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Selecting the Optimum Lipped Channel Beam

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SELECTING THE OPTIMUM LIPPED CHANNEL BEAM

by

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General Approach

In the 1980 Cold-Formed Steel Specification, there were only stiffened and unstiffened elements. An element was deemed stiffened if it had an adequate stiffener on both edges of the element. The stiffener's adequacy was a clearly defined limiting moment of inertia, dependent on the slenderness of the element being stiffened. If stiffened elements were very slender, the real width might have to be reduced to an effective width and the effective area thus computed, when divided by the gross area, produced an area reduction factor called Q_a.

Effective area was not calculated for unstiffened elements. The lower buckling stress on an unstiffened element was calculated according to formulas which were a function of the slenderness of the element. The resulting stress, when divided by the design stress, usually $0.6F_y$, produced a stress reduction factor, called Q_s. The total reduction on a section in compression was a product of $Q_a \times Q_s$.

In the 1986 Cold-Formed Steel Specification, all elements are treated with an effective width approach. There is one basic effective width equation and the only difference that separates one element from another is the plate buckling constant, k. Even though the specification still speaks of stiffened

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and unstiffened elements, all elements are stiffened to some degree, according to their edge conditions and stress gradients and one can begin to think in terms of only one kind of element: a partially stiffened element.

Adequate Stiffening

Formerly, in a section such as a channel that has a flange stiffened by a web on one side and an adequate lip on the other, the flange was considered a stiffeded element. Now, there is a distinction between the flange of a channel and the flange of a hat section, which is attached to webs on both sides. The channel flange is called an edge-stiffened element and the hat flange is called a stiffened element.

The web of a section, which has a portion of its depth in compression, is also treated with an effective width approach, as are all elements with a stress gradient. The only item that changes is the k factor.

For a channel with an edge-stiffened flange, the rules for adequacy of the stiffening lip are new and reflect the various conditions of flange slenderness, lip slenderness, and lip length-to-flange width ratio, as shown in Figure 1 (reproduced from Figure 2.5-2 of Reference 3). If the flange is uniformly compressed, as it is in a channel bent about the x-axis, the rules for adequate stiffeners are presented in Section B4.2 of the 1986 Specification. These are plotted in Figure 2. It can be seen that, for high flange slenderness ratios, the lipped channel will require a slightly longer lip than previously. However, because of the complete change of approach in the 1986 Specification, it is difficult to assess this effect on the design of sections without looking at all the areas of the Spec that are involved. For this reason, it is necessary to calculate the moment capacity of a series of lipped channels by both the 1980 and the 1986 Specifications in order to make comparisons.

Channel Moment Capacity

Another new feature of the 1986 Specification is that allowable stresses have been replaced by allowable forces and moments. Actually, the formulas are in terms of ultimate forces and moments, which are, at the end, divided by an appropriate factor of safety. This format was adopted so that, when AISI decides to publish an LRFD Specification, it will be easy to convert simply by removing the safety factor and adding a load factor to the loads and a resistance factor to the resistance.

In this study, allowable moments were calculated on 667 lipped channel by both the 1980 and 1986 Specifications and compared. Figure 3 shows a typical comparison. Note that the moment capacity is slightly less with the 1986 Spec, even at the optimum lip length. The major difference, however, occurs when the lip length would have been less than adequate under the 1980 Spec. As the lip length is decreased to below 0.7 inches, there is a dramatic drop in the moment capacity. This occurs because the lip is now an inadequate stiffener and the flange must be treated as if it were an unstiffened element. In the 1986 Spec, all stiffeners have some partial stiffening effect, as was explained earlier, and the loss of capacity with a reduced lip length is a gradual process. Thus a 7" x 3" x 14 ga. channel with a lip of 1/2" long would have a moment capacity of around 22 in-k according to the 1980 Spec and around 54 in-k by the 1986 Spec.

Making the lip longer at some point no longer results in much strength increase. It also adds weight to the cross section. To determine the most economical length of lip for a given channel, it is useful to re-work Figure 3 and plot the lip length against the strength-to-weight ratio. This is done in Figure 4 by dividing the moment capacity by the area. In 1980, the optimum length for this channel would have been around 0.7"; in 1986, the optimum length is about 1.1" and the moment capacity is slightly less.

The Optimum Section

It should be noted that Figures 3 and 4 represent only one channel size. Those of different dimensions will have different curves. In this study, almost 700 variations of web depth flange width and gage were studied and curves were generated similar to those in Figure 4.

The optimum dimensions of each group (that is, the ones with the highest strength-to-weight ratio) are tabulated in Table 1. Note that there is a consistant relationship between the full stiffener length, C, and the flange width, B. We could let C/B = 3/8 with very little error.

It can also be observed that the best flange width and thickness is that which will make the flange fully effective, that is, where B/t is approximately equal to S as defined by the AISI specification ($1.28\sqrt{E/f}$) .

Summary and Conclusions

The bending capacities of nearly 700 variations in channel depth, flange width, thickness and lip length were studied, using both the 1980 and 1986 AISI Cold Formed Steel Specifications. The conclusions which may be drawn are:

1.) The moment capacity of lipped channels, bent about the strong axis, is generally slightly less using the 1986 Specification.

2.) It will in general require a slightly longer edge stiffener with the 1986 spec to produce the same moment capacity as calculated by the 1980 spec, assuming all other dimensions are the same.

3.) The optimum channel flange is one in which B/t is closest to S (or $1.28\sqrt{E/f}$).

4.) The optimum lip/flange width ratio (out-to-out dimensions) is around 3/8.

Table 1 Summary of Optimum Channel Dimensions

A	T	B	C	C/B
12	0.165	5.25	1.95	0.371
	0.135	4.50	1.70	0.378
	0.105	3.75	1.45	0.387
	0.075	2.25	0.95	0.422
10	0.165	5.25	1.95	0.371
	0.135	4.25	1.55	0.365
	0.105	3.50	1.30	0.371
	0.075	2.50	0.95	0.380
	0.060	1.75	0.75	0.429
9	0.165	5.25	1.90	0.362
	0.135	4.25	1.55	0.365
	0.105	3.50	1.30	0.371
	0.075	2.50	0.95	0.380
	0.060	2.00	0.75	0.375
	0.048	1.50	0.60	0.400
8	0.165	5.25.	1.90	0.362
	0.135	4.25	1.55	0.365
	0.105	3.50	1.30	0.371
	0.075	2.50	0.95	0.380
	0.060	2.00	0.75	0.375
	0.048	1.50	0.60	0.400
7	0.165	5.25	1.90	0.362
	0.135	4.25	1.55	0.365
	0.105	3.50	1.30	0.371
	0.075	2.50	0.95	0.380
	0.060	2.00	0.75	0.375
	0.048	1.50	0.60	0.400
6	0.135	4.25	1.55	0.365
	0.105	3.50	1.30	0.371
	0.075	2.50	0.95	0.380
	0.060	2.00	0.75	0.375
	0.048	1.75	0.60	0.400
5	0.135	4.25	1.50	0.353
	0.105	3.50	1.30	0.371
	0.075	2.50	0.95	0.380
	0.060	2.00	0.75	0.375
	0.048	1.50	0.55	0.367
4	0.135	3.75	1.25	0.333
	0.105	3.25	1.15	0.354
	0.075	2.25	0.80	0.355
	0.060	2.00	0.75	0.375
	0.048	1.50	0.55	0.367

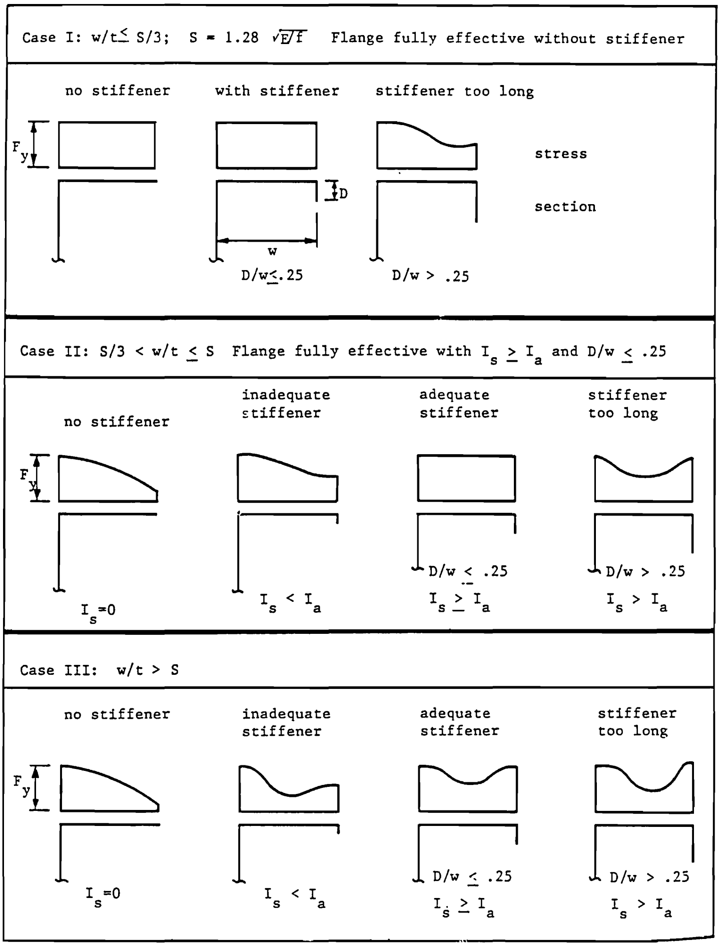

Figure 1 Edge Stiffener Design Criteria

(Reproduced from AISI Report SG 86-4, "Development of a Unified Approach to the Design of Cold-Formed Steel Members", by T. Pekoz)

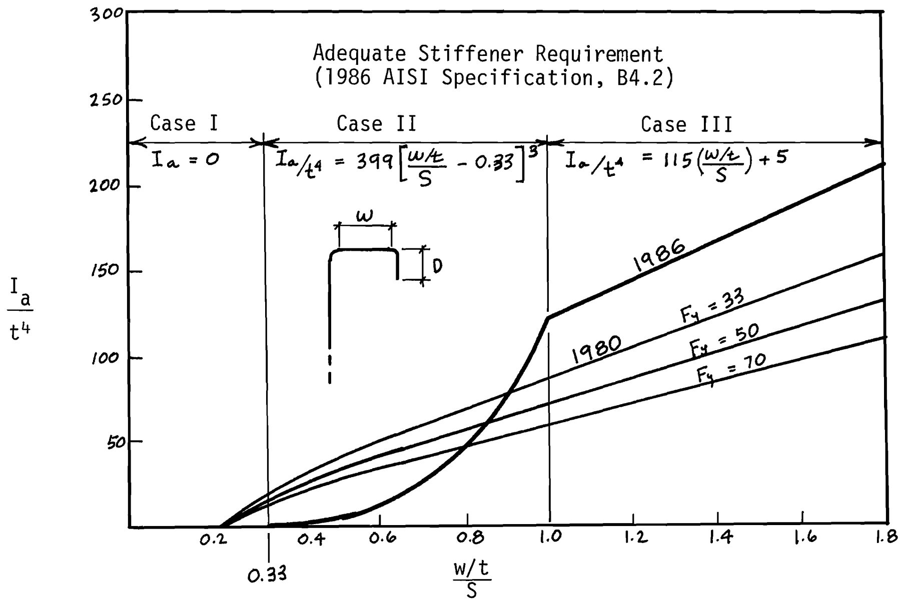

Figure 2 Comparison of Flange Stiffener Requirements by 1980 and 1986 AISI Specifications.

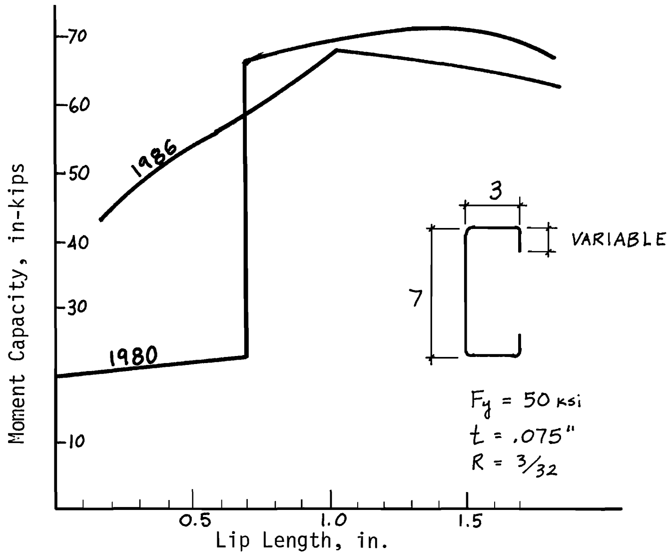

Figure 3 Channel Moment Capacity as a Function of Lip Length.

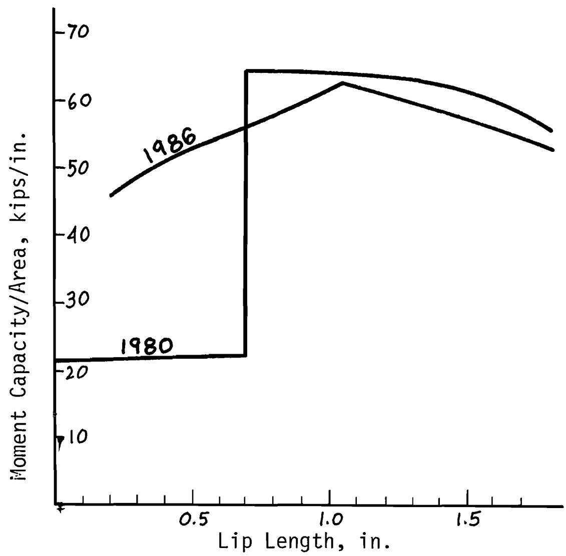

Figure 4 Channel Strength-to-Weight Ratio as a Function of Lip Length.