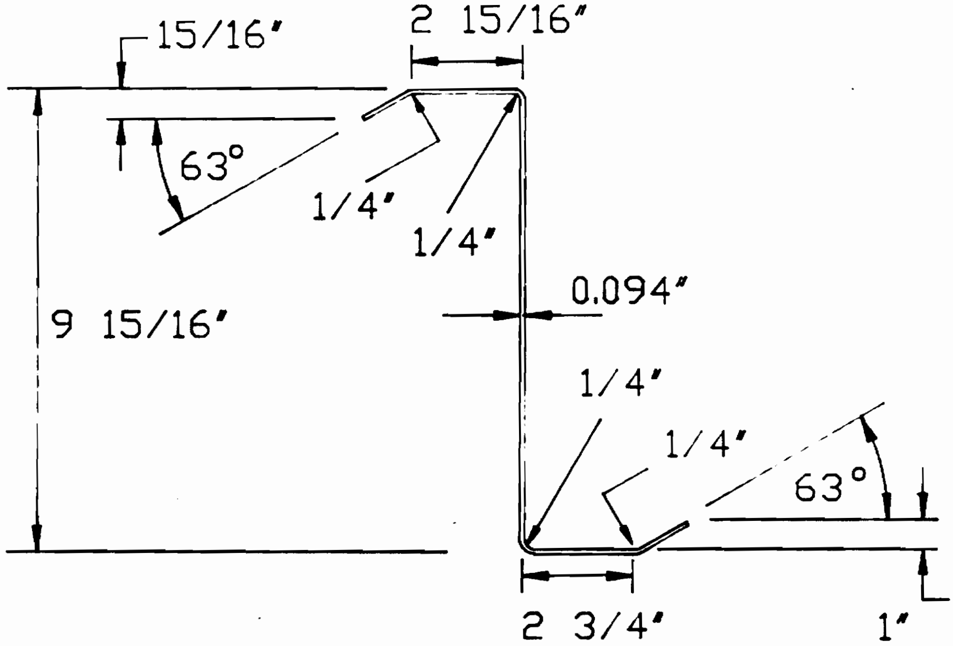
Predicted Constrained Bending Failure load: 285.3 plf

Actual Failure Load/Predicted Constrained Bending Failure Load: 60.1 %

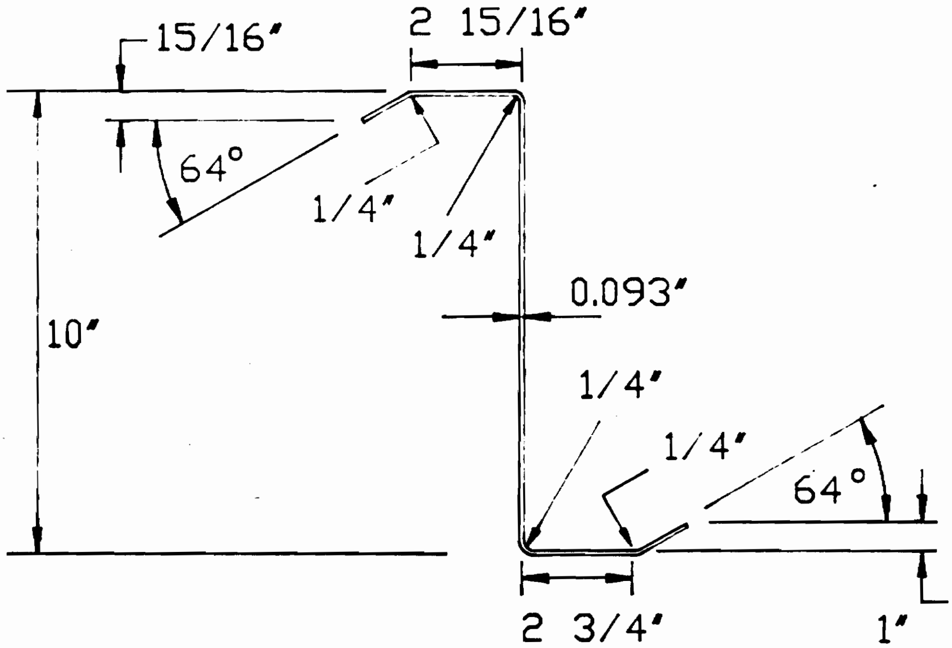
Discussion:

- Failure load includes 9.6 plf deadload.
- Vacuum chamber used to test system.
- Manometer used to measure load.
- Load deflection curve essentially linear.
- Failure occurred in eave purlin by local buckling.
- 1" movement of clip W.R.T. deck at mid-span.
- Two piece sliding clips near mid-span moved the full extent of the sliding mechanism and separated.

TEST R-S-10Z0.094-25
SERIES II



RIDGE PURLIN



EAVE PURLIN

Roof System Design Version 1.00

Date: 11/12/90 By: BLR

Job Id.: SERIES II R-S-10Z0.094-25
Roof Id.: RIDGE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Applied Loads

Bay Information
Bay # 1:
Distance between supports: 25'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 172.44 psf
Uplift Capacity: 86.22 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

Total System Weight: 137.3 Lbs.

Cross-Sections

Purlin Identification for Bay # 1: Z 9.94x0.094

	Top		Bottom	
Lip Length:	1.0522		1.1223	in.
Lip Angle:	63.000		63.000	Deg.
Radii:				
Lip to Flange:	0.2500		0.2500	in.
Flange to web:	0.2500		0.2500	in.
Flange Width:	2.9375		2.7500	in.
Total Depth:	9.938	in.		
Thickness:	0.0940	in.		
Yield Stress:	62.20	ksi		
Young's Modulus:	29500.0	ksi		

Roof System Design Version 1.00

Date: 11/12/90 By: BLR

Job Id.: SERIES II R-S-10Z0.094-25
Roof Id.: EAVE PURLINN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Applied Loads

Bay Information
Bay # 1:
Distance between supports: 25'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 170.84 psf
Uplift Capacity: 85.42 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

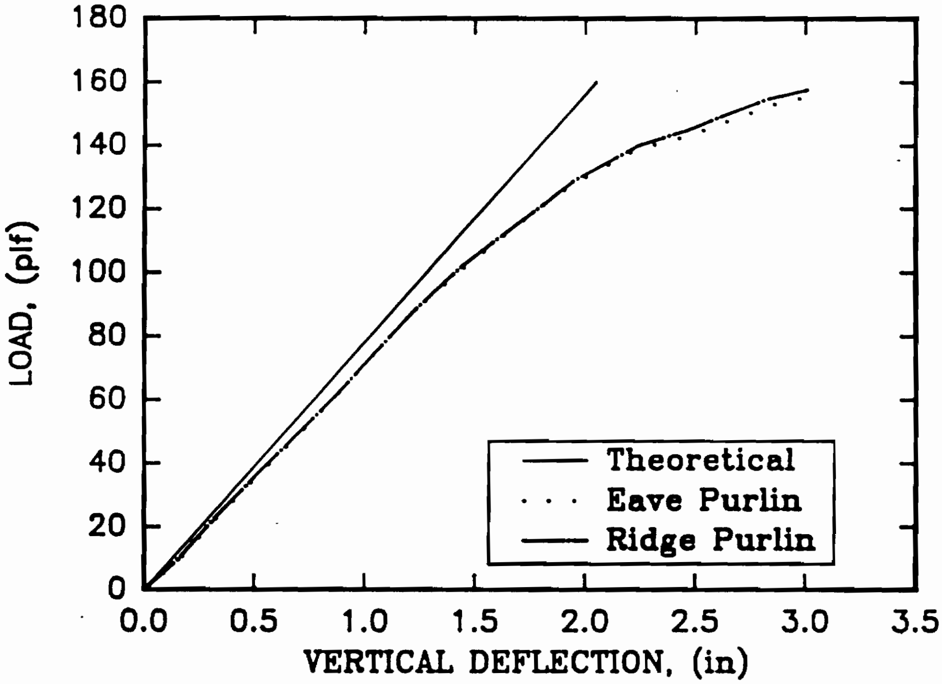
Total System Weight: 136.1 Lbs.

Cross-Sections

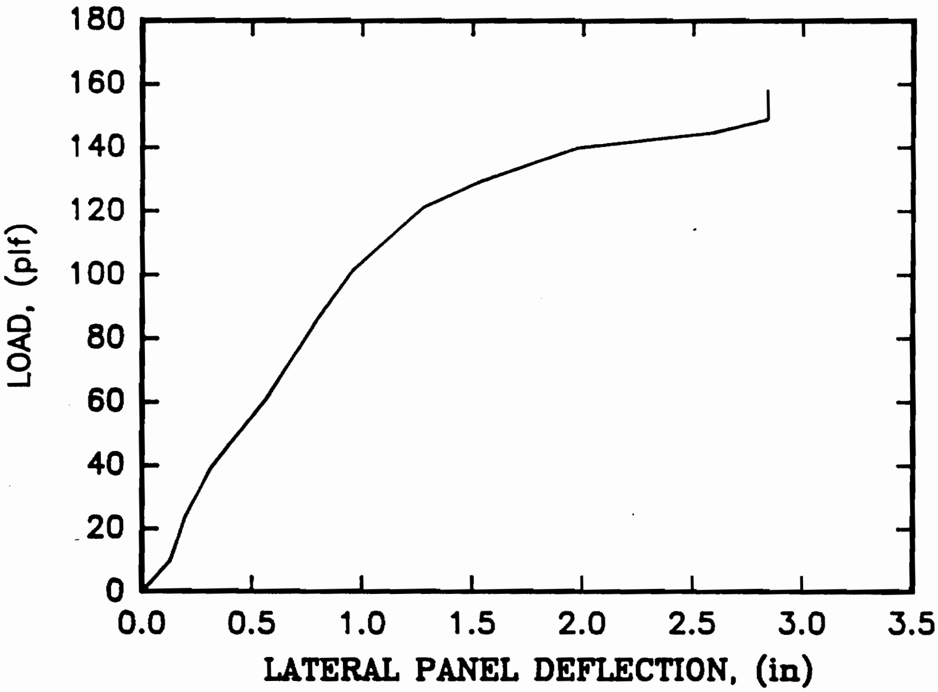
Purlin Identification for Bay # 1: Z 10x0.093

	Top		Bottom	
Lip Length:	1.0431		1.1126	in.
Lip Angle:	64.000		64.000	Deg.
Radii:				
Lip to Flange:	0.2500		0.2500	in.
Flange to web:	0.2500		0.2500	in.
Flange Width:	2.9375		2.7500	in.
Total Depth:	10.000	in.		
Thickness:	0.0930	in.		
Yield Stress:	62.20	ksi		
Young's Modulus:	29500.0	ksi		

SERIES II
TEST R-S-10Z0.094-25



a) Load vs. Vertical Deflection



b) Load vs. Lateral Panel Deflection

APPENDIX C

SERIES III TEST SUMMARIES

MBMA PROJECT 502

Test Summary

Series III

P-F-9C0.063-25

Test Date: June 22, 1990

Purpose: Single Span Base Test

Span: 25'-0"

Purlin:	Eave	Ridge
Thickness	0.064"	0.063"
Sweep	3/8"	3/8"

Parameters: Gravity Loading, Bracing @ Supports Only

Two Purlin Lines, 5'-0" O.C.; 1'-0" Deck Overhang

Purlins Facing Same Direction

Pan Type Deck with Fixed Clips

Failure Load: 106.8 plf Failure Mode: Local Buckling

Yield Stress: 58.3 ksi

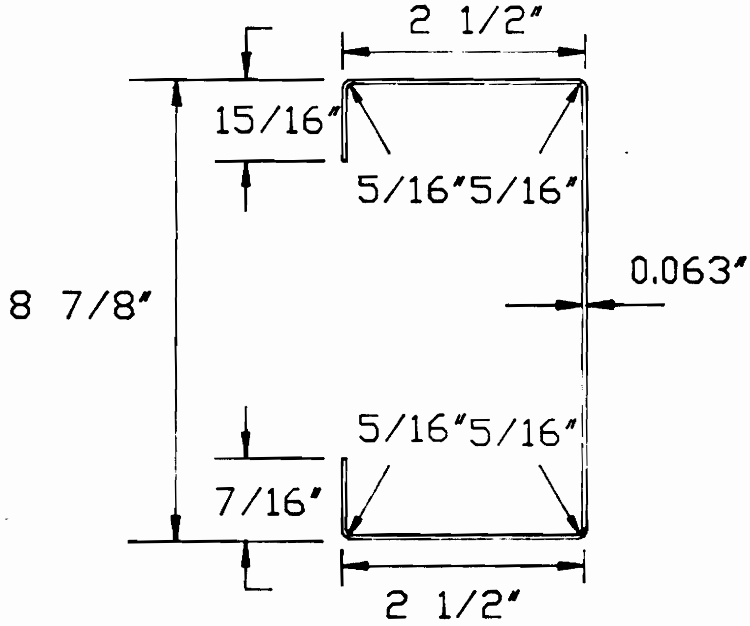
Predicted Constrained Bending Failure load: 131.5 plf

Actual Failure Load/Predicted Constrained Bending Failure Load: 81.2 %

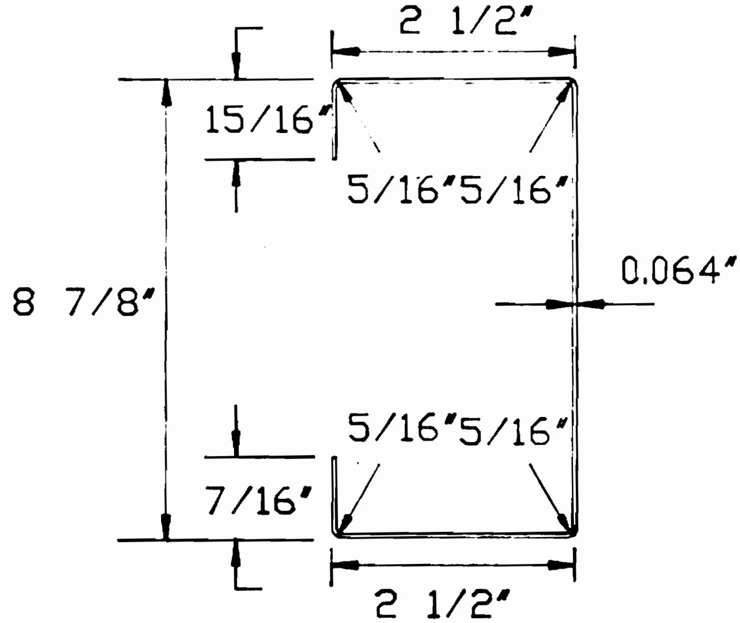
Discussion:

- Failure load includes 7.6 plf deadload.
- Vacuum chamber used to test system.
- Manometer used to measure load.
- Load deflection curve essentially linear.
- Failure occurred in ridge purlin by local buckling.
- 1" movement of clip W.R.T. deck at mid-span.

TEST P-F-9C0.063-25
SERIES III



RIDGE PURLIN



EAVE PURLIN

Roof System Design Version 1.00

Date: 11/12/90 By: BLR

Job Id.: SERIES III P-F-9C0.063-25
Roof Id.: RIDGE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Bay Information
Bay # 1:
Distance between supports: 25'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 78.73 psf
Uplift Capacity: 39.36 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

Total System Weight: 78.4 Lbs.

Cross-Sections

Purlin Identification for Bay # 1: C 8.88x0.064

	Top		Bottom	
Lip Length:	0.9375		0.4375	in.
Lip Angle:	90.000		90.000	Deg.
Radii:				
Lip to Flange:	0.3125		0.3125	in.
Flange to web:	0.3125		0.3125	in.
Flange Width:	2.5000		2.5000	in.
Total Depth:	8.875	in.		
Thickness:	0.0640	in.		
Yield Stress:	58.30	ksi		
Young's Modulus:	29500.0	ksi		

Roof System Design Version 1.00

Date: 11/12/90 By: BLR

Job Id.: SERIES III P-F-9C0.063-25
Roof Id.: EAVE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Bay Information
Bay # 1:
Distance between supports: 25'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 78.73 psf
Uplift Capacity: 39.36 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

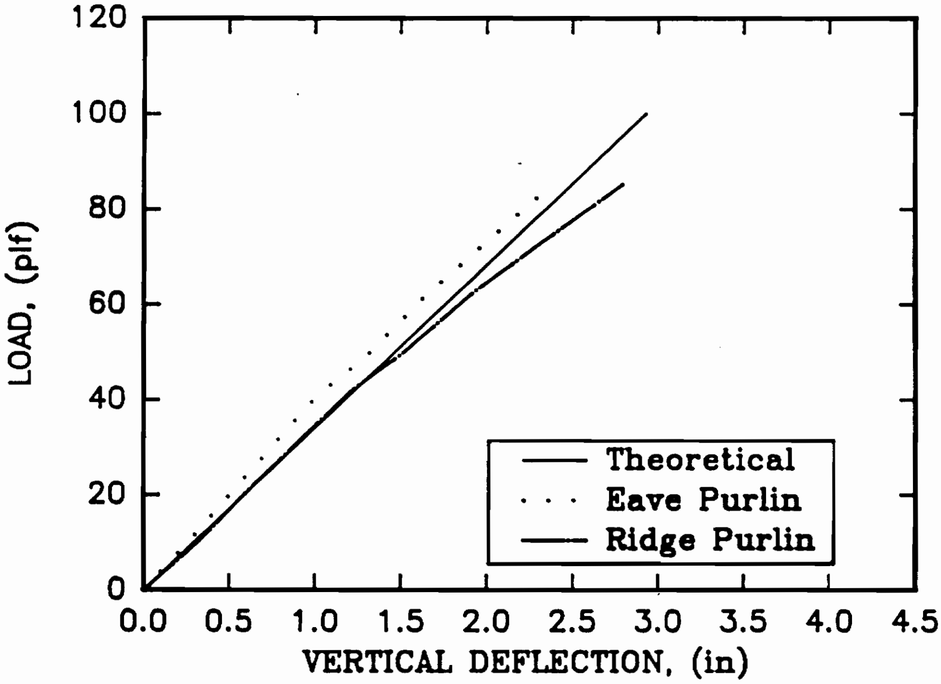
Total System Weight: 0.0 Lbs.

Cross-Sections

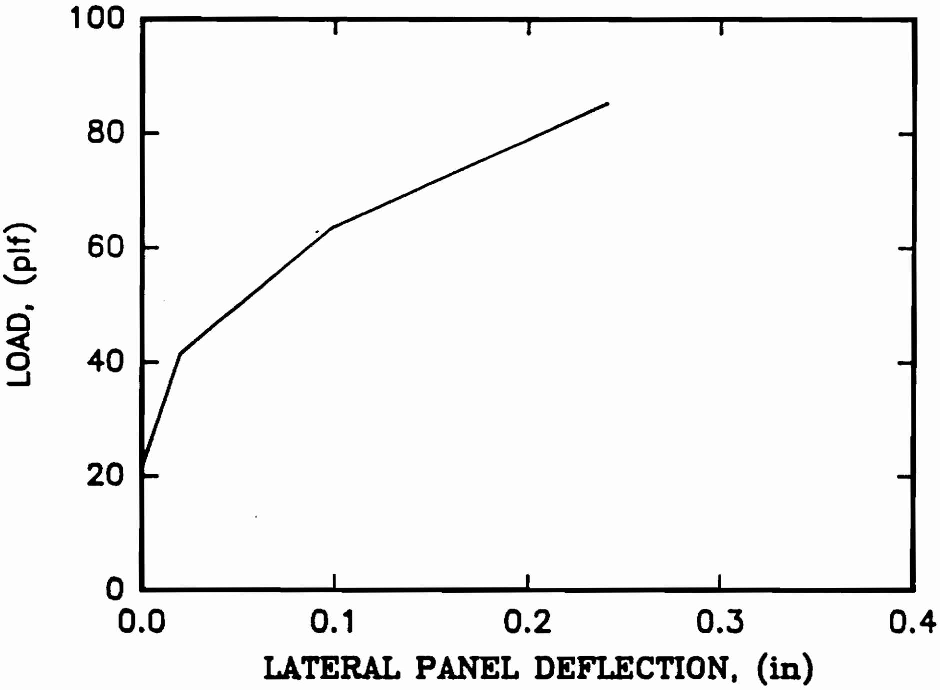
Purlin Identification for Bay # 1: C 8.88x0.064

	Top		Bottom	
Lip Length:	0.9375		0.4375	in.
Lip Angle:	90.000		90.000	Deg.
Radii:				
Lip to Flange:	0.3125		0.3125	in.
Flange to web:	0.3125		0.3125	in.
Flange Width:	2.5000		2.5000	in.
Total Depth:	8.875	in.		
Thickness:	0.0640	in.		
Yield Stress:	58.30	ksi		
Young's Modulus:	29500.0	ksi		

SERIES III
TEST P-F-9C0.063-25



a) Load vs. Vertical Deflection



b) Load vs. Lateral Panel Deflection

MBMA PROJECT 502

Test Summary

Series III

P-F-9C0.064-25

Test Date: July 12, 1990

Purpose: Single Span Base Test

Span: 25'-0"

	Eave	Ridge
Thickness	0.063"	0.063"
Sweep	neg.	neg.

Parameters: Gravity Loading, Bracing @ Supports Only

Two Purlin Lines, 5'-0" O.C.; 1'-0" Deck Overhang

Purlins Facing Same Direction

Pan Type Deck with Fixed Clips

4" Insulation

Failure Load: 93.3 plf   Failure Mode: Local Buckling

Yield Stress: 51.5 ksi

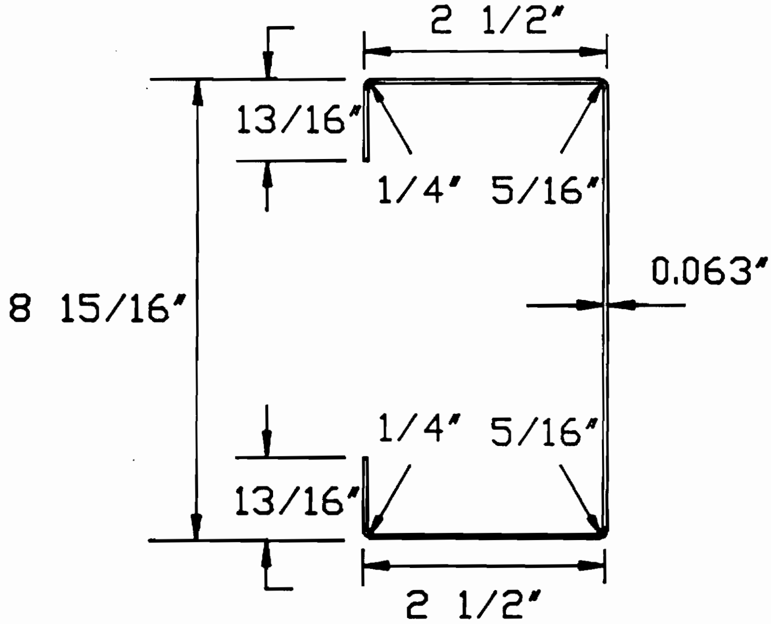
Predicted Constrained Bending Failure load: 117.7 plf

Actual Failure Load/Predicted Constrained Bending Failure Load: 79.3 %

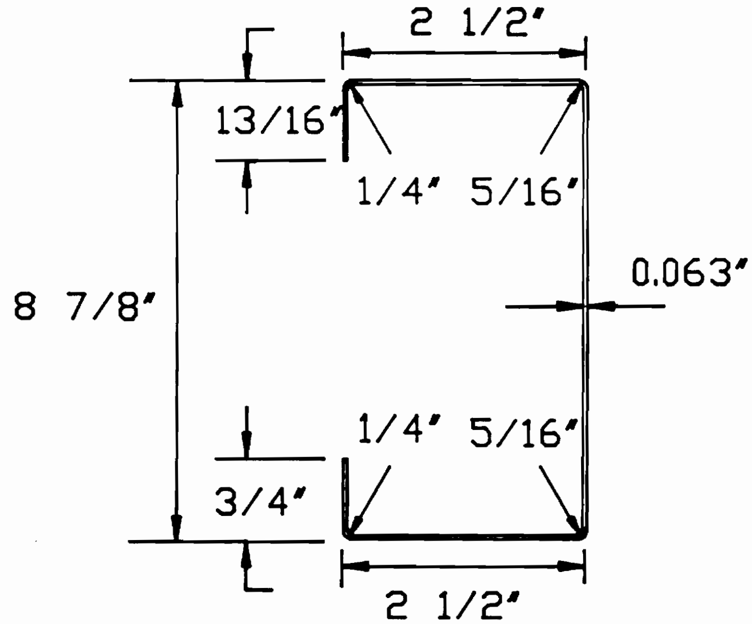
Discussion:

- Failure load includes 7.6 plf deadload.
- Vacuum chamber used to test system.
- Manometer used to measure load.
- Load deflection curve essentially linear.
- Failure occurred in eave purlin by local buckling.
- 1 1/2" movement of clip W.R.T. deck at mid-span.

TEST P-F-9C0.064-25 w/Ins.
SERIES III



RIDGE PURLIN



EAVE PURLIN

Roof System Design Version 1.00

Date: 12/20/90 By: BLR

Job Id.: SERIES III P-F-9C0.064-25 w/Insulation
Roof Id.: RIDGE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Applied Loads

Bay Information
Bay # 1:
Distance between supports: 25'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 70.45 psf
Uplift Capacity: 35.22 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

Total System Weight: 78.5 Lbs.

Cross-Sections

Purlin Identification for Bay # 1: C 8.94x0.063

	Top		Bottom	
Lip Length:	0.8125		0.8125	in.
Lip Angle:	99.000		99.000	Deg.
Radii:				
Lip to Flange:	0.2500		0.2500	in.
Flange to web:	0.3125		0.3125	in.
Flange Width:	2.5000		2.5000	in.
Total Depth:	8.938	in.		
Thickness:	0.0630	in.		
Yield Stress:	51.50	ksi		
Young's Modulus:	29500.0	ksi		

Roof System Design Version 1.00

Date: 12/20/90 By: BLR

Job Id.: SERIES III P-F-9C0.064-25 w/Insulation
Roof Id.: EAVE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Applied Loads

Bay Information
Bay # 1:
Distance between supports: 25'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 70.49 psf
Uplift Capacity: 35.25 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

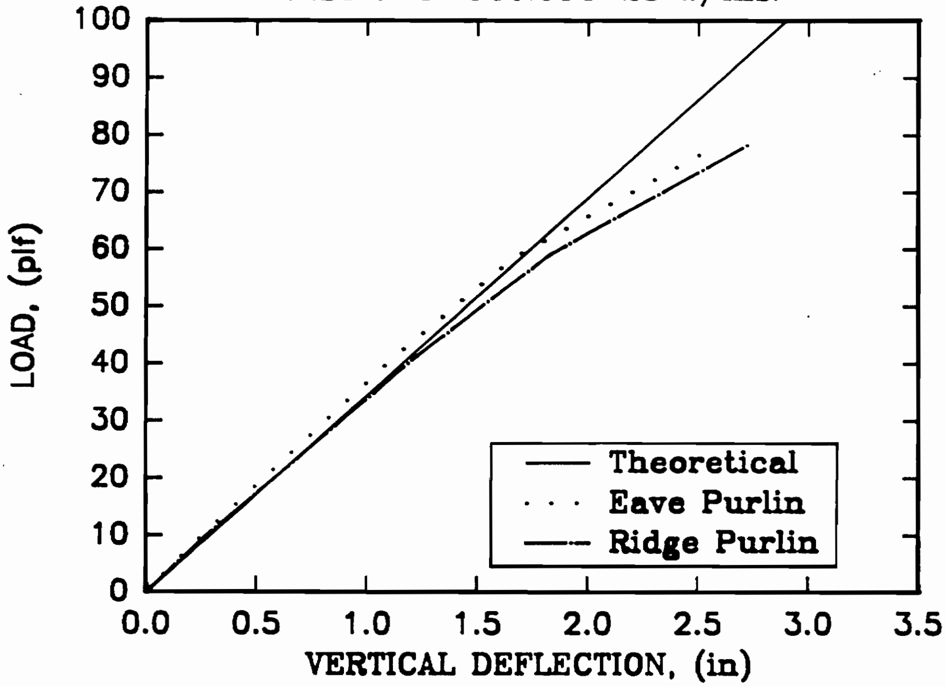
Total System Weight: 79.0 Lbs.

Cross-Sections

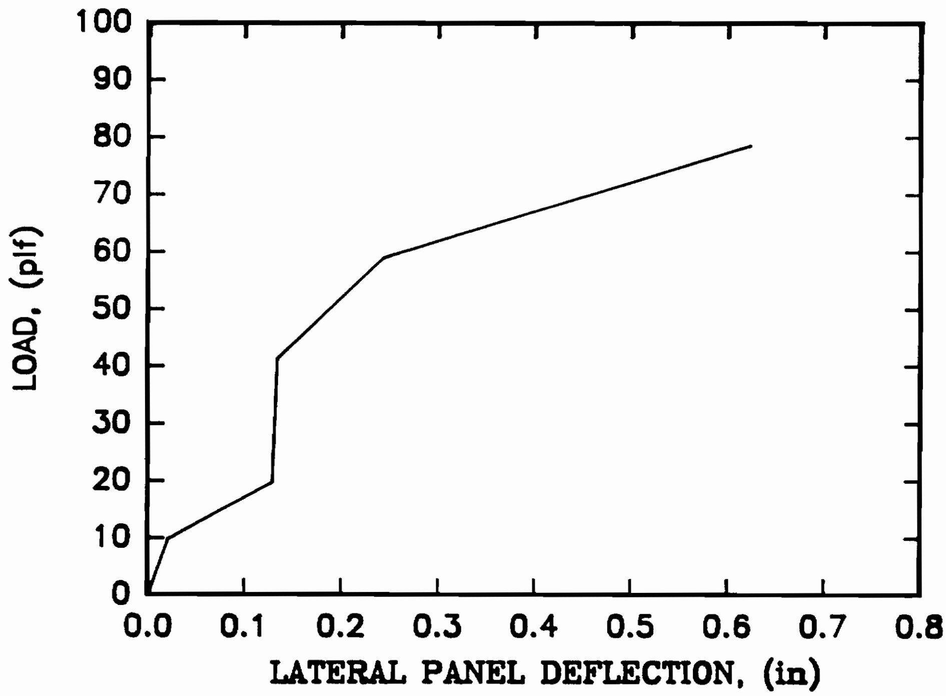
Purlin Identification for Bay # 1: C 8.88x0.064

	Top		Bottom	
Lip Length:	0.8125		0.7500	in.
Lip Angle:	100.000		100.000	Deg.
Radii:				
Lip to Flange:	0.2500		0.2500	in.
Flange to web:	0.3125		0.3125	in.
Flange Width:	2.5000		2.5000	in.
Total Depth:	8.875	in.		
Thickness:	0.0640	in.		
Yield Stress:	51.50	ksi		
Young's Modulus:	29500.0	ksi		

SERIES III
TEST P-F-9C0.064-25 w/Ins.



a) Load vs. Vertical Deflection



b) Load vs. Lateral Panel Deflection

MBMA PROJECT 502

Test Summary

Series III

P-F-9C0.065-25

Test Date: June 19, 1990

Purpose: Single Span Base Test

Span: 25'-0"

Purlin:	Eave	Ridge
Thickness	0.063"	0.064"
Sweep	1"	1 1/4"

Parameters: Gravity Loading, Bracing @ Supports Only

Two Purlin Lines, 5'-0" O.C.; 1'-0" Deck Overhang

Purlins Facing Same Direction

Pan Type Deck with Fixed Clips

Failure Load: 116.8 plf Failure Mode: Local Buckling

Yield Stress: 57.2 ksi

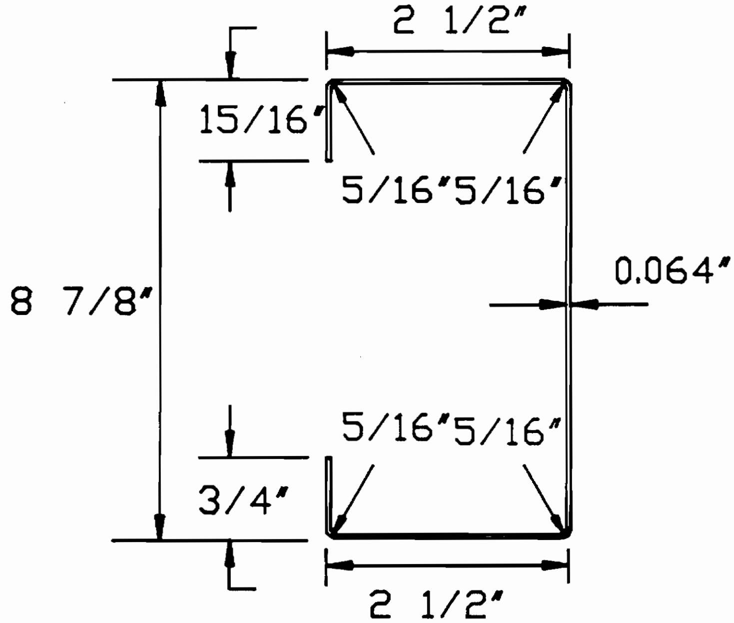
Predicted Constrained Bending Failure load: 137.3 plf

Actual Failure Load/Predicted Constrained Bending Failure Load: 85.1 %

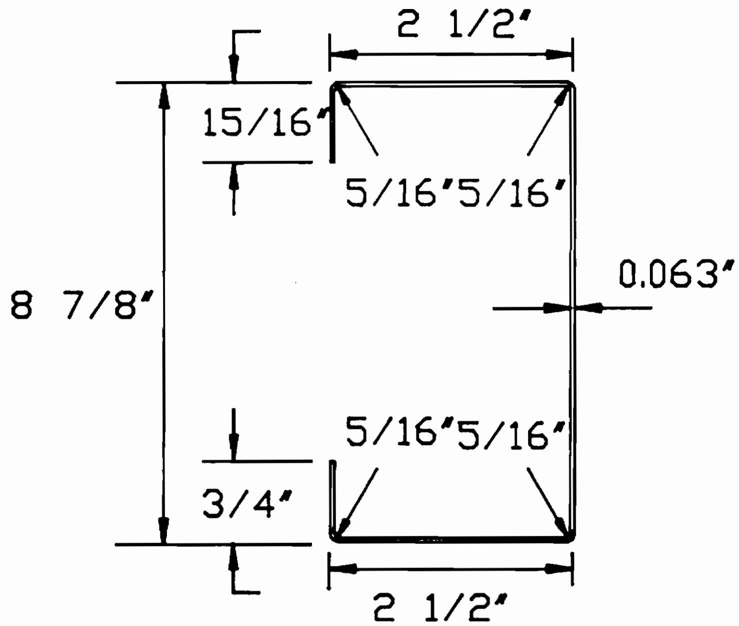
Discussion:

- Failure load includes 7.7 plf deadload.
- Vacuum chamber used to test system.
- Manometer used to measure load.
- Load deflection curve essentially linear.
- Failure occurred in ridge purlin by local buckling.
- 1 3/4" movement of clip W.R.T. deck at mid-span.

TEST P-F-9C0.065-25
SERIES III



RIDGE PURLIN



EAVE PURLIN

Roof System Design Version 1.00

Date: 12/20/90 By: BLR

Job Id.: SERIES III P-F-9C0.065-25
Roof Id.: RIDGE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Applied Loads

Bay Information
Bay # 1:
Distance between supports: 25'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 82.22 psf
Uplift Capacity: 41.11 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

Total System Weight: 0.0 Lbs.

Cross-Sections

Purlin Identification for Bay # 1: C 8.88x0.065

	Top		Bottom	
Lip Length:	0.9375		0.7500	in.
Lip Angle:	90.000		90.000	Deg.
Radii:				
Lip to Flange:	0.3125		0.3125	in.
Flange to web:	0.3125		0.3125	in.
Flange Width:	2.5000		2.5000	in.
Total Depth:	8.875	in.		
Thickness:	0.0650	in.		
Yield Stress:	57.19	ksi		
Young's Modulus:	29500.0	ksi		

Roof System Design Version 1.00

Date: 12/20/90 By: BLR

Job Id.: SERIES III P-F-9C0.065-25
Roof Id.: EAVE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only
half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Applied Loads

Bay Information
Bay # 1:
Distance between supports: 25'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 78.89 psf
Uplift Capacity: 39.44 psf

Note: Specified overstress allowances were taken into
consideration for system capacity determination.

Total System Weight: 78.9 Lbs.

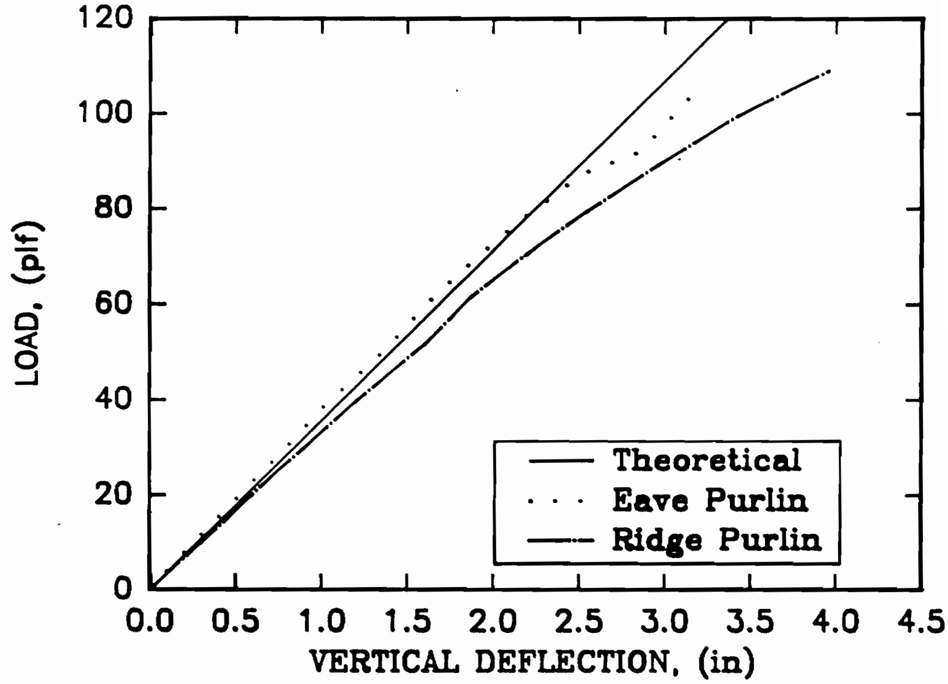
Cross-Sections

Purlin Identification for Bay # 1: C 8.88x0.063

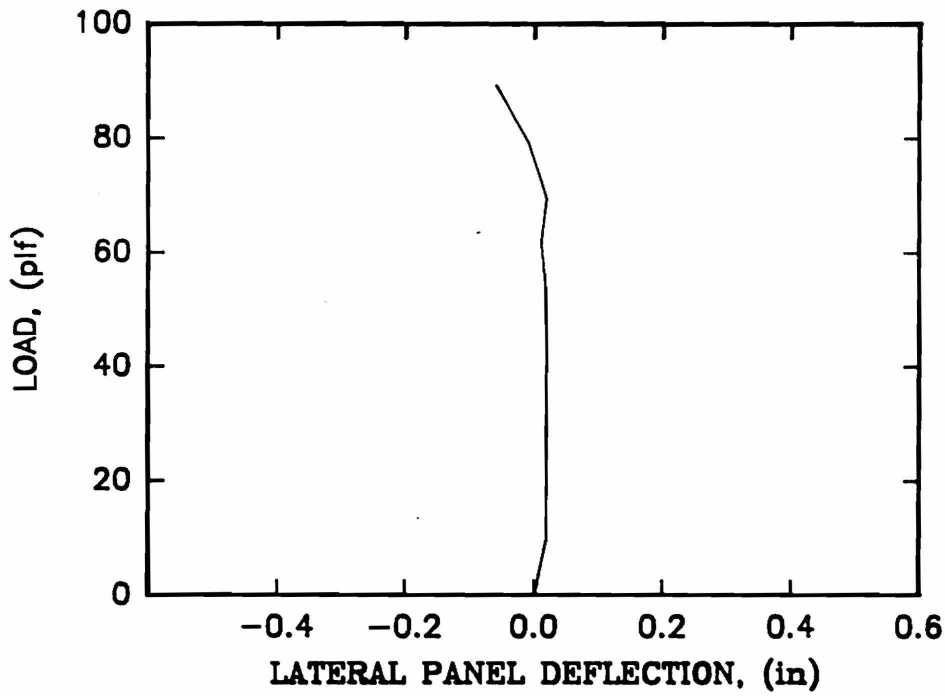
	Top		Bottom	
Lip Length:	0.9375		0.7500	in.
Lip Angle:	90.000		90.000	Deg.
Radii:				
Lip to Flange:	0.3125		0.3125	in.
Flange to web:	0.3125		0.3125	in.
Flange Width:	2.5000		2.5000	in.
Total Depth:	8.875	in.		
Thickness:	0.0630	in.		
Yield Stress:	57.19	ksi		
Young's Modulus:	29500.0	ksi		

SERIES III

TEST P-F-9C0.065-25



a) Load vs. Vertical Deflection



b) Load vs. Lateral Panel Deflection

MBMA PROJECT 502

Test Summary

Series III

P-F-9C0.075-25

Test Date: July 2, 1990

Purpose: Single Span Base Test

Span: 25'-0"

Purlin:	Eave	Ridge
Thickness	0.074"	0.074"
Sweep	1/2"	1/2"

Parameters: Gravity Loading, Bracing @ Supports Only

Two Purlin Lines, 5'-0" O.C.; 1'-0" Deck Overhang

Purlins Facing Same Direction

Pan Type Deck with Fixed Clips

Failure Load: 147.7 plf Failure Mode: Local Buckling

Yield Stress: 59.2 ksi

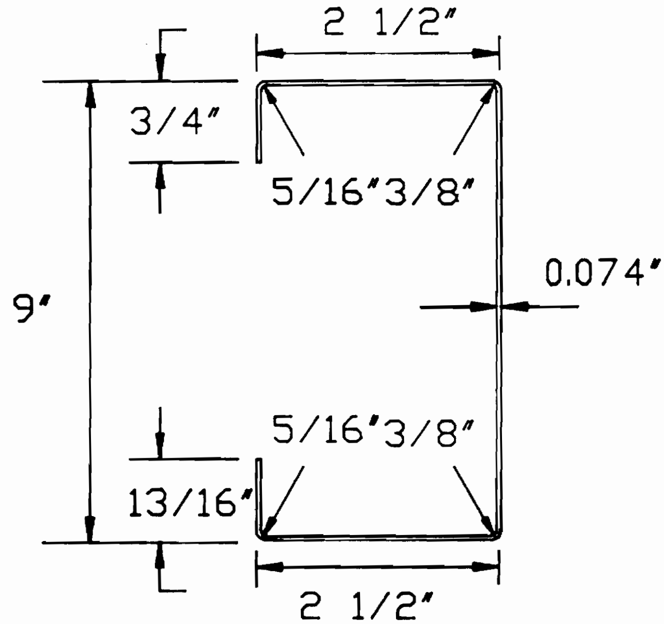
Predicted Constrained Bending Failure load: 161.3 plf

Actual Failure Load/Predicted Constrained Bending Failure Load: 91.6 %

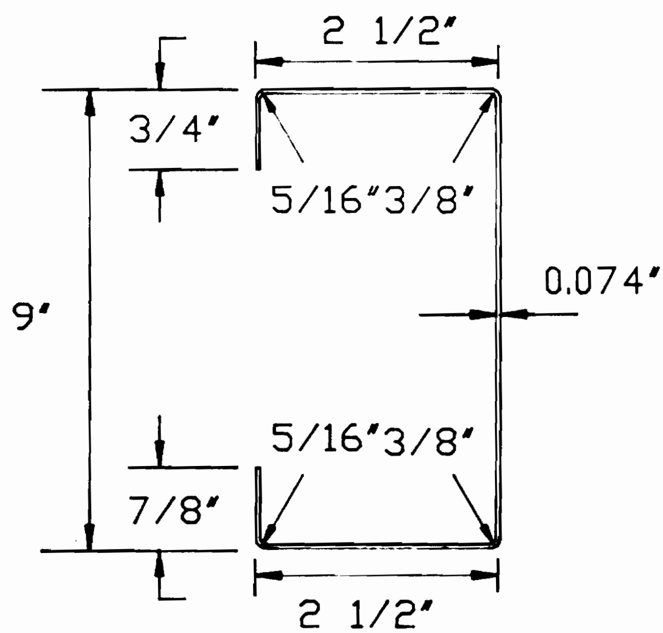
Discussion:

- Failure load includes 8.2 plf deadload.
- Vacuum chamber used to test system.
- Manometer used to measure load.
- Load deflection curve essentially linear.
- Failure occurred in ridge purlin by local buckling.
- 1 1/4" movement of clip W.R.T. deck at mid-span.

TEST P-F-9C0.074-25
SERIES III



RIDGE PURLIN



EAVE PURLIN

Roof System Design Version 1.00

Date: 11/12/90 By: BLR

Job Id.: SERIES III P-F-9C0.074-25
Roof Id.: RIDGE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Bay Information
Bay # 1:
Distance between supports: 25'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 96.62 psf
Uplift Capacity: 48.31 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

Total System Weight: 92.0 Lbs.

Cross-Sections

Purlin Identification for Bay # 1: C 9x0.074

	Top		Bottom	
Lip Length:	0.7500		0.8125	in.
Lip Angle:	90.000		90.000	Deg.
Radii:				
Lip to Flange:	0.3125		0.3125	in.
Flange to web:	0.3750		0.3750	in.
Flange Width:	2.5000		2.5000	in.
Total Depth:	9.000	in.		
Thickness:	0.0740	in.		
Yield Stress:	59.20	ksi		
Young's Modulus:	29500.0	ksi		

Roof System Design Version 1.00

Date: 11/12/90 By: BLR

Job Id.: SERIES III P-F-9C0.074-25
Roof Id.: EAVE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only
half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Bay Information
Bay # 1:
Distance between supports: 25'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 96.76 psf
Uplift Capacity: 48.38 psf

Note: Specified overstress allowances were taken into
consideration for system capacity determination.

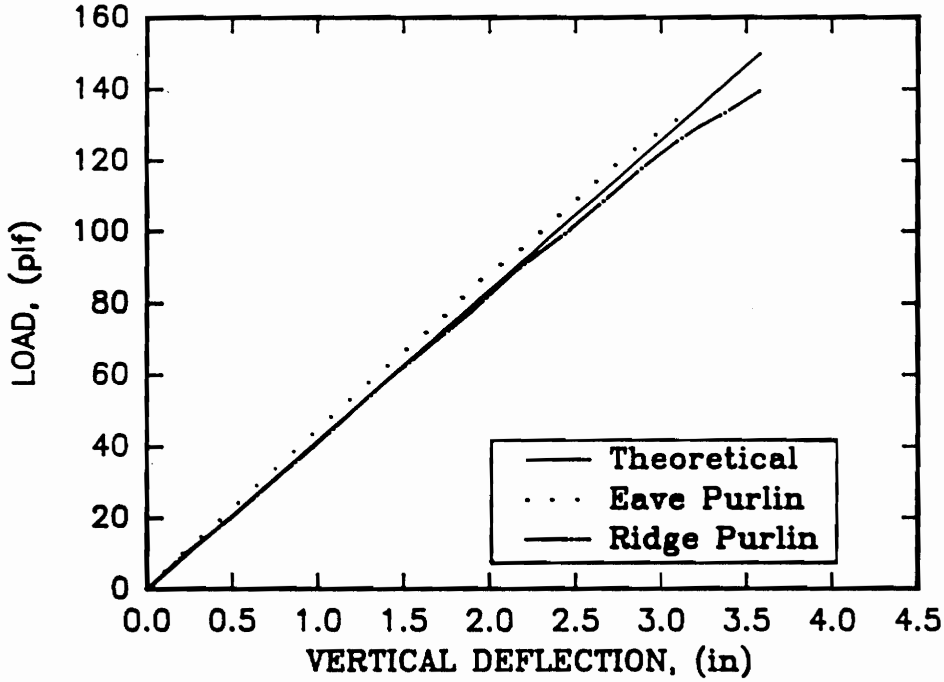
Total System Weight: 92.4 Lbs.

Cross-Sections

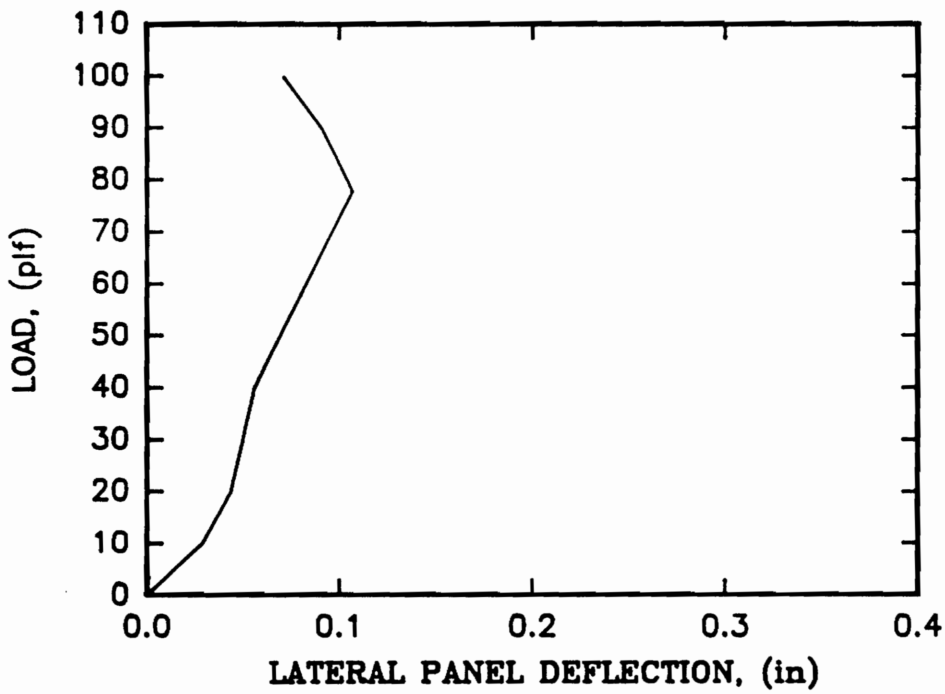
Purlin Identification for Bay # 1: C 9x0.074

	Top		Bottom	
Lip Length:	0.7500		0.8750	in.
Lip Angle:	90.000		90.000	Deg.
Radii:				
Lip to Flange:	0.3125		0.3125	in.
Flange to web:	0.3750		0.3750	in.
Flange Width:	2.5000		2.5000	in.
Total Depth:	9.000	in.		
Thickness:	0.0740	in.		
Yield Stress:	59.20	ksi		
Young's Modulus:	29500.0	ksi		

SERIES III
TEST P-F-9C0.074-25



a) Load vs. Vertical Deflection



b) Load vs. Lateral Panel Deflection

MBMA PROJECT 502

Test Summary

Series III

P-F-9C0.10-25

Test Date: July 6, 1990

Purpose: Single Span Base Test

Span: 25'-0"

	Eave	Ridge
Thickness	0.105"	0.105"
Sweep	1"	1"

Parameters: Gravity Loading, Bracing @ Supports Only

Two Purlin Lines, 5'-0" O.C.; 1'-0" Deck Overhang

Purlins Facing Same Direction

Pan Type Deck with Fixed Clips

Failure Load: 264.2 plf   Failure Mode: Local Buckling

Yield Stress: 59.1 ksi

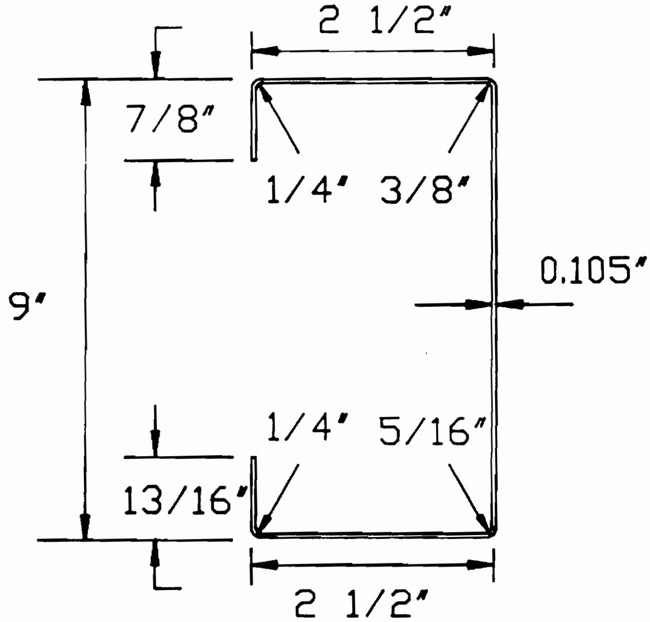
Predicted Constrained Bending Failure load: 251.5 plf

Actual Failure Load/Predicted Constrained Bending Failure Load: 105.0 %

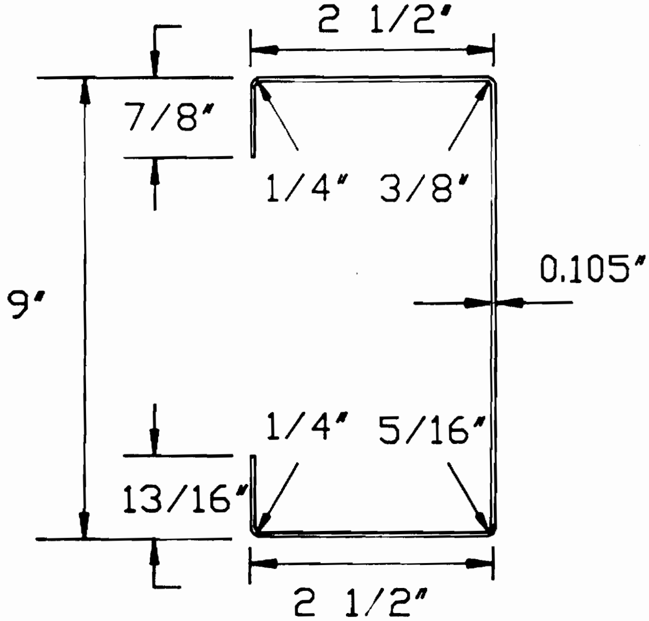
Discussion:

- Failure load includes 9.74 plf deadload.
- Vacuum chamber used to test system.
- Manometer used to measure load.
- Load deflection curve essentially linear.
- Failure occurred in ridge purlin by local buckling.
- 1" movement of clip W.R.T. deck at mid-span.

TEST P-F-9C0.10-25
SERIES III



RIDGE PURLIN



EAVE PURLIN

Roof System Design Version 1.00

Date: 11/12/90 By: BLR

Job Id.: SERIES III P-F-9C0.10-25
Roof Id.: RIDGE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only
half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: .0.00 %
For Web Crippling Strength: 100.00 %

Bay Information
Bay # 1:
Distance between supports: 25'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 150.62 psf
Uplift Capacity: 75.31 psf

Note: Specified overstress allowances were taken into
consideration for system capacity determination.

Total System Weight: 134.1 Lbs.

Cross-Sections

Purlin Identification for Bay # 1: C 9x0.108

	Top		Bottom	
Lip Length:	0.8750		0.8125	in.
Lip Angle:	90.000		90.000	Deg.
Radii:				
Lip to Flange:	0.3125		0.3125	in.
Flange to web:	0.3750		0.3125	in.
Flange Width:	2.5000		2.5000	in.
Total Depth:	9.000	in.		
Thickness:	0.1080	in.		
Yield Stress:	59.10	ksi		
Young's Modulus:	29500.0	ksi		

Roof System Design Version 1.00

Date: 11/12/90 By: BLR

Job Id.: SERIES III P-F-9C0.10-25
Roof Id.: EAVE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Bay Information
Bay # 1:
Distance between supports: 25'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 147.71 psf
Uplift Capacity: 73.85 psf

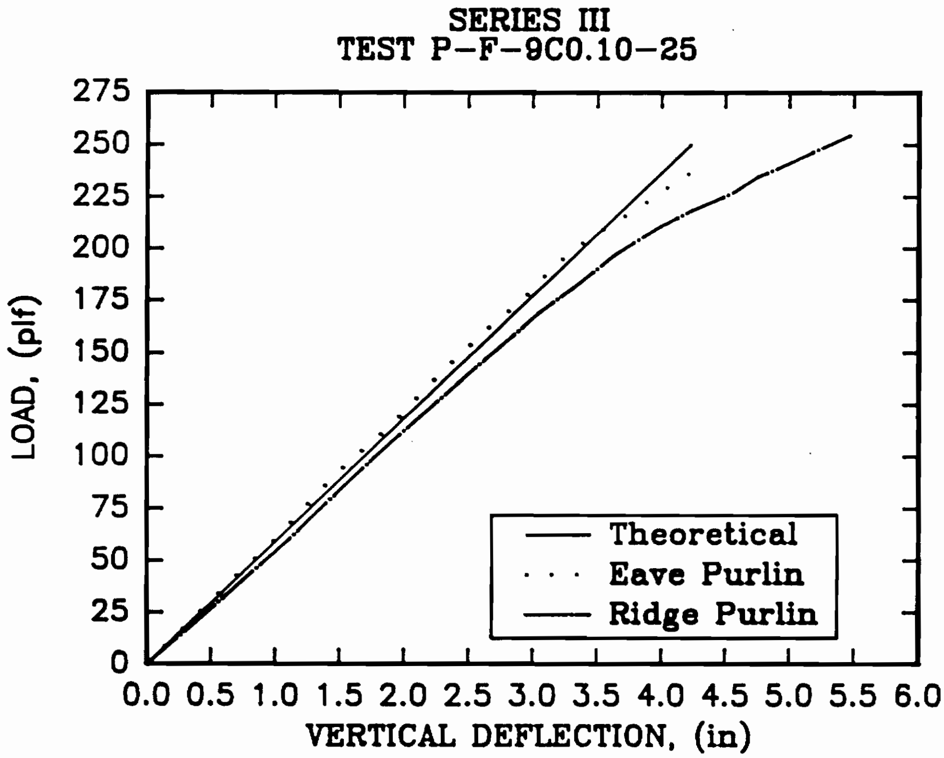
Note: Specified overstress allowances were taken into consideration for system capacity determination.

Total System Weight: 131.0 Lbs.

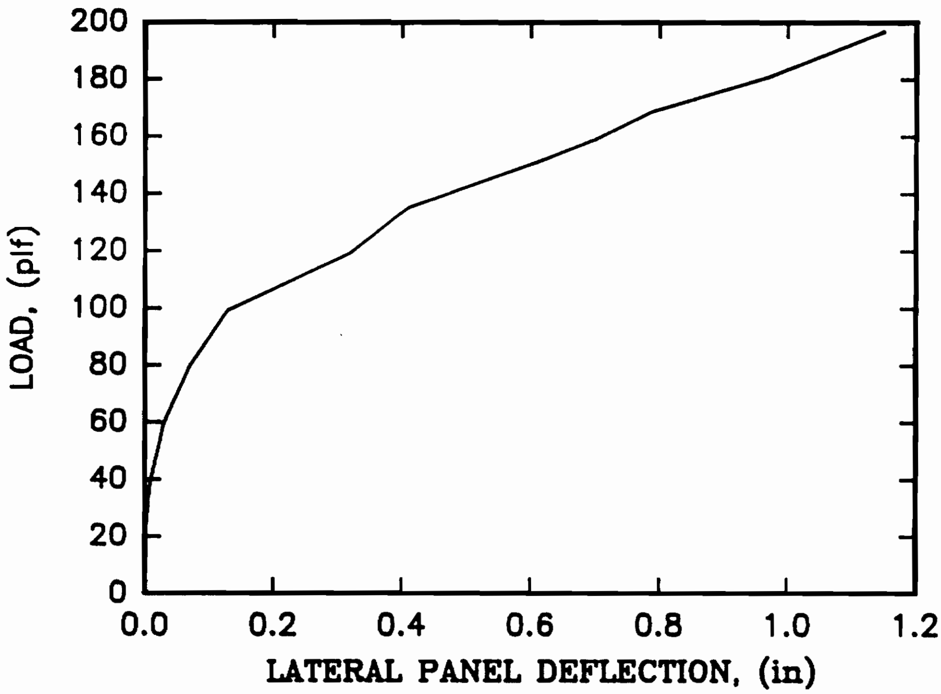
Cross-Sections

Purlin Identification for Bay # 1: C 9x0.105

	Top		Bottom	
Lip Length:	0.8750		0.8125	in.
Lip Angle:	90.000		90.000	Deg.
Radii:				
Lip to Flange:	0.2500		0.2500	in.
Flange to web:	0.3750		0.3125	in.
Flange Width:	2.5000		2.5000	in.
Total Depth:	9.000	in.		
Thickness:	0.1050	in.		
Yield Stress:	59.10	ksi		
Young's Modulus:	29500.0	ksi		



a) Load vs. Vertical Deflection



b) Load vs. Lateral Panel Deflection

APPENDIX D

SERIES IV TEST SUMMARIES

MBMA PROJECT 502
Test Summary
Series IV
R-S-10Z0.094-20-0

Test Date: August 7, 1990

Purpose: Single Span Base Test

Span: 20'-0"

Purlin:	Eave	Ridge
Thickness	0.093"	0.092"
Sweep	neg.	neg.

Parameters: Gravity Loading, Bracing @ Supports Only
Two Purlin Lines, 5'-0" O.C.; 1'-0" Deck Overhang
Purlins Facing Opposite Direction
Rib Type Deck with sliding Clips

Failure Load: 261.6 plf   Failure Mode: Lateral Buckling

Yield Stress: 59.3 ksi

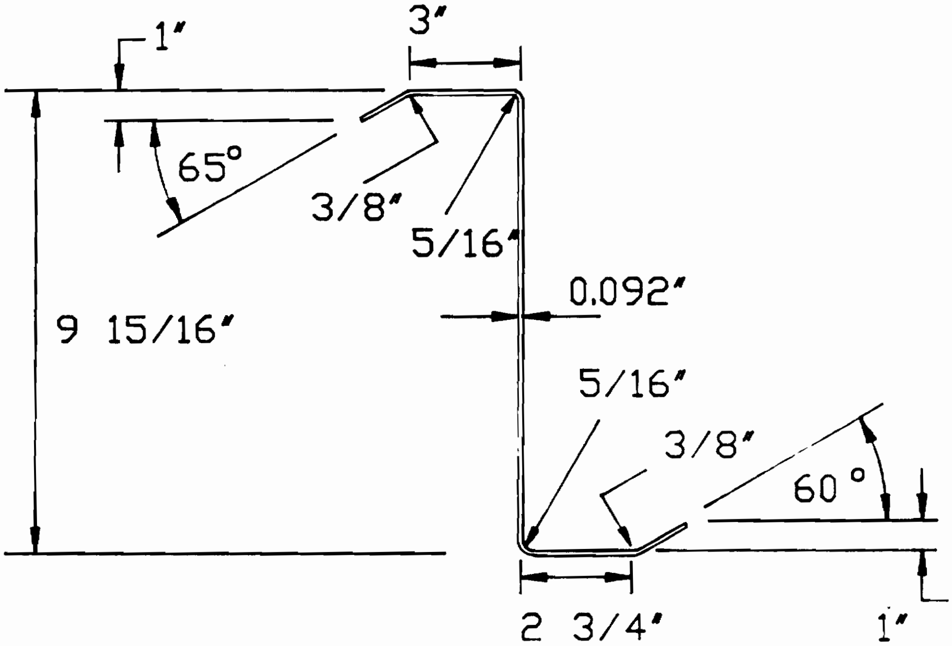
Predicted Constrained Bending Failure load: 445.8 plf

Actual Failure Load/Predicted Constrained Bending Failure Load: 58.7 %

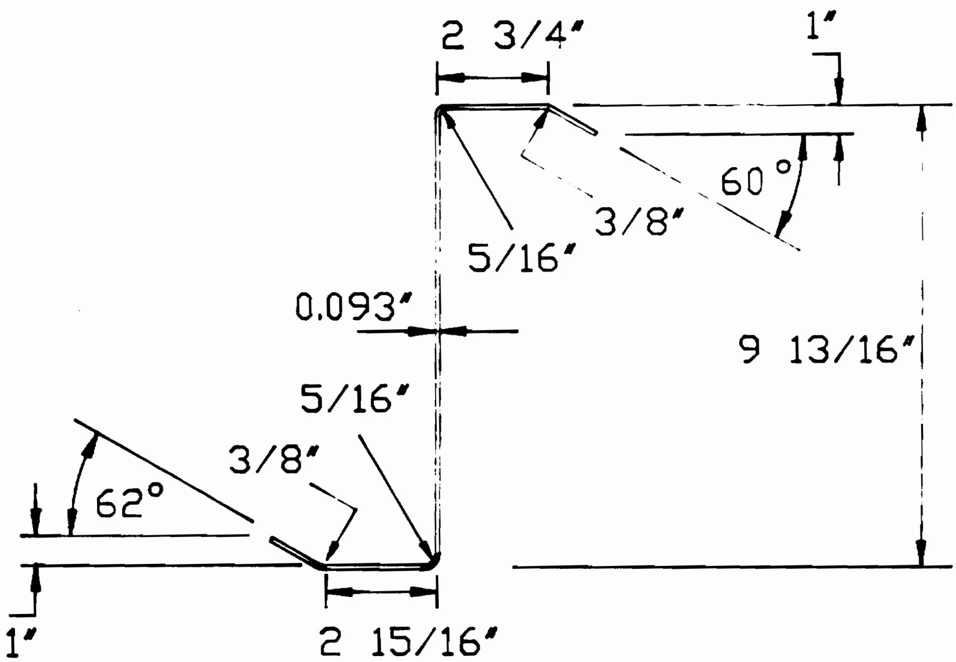
Discussion:

- Failure load includes 9.6 plf deadload.
- Vacuum chamber used to test system.
- Manometer used to measure load.
- Load deflection curve essentially linear.
- Failure occurred in ridge purlin by local buckling.
- No movement of clip W.R.T. deck at mid-span.
- Two piece sliding clips near mid-span moved the full extent of the sliding mechanism, and separated.

TEST R-S-10Z0.093-20-D
SERIES IV



RIDGE PURLIN



EAVE PURLIN

Roof System Design Version 1.00

Date: 11/15/90 By: BLR

Job Id.: SERIES IV R-S-10Z0.093-20-0
Roof Id.: RIDGE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Bay Information
Bay # 1:
Distance between supports: 20'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 258.66 psf
Uplift Capacity: 129.33 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

Total System Weight: 107.9 Lbs.

Cross-Sections

Purlin Identification for Bay # 1: Z 9.94x0.092

	Top		Bottom	
Lip Length:	1.1034		1.1547	in.
Lip Angle:	65.000		60.000	Deg.
Radii:				
Lip to Flange:	0.3750		0.3750	in.
Flange to web:	0.3125		0.3125	in.
Flange Width:	3.0000		2.7500	in.
Total Depth:	9.938	in.		
Thickness:	0.0920	in.		
Yield Stress:	59.30	ksi		
Young's Modulus:	29500.0	ksi		

Roof System Design Version 1.00

Date: 11/15/90 By: BLR

Job Id.: SERIES IV R-S-10Z0.093-20-O
Roof Id.: EAVE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Bay Information
Bay # 1:
Distance between supports: 20'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 266.93 psf
Uplift Capacity: 133.47 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

Total System Weight: 108.0 Lbs.

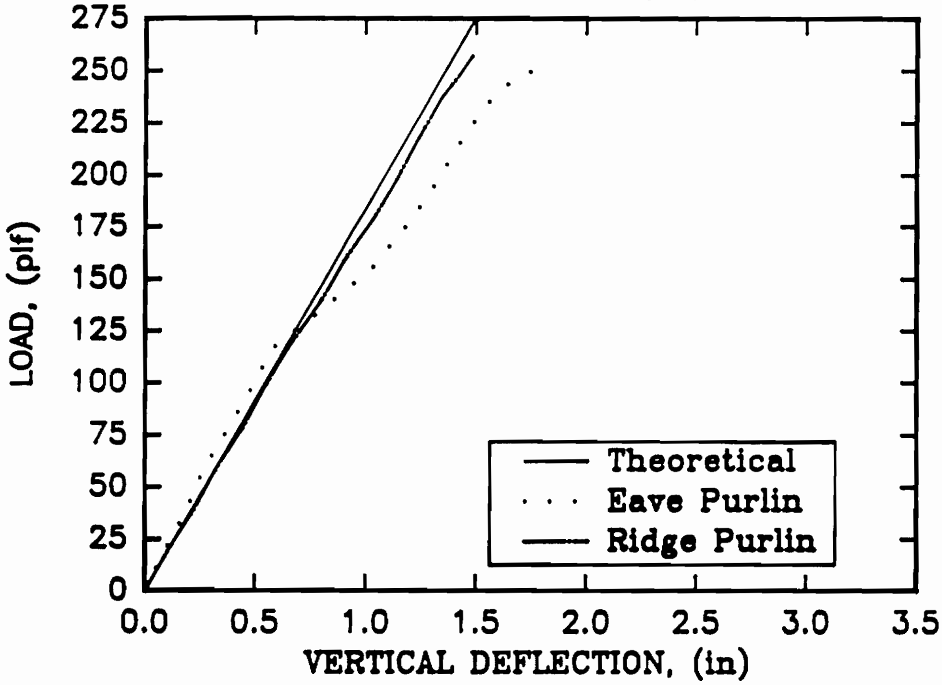
Cross-Sections

Purlin Identification for Bay # 1: Z 9.81x0.093

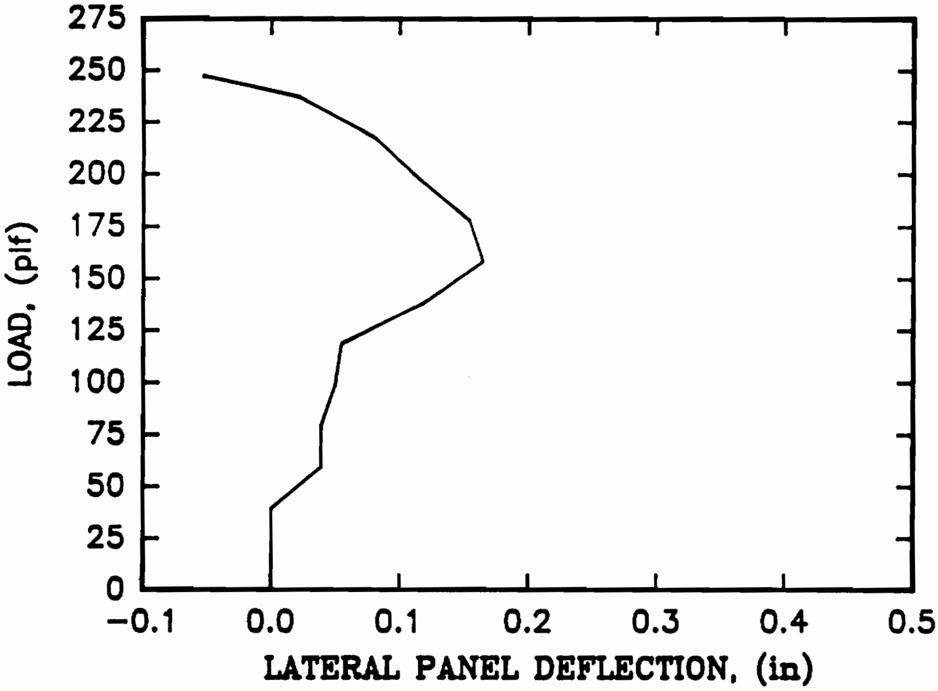
	Top		Bottom	
Lip Length:	1.1547		1.1326	in.
Lip Angle:	65.000		62.000	Deg.
Radii:				
Lip to Flange:	0.3750		0.3750	in.
Flange to web:	0.3125		0.3125	in.
Flange Width:	2.7500		2.9375	in.
Total Depth:	9.813	in.		
Thickness:	0.0930	in.		
Yield Stress:	59.30	ksi		
Young's Modulus:	29500.0	ksi		

SERIES IV

R-S-10Z0.093-20-0



a) Load vs. Vertical Deflection



b) Load vs. Lateral Panel Deflection

MBMA PROJECT 502

Test Summary

Series IV

R-S-10Z0.093-30-0

Test Date: September 6, 1990

Purpose: Single Span Base Test

Span: 30'-0"

Purlin:	Eave	Ridge
Thickness	0.093"	0.094"
Sweep	1 1/8"	1"

Parameters: Gravity Loading, Bracing @ Supports Only

Two Purlin Lines, 5'-0" O.C.; 1'-0" Deck Overhang

Purlins Facing Opposite Direction

Rib Type Deck with Sliding Clips

Failure Load: 80.6 plf Failure Mode: Lateral Buckling

Yield Stress: 60.6 ksi

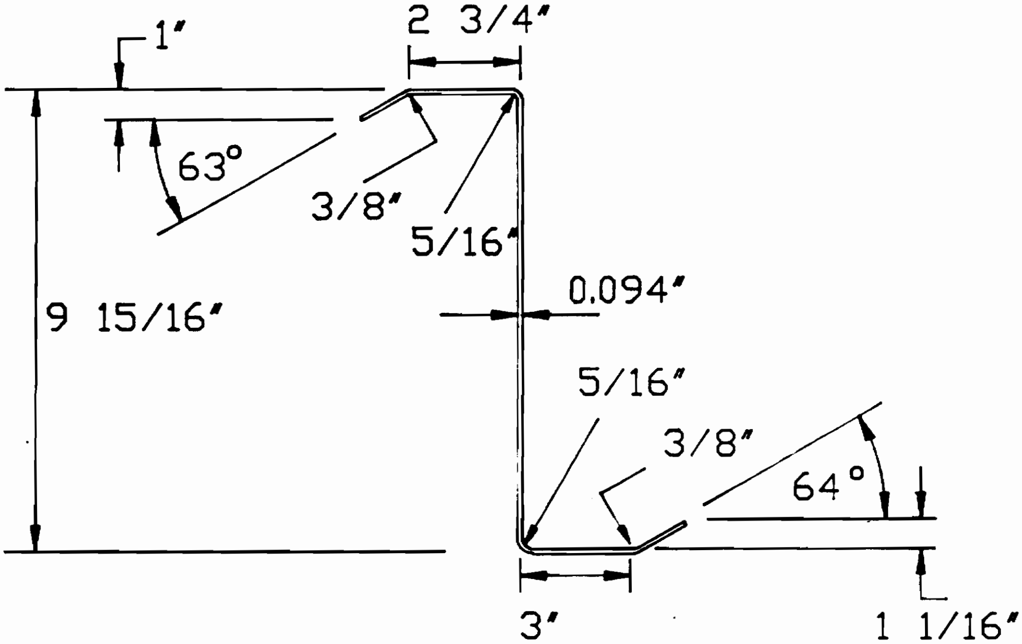
Predicted Constrained Bending Failure load: 208.3 plf

Actual Failure Load/Predicted Constrained Bending Failure Load: 38.7 %

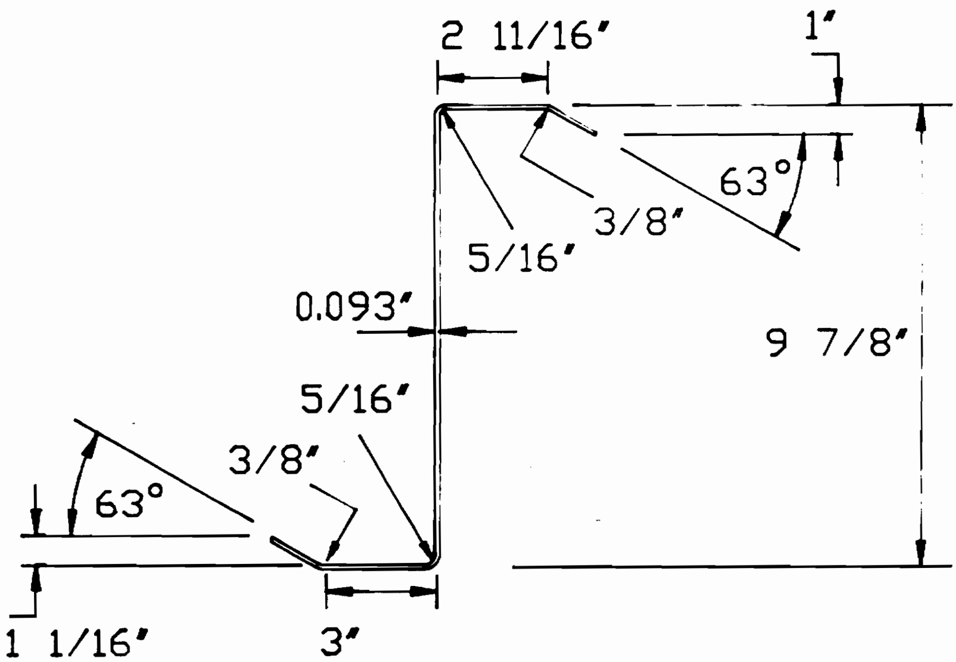
Discussion:

- Failure load includes 9.7 plf deadload.
- Vacuum chamber used to test system.
- Manometer used to measure load.
- Load deflection curve essentially linear.
- Failure occurred in ridge purlin by lateral buckling.
- All two piece sliding clips except the ones near the rafters moved the full extent of the sliding mechanism and separated.
- No local buckling of compression elements.

TEST R-S-10Z0.093-30-□
SERIES IV



RIDGE PURLIN



EAVE PURLIN

Roof System Design Version 1.00

Date: 11/15/90 By: BLR

Job Id.: SERIES IV R-S-10Z0.093-30-0
Roof Id.: RIDGE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Bay Information
Bay # 1:
Distance between supports: 30'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 124.72 psf
Uplift Capacity: 62.36 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

Total System Weight: 165.7 Lbs.

Cross-Sections

Purlin Identification for Bay # 1: Z 9.94x0.094

	Top		Bottom	
Lip Length:	1.1223		1.1821	in.
Lip Angle:	63.000		64.000	Deg.
Radii:				
Lip to Flange:	0.3750		0.3750	in.
Flange to web:	0.3125		0.3125	in.
Flange Width:	2.7500		3.0000	in.
Total Depth:	9.938	in.		
Thickness:	0.0940	in.		
Yield Stress:	60.60	ksi		
Young's Modulus:	29500.0	ksi		

Roof System Design Version 1.00

Date: 11/15/90 By: BLR

Job Id.: SERIES IV R-S-10Z0.093-30-0
Roof Id.: EAVE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Bay Information
Bay # 1:
Distance between supports: 30'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 121.22 psf
Uplift Capacity: 60.61 psf

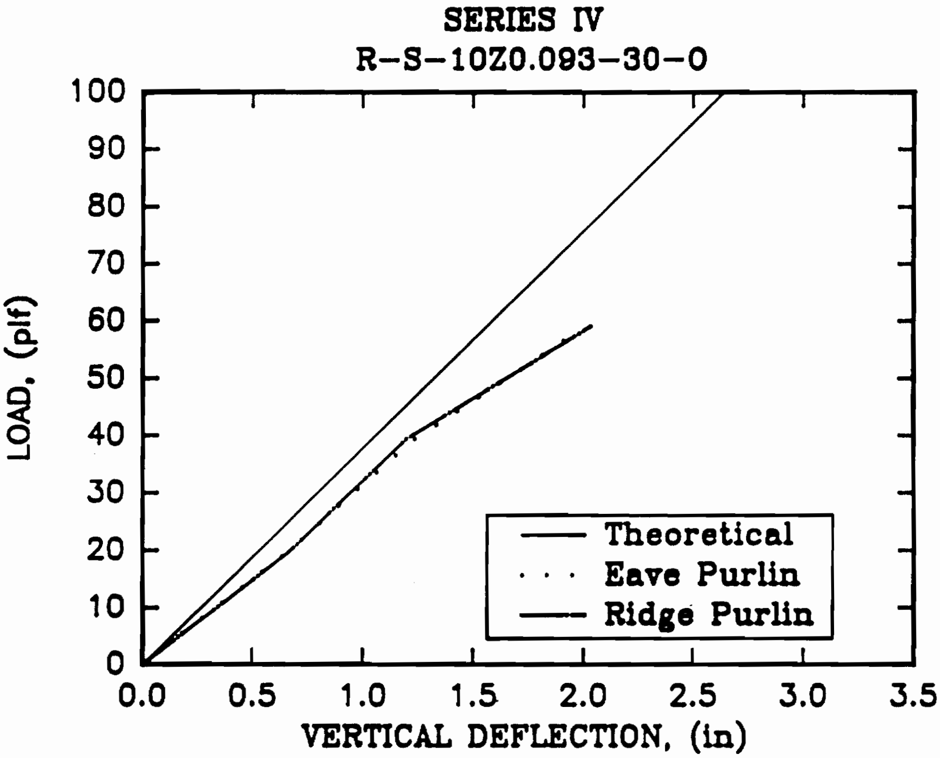
Note: Specified overstress allowances were taken into consideration for system capacity determination.

Total System Weight: 162.9 Lbs.

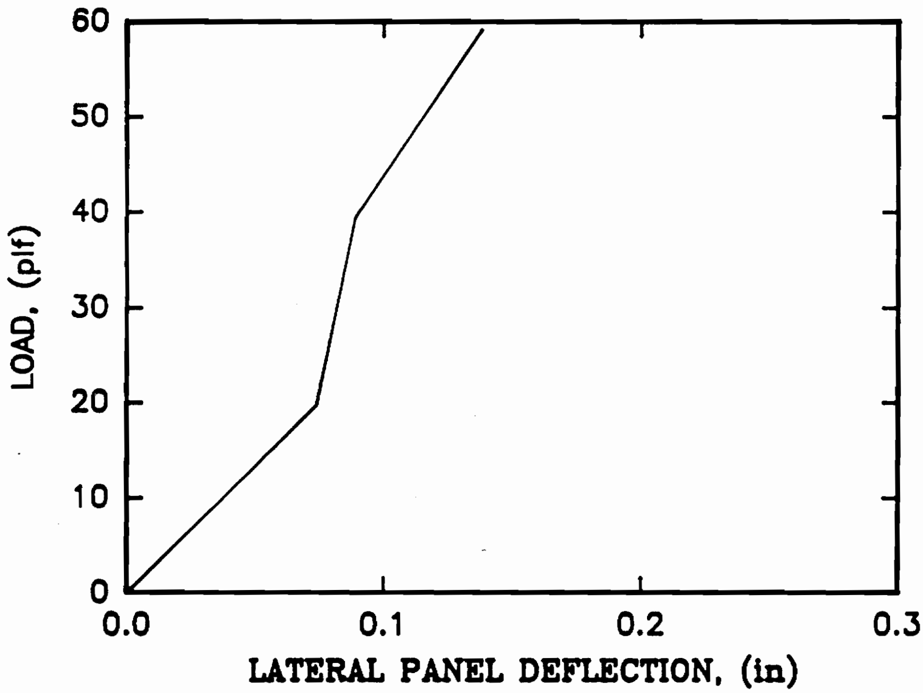
Cross-Sections

Purlin Identification for Bay # 1: Z 9.88x0.093

	Top		Bottom	
Lip Length:	1.1223		1.1925	in.
Lip Angle:	63.000		63.000	Deg.
Radii:				
Lip to Flange:	0.3750		0.3750	in.
Flange to web:	0.3125		0.3125	in.
Flange Width:	2.6875		3.0000	in.
Total Depth:	9.875	in.		
Thickness:	0.0930	in.		
Yield Stress:	60.60	ksi		
Young's Modulus:	29500.0	ksi		



a) Load vs. Vertical Deflection



b) Load vs. Lateral Panel Deflection

MBMA PROJECT 502
Test Summary
Series IV
P-F-9C0.0.075-20

Test Date: July 23, 1990

Purpose: Single Span Base Test

Span: 20'-0"

Purlin:	Eave	Ridge
Thickness	0.075"	0.075"
Sweep	neg.	neg.

Parameters: Gravity Loading, Bracing @ Supports Only
Two Purlin Lines, 5'-0" O.C.; 1'-0" Deck Overhang
Purlins Facing Same Direction
Pan Type Deck with Fixed Clips

Failure Load: 245.6 plf   Failure Mode: Local Buckling

Yield Stress: 57.7 ksi

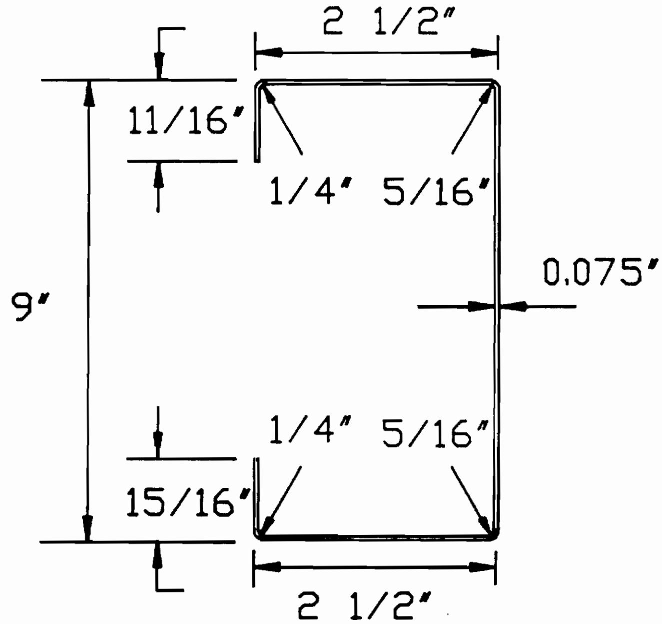
Predicted Constrained Bending Failure load: 246.2 plf

Actual Failure Load/Predicted Constrained Bending Failure Load: 99.8 %

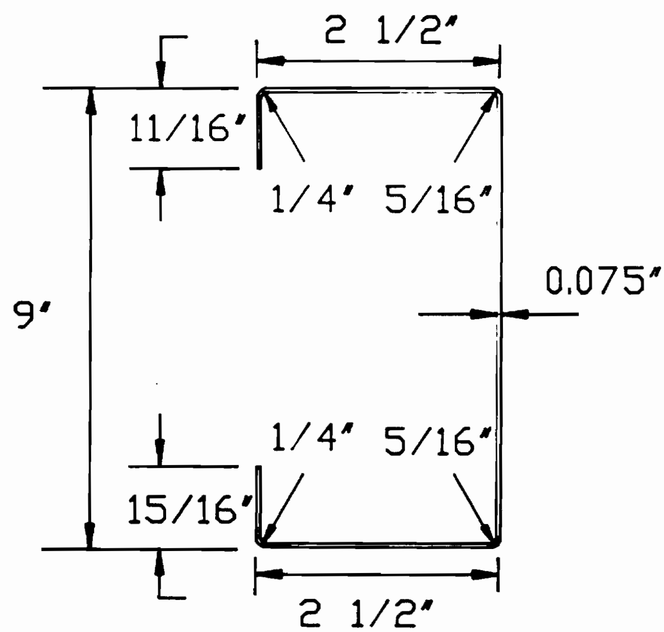
Discussion:

- Failure load includes 8.3 plf deadload.
- Vacuum chamber used to test system.
- Manometer used to measure load.
- Load deflection curve essentially linear.
- Failure occurred in ridge purlin by local buckling.
- 1 1/4" movement of clip W.R.T. deck at mid-span.

TEST P-F-9C0.075-20
SERIES IV



RIDGE PURLIN



EAVE PURLIN

Roof System Design Version 1.00

Date: 11/15/90 By: BLR

Job Id.: SERIES IV P-F-9C0.075-20
Roof Id.: RIDGE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Bay Information
Bay # 1:
Distance between supports: 20'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 147.42 psf
Uplift Capacity: 73.71 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

Total System Weight: 75.4 Lbs.

Cross-Sections

Purlin Identification for Bay # 1: C 9x0.075

	Top		Bottom	
Lip Length:	0.6875		0.9375	in.
Lip Angle:	90.000		90.000	Deg.
Radii:				
Lip to Flange:	0.2500		0.2500	in.
Flange to web:	0.3125		0.3125	in.
Flange Width:	2.5000		2.5000	in.
Total Depth:	9.000	in.		
Thickness:	0.0750	in.		
Yield Stress:	57.70	ksi		
Young's Modulus:	29500.0	ksi		

Roof System Design Version 1.00

Date: 11/15/90 By: BLR

Job Id.: SERIES IV P-F-9C0.075-20
Roof Id.: EAVE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Bay Information
Bay # 1:
Distance between supports: 20'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 147.46 psf
Uplift Capacity: 73.73 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

Total System Weight: 75.5 Lbs.

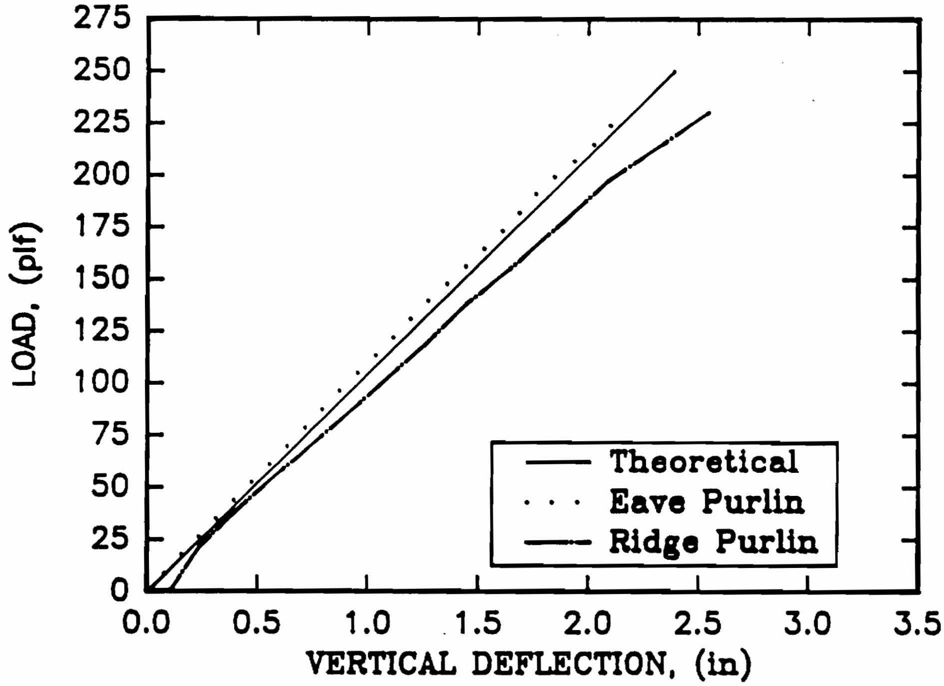
Cross-Sections

Purlin Identification for Bay # 1: C 9x0.075

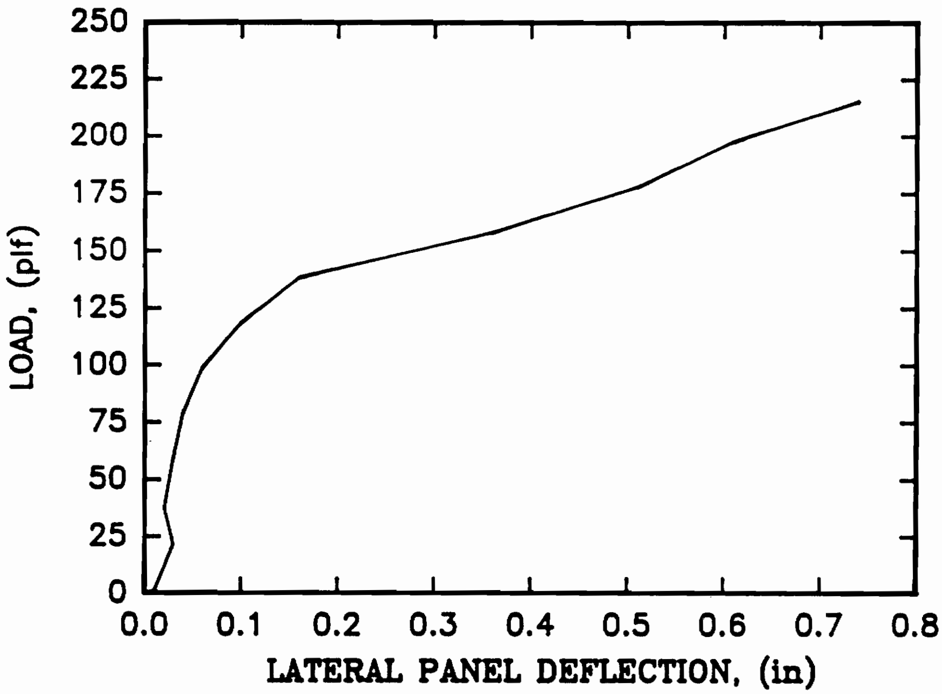
	Top		Bottom	
Lip Length:	0.6875		0.9375	in.
Lip Angle:	90.000		89.000	Deg.
Radii:				
Lip to Flange:	0.2500		0.2500	in.
Flange to web:	0.3125		0.3125	in.
Flange Width:	2.5000		2.5000	in.
Total Depth:	9.000	in.		
Thickness:	0.0750	in.		
Yield Stress:	57.70	ksi		
Young's Modulus:	29500.0	ksi		

SERIES IV

P-F-9C0.075-20



a) Load vs. Vertical Deflection



b) Load vs. Lateral Panel Deflection

MBMA PROJECT 502

Test Summary

Series IV

P-F-9C0.105-30

Test Date: September 12, 1990

Purpose: Single Span Base Test

Span: 30'-0"

Purlin:	Eave	Ridge
Thickness	0.105"	0.105"
Sweep	1 3/4"	1 3/4"

Parameters: Gravity Loading, Bracing @ Supports Only

Two Purlin Lines, 5'-0" O.C.; 1'-0" Deck Overhang

Purlins Facing Same Direction

Pan Type Deck with Fixed Clips

Failure Load: 142.4 plf Failure Mode: Local Buckling

Yield Stress: 57.8 ksi

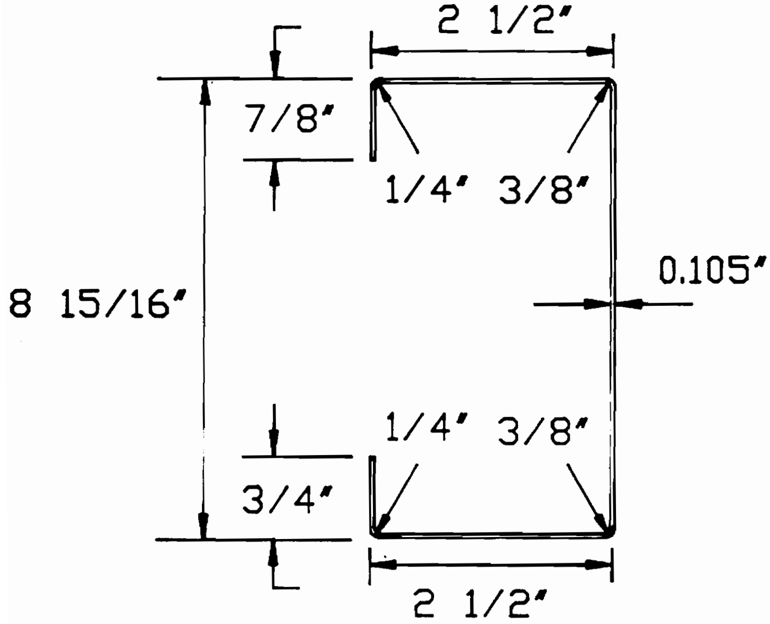
Predicted Constrained Bending Failure load: 162.0 plf

Actual Failure Load/Predicted Constrained Bending Failure Load: 87.9 %

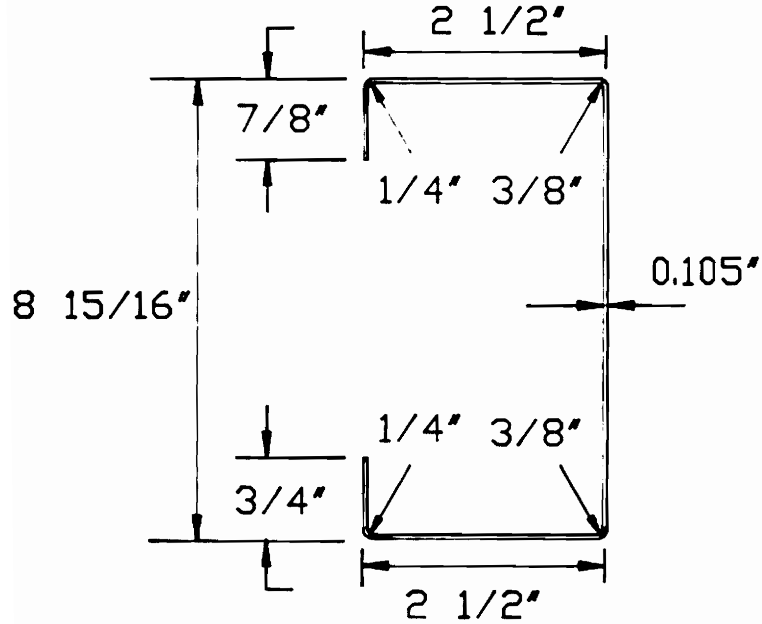
Discussion:

- Failure load includes 9.6 plf deadload.
- Vacuum chamber used to test system.
- Manometer used to measure load.
- Load deflection curve essentially linear.
- Failure occurred in ridge purlin by local buckling.
- 2" movement of clip W.R.T. deck at mid-span.

TEST P-F-9C0.105-30
SERIES IV



RIDGE PURLIN



EAVE PURLIN

Roof System Design Version 1.00

Date: 11/15/90 By: BLR

Job Id.: SERIES IV P-F-9C0.105-30
Roof Id.: RIDGE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only
half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Bay Information
Bay # 1:
Distance between supports: 30'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 97.00 psf
Uplift Capacity: 48.50 psf

Note: Specified overstress allowances were taken into consideration for system capacity determination.

Total System Weight: 154.5 Lbs.

Cross-Sections

Purlin Identification for Bay # 1: C 8.94x0.105

	Top		Bottom	
Lip Length:	0.8750		0.7500	in.
Lip Angle:	98.000		95.000	Deg.
Radii:				
Lip to Flange:	0.2500		0.2500	in.
Flange to web:	0.3750		0.3750	in.
Flange Width:	2.5000		2.5000	in.
Total Depth:	8.938	in.		
Thickness:	0.1050	in.		
Yield Stress:	57.80	ksi		
Young's Modulus:	29500.0	ksi		

Roof System Design Version 1.00

Date: 11/15/90 By: BLR

Job Id.: SERIES IV P-F-9C0.105-30
Roof Id.: EAVE PURLIN
Panel Type: Screw Down
Number of Bays: 1
Note: Since this roof system is symmetric, only half of it needs to be modeled and analyzed
Purlin Spacing: 1'-0"

Allowable Overstresses:
For Bending Moment and Shear: 0.00 %
For Web Crippling Strength: 100.00 %

Bay Information
Bay # 1:
Distance between supports: 30'-0"
Extension over left support: 0'-0"
Extension over right support: 0'-0"
Lateral bracing: at supports only

System Capacity
Load Capacity: 97.48 psf
Uplift Capacity: 48.74 psf

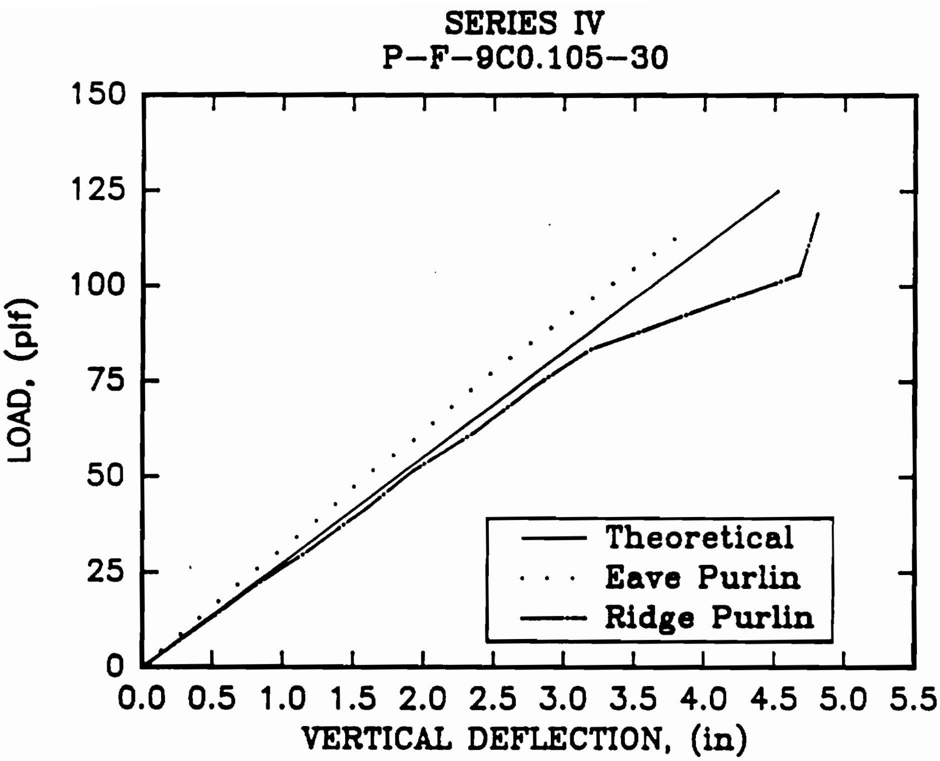
Note: Specified overstress allowances were taken into consideration for system capacity determination.

Total System Weight: 155.1 Lbs.

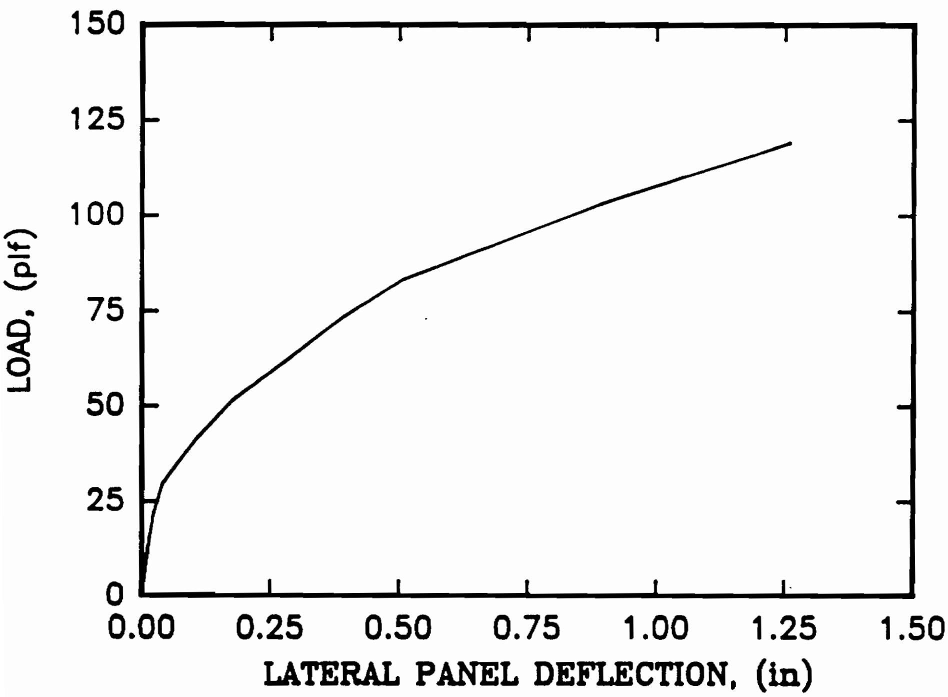
Cross-Sections

Purlin Identification for Bay # 1: C 8.94x0.105

	Top		Bottom	
Lip Length:	0.8750		0.7500	in.
Lip Angle:	93.000		93.000	Deg.
Radii:				
Lip to Flange:	0.2500		0.2500	in.
Flange to web:	0.3750		0.3750	in.
Flange Width:	2.5000		2.5000	in.
Total Depth:	8.938	in.		
Thickness:	0.1050	in.		
Yield Stress:	57.80	ksi		
Young's Modulus:	29500.0	ksi		



a) Load vs. Vertical Deflection



b) Load vs. Lateral Panel Deflection

VITA

The author was born September 14, 1964, in Logan, West Virginia. He attended Chapmanville High School and graduated in 1982. His undergraduate studies were done at Southern West Virginia Community College, and West Virginia Institute of Technology. He received a Bachelor of Science Degree in Civil Engineering From West Virginia Institute of Technology in 1988.

The author began his graduate studies in September 1989 at Virginia Polytechnic Institute and State University.

Brian Lee Rayburn