DEVELOPMENT OF PERFORMANCE SECTIONS FOR COLD-FORMED STEEL RESIDENTIAL CONSTRUCTION

by

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(ABSTRACT)

The wider use of cold-formed steel framing is hindered by the lack of generic sections. This study puts forth an effort to develop a performance section designation code without specifying the geometry of the sections. A PC-based program to analyze C-section was developed and used to produce typical Performance Section Tables for both wall studs and joists.

For curtain walls the Uniform Lateral Load Capacity Tables and for bearing walls the Axial Load with Specified Lateral Load Tables, the Strong Axis Axial Load Capacity Charts, and the Weak Axis and Torsional Axial Load Capacity Charts were developed. The typical design aids for roof/floor joists include the Uniform Load Capacity Tables for single and two continuous spans, the Moment-Shear Interaction Capacity Charts, and the Web Crippling Capacity Tables. Design examples are provided to illustrate the usage of the above tables and charts.
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Finally, I would like to acknowledge my parents, Cecilia Szalay and Zoltan Nemedi for their love, support and encouragement.

This work is dedicated to my father, Zoltan Nemedi, who is no longer with us to share my joy and pride upon the successful completion of my Master of Science degree.
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CHAPTER I

INTRODUCTION

1.1 Purpose of Study

The use of light gauge steel framing (LSF) is growing in popularity in the residential construction market especially for multi-family housing and nursery homes (Steel Framing and Roofing Opportunities 1992). In 1987, LSF only covered two percent of the market but it has a potential for much more (Walls and Ceilings, 1987).

Fire resistance and low maintenance cost of steel walls provide substantial advantages over both wood framing and masonry. Pre-punched holes allow easier installation of pipes and conduits and placing insulation in stud cavities makes thermal performance excellent. In price, LSF can be competitive with wood or masonry construction; in areas with expensive labor costs it might even be cheaper. Cold-formed steel wall studs - especially in the southern states - can also benefit from problems associated with lumber like termite infestation, rot decay, and shrinkage.

Steel roofing and floor systems - despite their relatively higher cost - also have their advantages. Similar to metal framing, they possess good maintenance and fire resistance characteristics and their better performance makes them favorable in areas with bad environmental conditions like snow build up, high wind and, intense sun exposure. Cold-formed metal roofing also has lighter weight and in certain areas regional aesthetic preferences can be beneficial also (Steel Framing and Roofing Opportunities 1992).
Light gauge metal sections are adaptable to numerous different structural systems. Floor joists can rest on concrete or masonry walls; load bearing studs can support steel joists, wood trusses or concrete slabs.

To further increase cold-formed steel popularity and usability, generic guidelines should be developed, minimizing engineering analysis, making design more uniform and increasing the number of off-the-shelf components which would be available all over the country. Today each manufacturer has optimized cross-sections available for various purposes. The number of different, specifically developed, innovative and highly optimized cross-sections on the market is extremely high*. On one hand the ability to do this is a very positive feature of cold-formed steel. On the other hand, it does not allow the designer to specify generic sections with required structural properties and makes pre-engineered design impossible.

There are two basic ways to overcome this hindrance. First, one could specify generic sections with prescribed geometry such as thickness, radii, lip length, etc. This approach would certainly make the market more uniform but its drawbacks are far larger than the advantages. The construction industry could no longer use its optimized sections and existing tooling and machinery might become obsolete.

A second, more promising approach is to develop performance section designations, similarly to what is already used in the open-web steel joist industry. No geometry, only certain performance requirements would be specified and published. Existing sections can simply be renamed in accordance with the new designation code, or manufacturers can develop new sections in any number of ways to make their products more competitive. Designers then can specify desired performances using the new designation system.

*A survey of 17 companies found that over 410 different studs and 280 different joists are produced.
The intent of this research is to provide the above outlined performance section tables and a set of design aids for wall studs and roof/floor joists.

1.2 Description of Wall Stud and Floor/Roof Joist Systems

Light gauge steel sections can be used in many different ways. Figure 1.1 shows how studs, joists, tracks, channels and angels are utilized in an all-metal building.

1.2.1 Wall Studs

Vertical framing elements are commonly referred to as wall studs. They can be used in curtain-walls on exterior of buildings to resist lateral (wind) loads or as axial load bearing studs on the inside or outside of the structure to support floor and roof loads. The thickness of these sections generally ranges from 20 to 12 gauge (0.030 in. to 0.105 in.). The 25 gauge drywall studs systems are used for interior walls to withstand small lateral loads, usually without axial loads. In Figure 1.1 one can see exterior axial load bearing studs which are also subjected to lateral loads.

Wall studs frame into tracks which restrain rotation and horizontal displacement of the stud ends. All wall studs subjected to lateral loads require horizontal bridging. The purpose of bridging is multi-fold; it keeps the studs straight, helps resisting various forces and impacts under construction, and provides added stability against weak axis and torsional buckling. The most common type of bridging is a channel inserted through the knock-outs of the stud webs (Fig. 1.2a), but X-bridging (Fig. 1.2b), or straps are also acceptable.
Figure 1.1 Typical Light Gauge Steel Building  
(from CSSBI, 1988)
a Bridging with Channel

b X-bridging

Figure 1.2 Typical Wall Stud Bridgings (from AISI Construction Details)
To withstand forces parallel to the plane of the wall, which may result from wind or seismic loading, adequate bracing is required. The most effective way to provide this in-plane stiffness is by means of diagonal straps welded to the flanges of the studs and anchored at the ends. Since these straps carry tension loads only, they are normally used in both diagonals (Fig. 1.1).

Light gauge steel walls may be covered with various types of sheathing providing adequate to less than adequate lateral support. For interior, walls usually 3/8 to 5/8 inch thick gypsum boards are applied, which restrain studs against weak axis or torsional buckling giving additional axial strength. In the case of exterior walls, sheathing boards, cement stucco, bricks, plaster, etc. may also be attached to the studs.

1.2.2 Joists

Cold-formed joists are horizontal or inclined structural elements resisting floor and roof loads. The usual range of thickness range is the same as for wall studs 20 - 12 gauge, but their flange width is larger; 2 - 3 in. as opposed to 1 1/4 - 1 3/4 in. for studs.

Floor joists are supported by the top track and usually aligned with the wall studs (Fig. 1.1). Rafters can be attached to the joists (Fig. 1.3), or to clip angels resting on the top track. For bridging, channels (Fig. 1.3), or X-bracing can be used.

In case of large spans and/or high web height/thickness ratios web crippling may be a problem. Track or wall stud along the whole depth of the joist can be used to increase strength (Fig. 1.4b).

Joists can be covered with metal deck, concrete floor or plywood. At the stud-joist connection, angles prevent concrete from pouring into the stud cavities (Fig 1.1). For single spans the concrete floor provides continuous support all along the top (tension)
Figure 1.3 Roof Eave
(from AISI Construction Details)
**Figure 1.4** Two Examples for Joists Supported on Studs (from AISI Construction Details)
flange. Figure 1.4a shows details of support of two adjacent single spans. For the negative moment zones of continuous spans (Fig 1.4b), however, additional bridging is required to prevent joists from lateral torsional buckling. If the joists are not long enough to bridge two or more spans, lapping can be used to provide adequate continuity.

1.2.3 Scope of Study

Through the next five chapters this study will describe the development of performance sections and related tables. The computer program written for the purpose of analyzing cold-formed C-sections is dealt with in detail in Chapter II. The performance section tables for wall studs and joists are included in Chapter III. The next chapter contains the developed design aids for wall studs:

- uniform lateral load capacity tables,
- axial loads capacity with specified lateral loads tables,
- strong axis axial load capacity charts, and
- weak axis and torsional axial load capacity charts.

Chapter V provides further information about joists such as;

- uniform load capacities for single span,
- uniform load capacities for two continuous spans,
- moment-shear interaction capacity charts,
- web crippling capacity tables.

The last chapter gives a short summary of the work done.
CHAPTER II

PROGRAM FOR ANALYZING COLD-FORMED C-SECTIONS

2.1 General

The initial effort in this study was to develop a computer program for analyzing cold-formed sections. The program computes various properties and capacities of a cold-formed C-section with or without lips (Fig. 2.2), without taking the effects of cold forming into account. The program is written in QuickBasic, based on the 1986 Allowable Stress Design Edition of Cold-Formed Steel Design Specification (AISI Cold-Formed Steel Design Manual, 1986). It has a modular structure, each distinct set of calculations being performed by different subroutines. The main and sub-functions of the code are the following:

- input
- computation
  - section properties
  - flexural capacity
  - shear capacity
  - compression capacity
- output
  - screen
    - graphics
    - numerical data
  - printer
START

DESCRIBE
Gives a short description of the program

Screen or printer mode?

screen

INPUTDATA
Inputs the required data

COMPsecprop
Computes the cross-sectional properties of the section

COMPflexcap
Computes the flexural capacity of the section

COMPshearcap
Computes the shear capacity of the section

COMPcompcap
Computes the compression cap. of the section

1. Send output to printer
2. Compute a new section
3. Exit

3

END

Figure 2.1 Flow Chart Of The Program
Inputting the required data is carried out solely by one subroutine. Usually the same applies to the output, but that would require passing too many variables. Another approach is when each computing module displays the just determined relevant data on the screen or printer, and this way only those variables have to be passed (i.e. included in the parameter list of the subroutine) which will be used later on.

Figure 2.1 shows the flowchart of the main routine. If at the end, the 'Send output to printer' option is selected, the program, since for the above outlined reasons it does not store and pass every variable, goes back to the beginning and recomputes everything but this time it uses the printer and not the screen for the output. In that case, the same data is used as previously and the INPUTDATA subroutine is be skipped.

The complete program listing is enclosed in Appendix A. A Load and Resistance Factor Design version, which for the most part requires only minor changes, was also developed.

2.2 Description Of The Subroutines

The structured program format and the large number of comments provided makes the code clear and easy to comprehend. An additional feature of each subroutine is that at the beginning a brief description and a complete list of the variables used is given.

2.2.1 Inputting The Data

This function is performed by the INPUTDATA subroutine. The information needed for the further computation is the following:
- yield strength of steel
- depth of section (A')
- width of flange (B')
- length of lip (C')
- radius of corners (R)
- material thickness (t)
- buckling length

As it is illustrated on Figure 2.2 these are outside dimensions with the exception of the radius of the corners.

2.2.2 Computing The Sectional Properties

Subroutine COMPsecprop computes the sectional properties based on the Supplementary Information Section 1.2.2 of the 1986 Cold-Formed Steel Design Manual. In the second part the program plots the section on the screen and marks the relevant data with dimension lines. It displays the computed properties on the right side of the screen or sends it to the printer depending on the active output mode.

2.2.3 Determining The Flexural Capacity

Before discussing subroutine COMPflexcap - the longest and most complex part of the program - one must have a look at its auxiliary routines.

2.2.3.1 Subroutine COMPeffwidth

This routine (Fig. 2.3) is used for computing the effective width of elements under the following conditions:
Figure 2.2  C-section With And Without Lips

\[ \lambda = \frac{1.052}{\sqrt{k}} \cdot \frac{w}{\sqrt{\frac{f}{E}}} \]

\[ \lambda > 0.673 \]

yes

reduction
\[ \rho = \frac{(1 - 0.22 / \lambda)}{\lambda} \]

\[ \text{be} = \rho \times w \]

no

no reduction
\[ \rho = 1 \]

Figure 2.3  Flow Chart Of Subroutine COMPeffwidth
(See page 94 for explanation of variables)
• uniformly compressed stiffened elements (Sect. B2.1)
  e.g. web, if section is subjected to compression
• uniformly compressed unstiffened elements (Sect. B3.1)
  e.g. flange if there is no lip and section is in bending or compression,
    lip if section is in compression
• edge stiffeners with stress gradient (Sect. B3.2)
  e.g. lip if section is subjected to bending
• uniformly compressed elements with edge stiffeners (Sect. B4.2)
  called from subroutine COMPflange after the calculation of the
    plate buckling coefficient (k)
  e.g. flange in bending or compression
• stiffened element with stress gradient (Sect. B2.3)
  called from COMPweb after the computation of k and the
    appropriate stress level (f)
  e.g. web in bending

2.2.3.2 Subroutine COMPflange

This routine (Fig 2.4) computes the effective width of a uniformly compressed
stiffened element based on Section B4.2.

If w/t, the ratio of the flat width to the thickness, is small enough (Case I) there is
no reduction to either the flange or to the lip. On the other hand if w/t exceeds a certain
number (Case II and III), the plate buckling coefficient (k) and then the slenderness (λ)
must be calculated (by calling the previously described subroutine COMPeffectwidth) to
determine if the flange and lip are fully effective or not.
Figure 2.4  Flow Chart Of Subroutine COMPflange
(See page 95 for explanation of variables)

16
2.2.3.3 Subroutine COMPweb

This routine (Fig. 2.5) computes the location of the neutral axis and the effective portions of the web based on Section B2.3.

The program assumes that the web is fully effective. If the assumption is correct the program returns to the main routine, if not iteration is needed to find the effective portions of the web. The approximation continues until the difference between two consecutive values of $b_1 + b_2$ is less the one percent.

2.2.3.4 Subroutine COMPflexcap

The previously described smaller routines are controlled by this subroutine (Fig. 2.6).

After plotting the section on the screen, the effective width of the flange ($b_e$) and the reduced effective width of the lip ($d_e$) is computed. By comparing these values to the flat widths ($b, c$), it can be determined whether they are fully effective or not. The appropriate message is then printed on the screen or printer. Next, the program determines the neutral axis and the effectiveness of the web. After analyzing every element of the section, the effective moment of inertia ($I_{xe}$), the section modulus ($S_{xe}$), the nominal and the allowable moment capacities ($M_n, M_a$) are computed.
Figure 2.5  Flow Chart Of Subroutine COMPweb
(See page 98 for explanation of variables)
Figure 2.6 Flow Chart Of Subroutine COMPflexcap
2.2.4 Determining The Shear Capacity

Subroutine COMPshearcap (Fig. 2.8) calculates the shear capacity \( (V_s) \) of the section based on Section C3.2 of the 1986 Cold-Formed Steel Design Specification.

Depending on \( h/t \) (flat width to thickness ratio) either elastic or inelastic buckling governs. After yielding, the web can not carry any more shear therefore this value is the upper limit of the inelastic equation.

It is interesting to note - looking at the three equations - how the contribution of the thickness becomes more significant and that of the yield stress less significant as the \( h/t \) ratio increases.

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<th>yield stress</th>
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<td>yield: ( V_s = 0.4F_y )</td>
<td>( t )</td>
<td>( F_y )</td>
</tr>
<tr>
<td>inelastic buckling: ( V_s = 0.38r^2 \sqrt{kF_yE} )</td>
<td>( t^2 )</td>
<td>( \sqrt{F_y} )</td>
</tr>
<tr>
<td>elastic buckling: ( V_s = 0.53Ekf^3/h )</td>
<td>( t^3 )</td>
<td>-</td>
</tr>
</tbody>
</table>

2.2.5 Computing The Compression Capacity

Subroutine COMPcompcap (Fig. 2.7) computes the maximum allowable load the given section can carry based on Section C4 of the 1986 Cold-Formed Steel Design Specification.

The structure of this routine is very similar to the structure of subroutine COMPflexcap. First the elastic buckling stress \( (F_e) \) - the least of flexural, torsional and torsional-flexural buckling stresses - is determined, followed by the nominal buckling stress \( (F_n) \), which is used for the effective area calculations.
Figure 2.7 Flow Chart Of Subroutine COMParamcap
The lips and the flanges are handled the same way as for the flexural capacity determination with two differences. First the lips are uniformly compressed elements as opposed to elements with stress gradient. This does not change anything, since both Section B3.1 and B3.2 prescribe $k = 0.43$. The other, more significant change, is that in this case $F_n$ is used instead of the yield stress $F_y$, and because $F_n < F_y$ the section will now be more effective.

The web is a uniformly compressed element, therefore its effective width can be determined simply by calling COMPeffectwidth. The final step is to compute the effective area ($A_{et}$) and the compression capacities ($P_m$, $P_a$).

2.2.6 Graphical Subroutines

Subroutine PLOTSEC plots the section proportionally on the left side of the screen, leaving enough room on the other side for numerical data.

Subroutines SHOWSIZE and SHOWSIZE2 draw dimension lines and label them.

2.3 Example

Example 4.2 on page 128 of Cold Formed Steel Design by Wei-Wen Yu was solved by the program. Figures 2.9 through 2.11 show the screen output. The ineffective portions of the section shaded are. The printer output can be found on pages 25-27.
Figure 2.8 Flow Chart Of Subroutine COMPshearcap

Figure 2.9 Computing Section Properties

<table>
<thead>
<tr>
<th>Section Properties</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$A' = 10.000$ in</td>
<td>$a = 9.663$ in</td>
</tr>
<tr>
<td>$b' = 3.500$ in</td>
<td>$b = 3.162$ in</td>
</tr>
<tr>
<td>$C' = 0.720$ in</td>
<td>$c = 0.551$ in</td>
</tr>
<tr>
<td>$r_i = 0.094$ in</td>
<td>$r = 0.131$ in</td>
</tr>
<tr>
<td>$t = 0.075$ in</td>
<td>$u = 0.206$ in</td>
</tr>
<tr>
<td>$A = 1.344$ in²</td>
<td></td>
</tr>
<tr>
<td>$ix = 20.532$ in⁴</td>
<td>$nx = 3.909$ in</td>
</tr>
<tr>
<td>$Sx = 4.106$ in³</td>
<td></td>
</tr>
<tr>
<td>$iy = 2.035$ in⁴</td>
<td>$ny = 1.231$ in</td>
</tr>
<tr>
<td>$Sy = 0.792$ in³</td>
<td>$Sly = 2.184$ in³</td>
</tr>
<tr>
<td>$r_a = 4.733$ in</td>
<td></td>
</tr>
<tr>
<td>$x_h = 0.894$ in</td>
<td>$m = 1.473$ in</td>
</tr>
<tr>
<td>$C_w = 39.267$ in⁶</td>
<td></td>
</tr>
<tr>
<td>$J = 0.002619$ in⁴</td>
<td></td>
</tr>
</tbody>
</table>

Press any key to continue.
Figure 2.10 Computing Flexural Strength

Comp. flange isn't fully eff.
be = 2.229 in < b = 3.162 in

Comp. lip isn't fully eff.
ad = 0.113 in < d = 0.551 in

Assuming web is fully eff.
Assumption incorrect.
Iteration needed.

\[
\begin{array}{ccc}
\text{ycg} & \text{b1+b2} & \text{diff.}\% \\
5.399 & 4.037 & \\
5.460 & 4.900 & 0.752 \\
5.480 & 4.888 & 0.242 \\
5.487 & 4.885 & 0.077 \\
\end{array}
\]

Ixe = 17.845 in^4  Sxe = 3.192 in^3

Mn = 159.881 in-kips
Max = 95.737 in-kips

Press any key to continue

Figure 2.11 Computing Shear And Axial Strength

\[\text{Va} = 3.645 \text{ kips}\]

Flexural buckling stress:
\((Fe)_1 = 47.348 \text{ ksf}\)

Tors.-flex. buckling stress:
\((Fe)_2 = 41.202 \text{ ksf}\)

Fe = 41.202 ksf  \(F_n = 34.831 \text{ ksf}\)

Flanges are not fully eff.
be = 2.588 in < b = 3.162 in

Lips are not fully eff.
ad = 0.135 in < d = 0.551 in

Web is not fully eff.
\(a_e = 3.758 \text{ in} < \alpha = 9.663 \text{ in}\)

\(\text{Ae} = 0.752 \text{ in}^2\)

Comp. strength of section:
\(\text{Pa} = 13.645 \text{ ksf}\)

Press any key to continue
Material and Section Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield strength of steel</td>
<td>( F_y = 50.000 \text{ ksi} )</td>
</tr>
<tr>
<td>Effective length</td>
<td>( K_L = 8.000 \text{ ft} )</td>
</tr>
<tr>
<td>Depth of section</td>
<td>( A' = 10.000 \text{ in} )</td>
</tr>
<tr>
<td>Width of section</td>
<td>( B' = 3.500 \text{ in} )</td>
</tr>
<tr>
<td>Length of lip</td>
<td>( C' = 0.720 \text{ in} )</td>
</tr>
<tr>
<td>Inner radius of corners</td>
<td>( R = 0.0938 \text{ in} )</td>
</tr>
<tr>
<td>Thickness</td>
<td>( t = 0.0756 \text{ in} )</td>
</tr>
<tr>
<td>Flat portion of web</td>
<td>( a = 9.663 \text{ in} )</td>
</tr>
<tr>
<td>Flat portion of flanges</td>
<td>( b = 3.162 \text{ in} )</td>
</tr>
<tr>
<td>Flat portion of lips</td>
<td>( c = 0.551 \text{ in} )</td>
</tr>
<tr>
<td>Midplane radius of corners</td>
<td>( r = 0.131 \text{ in} )</td>
</tr>
<tr>
<td>Length of arc</td>
<td>( u = 0.206 \text{ in} )</td>
</tr>
<tr>
<td>Area of cross section</td>
<td>( A = 1.344 \text{ in}^2 )</td>
</tr>
<tr>
<td>Moment of inertia about ( x )</td>
<td>( I_x = 20.532 \text{ in}^4 )</td>
</tr>
<tr>
<td>Moment of inertia about ( y )</td>
<td>( I_y = 2.035 \text{ in}^4 )</td>
</tr>
<tr>
<td>Radius of gyration about ( x )</td>
<td>( r_x = 3.905 \text{ in} )</td>
</tr>
<tr>
<td>Radius of gyration about ( y )</td>
<td>( r_y = 1.231 \text{ in} )</td>
</tr>
<tr>
<td>Polar radius of gyration</td>
<td>( r_o = 4.733 \text{ in} )</td>
</tr>
<tr>
<td>Section modulus about ( x )</td>
<td>( S_x = 4.106 \text{ in}^3 )</td>
</tr>
<tr>
<td>Section mod. about ( y ) (right)</td>
<td>( S_y = 0.792 \text{ in}^3 )</td>
</tr>
<tr>
<td>Section mod. about ( x ) (left)</td>
<td>( S_y = 2.184 \text{ in}^3 )</td>
</tr>
<tr>
<td>Dist. bw cent. and web centerline</td>
<td>( x_h = 0.894 \text{ in} )</td>
</tr>
<tr>
<td>Dist. bw shear cent. and web cl.</td>
<td>( m = 1.473 \text{ in} )</td>
</tr>
<tr>
<td>Warping constant</td>
<td>( C_w = 39.267 \text{ in}^6 )</td>
</tr>
<tr>
<td>St. Venant constant</td>
<td>( J = 0.002519 \text{ in}^4 )</td>
</tr>
</tbody>
</table>
Computing flexural strength

Effective width of edge stiffener  
Section B3.2 of Spec.

- Buckling coefficient  \( k = 0.430 \)
- Slenderness ratio  \( la = 0.485 \)
- Reduction factor  \( ro = 1.000 \)
- Effective width  \( b = 0.551 \) in

Effective width of compression flange  
Section B4.2 of Spec.

\[
\begin{align*}
\frac{w}{t} &= 42.167 > 8 = 31.091 \quad \text{case III} \\
\text{Req'd moment of inertia of stiffener } I_a &= 0.005093 \text{ in}^4 \\
\text{Actual moment of inertia of stiffener } I_s &= 0.001047 \text{ in}^4 \\
\frac{D}{w} &= 0.228 < 0.25 \\
\text{Buckling coefficient } k &= 2.537 \\
\text{Slenderness ratio } la &= 1.147 \\
\text{Reduction factor } ro &= 0.705 \\
\text{Effective width } b &= 2.229 \text{ in} \\
\text{Reduced eff. width of stiffener } ds &= 0.113 \text{ in} \\
be &= 2.229 \text{ in} < b = 3.162 \text{ in} \quad \text{Comp. flange is not fully eff.} \\
ds &= 0.113 \text{ in} < d = 0.551 \text{ in} \quad \text{Comp. stiffener is not fully eff.}
\end{align*}
\]

Computing the location of neutral axis and effective width of web

Assuming web is fully effective

\[
\begin{align*}
\text{Location of neutral axis } y_{cg} &= 5.399 \text{ in} \\
\text{Compression portion of web } a_{comp} &= 5.230 \text{ in} \quad f_1 = 48.437 \text{ ksi} \\
\text{Tension portion of web } a_{ten} &= 4.432 \text{ in} \quad f_2 = -41.045 \text{ ksi} \\
\text{Buckling coefficient } k &= 20.304 \\
\text{Slenderness ratio } la &= 1.219 \\
\text{Reduction factor } ro &= 0.672 \\
\text{Effective width } b &= 6.497 \text{ in} \\
f_1 &= -0.847 \quad b_1 = 1.689 \text{ in} \quad b_2 = 3.248 \text{ in} \quad b_1+b_2 = 4.937 \text{ in} > a_{comp} = 5.230 \text{ in} \quad \text{Assumption incorrect} \\
\text{Iteration needed to find effective portion of web}
\end{align*}
\]

<table>
<thead>
<tr>
<th>iter</th>
<th>( y_{cg} )</th>
<th>( f_i )</th>
<th>( k )</th>
<th>( la )</th>
<th>( b_1+b_2 )</th>
<th>diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.399</td>
<td>-0.847</td>
<td>20.304</td>
<td>1.219</td>
<td>4.937</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>5.460</td>
<td>-0.826</td>
<td>19.828</td>
<td>1.234</td>
<td>4.900</td>
<td>0.752</td>
</tr>
<tr>
<td>3</td>
<td>5.480</td>
<td>-0.819</td>
<td>19.678</td>
<td>1.238</td>
<td>4.888</td>
<td>0.242</td>
</tr>
<tr>
<td>4</td>
<td>5.487</td>
<td>-0.817</td>
<td>19.630</td>
<td>1.240</td>
<td>4.885</td>
<td>0.077</td>
</tr>
</tbody>
</table>

Difference is less then .1 percent, close enough

Computation of \( I_{xe} \) and \( S_{xe} \)

- Effective moment of inertia  \( I_{xe} = 17.545 \text{ in}^4 \)
- Effective section modulus  \( S_{xe} = 3.198 \text{ in}^3 \)
- Nominal moment capacity  \( M_n = 159.881 \text{ kip-in} \)
- Allowable moment capacity  \( M_a = 95.737 \text{ kip-in} \)
Computing shear capacity  (Section C 3.2 of Spec.)

\[ h/t = 128.833 > 1.38 \times (E \cdot k_{vFy})^{.5} = 77.460 \quad \text{case B} \]
Elastic buckling governs

Shear capacity  \[ V_a = 3.645 \text{ kips} \]

Computing axial strength

Determining \( F_n \)

Flexural buckling stress  \[ (Fe)_1 = 47.848 \text{ ksi} \]
\[ \sigma_{ex} = 482.782 \text{ ksi} \]
\[ \sigma_t = 42.164 \text{ ksi} \]

Tors.-flex. buckling stress  \[ (Fe)_2 = 41.202 \text{ ksi} \]
\[ Fe = 41.202 \text{ ksi} \]
\[ F_n = 34.831 \text{ ksi} \]

Effective width of edge stiffeners  Section B3.2 of Spec.

Buckling coefficient  \[ k = 0.430 \]
Slenderness ratio  \[ l_a = 0.405 \]
Reduction factor  \[ ro = 1.000 \]
Effective width  \[ b = 0.551 \text{ in} \]

Effective width of flanges  Section B4.2 of Spec.

\[ w/t = 42.167 > S = 37.251 \quad \text{case III} \]
Req'd moment of inertia of stiffener  \( I_a = 0.004277 \text{ in}^4 \)
Actual moment of inertia of stiffener  \( I_s = 0.001047 \text{ in}^4 \)
\[ D/w = 0.228 < 0.25 \]
Buckling coefficient  \[ k = 2.663 \]
Slenderness ratio  \[ l_a = 0.934 \]
Reduction factor  \[ ro = 0.819 \]
Effective width  \[ b = 2.588 \text{ in} \]
Reduced eff. width of stiffener  \( ds = 0.135 \text{ in} \)
\[ be = 2.588 \text{ in} < b = 3.162 \text{ in} \quad \text{Flanges are not fully effective} \]
\[ ds = 0.135 \text{ in} < d = 0.551 \text{ in} \quad \text{Stiffeners are not fully effective} \]

Effective width of web

Buckling coefficient  \[ k = 4.000 \]
Slenderness ratio  \[ l_a = 2.329 \]
Reduction factor  \[ ro = 0.389 \]
Effective width  \[ b = 3.758 \text{ in} \]
\[ ae = 3.758 \text{ in} < a = 9.663 \text{ in} \quad \text{Web is not fully effective} \]

Computing effective cross-sectional area and axial strengths

Effective cross-sectional area  \[ Ae = 0.752 \text{ in}^2 \]
Nominal axial strength  \[ P_n = 26.197 \text{ kip} \]
Allowable axial strength  \[ P_a = 13.645 \text{ kip} \]
CHAPTER III

PERFORMANCE SECTION TABLES FOR WALL STUDS AND JOISTS

3.1 Performance Section Properties And Capacities

This chapter of the study provides performance section properties for wall studs and floor/roof joists. Performance section descriptions consist of depth, type and relative strength indicators:

```
  x.x a yy
```

Relative strength indicator 00 to 17

Section type: Stud or Joist

Depth in inches except x.6 represents x 5/8 in.

Nine wall stud depths (2 1/2, 3 1/2, 3 5/8, 4, 5 1/2, 6, 7, 8, and 9 in.) and ten joist depths (2 1/2, 3 5/8, 4, 6, 7, 8, 9, 10, 12, and 14 in.) were selected with between eight and eighteen section sizes per depth. Three performance properties are listed for each section: allowable moment, allowable shear and minimum strong axis moment of inertia. Other performance properties were developed as design aids, these are found in Chapter IV and V, respectively. All properties and capacities correspond to values calculated using the AISI Specification for Cold-Formed Steel, August 19, 1986 (Allowable Stress Design).
3.2 Development Of Performance Sections

As a first step, a large number of manufacturers' catalogs were obtained and available sections were tabulated to make sure that the proposed tables encompass the current market. Over 410 different studs and 280 different joists were identified and the above stud and joist depths selected. The previously described analysis program was then used to calculate feasible values for the allowable moment, shear, and moment of inertia for each performance section. The base material was 33 ksi for wall studs and 50 ksi for joists, with thicknesses ranging from 22 to 6 gauge (Table 3.1). The flange and lip dimensions were selected to obtain fully or almost fully effective sections for flexure. Table 3.2 shows the results for 4 in. studs and for 3 5/8 in. joists. The horizontal line denotes the level below which the sections are fully effective. The lower yield stress studs are almost all fully effective for flexure, for joists this was not always possible to achieve. For axial compression, the studs are less effective than in flexure, because in that case the whole web is subjected to uniform compression. Plotting the computed values quickly reveals that these curves are not very smooth (Table 3.3 and 3.4 solid lines). The main reason for that is the uneven increments between the thicknesses (Table 3.1). To overcome this, the computed values were replaced by functions with gradually increasing increments. (dashed lines). Since shear capacity rarely controls the design, 80% of the original values were taken as the base of the approximation. Similarly the calculated values of the minimum moment of inertia were multiplied by a factor of 0.9. These modifications will result in more economical design.

Next the intervals were halved ensuring that an already existing section will not be very far from a proposed performance section.
### Table 3.1 Initial Performance Section Designations And Gauge Thicknesses

<table>
<thead>
<tr>
<th>Designation</th>
<th>Gauge</th>
<th>Thickness [in]</th>
<th>Difference [in]</th>
</tr>
</thead>
<tbody>
<tr>
<td>S01</td>
<td>22</td>
<td>0.0299</td>
<td></td>
</tr>
<tr>
<td>S02</td>
<td>20</td>
<td>0.0359</td>
<td>0.0060</td>
</tr>
<tr>
<td>S03</td>
<td>18</td>
<td>0.0478</td>
<td>0.0119</td>
</tr>
<tr>
<td>S04</td>
<td>16</td>
<td>0.0598</td>
<td>0.0120</td>
</tr>
<tr>
<td>S05</td>
<td>14</td>
<td>0.0747</td>
<td>0.0149</td>
</tr>
<tr>
<td>S06</td>
<td>12</td>
<td>0.1046</td>
<td>0.0299</td>
</tr>
<tr>
<td>S07</td>
<td>10</td>
<td>0.1345</td>
<td>0.0299</td>
</tr>
<tr>
<td>S08</td>
<td>8</td>
<td>0.1644</td>
<td>0.0299</td>
</tr>
<tr>
<td>S09</td>
<td>6</td>
<td>0.1943</td>
<td>0.0299</td>
</tr>
</tbody>
</table>

### Table 3.2 Section Properties For 4 in. Studs And 3 5/8 in Joists

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0S01</td>
<td>33</td>
<td>1.250</td>
<td>0.40</td>
<td>4.965</td>
<td>0.590</td>
<td>0.503</td>
<td>0.504</td>
<td>0.186</td>
<td>0.212</td>
<td>1.543</td>
<td>0.458</td>
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<tr>
<td>4.0S02</td>
<td>33</td>
<td>1.300</td>
<td>0.40</td>
<td>6.034</td>
<td>1.029</td>
<td>0.611</td>
<td>0.611</td>
<td>0.238</td>
<td>0.256</td>
<td>1.546</td>
<td>0.472</td>
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<td>4.0S03</td>
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<td>0.40</td>
<td>8.108</td>
<td>1.996</td>
<td>0.821</td>
<td>0.821</td>
<td>0.343</td>
<td>0.343</td>
<td>1.546</td>
<td>0.492</td>
</tr>
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<td>1.500</td>
<td>0.40</td>
<td>10.441</td>
<td>2.883</td>
<td>1.067</td>
<td>1.057</td>
<td>0.438</td>
<td>0.438</td>
<td>1.553</td>
<td>0.530</td>
</tr>
<tr>
<td>4.0S05</td>
<td>33</td>
<td>1.625</td>
<td>0.40</td>
<td>13.340</td>
<td>3.515</td>
<td>1.350</td>
<td>1.350</td>
<td>0.557</td>
<td>0.557</td>
<td>1.557</td>
<td>0.566</td>
</tr>
<tr>
<td>4.0S06</td>
<td>33</td>
<td>1.625</td>
<td>0.50</td>
<td>17.981</td>
<td>4.671</td>
<td>1.820</td>
<td>1.821</td>
<td>0.775</td>
<td>0.775</td>
<td>1.533</td>
<td>0.565</td>
</tr>
<tr>
<td>4.0S07</td>
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<td>1.625</td>
<td>0.60</td>
<td>22.157</td>
<td>5.685</td>
<td>2.243</td>
<td>2.246</td>
<td>0.989</td>
<td>0.989</td>
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<td>0.564</td>
</tr>
<tr>
<td>4.0S08</td>
<td>33</td>
<td>1.625</td>
<td>0.70</td>
<td>25.774</td>
<td>6.540</td>
<td>2.609</td>
<td>2.615</td>
<td>1.198</td>
<td>1.198</td>
<td>1.478</td>
<td>0.561</td>
</tr>
<tr>
<td>4.0S09</td>
<td>33</td>
<td>1.625</td>
<td>0.80</td>
<td>28.913</td>
<td>7.269</td>
<td>2.926</td>
<td>2.940</td>
<td>1.406</td>
<td>1.406</td>
<td>1.446</td>
<td>0.556</td>
</tr>
<tr>
<td>3.6J01</td>
<td>50</td>
<td>2.000</td>
<td>0.50</td>
<td>7.140</td>
<td>0.648</td>
<td>0.475</td>
<td>0.555</td>
<td>0.224</td>
<td>0.250</td>
<td>1.488</td>
<td>0.755</td>
</tr>
<tr>
<td>3.6J02</td>
<td>50</td>
<td>2.000</td>
<td>0.60</td>
<td>9.249</td>
<td>1.133</td>
<td>0.600</td>
<td>0.670</td>
<td>0.285</td>
<td>0.285</td>
<td>1.479</td>
<td>0.768</td>
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<td>3.6J03</td>
<td>50</td>
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<td>0.70</td>
<td>13.469</td>
<td>2.437</td>
<td>0.843</td>
<td>0.886</td>
<td>0.408</td>
<td>0.408</td>
<td>1.465</td>
<td>0.775</td>
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<td>2.000</td>
<td>0.80</td>
<td>17.884</td>
<td>3.814</td>
<td>1.089</td>
<td>1.097</td>
<td>0.522</td>
<td>0.522</td>
<td>1.450</td>
<td>0.781</td>
</tr>
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<td>50</td>
<td>2.300</td>
<td>0.80</td>
<td>24.258</td>
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## Table 3.3 Computing Performance Section Table For 4 in. Studs

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<th>Va</th>
<th>0.8*V</th>
<th>diff.</th>
<th>( \text{lx}_{\text{eff}} )</th>
<th>( 0.9*\text{lx} )</th>
<th>diff.</th>
<th>Ma</th>
<th>diff.</th>
<th>Va</th>
<th>diff.</th>
<th>( \text{min lx}_{\text{e}} )</th>
<th>diff.</th>
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<td></td>
<td>0.440</td>
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<td>0.61</td>
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</table>

\( dd = 0.52 \)  

---

### Graphs

**Ma [kip-inch]**

solid line: computed values  
dashed line: proposed values

**Va [kips]**

**min lx_{e} [in4]**

solid line: computed values  
dashed line: proposed values
Table 3.4  Computing Performance Section Table For 3 5/8 in. Joists

<table>
<thead>
<tr>
<th>Section</th>
<th>Exact values based on computation</th>
<th>Proposed values</th>
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<tr>
<td>3.6J07</td>
<td>42.02</td>
<td>7.55</td>
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</tbody>
</table>

\[dd = 1.45 \quad 0.200 \quad 0.080\]

\[\text{solid line: computed values}\]

\[\text{dashed line: proposed values}\]
Table 3.5 and 3.6 illustrates the final tables for the performance section properties of the above two examples, and Figure 3.1 and 3.2 shows how the sections of 12 suppliers meet the requirements. The horizontal lines indicate the proposed moment capacities, whereas the dots represent the moment capacities of the existing sections of various suppliers.
### Table 3.5 4 in. Wall Studs Performance Properties

<table>
<thead>
<tr>
<th>Section</th>
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<th>$Va$ [kips]</th>
<th>min $Ixe$ [in$^4$]</th>
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<tr>
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<td>1.33</td>
<td>0.73</td>
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<td>1.61</td>
<td>0.83</td>
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</table>

### Table 3.6 3 5/8 in. Joists Performance Properties

<table>
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<tr>
<th>Section</th>
<th>$Ma$ [k-in.]</th>
<th>$Va$ [kips]</th>
<th>min $Ixe$ [in$^4$]</th>
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<td>0.38</td>
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<td>0.93</td>
<td>0.53</td>
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<td>1.23</td>
<td>0.62</td>
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<td>0.97</td>
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<td>2.23</td>
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</table>
Figure 3.1 Comparison Of Performance Capacities With Available Sections For 4 in. Studs
Figure 3.2  Comparison Of Performance Capacities With Available Sections For 3 5/8 in. Joists
CHAPTER IV
DESIGN AIDS FOR WALL STUDS

4.1 Development Of Design Aids

To further assist designers the following aids were developed. If the performance section concept is implemented, suppliers of wall studs and joists will be required to meet or exceed both the performance properties capacities and the values given in the design aids.

4.2 Uniform Lateral Load Capacity Of Wall Studs

In curtain wall applications the members resist wind loads only. Table 4.1 is an example of the type of performance section load table that can be developed. The table shows the maximum uniformly distributed load a section can withstand over a certain span. The considered limit states were flexure, shear, and excessive deflection.

For a simply supported beam the moment at midspan is calculated from

\[ M = \frac{wl^2}{8} \]  \hspace{1cm} (4.1)

which gives

\[ w[plf] = \frac{8}{l[\text{ft}]} M_s[k-in] \frac{10^3}{12} \]  \hspace{1cm} (4.2)
where \( M_a \) is the moment capacity of the section from the performance capacities tables,

\( i \) is the clear span and,

\( w \) is the uniform lateral load capacity.

For deep sections with small material thickness, shear can be the controlling factor. From

\[ V = \frac{hw}{2}, \quad (4.3) \]

we get

\[ w[plf] = \frac{2V_e[kips]10^3}{fl[ft]}, \quad (4.4) \]

where \( V_a \) is the shear capacity of the section from the performance capacities tables.

The values computed from Equations 4.2 and 4.4 (labelled as total loads) are tabulated in the first column for each span length in Table 4.1. Shaded cells indicate that shear controls over flexure.

The deflection of a single span is

\[ \Delta = \frac{5}{384} \frac{wl^4}{EI}, \quad (4.5) \]

which for the two considered limits \( L/360 \) and \( L/240 \) gives

\[ w_{L/360}[plf] = \frac{l[ft]}{360} \frac{384 E[ksi](10^3)(12^2)}{5} \frac{\min I_{xy}[in^4]}{l[ft]^4} \frac{12^4}{}, \quad (4.6) \]

\[ w_{L/240}[plf] = \frac{l[ft]}{240} \frac{384 E[ksi](10^3)(12^2)}{5} \frac{\min I_{xy}[in^4]}{l[ft]^4} \frac{12^4}{}, \quad (4.7) \]

where \( E = 29500 \text{ ksi} \) is the modulus of elasticity for cold-formed steel, and \( \min I_{xy} \) is the minimum moment of inertia of the section from the performance capacities tables.
Table 4.1  Uniform Lateral Load Capacity Of Wall Studs in plf

<table>
<thead>
<tr>
<th>Height</th>
<th>8 ft.</th>
<th>10 ft.</th>
<th>12 ft.</th>
<th>14 ft.</th>
<th>16 ft.</th>
<th>18 ft.</th>
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<table>
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Shaded cells indicate that shear controls over flexure.
The total loads are based on strength, i.e. this is the maximum a member can carry without failure. If the loads from the deflection equation exceed the total loads then of course the total load is shown.

For deflection calculations a different I value should be used, which is the one corresponding to the stress level in the extreme fibers, if the section is subject to the allowable moment (Mₐ). This moment of inertia is between the full-section moment of inertia and the effective section moment of inertia.

\[ I_x \geq I_{x\text{eff}} \geq I_{xe} \]

For studs, however, as it was pointed out earlier, the sections are almost all fully effective, in which case the above three values are equal, i.e. using \( I_{xe} \) instead of \( I_{x\text{eff}} \) does not make any difference for most cases.

### 4.3 Axial Load Capacity With Specified Lateral Loads

Load bearing wall studs, especially in exterior walls, are subjected both to axial and lateral loads. Section C5 of the 1986 Cold-Formed Steel Specification deals with combined axial load and bending. Its provisions for single axis bending are the following:

\[
\frac{P}{P_a} + \frac{C_{mx}M_x}{\alpha_x M_{ax}} \leq 1.0 , \tag{4.8}
\]

\[
\frac{P}{P_{ao}} + \frac{M_x}{M_{ax}} \leq 1.0 \tag{4.9}
\]

When \( P/P_a \leq 0.15 \) then

\[
\frac{P}{P_a} + \frac{M_x}{M_{ax}} \leq 1.0 , \tag{4.10}
\]
where $P$ is the applied axial load,

$M_x$ is the applied moment,

$P_a$ is the allowable axial load,

$P_{ao}$ is the allowable axial load with $F_n = F_y$,

$M_{ax}$ is the allowable moment, lateral-torsional buckling taken into account,

$M_{axo}$ is the allowable moment excluding lateral-torsional buckling,

$1/\alpha_x = 1/[1 - (\Omega_c P / P_{cr})]$ magnification factor, \hspace{1cm} (4.11)

$\Omega_c$ factor of safety used for determining $P_{cr}$, now 1.92,

$P_{cr} = \frac{\pi^2 E \min I_{x,x}}{KL^2}$, \hspace{1cm} (4.12)

$KL$ is the buckling length, now height of the wall since $K=1$,

$C_{mx} = 1$ because the frame is assumed to be braced in the plane of loading, the members are subjected to transverse loading between their support, and the ends are unrestrained (pinned).

The tabulated values were computed with a modified version of the program described in Chapter II. Figure 4.1 illustrates the flowchart, and Appendix B contains the program listing. The equations and assumptions used are the following:

$$M_x[k-in] = \frac{KL[in]^2}{8} \frac{s[in]w[psf]}{(10^3)(12^2)} \hspace{1cm} (4.13)$$

where $w$ is the lateral load (i.e. wind load),

$s$ is the spacing of studs: 12, 16, and 24 in. on center respectively,

$P_a$ is computed with a modified version of subroutine COMPcompcap (see Chapter 2.2.5 and page 104 of Appendix B) assumed that:
-the sections are braced by the sheathing material therefore the flexural-torsional buckling mode is not considered,

-the studs are subjected to strong axis bending therefore \( r_y \) is replaced by \( r_x \) in the first equation of the subroutine.

\( P_{ao} \) is calculated the same way as \( P_a \) except that \( F_y \) is used instead of \( F_n \) (Eq. 4.20). Since \( F_y > F_n \) the corresponding effective area will be smaller and therefore \( P_{ao} < P_a \) (Table 4.2).

\( M_{ax} = M_{axo} = M_a \), since lateral-torsional buckling is prevented.

Expressing \( P \) from Equations 4.9 and 4.10 and substituting \( M_a \) for \( M_{ax} \) and \( M_{axo} \) gives the following:

\[
P_{max} = (1 - \frac{M_x}{M_a})P_{ao} \tag{4.14}
\]

\[
P_{max} = (1 - \frac{M_x}{M_a})P_a \tag{4.15}
\]

Since in Equation 4.8 \( \alpha_x \) is a function of \( P \) (Eq. 4.11) expressing \( P \) will result in a second order equation where the smaller root is \( P_{max} \):

\[
\frac{P}{P_a} + \frac{M_x}{(1 - \frac{1.92P}{P_{cr}})M_a} \leq 1.0 \tag{4.16}
\]

\[
-\frac{1.92M_{ax}}{P_{cr}}P^2 + (1 + \frac{1.92P}{P_{cr}})P + P_a(M_x - M_{ax}) = 0 \tag{4.17}
\]

Table 4.2 shows typical output from the program. These values are tabulated to a typical Axial Load Capacity With Specified Lateral Loads Table, Table 4.3.
Figure 4.1 Flow Chart Of The Program For Computing Axial Loads
### Table 4.2 Output Of The Program Computing The Axial Loads For 6 in. Studs

**lateral load : w = 25 psf**

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Table 4.3 Axial Load Capacity With Specified Lateral Load Of Wall Studs in kips

25 psf Lateral Load
4.4 Strong Axis Axial Load Capacity Charts

Interior bearing walls are generally not subject to lateral loads; they only carry the axial loads transmitted from the supported slab. In a wall assembly, the bracing and sheathing prevents weak axis (in the plane of the wall) or lateral torsional buckling, so that the only controlling mode is strong axis buckling.

Section C4 of the 1986 Cold-Formed Steel Specification contains the provisions for compression members. The allowable axial load is determined the following way:

$$ P_a = \frac{P_n}{\Omega_c} \quad (4.18) $$

where \( \Omega_c \) is the factor of safety, now 1.92,

$$ P_n = A_e F_n \quad (4.19) $$

\( A_e \) Effective area at the stress \( F_n \). This was computed for each section with the C-section analysis program.

$$ F_n = F_y \left(1 - \frac{F_y}{4 F_y}\right) \quad \text{if} \quad F_y > \frac{F_y}{2} \quad (4.20) $$

$$ F_y = \frac{\pi^2 E}{(KL/r_y)^2} \quad \text{since the section is not subject to torsional-flexural buckling (Section C4.1).} $$

Table 4.4 illustrates a portion of the table used for calculating the axial load capacities, and Figure 4.2 shows typical buckling curves for 6 inch studs.
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Computing Strong Axis Axial Load Capacities For 6 in. Studs

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Figure 4.2  Typical Strong Axis Axial Load Capacity Chart
4.5 Weak Axis And Torsional Axial Load Capacity Charts

If the sheathing material does not provide sufficient support, or the member is used as a single column, either weak axis or flexural-torsional buckling modes can control.

Determination of $P_a$, $P_n$ and $F_y$ is the same as previously described (Eq. 4.18 through 4.20), but the procedure to find $F_e$, in Section C4.2 of the 1986 Cold-Formed Steel Specification, is more complex and is as follows:

$$F_e = \min \left\{ \frac{\pi^2 E}{(KL/r_y)^2} \right\}$$

$$= \frac{1}{2\beta} \left[ (\delta_x + \delta_t) - \sqrt{(\delta_x + \delta_t)^2 - 4\beta \delta_x \delta_t} \right]$$

(4.21)

where $\beta$ is a cross sectional property, computed with the C-section analysis program for each section,

$$\delta_x = \frac{\pi^2 E}{(KL/r_y)^2},$$

(4.22)

$$\delta_t = \frac{1}{Ar_o^2} \left[ GJ + \frac{\pi^2 EC_w}{(KL)^2} \right].$$

(4.23)

See page 104 of Appendix A for more detailed explanation of variables. Table 4.5 illustrates a portion of the table used for calculating the axial capacities. As we can see the weak axis buckling mode ($F_{e1}$) controls over the torsional one ($F_{e2}$). Figure 4.3 shows typical buckling curves for 6 inch studs.
### Table 4.5  Computing Weak Axial And Torsional Load Capacities For 6 in. Wall Studs

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Figure 4.3  Typical Weak Axis-Torsional Axial Load Capacity Chart
CHAPTER V

DESIGN AIDS FOR JOISTS

5.1 Uniform Load Capacity Of Single Span Joists

Joists in slabs or roofs are subject to the uniformly distributed load of the floor or the live loads (snow etc.).

Typical design aid tables were developed the same way, using the same formulas as the Uniform Lateral Load Capacity of Wall Studs Tables described in Chapter 4.1.1. For the joists, however, because of the higher yield stress, only the sections with higher relative thicknesses are fully effective. In case of the thinner sections $I_{x_{def}}$ could be as much as 10-15% larger then $I_{xe}$, so for sections with a relative thickness of 00 to 07 $I_{x_{def}}$ is used in Equations 4.6 and 4.7, as opposed to the $I_{xe}$ values tabulated in the performance section tables. Table 5.1 shows the typical values for 3 5/8 and 10 in. joists.

5.2 Uniform Load Capacity Of Two Continuous Spans Joists

Another common way to use joists is to bridge two spans with one continuous member (Fig. 1.4b). The controlling limit state in this case is the combined moment and shear over the support.

$$M = \frac{wL^2}{8}, \quad V = \frac{5}{8}wl$$ (5.1)
Substituting into the interaction equation in Section C3.3 of the 1986 Cold-Formed Steel Specification gives

\[
\left( \frac{wl^2}{\frac{8}{M_a}} \right)^2 + \left( \frac{5wl}{8V_a} \right)^2 \leq 1.0 .
\] (5.2)

Expressing \( w \) results in

\[
w_{[plf]} = \frac{8(10^3)}{[ft]} \frac{1}{\left( \frac{[ft]}{M_a[k-in]} \right)^2 + \left( \frac{5}{V_a[k]} \right)^2},
\] (5.3)

where \( M_a, V_a, l, \) and \( w \) are as described in Chapter IV.

The uniform loads which produce deflections of 1/360 of the span are also shown unless that loading exceeds the total capacity. The L/240 values were always greater than the total load capacity therefore they were omitted. The deflection formula for double span is

\[
\Delta = \frac{1}{185} \frac{wl^4}{EI},
\] (5.4)

which for L/360 gives

\[
w_{L/360}[plf] = \frac{[ft]}{360} \frac{185E[ksi](10^3)(12^2) \min I_{xx}[in^4]}{[ft]^4\cdot 12^4},
\] (5.5)

where \( E \) and \( \min I_{xx} \) are as before, except that for the lighter sections, \( I_{xx} \) is used. The typical uniform load capacities of two continuous spans are shown in Table 5.2.

5.3 Moment-Shear Interaction Capacity Charts

The total load column of the previous tables are based the combined moment and shear capacity of the section. There might be a need to check this limit state at other locations of the member (e.g. fixed end of a cantilever or end of laps). In this case the
Table 5.1 Uniform Load Capacity of Single Span Joists in plf

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### Table 5.2 Uniform Load Capacity of Two Continuous Span Joists in plf

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provisions of Section C3.3 of the 1986 Cold-Formed Steel Specification should be applied:

\[
\left( \frac{M}{M_a} \right)^2 + \left( \frac{V}{V_a} \right)^2 \leq 1.0
\]

(5.6)

Figure 5.1 shows a typical interaction chart for 7 in. Joists.

5.4 Web Crippling Capacity Tables

For deep section with relatively small thicknesses web crippling can be a problem. Section C3.4 of the 1986 AISI Specification for Cold-Formed Steel gives equations for four different conditions as follows:

Condition 1: End Reaction, Opposing Loads Spaced > 1.5h

Condition 2: Interior Reaction, Opposing Loads Spaced > 1.5h

Condition 3: End Reaction, Opposing Loads Spaced < 1.5h

Condition 4: Interior Reaction, Opposing Loads Spaced < 1.5h

where h is the depth of the flat portion of the web.

Web crippling capacities are tabulated for a basic bearing length of 3.5 in. and for +/- 0.5 in. increment. The web crippling capacity for any length is then determined from

\[
P_a = (P_a)_{3.5} + \left( \frac{L_a - 3.5}{0.5} \right)(P_a)_{0.5}
\]

(5.7)

where

\( P_a \) web crippling capacity for bearing length \( L_a \), kips

\( (P_a)_{3.5} \) web crippling capacity for 3.5 in bearing length (from table), kips

\( (P_a)_{0.5} \) web crippling capacity for 0.5 in bearing length increment (from table), kips

\( L_a \) actual bearing length, in

Table 5.3 shows typical web crippling capacities for 7 and 10 in. joists.
Figure 5.1 Typical Moment-Shear Interaction Capacity Chart
<table>
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<th>3 3.5 in. +/- 0.5 in.</th>
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<td>7.0J05</td>
<td>0.56 0.034</td>
<td>1.03 0.050</td>
<td>0.37 0.023</td>
<td>0.78 0.010</td>
</tr>
<tr>
<td>7.0J06</td>
<td>0.71 0.040</td>
<td>1.30 0.057</td>
<td>0.48 0.027</td>
<td>1.07 0.012</td>
</tr>
<tr>
<td>7.0J07</td>
<td>0.86 0.045</td>
<td>1.57 0.065</td>
<td>0.59 0.031</td>
<td>1.37 0.014</td>
</tr>
<tr>
<td>7.0J08</td>
<td>1.08 0.053</td>
<td>1.98 0.075</td>
<td>0.75 0.036</td>
<td>1.84 0.016</td>
</tr>
<tr>
<td>7.0J09</td>
<td>1.31 0.060</td>
<td>2.40 0.085</td>
<td>0.91 0.042</td>
<td>2.32 0.019</td>
</tr>
<tr>
<td>7.0J10</td>
<td>1.89 0.074</td>
<td>3.47 0.104</td>
<td>1.34 0.052</td>
<td>3.63 0.024</td>
</tr>
<tr>
<td>7.0J11</td>
<td>2.47 0.089</td>
<td>4.55 0.123</td>
<td>1.76 0.063</td>
<td>4.94 0.029</td>
</tr>
<tr>
<td>7.0J12</td>
<td>3.23 0.103</td>
<td>5.96 0.143</td>
<td>2.31 0.074</td>
<td>6.73 0.035</td>
</tr>
<tr>
<td>7.0J13</td>
<td>3.98 0.117</td>
<td>7.36 0.162</td>
<td>2.86 0.084</td>
<td>8.52 0.040</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Condition Bearing Length</th>
<th>1 3.5 in. +/- 0.5 in.</th>
<th>2 3.5 in. +/- 0.5 in.</th>
<th>3 3.5 in. +/- 0.5 in.</th>
<th>4 3.5 in. +/- 0.5 in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.0J04</td>
<td>0.33 0.023</td>
<td>0.65 0.037</td>
<td>0.19 0.013</td>
<td>0.27 0.005</td>
</tr>
<tr>
<td>10.0J05</td>
<td>0.47 0.029</td>
<td>0.92 0.044</td>
<td>0.29 0.018</td>
<td>0.53 0.007</td>
</tr>
<tr>
<td>10.0J06</td>
<td>0.62 0.034</td>
<td>1.18 0.052</td>
<td>0.39 0.022</td>
<td>0.80 0.009</td>
</tr>
<tr>
<td>10.0J07</td>
<td>0.76 0.040</td>
<td>1.44 0.060</td>
<td>0.50 0.026</td>
<td>1.07 0.011</td>
</tr>
<tr>
<td>10.0J08</td>
<td>0.98 0.047</td>
<td>1.84 0.070</td>
<td>0.65 0.031</td>
<td>1.51 0.013</td>
</tr>
<tr>
<td>10.0J09</td>
<td>1.19 0.054</td>
<td>2.25 0.079</td>
<td>0.81 0.037</td>
<td>1.95 0.016</td>
</tr>
<tr>
<td>10.0J10</td>
<td>1.76 0.069</td>
<td>3.30 0.099</td>
<td>1.21 0.047</td>
<td>3.19 0.021</td>
</tr>
<tr>
<td>10.0J11</td>
<td>2.32 0.083</td>
<td>4.35 0.118</td>
<td>1.62 0.058</td>
<td>4.44 0.026</td>
</tr>
<tr>
<td>10.0J12</td>
<td>3.06 0.098</td>
<td>5.74 0.137</td>
<td>2.16 0.069</td>
<td>6.16 0.032</td>
</tr>
<tr>
<td>10.0J13</td>
<td>3.80 0.112</td>
<td>7.12 0.157</td>
<td>2.69 0.079</td>
<td>7.88 0.037</td>
</tr>
</tbody>
</table>
CHAPTER VI

SUMMARY AND APPLICATION

6.1 Summary

The wider use of cold-formed steel framing is hindered by the lack of generic sections. This study puts forth an effort to develop a performance section designation code without specifying the geometry of the sections. A PC-based program to analyze C-section was developed and used to produce typical Performance Section Tables for both wall studs and joists. For curtain walls the Uniform Lateral Load Capacity Tables and for bearing walls the Axial Load with Specified Lateral Load Tables, the Strong Axis Axial Load Capacity Charts, and the Weak Axis and Torsional Axial Load Capacity Charts were developed. The typical design aids for roof/floor joists include the Uniform Load Capacity Tables for single and two continuous spans, the Moment-Shear Interaction Capacity Charts, and the Web Crippling Capacity Tables.

6.2 Application

In this chapter design examples are provided for the better understanding of the concept and usage of this study.
6.2.1 Design Examples For Wall Studs

Design Example 1. Non-load Bearing Wall Stud with Continuous Lateral Support

1. Given

   Depth: 3 5/8 in.
   Height: 14 ft
   Spacing: 24 in. o.c.
   Load: 25 psf lateral
   Deflection: < L/240

2. Required

   Choose and check a section using the design aids.

3. Solution

   3.1 Assumption

   The wall studs are prevented from weak axis lateral and lateral-torsional buckling by sheathing.

   3.2 Maximum Moment and Shear

   \[ w = 25.0 \times 2 = 50 \text{ plf} \]
   \[ V_{\text{max}} = 0.35 \text{ kips} \]
   \[ M_{\text{max}} = 14.7 \text{ k-in} \]
3.3 Section Selection

From *Uniform Lateral Load Capacity of Wall Studs Table*, select 6.0S06. Total load capacity is 54.8 plf; L/240 deflection limit is 51.8 plf.

51.8 plf > 50.0 plf  OK

3.4 Check Shear Capacity

Since the total load column in the *Uniform Lateral Load Capacity of Wall Studs Table* already includes the shear capacity, choosing the section based on that table inherently satisfies this criterion.

4. Final Selection

Use 6.0S06 Stud

Design Example 2.  Load Bearing Wall Stud with Continuous Lateral Support

1. Given

Depth: 3 1/2 in.
Height: 14 ft
Spacing: 24 in. o.c.
Loadings: 25 psf  lateral
          2.0 kips  axial
Deflection: < L/360

2. Required

Choose and check a section using the design aids.
3. Solution

3.1 Assumptions

a. The wall studs are prevented from weak axis lateral and lateral-torsional buckling by sheathing.

b. The strong axis effective length factor is 1.0.

3.2 Maximum Moment and Shear

The same as for Example 1.

3.3 Section Selection

From *Axial Load Capacity with Specified Lateral Load of Wall Stud Tables* choose 6.0S09 (height = 14 ft, spacing = 24 in), $P_a = 2.3$ kips

$P_a = 2.3$ kips $> P = 2.0$ kips OK

3.4 Check Deflection

From *Uniform Lateral Load Capacity of Wall Studs Table*, the limiting uniform load for L/360 deflection is 50.7 plf

50.7 plf $> 2 \times 25 = 50$ plf OK

3.5 Check Shear Capacity

Since the *Uniform Lateral Load Capacity of Wall Studs Tables* were developed with the shear capacities taken into consideration, satisfying the previous check also means that the section is adequate for shear.

4. Final Selection

Use 6.0S09 Stud
Design Example 3. Load Bearing Wall Stud without Continuous Lateral Support

1. Given

   Depth: 6 in.
   Height: 12 ft
   Load: 5 kips axial
   Bracing Spacing: 4 ft (weak axis lateral and lateral-torsional)

2. Required

   Choose and check a section using the design aids.

3. Solution

   3.1 Assumptions

       The weak axis lateral and lateral-torsional effective length factors are 1.0.

   3.2 Section Selection

       From Weak Axis Axial Load Capacity Charts for Wall Studs choose
       6.0S06 (height = 4 ft) $P_a = 5.6$ kips.

       $P_a = 5.6$ kips $> P = 5.0$ kips OK

   3.3 Check Strong Axis Buckling

       From Strong Axis Axial Load Capacity Charts for Wall Studs, $P_a = 6.8$
       kips (height = 12 ft)

       $P_a = 6.8$ kips $> P = 5.0$ kips OK

4. Final Selection

   Use 6.0S06 Stud
6.2.2 Design Examples For Joists

Design Example 1. Single Span C-Joist

1. Given

Single span C-joist system
Span: 20 ft
Spacing: 24 in. o.c.
Loads: 15 psf dead
      50 psf live
Deflection: < L/240 for Live Load
Bearing Length: 6 in.

2. Required

Choose and check a C-Joist section using the design aids.

3. Solution

3.1 Assumptions

The sheathing provides continuous lateral support to the top flange.

3.2 Moment and Shear Diagrams

\[ w_D = 15 \times 2 = 30 \text{ plf} \]
\[ w_L = 50 \times 2 = 100 \text{ plf} \]
\[ w_T = 130 \text{ plf} \]
\[ V_{\text{max}} = 1.30 \text{ kips} \]
\[ M_{\text{max}} = 78.0 \text{ k-in} \]

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3.3 Section Selection

Using the Uniform Load Capacity of Single Span Joists Table, possible choices are

<table>
<thead>
<tr>
<th>Joist</th>
<th>Total Load Capacity, plf</th>
<th>L/240 Live Load Deflection, plf</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.0J13</td>
<td>190.8</td>
<td>100.8</td>
</tr>
<tr>
<td>8.0J12</td>
<td>175.0</td>
<td>101.6</td>
</tr>
<tr>
<td>9.0J10</td>
<td>174.6</td>
<td>117.0</td>
</tr>
<tr>
<td>10.0J08</td>
<td>138.3</td>
<td>105.7</td>
</tr>
<tr>
<td>12.0J08</td>
<td>170.8</td>
<td>165.0</td>
</tr>
<tr>
<td>14.0J08</td>
<td>155.0</td>
<td>155.0</td>
</tr>
</tbody>
</table>

Try 10.0J08

3.4 Check Shear Capacity

This criterion is automatically satisfied if the Uniform Load Capacity of Single Span Joists Tables are used for section selection.

3.5 Web Crippling Strength

From the Web Crippling Capacity of 10 in. Joists Table for Condition 1, the web crippling capacity is

\[ P_a = 0.98 + [(6-3.5)/0.5](0.047) = 1.10 \text{ kips} < 1.3 \text{ kips} \quad \text{NG} \]

Either a bearing stiffener could be used or the section increased to a 10.0J09, where

\[ P_a = 1.19 + [(6-3.5)/0.5](0.054) = 1.33 \text{ kips} > 1.3 \text{ kips} \quad \text{OK} \]

4. Final Selection

Use 10.0J08 with bearing stiffener at supports or 10.0J09 without bearing stiffener at supports.
Design Example 2. Two Span Continuous C-Joist

1. Given

   Two span C-joist system
   Spans: 2 x 16 ft
   Spacing: 24 in. o.c.
   Loads:
       10 psf  dead
       40 psf  live
   Deflection: < L/360 for Live Load
   Bearing Length: 6 in.

2. Required

   Choose and check a C-joist section using the design aids.

3. Solution

   3.1 Assumptions
       a. The joist is prismatic, e.g. laps are not used.
       b. The sheathing provides a continuous lateral support to the top flange.
       c. The compression (bottom) flange near the interior support is fully braced.

   3.2 Moment and Shear Diagrams

   ![Shear Diagram]

   \[ w_D = 10 \times 2 = 20 \text{ plf} \]
   \[ w_L = 40 \times 2 = 80 \text{ plf} \]
   \[ w_T = 100 \text{ plf} \]
3.3 Section Selection

Using the *Uniform Load Capacity of Two Continuous Span Joists Table*, possible choices are

<table>
<thead>
<tr>
<th>Joist</th>
<th>Total Load Capacity, plf</th>
<th>L/360 Live Load Deflection, plf</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.0J08</td>
<td>109.8</td>
<td>104.1</td>
</tr>
<tr>
<td>7.0J07</td>
<td>107.4</td>
<td>107.4</td>
</tr>
<tr>
<td>8.0J07</td>
<td>105.9</td>
<td>105.9</td>
</tr>
<tr>
<td>9.0J07</td>
<td>101.8</td>
<td>101.8</td>
</tr>
<tr>
<td>10.0J08</td>
<td>160.6</td>
<td>160.6</td>
</tr>
<tr>
<td>12.0J07</td>
<td>104.0</td>
<td>104.0</td>
</tr>
</tbody>
</table>

Try 7.0J07
3.4 Check Web Crippling Capacity

From the *Web Crippling Capacity of 7 in. Joists Table*:

At exterior support, Condition 1

\[ P_a = 0.86 + [(6.0-3.5)/0.5](0.045) = 1.09 \text{ kips} > 0.60 \text{ kips} \quad \text{OK} \]

At interior support, Condition 2

\[ P_a = 2(1.57 + [(6.0-3.5)/0.5](0.065)) = 3.79 \text{ kips} > 2.0 \text{ kips} \text{OK} \]

3.5 Check Combined Bending and Web Crippling Capacity

Using AISI Specification Equation 3.5.2-1:

\[ 1.2\left(\frac{P}{P_a}\right) + \left(\frac{M}{M_a}\right) \leq 1.5 \]

At the interior support with \( M_a = 46.10 \) k-in. from *7 in. Joist Performance Properties Table*:

\[ 1.2\left(\frac{2.0}{3.79}\right) + \left(\frac{38.40}{2 \times 46.1}\right) = 1.05 < 1.50 \quad \text{OK} \]

4. Final Selection

Use 7.0J07
Design Example 3. Two Span Lapped C-Joist Non-Prismatic Member

1. Given

Two span C-joist system using laps to create continuity.

- Spans: 2 x 16 ft with 1.0 ft lap each side of interior support.
- Spacing: 24 in. o.c.
- Loads: 10 psf dead
  40 psf live
- Bearing Length: 6 in.

2. Required

Choose and check a C-joist section using the design aids.

3. Solution

Increased stiffness within the lapped portion of each span is considered when determining design moments, shears and reactions.

3.1 Assumptions

- a. Full continuity is achieved through the laps.
- b. The continuous beam analysis to establish the shear and moment diagrams assumes continuous members in which the $I_x$ value within the lapped portions is the sum of the individual members.
- c. The capacity within the lap portion of each span is equal to the sum of the individual purlin capacities.
- d. The sheathing provides a continuous lateral support to the top flange.
- e. The compression (bottom) flange near the interior support is fully braced.
3.2 Moment and Shear Diagrams

Total load = 100 plf

1.0 ft 1.0 ft
16.0 ft 16.0 ft

V, kips

M, k-in.

3.3 Section Selection

The required moment capacity for each purlin is 30.05 k-in. (moment at start of lap). Using the Joist Performance Properties Tables, possible choices are

<table>
<thead>
<tr>
<th>Joist</th>
<th>( M_a ) k-in.</th>
<th>( V_a ) kips</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.0J06</td>
<td>30.20</td>
<td>1.90</td>
</tr>
<tr>
<td>7.0J05</td>
<td>30.50</td>
<td>0.90</td>
</tr>
<tr>
<td>8.0J05</td>
<td>36.00</td>
<td>0.90</td>
</tr>
<tr>
<td>9.0J05</td>
<td>40.00</td>
<td>0.85</td>
</tr>
</tbody>
</table>

Try 7.0J05
3.4 Check Shear Capacity

From the 7 in. Joist Performance Properties Table, \( V_a = 0.90 \) kips

At start of lap

\[ V_a = 0.90 \text{ kips} < V = 0.92 \text{ kips} \quad \text{NG} \]

Try 7.0 J06 \( V_a = 1.650 \) kips

\[ V_a = 1.650 \text{ kips} > V = 0.92 \text{ kips} \quad \text{OK} \]

At interior support

\[ V_a = 2 \times 1.650 = 3.30 \text{ kips} > V = 1.0 \text{ kips} \quad \text{OK} \]

3.5 Check Combined Moment and Shear Capacity

Using the Moment-Shear Inaction Capacities of 7 in. Joists Chart, at start of lap:

\[ M = 30.05 \text{ k-in.} \]
\[ V = 0.92 \text{ kips} \]

which plots below the interaction curve for the 7.0J06 section. \( \text{OK} \)

3.6 Check Web Crippling Capacity

From the Web Crippling Capacity of 7 in. Joists Table:

At exterior support, Condition 1

\[ P_a = 0.71 + [(6.0-3.5)/0.5](0.040) = 0.91 \text{ kips} > 0.583 \text{ kips} \quad \text{OK} \]

At interior support, Condition 2

\[ P_a = 2\{1.30 + [(6.0-3.5)/0.5](0.057)\} = 3.17 \text{ kips} > 2 \times 1.017 = 2.034 \text{ kips} \quad \text{OK} \]
3.7 Check Combined Bending and Web Crippling Capacity

Using AISI Specification Equation 3.5.2-1:

\[ 1.2 \left( \frac{P}{P_a} \right) + \left( \frac{M}{M_a} \right) \leq 1.5 \]

At the interior support with \( M_a = 38.30 \text{ k-in.} \) from 7 in. Joist Performance Properties Table:

\[ 1.2 \left( \frac{2.034}{3.17} \right) + \left( \frac{41.65}{2 \times 38.3} \right) = 1.31 < 1.50 \text{ OK} \]

4. Final Selection

Use 70J06
REFERENCES


3. *Steel Framing Systems*, Steel Benders Inc., April, 1992


5. *American Iron and Steel Institute Low-rise Residential Construction Details Index*, AISI

6. AISI (1986), *Cold-Formed Steel Design Manual*, American Iron and Steel Institute, Washington, DC

7. AISI (1991), *LRFD Cold-Formed Steel Design Manual*, American Iron and Steel Institute, Washington, DC


APPENDIX A

PROGRAM LISTING
DECLARE SUB DESCRIBE()
DECLARE SUB INPUTDATA (Fy!, aa!, bb!, cc!, rr!, tl, KL!, lip%)

DECLARE SUB COMPSecprop (Fy!, aa!, bb!, cc!, rr!, tl, KL!, lip%, grap%,
                   Area!, al!, bl!, cl, rl, ul!, xhl!, !, rxl!, ry!, rol!, beta!, Jstv!, Cw!, xwcl!)
DECLARE SUB COMPSflexcap (Fy!, aa!, bb!, cc!, rr!, tl, al!, bl!, cl, rl, ul,
                   lip%, xwcl!, grap%, bel, C11, C21, ds!)
DECLARE SUB COMPsheight (wl!, tl, kl, fl, grap%, lal, bl!)
DECLARE SUB COMPSflange (wl!, tl, fl, cc!, cl, dspl, grap%, bel!, C11, C21, ds!)
DECLARE SUB COMPsweb (Fy!, aa!, tl, al!, bl!, cl, rl, ul!, bel, ds!, sumLY!, lip%,
                   grap%, b1!, b2!, b3!, le!, ycg!, yu!, yl!, l%)
DECLARE SUB COMPshearcap (Fy!, a!, tl, grap%)
DECLARE SUB COMPscumpcap (Fy!, aa!, bb!, cc!, tl, KL!, Area!, al!, bl!, cl, rl, ul!,
                   xhl!, ry!, rol!, beta!, Jstv!, Cw!, bel!, C11, C21, ds!, gfl!, vcl!, hcl!, lip%, xwcl!, grap%)
DECLARE SUB PLOTSECT (aa!, bb!, cc!, rr!, tl, al!, bl!, cl, rl, lip%, gfl!, vcl!, hcl!, xwcl!)
DECLARE SUB SHOWSIZE (value$, bl!, x1!, y1!, x2!, y2!, po$)
DECLARE SUB SHOWSIZE2 (label$, ul!, x1!, y1!, x2!, y2!, po$)

DECLARE SUB CORRECT (a$)
DECLARE SUB presskey (x!, y!)

******************************************************************************
  *
  * Program for computing the flexural, shear and axial capacities
  * of cold-formed C-sections based on the Allowable Stress Design
  *
  * Version 1.0a
******************************************************************************

******************************************************************************
  *
  * INPUT VARIABLES:
  * Fy - yield strength of steel (ksi)
  * aa - depth of section (in)
  * bb - width of flange (in)
  * cc - length of lip (in)
  * rr - radius of corners (in)
  * t - thickness (in)
  * KL - effective length (ft)
  *
  * LOCAL VARIABLES:
  * grap% = 1 print graphics and result on screen
  * = 0 print results on paper
  * exitp% = 0
******************************************************************************

CALL DESCRIBE

grap% = 1
exitp% = 0
DO

IF grap% = 1 THEN
    CALL INPUTDATA(Fy, aa, bb, cc, rr, t, KL, lip%)
END IF

CALL COMPsectprop(Fy, aa, bb, cc, rr, t, KL, lip%, grap%,
    Area, a, b, c, r, u, xh, m, rx, ry, ro, beta, Jstv, Cw, xwcl)

CALL COMPflexcap(Fy, aa, bb, cc, rr, t, a, b, c, r, u, lip%, xwcl, grap%, be, C2, C1, ds)

IF grap% = 1 THEN
    CLS
    CALL PLOTSECT(aa, bb, cc, rr, t, a, b, c, r, lip%, gf, vc, hc, xwcl)
END IF

CALL COMPshearcap(Fy, a, t, grap%)

CALL COMPcompcap(Fy, aa, bb, cc, t, KL, Area, a, b, c, r, u,
    rx, ry, ro, beta, Jstv, Cw, be, C1, C2, ds, gf, vc, hc, lip%, xwcl, grap%)

SCREEN 0
CLS
LOCATE 10, 15
PRINT "Enter your choice:"
LOCATE 12, 20
PRINT "(1) Send output to printer"
LOCATE 14, 20
PRINT "(2) Compute another section"
LOCATE 16, 20
PRINT "(3) Exit program"

DO
    a$ = INKEY$
LOOP UNTIL a$ = "1" OR a$ = "2" OR a$ = "3"

LOCATE 10, 35
PRINT a$

SELECT CASE a$
    CASE "1"
        grap% = 0
    CASE "2"
        grap% = 1
    CASE "3"
        exitp% = 1
END SELECT

LOOP UNTIL exitp% = 1

END
SUB DESCRIBE

CLS
LOCATE 5
PRINT "***************************************************************************"
PRINT "*
PRINT "*    Program for analyzing cold-formed C-sections    *
PRINT "*
PRINT "*      Version 1.0a      *
PRINT "*
PRINT "*        by Zsolt V. NEMEDI *
PRINT "*
PRINT "***************************************************************************"
LOCATE 16, 31
PRINT "(1) Description"
PRINT TAB(31); "(2) Start analysis"

DO
    a$ = inkey$
LOOP UNTIL a$ = "1" OR a$ = "2"

IF a$ = "1" THEN

CLS
LOCATE 5

PRINT TAB(17); "The program computes the flexural, shear and axial"
PRINT TAB(17); "capacities of cold-formed C-sections (with or"
PRINT TAB(17); "without lips) based on the August 19, 1986 Edition"
PRINT TAB(17); "of the Allowable Stress Design Cold-Formed"
PRINT TAB(17); "Specification. It does not take the effect of"
PRINT TAB(17); "cold-forming into account."
PRINT TAB(22); "After inputing the yield strength (ksi), the"
PRINT TAB(17); "dimensions of the cross-section (in) and the"
PRINT TAB(17); "effective length (ft), it prints the computed"
PRINT TAB(17); "results on the screen. It also plots the cross-"
PRINT TAB(17); "section proportionally, marking the relevant data"
PRINT TAB(17); "with dimension lines. For bending and compression"
PRINT TAB(17); "the ineffective portions of the section are"
PRINT TAB(17); "shaded. The results can also be printed out on a"
PRINT TAB(17); "printer if requested."

CALL presskey(23, 29)
CLS

END IF

END SUB
SUB INPUTDATA (Fy, aa, bb, cc, rr, t, KL, lip%)

*****************************************************************************

* SUBROUTINE INPUTDATA

* This routine reads in the required data.

* OUTPUT VARIABLES:
  * Fy  - yield strength of steel (ksi)
  * aa  - depth of section (in)
  * bb  - width of flange (in)
  * cc  - length of lip (in)
  * rr  - inner radius of corners (in)
  * t   - thickness (in)
  * KL  - effective length (in)
  * lip% = 0 if there is no lip
        = 1 if there is a lip

* LOCAL VARIABLES:
  * a$

* For further information see p III-10 of AISI ASD COLD-FORMED
  STEEL DESIGN MANUAL.
  Capital letters are here double letters, i.e. aa corresponds to A.

*****************************************************************************

DO

CLS
LOCATE 2, 10
PRINT "Defining geometry and material properties"
PRINT TAB(10); "==================================
PRINT
PRINT

78
LOCATE 5, 10
PRINT "Select yield strength of section :"
PRINT
PRINT TAB(22); "(1) 50 ksi"
PRINT TAB(22); "(2) 33 ksi"
PRINT TAB(22); "(3) other"
PRINT
DO
  a$ = INKEY$
LOOP UNTIL a$ = "1" OR a$ = "2" OR a$ = "3"
END DO
LOCATE 5, 58
PRINT a$
SELECT CASE a$
  CASE "1"
    Fy = 50!
  CASE "2"
    Fy = 33!
  CASE "3"
    DO
      LOCATE 11, 10
      INPUT "Enter yield strength (ksi) "; Fy
      LOOP UNTIL Fy > 0!
    END DO
END SELECT

DO
  LOCATE 13, 10
  INPUT "Enter depth of section (in) "; aa
LOOP UNTIL aa > 0!
END DO

DO
  LOCATE 15, 10
  INPUT "Enter width of flange (in) "; bb
LOOP UNTIL bb > 0!
END DO
LOCATE 22, 10
PRINT "(Press enter if there is no lip)"
DO
   LOCATE 17, 10
   INPUT "Enter length of lip (in) "; cc
LOOP UNTIL cc >= 0!
LOCATE 22, 10
PRINT " "
IF cc = 0 THEN
   lip% = 0
ELSE
   lip% = 1
END IF
DO
   LOCATE 19, 10
   INPUT "Enter radius of corners (in) "; rr
LOOP UNTIL rr > 0!
DO
   LOCATE 21, 10
   INPUT "Enter thickness (in) "; t
LOOP UNTIL t > 0!
DO
   LOCATE 23, 10
   INPUT "Enter buckling length (ft) "; KL
LOOP UNTIL KL > 0!
KL = KL * 12!
LOCATE 25
CALL CORRECT(a$)

IF a$ = "y" OR a$ = "Y" THEN EXIT DO

LOOP WHILE a$ = "n" OR a$ = "N"

END SUB
SUB COMPssecprop (Fy, aa, bb, cc, rr, t, KL, lip%, grap%,
    Area, a, b, c, r, u, xh, m, rx, ry, ro, beta, Jstv, Cw, xwcl)

*SUBROUTINE COMPssecprop
*
* This routine computes the cross-sectional properties of the section,
* based on the Supplementary Information 1.2.2. Section of the Manual.
*
* INPUT VARIABLES:
*  Fy   - yield strength of steel (ksi)
*  aa   - A' depth of section (in)
*  bb   - B' width of flange (in)
*  cc   - C' length of lip (in)
*  rr   - R inner radius of corners (in)
*  t    - thickness (in)
*  lip% = 0 if there is no lip
*       = 1 if there is a lip
*  grap% = 1 print graphics and result on screen
*       = 0 print results on paper
*
* OUTPUT VARIABLES:
*  a    - cross-sectional area of the section (in2)
*  b    - flat portion of web (in)
*  c    - flat portion of flange (in)
*  r    - midplane radius of corners (in)
*  u    - length of arc of 90 degree corners (in)
*  xh   - distance between centroid and web centerline (in)
*  m    - distance between shear center and web centerline (in)
*  ro   -
*  beta
*  Jstv - St. Venant torsion constant (in4)
*  Cw   - warping constant (in6)
*  xwcl - x coordinate of the centerline of the web
*
* LOCAL VARIABLES:
*  I    - midplane length of the section (in)
*  Ix, Iy - moments of inertia about the main axes (in4)
*  Sx, Sy, Syl - section moduli (in3)
*  ah, bh, ch - section dimensions defiened on Fig.1.2.2-1
*  Cw1-Cw6 - helping variables for computing Cw
*
* gf   - (graphical) factor for defining window
* vc   - vertical centerline
* hc   - horizontal centerline (center of flanges)
* xwcl - coordinate of web center line
* xcgs, ycgs - coordinates of center of gravity
* xsc, ysc - coordinates of shear center

***********************************************************************
'--------computing inner sizes

\[
\begin{align*}
    r &= r + t / 2! \\
    a &= a - 2! * r - t \\
    b &= b - (r + t / 2!) - \text{lip} \% (r + t / 2!) \\
    c &= \text{lip} \% (c - r - t / 2!) \\
    u &= 1.57 * r
\end{align*}
\]

'--------computing area and moment of inertia

\[
\begin{align*}
    i &= a + 2! * b + 2! * u + \text{lip} \% (2! * c + 2! * u) \\
    \text{Area} &= i * t \\
    Ix1 &= a \times 3! / 24! + b - (a / 2! + r) \times 2! + u - (a / 2! + .637 \times r) \times 2! + .149 \times r \times 3! \\
    Ix2 &= \text{lip} \% (c \times 3! / 12! + c - (a - c) \times 2! / 4! + u - (a / 2! + .637 \times r) \times 2! + .149 \times r \times 3!) \\
    Ix &= 2! * t * (Ix1 + Ix2) \\
    Sx &= 2! * Ix / aa \\
    rX &= (Ix / Area) \times .5
\end{align*}
\]

'--------distances of centroid and shear center from web centerline

\[
\begin{align*}
    xh &= 2! * t * (b - (b / 2! + r) + u \times .363 \times r + \text{lip} \% (u \times (b + 1.637 \times r) + c \times (b + 2! \times r))) / \text{Area} \\
    ah &= a - t \\
    bh &= b - t / 2! - \text{lip} \% t / 2! \\
    ch &= \text{lip} \% (c - t / 2!) \\
    m &= bh \times t \times (6! \times ch \times ah \times 2! + 3! \times bh \times ah \times 2! - 8! \times ch \times 3!) / 12! / Ix \\
    Iy &= 2! * t * (b - (b / 2! + r) \times 2! + b \times 3! / 12! + .356 \times r \times 3! + \text{lip} \% (c \times (b + 2! \times r) \times 2! + u \times (b + 1.637 \times r) \times 2! + .149 \times r \times 3!)) - \text{Area} \times xh \times 2! \\
    Syr &= Iy / (bb - xh - t / 2!) \\
    Syl &= Iy / (xh + t / 2!) \\
    ry &= (Iy / \text{Area}) \times .5 \\
    ro &= (rx \times 2! + ry \times 2! + (xh + m) \times 2!) \times .5 \\
    beta &= 1! - ((xh + m) / ro) \times 2!
\end{align*}
\]
St. Venant's and warping constants

\[ Jstv = t^3 \cdot (a + 2! \cdot b + 2! \cdot u + \text{lip} \% \cdot (2! \cdot c + 2! \cdot u)) / 3 \]

IF \text{lip} \% = 1 THEN

\[ Cw1 = xh \cdot \text{Area} \cdot ah \cdot 2! \cdot (bh \cdot 2! / 3! + m \cdot 2! - m \cdot bh) / t \]
\[ Cw2 = \text{Area} \cdot (m \cdot 2! \cdot ah \cdot 3! + bh \cdot 2! \cdot ch \cdot 2! \cdot (2! \cdot ch + 3! \cdot ah)) / 3! / t \]
\[ Cw3 = -Ix \cdot m \cdot 2! \cdot (2! \cdot ah + 4! \cdot ch) / t \]
\[ Cw4 = m \cdot ch \cdot 2! \cdot (8! \cdot bh \cdot 2! \cdot ch + 2! \cdot m \cdot (2! \cdot ch \cdot (ch - ah) + bh \cdot (2! \cdot ch - 3! \cdot ah))) / 3! \]
\[ Cw5 = bh \cdot 2! \cdot ah \cdot 2! \cdot ((3! \cdot ch + bh) \cdot (4! \cdot ch + ah) - 6! \cdot ch \cdot 2! / 6! \]
\[ Cw6 = -m \cdot 2! \cdot ah \cdot 4! / 4! \]

ELSE

\[ Cw = t \cdot ah \cdot 2! \cdot bh \cdot 3! \cdot (3! \cdot bh + 2! \cdot ah) / 12! / (6! \cdot bh + ah) \]

END IF

graphical part

IF \text{grap} \% = 1 THEN

CALL PLOTSECT(aa, bb, cc, rr, t, a, b, c, t, \text{lip} \%, \text{gf}, \text{vc}, \text{hc}, \text{xwcl})

ploting cgs of the section

\[ xcgs = xwcl + xh \]
\[ ycgs = vc \]

LINE (xcgs - .015 * gf * aa, ycgs)-STEP(.03 * gf * aa, 0!)
LINE (xcgs, ycgs + .015 * gf * aa)-STEP(0!, .03 * gf * aa)
CIRCLE (xcgs, ycgs), .007 * gf * aa

ploting shear center

\[ xsc = xwcl - m \]
\[ ysc = ycgs \]

LINE (xsc - .015 * gf * aa, ysc)-STEP(.03 * gf * aa, 0!)
LINE (xsc, ysc + .015 * gf * aa)-STEP(0!, .03 * gf * aa)

labeling section with light cyan

COLOR 11
IF lip% = 1 THEN
    x1 = hc + bb / 2 ! + .025 * gf * aa
    y1 = vc + aa / 2!
    CALL SHOWSIZE2("C", gf * aa, x1, y1, x1, y1 - cc, "vb")
    x1 = hc + bb / 2 ! + .025 * gf * aa
    y1 = vc - aa / 2! + cc
    CALL SHOWSIZE2("c", gf * aa, x1, y1, x1, y1 - c, "vt")
END IF

x1 = hc + bb / 2! + .07 * gf * aa
y1 = vc + aa / 2!
CALL SHOWSIZE("A", gf * aa, x1, y1, x1, y1 - aa, "v")

x1 = xwcl - .04 * gf * aa
y1 = vc + a / 2!
CALL SHOWSIZE("a", gf * aa, x1, y1, x1, y1 - a, "v")

x1 = xwcl - t / 2!
    "labeling bb
y1 = vc + aa / 2 + .03 * gf * aa
CALL SHOWSIZE("B", gf * aa, x1, y1, x1 + bb, y1, "h")

x1 = hc - b / 2!
    "labeling b
y1 = vc - aa / 2 - .068 * gf * aa
CALL SHOWSIZE("b", gf * aa, x1, y1, x1 + b, y1, "h")

x1 = xwcl - m
    "labeling m
y1 = .43 * gf * aa
CALL SHOWSIZE("m", gf * aa, x1, y1, x1 + m, y1, "h")

x1 = xwcl
    "labeling xh
y1 = .43 * gf * aa
CALL SHOWSIZE2("xh", gf * aa, x1, y1, x1 + xh, y1, "hl")

'----------Printing section properties on screen

COLOR 7
l = 3
LOCATE l, 52
PRINT "Section Properties"
LOCATE l + 1, 52
PRINT "---------------------"

LOCATE l + 3, 52
PRINT "A=": USING "####"; aa; : PRINT " in ",
PRINT "a= ", USING "####"; a; : PRINT " in";

LOCATE l + 4, 52
PRINT "B=": USING "####"; bb; : PRINT " in ",
PRINT "b= ", USING "####"; b; : PRINT " in"
LOCATE 1 + 5, 52
PRINT "C="; USING "##.####"; cc; : PRINT " in ";
PRINT "c="; USING "##.####"; c; : PRINT " in"

LOCATE 1 + 6, 52
PRINT "R="; USING "##.###"; rr; : PRINT " in ";
PRINT "r="; USING "##.###"; r; : PRINT " in"

LOCATE 1 + 7, 52
PRINT "t="; USING "##.#"; t; : PRINT " in ";
PRINT "u="; USING "##.#"; u; : PRINT " in"

LOCATE 1 + 9, 52
PRINT "A="; USING "##.###"; Area; : PRINT " in2"

LOCATE 1 + 11, 52
PRINT "Ix="; USING "##.###"; Ix; : PRINT " in4 ";
PRINT "rx="; USING "##.###"; rx; : PRINT " in"

LOCATE 1 + 12, 52
PRINT "Sx="; USING "##.###"; Sx; : PRINT " in3"

LOCATE 1 + 14, 52
PRINT "Iy="; USING "##.###"; Iy; : PRINT " in4 ";
PRINT "ry="; USING "##.###"; ry; : PRINT " in"

LOCATE 1 + 15, 51
PRINT "Syr="; USING "##.###"; Syr; : PRINT " in3 ";
PRINT "Syl="; USING "##.###"; Syl; : PRINT " in3"

LOCATE 1 + 17, 52
PRINT "ro="; USING "##.###"; ro; : PRINT " in"

LOCATE 1 + 19, 52
PRINT "xh="; USING "##.###"; xh; : PRINT " in ";
PRINT "m="; USING "##.###"; m; : PRINT " in"

LOCATE 1 + 21, 52
PRINT "Cw="; USING "##.###"; Cw; : PRINT " in6"

LOCATE 1 + 22, 52
PRINT "J="; USING "##.####"; Jstv; : PRINT " in4"

CALL presskey(27, 52)

SCREEN 0
ELSE

LPRINT"**************************************************************************
LPRINT "*
LPRINT "* Program for computing the flexural, shear and axial capacity *
LPRINT "* of a C section based on the Allowable Stress Design *
LPRINT "*
LPRINT**************************************************************************
LPRINT LPRINT LPRINT
LPRINT TAB(5); "Material and Section Properties"
LPRINT TAB(5); "---------------------------------------------"
LPRINT LPRINT LPRINT
LPRINT TAB(10); "Yield strength of steel" Fy = "; USING "###.###"; Fy; : LPRINT " ksi"
LPRINT TAB(10); "Effective length" KL = "; USING "###.###"; KL / 12; : LPRINT " ft"
LPRINT TAB(10); "Depth of section" A' = "; USING "###.###"; aa; : LPRINT " in"
LPRINT TAB(10); "Width of section" B' = "; USING "###.###"; bb; : LPRINT " in"
LPRINT TAB(10); "Length of lip" C' = "; USING "###.###"; cc; : LPRINT " in"
LPRINT TAB(10); "Inner radius of corners" R = "; USING "###.###"; rr; : LPRINT " in"
LPRINT TAB(10); "Thickness" t = "; USING "###.###"; t; : LPRINT " in"
LPRINT TAB(10); "Flat portion of web" a = "; USING "###.###"; a; : LPRINT " in"
LPRINT TAB(10); "Flat portion of flanges" b = "; USING "###.###"; b; : LPRINT " in"
LPRINT TAB(10); "Flat portion of lips" c = "; USING "###.###"; c; : LPRINT " in"
LPRINT TAB(10); "Midplane radius of corners" r = "; USING "###.###"; r; : LPRINT " in"
LPRINT TAB(10); "Length of arc" u = "; USING "###.###"; u; : LPRINT " in"
LPRINT TAB(10); "Area of cross section" A = "; USING "###.###"; Area; : LPRINT " in2"
LPRINT TAB(10); "Moment of inertia about x" Ix = "; USING "###.###"; Ix; : LPRINT " in4"
LPRINT TAB(10); "Moment of inertia about y" Iy = "; USING "###.###"; Iy; : LPRINT " in4"
LPRINT TAB(10); "Radius of gyration about x" rx = "; USING "###.###"; rx; : LPRINT " in"
LPRINT TAB(10); "Radius of gyration about y" ry = "; USING "###.###"; ry; : LPRINT " in"
LPRINT TAB(10); "Polar radius of gyration" ro = "; USING "###.###"; ro; : LPRINT " in"
LPRINT TAB(10); "Section modulus about x" Sx = "; USING "###.###"; Sx; : LPRINT " in3"
LPRINT TAB(10); "Section mod. about y (right)" Sy = "; USING "###.###"; Sy; : LPRINT " in3"
LPRINT TAB(10); "Section mod. about x (left)" Sy = "; USING "###.###"; Sy; : LPRINT " in3"
LPRINT TAB(10); "Dist. bw cent. and web centerline" xh = "; USING "###.###"; xh; : LPRINT " in"
LPRINT TAB(10); "Dist. bw shear cent. and web cl." m = "; USING "###.###"; m; : LPRINT " in"
LPRINT TAB(10); "Warping constant" Cw = "; USING "###.###"; Cw; : LPRINT " in6"
LPRINT TAB(10); "St. Venant constant" J = "; USING "#####.####"; Jstv; : LPRINT " in4"
LPRINT CHRS(12) 'end of page
END IF
END SUB
SUB COMPflexcap (Fy, aa, bb, cc, rr, t, a, b, c, r, u, lip%, xwcl, grap%, be, C1, C2, ds)

This routine computes the flexural capacity of the section

**INPUT VARIABLES:**
- Fy - yield strength of steel (ksi)
- aa - depth of section (in)
- bb - width of flange (in)
- cc - length of lip (in)
- rr - inner radius of corners (in)
- t - thickness (in)
- a - flat portion of web (in)
- b - flat portion of flange (in)
- c - flat portion of lip (in)
- r - midplane radius of corners (in)
- u - length of arc of 90 degree corners (in)
- lip% = 0 if there is no lip
  = 1 if there is a lip
- xwcl - x coordinate of the centerline of the web
- grap% = 1 print graphics and result on screen
  = 0 print results on paper

**OUTPUT VARIABLES:**
- be - effective width of flange
- C1, C2 - coefficients of effective portions of flange
- ds - reduced effective width of stiffener

**LOCAL VARIABLES:**
- E - modulus of elasticity
- dsp - effective width of stiffener
- gf - (graphical) factor for defining window
- vc - vertical centerline
- hc - horizontal centerline (center of flanges)
- x1, y1 - coordinates of dimension lines
- lpix - linear effective moment of inertia (in3)
- lxe - effective moment of inertia (in4)
- Sxet - effective section modulus (top) (in3)
- Sxeb - effective section modulus (bottom) (in3)
- Sxe - smallest effective section modulus (in3)
- Mn - nominal moment capacity (kip-in)

IF grap% = 1 THEN

SCREEN 12
CLS
CALL PLOTSECT(aa, bb, cc, rr, t, a, b, c, r, lip%, gf, vc, hc, xwcl)
COLOR 7
LOCATE 1, 52
PRINT "Computing flexural strength"
LOCATE 2, 52
PRINT "="

ELSE
    LPRINT TAB(5); "Computing flexural strength"
    LPRINT TAB(5); "="
    LPRINT
    LPRINT
    IF lip% = 1 THEN
        LPRINT TAB(10); "Effective width of edge stiffener  Section B3.2 of Spec."
        LPRINT
    END IF
END IF

E = 29500

'----------------------------------
'Computing the flange and the lip
'----------------------------------

IF lip% = 1 THEN
    'Effective width of lip (stiffener)
    'Unstiffened Element with Stress Gradient:
    'Sect. B3.2 of Spec.
    CALL COMPeffwidth(c, t, .43, Fy, grap%, la, dsp)  'dsp: ds prime: effective width of stiffener

    'Effective width of compression flange
    'Uniformly Compressed Element with Edge Stiffener:
    'Sect. B4.2 of Spec.

    IF grap% = 0 THEN
        LPRINT
        LPRINT
        LPRINT TAB(10); "Effective width of compression flange  Section B4.2 of Spec."
        LPRINT
    END IF

    CALL COMPflange(b, t, Fy, cc, c, dsp, grap%, be, C1, C2, ds)
ELSE

    'Uniformly Compressed Unstiffened Element:
    'Sect. B3.1 of Spec.

    IF grap% = 0 THEN
        LPRINT
        LPRINT
        LPRINT TAB(10); "Effective width of compression flange  Section B3.1 of Spec."
        LPRINT
    END IF

    CALL COMPeffwidth(b, t, .43, Fy, grap%, la, be)
END IF
'-------writing message about effectiveness of comp.flange -------

IF be < b THEN

    IF grap% = 1 THEN
        LOCATE 4, 52
        PRINT "Comp. flange isn't fully eff."
        LOCATE 5, 52
        PRINT "be=", USING "##.##"; be; : PRINT " in < ";
        PRINT "b=", USING "##.##"; b; : PRINT " in"

    '--------showing uneffective portion of flange-------

    COLOR 10

    IF lip% = 1 THEN
        LINE (hc + b / 2! - C2 * be / 2!, vc + aa / 2!)-STEP(0, -t)
        LINE (hc - b / 2! + C1 * be / 2!, vc + aa / 2!)-STEP(0, -t)
        PAINT (hc + b / 2! - C2 * be / 2! - (b - be) / 2!, vc + aa / 2! - t / 2!)

        COLOR 11
        x1 = hc - b / 2! + C1 * be / 2!  'labeling b-be
        y1 = vc + aa / 2 + .03 * gf * aa
        CALL SHOWSIZE2("b-be", gf * aa, x1, y1, x1 + (b - be), y1, "hl")

    ELSE
        LINE (hc + b / 2!, vc + aa / 2!)-STEP(0, -t)
        LINE (hc + b / 2! - (b - be), vc + aa / 2!)-STEP(0, -t)
        PAINT (hc + b / 2! - (b - be) / 2!, vc + aa / 2! - t / 2!)

        COLOR 11
        x1 = hc - b / 2!  'labeling be
        y1 = vc + aa / 2 + .03 * gf * aa
        CALL SHOWSIZE("be", gf * aa, x1, y1, x1 + be, y1, "h")

    END IF

    ELSE
        LPRINT TAB(15); "be=", USING "##.##"; be; : LPRINT " in < b ="; USING "##.##"; b;
        LPRINT " in Comp. flange is not fully eff."

    END IF

ELSE

    IF grap% = 1 THEN
        LOCATE 4, 52
        PRINT "Comp. flange is fully eff."
        LOCATE 5, 52
        PRINT TAB(52); "be = b =", USING "##.##"; b; : PRINT " in"

    ELSE
        LPRINT TAB(15); "be = b ="; USING "##.##"; b;
        LPRINT " in Comp. flange is fully effective"

    END IF

END IF

END IF
IF grap% = 1 THEN
   COLOR 11
   x1 = hc - b / 2!                   'labeling b
   y1 = vc - aa / 2 - .068 * gf * aa
   CALL SHOWSIZE("b", gf * aa, x1, y1, x1 + b, y1, "h")
END IF

IF lip% = 1 THEN

'----------writing message about effectiveness of comp lip on screen-----

IF ds < c THEN

   IF grap% = 1 THEN
      COLOR 7
      LOCATE 7, 52
      PRINT "Comp. lip isn't fully eff."
      LOCATE 8, 52
      PRINT "ds="; USING "###.###"; ds; : PRINT " in < ";
      PRINT "d="; USING "##.##"; c; : PRINT " in"

      '---------showing uneffective portions of lip------
      COLOR 10
      LINE (hc + bb / 2!, vc + a / 2! - ds)-STEP(-t, 0)
      PAINT (hc + bb / 2! - t / 2!, vc + a / 2! - ds - (c - ds) / 2!)

      COLOR 11
      x1 = hc + bb / 2! + .023 * gf * aa                   'labeling ds
      y1 = vc + a / 2!
      CALL SHOWSIZE2("ds", gf * aa, x1, y1, x1, y1 - ds, "vb")
   ELSE
      LPRINT TAB(15); "ds="; USING "###.###"; ds; : LPRINT " in < d =";
      USING "##.##"; c;
      LPRINT " in Comp. stiffeaer is not fully eff." 
   END IF

ELSE

   IF grap% = 1 THEN
      COLOR 7
      LOCATE 7, 52
      PRINT "Comp. lip is fully eff."
      LOCATE 8, 52
      PRINT "ds = d ="; USING "###.###"; c; : PRINT " in"
   ELSE
      LPRINT TAB(15); "ds = d ="; USING "###.###"; c;
      LPRINT " in Comp. stiffeaer is fully effective*
   END IF

END IF

END IF
IF grap% = 1 THEN
COLOR 11
x1 = hc + bb / 2! + .08 * gf * aa
  labeling d on upper lip
y1 = vc + a / 2!
CALL SHOWSIZE2("d", gf* aa, x1, y1, x1, y1 - c, "vb")
END IF

END IF

'-------------------------------
Computing the location of neutral axis and effectiveness of web

'-------------------distances from top fiber
y1 = (1! - .637) * r + t / 2!  'top corners
y2 = t / 2!  'top flange
y3 = aa - t / 2!  'bottom flange
y4 = aa - (1! - .637) * r - t / 2!  'bottom corners
y5 = t / 2! + r + ds / 2!  'top lip
y6 = aa - t / 2! - r - c / 2!  'bottom lip

'---------------summa Ly
Ly1 = u * y1 + lip% * (u * y1)
Ly2 = be * y2
Ly3 = b * y3
Ly4 = u * y4 + lip% * (u * y4)
Ly5 = lip% * (ds * y5)
Ly6 = lip% * (c * y6)
sumLy = Ly1 + Ly2 + Ly3 + Ly4 + Ly5 + Ly6

'-----------------Computing ycg and effective width of web

IF grap% = 0 THEN
  LPRINT
  LPRINT
  LPRINT TAB(10); "Computing the location of neutral axis and effective width of web"
  LPRINT
END IF

CALL COMPweb(Fy, aa, t, a, b, c, r, u, be, ds, sumLy, lip%, grap%, b1, b2, b3, le, ycg, y7, y8, 1%)

IF grap% = 1 THEN

'----dashline for ycg and labeling ycg

  length = 1.4 * bb  'length of the whole line
  lengthdash = length / 20!  'length of one segment
  COLOR 10

  FOR j% = 0 TO 19 STEP 2
    LINE (hc - .7 * bb + j% * lengthdash, vc + aa / 2! - ycg)-STEP(lengthdash, 0)
  NEXT j%
COLOR 11
xx1 = hc - bb / 2! - .07 * gf * aa
yy1 = vc + aa / 2!
CALL SHOWSIZE("ycg", gf * aa, xx1, yy1, xx1, yy1 - ycg, "v")

'----------showing uneffective portion of web, labelling b1 and b2-------
IF I% <> 1 THEN

COLOR 10
yy4 = vc + a / 2! - b1
yy5 = vc + aa / 2! - ycg + b2
LINE (xwcl - t / 2!, yy4)-STEP(t, 0)
LINE (xwcl - t / 2!, yy5)-STEP(t, 0)
PAINT (xwcl, (yy4 + yy5) / 2!)

COLOR 11
xx2 = xwcl - t / 2! + .04 * gf * aa
yy2 = vc + a / 2!
CALL SHOWSIZE("b1", gf * aa, xx2, yy2, xx2, yy2 - b1, "v")

xx3 = xwcl - t / 2! + .04 * gf * aa
yy3 = vc + aa / 2! - ycg + b2
CALL SHOWSIZE("b2", gf * aa, xx3, yy3, xx3, yy3 - b2, "v")

END IF
END IF

'----------calculation of Ixe and Sxe

I1p = lip% * (ds ^ 3! / 12!)
I6p = lip% * (c ^ 3! / 12!)

sumLy2 = u * y1 ^ 2! + be * y2 ^ 2! + b * y3 ^ 2! + u * y4 ^ 2! +
        lip% * (u * y1 ^ 2! + u * y4 ^ 2! + ds * y5 ^ 2! + c * y6 ^ 2!)

IF I% = 1 THEN
   I7p = 0!
   I8p = a ^ 3! / 12!
   sumLy2 = sumLy2 + a * y8 ^ 2
ELSE
   'the web is not fully eff.
   I7p = b1 ^ 3! / 12!
   I8p = b3 ^ 3! / 12!
   sumLy2 = sumLy2 + b1 * y7 ^ 2! + b3 * y8 ^ 2!
END IF

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\[ \text{sunlp} = 11p + 16p + 17p + 18p \]
\[ \text{lpxe} = \text{sumLy2} - 1e \times ycg \times 2l + \text{sumlp} \]
\[ \text{lxe} = \text{lpxe} \times t \]
\[ \text{Sxet} = \text{lxe} / \text{ycg} \]
\[ \text{Sxeb} = \text{lxe} / (a - \text{ycg}) \]

\[ \text{Sxe} = \text{Sxet} \]
\[ \text{IF} \ Sxe > \text{Sxeb} \text{ THEN } \text{Sxe} = \text{Sxeb} \]

\[ \text{Mn} = \text{Sxe} \times Fy \]

'---------printing results on the screen---------'

\[ \text{IF} \ \text{grap\%} = 1 \text{ THEN} \]

\[ \text{COLOR 7} \]
\[ \text{LOCATE 18 + 1\%, 52} \]
\[ \text{PRINT } "\text{lxe} = \text{\%4.4f}; \text{ lxe}; \text{ PRINT } " \text{ in4 Sxe} = \text{\%4.4f}; \text{ PRINT } " \text{ in3}" \]

\[ \text{LOCATE 20 + 1\%, 52} \]
\[ \text{PRINT } "\text{Mn} = \text{\%4.4f}; \text{ Mn}; \text{ PRINT } " \text{ in-kips}" \]

\[ \text{LOCATE 21 + 1\%, 52} \]
\[ \text{PRINT } "\text{Ma} = \text{\%4.4f}; \text{ Mn} / 1.67; \text{ PRINT } " \text{ in-kips}" \]

\[ \text{CALL presskey(28, 52)} \]

\[ \text{ELSE} \]
\[ \text{LPRINT} \]
\[ \text{LPRINT} \]
\[ \text{LPRINT TAB(10); "Computation of lxe and Sxe"} \]
\[ \text{LPRINT} \]
\[ \text{LPRINT TAB(15); "Effective moment of inertia}\]
\[ \text{lxe} = \text{\%4.4f}; \text{ lxe}; \text{ LPRINT } " \text{ in4}" \]
\[ \text{LPRINT TAB(15); "Effective section modulus}\]
\[ \text{Sxe} = \text{\%4.4f}; \text{ Sxe}; \text{ LPRINT } " \text{ in3}" \]
\[ \text{LPRINT TAB(15); "Nominal moment capacity}\]
\[ \text{Mn} = \text{\%4.4f}; \text{ Mn}; \text{ LPRINT } " \text{ kip-in}" \]
\[ \text{LPRINT TAB(15); "Allowable moment capacity}\]
\[ \text{Ma} = \text{\%4.4f}; \text{ Mn} / 1.67; \text{ LPRINT } " \text{ kip-in}" \]
\[ \text{LPRINT CHR$\%(12)} \]

\[ \text{END IF} \]

\[ \text{END SUB} \]
SUB COMPeffwidth (w, t, k, f, grap%, la, b)

*******************************************************************************

** Subroutine COMPeffwidth **

** This routine computes the effective width of an **
** element, based on section B2.1 of the Spec. **

** INPUT VARIABLES: **
** w - flat width of element **
** t - thickness of element **
** k - plate buckling coefficient **
** f - specified stress in element **
** grap% = 1 print graphics and result on screen **
** = 0 print results on paper **

** OUTPUT VARIABLE: **
** la - slenderness factor **
** b - effective width of element **

** LOCAL VARIABLES: **
** ro - reduction factor **

*******************************************************************************

la = 1.052 / k ^ .5 * w / t * (f / 295001) ^ .5

IF la <= .673 THEN 'no reduction
    ro = 1!
ELSE 'reduction
    ro = (1 - .22 / la) / la
END IF

b = ro * w

IF grap% = 0 THEN
    LPRINT TAB(15); "Buckling coefficient" k = ": USING "###.###"; k
    LPRINT TAB(15); "Slenderness ratio" la = ": USING "###.###"; la
    LPRINT TAB(15); "Reduction factor" ro = ": USING "###.###"; ro
    LPRINT TAB(15); "Effective width" b = ": USING "###.###"; b; : LPRINT " in"
END IF

END SUB
SUB COMPflange (w, t, f, dd, d, dsp, grap%, be, C1, C2, ds)

This routine computes the effective width of a uniformly compressed
stiffened element, based on sect. B4.2.

INPUT VARIABLES:
- w - flat width of element
- t - thickness of element
- f - specified stress in element
- dd - D length of stiffener including bend (see Fig. B4-2)
- d - width of the flat portion of stiffener (lip)
- dsp - effective width of stiffener
- grap% = 1 print graphics and result on screen
- = 0 print results on paper

OUTPUT VARIABLES:
- be - effective width of element (compression flange)
- C1, C2 - coefficients of effective portions of flange
- ds - reduced effective width of stiffener (lip)

LOCAL VARIABLES:
- E - modulus of elasticity (kip)
- S - quantity defined in sect. B4 of Spec.
- Ia - adequate moment of inertia of stiffener
- n - power for calculating k
- Iss - Is moment of inertia of stiffener
- k - plate buckling coefficient

E = 29500
S = 1.28 * (E / f) ^ .5

SELECT CASE w / t
CASE IS <= S / 3!               'Case I

    be = w
    ds = dsp

IF grap% = 0 THEN
    LPRINT TAB(15); "w/t = "; USING "###.###"; w / t;
    LPRINT " < S/3 ="; USING "###.###"; S / 3!;
    LPRINT " case I"
    LPRINT TAB(15); "Effective width of element b="; be; " in" END IF
CASE IS > S / 3!

'Case II and III (same procedure applies
'only Ia and n are different)

IF w / t < S THEN

'Calculating Ia and n for Case II

Ia = 399! * (w / t / S - .33) ^ 3! * t ^ 4!
n = .5

IF grap% = 0 THEN
LPRINT TAB(15); "S/3 = "; USING "##,###", S / 3;
LPRINT "< w/t = "; USING "##,###", w / t!;
LPRINT "< S = "; USING "##,###", S;
LPRINT " case II"
END IF

ELSE

'Calculating Ia and n for Case III

Ia = (115! * w / t / S + 5!) * t ^ 4
n = 1! / 3!

IF grap% = 0 THEN
LPRINT TAB(15); "w/t = "; USING "##,###", w / t!;
LPRINT " > S = "; USING "##,###", S;
LPRINT " case III"
END IF

END IF

Iss = d ^ 3 * t / 12!
C2 = Iss / Ia
IF C2 > 1! THEN C2 = 1!
C1 = 2! - C2

IF grap% = 0 THEN
LPRINT TAB(15); "Req'd moment of inertia of stiffener Ia = ";
USING "##,#####", Ia; : LPRINT " in4"
LPRINT TAB(15); "Actual moment of inertia of stiffener Iss = ";
USING "##,#####", Iss; : LPRINT " in4"
END IF
SELECT CASE dd / w

CASE IS <= .25
    k = 3.57 * (Iss / Ia) ^ n + .43
    IF k > 4! THEN k = 4!
    IF grap% = 0 THEN
        LPRINT TAB(15); "D/w = "; USING "###.###"; dd / w; :
        LPRINT " < 0.25"
    END IF

CASE IS > .8
    PRINT "no provisions of the Spec. applies to D/w > .8 ratios"
    END

CASE ELSE
    k = (4.82 - 5 * dd / w) * (Iss / Ia) ^ n + .43
    IF k > 5.25 - 5 * dd / w THEN k = 5.25 - 5 * dd / w
    IF grap% = 0 THEN
        LPRINT TAB(15); "0.8 > D/w = "; USING "###.###"; dd / w; :
        LPRINT " > 0.25"
    END IF

END SELECT

CALL COMPeefwidth(w, t, k, f, grap%, la, be) be: effective width of flange

ds = dsp * (Iss / Ia) 'reduced effective width of lip
IF ds > dsp THEN ds = dsp

IF grap% = 0 THEN LPRINT TAB(15); "Reduced eff. width of stiffener ds = ";
    USING "###.###"; ds; : LPRINT " in"

END SELECT

END SUB
SUB COMPweb (Fy, aa, t, a, b, c, r, u, be, ds, sumLy, lip%, grap%, b1, b2, b3, le, ycg, yu, yl, l%)

* This routine computes the location of neutral axis (ycg) and
* the effective portions of the web, based on Sect. B2.3

* INPUT VARIABLES:
* Fy - yield strength of steel (ksi)
* aa - depth of section (in)
* t - thickness (in)
* a - flat portion of web (in)
* b - flat portion of flange (in)
* c - flat portion of lip (in)
* r - midplane radius of corners (in)
* u - length of arc of 90 degree corners (in)
* be - effective width of flange (in)
* ds - reduced effective width of stiffener (in)
* sumLy - summation of the L*y terms of the other elements then web
* lip% = 0 if there is no lip
* = 1 if there is a lip
* grap% = 1 print graphics and result on screen
* = 0 print results on paper

* OUTPUT VARIABLES: (Fig. B2.3-1)
* b1 - upper effective portion of web
* b2 - lower effective portion of web (until ycg)
* b3 - total lower effective portion of web (b3 = b2 + aten)
* le - effective length of the section
* ycg - location of neutral axis
* yu - distance of the upper effective portion (b1) from top
* extreme fiber
* yl - same for the lower effective portion (b3)
* l% - loop counter (used in the LOCATE statements)

* LOCAL VARIABLES:
* ssumLy - summation of the L*y terms for all elements
* b12prev - variable for storing the value of b1+b2 for the next iteration (so that we can compare them)
* acomp - compression part of the web
* f1 - stress at upper end of the flat portion of the web
* aten - tension part of the web
* f2 - stress at lower end of the flat portion of the web
* fi = f2 / f1 coefficient for computing k
* k - plate buckling coefficient
* ae - effective width of web
* diff - difference between the last two b1+b2 values

******************************************************************************
I% = 0

DO
   I% = I% + 1
   IF I% = 1 THEN
      IF grap% = 1 THEN
         COLOR 7
         LOCATE 10, 52
         PRINT "Assuming web is fully eff."
      ELSE
         LPRINT TAB(15); "Assuming web is fully effective"
         LPRINT
      END IF
   le = 2! * u + be + b + a + lip% * (2! * u + ds + c) 'effective length
   yl = aa / 2!
   ssumLy = sumLy + a * yl
   ELSE
      'iteration to find effective portions of web
      le = 2! * u + be + b + b1 + b3 + lip% * (2! * u + ds + c)
      yu = b1 / 2! + r + t / 2!
      ssumLy = sumLy + b1 * yu
      yl = aa - t / 2! - r - b3 / 2!
      ssumLy = ssumLy + b3 * yl
      b12prev = b1 + b2
   END IF
   ycg = ssumLy / le
   '--------------Effective width of web
   '--------------Stiffened Element with Stress Gradient:
   acomp = ycg - r - t / 2!
   f1 = Fy * acomp / ycg
   aten = aa - ycg - r - t / 2!
   f2 = -Fy * aten / ycg
   fi = f2 / f1
   k = 4! + 2! * (1! - fi) ^ 3! + 2! * (1! - fi)
IF grap% = 0 AND 1% = 1 THEN 'this routine will only print
   prin% = 0 'to printer for the first loop
ELSE
   prin% = 1
END IF

IF prin%=0 THEN
   LPRINT TAB(15); "Location of neutral axis \ ycg = ", USING "##.#####"; ycg; : LPRINT " in"
   LPRINT TAB(15); "Compression portion of web \ acomp = "; USING "##.#####"; acomp;
   LPRINT " in \ f1 = "; USING "##.#####"; f1; : LPRINT " ksi"
   LPRINT TAB(15); "Tension portion of web \ aten = "; USING "##.#####"; aten;
   LPRINT " in \ f2 = "; USING "##.#####"; f2; : LPRINT " ksi"
END IF

CALL COMPeffectwidth(a, t, k, f1, prin%, la, ae) 'ae: effective width of web
b1 = ae / (3! - f1)

IF fi <= .236 THEN
   b2 = ae / 2!
ELSE
   b2 = ae - b1
END IF

IF prin%=0 THEN
   LPRINT TAB(15); "fi = ", USING "##.#####"; fi;
   LPRINT "; \ b1 = "; USING "##.#####"; b1;
   LPRINT " in \ b2 = "; USING "##.#####"; b2; : LPRINT " in"
END IF

'-------------deciding whether assumption was correct or not---

IF b1 + b2 > acomp THEN 'assumption is correct: web is fully
   'effective, we can compute Ixe, Sxe
      IF grap% = 1 THEN
         COLOR 7
         LOCATE 12, 52
         PRINT "Assumption correct"
         LOCATE 14, 52
         PRINT "ycg=", USING "##.#####"; ycg; : PRINT " in"
         LOCATE 16, 52
         PRINT "b1+b2=", USING "##.#####"; b1 + b2; : PRINT "< acomp="; :
         PRINT USING "##.#####"; acomp
      ELSE
         LPRINT TAB(15); "b1+b2 = "; USING "##.#####"; b1 + b2; : LPRINT " in > acomp = ";
         USING "##.#####"; acomp;
         LPRINT " in Assumption correct"
      END IF
   END IF
EXIT DO
ELSE

IF l% = 1 then

IF grap% = 1 THEN
    COLOR 7
    LOCATE 12, 52
    PRINT "Assumption incorrect,"
    LOCATE 13, 52
    PRINT "iteration needed."
    LOCATE 15, 52
    PRINT "ycg   b1+b2   diff."
ELSE
    LPRINT TAB(15); "b1+b2 =\n", USING "####", b1 + b2;
    LPRINT " in > acomp =\n", USING "####"; acomp;
    LPRINT " in Assumption incorrect"
    LPRINT TAB(15); "Iteration needed to find effective portion of web"
    LPRINT
    LPRINT TAB(15); "iter ycg   fi   k   ia b1+b2 diff"
END IF

END IF

b3 = aten + b2
END IF

diff = ABS(1 - b12prev / (b1 + b2)) * 100!

IF grap% = 1 THEN
    COLOR 7
    LOCATE 16 + l%, 52
    PRINT USING "####"; ycg; PRINT "   ";
    PRINT USING "####"; b1 + b2; PRINT "   ";
    IF l% > 1 THEN PRINT USING "####.####"; diff
    PRINT
ELSE
    LPRINT TAB(15); l%;
    LPRINT TAB(21); USING "####"; ycg; :
    LPRINT TAB(31); USING "####"; fi;
    LPRINT TAB(41); USING "####"; k;
    LPRINT TAB(50); USING "####"; la;
    LPRINT TAB(59); USING "####"; b1 + b2;
    IF l% > 1 THEN
        LPRINT TAB(67); USING "####.####"; diff
    ELSE
        LPRINT
    END IF
END IF

LOOP UNTIL diff < .1
IF grap% = 0 AND I% > 1 THEN
    LPRINT
    LPRINT TAB(15); "Difference is less then .1 percent, close enough"
END IF
END SUB

SUB COMPshearcap (Fy, a, t, grap%)
******************************************************************************
* This routine computes the shear capacity of the section,
* based on section C3.2 of Spec.
*
* INPUT VARIABLES:
* Fy  - yield strength of steel (ksi)
* a   - flat portion of web (in)
* t   - thickness (in)
* grap% = 1 print graphics and result on screen
*      = 0 print results on paper
*
* INPUT VARIABLES:
* h   - height of element
* kv  - plate buckling coefficient
* E   - modulus of elasticity
* x   - shear capacity of the section (kip)
******************************************************************************

IF grap% = 0 THEN
    LPRINT TAB(5); "Computing shear capacity   (Section C 3.2 of Spec.)"
    LPRINT TAB(5); "-----------------------------------------------"
    LPRINT
END IF

h = a
kv = 5.34
E = 29500!

x = (E * kv / Fy) ^ .5
IF h / t <= 1.38 * x THEN 'case a

Va = .38 * t ^ 21 * (kv * Fy * E) ^ .5

IF grap% = 0 THEN
  LPRINT TAB(15); "h/t = ", USING ":####.####", h / t;
  LPRINT " < 1.38 * (E kv/Fy) ^ .5 = ", USING ":####.####", 1.38 * x;
  LPRINT " case A"
  LPRINT TAB(15); "Shear capacity (inelastic) (Va)1 =", USING ":####.####", Va:
  LPRINT " kips"
  LPRINT TAB(15); "Shear capacity (yield) (Va)2 =", USING ":####.####", .4 * Fy * h * t;
  LPRINT " kips"
END IF

IF Va > .4 * Fy * h * t THEN
  Va = .4 * Fy * h * t

ELSE IF grap% = 0 THEN LPRINT TAB(15); "Yield governs"
ELSE IF grap% = 0 THEN LPRINT TAB(15); "Inelastic buckling governs"
END IF
ELSE 'case b

IF grap% = 0 THEN
  LPRINT TAB(15); "h/t = ", USING ":####.####", h / t;
  LPRINT " > 1.38 * (E kv/Fy) ^ .5 = ", USING ":####.####", 1.38 * x;
  LPRINT " case B"
  LPRINT TAB(15); "Elastic buckling governs"
END IF

Va = .53 * E * kv * t ^ 3! / h

END IF

IF grap% = 1 THEN

COLOR 7

LOCATE 2, 52
PRINT "Shear and axial strength"
LOCATE 3, 52
PRINT "-----------------------------"

LOCATE 5, 52
PRINT "Va="; USING ":####.####", Va; : PRINT " kips"
ELSE
  LPRINT
  LPRINT TAB(15); "Shear capacity Va =", USING ":####.####", Va; : LPRINT " kips"
END IF

END SUB
SUB COMPcompcap (Fy, aa, bb, cc, t, KL, Area, a, b, c, r, u, rx, ry, ro, beta, Jstv, Cw, be, C1, C2, ds, gf, vc, hc, lip%, xwcl, grap%)  

* This routine computes the compression capacity of the section based on Sect. C4  
*  
** INPUT VARIABLES:  
** Fy - yield strength of steel (ksi)  
** aa - A’ depth of section (in)  
** bb - B’ width of flange (in)  
** cc - C’ length of lip (in)  
** t  - thickness (in)  
** KL - effective length (in)  
** Area - cross-sectional area of the section (in2)  
** a  - flat portion of web (in)  
** b  - flat portion of flange (in)  
** c  - flat portion of lip (in)  
** r  - midplane radius of corners (in)  
** u  - length of arc of 90 degree corners (in)  
** rx, ry - radii of giration (in)  
** ro  
** beta  
** Jstv - St. Venant torsion constant (in4)  
** Cw - warping constant (in6)  
** be - effective width of flange  
** C1,C2 - coefficients of effective portions of flange  
** ds - reduced effective width of stiffener  
** gf - (graphical) factor for defining window  
** vc - location of vertical centerline of section  
** hc - location of horizontal centerline of section  
** lip% = 0 if there is no lip  
** = 1 if there is a lip  
** xwcl - x coordinate of the centerline of the web  
** grap% = 1 print graphics and result on screen  
** = 0 print results on paper  
*  
** LOCAL VARIABLES:  
* pi  
** E - modulus of elasticity  
** GG - shear modulus  
*  
pi = 3.1415927#  
E = 29500  
GG = 11300
\[
\text{Fe1} = \pi \cdot 2! \cdot E / (K L / ry)^2.
\]

\[
\text{sigex} = \pi \cdot 2! \cdot E / (K L / rx)^2.
\]

\[
\text{sigt} = (G G \cdot J s t v + \pi \cdot 2! \cdot E \cdot C w / K L ^ 2) / \text{Area} / ro^2.
\]

\[
\text{Fe} = \text{Fe1} \times \text{sigex} \times \text{sigt} - ((\text{sigex} + \text{sigt})^2 - 4! \cdot \beta \cdot \text{sigex} \cdot \text{sigt}^2 - 0.5) / 2! / \beta
\]

IF Fe > Fe2 THEN Fe = Fe2

'---------------------------------'determining Fn---------------------------------

IF Fe > Fy / 2! THEN
    FFn = Fy * (1! - Fy / 4! / Fe)
ELSE
    FFn = Fe
END IF

'-----------------printing relevant data on the screen-----------------

IF grap% = 1 THEN
    LOCATE 7, 52
    PRINT "Flexural buckling stress:"
    LOCATE 8, 52
    PRINT "(Fe)1 = " USING "###.###"; Fe1; : PRINT " ksi"
    LOCATE 10, 52
    PRINT "Tors.-flex. buckling stress:"
    LOCATE 11, 52
    PRINT "(Fe)2 = " USING "###.###"; Fe2; : PRINT " ksi"
    LOCATE 13, 52
    PRINT "Fe = " USING "###.###"; Fe; : PRINT " ksi"
    PRINT "Fn = " USING "###.###"; FFn; : PRINT " ksi"
ELSE
    LPRINT
    LPRINT
    LPRINT TAB(5); "Computing axial strength"
    LPRINT TAB(5); "-----------------------------"
    LPRINT
    LPRINT TAB(10); "Determining Fn"
    LPRINT
    LPRINT TAB(15); "Flexural buckling stress (Fe)1 = " USING "###.###"; Fe1; : LPRINT " ksi"
    LPRINT TAB(42); "sigma ex = " USING "###.###"; sigex; : LPRINT " ksi"
    LPRINT TAB(43); "sigma t = " USING "###.###"; sigt; : LPRINT " ksi"
    LPRINT TAB(15); "Tors.-flex. buckling stress (Fe)2 = " USING "###.###"; Fe2; : LPRINT " ksi"
    LPRINT
    LPRINT TAB(48); "Fe = " USING "###.###"; Fe; : LPRINT " ksi"
    LPRINT TAB(48); "Fn = " USING "###.###"; FFn; : LPRINT " ksi"
    LPRINT IF lip% = 1 THEN
        LPRINT TAB(10); "Effective width of edge stiffeners Section B3.2 of Spec."
LPRINT
END IF
END IF

'-------------Computing the flange and the lip

IF lip% = 1 THEN

'-------------Effective width of lip (stiffener)
'-------------Uniformly Compressed Unstiffened Element:
'-------------Sect. B3.1

CALL COMPeffwidth(c, t, .43, FFn, grap%, la, dsp) 'dsp: ds prime: effective
' width of stiffener

'-------------Effective width of compression flange
'-------------Uniformly Compressed Element with Edge Stiffener:
'-------------Sect. B4.2 of Spec.

IF grap% = 0 THEN
LPRINT
LPRINT TAB(10); "Effective width of flanges Section B4.2 of Spec."
LPRINT
END IF
ELSE

CALL COMPflange(b, t, FFn, cc, c, desp, grap%, be, C1, C2, ds)

'-------------Uniformly Compressed Unstiffened Element:
'-------------Sect. B3.1 of Spec.

IF grap% = 0 THEN
LPRINT
LPRINT TAB(10); "Effective width of flanges Section B3.1 of Spec."
LPRINT
END IF

CALL COMPeffwidth(b, t, .43, FFn, grap%, la, be)

END IF

'-------------writing message about effectiveness of flanges on screen---

IF be < b THEN

IF grap% = 1 THEN
LOCATE 15, 52
PRINT "Flanges are not fully eff."
LOCATE 16, 52
PRINT "be="; USING "###.###", be; ; PRINT " in < ";
PRINT "b="; USING "###.###", b; ; PRINT " in"
COLOR 10

IF lip% = 1 THEN
  LINE (hc + b / 2! - C2 * be / 2!, vc + aa / 2!)-STEP(0, -t)
  LINE (hc - b / 2! + C1 * be / 2!, vc + aa / 2!)-STEP(0, -t)
  PAINT (hc + b / 2! - C2 * be / 2! - (b - be) / 2!, vc + aa / 2! - t / 2!)
  LINE (hc + b / 2! - C2 * be / 2!, vc - aa / 2!)-STEP(0, t)
  LINE (hc - b / 2! + C1 * be / 2!, vc - aa / 2!)-STEP(0, t)
  PAINT (hc + b / 2! - C2 * be / 2! - (b - be) / 2!, vc - aa / 2! + t / 2!)

COLOR 11
x1 = hc - b / 2! + C1 * be / 2
y1 = vc + aa / 2! + 0.03 * gf * aa
'labeling b-be
CALL SHOWSIZE2("b-be", gf * aa, x1, y1, x1 + (b - be), y1, "h")

ELSE
  LINE (hc + b / 2!, vc + aa / 2!)-STEP(0, -t)
  LINE (hc + b / 2! - (b - be), vc + aa / 2!)-STEP(0, -t)
  PAINT (hc + b / 2! - (b - be) / 2!, vc + aa / 2! - t / 2!)

COLOR 11
x1 = hc - b / 2
y1 = vc + aa / 2! + 0.03 * gf * aa
'labeling be
CALL SHOWSIZE("be", gf * aa, x1, y1, x1 + be, y1, "h")

END IF

ELSE
  LPRINT TAB(15); "be=", USING "#####": be; : LPRINT " in < b ="; USING "#####": b;
  LPRINT " in Flanges are not fully effective"

END IF

ELSE
  IF grap% = 1 THEN
    LOCATE 15, 52
    PRINT "Flanges are fully eff."
    LOCATE 16, 52
    PRINT TAB(52); "be = b ="; USING "#####": be; : PRINT " in"
  ELSE
    LPRINT TAB(15); "be = b ="; USING "#####": b;
    LPRINT " in Flanges are fully effective"
  END IF

END IF

ELSE
  IF grap% = 1 THEN
    COLOR 11
    x1 = hc - b / 2!
    y1 = vc - aa / 2! - .068 * gf * aa
    'labeling b
    CALL SHOWSIZE("b", gf * aa, x1, y1, x1 + b, y1, "h")

END IF

END IF
IF lip% = 1 THEN

'-------writing message about effectiveness of lips on screen-----

IF ds < c THEN

IF grap% = 1 THEN
  COLOR 7
  LOCATE 18, 52
  PRINT "Lips are not fully eff."
  LOCATE 19, 52
  PRINT "ds=", USING "###.###", ds; : PRINT " in < ";
  PRINT "d=", USING "###.###", c; : PRINT " in"

'-------showing uneffective portion of lip------
  COLOR 10
  LINE (hc + bb / 2! + vc + a / 2! - ds)-STEP(-t, 0)
  PAINT (hc + bb / 2! - t / 2!, vc + a / 2! - ds - (c - ds) / 2!)
  LINE (hc + bb / 2! + vc - a / 2! + ds)-STEP(t, 0)
  PAINT (hc + bb / 2! + t / 2!, vc - a / 2! + ds + (c - ds) / 2!)

  COLOR 11
  x1 = hc + bb / 2! + .023 * gf * aa
  y1 = vc + a / 2!
  CALL SHOWSIZE2("ds", gf * aa, x1, y1, x1, y1 - ds, "vb")
ELSE
  LPRINT TAB(15); "ds=", USING "###.###", ds; : LPRINT " in < d ="
    USING "###.###", c;
  LPRINT " in Stiffeners are not fully effective"
ENDIF
ELSE
  IF grap% = 1 THEN
    COLOR 7
    LOCATE 18, 52
    PRINT "Lips are fully eff."
    LOCATE 19, 52
    PRINT "ds = d =", USING "###.###", c; : PRINT " in"
  ELSE
    LPRINT TAB(15); "ds = d =", USING "###.###", c;
    LPRINT " in Stiffeners are fully effective"
  END IF
ENDIF
ENDIF

IF grap% = 1 THEN
  COLOR 11
  x1 = hc + bb / 2! + .08 * gf * aa
  y1 = vc + a / 2!
  CALL SHOWSIZE2("d", gf * aa, x1, y1, x1, y1 - c, "vb")
ENDIF
IF grap% = 0 THEN
    LPRINT
    LPRINT TAB(10); "Effective width of web"
    LPRINT
END IF

CALL COMPeffwidth(a, t, 41, FFn, grap%, la, ae) 'ae effective width of web

'--------writing message about effectiveness of web on screen----

IF ae < a THEN

    IF grap% = 1 THEN
        COLOR 7
        LOCATE 21, 52
        PRINT "Web is not fully eff."
        LOCATE 22, 52
        PRINT "ae="; USING "###.###"; ae; : PRINT " in < ";
        PRINT "a="; USING "###.###"; a; : PRINT " in"

        '--------showing uneffective portion of web------
        COLOR 10
        LINE (xwcl - t / 2! + 0.04 * gf * aa
        LINE (xwcl - t / 2! - a / 2! + ae / 2!) - STEP(t, 0)
        LINE (xwcl - t / 2! - a / 2! + ae / 2!) - STEP(t, 0)
        PAINT (xwcl, vc)

        COLOR 11
        x1 = xwcl - t / 2! + 0.04 * gf * aa
        y1 = vc + a / 2!
        CALL SHOWSIZE("ae/2", gf * aa, x1, y1, x1, y1 - ae / 2!, "v")
        y1 = vc - a / 2! + ae / 2!
        CALL SHOWSIZE("ae/2", gf * aa, x1, y1, x1, y1 - ae / 2!, "v")
    ELSE
        PRINT TAB(15); "ae="; USING "###.###"; ae; : LPRINT " in < a =";
        USING "###.###"; a;
        LRINT " in Web is not fully effective"
    END IF
ELSE

IF grap% = 1 THEN
  COLOR 7
  LOCATE 21, 52
  PRINT "Web is fully eff."
  LOCATE 22, 52
  PRINT "ae = a ="; USING "####.####"; a; : PRINT " in" ELSE
  LPRINT TAB(15); "ae = a ="; USING "####.####"; a;
  LPRINT " in Web is fully effective"
END IF
END IF

IF grap% = 1 THEN
  COLOR 11
  x1 = xwc1 - t / 2! - .03 * gf * aa
      'labeling a
  y1 = vc + a / 2!
  CALL SHOWSIZE("a", gf * aa, x1, y1, x1, y1 - a, "v")
END IF

'-------------------determining Aeff, Pn, & Pa-------------------

Aeff = Area - (lip% * 2! * (c - ds) + 2! * (b - be) + (a - ae)) * t
Pn = FFn * Aeff
Pa = Pn / 1.92

ELSE
  LOCATE 24, 52
  PRINT "Ae="; USING "####.####"; Aeff; : PRINT " in2"
  LOCATE 26, 52
  PRINT "Comp. strength of section:"
  LOCATE 27, 52
  PRINT "Pa="; USING "####.####"; Pa; : PRINT " ksi"
  CALL presskey(30, 52)
END IF

ELSE
  LPRINT
  LPRINT TAB(10); "Computing effective cross-sectional area and axial strengths"
  LPRINT
  LPRINT TAB(15); "Effective cross-sectional area   Ae ="; USING "####.####"; Aeff; : LPRINT " in2"
  LPRINT TAB(15); "Nominal axial strength      Pn ="; USING "####.####"; Pn; : LPRINT " kip"
  LPRINT TAB(15); "Allowable axial strength   Pa ="; USING "####.####"; Pa; : LPRINT " kip"
END IF
END SUB
SUB PLOTSECT (aa, bb, cc, rr, t, a, b, c, r, lip%, gf, vc, hc, xwcl)

This routine plots and labels the given cross-section.

INPUT VARIABLES:
- aa - A' depth of section (in)
- bb - B' width of flange (in)
- cc - C' length of lip (in)
- rr - R inner radius of corners (in)
- t - thickness (in)
- a - flat portion of web (in)
- b - flat portion of flange (in)
- c - flat portion of lip (in)
- r - midplane radius of corners (in)
- lip% = 0 if there is no lip
  = 1 if there is a lip

OUTPUT VARIABLES:
- gf - (graphical) factor for defining window
- vc - location of vertical centerline of section
- hc - location of horizontal centerline of section
- xwcl - x coordinate of the centerline of the web

LOCAL VARIABLES:
- pi

SCREEN 12

IF .725 * aa > bb THEN
  gf = 1.5
ELSE
  gf = 1.5 * (bb / (.725 * aa))
END IF

'exact square is gain with 3.9 / 3 factor
WINDOW (0!, 0!)-(3.9 / 3! * gf * aa, gf * aa)

pi = 3.14159265#
vc = gf / 2! * aa
hc = .6125 * aa * (gf / 1.5)

IF lip% = 1 THEN
  xwcl = hc - bb / 2! + t / 2!
ELSE
  xwcl = hc - b / 2! - (bb - b) + t / 2!
END IF

note: for the no lip case b
and bb will not be concentric
anymore, hc will only be at the
center of b
'drawing the section with light green
COLOR 10

IF lip% = 1 THEN
    LINE (hc + bb / 2!, vc + aa / 2! - cc)-STEP(0, c) 'outer part of upper lip
    CIRCLE (hc + b / 2!, vc + a / 2), r + t / 2!, , 0, pi / 2! 'outer p. of top right circle
END IF

LINE (hc + b / 2!, vc + aa / 2!)-STEP(-b, 0) 'outer p. of upper flange
CIRCLE (hc - b / 2!, vc + a / 2), r + t / 2!, , pi / 2!, pi 'outer p. of top left circle
LINE (xwcl + t / 2!, vc + a / 2!)-STEP(0, -a) 'outer p. of web
CIRCLE (hc - b / 2!, vc - a / 2), r + t / 2!, , pi, 1.5 * pi 'outer p. of bottom left circle
LINE (hc - b / 2!, vc - aa / 2!)-STEP(b, 0) 'outer p. of lower flange

IF lip% = 1 THEN
    CIRCLE (hc + b / 2!, vc - a / 2), r + t / 2!, , 1.5 * pi, 2! * pi 'outer p. of bottom right circle
    LINE (hc + bb / 2, vc - a / 2!)-STEP(0, c) 'outer p. of lower lip
    'back to where we started
    LINE (hc + bb / 2!, vc + aa / 2! - cc)-STEP(-t, 0) 'end of upper lip
    LINE -STEP(0, c) 'inner p of upper lip
    CIRCLE (hc + b / 2!, vc + a / 2), r - t / 2!, , 0, pi / 2! 'inner p. of top right circle
ELSE
    LINE (hc + b / 2!, vc + aa / 2!)-STEP(0, -t) 'end of upper flange
END IF

LINE (hc + b / 2!, vc + aa / 2! - t)-STEP(-b, 0) 'inner p. of upper flange
CIRCLE (hc - b / 2!, vc + a / 2), r - t / 2!, , pi / 2!, pi 'inner p. of top left circle
LINE (xwcl - t / 2!, vc + a / 2!)-STEP(0, -a) 'inner p. of web
CIRCLE (hc - b / 2!, vc - a / 2), r - t / 2!, , pi, 1.5 * pi 'inner p. of bottom left circle
LINE (hc - b / 2!, vc - aa / 2! + t)-STEP(b, 0) 'inner p. of lower flange

IF lip% = 1 THEN
    CIRCLE (hc + b / 2!, vc - a / 2), r - t / 2!, , 1.5 * pi, 2! * pi 'inner p. of bottom right circle
    LINE (hc + bb / 2 - t, vc - a / 2!)-STEP(0, c) 'inner p. of lower lip
    LINE -STEP(t, 0) 'end of lower lip
ELSE
    LINE -STEP(0, -t) 'end of lower flange
END IF

END SUB
SUB SHOWSIZE (label$, u, x1, y1, x2, y2, po$)

* SUBROUTINE SHOWSIZE

* This routine draws a dimension line with arrows on the end and
  labels it.  [<-------->]

* INPUT VARIABLES:
  * label$ - label to be written on the line
  * u - height of the window
  * x1, y1 - starting point of line (absolute)
  * x2, y2 - ending point of line (absolute)
  * po$ - indicates position of line:
    v vertical, h horizontal

* LOCAL VARIABLES:
  * larr - length of the arrow : u/42.
  * warr - width of the arrow : larr/2.

'drawing dimensionline
LINE (x1, y1)-(x2, y2)

'arrow dimensions
larr = u / 42!
warr = larr / 2!

SELECT CASE po$
  CASE "v"
    'vertical line
    LINE -STEP(-warr / 2l, larr)
    LINE (x2, y2)-STEP(warr / 2l, larr)
    LINE (x1, y1)-STEP(-warr / 2l, -larr)
    LINE (x1, y1)-STEP(warr / 2l, -larr)
    LINE (x1 - .015 * u, y1)-STEP(.03 * u, 0l)
    LINE (x1 - .015 * u, y2)-STEP(.03 * u, 0l)
  ' at the end

'computing coordinates of LOCATE statement
  horizontal:
  ' No of columns: 80 horizontal size of sc.: 3.9 / 3 * u
  ' Label to be printed at: x = x1 + .022 * u
  ' vertical:
  ' No of rows: 30 vertical size of sc.: u
  ' Label to be printed at: y = (y1 + y2) / 2.

x = CINT((x1 + .022 * u) / (3.9 / 3 * u) * 80l)
y = CINT((u - (y1 + y2) / 2l) / u * 30l)

'locate statement: row, column (y,x) !!!!
CASE "h"

LINE -STEP(-larr, warr / 2!)
LINE (x2, y2) -STEP(-larr, -warr / 2!)
LINE (x1, y1) -STEP(larr, warr / 2!)
LINE (x1, y1) -STEP(larr, -warr / 2!)
LINE (x1, y1 - .015 * u) -STEP(0!, .03 * u)
LINE (x2, y1 - .015 * u) -STEP(0!, .03 * u)

'right arrow'
'left arrow'
'perpendicular lines'
'at the end'

'computing coordinates of LOCATE statement
horizonal:
  No of columns : 80 horizontal size of sc. : 3.9 / 3.* u
  Label to be printed at : x (x1 + x2) / 2.
vertical:
  No of rows : 30 vertical size of sc. : u
  Label to be printed at : y y1

x = CINT(((x1 + x2) / 2!) / (3.9 / 3! * u) * 80!)
y = CINT((u - y1) / u * 30!)

END SELECT

LOCATE y, x
PRINT label$

END SUB

SUB SHOWSIZE2 (label$, u, x1, y1, x2, y2, po$)

'SUBROUTINE SHOWSIZE2

This routine draws a dimension line with arrows on the end and
labels it.  -->| |<--

INPUT VARIABLES:
label$ - label to be written on the line
u - height of the window
x1, y1 - starting point of line (absolute)
x2, y2 - ending point of line (absolute)
point (x1, y1) must be to the left or above point (x2,y2)
po$ - indicates position of line:
vt: vertical, label on top
vb: vertical, label on bottom
hr: horizontal, label on the right
hl: horizontal, label on the left

LOCAL VARIABLES:
larr - length of the arrow : u/42.
warr - width of the arrow : larr/2.'
'arrow dimensions
larr = u / 42!
warr = larr / 2!

SELECT CASE LEFT$(po$, 1)
    CASE "v"  
        'vertical line
        LINE (x1, y1)-STEP(-warr / 2!, larr)  
        LINE (x1, y1)-STEP(warr / 2!, larr)  
        LINE (x2, y2)-STEP(-warr / 2!, -larr)  
        LINE (x2, y2)-STEP(warr / 2!, -larr)
        LINE (x1 - .015 * u, y1)-STEP(.03 * u, 0!)  
        LINE (x1 -.015 * u, y2)-STEP(.03 * u, 0!)
        'perpendicular lines
        'at the end

' computing coordinates of the LOCATE statement
' horizontal:
'    No of columns : 80  horizontal size of sc. : 3.9 / 3 * u
'    Label to be printed at : x  x1 + .022 * u

x = CINT((x1 + .022 * u) / (3.9 / 3! * u) * 80!)

IF po$ = "vt" THEN
    'label at upper end
    'upper portion of dimension line,  length: 3 * arrowlength
    LINE (x1, y1 + 3! * larr)-(x1, y1)
    'lower portion of dimension line,  length: 1.5 * arrowlength
    LINE (x2, y2)-(x2, y2 - 1.5 * larr)

    ' vertical :
    '    No of rows : 30  vertical size of sc. : u
    '    Label to be printed at : y  y1 + 1.5 * larr

    y = CINT((u - (y1 + 1.5 * larr)) / u * 30!)

ELSE
    'label at lower end
    LINE (x1, y1 + 1.5 * larr)-(x1, y1)
    LINE (x2, y2)-(x2, y2 - 3! * larr)

    ' vertical :
    '    No of rows : 30  vertical size of sc. : u
    '    Label to be printed at : y  y2 - 1.5 * larr

    y = CINT((u - (y2 - 1.5 * larr)) / u * 30!)
END IF
CASE "h"

LINE (x1, y1)-STEP(-larr, warr / 2!)
LINE (x1, y1)-STEP(-larr, -warr / 2!)
LINE (x2, y2)-STEP(larr, warr / 2!)
LINE (x2, y2)-STEP(larr, -warr / 2!)
LINE (x1, y1 - .015 * u)-STEP(0!, .03 * u)
LINE (x2, y1 - .015 * u)-STEP(0!, .03 * u)

' horizontal line
' left arrow
' right arrow
' perpendicular lines
' at the end

' vertical:
' No of rows : 30 vertical size of sc. : u
' Label to be printed at : y y1

y = CINT((u - y1) / u * 30!)

IF po$ = "hr" THEN

' right portion of dimension line, length: 3 * arrowlength
LINE (x1 - 3! * larr, y1)-(x1, y1)
' left portion of dimension line, length: 1.5 * arrowlength
LINE (x2, y2)-(x2 + 1.5 * larr, y2)

' horizontal:
' No of columns : 80 horiz. size of sc. : 3.9 / 3! * u
' Label to be printed at : x x1-1.5 * larr

x = CINT((x1 - 1.5 * larr) / (3.9 / 3! * u) * 80!)

ELSE

' label at left end

LINE (x1 - 1.5 * larr, y1)-(x1, y1)
LINE (x2, y2)-(x2 + 3! * larr, y2)

' horizontal:
' No of columns: 80 horiz. size of sc. : 3.9 / 3! * u
' Label to be printed at : x x2+1.5 * larr

x = CINT((x2 + 1.5 * larr) / (3.9 / 3! * u) * 80!)

END IF

END SELECT

LOCATE y, x
PRINT label$
SUB CORRECT (a$)

* SUBROUTINE: CORRECT

* This routine asks you if the data you entered is correct or not.

* OUTPUT VARIABLE: A$

PRINT TAB(26); "Is this correct ? (y/n) ";

DO
    a$ = INKEY$
LOOP UNTIL a$ = "y" OR a$ = "Y" OR a$ = "n" OR a$ = "N"

PRINT a$;

END SUB

SUB presskey (x, y)

* SUBROUTINE: PRESSKEY

* This routine waits for pressing any key to continue the program,
  * and writes the message to LOCATE x,y

LOCATE x, y
PRINT "Press any key to continue";

DO
LOOP WHILE INKEY$ = ""

END SUB
APPENDIX B

LISTING OF THE MODIFIED PROGRAM FOR COMPUTING AXIAL CAPACITIES WITH SPECIFIED LATERAL LOADS
DECLARE SUB COMPSecprop (Fy!, AA!, BB!, CC!, rl!, tl!, KL!, lip%, gra%, Areal!, Al!, bl!, cl!, rl!, ul!, xhl!, Ml!, rx!, ry!, rol!, beta!, Jstv!, Cw!, xwcl!)  
DECLARE SUB COMPSefwwidth (wl!, tl!, kl!, fl!, gra%, la!, b!)  
DECLARE SUB COMPflange (wl!, tl!, fl!, CC!, cl!, dsp!, gra%, be!, C1!, C2!, ds!)  
DECLARE SUB COMPweb (Fy!, AA!, tl!, Al!, bl!, cl!, rl!, ul!, be!, bel, ds!, sumLly!, lip%, gra%, B1!, b2!, b3!, le!, ycgl!, yul!, yll!, l%)  
DECLARE SUB COMPcompcap (Fy!, AA!, BB!, CC!, tl!, KL!, Areal!, Al!, bl!, cl!, rl!, ul!,  
rx!, ry!, rol!, beta!, Jstv!, Cw!, bel, C1!, C2!, ds!, gfl!, vcl!, hcl!, lip%, xwcl!, gra%, Pa!)  
DECLARE SUB COMPcompcap2 (Fy!, AA!, BB!, CC!, tl!, KL!, Areal!, Al!, bl!, cl!, rl!, ul!,  
rx!, ry!, rol!, beta!, Jstv!, Cw!, bel, C1!, C2!, ds!, gfl!, vcl!, hcl!, lip%, xwcl!, gra%, Pa!)  

DECLARE SUB SECORDSOLV (AA!, BB!, CC!, x1!, x2!)  
**************************************************************************************************  
  
*  
* Program for computing the flexural, shear and axial capacity  
* of a C section based on the Allowable Stress Design  
*  
* This modified version computes the max axial load for a  
* given lateral load based on sect C5 of the Spec.  
*  
* The bending moment Mx is computed from  
*  
* w (psf)  lateral load (eg. wind load)  
* s (in)  spacing of the studs and  
* KL(in)  height of the wall (length of studs)  
*  
* K[1][1] x s [in]  
* Mx [k-in] = -------- ** --------  
*  
*  
*  
* (Mx is to be recomputed for each case, ie in the innermost loop)  
*  
* The Ma and Ix values are not computed from the section properties  
* but taken from the performance section tables  
* (varies for each section)  
*  
* Mao = Ma for this case since flex.-tors. buckling is prevented  
*  
* The Pa value is gain from a modified version of subroutine  
* COMPcompcap  
*  
* -the sections are braced by the sheathing material  
* therefore the torsional-flexural buckling mode is not  
* considered  
* -the studs are subject to strong axis bending  
* therefore ry is replaced by rx in the first equation  
* Pao is computed with the above mentioned modified COMPcompcap  
* routine except that Fy is used instead of Fy  
* Pcr : eq C5-5  
* (Pa, Pao and Pcr are function of the section and the height,  
* must be recomputed in the second loop)  
*
Cm = 1 since joint translation is prevented, and 
the ends are unrestrained

Since \( \alpha \) is a function of \( P \), solving eq. C5-1 for \( P \) leads to 
a second order equation where the smaller root is \( P \)
For the 8 x 9 studs this was usually the governing case as opposed
to eq. C5-2 (in fact this was always the governing case for \( \alpha \) those cases I checked)
If \( P/r \leq 0.15 \) (or \( Mx/Ma > 0.85 \) i.e. the axial force is small
then eq.C5-3 is used which gives larger values for \( P \) then the
other two equations.

```
grap% = 1
lip% = 1
SCREEN 0
CLS
Fy = 33
w = 35

LPRINT "lateral load : w=", w; "psf"

AA = 9.25
sect$1 = "9.25S01": BB(1) = 1.25: CC(1) = .4: t(1) = .03: rr(1) = 2! * t(1)
sect$2 = "9.25S02": BB(2) = 1.3: CC(2) = .4: t(2) = .036: rr(2) = 2! * t(2)
sect$3 = "9.25S03": BB(3) = 1.375: CC(3) = .4: t(3) = .048: rr(3) = 2! * t(3)
sect$4 = "9.25S04": BB(4) = 1.5: CC(4) = .4: t(4) = .06: rr(4) = 2! * t(4)
sect$5 = "9.25S05": BB(5) = 1.625: CC(5) = .4: t(5) = .075: rr(5) = 2! * t(5)
sect$6 = "9.25S06": BB(6) = 1.625: CC(6) = .5: t(6) = .105: rr(6) = 2! * t(6)
sect$7 = "9.25S07": BB(7) = 1.625: CC(7) = .6: t(7) = .135: rr(7) = 2! * t(7)
sect$8 = "9.25S08": BB(8) = 1.625: CC(8) = .7: t(8) = .1644: rr(8) = 2! * t(8)
sect$9 = "9.25S09": BB(9) = 1.625: CC(9) = .8: t(9) = .1943: rr(9) = 2! * t(9)

Ma(1) = 0: Ix(1) = 0
Ma(2) = 16.4: Ix(2) = 3.8
Ma(3) = 25!: Ix(3) = 5.3
Ma(4) = 34.95: Ix(4) = 7.19
Ma(5) = 46.26: Ix(5) = 9.471
Ma(6) = 58.91: Ix(6) = 12.143
Ma(7) = 72.92: Ix(7) = 15.205
Ma(8) = 88.29: Ix(8) = 18.657
Ma(9) = 105!: Ix(9) = 22.5

s(1) = 12: s(2) = 16: s(3) = 24

'* spacings [in]

pi = 3.1415927#
FOR kk% = 2 TO 9

' section loop

LPRINT
LPRINT sect$(kk%); " Ma="; Ma(kk%); "kip-inch lx="; lx(kk%); "in4"
LPRINT

' printing header

LPRINT TAB(36); "s= 12"; TAB(56); "16"; TAB(72); "24"
LPRINT " H"; TAB(12); "Pa"; TAB(20); "Pao"; TAB(28); "Pcr"
LPRINT TAB(36); "Mx"; TAB(44); "P"
LPRINT TAB(52); "Mx"; TAB(60); "P"
LPRINT TAB(68); "Mx"; TAB(76); "P"
LPRINT "[ft]"; TAB(11); "[kip]"; TAB(19); "[kip]"; TAB(27); "[kip]"
LPRINT TAB(35); "[k-i]"; TAB(42); "[kip]"
LPRINT TAB(51); "[k-i]"; TAB(58); "[kip]"
LPRINT TAB(67); "[k-i]"; TAB(74); "[kip]"

CALL COMPsecprop(Fy, AA, BB(kk%), CC(kk%), rr(kk%), t(kk%), KL, lip%, grap%,
Area, A, b, c, r, u, xh, M, rx, ry, ro, beta, Jstv, Cw, xwcl)

FOR ll% = 1 TO 7

' height routine, height varies with an increment of
' 2 ft from 8' to 20'

KL = (6! + 2! * ll%) * 12

CALL COMPcompcap(Fy, AA, BB(kk%), CC(kk%), t(kk%), KL, Area, A, b, c, r, u,
rx, ry, ro, beta, Jstv, Cw, be, C1, C2, ds, gf, vc, hc, lip%, xwcl, 1, Pa)
CALL COMPcompcap2(Fy, AA, BB(kk%), CC(kk%), t(kk%), KL, Area, A, b, c, r, u,
rx, ry, ro, beta, Jstv, Cw, be, C1, C2, ds, gf, vc, hc, lip%, xwcl, 1, Pao)

Pcr = (pi ^ 2 * 29500! * lx(kk%)) / KL ^ 2
LPRINT USING "###.###"; KL / 12;
LPRINT TAB(10); USING "###.###"; Pa;
LPRINT TAB(18); USING "###.###"; Pao;
LPRINT TAB(26); USING "###.###"; Pcr;

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FOR JJ% = 1 TO 3 'spacing loop

Mx = KL ^ 2l / 8l * s * w / (1000l * 12l ^ 2)

IF Mx / Ma(kk%) >= .85 THEN

    P = (1 - Mx / Ma(kk%)) * Pa 'Eq. C5-3

ELSE

    A1 = -1.92 * Ma(kk%) / Pcr 'Eq. C5-1
    B1 = (1 + 1.92 * Pa / Pcr) * Ma(kk%)
    C1 = Pa * (Mx - Ma(kk%))

    CALL SECORDSOLV(A1, B1, C1, x1, x2) 'Eq. C5-2

    P = x1

    P2 = (1 - Mx / Ma(kk%)) * Pao

    IF P2 < P THEN P = P2

END IF

LPRINT TAB(18 + JJ% * 16); USING "####.##"; Mx;
LPRINT TAB(25 + JJ% * 16); USING "####.##"; P;

NEXT JJ%

LPRINT

NEXT II%

IF kk% = 5 THEN

    LPRINT CHR$(12)
    LPRINT "lateral load : w="; w; "psf"

END IF

NEXT kk%

LPRINT CHR$(12)

END
SUB COMPcompcap (Fy, AA, BB, CC, t, KL, Area, A, b, c, r, u,  
  rx, ry, ro, beta, Jstv, Cw, be, C1, C2, ds, gf, vc, hc, lip%, xwcl, grap%, Pa) 

'-------------computing Fe-------------'

Fe = pi ^ 2! * E / (KL / rx)^2!  'strong axis buckling

'for this modified vers. the wall studs are braced against
'weak axis and flexural-torsional buckling

.
.
.
.

CALL COMPeffwidth(A, t, 4!, FFn, grap%, la, ae)  'ae effective width of web
.
.
.
.

END SUB

SUB COMPcompcap2 (Fy, AA, BB, CC, t, KL, Area, A, b, c, r, u,  
  rx, ry, ro, beta, Jstv, Cw, be, C1, C2, ds, gf, vc, hc, lip%, xwcl, grap%, Pa) 

'this routine is the same as COMPcompcap except that it calculates Pao
'i.e. uses Fy instead of FFn when computing the effective area (Ae) of
'the section. Since Fy > Fn the Ae value computed this way will be less than
'the usual one, and as a result of that the corresponding P value (Pao) too

.
.
.
.

CALL COMPeffwidth(A, t, 4!, Fy, grap%, la, ae)  'ae effective width of web
.
.
.
.

END SUB
VITA

Zsolt V. Némedi was born in Budapest, Hungary on April 1, 1968. After receiving his Civil Engineering Degree from the Technical University of Budapest in 1991, he worked as a Structural Engineer in Austria. He enrolled in the graduate program at Virginia Polytechnic Institute and State University in January, 1992.

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