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Eighth International Specialty Conference on Cold-Formed Steel Structures
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VERIFICATION OF 1986 AISI PROVISIONS FOR PURLIN DESIGN

by
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and
Thomas M. Murray[2]

INTRODUCTION

A common method to design gravity loaded C- and Z-purlins is to assume that flexural stresses can be calculated using the elastic flexure formula, e.g. constrained bending, and then evaluate cross-section strength using the provisions of the American Iron and Steel Institute (AISI) "Specification for the Design of Cold-Formed Steel Structured Members" (referred herein as the Specification) [1]. Pertinent provisions of the 1980 version of the Specification include minimum edge stiffener moment of inertia requirements, effective compression flange width and allowable compression stresses in the edge stiffener and web. A major drawback of these provisions is that if the edge stiffener does not satisfy the minimum requirements, even to a very small degree, the compression flange must be considered unstiffened with a substantial reduction in usable flexural capacity.

Corresponding provisions of the 1986 version of the Specification are based on a unified approach which accounts for the interaction between the compression area edge stiffener, flange and web. Further, contribution of any size edge stiffener can be included in the design calculations.

During the development of the unified provisions, a number of methods were proposed. The purpose of the study reported here was to evaluate the adequacy of each method for C- and Z-purlin design using the results of simple span, gravity loaded, flexural tests to failure as reference data. The methods used are based on the work of Desmond, Pekoz and Winter [2], Galavin [3], LaBoube and Yu [4] and Pekoz [5].

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All of the approaches allow for the flange to be partially stiffened, fully stiffened or unstiffened depending on the geometry of the edge stiffener. An effective web depth concept is also introduced and used in some of the methods, in addition to the usual effective flange width concept. For all methods, stresses are computed using the elastic flexure formula.

For evaluation purposes, simple span test results were collected from six independent sources. Computer programs were then written to allow for automated analyses of the large set of experimental data. Experimental failure loads were compared to predicted failure loads and statistical evaluations made to determine the most reliable method.

EVALUATION OF THE EXPERIMENTAL DATA

Results of laboratory tests performed on 141 purlins loaded to failure were collected from six independent sources. The provided information included measured dimensions, material properties and failure load of each purlin, and detailed descriptions of test setups and testing procedures. However, only 119 of these results were used to investigate the adequacy of the proposed design methods; the other 22 results were rejected because they were found to be inadequate for the purpose of this study, generally because of test setup details.

To determine if the experimental data set adequately represented the range of sections used in the metal building industry, web, flange and lip slendernesses and the lip angles of 92 sections produced by the metal building manufacturers were tabulated. From statistical analysis, it was found that the range of variation of the web slenderness, H/t, where H is the clear distance between flanges and t is the material thickness can be divided into three subranges, high, intermediate and low, as follows:

Low range : $H/t < 102.6$

Intermediate: $102.6 \le H/t \le 112.4$

High range : $112.4 < H/t$

Similarly, the range of variation of the flange slenderness, w/t, where w is the flat flange width can be partitioned as:

Low range : $w/t < 34.5$

Intermediate: $34.5 \le w/t \le 37.4$

High range : $37.4 < w/t$

Further, the range of variation of the lip slenderness, b/t, where b is the lip length can be partitioned as:

Low range : $b/t < 11.3$

Intermediate: $11.3 \leq b/t \leq 12.0$

High range : $12.0 < b/t$

Finally, the range of variation of the edge stiffener angle from the horizontal, Θ, can be divided into the following divisions:

Low range : $\Theta < 46.5°$

Intermediate: $46.5° \leq \Theta \leq 85.2°$

High range : $\Theta > 85.2°$

With the above ranges established, the web, flange, and lip slendernesses and the lip angle of each purlin in the experimental data set was classified. Figure 1 graphically displays the results with the numeral in each shaded square representing number of experimental observations for the particular subclassification. The wide dispersion of the shaded squares indicates that the experimental data used in the study adequately represents the range of parameters found in commercially produced purlins.

EVALUATION OF THE DESIGN PROCEDURES

The evaluation of the proposed design procedures is based on pure statistical considerations. Ratios of theoretical-to-experimental failure loads are the basis for the comparisons. The most important measure is the mean value of these ratios. The method is good if the mean is equal to 1, conservative if less than 1, and unconservative if greater than 1. Practically, the method is judged acceptable if the mean value of the ratios is between 0.9 and 1.1, that is, a 10% error is allowed on either the conservative or unconservative side. Also of importance are the standard deviation and the range of the aforementioned ratios. These measures are most helpful in comparing the design methods with each other. The results of the evaluations are shown in Table 1 for the ten proposed methods. The 1986 AISI procedure is designated as Method 10 and the 1980 AISI procedure is Method 11.

For further evaluation, scatter diagrams of the failure load ratios were plotted for each method. These plots are important in that they help visualize the region where a given design method is "acceptable" and dispersion of the ratios around their means.

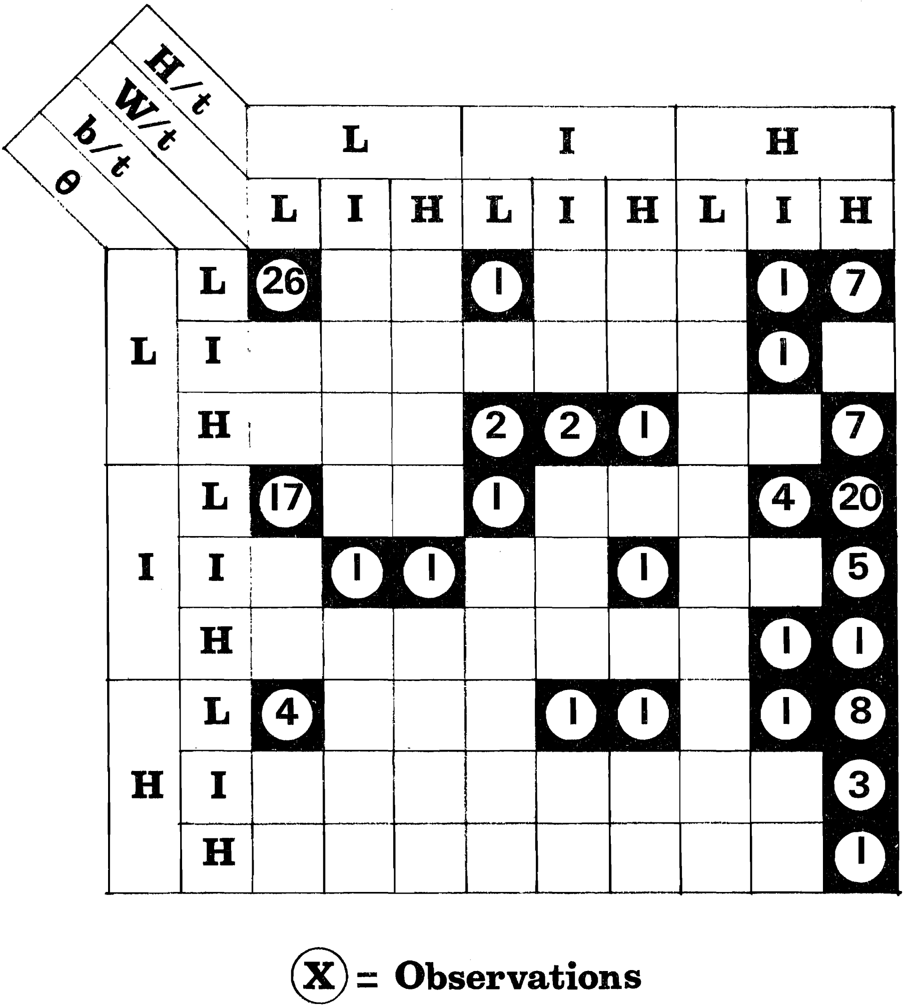

Figure 1. Distribution of Test Data Over Range of Available Sections

Table 1

Statistical Results of Evaluations

	Theoretical/Experimental Failure Loads			
Method	Mean	Standard Deviation	Minimum Value	Maximum Value
1	1.023	0.110	0.791	1.268
2	1.032	0.110	0.760	1.268
3	1.033	0.110	0.796	1.268
4	1.015	0.107	0.784	1.268
5	1.017	0.124	0.759	1.315
6	1.092	0.125	0.793	1.347
7	1.033	0.105	0.784	1.264
8	1.084	0.119	0.823	1.320
9	1.078	0.120	0.793	1.347
10	1.042	0.098	0.809	1.269
11	1.121	0.177	0.476	1.450

Notes: Method 10 is 1986 AISI procedure.
Method 11 is 1980 AISI procedure.

For illustration, scatter diagrams for the 1980 and 1986 AISI procedures are shown in Figures 2 and 3, respectively. The 1986 AISI procedures gave ratios with a mean value of 1.042, a standard deviation of 0.098, a minimum value of 0.809, and a maximum value of 1.269. Eighty-six observations were satisfactory, seven were conservative and 26 were unconservative. The 1980 AISI procedures gave ratios with a mean value of 1.121, a standard deviation of 0.177, a minimum value of 0.476 and a maximum value of 1.45. Of the 119 observations, 42 were found to be satisfactory, 9 were in the conservative range, and 68 were in the unconservative range. Similar analyses were performed on the remaining proposed methods and the results were used to determine the method that best represents the experimental data.

COMPARISON BETWEEN THE PROPOSED DESIGN PROCEDURES

Six criteria were were used to classify the proposed procedures. The first criterion is the absolute difference between the mean value of the moment ratios of each method and 1.0; the method with the smallest difference is classified best according to this measure. The second and third criteria are the magnitude of standard deviation and the range of values. These quantities are related to the dispersion of the moment ratios of each method around their mean. The last three criteria are the number of satisfactory observations (moment ratio between 0.9 and 1.1), conservative observations (moment ratios less than 0.9) and unconservative observations (moment ratio greater than 1.1). The results of these analyses are shown here in Table 2.

Method 10, the 1986 AISI procedure, is classified best according to three out of the six criteria; Methods 4 and 7 are best according to two out of the six criteria. Method 10 is ranked first in the general classification and Methods 4 and 7 are ranked second. Method 11, the 1980 AISI Specification procedure, was classified last according to five out of the six comparison criteria, and is last in the general classification.

CONCLUSIONS

Data for 141 purlins failed in simple span, were collected from six sources to investigate the adequacy of ten proposed design approaches for determining cross-section flexural capacity. After a careful examination of the collected experimental data, 119 sets were used in the study. Each of the ten proposed methods and the current specification method was used to predict the failure moment for each of the 119 sets of test data. The ratio of theoretical-to-experimental moments was then calculated and statistics for each of the ten methods were determined.

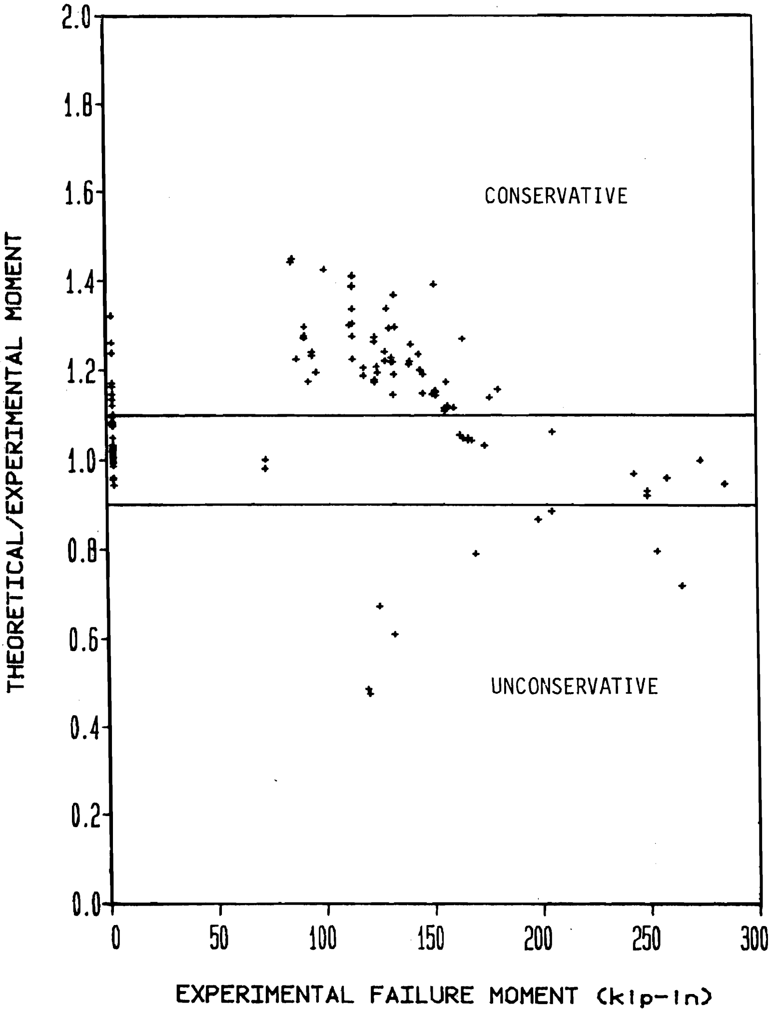

Figure 2. Scatter Diagram for 1980 AISI Procedure

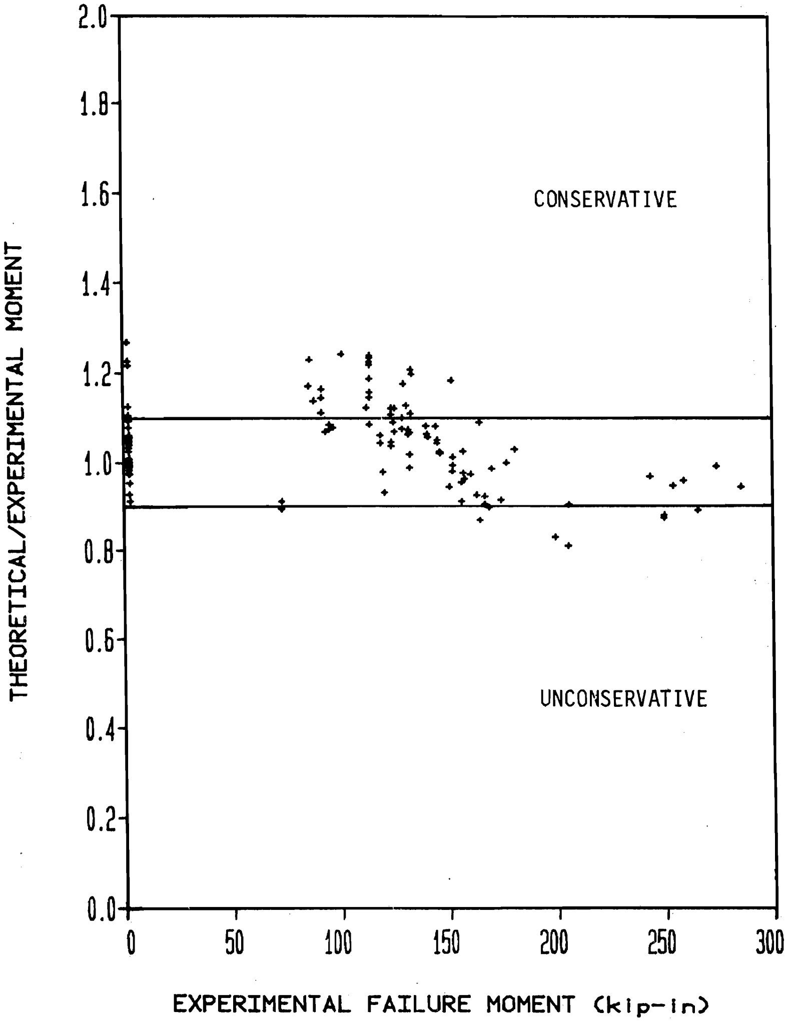

Figure 3. Scatter Diagram for 1986 AISI Procedure

Table 2
Ranking of Design Methods

Ranking	Criterion / Method						
	A	B	C	D	E	F	ALL
1	4	10	10	7,10	5	7,4	10
2	5	7	3	-	4,1	-	7,4
3	1	4	1	2,4	-	1	-
4	2	1,2,3	7	-	3	2,10	1
5	7,3	-	4	1	2	-	2
6	-	-	8	3	7	3	3
7	10	8	2	5	11	5	5
8	9	9	6,9	9	10	9	9
9	8	5	-	8	6,8,9	8	8
10	6	6	5	6	-	6	6
11	11	11	11	11	-	11	11

Criterion:

A : Difference between mean and 1.0
B : Standard deviation
C : Range
D : Satisfactory cases
E : Conservative cases
F : Unconservative cases

Statistical comparisons between the methods resulted in Method 10 being ranked first. This method is to be used in the 1986 AISI Specification provisions.

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