ANALYSIS AND DESIGN FOR TORSIONALLY LOADED COMBINATION SECTIONS

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ABSTRACT

In this study, a procedure for the design and analysis of unsymmetrically loaded combination sections was accomplished; combination sections being defined here as wide-flange shapes that have a channel section attached to the top flange.

The torsional method of analysis took into account that the entire combination section resists the vertical and lateral loads while current design practice usually considers the entire section to resist the vertical force and the top flange alone to resist the lateral force.

In order to conduct the torsion analysis of such combination sections, certain warping and torsional factors were evaluated. Once these elastic section properties were calculated, the torsional theory was first verified and then applied to a beam loaded by a two wheel crane. The torsional method was compared to the so-called conventional method of analysis with the result that the conventional method of analysis is perhaps not as conservative in some cases as originally thought.

Design aids for the torsional theory were developed in the format of design tables that list combination section properties for over 150 sections as well as tables which list the maximum allowable length of a crane beam for a given vertical load, lateral load, crane wheelbase, and steel strength.

ACKNOWLEDGEMENTS

During the course of working on this thesis, much information and time was required. It would have been impossible for the author of this manuscript to do all the thinking. I would therefore like to thank my advisor, Dr. Jack D. Bakos for all of the help, technical input, and criticisms which aided the completion of this thesis. The author would also like to thank V. E. Shogren for all of his help, input, and use of technical literature. I would also like to thank my family for their understanding and encouragement in the pursuit of my education. To all of these people I am indebted.

This thesis is dedicated to my grandfather, John W. Susor Sr., who may not have understood a word of this thesis, but would have been proud of it.

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LIST OF SYMBOLS

SYMBOLS	DEFINITION	UNITS
A	$1/\beta$	
A	Area of cross-section	in^2
C_w	Warping constant for a cross-section	in^6
B	L/2 - S/4	feet*
e	Distance from top of combination section to shear center of top flange only	in.
E	Modulus of elasticity	ksi
E_b	Distance from shear center of a combination section to bottom flange	in.
E_t	Distance from shear center of a combination section to top flange	in.
f_b	Normal bending stress at a point	ksi
f_{bC}	Actual bending stress in compression	ksi
f_{bT}	Actual bending stress in tension	ksi
f_{bw}	Normal warping stress at a point	ksi
F_{bC}	Allowable bending stress in compression	ksi
F_{bT}	Allowable bending stress in tension	ksi
G	Shear modulus of elasticity	ksi
I_x	Moment of inertia of section about X-axis	in^4
I_{xy}	Product of inertia	in^4
I_y	Moment of inertia of a section about Y-axis	in^4
I_{ycf}	Moment of inertia of top flange of a combination section about the Y-axis	in^4
K	Torsional constant of a combination section	in^4
L	Length of a beam	feet
L_{ij}	Length of an element between points i and j	in.

M_x	Bending moment about X-axis	kip-in
M_y	Bending moment about Y-axis	kip-in
P_x	Vertical wheel load	kips
P_y	Lateral wheel load	kips
q	Shear flow on a cross-section	kip/in
r_T	Radius of gyration comprising the compression flange plus one-third of the compression web area, taken about the Y-axis	in.
R	A constant involving sinh (see eq(3-6))	---
RH	Crane rail height	in.
S	Crane wheelbase	feet
T_0	Applied torque on a span	kip-in
t_{ij}	Thickness of an element between points i and j	in.
V	Shear stress on a beam web	ksi
w_{oi}	Unit warping function	in^2
W_{nA}	Normalized warping function at a point A on the top flange of a combination section	in^2
W_{nB}	Normalized warping function at a point B on the bottom flange of a combination section	in^2
β	A constant equal to $(GK/EC_w)^{\frac{1}{2}}$	in^{-1}
λ	Ratio of I_{ycf}/I_y	---
ρ_o	Distance from shear center to an element	in.
θ''	Second derivative of the angle of twist with respect to the distance along the beam	---
θ	The angle of twist of a torsionally loaded beam, at a point on the span	---

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Chapter 1

INTRODUCTION

In many tndustrial buildings, overhead cranes are incorporated into the manufacturing and handling of goods and equipment. For example. cranes are used extensively in steel fabrication plants, in production or assembly lines, in mill operations, in mining and countless other operations. These cranes serve these operations by lifting and transporting loads from one location to another. For this process to be implemented, a suitable system of crane beams and columns, called a crane runway, must be designed to handle all anticipated leads the crane nay ecnounter. The design of these crane beams is much more complicated than designing an ordinary steel beam. The design of these sophisticated systems witl be discussed in this paper.

In the design of crane beams, the structural engineer must take into account all of the loading conditions that could possibly be encountered. The major load on a crane beam is the direct, vertical force or wheel load. This is the largest force on a crane beam and is usually listed in catalogs provided by crane manufacturers. In addition, this wheel load must be given a percentage increase to account far any impact that could be produced when the crane load is raised and lowered and due to any subsequent movement of the load. This increase for impact is listed in section 1.3.3 of the design specifications of the American Institute of Steel Construction Manual of Steel Construction (1)* (herein referred to as "AISC Steel Code"). The next significant force on a crane beam is the lateral load that acts perpendicular to the beam

* Number in parentheses indicates reference cited.

span and is produced by the rocking movement of the crane trolley wheels. As outlined in section 1.3.4 of the AISC Steel Code (1) this force, which is assumed to act at the top of the crane rail, is specified as twenty percent of the lifted load plus the weight of the crane trolley. This force is divided equally between the two crane rails. The third force on the beam is the longitudinal force produced by the crane traveling along the crane rail. This force, which is resisted by the top flange of the beam, is usually not of much consequence and is often neglected. Lastly, the beam and rail weights must be considered.

Any type of beam must be designed to resist lateral torsional buckling. In addition, the lateral force on a crane beam is not contained in the plane of the minor or major axes and does not pass through the section's shear center and thus, these considerations are critical in the design. The AISC Steel Code specifies the maximum unbraced length that may be used,while still utilizing the full, permissible compressive bending stress. If this maximum length is exceeded, the allowable compressive stress must be reduced. This allowable compressive stress is directly controlled by the size or lateral stiffness of the compression flange. So, a beam with a larger top flange has more lateral stiffness and is permitted to have a longer unbraced length.

For most rolled beam shapes, the flanges are relatively narrow. Oftentimes, the size of the compression flange is increased to give the section a greater lateral stiffness. The most common procedure for reinforcing the top flange is by welding a channel section to that flange. This is called a built-up or a combination section and is shown in Figure (1-1).

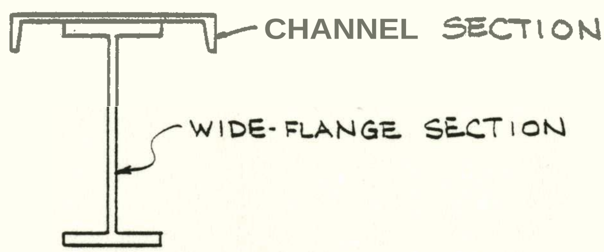


Fig. 1-1: Typical Combination Section

Such a profile is often used for a crane runway beam.

In the past, built-up crane beams, which are unsymmetrically loaded have been designed using a simplified procedure. This procedure considered the vertical wheel load to be carried by the entire built-up section and the lateral force to be applied at the top of the channel and resisted by only the added channel and top flange. This simplification is shown in Figure (1-2). This procedure has been considered

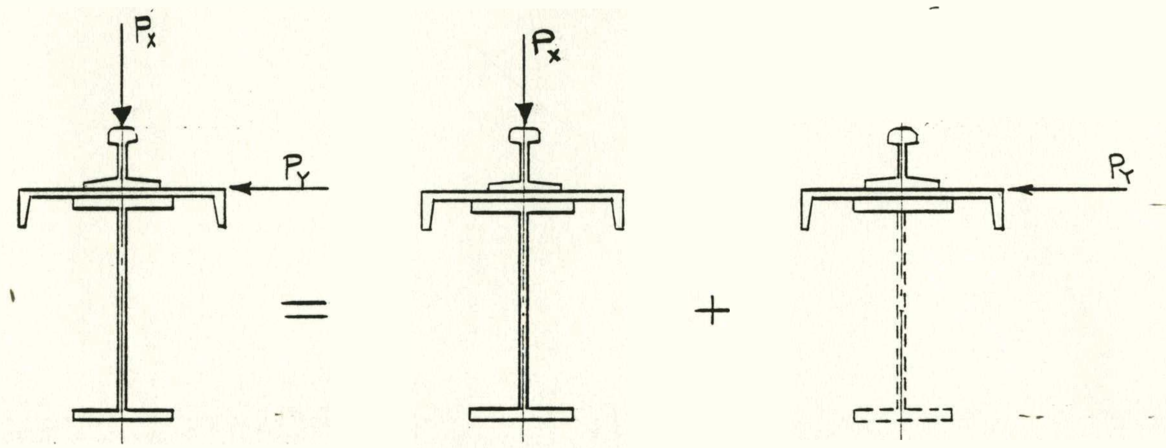


Fig. 1-2: Conventional Design Loading Procedure

conservative by most design engineers and thus not very precise since the lateral load is actually resisted by the entire cross section.

In order to obtain a more exact stress analysis of the unsymmetrically loaded section, a more rigorous procedure utilizing the equations for unsymmetrical bending of an elastic beam should be used. These equations are presented in many advanced strength of materials (3, 5) and steel design books (7, 8), but the use of these equations alone is insufficient since such an application assumes that the beam is loaded through its shear center. The shear center is defined as the point on a beam cross-section through which a force must act so that all twisting effects are eliminated. For a typical rolled wide-flange shape, and any other doubly-symnetric section, the shear center and the centroid are coincident. For a built-up section this is not the case. Obviously, the forces on a crane beam do not act through the shear center (See Figure 1-3).

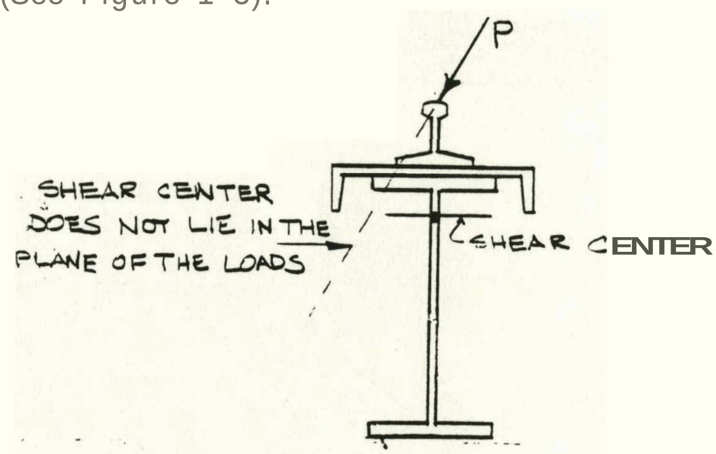


Fig. 1-3: Unsymmetrical and Torsional Loading of a Combination Section

Therefore, in addition to the unsymmetrical bending equations, a torsional analysis should be incorporated. The torsional analysis of wide-flanges, standard channels, and other individual shapes have been compiled by many other sources (2, 3, 4, 5). The Bethlehem Steel Company publishes an excellent handbook (2) for torsion of common rolled shapes. The torsion analysis is also presented by other sources. But, no reference could be found that lists such torsional properties for the previously mentioned combination sections. The intent of this paper is to compile the various torsion and warping properties of combination sections and

and to apply them to the case of a torsionally, unsymmetrically loaded crane beam.

Chapter 2

BENDING AND TORSION THEORY OF COMBINATION SECTIONS:

As previously stated, the unsymmetrical bending equation (3) will be used for the crane beam analysis. The modified equation for bending stress in an unsymmetrically loaded beam is given as

$$f_b = \frac{M_x(y - x\tan\alpha)}{I_x - I_{xy}\tan\alpha} \qquad (2\text{-}1)$$

where,

$$\tan\alpha = \frac{I_{xy} - I_x\cot\phi}{I_y - I_{xy}\cot\phi} \qquad (2\text{-}2)$$

and,

M_x = Bending moment about X-axis

I_x = Moment of inertia about X-axis

I_y = Moment of inertia about Y-axis

I_{xy} = Product of inertia

x, y = Coordinates of a point under consideration, using positive axes as shown.

= Angle between the plane of load, P, and the Xaxis.

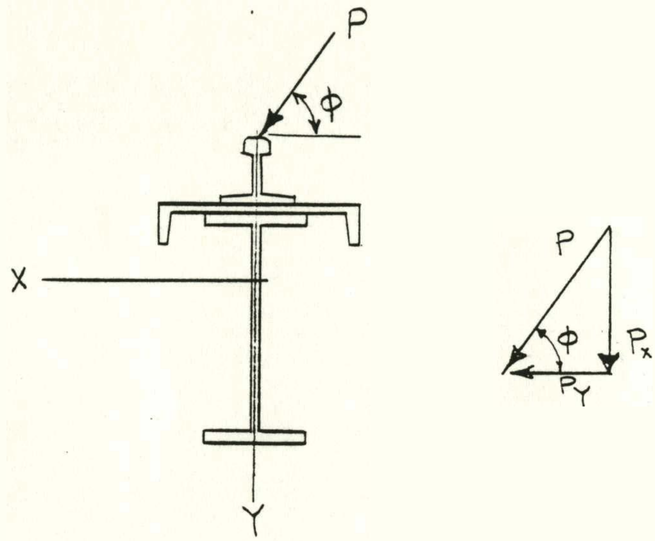


Fig. 2-1: Combination Section Subject to Unsymmetrical Bending.

In the case of a section that is symmetrical about one or both axes (see Fig. 2-1):

$$I_{xy} = 0$$

so;

$$\tan\alpha = -\frac{I_x}{I_y}\cot\phi \tag{2-3}$$

and

$$f_b = \frac{M_x}{I_x}(y - x\tan\alpha) \tag{2-4}$$

Substituting (2-3) into (2-4) yields:

$$f_b = \frac{M_x y}{I_x} + \frac{M_x x}{I_y}\cot\phi \tag{2-5}$$

From Figure 2-1, it is seen that ϕ is related to the horizontal and vertical loads. More specifically,

$$\cot\phi = \frac{P_y}{P_x} \tag{2-6}$$

The maximum live bending moment, M_x, may be easily calculated using a table of beam formulas. For a two wheel crane beam, the exact point of maximum moment varies with the span and crane wheelbase. There are two different loading conditions in which the maximum live moment might occur.

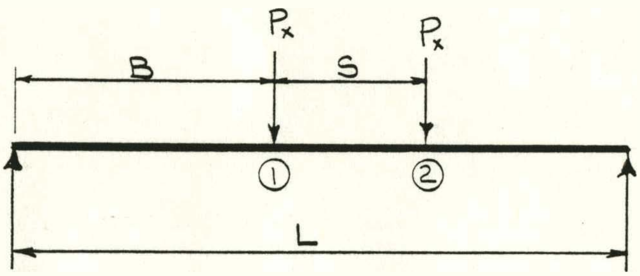


Fig. 2-2: Beam Loading Diagram if $S \leq 0.586L$

First, if $S \leq 0.586L$ (see Fig. 2-2),

$$M_x = \frac{P_x}{2L}\left(L - \frac{B}{2}\right)^2 \qquad (2\text{-}7)$$

under load 1 at $B = L/2 - S/4$.

But, if $S > 0.586L$, then

$$M_x = \frac{P_x L}{4} \qquad (2\text{-}8)$$

with one direct wheel load at the point $L/2$ on the beam span.

Once the maximum live moment is calculated, EQ. (2-5) can be used to calculate the maximum live unsymmetrical bending stress due to beam action. This would, however, be an incomplete analysis since additional bending stress is caused by torsion on the section since the load does not pass through the shear center. This additional stress is called the warping normal stress.

The warping normal stress is produced by the rotation of a beam about its shear center when a torque is applied. As this beam is twisted, cross-sections through the beam do not remain plane but warp out of plane. As the beam begins to warp, stresses normal to the cross-section develop (see Figure 2-3).

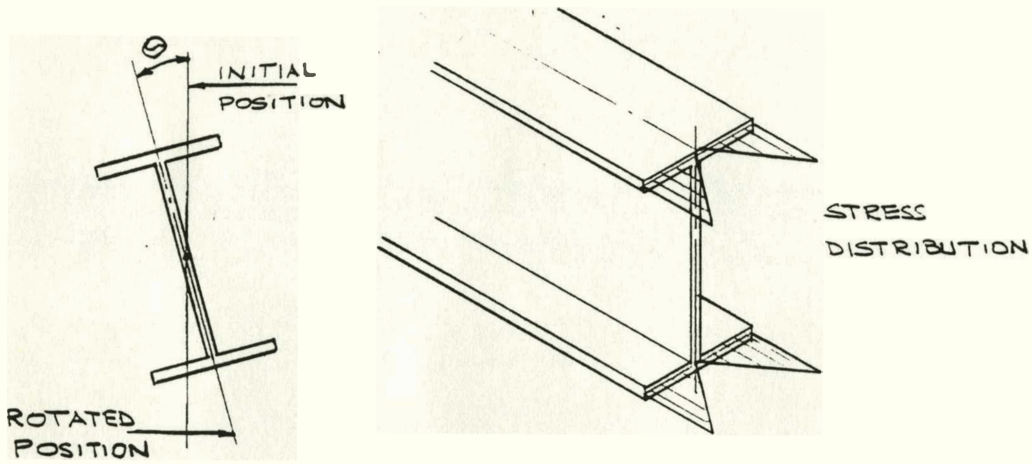


Fig. 2-3: Warping Normal Stress Distribution in a Wide-Flange Shape

$$f_{bw} = E\, W_n\, \theta'' \tag{2-9}$$

where

E = Modulus of elasticity

W_n = Normalized warping constant at a point on the cross-section

θ'' = Second derivative of the angle of rotation with respect to the distance along the length of the member.

The value of θ'' is a function of the torque on a beam, the beam length, and torsion and warping constants of the cross-section. Many sources list equations used to evaluate θ'' for various loading conditions and cross-sections (2,5) to evaluate θ''. The values for the torsion and warping constants are also needed. For wide flange shapes, these values are listed in Part 1 of the AISC Steel Manual, For combination sections, these constants are not, unfortunately, listed. The elastic properties for a limited number of combinations are listed. It will be necessary to develop expressions for these required constants.

The first parameter needed is the location of the shear center for the combination section. To locate it, the process outlined by Seely and Smith (3) will be used. Referring to Figure 2-4, a typical combination section is loaded through a point assumed to be the shear center. This force, V_x, will cause a shear flow on the cross-section to develop. This flow will produce forces F_1, F_2, F_3, and F_4.

$$F_1 = \int_0^{b_1} q_1 \, ds$$

where, q_1 , the shear flow is

$$q_1 = \frac{Vx}{I_y} t_1 \; s \; d_c/2$$

substituting and solving;

$$F_1 = \frac{V_x}{4I_y} t_1 d_c b_1^2$$

Likewise, F_2 and F_3 may be found to bet

$$F_2 = \frac{V_x}{2I_y}\left(\frac{b_1 t_1 d_c^2}{2} + \frac{t_2 d_c^3}{12}\right)$$

$$F_3 = \frac{V_x}{I_y}\left(t_3 b_3/3\right)$$

Now, taking the summation of the moments about point A:

$$V_x E_b = F_1 d_c + 2F_2 d_t + 2F_3 (d_T - \frac{t_2}{2} - \frac{t_3}{2})$$

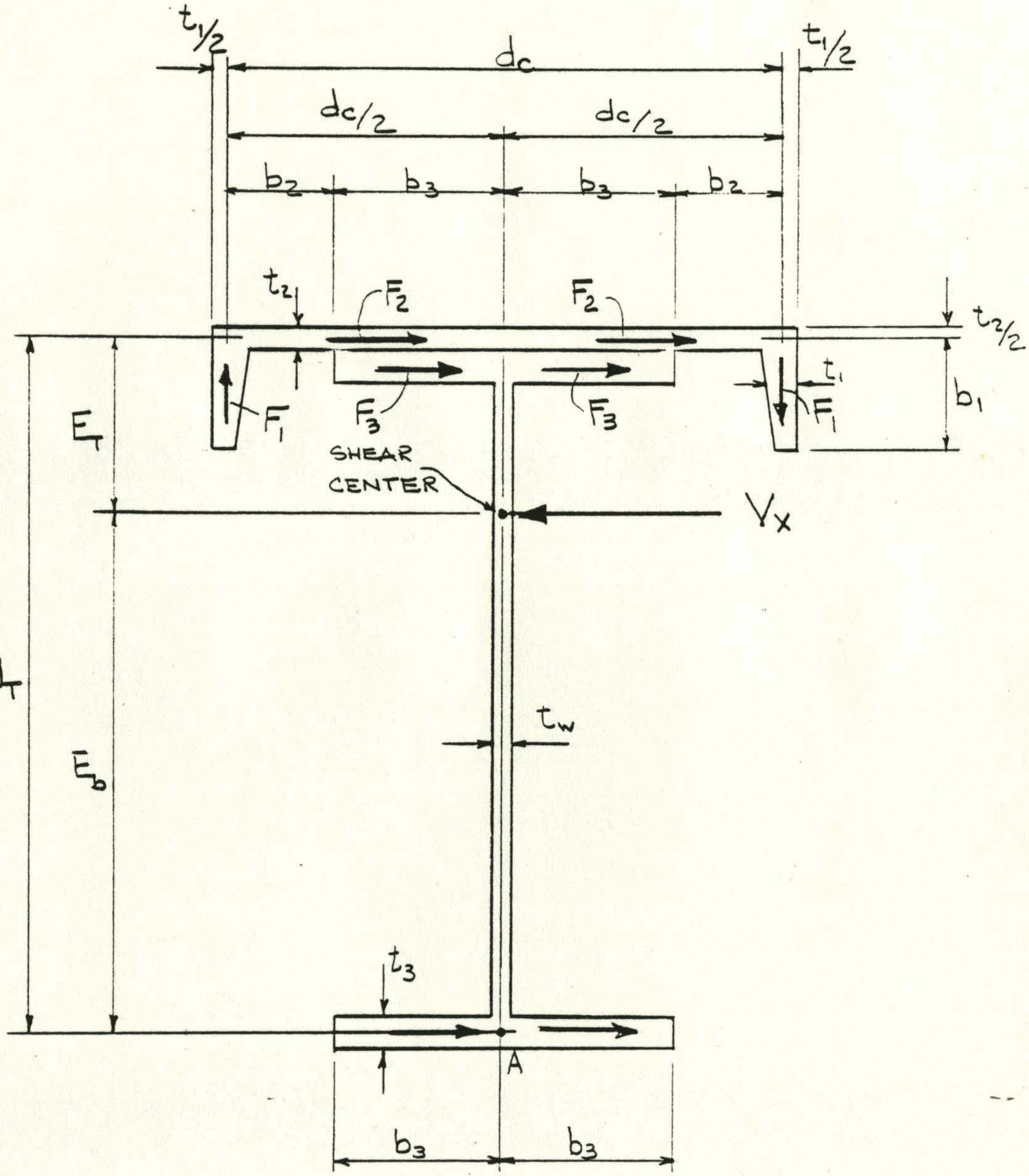


Fig. 2-4: Shear Flow in a Combination Section for the Determination of the Shear Center

Substituting for F_1, F_2, F_3, and solving yields:

$$E_b = \frac{1}{I_y}\left[b_1 t_1 d_c^2\left(\frac{b_1}{4} + \frac{d_T}{2}\right) + \frac{t_2 d_T d_c^3}{12} + \frac{2}{3}\left(d_T - \frac{t_2}{2} - \frac{t_3}{2}\right)t_3 b_3^3\right] \tag{2-10}$$

Now, that the expression for the shear center has been found, the remaining torsional and warping properties must be determined. The general mathematical expressions for these torsional and warping properties can be found in many references (2, 4, 8). C. P. Heins(4) has developed a numerical evaluation for standard steel sections, such as wide-flange shapes and channels. By expanding this numerical procedure, the warping and torsional properties for a combination section can be evaluated. The normalized warping function, W_{ni}, at point i on the cross section is given as:

$$W_{ni} = \frac{1}{2A}\sum(w_{oi} + w_{oj})t_{ij}L_{ij} - w_{oi} \tag{2-11}$$

where, w_{oi} = unit warping function = $\rho_{oi}L_{ij}$

t_{ij} = thickness of an element between i and j

L_{ij} = length of an element between i and j

A = total area = $\sum t_{ij}L_{ij}$

ρ_o = distance from shear center to element

The warping constant, C_w for the entire section is:

$$C_w = \frac{1}{3}\sum(W_{ni}^2 + W_{ni}W_{nj} + W_{nj}^2)\ t_{ij}L_{ij} \tag{2-12}$$

with the terms the same as for eq.(2-11).

The determination of both W_{ni} and C_w is best achieved utilizing a tabular format. First, the combination section is considered to be

TABLE 2-1: Combination Section Warping Properties

Point	ρ_o	L_{ij}	$\rho_o L_{ij}$		w_o	$t_{ij}L_{ij}$	$(w_{oi} + w_{oj})t_{ij}L_{ij}$	W_n
1					0			$E_b b_3$
	E_b	b_3	$E_b b_3$			$t_3 b_3$	$E_b t_3 b_3^2$	
2					$E_b b_3$			0
	0	h	0			$t_w h$	$2E_b b_3 t_w h$	
3					$E_b b_3$			0
	$E_t - t_3/2$	b_3	$b_3(E_t - t_3/2)$			$b_3(t_2+t_3)$	$b_3^2(t_2+t_3)(h+E_b-t_3/2)$	
4					$b_3(h-t_3/2)$			$b_3(t_3/2-E_t)$
	E_t	b_2	$E_t b_2$			$t_2 b_2$	$E_t t_2 b_2^2 + 2t_2 b_2 b_3(h-t_3/2)$	
5					$E_t b_2 + b_3(h-t_3/2)$			$b_3(t_3/2-E_t)-E_t b_2$
	b_2+b_3	b_1	$b_1(b_2+b_3)$			$t_1 b_1$	$t_1 b_1 b_2(2E_t+b_1)+t_1 b_1 b_3(2h+b_1-t_3/2)$	
6					$b_2(E_t+b_1)+b_3(h+b_1-t_3/2)$			$b_3 t_3/2-(b_2+b_3)(E_t+b_1)$
7					$2E_b b_3$			$-E_b b_3$
	$-E_b$	b_3	$-E_b b_3$			$b_3 t_3$	$3E_b t_3 b_3^2$	
2					$E_b b_3$			0
10					$b_3(E_b-E_t+t_3/2-b_1)-b_2(E_t+b_1)$			$(b_2+b_3)(E_t+b_1)-b_3 t_3/2$
	b_2+b_3	b_1	$b_1(b_2+b_3)$			$b_1 t_1$	$t_1 b_1(b_3(2E_b+t_3)-(b_2+b_3)(2E_t+b_1))$	
9					$b_3(E_b+t_3/2)-E_t(b_2+b_3)$			$E_t(b_2+b_3)-b_3 t_3/2$
	E_t	b_2	$E_t b_2$			$b_2 t_2$	$t_2 b_2(b_3(2E_b+t_3)-E_t(2b_3+b_2))$	
8					$b_3(E_b-E_t)+b_3 t_3/2$			$b_3(E_t-t_3/2)$
	$E_t-t_3/2$	b_3	$b_3(E_t-t_3/2)$			$b_3(t_2+t_3)$	$b_3^2(2E_b-E_t+t_3/2)(t_2+t_3)$	
3					$E_b b_3$			0

a sequence of inter-connected rectangular plate elements with the ends and intersections of the plates numbered arbitrarily (See Figure 2-5).

A continuous flow is assumed across the section points 1-2-3-4-5-6, with the flow on the elements 7-2 and 10-9-8-3 assumed to act from the free edges to the intersections.

The first term to be calculated is $w_o = \rho_o L$. The values of ρ_o are given in Table 2-1 and the sign of ρ_o is determined by the rule that moving from point i to point j, if the shear center is located to the left with respect to the flow, the value of ρ_o is positive. Thus, the values for w_o at the edges and intersections can be determined since ρ_o and L_{ij} for each element can be easily tabulated. It is first assumed that point 1 has $w_o = 0$ and, the summation of the results of $\rho_o L$ around the loop 1-2-3-4-5-6 yields the w_o at the respective points. Now, in order to calculate the w_o at point 7 and the w_o around the loop 10-9-8-3, the values of w_o at points 2 and 3 are used. These values are known since they were calculated in the previous loop. Since the flow is known to act from 7-2 and from 10 to 9 to 8 to 3, the w_o at the points 7, 8, 9, and 10 can be found directly as shown in Table 2-1.

Now, the equation for W_n can now be evaluated since the w_o are known. In Table 2-1, the areas, $t_{ij} L_{ij}$, and the sum of the $(w_{oi} + w_{oj}) \cdot t_{ij} L_{ij}$ are listed. The expression for w_{ni} can now be evaluated as

$$W_{ni} = E_b b_3 - w_{oi} \tag{2-13}$$

Therefore, by using equation (2-13), the values of W_n at the points on the section can be determined and are listed in Table 2-1.

Now, with the values of W_n at the points on the cross-section known, the warping constant, C_w, can be determined. Using EQ (2-12), the expression for C_w is found to be:

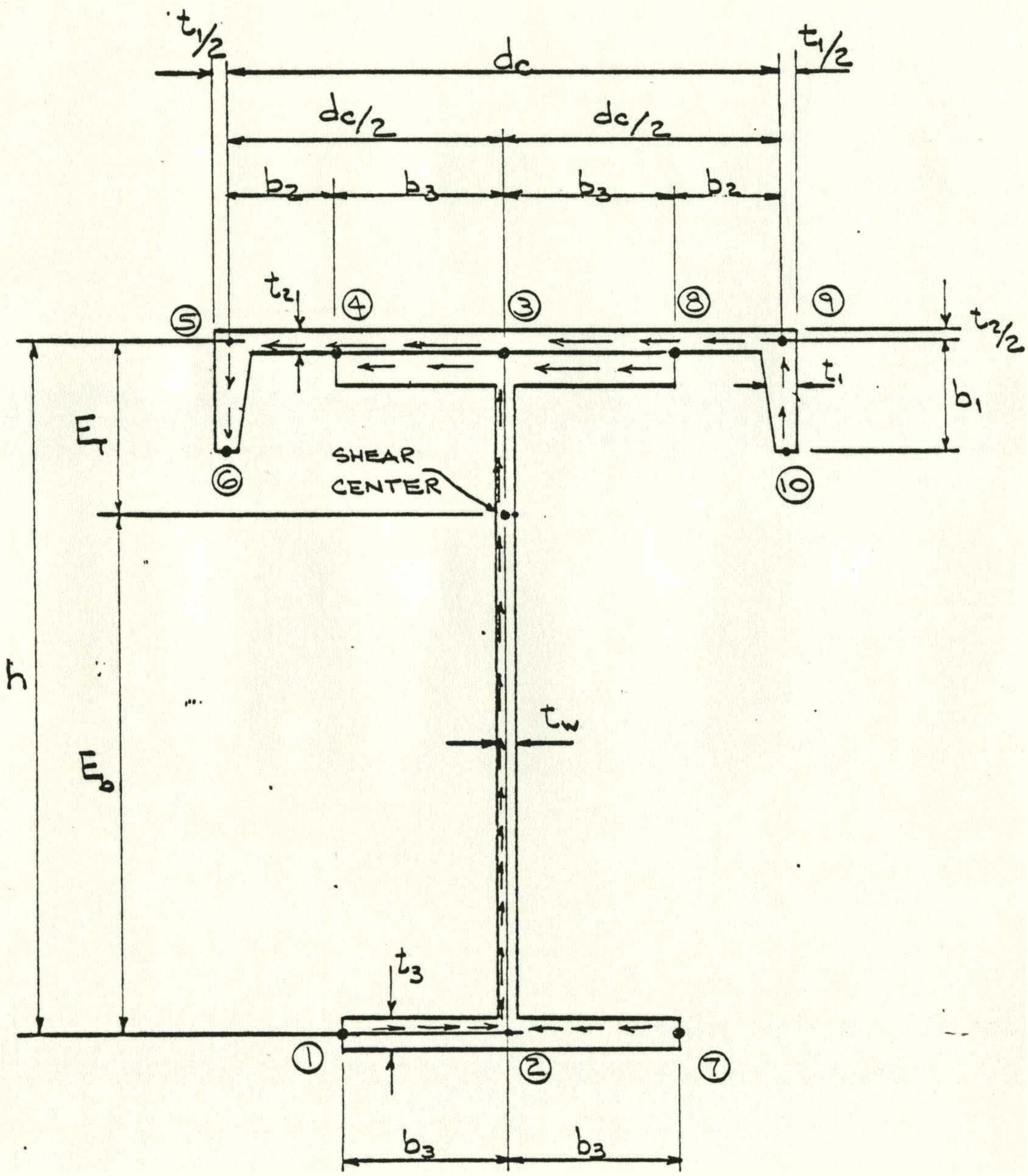


Fig. 2-5: Initially Assumed Shear Flow in a Combination Section for the Determination of C_w and W_n

$$C_w = \frac{2}{3}\Big\{t_3 b_3^3 E_b^2 + (t_2+t_3)(E_t-0.5t_3)^2 b_3^3 + b_2 t_2\Big[3b_3^2(E_t-0.5t_3)^2 + 3E_t b_2 b_3(E_t-0.5t_3) + (E_t b_2)^2\Big] + b_1 t_1\Big[3(E_t b_4-0.5b_3t_3)^2 + b_1 b_4(3E_t b_4-\frac{3}{2}b_3t_3+b_1b_4)\Big]\Big\} \quad (2\text{-}14)$$

Another torsional property required is the term:

$$\beta = \sqrt{\frac{GK}{EC_w}} \quad (2\text{-}15)$$

where: G = shear modulus of elasticity

E = modulus of elasticity

C_w = warping constant

$$K = \frac{1}{3}\Sigma(b_i t_i^3) \quad (2\text{-}16)$$

and t_i is always the smallest dimension and $b_i >> t_i$. Refering to figure(2-5), K may be expressed as follows:

$$K = \frac{1}{3}\left(2b_1t_1^3 + d_ct_2^3 + 4b_3t_3^3 + ht_w^3\right) \quad (2\text{-}17)$$

Now, with the values of K and C_w found, they may be substituted into EQ (2-15) and a value for β can be evaluated. The value for β usually is much less than zero and does not lend itself suitable for compiling into a tabular form. Therefore, the reciprocal of β is often tabulated as is the case for wide-flange shapes listed in the AISC Steel Manual. It is given as:

$$A = \frac{1}{\beta} = \sqrt{\frac{EC_w}{GK}} \quad (2\text{-}18)$$

Now, with the expression for the torsion and warping properties evaluated, the value of θ'' may be determined as described before. For the live load case of a two-wheel crane which was considered previously in an unsymmetrical banding mode, the expression for θ'' for the two load cases ($S \leq 0.586L$ and $S > 0.586L$) will be evaluated.

Case 1: $S \leq 0.586L$

For this case, two wheel loads are applied on the beam span. The two loads must be considered separately and the principle of superposition is used by taking the sum of the two values for θ'' at a point. See Figure 2-6.

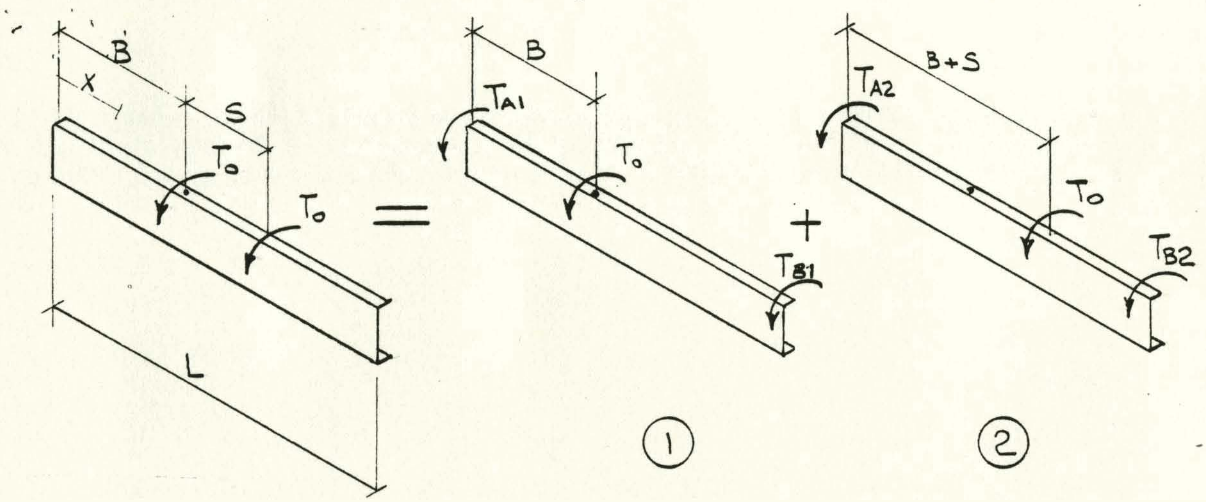


Fig. 2-6: Superposition of Two Torques on a Crane Beam

From Roark and Young (5), the value of θ'' for a concentrated intermediate torque on any beam is given as

$$\theta'' = \theta''_A \cosh\beta x + \theta'_A \beta \sinh\beta x + \frac{T_A}{C_w E \beta} \sinh\beta x + \frac{T_0}{C_w E \beta} \sinh\beta \langle x - b \rangle \tag{2-19}$$

where,

T_A = reaction torque at end, A

θ'_A = first derivative of θ at left end

θ''_A = second derivative of θ at left end

T_0 = applied torque on span.

For a crane beam, the applied torque, T_0, is defined as:

$$T_0 = P_y(E_t + RH) \tag{2-20}$$

where,

P_y' = lateral force at top of crane rail

E_t = distance from shear center to the top of the section

RH = crane rail height.

It must be mentioned that the boundary conditions to be used in evaluating θ'' are for a beam with ends that are resisted from rotating about the shear center but not resisted from warping out of plane. This is consistent with actual design practice because the crane beam ends are bolted on the bottom flange to form a seat while the top flange is connected to a stationary object such as a building column to prevent rotation.

Now, referring again to Figure (2 - 6), two torques must be considered. First, θ'' must be evaluated at X = B for the torque applied at X = B. The boundary conditions for this case are given as:

$$\theta''_A = 0 \qquad T_A = -T_0\left(1-\frac{B}{L}\right)$$

$$\theta'_A \equiv \frac{T_0}{C_w E \beta^2}\left(1 - \frac{B}{L} - \frac{\sinh\beta(L - B)}{\sinh\beta L}\right)$$

By applying these boundary conditions to EQ (2 - 19) and evaluating at the point X = B, yields:

$$\theta''_1 = \frac{T_0}{C_w E \beta}\,\frac{\sinh\beta B\,\sinh\beta(L - B)}{\sinh\beta L} \tag{2-21}$$

Next, the value for θ'' at the point X = B with T_0 applied at the point X = B + S must be evaluated. The boundary conditions for this loading are given as:

$$\theta_A'' = 0 \qquad T_A = -T_0\left(1 - \frac{(B + S)}{L}\right)$$

$$\theta_A' = \frac{T_0}{C_w E \beta^2}\left(1 - \frac{(B + S)}{L} - \frac{\sinh\beta(L - B - S)}{\sinh\beta L}\right)$$

Again, substituting these boundary conditions into eq. (2-19) and evaluating at X = B yields:

$$\theta_2'' = \frac{T_0}{C_w E \beta}\frac{\sinh\beta B \sinh\beta(L - B - S)}{\sinh\beta L} \tag{2-22}$$

Now, using the principle of superposition, it is possible to evaluate θ'' at the point X = B, which is the point of maximum moment. Therefore,

$$\theta_B'' = \theta_1'' + \theta_2''$$

or,

$$\theta_B'' = \frac{T_0}{C_w E \beta}\frac{\sinh\beta B}{\sinh\beta L}\left(\sinh\beta(L - B) + \sinh\beta(L - B - S)\right) \tag{2-23}$$

<u>Case 2:</u> $S > 0.586L$

For this case, the maximum moment due to the wheel loads occurs with one wheel located at midspan. For a concentrated torque at the midspan of a beam with the same end condition as in Case 1, the formula for θ'' has been evaluated by many sources. From Roark and Young (5), the equation for θ'' is given as:

$$\theta'' = \frac{T_0}{2 C_w E \beta}\tanh\frac{\beta L}{2} \tag{2-24}$$

Now, with the expressions for θ'' evaluated, and the expressions for the torsion and warping constants for any combination section, a crane beam can now be analyzed or designed easily and accurately.

Chapter 3

APPLICATIONS OF THE TORSIONAL THEORY OF COMBINATION SECTIONS

In order to analyze or design a torsionally loaded combination section as a crane beam, elastic section properties for the sections are required. As noted before, although the AISC Steel Manual lists some elastic section properties for some thirty different combination sections, no torsion or warping properties are given. Utilizing the equations developed for these properties as in Chapter 2, a computer program was developed to conveniently compute the elastic torsional, and warping properties for a large quantity of possible combination sections (See Appendix "A" for a listing). The output from this program was neatly arranged into a tabular form and is presented by Table 3-1.

In calculating the elastic section properties of the combination sections in Table 3-1, a check can be made for the values of E_b and .

In a paper by Kitipornchai and Trahair (6) dealing with monosymmetric I-Beams, an approximate solution for these two properties was outlined. In this approach, the ratio of the moment of inertia for the top flange versus the moment of inertia of the entire section, both about the Y-Y axis, is calculated (See Figure 3-1).

$$\lambda = \frac{I_{ycf}}{I_y} \tag{3-1}$$

Also, the shear center location of the too flange; e, is:

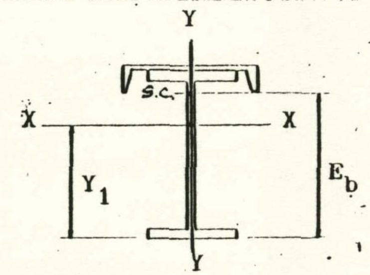
$$e = \frac{t_1 b_1^2 d_c^2}{4I_x} \tag{3-2}$$

The expressions for a and b are defined as:

$a = (1 - \lambda)h$ $\qquad$ $b = \lambda h$

TABLE 3-1

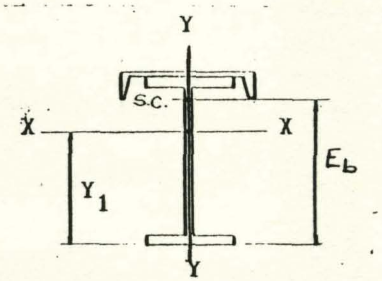
Section properties of combination sections



SECTION	TOTAL AREA	ELASTIC PROPERTIES				TORSION PROPERTIES					
		I_x	I_y	Y_1	r_T	E_b	K	C_w	A	W_{NA}	W_{NB}
	In^2	In^4	In^4	In	In	In	In^4	In^6	In	In^2	In^2
W12X 26-C10X15.3	12.14	298.7	84.7	8.22	3.24	11.54	0.467	1329.6	86.08	-2.31	37.44
W12X 26-C12X20.7	13.74	317.8	146.3	8.63	3.95	12.28	0.606	1499.2	80.19	1.24	39.85
W12X 30-C10X15.3	13.26	339.4	87.7	8.12	3.16	11.42	0.621	1541.8	80.34	-3.19	37.24
W12X 30-C12X20.7	14.66	361.0	149.3	8.52	3.88	12.23	0.761	1740.3	77.12	0.56	39.68
W12X 35-C10X15.3	14.79	394.5	91.9	8.03	3.10	11.27	0.904	1829.5	72.54	-4.38	36.95
W12X 35-C12X20.7	16.39	419.1	153.5	8.42	3.79	12.17	1.044	2071.1	71.83	-0.38	39.91
W12X 40-C10X15.3	16.29	413.4	111.5	7.51	3.15	9.89	1.006	2714.0	83.68	-8.10	39.59
W12X 40-C12X20.7	17.89	437.8	173.1	7.86	3.78	10.98	1.147	3131.5	84.23	-3.81	43.95
W12X 45-C10X15.3	17.69	458.7	117.4	7.46	3.11	9.74	1.345	3031.5	76.56	-9.11	39.20
W12X 45-C12X20.7	19.29	485.2	179.0	7.80	3.72	10.68	1.484	3512.3	78.44	-4.79	43.76
W12X 50-C10X15.3	19.19	508.1	123.7	7.43	3.06	9.61	1.708	3372.9	70.03	-10.08	38.83
W12X 50-C12X20.7	20.79	536.8	185.3	7.76	3.66	10.78	1.928	3923.2	72.74	-5.76	43.57
W12X 53-C12X20.7	21.69	566.9	224.6	7.61	3.79	9.80	1.739	5860.5	93.61	-10.72	48.75
W12X 58-C12X20.7	23.09	623.5	236.0	7.59	3.75	9.71	2.250	6542.4	86.95	-11.63	48.59
W14X 30-C10X15.3	13.34	420.1	87.0	9.12	3.21	12.61	0.525	1857.0	95.86	-3.92	43.11
W14X 30-C12X20.7	14.94	447.5	148.6	9.57	3.92	13.68	0.665	2072.0	90.00	0.05	46.05
W14X 34-C10X15.3	14.49	477.1	90.7	9.03	3.15	12.65	0.709	2179.1	89.39	-5.07	42.67
W14X 34-C12X20.7	16.09	507.5	152.3	9.48	3.84	13.61	0.849	2439.4	86.45	-0.87	45.90
W14X 38-C10X15.3	15.69	529.3	94.1	8.95	3.09	12.51	0.932	2466.3	82.92	-6.08	42.34
W14X 38-C12X20.7	17.29	562.5	155.7	9.39	3.77	13.54	1.072	2770.3	81.96	-1.69	45.83
W14X 43-C10X15.3	17.09	567.4	112.6	8.52	3.13	11.21	1.099	3575.4	91.98	-9.95	44.82
W14X 43-C12X20.7	18.69	600.8	174.2	8.92	3.75	12.43	1.236	4091.7	92.68	-5.28	49.70
W14X 48-C12X20.7	20.19	667.4	180.4	8.85	3.70	12.51	1.659	5037.3	88.84	-5.25	51.50
W14X 53-C10X15.3	20.09	693.6	125.1	8.43	3.04	10.88	1.950	4435.7	76.91	-12.20	43.85
W14X 53-C12X20.7	21.69	732.5	186.7	8.80	3.63	12.19	2.089	5119.7	79.82	-7.52	49.14
W14X 61-C12X20.7	23.99	837.6	236.0	8.60	3.73	11.03	2.342	8426.3	96.73	-13.00	55.11
W14X 61-C15X33.9	27.86	923.3	422.0	9.29	4.67	12.70	2.913	10207.5	95.45	-6.07	63.45
W14X 68-C12X20.7	26.09	930.5	250.0	8.56	3.68	10.85	3.135	9384.5	88.22	-15.25	54.46
W14X 68-C15X33.9	29.96	1023.7	436.0	9.23	4.60	12.59	3.706	11430.2	89.54	-7.44	63.13
W14X 74-C15X33.9	31.76	1110.8	449.0	9.19	4.54	12.49	4.546	12505.6	84.57	-8.71	62.88
W14X 82-C15X33.9	34.06	1212.9	463.0	9.13	4.48	12.40	5.708	13758.6	79.17	-9.89	62.82
W16X 36-C10X15.3	15.09	629.4	91.9	10.17	3.15	14.20	0.683	2889.7	104.85	-6.72	49.60

TABLE 3-1 (cont.)

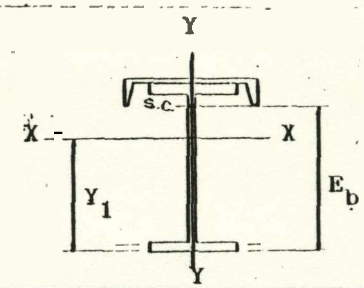
Section properties of combination sections



SECTION	TOTAL AREA	ELASTIC PROPERTIES				TORSION PROPERTIES					
		I_x	I_y	Y_1	r_T	E_b	K	C_w	A	W_{NA}	W_{NB}
	In^2	In^4	In^4	In	In	In	In^4	In^6	In	In^2	In^2
W16X 36-C12X20.7	16.69	670.3	153.5	10.67	3.84	15.29	0.823	3209.7	100.69	-2.10	53.40
W16X 36-C15X33.9	20.56	748.3	339.5	11.58	4.95	16.16	1.394	3694.6	83.00	2.99	56.43
W16X 40-C10X15.3	16.29	708.7	96.3	10.10	3.09	13.99	0.928	3359.4	97.00	-8.12	48.94
W16X 40-C12X20.7	17.89	753.2	157.5	10.59	3.76	15.18	1.068	3750.7	95.56	-3.27	53.08
W16X 40-C15X33.9	21.76	839.6	343.5	11.49	4.87	16.15	1.639	4308.8	82.67	2.29	56.50
W16X 45-C10X15.3	17.79	785.8	100.2	10.00	3.03	13.83	1.240	3776.0	88.98	-9.24	48.64
W16X 45-C12X20.7	19.39	834.3	161.8	10.47	3.69	15.08	1.380	4234.9	89.33	-4.24	53.04
W16X 45-C15X33.9	23.26	929.9	347.8	11.35	4.79	16.14	1.951	4865.0	80.52	1.69	56.79
W16X 50-C10X15.3	19.19	867.1	104.6	9.94	2.98	13.64	1.646	4222.4	81.68	-10.48	48.22
W16X 50-C12X20.7	20.79	919.1	166.2	10.39	3.63	14.96	1.785	4757.3	83.24	-5.33	52.90
W16X 50-C15X33.9	24.66	1023.1	352.2	11.26	4.72	16.13	2.356	5472.0	77.70	1.00	57.01
W16X 57-C10X15.3	21.29	977.0	110.5	9.86	2.52	13.42	2.333	4822.9	73.32	-11.97	47.79
W16X 57-C12X20.7	22.89	1033.7	172.1	10.29	3.55	14.63	2.472	5465.1	75.81	-6.71	52.78
W16X 57-C15X33.9	26.76	1149.3	358.1	11.13	4.63	16.11	3.044	6304.1	73.39	0.09	57.35
W16X 67-C15X33.9	29.66	1362.3	434.0	10.78	4.64	14.60	3.220	14987.1	110.00	-9.74	74.73
W16X 77-C15X33.9	32.56	1546.6	453.0	10.67	4.55	14.44	4.400	17222.6	100.88	-11.69	74.32
W16X 89-C15X33.9	36.16	1768.6	478.0	10.58	4.46	14.21	6.287	19975.6	90.89	-14.22	73.67
W16X100-C15X33.9	39.36	1986.0	501.0	10.53	4.38	14.06	8.601	22643.8	82.74	-16.22	73.28
W18X 35-C10X15.3	14.79	735.9	82.7	11.42	3.14	16.59	0.644	2371.4	97.87	-4.21	49.78
W18X 35-C12X20.7	16.39	786.1	144.3	11.98	3.86	17.52	0.783	2590.3	92.72	-0.01	52.55
W18X 35-C15X33.9	20.26	880.8	330.3	13.01	4.99	18.18	1.355	2974.9	75.57	4.17	54.54
W18X 40-C10X15.3	16.29	852.4	86.5	11.31	3.05	16.37	0.942	2912.7	89.64	-5.87	49.22
W18X 40-C12X20.7	17.89	908.4	148.1	11.86	3.75	17.42	1.082	3195.1	87.62	-1.27	52.39
W18X 40-C15X33.9	21.76	1016.2	334.1	12.87	4.89	18.21	1.653	3638.8	79.65	3.49	54.78
W18X 46-C10X15.3	17.99	965.6	89.9	11.19	2.97	16.17	1.347	3394.0	80.93	-7.23	49.01
W18X 46-C12X20.7	19.59	1027.3	151.5	11.71	3.66	17.33	1.487	3739.5	80.86	-2.34	52.52
W18X 46-C15X33.9	23.46	1148.3	337.5	12.70	4.79	18.23	2.058	4243.9	73.22	2.88	55.24
W18X 50-C10X15.3	19.19	1056.7	107.5	11.01	3.03	14.91	1.366	5496.8	102.28	-12.86	55.88
W18X 50-C12X20.7	20.79	1120.8	169.1	11.51	3.67	16.39	1.506	6175.2	103.26	-7.30	61.42
W18X 50-C15X33.9	24.66	1248.1	355.1	12.47	4.75	17.71	2.077	7036.0	93.85	-0.32	66.37
W18X 55-C10X15.3	20.69	1156.0	112.3	10.93	2.98	14.72	1.782	6082.2	94.20	-14.12	55.40

TABLE 3-1 (cont.)

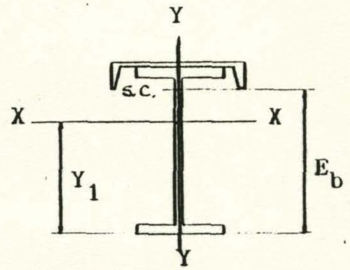
Section properties of combination sections



SECTION	TOTAL AREA	ELASTIC PROPERTIES				TORSION PROPERTIES					
		I_x	I_y	Y_1	r_T	E_b	K	C_w	A	W_{NA}	W_{NB}
	In^2	In^4	In^4	In	In	In	In^4	In^6	In	In^2	In^2
W18X 55-C12X20.7	22.29	1224.2	173.9	11.42	3.61	16.25	1.922	6863.8	96.37	-8.48	61.20
W18X 55-C15X33.9	26.16	1361.5	359.9	12.36	4.69	17.67	2.493	7845.9	90.46	-1.12	66.54
W18X 60-C10X15.3	22.09	1258.7	117.5	10.89	2.94	14.51	2.290	6696.0	87.19	-15.42	54.83
W18X 60-C12X20.7	23.69	1330.6	179.1	11.36	3.55	16.11	2.430	7588.7	90.12	-9.74	60.86
W18X 60-C15X33.9	27.56	1477.2	365.1	12.28	4.62	17.63	3.001	8707.2	86.86	-1.99	66.61
W18X 65-C10X15.3	23.59	1352.6	122.2	10.85	2.91	14.35	2.850	7251.0	81.33	-16.49	54-46
W18X 65-C12X20.7	25.19	1428.1	183.8	11.29	3.50	15.99	2.990	8246.1	84.68	-10.80	60.68
W18X 65-C15X33.9	29.06	1583.7	369.8	12.19	4.56	17.59	3.561	9494.9	83.26	-2.75	66.77
W18X 71-C10X15.3	25.29	1460.9	127.7	10.80	2.67	14.17	3.600	7882.7	75.49	-17.66	54.09
W18X 71-C12X20.7	26.89	1540.3	189.3	11.23	3.45	15.85	3.740	8995.4	79.08	-12.01	60-50
W18X 71-C15X33.9	30.76	1705.4	375.3	12.10	4.50	17.54	4.311	10400.3	79.20	-3.63	66-91
W18X 76-C15X33.9	32.26	1861.4	467.0	11.80	4.63	15.69	3.654	22626.3	126.89	-15.20	86.57
W18X 86-C15X33.9	35.26	2092.6	490.0	11.68	4.55	15.46	4.917	25658.4	116.48	-11.54	85.74
W18X 97-C15X33.9	38.46	2343.8	516.0	11.60	4.47	15.23	6.689	29039.8	106.24	-19.58	84.88
W18X106-C15X33.9	41.06	2526.2	535.0	11.54	4.42	15.09	8.312	31552.3	99.35	-21.56	84.49
W18X119-C15X33.9	45.06	2840.3	568.0	11.50	4.35	14.65	11.514	35737.9	89.83	-24.24	63-62
W21X 44-C10X15.3	17.49	1174.8	88.1	12.88	3.07	16.68	0.865	4130.3	111.43	-8.24	60.71
W21X 44-C12X20.7	19.09	1254.5	149.7	13.49	3.77	19.92	1.004	4502.9	107.96	-3.03	64.74
W21X 44-C15X33.9	22.96	1408.7	335.7	14.64	4.90	20.86	1.576	5026.6	91.07	2-34	67.79
W21X 50-C10X15.3	19.19	1331.7	92.3	12.76	2.99	18.40	1.219	4903.8	102.27	-10.06	60.06
W21X 50-C12X20.7	20.79	1418.4	153.9	13.34	3.68	19.77	1.359	5379.0	101.46	-4.50	64.55
W21X 50-C15X33.9	24.66	1589.2	339.9	14.47	4.80	20.85	1.930	6002.0	89.92	1.49	68.07
W21X 57-C10X15.3	21.19	1535.8	98.0	12.68	2.90	18.05	1.833	5923.6	91.66	-12.35	59.16
W21X 57-C12X20.7	22.79	1630.4	159.6	13.23	3.57	19.57	1.973	6548.2	92.90	-6.42	64.15
W21X 57-C15X33.9	26.66	1820.0	345.6	14.32	4.69	20.83	2.544	7323.2	86.51	0.33	68.20
W21X 62-C12X20.7	24.39	1798.1	186.5	13.01	3.60	18.18	2.033	11251.0	119.95	-13.95	74.89
W21X 62-C15X33.9	28.26	1997.1	372.5	14.06	4.65	20.02	2.604	12841.7	113.22	-4.95	82-41
W21X 68-C12X20.7	26.09	1964.7	193.7	12.93	3.55	17.96	2.635	12528.2	111.19	-15.63	74.28
W21X 68-C15X33.9	29.96	2176.9	379.7	13.95	4.58	19.92	3.206	14382.1	108.00	-6.22	82.38
W21X 73-C12X20.7	27.59	2098.0	199.6	12.87	3.50	17.79	3.205	13543.8	104.81	-16.97	73.80

TABLE 3-1 (cont.)

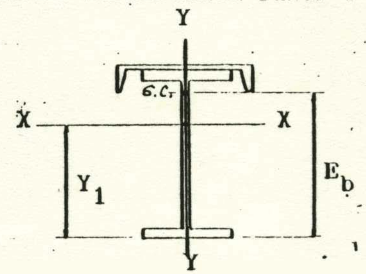
Section properties of combination sections



SECTION	TOTAL AREA	ELASTIC PROPERTIES				TORSION PROPERTIES					
		I_x	I_y	Y_1	r_T	E_b	K	C_w	A	W_{NA}	W_{NB}
	In^2	In^4	In^4	In	In	In	In^4	In^6	In	In^2	In^2
W21X 73-C15X33.9	31.46	2320.9	385.6	13.86	4.52	19.64	3.777	15617.1	103.69	-7.26	82.30
W21X 83-C12X20.7	30.39	2350.4	210.4	12.78	3.43	17.51	4.501	15392.6	94.29	-19.20	73.15
W21X 83-C15X33.9	34.26	2591.7	396.4	13.72	4.43	19.70	5.072	17884.4	95.74	-9.08	82.31
W21X 93-C12X20.7	33.39	2611.8	221.9	12.71	3.37	17.23	6.182	17308.0	85.32	-21.41	72.55
W21X 93-C15X33.9	37.26	2870.9	407.9	13.60	4.34	19.56	6.753	20254.6	88.31	-10.95	82.33
W24X 68-C12X20.7	26.19	2446.5	199.4	14.53	3.62	19.52	2.069	16971.7	146.05	-19.70	89.31
W24X 68-C15X33.9	30.06	2715.5	385.4	15.67	4.64	22.17	2.640	19427.0	138.32	-5.18	95.40
W24X 68-C18X42.7	32.70	2857.7	624.4	16.27	5.60	23.12	2.882	20592.4	137.62	-3.38	103.64
W24X 76-C12X20.7	28.49	2742.0	211.5	14.43	3.55	19.55	2.865	19543.5	133.17	-22.44	87.88
W24X 76-C15X33.9	32.36	3031.5	397.5	15.52	4.55	21.97	3.436	22565.3	130.66	-11.43	98.77
W24X 76-C18X42.7	35.00	3187.0	636.5	16.11	5.49	23.03	3.678	24437.3	131.43	-5.19	103.53
W24X 84-C12X20.7	30.79	3035.1	223.4	14.35	3.49	19.22	3.873	22011.4	121.55	-24.91	86.69
W24X 84-C15X33.9	34.66	3343.6	409.4	15.40	4.47	21.78	4.445	25604.5	122.38	-13.55	98.25
W24X 84-C18X42.7	37.30	3511.6	648.4	15.98	5.39	22.94	4.687	27801.1	124.19	-6.94	103.47
W24X 94-C12X20.7	33.79	3391.9	238.0	14.27	3.43	18.86	5.436	24969.7	109.28	-27.64	85.48
W24X 94-C15X33.9	37.66	3722.7	424.0	15.27	4.38	21.56	6.008	29273.2	112.56	-16.03	97.73
W24X 94-C18X42.7	40.30	3905.6	663.0	15.82	5.28	22.83	6.250	31893.7	115.19	-9.04	103.47
W27X 84-C12X20.7	30.89	3672.4	235.0	15.91	3.60	20.91	2.907	29808.7	163.27	-30.74	104.12
W27X 84-C15X33.9	34.76	4053.2	421.0	17.07	4.56	23.82	3.478	34693.8	161.03	-18.25	116.64
W27X 84-C18X42.7	37.40	4260.8	660.0	17.71	5.47	25.18	3.721	37570.0	162.03	-10.90	125.38
W27X 94-C12X20.7	33.79	4123.3	253.0	15.81	3.54	20.47	4.101	34275.2	147.41	-33.87	102.26
W27X 94-C15X33.9	37.66	4530.1	439.0	16.92	4.46	23.52	4.672	40226.7	149.62	-21.29	117.49
W27X 94-C18X42.7	40.30	4755.5	678.0	17.53	5.36	25.00	4.914	43761.2	152.16	-13.55	124.87
W27X102-C12X20.7	36.09	4496.5	268.0	15.76	3.50	20.15	5.334	37893.9	135.91	-36.24	100.91
W27X102-C15X33.9	39.96	4922.7	454.0	16.82	4.40	23.28	5.905	44721.5	140.32	-23.70	116.58
W27X102-C18X42.7	42.60	5161.3	693.0	17.42	5.27	24.85	6.147	48828.2	143.71	-15.70	124.45
W27X114-C15X33.9	43.46	5447.6	474.0	16.68	4.32	22.55	7.519	50347.4	128.57	-26.90	115.55
W27X114-C18X42.7	46.10	5704.1	713.0	17.26	5.17	24.64	8.161	55212.7	132.63	-18.61	124.05
W30X 99-C15X33.9	39.06	4944.9	443.0	18.51	4.49	25.77	4.346	49577.0	172.92	-25.10	134.66
W30X 99-C18X42.7	41.70	5227.2	682.0	19.18	5.39	27.41	4.588	54216.0	175.29	-16.77	143.21

TABLE 3-1 (cont.)

Section properties of combination sections



SECTION	TOTAL AREA	ELASTIC PROPERTIES I_x	I_y	Y_1	r_T	TORSION PROPERTIES E_b	K	C_w	A	W_{NA}	W_{NB}
	In^2	In^4	In^4	In	In	In	In^4	In^6	In	In^2	In^2
W30X108-C15X33.9	41.66	6077.7	461.0	18.39	4.42	25.44	5.526	56391.2	162.89	-28.20	133.26
W30X108-C18X42.7	44.30	6376.9	700.0	19.04	5.29	27.19	5.768	61443.0	166.42	-19.56	142.43
W30X116-C15X33.9	44.16	6586.4	479.0	18.30	4.36	25.14	6.542	62722.2	153.27	-31.09	131.93
W30X116-C18X42.7	46.80	6901.2	718.0	18.93	5.21	26.99	7.184	68618.6	157.59	-22.23	141.65
W30X124-C15X33.9	46.46	7058.5	496.0	18.24	4.30	24.85	8.482	68375.5	144.77	-33.80	130.67
W30X124-C18X42.7	49.10	7386.9	735.0	18.85	5.14	26.79	8.724	75058.6	149.57	-24.79	140.87
W30X132-C15X33.9	48.86	7507.5	511.0	18.17	4.26	24.64	10.195	73543.9	136.95	-35.91	129.90
W30X132-C18X42.7	51.50	7848.8	750.0	18.76	5.07	26.64	10.437	80962.9	142.02	-26.84	140.47
W33X118-C15X33.9	44.66	7899.9	502.0	20.01	4.44	27.01	5.775	84123.4	194.62	-38.61	155.05
W33X118-C18X42.7	47.30	8281.6	741.0	20.69	5.28	29.13	6.017	92159.6	199.56	-29.05	167.19
W33X130-C15X33.9	48.26	8781.8	533.0	19.88	4.37	26.49	7.785	96236.3	179.28	-43.26	152.45
W33X130-C18X42.7	50.90	9187.4	772.0	20.53	5.18	28.73	8.027	105993.3	185.29	-33.62	165.37
W33X141-C15X33.9	51.56	9583.5	561.0	19.79	4.31	26.09	10.083	107204.1	166.27	-46.94	150.48
W33X141-C18X42.7	54.20	10009.6	800.0	20.42	5.09	28.42	10.325	118560.2	172.79	-37.39	163.93
W33X152-C15X33.9	54.66	10347.6	588.0	19.73	4.26	25.72	12.714	117296.8	154.88	-50.37	148.71
W33X152-C18X42.7	57.30	10791.7	827.0	20.33	5.02	28.12	12.956	130148.3	161.61	-40.96	162.61
W36X135-C15X33.9	49.66	10215.5	540.0	21.26	4.40	28.34	7.323	114376.6	201.52	-48.00	169.31
W36X135-C18X42.7	52.30	10692.8	779.0	21.95	5.20	30.75	7.565	125864.0	207.99	-37.89	183.71
W36X150-C15X33.9	54.16	11548.3	585.0	21.15	4.32	27.63	10.364	133898.9	183.28	-54.23	165.43
W36X150-C18X42.7	56.80	12056.5	824.0	21.81	5.09	30.18	10.606	148220.8	190.62	-44.34	180.69
W36X160-C15X33.9	56.96	12309.1	610.0	21.09	4.28	27.29	12.585	144584.0	172.83	-57.32	163.71
W36X160-C18X42.7	59.60	12834.6	849.0	21.72	5.03	29.89	12.827	160472.3	180.36	-47.64	179.33
W36X170-C15X33.9	59.96	13109.6	635.0	21.02	4.24	26.99	15.242	155448.9	162.84	-60.04	162.35
W36X170-C18X42.7	62.60	13652.4	874.0	21.64	4.97	29.63	15.484	172926.6	170.40	-50.66	176.24
W36X182-C15X33.9	63.56	13962.8	662.0	20.95	4.20	26.68	18.583	166873.0	152.80	-62.85	161.11
W36X182-C18X42.7	66.20	14524.3	901.0	21.54	4.91	29.36	18.825	186014.8	160.28	-53.82	177.26
W36X194-C15X33.9	66.96	14812.0	690.0	20.90	4.17	26.37	22.306	178249.8	144.14	-65.71	159.73
W36X194-C18X42.7	69.60	15390.5	929.0	21.47	4.86	29.08	22.548	199036.1	151.50	-57.08	176.12
W36X210-C18X42.7	74.40	16574.6	965.1	21.38	4.79	28.75	28.293	216142.3	140.93	-60.85	175.11

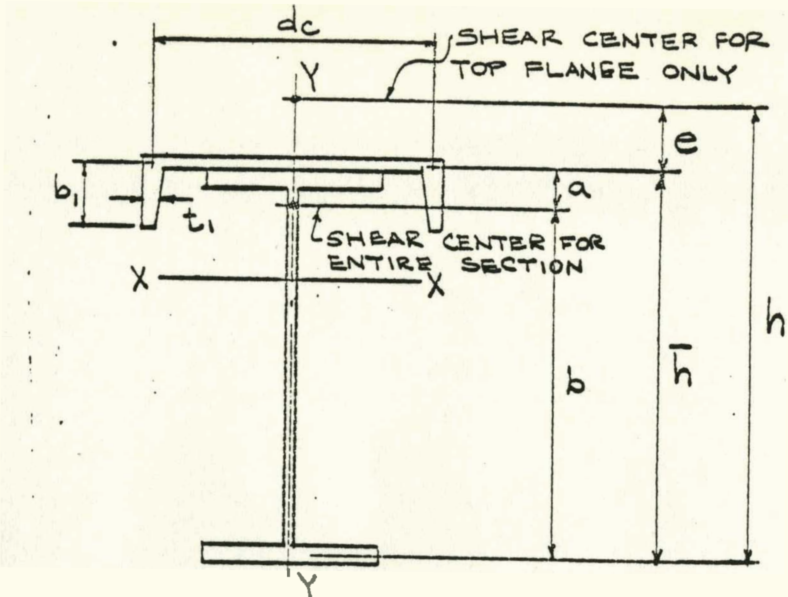


Fig. 3-1: Combination Section for the Determination of E_b and C_w by the Simplified Method

But, $b = E_b$, the distance from the shear center to the bottom flange. Therefore;

$$E_b = \lambda h \tag{3-3}$$

The expression for the warping constant is given as:

$$C_w = \lambda(1 - \lambda) I_y^2 h \tag{3-4}$$

By incorporating these solutions into the computer program for elastic section properties, a comparison of the different values for E_b and C_w can be made. Although the values for the approximate solution are not included in the elastic section properties of Table 3-1, they were calculated and compared. The values for C_w and E_b for the two methods agreed quite well as is shown in TABLE 3-2.

SECTION	E_b (in.)			C_w (in.^{6})		
	Eq(2-11)	Eq(3-3)	% diff.	Eq(2-14)	Eq(3-4)	% diff.
W14X30-C10X15.3	12.81	12.92	0.83	1857.	1847.	0.52
W18X50-C12X20.7	16.39	16.49	0.62	6175.	6205.	0.49
W24X84-C12X20.7	19.22	19.39	0.85	29809.	30594.	2.64
W30X116-C15X33.9	25.14	25.39	1.00	62722.	63912.	1.90
W36X150-C18X42.7	30.18	30.55	1.22	148221.	151281.	2.06

TABLE 3-2: Comparison Between the Exact Method and the Approximate Method for C_w and E_b.

In the determination of the normal warping stress, the value of θ'' is needed. The value of θ'' for a given loading condition and beam span may be evaluated using formulas or design charts. Roark, and Young (5) give formulas for obtaining θ'' for a multitude of loading conditions. The Bethlehem Steel Corporatfon publishes a torsional design handbook (2) that contains design charts for a rapid determination of θ'' for a limited quantity of load eases.

For the loading condition consisting of two crane wheels on a simply supported beam span, the equations for θ'' were given as EQ. (2-21) or EQ. (2-22). EQ (2-21) tan be rewritten as:

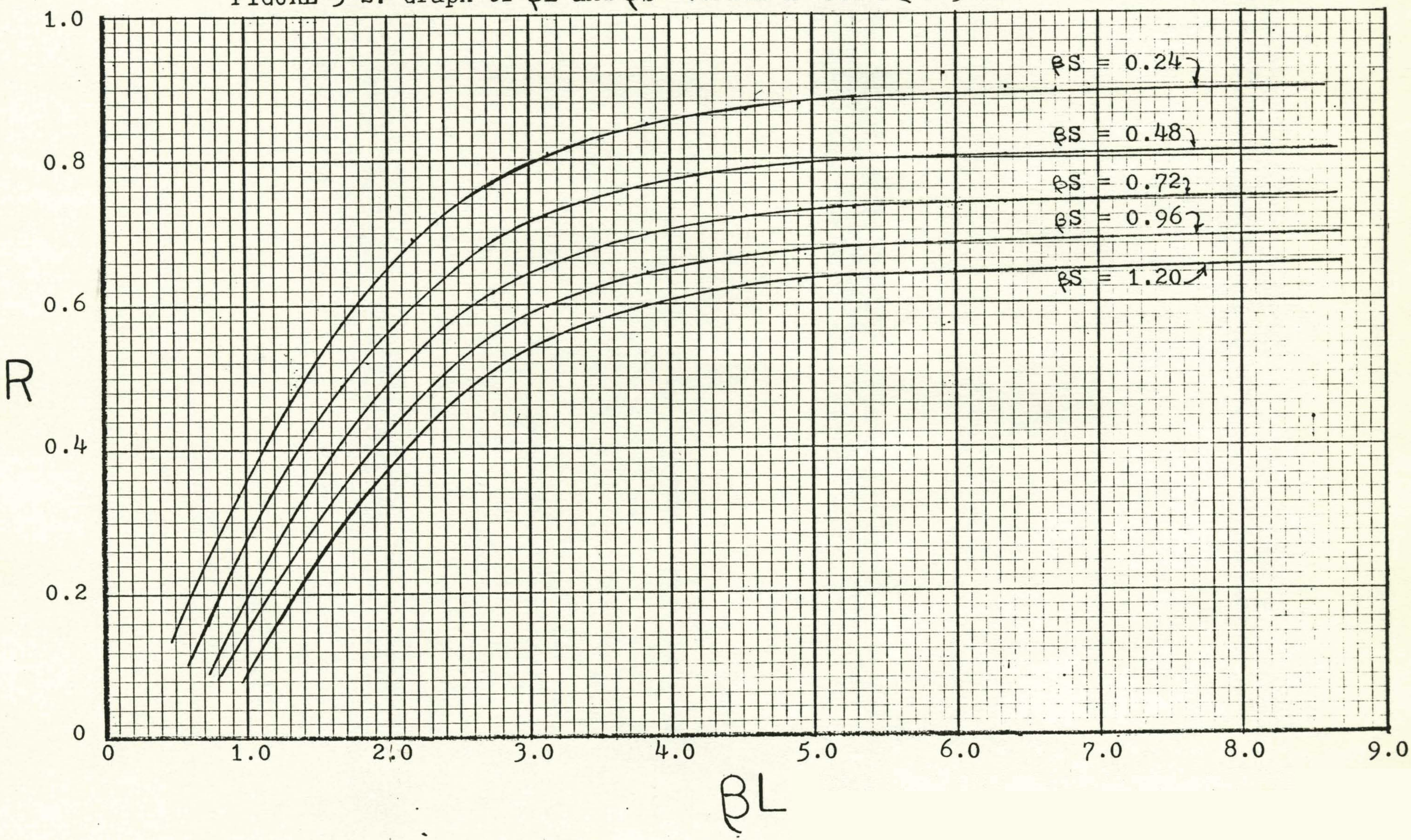
$$\theta'' = \frac{T_0}{C_w E \beta} R \tag{3-5}$$

where

$$R = \frac{\sinh\beta B}{\sinh\beta L}(\sinh\beta(L - B) + \sinh\beta(L - B - S)) \tag{3-6}$$

EQ. (2-21) is valid only if $S \leq 0.586L$. The expression for R is cumbersome to handle and evaluate, but a very efficient design chart can be developed relating βL, βB, θ''. Calculating a large quantity of values for θ'', a plot can then be made as shown as Figure 3-2. In order to use the chart, the value of βL for a given condition is located on the abscissa. Then, moving vertically until the correct curve for the value of βS is found. It is necessary to only move horizontally to the left and read the value for R on the ordinate. If the given value for βS falls between two curves on the chart, linear interpolation may be used to yield a satisfactory value for R. If the wheelbase $S > 0.586L$ is encountered, the chart <u>cannot</u> be used. In this instance,

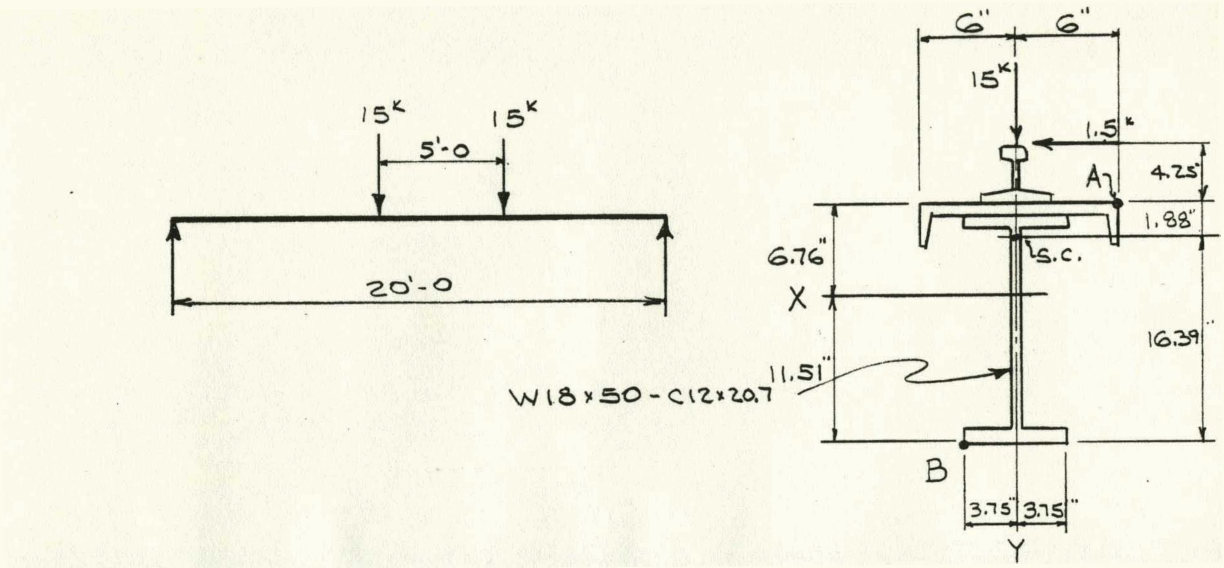
FIGURE 3-2: Graph of βL and βS Versus **R** for $S \leq 0.586L$



however, the value of θ'' as given by EQ. (2-22) can be easily calculated.

The following example showing the analysis of a crane beam will demonstrate the use of these tables and the torsion theory.

Example 3.1:



Given the beam section and load combination shown above, find the maximum live bending stresses using both the more exact torsion theory and the usually accepted conservative method.

Solution:

Since $S \leq 0.586L$, eq(2-7) is used to evalute M_x. Thus,

$$M_x = 1378.13 \text{ kip-in.}$$

Likewise, M_y is calculated as

$$M_y = 137.8 \text{ kip-in.}$$

The allowable bending stresses may be evaluated using the AISC Steel Manual (1) Specifications, Section 1.5.1.4.5. For this combination section,, the allowable tensile bending stress is:

$$F_{bT} = 0.60F_y = 22.0 \text{ ksi}$$

The allowable compression stress can be evaluated using either Code eq(1.5-6a) or eq(1.5-6b), whichever applies.

Since

$$L/r_t = \frac{20(12)}{3.67} = 65.40$$

it is seen that:

$$\frac{102(10^3)}{F_y} \leqslant L/r_t \leqslant \frac{510(10^3)}{F_y}$$

or $$53.2 \leqslant L/r_t \leqslant 119.2$$

Therefore, Code eq(1.5-6a) is used to calculate the allowable compressive bending stress. Hence,

$$F_{bC} = \left[\frac{2}{3} - \frac{F_y(L/r_t)^2}{1530(10)^3}\right] F_y$$

$$F_{bC} = 20.4 \text{ ksi}$$

With the allowable stresses calculated, the actual bending stresses can now be evaluated. The stresses at points A and B will first be evaluated using the conservative method. For this method, the bending stress for the top (compression) flange is given by the equation:

$$f_b = \frac{M_x c_x}{I_x} + \frac{M_y c_y}{I_{ycf}}$$

where I_{ycf} = moment of inertia of the top flange

c_x, c_y = distance to point under consideration from the X-axis and Y-axis, respectively

For the combination section in this example, $I_{ycf} = 149 \text{ in.}^4$

Now, evaluating the maximum compressive stress at point A:

$$f_{bA} = \frac{1378.13(6.76)}{1120.8} + \frac{137.8(6.0)}{149.0}$$

$$f_{bA} = 13.9 \text{ ksi} < F_{bC} = 20.4 \text{ ksi} \quad \underline{\text{O.K.}}$$

The tensile stress at point B is calculated as:

$$f_{bB} = \frac{M_x c_x}{I_x} = \frac{1378.13(11.51)}{1120.8}$$

$$f_{bB} = 14.15 \text{ ksi} < F_{bT} = 22.0 \text{ ksi} \quad \underline{\text{O.K.}}$$

Next, the bending stresses will be calculated using the more exact torsion theory.. First, the unsymmetrical bending stresses will be calculated using eq(2-5). Thus,

$$f_b = \frac{M_x y}{I_y} + \frac{M_x x}{I_y} \cot\phi \tag{2-5}$$

Calculating the compressive bending stress,

$$f_{bC} = 1378.13\left(\frac{6.76}{1120.8}\right) + \frac{6.00}{169.1}(0.10)$$

$$f_{bC} = 13.20 \text{ ksi} < F_{bC} = 20.4 \text{ ksi} .$$

The tensile bending stress is now calculated as,

$$f_{bT} = 1378.13\left(\frac{11.51}{1120.8}\right) + \frac{3.75}{169.1}(0.10)$$

$$f_{bT} = 17.21 \text{ ksi} < F_{bT} = 22.0 \text{ ksi} .$$

Now, the warping normal stresses have to be calculated and added to the unsymmetrical bending stresses calculated above. The warping normal stress can be evaluated using eq(2-9):

$$f_{bw} = EW_n \theta''$$

where θ'' is found using eq(3-5),

$$\theta'' = \frac{T_0}{C_w E \beta} R$$

with

$$T_0 = P_y(E_t + RH)$$

$$T_0 = 1.5(1.88 + 4.25)$$

$$T_0 = 9.20 \text{ kip-in.}$$

So, the value of θ'' is calculated as:

$$\theta'' = \frac{1}{E}\ \frac{9.20(102.28)}{6175.2}(0.687)$$

$$\theta'' = 0.10468/E \quad .$$

So, the normal warping stress (compressive) at point A is:

$$f_{bwA} = E\ W_{nA}\ \theta''$$

$$f_{bwA} = 7.30(0.10468)$$

$$f_{bwA} = 0.8 \text{ ksi}$$

and, the normal warping stress (tension) at point B is:

$$f_{bwB} = E\ W_{nB}\ \theta''$$

$$f_{bwB} = 61.42(0.10468)$$

$$f_{bwB} = 6.4 \text{ ksi} \quad .$$

Now, adding the warping normal stresses to the unsymmetrical bending stresses at points A and B will give the total bending stresses for the torsion method. So,

$$f_{bA} = 13.2 + 0.8$$

$$f_{bA} = 14.0 \text{ ksi} \leq F_{bC} = 20.4 \quad \underline{\text{O.K.}}$$

and

$$f_{bB} = 17.2 + 6.4$$

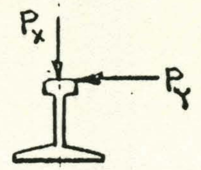
$$f_{bB} = 23.6 \text{ ksi} > F_{bT} = 22.0 \text{ ksi} \quad \underline{\text{No Good}}$$

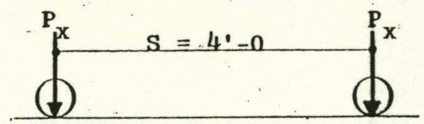
As shown, the allowable tension stress in the bottom flange is exceeded, so the torsion method of analysis indicates the beam is overstressed while the "conservative" method indicates it is not overstressed. Thus, it appears the "conservative" method may not always be conservative.

In comparing the stresses calculated by the two methods, a very interesting item is observed. The torsion method of analysis and the conventional method yielded almost equal values for the compressive bending stress; 13.9 ksi versus 14.0 ksi. But, the conventional method underestimated the tensile bending stress , grossly. The conventional method yielded a tensile bending stress of 14.2 ksi while the torsion analysis yielded a tensile bending stress of 23.6 ksi. So, it seems the conventional method is conservative only with respect to the compressive stress and is unconservative with respect to the tensile stress.

In the design of a crane beam, the process is not straight-forward due to the many unknown quantities encountered. Most often, the designer will know the required beam span and the capacity of the crane (along with all corresponding manufacturers' dimensions and wheel loads) that are to be employed. Therefore, a suitable combination section must be chosen. This usually requires a trial and error procedure, but the design can be considerably shortened if, for a given wheel loading condition and combination section, the maximum allowable span for the beam was known. By expanding the computer program used to calculate section properties for combination sections (see Appendix A), a set of tables has been constructed in which the maximum allowable lengths have been listed for a variety of wheel loads, lateral loads, and wheelbases. Also, tables are given for either 36 ksi or 50 ksi grade steel. These appear as Table 3-3. The combination sections listed in Table 3-3

TABLE 3-3 Maximum allowable beam lengths





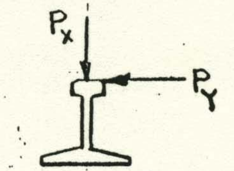
$P_y = 0.08P_x$

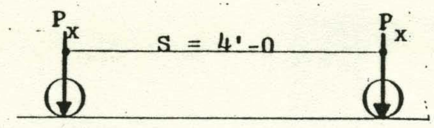
$F_y = 36$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	23.08	12.50	9.33	7.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	25.08	13.50	9.92	8.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	27.58	14.50	10.58	8.67	7.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	30.42	15.83	11.42	9.33	8.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	38.42	19.67	13.83	11.08	9.50	8.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	44.25	22.42	15.58	12.33	10.42	9.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	40.08	28.25	19.17	14.92	12.42	10.83	9.75	8.92	8.25	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C15X33.9	53.00	32.67	22.08	17.00	14.08	12.17	10.83	9.83	9.08	0.00	0.00	0.00	0.00	0.00	0.00
W21X 62-C12X20.7	42.17	33.50	24.33	18.67	15.33	13.25	11.75	10.67	9.83	9.17	8.58	8.17	0.00	0.00	0.00
W21X 62-C15X33.9	55.58	43.50	28.83	21.83	17.83	15.33	13.50	12.17	11.17	10.33	9.67	9.17	0.00	0.00	0.00
W21X 68-C12X20.7	42.42	33.83	26.67	20.25	16.58	14.25	12.58	11.33	10.42	9.67	9.08	8.58	8.17	0.00	0.00
W21X 68-C15X33.9	55.75	44.42	31.58	23.83	19.33	16.50	14.50	13.00	11.92	11.00	10.25	9.67	9.17	0.00	0.00
W24X 68-C12X20.7	43.92	34.92	27.25	20.75	17.08	14.67	13.00	11.75	10.75	10.00	9.42	8.83	8.42	8.00	0.00
W24X 68-C15X33.9	57.58	45.92	32.92	24.83	20.17	17.25	15.17	13.67	12.42	11.50	10.75	10.08	9.58	9.08	0.00
W24X 84-C12X20.7	44.83	35.75	30.83	25.50	20.58	17.50	15.33	13.75	12.50	11.58	10.83	10.17	9.58	9.17	8.75
W24X 84-C15X33.9	58.08	46.33	40.17	30.58	24.58	20.75	18.08	16.08	14.58	13.42	12.50	11.67	11.00	10.42	10.00
W27X 84-C12X20.7	46.50	37.00	32.00	25.58	20.75	17.67	15.58	14.00	12.75	11.83	11.00	10.33	9.83	9.33	8.92
W27X 84-C15X33.9	60.00	47.75	41.50	31.08	25.08	21.17	18.50	16.58	15.00	13.83	12.83	12.00	11.33	10.75	10.25
W27X 94-C12X20.7	47.33	37.58	32.75	28.75	23.17	19.58	17.08	15.33	13.92	12.83	11.92	11.17	10.58	10.08	9.58
W27X 94-C15X33.9	60.42	48.08	42.00	34.92	27.92	23.50	20.42	18.17	16.42	15.08	14.00	13.08	12.25	11.67	11.08
W30X 99-C15X33.9	60.42	48.08	41.92	34.08	27.42	23.08	20.17	17.92	16.25	14.92	13.83	13.00	12.25	11.58	11.00
W30X 99-C18X42.7	72.17	57.42	50.08	38.25	30.67	25.83	22.42	19.92	18.00	16.50	15.25	14.25	13.42	12.67	12.08
W30X116-C15X33.9	62.67	49.83	43.58	39.25	34.83	29.00	24.92	22.00	19.83	18.08	16.67	15.50	14.58	13.75	13.00
W30X116-C18X42.7	74.33	59.17	51.75	46.58	39.25	32.67	28.08	24.67	22.17	20.17	18.58	17.25	16.17	15.17	14.42
W33X118-C15X33.9	64.67	51.42	45.00	40.58	35.42	29.58	25.58	22.58	20.33	18.58	17.17	16.00	15.00	14.17	13.42
W33X118-C18X42.7	76.50	60.83	53.25	48.00	40.33	33.58	28.92	25.50	22.92	20.92	19.25	17.92	16.75	15.75	14.92
W33X141-C15X33.9	66.17	52.50	45.92	41.75	38.33	35.33	30.75	27.00	24.08	21.92	20.08	18.58	17.42	16.33	15.42
W33X141-C18X42.7	77.42	61.58	53.83	48.92	44.83	40.75	34.75	30.50	27.17	24.58	22.58	20.83	19.50	18.25	17.25
W36X150-C15X33.9	67.75	53.75	47.00	42.67	39.33	36.42	32.75	28.67	25.58	23.25	21.33	19.75	18.42	17.25	16.33
W36X150-C18X42.7	79.08	62.83	54.92	49.92	45.92	42.42	37.25	32.58	29.00	26.25	24.08	22.25	20.75	19.42	18.33

Note: Avalue of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



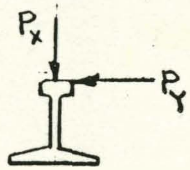


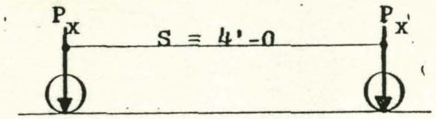
$P_y = 0.10P_x$ $F_y = 36$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	21.67	11.75	8.83	7.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	24.00	12.83	9.50	7.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	25.67	13.50	9.92	8.17	7.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	28.83	15.00	10.83	8.83	7.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	36.83	18.42	13.00	10.42	8.92	7.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	42.83	21.42	14.83	11.75	9.92	8.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	39.00	26.25	17.75	13.83	11.67	10.17	9.17	8.33	7.75	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C15X33.9	51.92	31.17	20.83	16.08	13.33	11.58	10.33	9.42	8.67	0.00	0.00	0.00	0.00	0.00	0.00
W21X 62-C12X20.7	40.92	32.25	22.33	17.08	14.17	12.25	10.92	9.92	9.17	8.58	8.08	7.67	0.00	0.00	0.00
W21X 62-C15X33.9	54.17	41.08	27.00	20.50	16.75	14.33	12.67	11.50	10.50	9.75	9.17	8.67	0.00	0.00	0.00
W21X 68-C12X20.7	41.17	32.58	24.42	18.50	15.25	13.08	11.67	10.50	9.67	9.00	8.50	8.00	7.67	0.00	0.00
W21X 68-C15X33.9	54.33	43.25	29.58	22.25	18.08	15.42	13.58	12.25	11.17	10.42	9.67	9.17	8.67	0.00	0.00
W24X 68-C12X20.7	42.50	33.67	24.67	18.83	15.58	13.42	11.92	10.83	10.00	9.25	8.75	8.25	7.83	7.50	0.00
W24X 68-C15X33.9	56.00	44.58	30.50	23.00	18.75	16.08	14.17	12.75	11.67	10.83	10.08	9.50	9.00	8.58	0.00
W24X 84-C12X20.7	43.33	34.50	29.50	23.08	18.67	15.92	14.00	12.58	11.50	10.67	9.92	9.42	8.92	8.50	8.08
W24X 84-C15X33.9	56.50	45.00	38.17	28.33	22.75	19.17	16.75	15.00	13.58	12.50	11.67	10.92	10.33	9.83	9.33
W27X 84-C12X20.7	44.92	35.67	30.42	22.92	18.75	16.08	14.17	12.75	11.67	10.83	10.08	9.58	9.08	8.58	8.25
W27X 84-C15X33.9	58.25	46.33	38.25	28.50	23.00	19.50	17.08	15.33	13.92	12.83	11.92	11.25	10.58	10.08	9.58
W27X 94-C12X20.7	45.67	36.25	31.33	25.75	20.83	17.67	15.50	13.92	12.67	11.75	10.92	10.25	9.75	9.25	8.83
W27X 94-C15X33.9	58.58	46.58	40.42	31.92	25.58	21.50	18.75	16.75	15.17	13.92	12.92	12.08	11.42	10.83	10.33
W30X 99-C15X33.9	58.58	46.58	40.42	31.17	25.08	21.17	18.50	16.58	15.00	13.83	12.83	12.00	11.33	10.75	10.25
W30X 99-C18X42.7	70.17	55.83	48.00	35.50	28.50	24.00	20.83	18.58	16.83	15.42	14.33	13.33	12.58	11.92	11.33
W30X116-C15X33.9	60.58	48.17	42.08	37.58	31.50	26.25	22.67	20.08	18.08	16.50	15.25	14.25	13.33	12.58	12.00
W30X116-C18X42.7	72.08	57.33	50.17	44.75	36.17	30.00	25.83	22.75	20.50	18.67	17.17	16.00	15.00	14.08	13.33
W33X118-C15X33.9	62.42	49.53	43.33	38.83	31.83	26.67	23.08	20.50	18.50	16.92	15.67	14.58	13.67	12.92	12.33
W33X118-C18X42.7	74.08	58.92	51.50	46.08	36.83	30.67	26.50	23.42	21.08	19.25	17.75	16.50	15.42	14.58	13.83
W33X141-C15X33.9	63.83	50.67	44.25	40.08	36.50	32.17	27.58	24.25	21.75	19.75	18.17	16.83	15.75	14.83	14.08
W33X141-C18X42.7	74.92	59.50	52.00	47.08	42.83	37.08	31.67	27.75	24.83	22.50	20.67	19.08	17.83	16.75	15.83
W36X150-C15X33.9	65.25	51.75	45.17	41.00	37.50	34.08	29.17	25.58	22.92	20.83	19.17	17.75	16.58	15.67	14.75
W36X150-C18X42.7	76.33	60.58	53.00	48.08	43.92	39.50	33.67	29.50	26.33	23.83	21.92	20.25	18.92	17.75	16.75

Note: Avalue of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



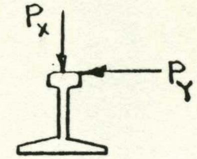


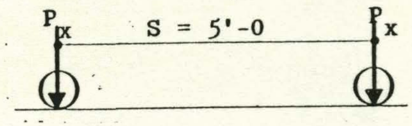
$P_y = 0.12P_x$ $F_y = 36$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	20.42	11.17	8.33	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	22.92	12.25	9.09	7.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	24.00	12.67	9.42	7.75	6.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	27.42	14.17	10.33	8.42	7.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	34.75	17.33	12.25	9.92	8.50	7.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	41.42	20.50	14.17	11.25	9.50	8.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	38.08	24.42	16.58	13.00	10.92	9.58	8.67	7.92	7.42	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C15X33.9	50.92	29.67	19.75	15.25	12.67	11.00	9.83	9.00	8.33	0.00	0.00	0.00	0.00	0.00	0.00
W21X 62-C12X20.7	39.83	31.00	20.58	15.83	13.17	11.42	10.25	9.33	8.58	8.08	7.58	7.25	0.00	0.00	0.00
W21X 62-C15X33.9	53.00	39.75	25.33	19.25	15.75	13.50	12.00	10.83	10.00	9.25	8.75	8.25	0.00	0.00	0.00
W21X 68-C12X20.7	40.00	31.50	22.42	17.08	14.08	12.17	10.83	9.83	9.08	8.50	8.00	7.58	7.25	0.00	0.00
W21X 68-C15X33.9	53.08	42.08	27.83	20.92	17.00	14.50	12.83	11.58	10.58	9.83	9.25	8.67	8.25	0.00	0.00
W24X 68-C12X20.7	41.25	32.50	22.50	17.33	14.42	12.42	11.08	10.08	9.33	8.67	8.17	7.75	7.42	7.08	0.00
W24X 68-C15X33.9	54.67	43.42	28.42	21.50	17.58	15.00	13.25	12.00	11.00	10.17	9.58	9.00	8.58	8.17	0.00
W24X 84-C12X20.7	42.08	33.42	26.08	21.08	17.17	14.67	12.92	11.67	10.67	9.92	9.25	8.75	8.33	7.92	7.58
W24X 84-C15X33.9	55.00	43.83	35.58	26.33	21.17	17.92	15.67	14.00	12.75	11.75	10.92	10.33	9.75	9.25	8.83
W27X 84-C12X20.7	43.50	34.50	27.50	20.83	17.08	14.75	13.00	11.75	10.83	10.08	9.42	8.92	8.42	8.08	7.75
W27X 84-C15X33.9	56.58	45.08	35.25	26.33	21.33	18.08	15.92	14.25	13.00	12.00	11.17	10.50	9.92	9.50	9.00
W27X 94-C12X20.7	44.17	35.08	29.92	23.33	18.92	16.17	14.25	12.75	11.67	10.83	10.08	9.50	9.00	8.58	8.25
W27X 94-C15X33.9	56.92	45.33	39.00	29.42	23.58	19.92	17.33	15.50	14.08	13.00	12.08	11.33	10.67	10.17	9.67
W30X 99-C15X33.9	56.92	45.33	38.58	28.67	23.17	19.58	17.17	15.33	14.00	12.92	12.00	11.25	10.67	10.08	9.67
W30X 99-C18X42.7	68.42	54.42	44.83	33.08	26.58	22.42	19.50	17.42	15.75	14.50	13.50	12.58	11.83	11.25	10.75
W30X116-C15X33.9	58.75	46.67	40.67	36.00	28.75	24.00	20.75	18.42	16.67	15.25	14.08	13.17	12.42	11.75	11.17
W30X116-C18X42.7	70.08	55.75	48.58	42.50	33.50	27.83	23.92	21.17	19.00	17.33	16.00	14.92	14.00	13.17	12.50
W33X118-C15X33.9	60.42	48.00	41.83	36.25	28.92	24.25	21.08	18.75	16.92	15.58	14.42	13.50	12.67	12.00	11.42
W33X118-C18X42.7	71.92	57.17	45.83	42.75	33.83	28.25	24.42	21.58	19.50	17.83	16.42	15.33	14.42	13.58	12.92
W33X141-C15X33.9	61.75	49.00	42.83	38.50	34.75	29.17	25.00	22.00	19.83	18.08	16.67	15.50	14.50	13.67	13.00
W33X141-C18X42.7	72.67	57.67	50.42	45.33	40.92	34.00	29.08	25.50	22.83	20.75	19.08	17.67	16.50	15.58	14.67
W36X150-C15X33.9	63.00	50.00	43.67	39.42	35.75	30.67	26.33	23.17	20.83	18.92	17.42	16.25	15.17	14.33	13.58
W36X150-C18X42.7	73.92	58.67	51.33	46.25	41.92	36.00	30.75	26.92	24.08	21.92	20.08	18.67	17.42	16.33	15.50

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



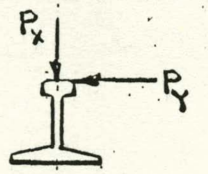


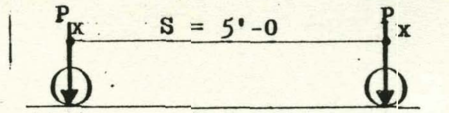
$P_y = 0.08P_x$ $F_y = 36$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	24.17	13.42	10.17	8.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	24.17	14.42	10.75	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	28.75	15.50	11.42	9.50	8.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	31.50	16.83	12.33	10.17	8.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	38.75	20.67	14.75	12.00	10.33	9.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	45.42	23.50	16.50	13.25	11.25	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	40.42	29.42	20.17	15.83	13.33	11.75	10.58	9.75	9.08	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C15X33.9	53.33	33.83	23.08	18.00	15.00	13.08	11.75	10.75	9.92	0.00	0.00	0.00	0.00	0.00	0.00
W21X 62-C12X20.7	42.50	33.92	25.42	19.67	16.33	14.17	12.67	11.58	10.67	10.00	9.42	8.92	0.00	0.00	0.00
W21X 62-C15X33.9	55.92	44.58	29.92	22.92	18.83	16.25	14.42	13.08	12.00	11.17	10.50	9.92	0.00	0.00	0.00
W21X 68-C12X20.7	42.83	34.17	27.83	21.25	17.58	15.17	13.50	12.25	11.33	10.50	9.92	9.42	9.00	0.00	0.00
W21X 68-C15X33.9	56.08	44.75	32.67	24.83	20.33	17.42	15.42	13.92	12.75	11.92	11.17	10.50	10.00	0.00	0.00
W24X 68-C12X20.7	44.25	35.33	28.33	21.75	18.00	15.58	13.83	12.58	11.67	10.83	10.25	9.67	9.25	8.83	0.00
W24X 68-C15X33.9	57.92	46.25	34.00	25.83	21.17	18.17	16.08	14.50	13.33	12.42	11.58	10.92	10.42	9.92	0.00
W24X 84-C12X20.7	45.25	36.08	31.33	26.67	21.67	18.50	16.25	14.67	13.42	12.42	11.67	11.00	10.42	10.00	9.58
W24X 84-C15X33.9	58.50	46.67	40.58	31.75	25.67	21.75	19.00	17.08	15.50	14.33	13.33	12.58	11.92	11.33	10.83
W27X 84-C12X20.7	46.92	37.33	32.42	26.58	21.75	18.67	16.50	14.92	13.67	12.67	11.83	11.17	10.67	10.17	9.75
W27X 84-C15X33.9	60.33	48.17	41.92	32.17	26.08	22.17	19.50	17.50	15.92	14.75	13.75	12.92	12.25	11.58	11.08
W27X 94-C12X20.7	47.67	38.00	33.17	29.42	24.17	20.58	18.08	16.25	14.83	13.75	12.83	12.08	11.42	10.92	10.42
W27X 94-C15X33.9	60.75	48.42	42.42	36.00	29.00	24.50	21.42	19.08	17.33	16.00	14.83	13.92	13.17	12.50	11.92
W30X 99-C15X33.9	60.75	48.42	42.33	35.17	28.42	24.08	21.08	18.92	17.17	15.83	14.75	13.83	13.08	12.42	11.83
W30X 99-C18X42.7	72.50	57.75	50.42	39.33	31.75	26.83	23.42	20.92	19.00	17.42	16.17	15.17	14.33	13.58	12.92
W30X116-C15X33.9	63.00	50.17	43.92	39.75	36.00	30.08	26.00	23.08	20.83	19.00	17.58	16.42	15.42	14.58	13.92
W30X116-C18X42.7	74.67	59.50	52.17	47.00	40.42	33.75	29.08	25.75	23.17	21.17	19.50	18.17	17.08	16.08	15.25
W33X118-C15X33.9	65.08	51.75	45.33	41.00	36.58	30.67	26.58	23.58	21.33	19.50	18.08	16.92	15.92	15.00	14.25
W33X118-C18X42.7	76.83	61.17	53.58	48.42	41.50	34.67	30.00	26.50	23.92	21.83	20.17	18.83	17.67	16.67	15.83
W33X141-C15X33.9	66.50	52.92	46.25	42.08	38.75	35.83	31.83	28.00	25.17	22.92	21.08	19.58	18.33	17.25	16.33
W33X141-C18X42.7	77.75	61.92	54.17	49.25	45.25	41.75	35.92	31.50	28.25	25.67	23.58	21.83	20.42	19.25	18.17
W36X150-C15X33.9	68.08	54.08	47.33	43.08	39.75	36.92	33.83	29.75	26.67	24.25	22.25	20.67	19.33	18.25	17.25
W36X150-C18X42.7	79.42	63.17	55.25	50.25	46.42	42.92	38.33	33.67	30.08	27.33	25.08	23.25	21.67	20.42	19.25

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



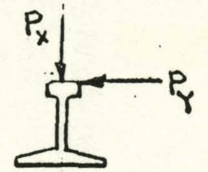


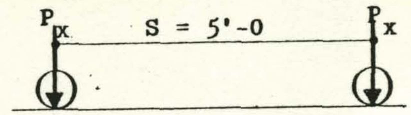
$P_y = 0.10P_x$ | $F_y = 36$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	22.75	12.67	9.67	7.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	25.08	13.75	10.33	8.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	26.83	14.50	10.75	9.00	7.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	30.00	15.92	11.75	9.67	8.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	37.92	19.42	13.92	11.33	9.75	8.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	44.00	22.50	15.83	12.67	10.83	9.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	39.33	27.42	18.83	14.83	12.50	11.00	10.00	9.17	8.58	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C15X33.9	52.25	32.25	21.92	17.08	14.25	12.42	11.17	10.25	9.50	0.00	0.00	0.00	0.00	0.00	0.00
W21X 62-C12X20.7	41.25	32.75	23.42	18.08	15.08	13.17	11.83	10.75	10.00	9.33	8.83	8.42	0.00	0.00	0.00
W21X 62-C15X33.9	54.58	42.25	28.17	21.50	17.75	15.33	13.58	12.33	11.42	10.58	10.00	9.50	0.00	0.00	0.00
W21X 68-C12X20.7	41.50	33.00	25.50	19.58	16.17	14.00	12.50	11.42	10.58	9.83	9.33	8.83	8.42	0.00	0.00
W21X 68-C15X33.9	54.67	43.58	30.75	23.33	19.08	16.42	14.50	13.17	12.08	11.25	10.58	10.00	9.50	0.00	0.00
W24X 68-C12X20.7	42.83	34.08	25.75	19.83	16.50	14.33	12.83	11.67	10.83	10.08	9.50	9.08	8.67	8.17	0.00
W24X 68-C15X33.9	56.42	45.00	31.67	24.08	19.75	17.00	15.08	13.67	12.50	11.67	10.92	10.33	9.83	9.42	0.00
W24X 84-C12X20.7	43.75	34.92	30.00	24.17	19.75	16.92	14.92	13.50	12.42	11.50	10.83	10.25	9.75	9.25	8.52
W24X 84-C15X33.9	56.83	45.33	39.17	29.42	23.83	20.25	17.75	15.92	14.50	13.42	12.50	11.83	11.17	10.67	10.17
W27X 84-C12X20.7	45.25	36.08	31.00	24.00	19.75	17.00	15.08	13.67	12.58	11.67	11.00	10.33	9.83	9.42	9.08
W27X 84-C15X33.9	58.58	46.67	39.50	29.58	24.08	20.50	18.00	16.25	14.83	13.75	12.83	12.08	11.42	10.92	10.42
W27X 94-C12X20.7	46.00	36.67	31.75	26.83	21.83	18.67	16.42	14.83	13.58	12.58	11.75	11.08	10.58	10.08	9.67
W27X 94-C15X33.9	58.92	47.00	40.92	33.08	26.67	22.58	19.75	17.67	16.08	14.83	13.83	13.00	12.25	11.67	11.17
W30X 99-C15X33.9	58.92	47.00	40.83	32.25	26.08	22.17	19.50	17.50	15.92	14.75	13.75	12.92	12.25	11.58	11.08
W30X 99-C18X42.7	70.50	56.17	48.83	36.67	29.50	25.00	21.83	19.50	17.75	16.33	15.17	14.25	13.50	12.75	12.17
W30X116-C15X33.9	60.92	48.50	42.50	38.08	32.67	27.33	23.67	21.08	19.00	17.50	16.17	15.17	14.25	13.50	12.83
W30X116-C18X42.7	72.42	57.67	50.50	45.17	37.33	31.17	26.92	23.83	21.42	19.58	18.17	16.92	15.92	15.00	14.25
W33X118-C15X33.9	62.75	49.92	43.75	39.25	32.92	27.67	24.08	21.42	19.42	17.83	16.58	15.50	14.58	13.83	13.17
W33X118-C18X42.7	74.42	59.25	51.83	46.50	38.00	31.75	27.50	24.42	22.00	20.17	18.67	17.42	16.33	15.50	14.67
W33X141-C15X33.9	64.17	51.00	44.67	40.50	37.00	33.33	28.67	25.25	22.75	20.75	19.17	17.83	16.75	15.75	15.00
W33X141-C18X42.7	75.25	59.83	52.42	47.50	43.33	38.25	32.75	28.83	25.83	23.50	21.67	20.08	18.83	17.75	16.75
W36X150-C15X33.9	65.58	52.08	45.58	41.42	37.92	34.92	30.25	26.67	23.92	21.83	20.08	18.75	17.58	16.58	15.67
W36X150-C18X42.7	76.67	61.00	53.33	49.42	44.33	40.67	34.83	30.58	27.33	24.83	22.83	21.25	19.83	18.67	17.67

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



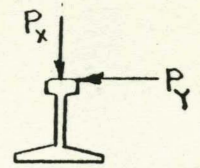


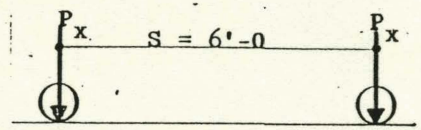
$P_y = 0.12P_x$ $F_y = 36$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	21.50	12.08	9.17	7.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	24.00	13.17	9.92	8.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	25.17	13.67	10.25	8.58	6.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	28.58	15.17	11.17	9.25	7.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	36.00	18.33	13.17	10.75	9.33	8.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	42.67	21.58	15.17	12.17	10.42	9.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	38.42	25.58	17.58	13.92	11.83	10.42	9.50	8.75	7.92	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C15X33.9	51.25	30.83	20.83	16.25	13.58	11.92	10.67	9.83	9.08	0.00	0.00	0.00	0.00	0.00	0.00
W21X 62-C12X20.7	40.17	31.58	21.67	16.83	14.08	12.33	11.08	10.17	9.42	8.83	8.33	7.58	0.00	0.00	0.00
W21X 62-C15X33.9	53.33	40.00	26.50	20.25	16.75	14.50	12.92	11.75	10.83	10.08	9.50	9.08	0.00	0.00	0.00
W21X 68-C12X20.7	40.42	31.92	23.58	18.17	15.08	13.08	11.75	10.75	9.92	9.33	8.75	8.25	7.58	0.00	0.00
W21X 68-C15X33.9	53.42	42.50	29.00	22.00	18.00	15.50	13.75	12.42	11.50	10.67	10.08	9.50	9.08	0.00	0.00
W24X 68-C12X20.7	41.58	32.92	23.58	18.33	15.33	13.33	12.00	10.92	10.17	9.50	9.00	8.58	7.92	7.33	0.00
W24X 68-C15X33.9	55.00	43.75	29.58	22.50	18.50	16.00	14.17	12.83	11.83	11.08	10.42	9.83	9.33	9.00	0.00
W24X 84-C12X20.7	42.42	33.83	28.75	22.17	18.17	15.58	13.83	12.58	11.58	10.75	10.08	9.58	9.17	8.75	8.33
W24X 84-C15X33.9	55.33	44.17	36.75	27.42	22.25	18.92	16.58	14.92	13.67	12.67	11.83	11.17	10.58	10.08	9.67
W27X 84-C12X20.7	43.83	34.92	28.58	21.92	18.08	15.67	13.92	12.67	11.67	10.92	10.25	9.67	9.25	8.83	8.50
W27X 84-C15X33.9	57.00	45.42	36.50	27.42	22.33	19.08	16.83	15.17	13.92	12.92	12.08	11.33	10.75	10.33	9.83
W27X 94-C12X20.7	44.50	35.50	30.42	24.33	19.92	17.08	15.17	13.67	12.58	11.67	11.00	10.33	9.83	9.42	9.08
W27X 94-C15X33.9	57.33	45.67	39.50	30.58	24.67	20.92	18.33	16.50	15.00	13.92	12.92	12.17	11.58	11.00	10.50
W30X 99-C15X33.9	57.33	45.67	39.42	29.75	24.17	20.58	18.08	16.33	14.92	13.75	12.92	12.17	11.50	10.92	10.50
W30X 99-C18X42.7	68.75	54.83	46.00	34.25	27.58	23.42	20.50	18.33	16.75	15.42	14.33	13.50	12.75	12.08	11.58
W30X116-C15X33.9	59.08	47.00	41.08	36.50	29.92	25.08	21.83	19.42	17.58	16.17	15.00	14.08	13.25	12.58	12.00
W30X116-C18X42.7	70.42	56.08	49.00	43.50	34.67	28.92	25.00	22.17	20.00	18.33	17.00	15.83	14.92	14.08	13.42
W33X118-C15X33.9	60.83	48.33	42.25	37.42	30.00	25.25	22.08	19.67	17.92	16.50	15.33	14.33	13.58	12.83	12.25
W33X118-C18X42.7	72.25	57.50	50.25	44.00	35.00	29.33	25.42	22.58	20.42	18.75	17.42	16.25	15.25	14.50	13.75
W33X141-C15X33.9	62.08	49.33	43.17	38.92	35.25	30.25	26.08	23.08	20.83	19.00	17.58	16.42	15.42	14.58	13.83
W33X141-C18X42.7	73.00	58.08	50.83	45.75	41.42	35.17	30.17	26.58	23.83	21.75	20.00	18.67	17.50	16.50	15.58
W36X150-C15X33.9	63.42	50.33	44.00	39.83	36.25	31.75	27.33	24.17	21.83	19.92	18.42	17.17	16.08	15.25	14.50
W36X150-C18X42.7	74.25	59.08	51.67	46.67	42.42	37.17	31.83	28.00	25.17	22.92	21.08	19.58	18.33	17.25	16.42

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



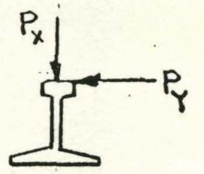


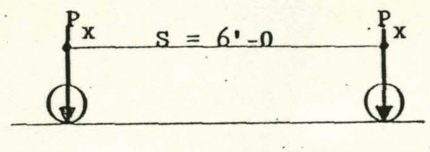
$P_y = 0.08P_x$ | $F_y = 36$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	25.17	14.33	10.92	8.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	27.25	15.33	11.58	9.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	29.83	16.42	12.33	10.33	8.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	32.67	17.75	13.17	11.00	9.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 36-C12X20.7	39.08	21.67	15.67	12.83	11.08	9.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	46.50	24.50	17.50	14.08	12.17	10.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	40.75	30.50	21.17	16.75	14.25	12.58	11.42	10.50	9.50	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C15X33.9	53.67	34.92	24.08	18.92	15.92	14.00	12.58	11.58	10.75	0.00	0.00	0.00	0.00	0.00	0.00
W21X 62-C12X20.7	42.92	34.25	26.50	20.58	17.25	15.08	13.50	12.42	11.50	10.75	10.25	9.33	0.00	0.00	0.00
W21X 62-C15X33.9	56.25	45.00	31.00	23.92	19.83	17.17	15.33	13.92	12.92	12.00	11.33	10.75	0.00	0.00	0.00
W21X 68-C12X20.7	43.17	34.58	28.92	22.25	18.50	16.08	14.33	13.08	12.17	11.33	10.75	10.17	9.33	0.00	0.00
W21X 68-C15X33.9	56.42	45.17	33.83	25.92	21.33	18.42	16.33	14.83	13.67	12.75	12.00	11.33	10.83	0.00	0.00
W24X 68-C12X20.7	44.58	35.67	29.33	22.75	18.92	16.50	14.75	13.50	12.50	11.67	11.00	10.50	9.83	9.17	0.00
W24X 68-C15X33.9	58.25	46.58	35.08	26.92	22.17	19.08	17.00	15.42	14.17	13.25	12.42	11.75	11.25	10.75	0.00
W24X 84-C12X20.7	45.58	36.42	31.75	27.67	22.67	19.42	17.25	15.58	14.33	13.33	12.50	11.83	11.25	10.75	10.33
W24X 84-C15X33.9	58.83	47.00	41.00	32.83	26.67	22.75	20.00	18.00	16.42	15.25	14.25	13.42	12.75	12.17	11.67
W27X 84-C12X20.7	47.25	37.75	32.92	27.67	22.75	19.58	17.42	15.75	14.50	13.50	12.67	12.00	11.42	10.92	10.50
W27X 84-C15X33.9	60.75	48.50	42.33	33.25	27.08	23.17	20.42	18.42	16.83	15.58	14.58	13.75	13.08	12.42	11.92
W27X 94-C12X20.7	48.00	38.33	33.58	29.92	25.25	21.58	19.00	17.17	15.75	14.58	13.67	12.92	12.25	11.67	11.25
W27X 94-C15X33.9	61.17	48.83	42.75	37.17	30.08	25.50	22.33	20.08	18.25	16.92	15.75	14.83	14.00	13.33	12.75
W30X 99-C15X33.9	61.08	48.83	42.75	36.25	29.50	25.08	22.08	19.83	18.08	16.75	15.67	14.75	13.92	13.25	12.67
W30X 99-C18X42.7	72.83	58.08	50.83	40.50	32.75	27.83	24.33	21.83	19.92	18.33	17.08	16.08	15.17	14.42	13.75
W30X116-C15X33.9	63.33	50.50	44.33	40.17	36.58	31.17	27.00	24.08	21.75	20.00	18.50	17.33	16.33	15.50	14.75
W30X116-C18X42.7	75.00	59.83	52.50	47.42	41.50	34.83	30.17	26.75	24.17	22.08	20.50	19.08	18.00	17.00	16.17
W33X118-C15X33.9	65.42	52.08	45.67	41.42	37.67	31.67	27.58	24.58	22.25	20.50	19.00	17.83	16.75	15.92	15.17
W33X118-C18X42.7	77.25	61.50	53.92	48.83	42.58	35.75	31.00	27.50	24.92	22.83	21.08	19.75	18.58	17.58	16.67
W33X141-C15X33.9	66.92	53.25	46.67	42.50	39.17	36.33	32.92	29.08	26.17	23.92	22.00	20.50	19.25	18.17	17.25
W33X141-C18X42.7	78.17	62.25	54.50	49.67	45.75	42.25	37.00	32.58	29.25	26.67	24.58	22.83	21.33	20.17	19.08
W36X150-C15X33.9	68.42	54.50	47.67	43.42	40.17	37.33	34.83	30.75	27.67	25.25	23.25	21.67	20.33	19.17	18.17
W36X150-C18X42.7	79.75	63.50	55.58	50.67	46.83	43.42	39.50	34.75	31.17	28.33	26.08	24.17	22.67	21.33	20.17

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



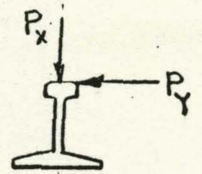


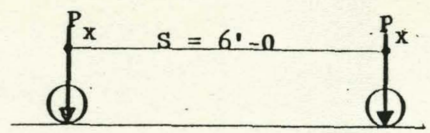
$P_y = 0.10P_x$ $F_y = 36$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	23.83	13.58	10.42	7.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	26.17	14.67	11.17	8.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	28.00	15.42	11.67	9.42	7.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	31.17	16.92	12.58	10.50	8.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	38.25	20.42	14.83	12.17	10.58	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	45.17	23.58	16.75	13.50	11.67	10.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	39.75	28.50	19.83	15.75	13.42	11.83	10.75	9.83	8.67	0.00	0.00	0.00	0.00	0.00	0.00
W19X 50-C15X33.9	52.58	33.42	22.92	18.00	15.17	13.33	12.00	11.08	10.33	0.00	0.00	0.00	0.00	0.00	0.00
W21X 62-C12X20.7	41.67	33.17	24.42	19.08	16.00	14.00	12.67	11.58	10.83	10.17	9.17	8.42	0.00	0.00	0.00
W21X 62-C15X33.9	54.92	43.42	29.25	22.50	18.67	16.25	14.50	13.25	12.25	11.42	10.83	10.25	0.00	0.00	0.00
W21X 68-C12X20.7	41.92	33.42	26.67	20.58	17.17	14.92	13.42	12.25	11.33	10.67	10.00	9.17	8.42	0.00	0.00
W21X 68-C15X33.9	55.00	44.00	31.83	24.42	20.08	17.33	15.42	14.00	12.92	12.08	11.33	10.75	10.33	0.00	0.00
W24X 68-C12X20.7	43.17	34.50	26.83	20.83	17.42	15.25	13.67	12.50	11.67	10.92	10.33	9.58	8.75	8.17	0.00
W24X 68-C15X33.9	56.75	45.33	32.75	25.08	20.75	17.92	15.92	14.50	13.42	12.50	11.75	11.17	10.67	10.17	0.00
W24X 84-C12X20.7	44.08	35.25	30.42	25.25	20.75	17.83	15.83	14.42	13.25	12.33	11.67	11.00	10.50	10.00	9.25
W24X 84-C15X33.9	57.17	45.67	39.58	30.58	24.83	21.17	18.67	16.83	15.42	14.33	13.42	12.67	12.00	11.50	11.00
W27X 84-C12X20.7	45.58	36.42	31.50	25.00	20.67	17.92	16.00	14.50	13.42	12.50	11.75	11.17	10.67	10.25	9.58
W27X 84-C15X33.9	58.92	47.08	40.67	30.67	25.08	21.50	19.00	17.17	15.75	14.58	13.67	12.92	12.25	11.75	11.25
W27X 94-C12X20.7	46.33	37.00	32.17	27.92	22.83	19.58	17.33	15.75	14.42	13.42	12.67	11.92	11.42	10.92	10.42
W27X 94-C15X33.9	59.25	47.33	41.33	34.25	27.67	23.58	20.67	18.58	17.00	15.75	14.67	13.83	13.08	12.50	12.00
W30X 99-C15X33.9	59.25	47.33	41.25	33.33	27.17	23.17	20.42	18.42	16.83	15.58	14.58	13.75	13.08	12.42	11.92
W30X 99-C18X42.7	70.83	56.58	49.25	37.75	30.58	26.00	22.83	20.50	18.67	17.25	16.08	15.17	14.33	13.58	13.00
W30X116-C15X33.9	61.25	48.83	42.83	38.50	33.83	28.42	24.75	22.00	20.00	18.42	17.08	16.00	15.17	14.33	13.75
W30X116-C18X42.7	72.83	58.08	50.92	45.67	38.50	32.25	27.92	24.83	22.42	20.58	19.08	17.83	16.75	15.92	15.17
W33X118-C15X33.9	63.17	50.33	44.08	39.75	34.00	28.75	25.08	22.42	20.33	18.75	17.42	16.42	15.50	14.67	14.00
W33X118-C18X42.7	74.75	59.58	52.25	47.00	39.08	32.83	28.50	25.42	23.00	21.08	19.58	18.33	17.25	16.33	15.58
W33X141-C15X33.9	64.50	51.33	45.00	40.83	37.42	34.50	29.75	26.33	23.75	21.75	20.08	18.75	17.67	16.67	15.83
W33X141-C18X42.7	75.58	60.25	52.75	47.92	43.75	39.42	33.92	29.92	26.83	24.50	22.58	21.00	19.75	18.67	17.67
W36X150-C15X33.9	65.92	52.42	45.92	41.75	38.42	35.50	31.33	27.67	24.92	22.83	21.08	19.67	18.50	17.50	16.58
W36X150-C18X42.7	77.00	61.33	53.67	48.83	44.83	41.33	35.92	31.67	28.42	25.83	23.83	22.17	20.75	19.58	18.58

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



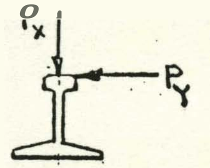


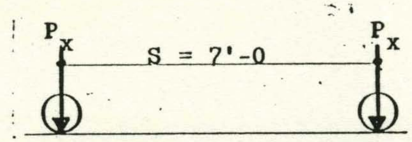
$P_y = 0.12P_x$ $F_y = 36$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	22.58	12.92	9.83	7.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	25.08	14.08	10.75	8.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	26.33	14.58	11.08	8.67	6.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	29.75	16.08	12.00	9.92	7.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 36-C12X20.7	37.25	19.33	14.08	11.58	10.08	8.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	43.83	22.58	16.08	13.00	11.25	9.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	38.75	26.75	18.58	14.83	12.67	11.25	10.25	9.00	7.[illegible]2	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C15X33.9	51.58	32.00	21.92	17.17	14.50	12.75	11.50	10.58	9.[illegible]7	0.00	0.00	0.00	0.00	0.00	0.00
W21X 62-C12X20.7	40.50	32.08	22.67	17.75	15.00	13.17	11.92	11.00	1[illegible].[illegible]5	9.17	8.33	7.58	0.00	0.00	0.00
W21X 62-C15X33.9	53.67	41.25	27.58	21.25	17.67	15.42	13.75	12.58	1[illegible].[illegible]7	10.92	10.33	9.50	0.00	0.00	0.00
W21X 68-C12X20.7	40.75	32.42	24.67	19.08	16.00	14.00	12.58	11.58	1[illegible].[illegible]5	10.00	9.08	8.25	7.58	0.00	0.00
W21X 68-C15X33.9	53.75	42.92	30.08	23.00	19.00	16.42	14.67	13.33	1[illegible].[illegible]3	11.50	10.83	10.33	9.58	0.00	0.00
W24X 68-C12X20.7	41.92	33.33	24.67	19.25	16.25	14.25	12.83	11.75	1[illegible].[illegible]0	10.33	9.42	8.58	7.92	7.33	0.00
W24X 68-C15X33.9	55.33	44.17	30.67	23.50	19.50	16.92	15.08	13.75	1[illegible].[illegible]7	11.83	11.17	10.67	10.17	9.33	0.00
W24X 84-C12X20.7	42.75	34.17	29.25	23.17	19.08	16.50	14.75	13.42	1[illegible].[illegible]2	11.58	10.92	10.42	9.67	9.00	8.33
W24X 84-C15X33.9	55.67	44.50	38.00	28.58	23.25	19.83	17.58	15.83	1[illegible].[illegible]8	13.50	12.67	12.00	11.42	10.92	10.50
W27X 84-C12X20.7	44.17	35.25	29.75	22.92	19.00	16.58	14.83	13.50	1[illegible].[illegible]0	11.67	11.08	10.50	9.92	9.17	8.50
W27X 84-C15X33.9	57.33	45.75	37.67	28.50	23.33	20.00	17.75	16.08	1[illegible].[illegible]5	13.75	12.92	12.17	11.58	11.08	10.67
W27X 94-C12X20.7	44.92	35.83	30.92	25.42	20.92	18.00	16.00	14.58	1[illegible].[illegible]2	12.50	11.83	11.17	10.67	10.25	9.50
W27X 94-C15X33.9	57.67	46.00	39.92	31.67	25.67	21.92	19.33	17.42	1[illegible].92	14.75	13.83	13.00	12.42	11.83	11.33
W30X 99-C15X33.9	57.67	46.00	39.83	30.83	25.17	21.58	19.08	17.17	1[illegible].[illegible]5	14.67	13.75	13.00	12.33	11.75	11.25
W30X 99-C18X42.7	69.08	55.17	47.25	35.33	28.67	24.42	21.42	19.25	1[illegible].[illegible]8	16.33	15.25	14.33	13.58	12.92	12.42
W30X116-C15X33.9	59.42	47.42	41.50	37.00	31.00	26.17	22.83	20.42	1[illegible].[illegible]0	17.08	15.92	14.92	14.17	13.42	12.83
W30X116-C18X42.7	70.83	56.50	49.42	44.00	35.75	30.00	26.00	23.17	2[illegible].[illegible]0	19.25	17.92	16.75	15.75	15.00	14.25
W33X118-C15X33.9	61.17	48.75	42.67	38.08	31.08	26.33	23.00	20.67	1[illegible].[illegible]3	17.33	16.17	15.25	14.42	13.67	13.08
W33X118-C18X42.7	72.67	57.83	50.67	45.17	36.08	30.33	26.42	23.58	2[illegible].[illegible]2	19.67	18.25	17.17	16.17	15.33	14.58
W33X141-C15X33.9	62.50	49.75	43.50	39.33	35.83	31.33	27.17	24.08	2[illegible].[illegible]5	20.00	18.50	17.33	16.33	15.50	14.75
W33X141-C18X42.7	73.33	58.42	51.17	46.17	42.00	36.25	31.25	27.58	2[illegible].[illegible]3	22.75	21.00	19.58	18.42	17.42	16.50
W36X150-C15X33.9	63.75	50.67	44.42	40.25	36.75	32.92	28.42	25.25	2[illegible].[illegible]5	20.83	19.33	18.08	17.00	16.08	15.33
W36X150-C18X42.7	74.67	59.42	52.00	47.08	42.92	38.25	32.92	29.08	2[illegible].17	23.83	22.00	20.50	19.25	18.17	17.25

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



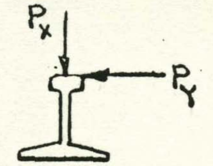


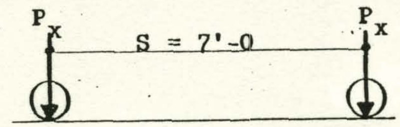
$P_y = 0.08P_x$ $F_y = 36$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	26.25	15.17	11.67	8.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	28.25	16.25	12.42	9.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X JQ-C10X15.3	30.83	17.31	13.17	10.42	8.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	33.67	18.75	14.00	11.67	9.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	39.42	22.67	16.58	13.67	11.92	9.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	47.58	25.50	18.42	15.00	12-92	11.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	41.00	31.58	22.17	1767	15.08	13.42	12.25	10.83	9.50	0.00	0.00	0.00	0.00	0.00	0.00
W19X 50-C15X33.9	54.00	36.00	25.08	19.83	16.83	14.83	13.42	12.33	11.25	0.00	0.00	0.00	0.00	0.00	0.00
W21X 62-C12X20.7	43.25	34.67	27.58	21.58	18.17	15.92	14.33	13.17	12.33	11.33	10.25	9-33	0.00	0.00	0.00
W21X 62-C15X33.9	56.58	45.33	32.08	24.92	20.75	18.08	16.17	14.75	13.67	12.83	12.17	11.25	0.00	0.00	0.00
W21X 68-C12X20.7	43.50	34.92	30.00	23.25	19.42	17.00	15.25	13-92	12.92	12-17	11-17	10.17	9.33	0.00	0.00
W21X 68-C15X33.9	56.75	45.50	34.83	26.92	22.33	19.33	17.25	15.67	14.50	13-58	12.75	12.17	11.33	0.00	0.00
W24X 68-C12X20.7	44.92	36.00	30.42	23.67	19.83	17.33	15.58	14.33	13.25	12-50	11.75	10.75	9.83	9.17	0.00
W24X 68-C15X33.9	58.58	46.92	36.17	27.92	23.17	20.00	17.92	16.25	15.00	14.08	13.25	12.58	12-00	11-17	0.00
W24X 84-C12X20.7	45.92	36.83	32.17	28.58	23.67	20.42	18.08	16.42	15.17	14.17	13.33	12.67	12.08	11.25	10.50
W24X 84-C15X33.9	59.17	47.31	41.42	33.92	27.67	23.75	20.92	18.92	17.33	16.08	15.08	14.25	13.58	12-92	12-42
W27X 84-C12X20.7	47.58	38.08	33.33	28.67	23.75	20.50	18.33	16.67	15.33	14.33	13.50	12-83	12.25	11.58	10.83
W27X 84-C15X33.9	61.08	48.83	42.75	34.33	28.08	24.17	21.33	19.33	17.75	16-50	15-42	14.58	13-92	13.25	12.75
W27X 94-C12X20.7	48.42	38.67	33.92	30.42	26.25	22.50	19.92	18.08	16.58	15.42	14.50	13.75	13.08	12-50	12.00
W27X 94-C15X33.9	61.50	49.17	43-17	38.25	31.08	26.50	23.33	21.00	19.17	17-75	16.58	15-67	14-03	14.17	13-58
W30X 99-C15X33.9	61.50	49.17	43.08	37.33	30.50	26.08	23.00	20.75	19.00	17-58	16.50	15-58	14-75	14-08	13-50
W30X 99-C18X42.7	73.17	58.50	51.25	41.50	33.83	28.83	25.33	22.75	20.75	19.25	18.00	16.92	16.00	15.25	14-58
W30X116-C15X33.9	63.75	50.92	44.67	40.58	37.08	32.17	28.08	25.00	22.75	20.92	19.42	18-25	17-25	16.33	15.58
W30X116-C18X42.7	75.42	60.17	52.83	47.83	42.67	35.92	31.17	27.75	25.08	23.08	21.42	20.00	18.83	17.92	17.00
W33X118-C15X33.9	65.75	52.50	46.00	41.83	38.33	32.75	28.58	25.50	23.25	21.42	19.92	18.67	17-67	16.75	16.00
W33X118-C18X42.7	77.58	61.92	54.25	49.25	43.67	36.75	32.00	28.50	25.83	23.75	22.00	20.67	19.42	18-42	17.58
W33X141-C15X33.9	67.25	53.58	47.00	42.83	39.67	36.83	34.00	30.08	27.17	24.83	23.00	21.50	20.11	19.08	18-17
W33X141-C18X42.7	78.50	62.58	54.92	50.00	46.17	42.75	38.08	33.67	30.25	27.67	25.50	23-75	22.33	21-08	20.00
W36X150-C15X33.9	68.83	54.81	66.08	43.75	40.58	37.83	35.42	31.83	28.67	26.17	24.25	22.58	21.25	20.08	19.08
W36X150-C18X42.7	80.08	63.81	56.00	51.00	41.25	43.92	40.58	35.75	32.17	29.33	27-00	25.17	23-58	22-25	21.08

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



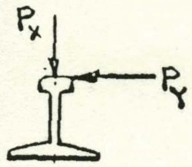


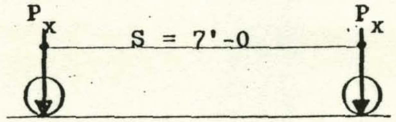
$P_y = 0.10P_x$ $F_y = 36$ ksi

SECTION	WHEEL LOAD P_x' (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	24.92	14.42	10.67	7.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	27.17	15.58	12.00	8.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	29.08	16.33	12.42	9.42	7.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	32.25	17.83	13.42	10.75	8.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	38.58	21.42	15.75	13.00	10.92	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	46.25	24.58	17.67	14.42	12.50	10.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	40.08	29.58	20.75	16.67	14.25	12.67	11.33	9.83	8.67	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C15X33.9	52.92	34.50	24.00	18.92	16.08	14.17	12.83	11.83	10.42	0.00	0.00	0.00	0.00	0.00	0.00
W21X 62-C12X20.7	42.00	33.58	25.50	20.00	16.92	14.92	13.50	12.42	11.33	10.17	9.17	8.42	0.00	0.00	0.00
W21X 62-C15X33.9	55.25	44.17	30.33	23.50	19.58	17.08	15.33	14.08	13.08	12.25	11.33	10.33	0.00	0.00	0.00
W21X 68-C12X20.7	42.25	33.83	27.67	21.58	18.08	15.83	14.25	13.08	12.17	11.08	10.00	9.17	8.42	0.00	0.00
W21X 68-C15X33.9	55.33	44.33	33.00	25.42	21.08	18.25	16.33	14.92	13.75	12.92	12.17	11.33	10.42	0.00	0.00
W24X 68-C12X20.7	43.50	34.83	27.83	21.83	18.33	16.08	14.50	13.33	12.42	11.58	10.42	9.58	8.75	8.17	0.00
W24X 68-C15X33.9	57.08	45.67	33.83	26.08	21.67	18.83	16.83	15.33	14.25	13.33	12.58	11.92	11.00	10.17	0.00
W24X 84-C12X20.7	44.42	35.58	30.92	26.25	21.67	18.75	16.75	15.25	14.08	13.17	12.42	11.75	10.83	10.00	9.25
W24X 84-C15X33.9	57.50	46.08	40.08	31.67	25.83	22.17	19.58	17.75	16.33	15.17	14.25	13.50	12.83	12.25	11.67
W27X 84-C12X20.7	46.00	36.75	31.92	26.00	21.67	18.83	16.83	15.33	14.25	13.33	12.58	12.00	11.08	10.25	9.58
W27X 84-C15X33.9	59.25	47.42	41.25	31.75	26.08	22.42	19.92	18.00	16.58	15.42	14.50	13.75	13.08	12.50	12.00
W27X 94-C12X20.7	46.75	37.33	32.58	29.00	23.83	20.58	18.25	16.58	15.33	14.25	13.42	12.75	12.17	11.50	10.67
W27X 94-C15X33.9	59.67	47.67	41.75	35.33	28.75	24.50	21.67	19.50	17.92	16.58	15.58	14.67	13.92	13.33	12.75
W30X 99-C15X33.9	59.67	47.67	41.67	34.42	28.17	24.17	21.33	19.33	17.75	16.50	15.42	14.58	13.92	13.25	12.75
W30X 99-C18X42.7	71.25	56.92	49.67	39.83	31.58	27.00	23.75	21.42	19.58	18.08	16.92	16.00	15.17	14.42	13.83
W30X116-C15X33.9	61.67	49.25	43.17	38.92	34.92	29.50	25.75	23.00	20.92	19.33	18.00	16.92	16.00	15.25	14.58
W30X116-C18X42.7	73.17	58.42	51.25	46.08	39.58	33.33	28.92	25.83	23.42	21.50	20.00	18.75	17.67	16.75	16.00
W33X118-C15X33.9	63.50	50.67	44.42	40.17	35.08	29.75	26.08	23.33	21.25	19.67	18.33	17.25	16.33	15.50	14.83
W33X118-C18X42.7	75.17	59.92	52.58	47.42	40.17	33.83	29.50	26.33	23.92	22.00	20.50	19.17	18.17	17.25	16.42
W33X141-C15X33.9	64.92	51.75	45.33	41.25	37.92	35.00	30.83	27.33	24.75	22.67	21.00	19.67	18.50	17.58	16.75
W33X141-C18X42.7	75.92	60.58	53.08	48.25	44.25	40.50	35.00	30.92	27.83	25.50	23.58	22.00	20.67	19.50	18.58
W36X150-C15X33.9	66.33	52.83	46.25	42.17	38.83	36.00	32.42	28.67	25.92	23.75	22.00	20.58	19.33	18.33	17.50
W36X150-C18X42.7	77.42	61.67	54.08	49.25	45.25	41.83	37.00	32.67	29.42	26.83	24.83	23.08	21.75	20.50	19.50

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



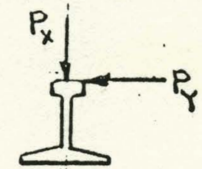


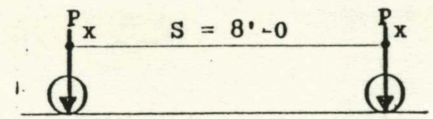
$P_y = 0.12P_x$ $F_y = 36$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	23.67	13.75	9.83	7.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	26.17	15.00	11.25	8.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	27.42	15.42	11.83	8.67	6.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	30.83	17.00	12.83	9.92	7.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	37.83	20.33	14.92	12.42	10.08	8.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	44.92	23.67	17.00	13.83	12.00	9.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	39.17	27.83	15.58	15.75	13.50	12.08	10.33	9.00	7.92	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C15X33.9	51.92	33.08	22.92	18.08	15.33	13.58	12.33	11.00	9.67	0.00	0.00	0.00	0.00	0.00	0.00
W21X 62-C12X20.7	40.83	32.50	23.67	18.75	15.92	14.00	12.75	11.67	10.25	9.17	8.33	7.58	0.00	0.00	0.00
W21X 62-C15X33.9	54.00	42.42	28.67	22.25	16.58	16.25	14.67	13.42	12.50	11.58	10.42	9.50	0.00	0.00	0.00
W21X 68-C12X20.7	41.08	32.83	25.75	20.08	16.92	14.83	13.42	12.33	11.25	10.00	9.08	8.25	7.58	0.00	0.00
W21X 68-C15X33.9	54.08	43.25	31.25	24.00	19.92	17.33	15.50	14.17	13.17	12.33	11.42	10.42	9.58	0.00	0.00
W24X 68-C12X20.7	42.25	33.75	25.67	20.25	17.08	15.08	13.67	12.58	11.58	10.42	9.42	8.58	7.92	7.33	0.00
W24X 68-C15X33.9	55.67	44.58	31.75	24.50	20.42	17.75	15.92	14.58	13.50	12.67	12.00	11.00	10.17	9.33	0.00
W24X 84-C12X20.7	43.17	34.58	29.75	24.25	20.08	17.42	15.58	14.25	13.25	12.42	11.58	10.58	9.67	9.00	8.33
W24X 84-C15X33.9	56.08	44.92	38.75	29.67	24.25	20.83	18.50	16.75	15.42	14.33	13.50	12.83	12.17	11.50	10.67
W27X 84-C12X20.7	44.58	35.67	30.67	23.83	19.92	17.42	15.67	14.33	13.33	12.50	11.75	10.75	9.92	9.17	8.50
W27X 84-C15X33.9	57.67	46.17	38.83	29.50	24.33	21.00	18.67	16.92	15.58	14.58	13.75	13.00	12.42	11.92	11.08
W27X 94-C12X20.7	45.25	36.17	31.42	26.50	21.92	18.92	16.92	15.42	14.25	13.33	12.58	12.00	11.08	10.25	9.50
W27X 94-C15X33.9	58.00	46.33	40.33	32.75	26.75	22.92	20.25	18.25	16.83	15.58	14.67	13.83	13.17	12.58	12.17
W30X 99-C15X33.9	58.00	46.33	40.33	31.92	26.17	22.50	20.00	18.08	16.67	15.50	14.58	13.75	13.17	12.58	12.08
W30X 99-C18X42.7	69.42	55.50	48.17	36.42	29.67	25.33	22.42	20.17	18.50	17.17	16.08	15.17	14.42	13.75	13.17
W30X116-C15X33.9	59.83	47.75	41.83	37.50	32.08	27.17	23.75	21.33	19.42	18.00	16.83	15.83	15.00	14.25	13.67
W30X116-C18X42.7	71.17	56.83	49.75	44.50	36.92	31.08	27.00	24.17	21.92	20.17	18.75	17.67	16.67	15.83	15.08
W33X118-C15X33.9	61.50	49.08	43.00	38.58	32.08	27.33	24.00	21.58	19.75	18.25	17.08	16.08	15.25	14.50	13.92
W33X118-C18X42.7	73.00	58.25	51.00	45.67	37.17	31.42	27.42	24.50	22.33	20.58	19.17	18.00	17.00	16.17	15.50
W33X141-C15X33.9	62.83	50.08	43.92	39.75	36.33	32.50	28.17	25.08	22.75	20.92	19.42	18.25	17.17	16.33	15.58
W33X141-C18X42.7	73.67	58.75	51.50	46.58	42.50	37.42	32.33	28.67	25.83	23.67	21.92	20.50	19.25	18.25	17.42
W36X150-C15X33.9	64.17	51.08	44.75	40.67	37.17	34.00	29.50	26.25	23.75	21.83	20.25	19.00	17.92	17.00	16.17
W36X150-C18X42.7	75.00	59.75	52.42	47.50	43.42	39.42	34.00	30.08	27.17	24.83	23.00	21.42	20.17	19.08	18.17

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



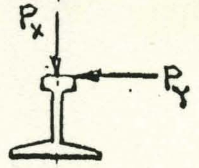


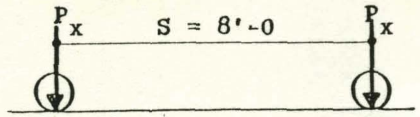
$P_y = 0.08P_x$ $F_y = 36$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	27.17	16.08	11.67	8.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	29.25	17.08	12.92	9.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	31.58	18.17	13.92	10.42	8.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	34.75	19.58	14.83	11.67	9.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	39.75	23.67	17.42	14.50	11.92	9.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	48.58	26.50	19.33	15.83	13.75	11.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	41.42	32.58	23.08	18.58	15.92	14.25	12.50	10.83	9.50	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C15X33.9	54.33	37.00	26.08	20.75	17.67	15.67	14.25	12.75	11.25	0.00	0.00	0.00	0.00	0.00	0.00
W21X 62-C12X20.7	43.58	35.00	28.58	22.50	19.08	16.75	15.17	14.00	12.67	11.33	10.25	9.33	0.00	0.00	0.00
W21X 62-C15X33.9	56.92	45.67	33.08	25.83	21.67	18.92	17.00	15.58	14.50	13.67	12.33	11.25	0.00	0.00	0.00
W21X 68-C12X20.7	43.83	35.25	30.50	24.25	20.33	17.83	16.08	14.75	13.75	12.42	11.17	10.17	9.33	0.00	0.00
W21X 68-C15X33.9	57.08	45.83	35.92	27.92	23.25	20.25	18.08	16.50	15.33	14.33	13.58	12.33	11.33	0.00	0.00
W24X 68-C12X20.7	45.33	36.42	31.42	24.67	20.75	18.25	16.42	15.08	14.08	13.00	11.75	10.75	9.83	9.17	0.00
W24X 68-C15X33.9	59.00	47.25	37.25	28.92	24.08	20.92	18.75	17.17	15.83	14.83	14.08	13.17	12.08	11.17	0.00
W24X 84-C12X20.7	46.33	37.17	32.58	29.08	24.67	21.33	19.00	17.33	16.00	15.00	14.17	13.25	12.17	11.25	10.50
W24X 84-C15X33.9	59.50	47.67	41.83	34.92	28.67	24.67	21.83	19.83	18.17	16.92	15.92	15.08	14.33	13.75	12.92
W27X 84-C12X20.7	48.00	38.42	33.75	29.67	24.67	21.42	19.17	17.50	16.17	15.17	14.33	13.67	12.58	11.58	10.83
W27X 94-C15X33.9	61.42	49.17	43.17	35.33	29.08	25.08	22.25	20.17	18.58	17.33	16.25	15.42	14.67	14.08	13.42
W27X 94-C12X20.7	48.75	39.08	34.33	30.92	27.25	23.50	20.83	18.92	17.50	16.25	15.33	14.58	13.83	13.00	12.08
W27X 94-C15X33.9	61.83	49.50	43.50	39.17	32.08	27.50	24.25	21.92	20.08	18.67	17.50	16.50	15.67	15.00	14.42
W30X 99-C15X33.9	61.83	49.50	43.50	38.42	31.50	27.00	23.92	21.67	19.83	18.50	17.33	16.42	15.58	14.92	14.33
W30X 99-C18X42.7	73.50	58.83	51.58	42.58	34.83	29.75	26.25	23.67	21.67	20.08	18.83	17.75	16.83	16.08	15.42
W30X116-C15X33.9	64.08	51.25	45.00	41.00	37.58	33.25	29.08	26.00	23.67	21.83	20.33	19.08	18.08	17.25	16.42
W30X116-C18X42.7	75.75	60.58	53.17	48.25	43.75	36.92	32.17	28.75	26.08	24.00	22.33	20.92	19.75	18.75	17.92
W33X118-C15X33.9	66.08	52.83	46.42	42.25	38.83	33.75	29.50	26.50	24.17	22.25	20.75	19.58	18.50	17.58	16.83
W33X118-C18X42.7	77.92	62.25	54.67	49.67	44.75	37.83	33.00	29.50	26.75	24.67	22.92	21.50	20.33	19.33	18.42
W33X141-C15X33.9	67.58	54.00	47.33	43.17	40.08	37.25	34.83	31.08	28.17	25.83	23.92	22.33	21.08	20.00	19.00
W33X141-C18X42.7	78.83	63.00	55.25	50.42	46.58	43.25	39.17	34.67	31.25	28.58	26.50	24.67	23.25	22.00	20.92
W36X150-C15X33.9	69.17	55.17	48.42	44.17	41.00	38.33	35.92	32.83	29.67	27.17	25.17	23.50	22.08	20.92	19.92
W36X150-C18X42.7	80.50	64.25	56.33	51.33	47.67	44.33	41.50	36.83	33.17	30.33	28.00	26.08	24.50	23.17	22.00

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



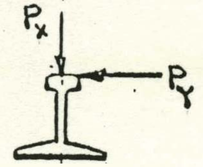


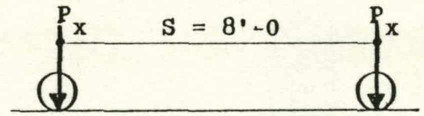
$P_y = 0.10P_x$ $F_y = 36$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	25.92	15.33	10.67	7.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	28.17	16.42	12.00	8.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	30.08	17.17	12.92	9.42	7.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	33.25	18.75	14.25	10.75	8.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	38.92	22.42	16.58	13.83	10.92	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	47.33	25.50	18.58	15.25	13.00	10.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	40.42	30.67	21.75	17.50	15.08	13.42	11.33	9.83	8.67	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C15X33.9	53.25	35.58	24.92	19.83	16.92	15.00	13.67	11.83	10.42	0.00	0.00	0.00	0.00	0.00	0.00
W21X 62-C12X20.7	42.33	33.92	26.50	20.92	17.83	15.75	14.33	12.92	11.33	10.17	9.17	8.42	0.00	0.00	0.00
W21X 62-C15X33.9	55.58	44.58	31.33	24.50	20.50	18.00	16.17	14.92	13.83	12.58	11.33	10.33	0.00	0.00	0.00
W21X 68-C12X20.7	42.58	34.25	28.75	22.50	19.00	16.67	15.08	13.92	12.42	11.08	10.00	9.17	8.42	0.00	0.00
W21X 68-C15X33.9	55.75	44.75	34.00	26.42	22.00	19.17	17.17	15.75	14.58	13.67	12.42	11.33	10.42	0.00	0.00
W24X 68-C12X20.7	43.92	35.25	28.83	22.75	19.25	17.00	15.33	14.17	12.92	11.58	10.42	9.58	8.75	8.17	0.00
W24X 68-C15X33.9	57.42	46.08	34.92	27.08	22.58	19.75	17.67	16.17	15.08	14.08	13.17	12.00	11.00	10.17	0.00
W24X 84-C12X20.7	44.83	35.92	31.33	27.33	22.67	19.67	17.58	16.08	14.92	14.00	12.92	11.75	10.83	10.00	9.25
W24X 84-C15X33.9	57.83	46.42	40.50	32.67	26.83	23.08	20.50	18.58	17.17	16.00	15.08	14.25	13.58	12.58	11.67
W27X 84-C12X20.7	46.33	37.17	32.42	27.00	22.58	19.67	17.67	16.17	15.08	14.17	13.17	12.00	11.08	10.25	9.58
W27X 84-C15X33.9	59.67	47.75	41.67	32.75	27.00	23.33	20.75	18.92	17.42	16.25	15.33	14.58	13.92	13.08	12.17
W27X 94-C12X20.7	47.08	37.75	33.08	29.50	24.83	21.50	19.17	17.42	16.17	15.08	14.25	13.50	12.42	11.50	10.67
W27X 94-C15X33.9	60.00	48.00	42.08	36.42	29.75	25.50	22.58	20.42	18.75	17.42	16.42	15.50	14.75	14.17	13.58
W30X 99-C15X33.9	60.00	48.00	42.08	35.50	29.17	25.08	22.25	20.17	18.58	17.33	16.25	15.42	14.67	14.08	13.42
W30X 99-C18X42.7	71.58	57.25	50.08	39.92	32.58	27.92	24.67	22.25	20.42	19.00	17.83	16.83	16.00	15.25	14.67
W30X116-C15X33.9	62.00	49.58	43.58	39.42	35.92	30.50	26.67	23.92	21.83	20.17	18.83	17.75	16.83	16.08	15.33
W30X116-C18X42.7	73.50	58.75	51.58	46.58	40.67	34.33	30.00	26.75	24.33	22.42	20.92	19.58	18.50	17.67	16.83
W33X118-C15X33.9	63.83	51.00	44.83	40.58	36.17	30.75	27.00	24.25	22.17	20.50	19.17	18.08	17.17	16.33	15.67
W33X118-C18X42.7	75.50	60.33	52.92	47.83	41.25	34.92	30.50	27.33	24.83	22.92	21.33	20.08	19.00	18.08	17.25
W33X141-C15X33.9	65.25	52.08	45.67	41.67	38.33	35.50	31.83	28.33	25.67	23.58	21.92	20.58	19.42	18.42	17.58
W33X141-C18X42.7	76.33	60.92	53.42	48.67	44.67	41.25	36.00	31.92	28.83	26.42	24.50	22.92	21.58	20.42	19.42
W36X150-C15X33.9	66.67	53.17	46.67	42.50	39.25	36.50	33.42	29.75	26.92	24.67	22.92	21.50	20.25	19.25	18.33
W36X150-C18X42.7	77.75	62.00	54.42	49.58	45.67	42.33	38.08	33.67	30.42	27.83	25.75	24.08	22.58	21.42	20.33

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



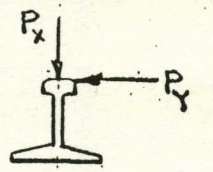


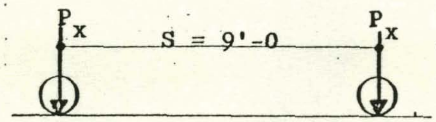
$P_y = 0.12P_x$ $F_y = 36$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	24.67	14.67	9.83	7.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	27.17	15.83	11.25	8.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	28.50	16.33	11.83	8.67	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	31.92	17.92	13.67	9.92	7.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	38.17	21.25	15.83	12.83	10.08	8.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	46.00	24.67	17.92	14.67	12.17	9.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	39.50	28.83	20.50	16.58	14.33	12.25	10.33	9.00	7.92	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C15X33.9	52.25	34.17	23.92	19.00	16.25	14.42	12.75	11.00	9.67	0.00	0.00	0.00	0.00	0.00	0.00
W21X 62-C12X20.7	41.25	32.92	24.67	19.67	16.75	14.83	13.50	11.67	10.25	9.17	8.33	7.58	0.00	0.00	0.00
W21X 62-C15X33.9	54.33	43.50	29.75	23.25	19.50	17.17	15.50	14.25	13.00	11.58	10.42	9.50	0.00	0.00	0.00
W21X 68-C12X20.7	41.42	33.25	26.75	21.00	17.83	15.67	14.25	12.75	11.25	10.00	9.08	8.25	7.58	0.00	0.00
W21X 68-C15X33.9	54.50	43.67	32.25	25.00	20.92	19.25	16.33	15.00	13.92	12.67	11.42	10.42	9.58	0.00	0.00
W24X 68-C12X20.7	42.67	34.17	26.67	21.17	18.00	15.92	14.50	13.17	11.58	10.42	9.42	8.58	7.92	7.33	0.00
W24X 68-C15X33.9	56.00	44.92	32.83	25.50	21.33	18.67	16.83	15.42	14.33	13.33	12.08	11.00	10.17	9.33	0.00
W24X 84-C12X20.7	43.50	34.92	30.17	25.25	21.00	18.33	16.50	15.08	14.00	12.83	11.58	10.58	9.67	9.00	8.33
W24X 84-C15X33.9	56.42	45.25	39.17	30.75	25.25	21.75	19.33	17.58	16.25	15.17	14.33	13.58	12.50	11.50	10.67
W27X 84-C12X20.7	44.92	36.00	31.17	24.83	20.83	18.33	16.50	15.17	14.17	13.00	11.75	10.75	9.92	9.17	8.50
W27X 84-C15X33.9	58.00	46.50	39.92	30.58	25.25	21.92	19.50	17.83	16.50	15.42	14.50	13.83	12.83	11.92	11.08
W27X 94-C12X20.7	45.67	36.58	31.83	27.50	22.83	19.83	17.83	16.25	15.08	14.17	13.25	12.08	11.08	10.25	9.50
W27X 94-C15X33.9	58.33	46.75	40.75	33.83	27.75	23.83	21.17	19.17	17.67	16.50	15.50	14.67	14.00	13.25	12.33
W30X 99-C15X33.9	58.33	46.75	40.75	32.92	27.17	23.42	20.83	19.00	17.50	16.33	15.42	14.58	13.92	13.17	12.25
W30X 99-C18X42.7	69.83	55.83	48.58	37.50	30.67	26.33	23.33	21.08	19.42	18.00	16.92	16.00	15.25	14.58	14.00
W30X116-C15X33.9	60.17	48.08	42.25	37.92	33.17	28.17	24.75	22.25	20.33	18.83	17.67	16.67	15.83	15.08	14.50
W30X116-C18X42.7	71.50	57.17	50.17	44.92	38.00	32.08	28.00	25.08	22.83	21.08	19.67	18.50	17.50	16.67	15.92
W33X118-C15X33.9	61.92	49.42	43.42	39.00	33.17	28.25	24.92	22.50	20.58	19.17	17.92	16.92	16.08	15.33	14.75
W33X118-C18X42.7	73.33	58.58	51.42	46.17	38.25	32.42	28.42	25.50	23.25	21.50	20.08	18.92	17.92	17.00	16.33
W33X141-C15X33.9	63.17	50.42	44.25	40.17	36.75	33.50	29.17	26.08	23.67	21.83	20.33	19.08	18.08	17.17	16.42
W33X141-C18X42.7	74.08	59.17	51.92	47.08	43.00	38.50	33.33	29.67	26.83	24.58	22.83	21.42	20.17	19.17	18.25
W36X150-C15X33.9	64.50	51.42	45.08	41.08	37.67	34.75	30.50	27.17	24.67	22.75	21.17	19.83	18.75	17.83	17.08
W36X150-C18X42.7	75.33	60.17	52.75	47.92	43.92	40.42	35.08	31.08	28.08	25.75	23.92	22.33	21.08	20.00	19.00

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



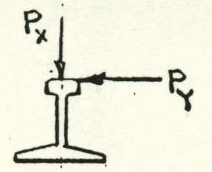


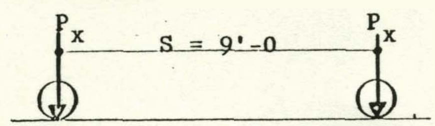
$P_y = 0.08P_x$ $F_y = 36$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	28.17	16.92	11.67	8.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	30.17	17.92	12.92	9.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	31.92	19.08	14.25	10.42	8.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	35.75	20.50	15.67	11.67	9.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	40.08	24.58	18.33	15.25	11.92	9.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	49.67	27.42	20.17	16.67	13.92	11.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	41.83	33.50	24.00	19.42	16.75	14.75	12.50	10.83	9.50	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C15X33.9	54.67	38.00	27.00	21.67	18.50	16.50	14.75	12.75	11.25	0.00	0.00	0.00	0.00	0.00	0.00
W21X 62-C12X20.7	43.92	35.42	29.58	23.42	19.92	17.67	16.00	14.33	12.67	11.33	10.25	9.33	0.00	0.00	0.00
W21X 62-C15X33.9	57.25	46.08	34.08	26.83	22.58	19.83	17.92	16.42	15.33	13.67	12.33	11.25	0.00	0.00	0.00
W21X 68-C12X20.7	44.25	35.58	31.00	25.17	21.25	18.67	16.92	15.58	13.92	12.42	11.17	10.17	9.33	0.00	0.00
W21X 68-C15X33.9	57.42	46.17	36.92	28.92	24.17	21.08	19.00	17.33	16.17	15.00	13.58	12.33	11.33	0.00	0.00
W24X 68-C12X20.7	45.67	36.75	32.00	25.58	21.67	19.08	17.25	15.92	14.50	13.00	11.75	10.75	9.83	9.17	0.00
W24X 68-C15X33.9	59.33	47.67	38.33	29.83	25.00	21.83	19.58	18.00	16.67	15.67	14.42	13.17	12.08	11.17	0.00
W24X 84-C12X20.7	46.67	37.50	33.00	29.58	25.58	22.25	19.92	18.17	16.83	15.75	14.58	13.25	12.17	11.25	10.50
W24X 84-C15X33.9	59.83	48.08	42.25	35.92	29.67	25.58	22.75	20.67	19.08	17.75	16.75	15.92	15.00	13.92	12.92
W27X 84-C12X20.7	48.33	38.83	34.08	30.58	25.58	22.33	20.00	18.33	17.00	16.00	15.00	13.67	12.58	11.58	10.83
W27X 84-C15X33.9	61.75	49.50	43.50	36.42	30.08	26.00	23.17	21.08	19.42	18.17	17.08	16.25	15.50	14.42	13.42
W27X 94-C12X20.7	49.08	39.42	34.67	31.33	28.17	24.42	21.75	19.83	18.33	17.08	16.17	15.33	14.08	13.00	12.08
W27X 94-C15X33.9	62.17	49.83	43.83	39.58	33.08	28.42	25.17	22.75	20.92	19.50	18.33	17.33	16.50	15.75	15.08
W30X 99-C15X33.9	62.17	49.83	43.83	39.42	32.50	28.00	24.83	22.50	20.75	19.33	18.17	17.25	16.42	15.67	14.92
W30X 99-C18X42.7	73.83	59.17	52.00	43.67	35.83	30.75	27.17	24.58	22.58	21.00	19.67	18.58	17.67	16.92	16.25
W30X116-C15X33.9	64.42	51.58	45.33	41.33	38.00	34.25	30.00	26.92	24.58	22.75	21.25	20.00	18.92	18.08	17.25
W30X116-C18X42.7	76.08	60.92	53.50	48.67	44.58	37.92	33.17	29.67	27.00	24.92	23.17	21.83	20.58	19.58	18.75
W33X118-C15X33.9	66.50	53.17	46.75	42.58	39.25	34.75	30.50	27.42	25.08	23.17	21.67	20.42	19.33	18.42	17.67
W33X118-C18X42.7	78.25	62.58	55.00	50.08	45.83	38.83	34.00	30.42	27.67	25.58	23.83	22.42	21.17	20.17	19.25
W33X141-C15X33.9	67.92	54.33	47.75	43.58	40.42	37.75	35.33	32.08	29.08	26.75	24.83	23.25	22.00	20.83	19.92
W33X141-C18X42.7	79.17	63.33	55.58	50.75	47.00	43.75	40.17	35.67	32.25	29.58	27.42	25.58	24.08	22.83	21.75
W36X150-C15X33.9	69.50	55.58	48.75	44.50	41.42	38.75	36.42	33.83	30.67	28.08	26.08	24.42	23.00	21.83	20.83
W36X150-C18X42.7	80.83	64.58	56.67	51.67	48.00	44.83	42.00	37.83	34.17	31.25	28.92	27.00	25.42	24.08	22.83

Note: A value of 0.00 indicates allowable web shear stress exceeded

TABLE 3-3 (cont.): Maximum allowable beam lengths



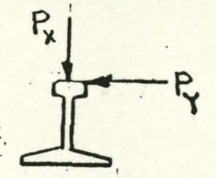


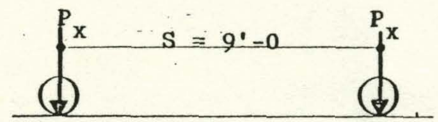
$P_y = 0.10P_x$ $F_y = 36$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	26.83	16.17	10.67	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	29.17	17.25	12.00	8.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	31.17	18.08	12.92	9.42	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	34.33	19.58	14.83	10.75	8.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	39.25	23.33	17.42	14.00	10.92	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	48.33	26.50	19.42	16.08	13.00	10.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	40.75	31.67	22.67	18.42	15.92	13.42	11.33	9.83	8.67	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C15X33.9	53.58	36.58	25.92	20.75	17.75	15.83	13.67	11.83	10.42	0.00	0.00	0.00	0.00	0.00	0.00
W21X 62-C12X20.7	42.67	34.33	27.50	21.83	18.67	16.58	14.92	12.92	11.33	10.17	9.17	8.42	0.00	0.00	0.00
W21X 62-C15X33.9	55.92	44.92	32.33	25.42	21.42	18.83	17.00	15.67	14.08	12.58	11.33	10.33	0.00	0.00	0.00
W21X 68-C12X20.7	42.92	34.58	29.75	23.42	19.83	17.50	15.92	14.17	12.42	11.08	10.00	9.17	8.42	0.00	0.00
W21X 68-C15X33.9	56.08	45.08	35.08	27.33	22.92	20.08	18.00	16.58	15.42	13.75	12.42	11.33	10.42	0.00	0.00
W24X 68-C12X20.7	44.25	35.58	29.83	23.67	20.08	17.83	16.17	14.67	12.92	11.58	10.42	9.58	8.75	8.17	0.00
W24X 68-C15X33.9	57.75	46.42	36.00	28.08	23.50	20.58	18.58	17.00	15.83	14.58	13.17	12.00	11.00	10.17	0.00
W24X 84-C12X20.7	45.17	36.33	31.75	28.33	23.58	20.58	18.50	16.92	15.75	14.33	12.92	11.75	10.83	10.00	9.25
W24X 84-C15X33.9	58.25	46.75	40.92	33.75	27.83	24.08	21.42	19.50	18.00	16.83	15.83	14.92	13.67	12.58	11.67
W27X 84-C12X20.7	46.67	37.50	32.83	28.00	23.50	20.58	18.50	17.00	15.83	14.58	13.17	12.00	11.08	10.25	9.58
W27X 84-C15X33.9	60.00	48.08	42.08	33.83	28.00	24.25	21.67	19.75	18.25	17.08	16.17	15.33	14.08	13.08	12.17
W27X 94-C12X20.7	47.42	38.08	33.42	30.00	25.75	22.42	20.00	18.33	17.00	15.92	14.83	13.50	12.42	11.50	10.67
W27X 94-C15X33.9	60.33	48.42	42.50	37.42	30.75	26.50	23.50	21.33	19.58	18.33	17.25	16.33	15.58	14.58	13.58
W30X 99-C15X33.9	60.33	48.42	42.50	36.50	30.08	26.00	23.17	21.08	19.42	18.17	17.08	16.25	15.50	14.42	13.42
W30X 99-C18X42.7	71.92	57.58	50.50	41.00	33.58	28.92	25.58	23.17	21.33	19.83	18.67	17.67	16.83	16.08	15.42
W30X116-C15X33.9	62.33	49.92	43.92	39.83	36.42	31.50	27.67	24.92	22.75	21.08	19.75	18.58	17.67	16.92	16.17
W30X116-C18X42.7	73.83	59.08	54.92	47.00	41.75	35.42	30.92	27.75	25.25	23.33	21.75	20.50	19.42	18.50	17.67
W33X118-C15X33.9	64.25	51.42	45.17	41.00	37.17	31.75	27.92	25.17	23.08	21.42	20.08	18.92	18.00	17.17	16.50
W33X118-C18X42.7	75.83	60.67	53.25	48.25	42.33	35.92	31.50	28.25	25.75	23.83	22.25	20.92	19.83	18.92	18.08
W33X141-C15X33.9	65.58	52.42	46.08	42.00	38.83	36.00	32.83	29.33	26.67	24.50	22.83	21.42	20.25	19.25	18.42
W33X141-C18X42.7	76.67	61.25	53.83	49.08	45.17	41.83	37.08	32.92	29.83	27.42	25.42	23.83	22.42	21.33	20.33
W36X150-C15X33.9	67.00	53.50	47.00	42.92	35.75	36.92	34.42	30.67	27.83	25.67	23.83	22.33	21.17	20.08	19.17
W36X150-C18X42.7	78.08	62.42	54.75	49.92	46.17	42.83	39.08	34.75	31.42	28.75	26.67	25.00	23.50	22.33	21.25

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



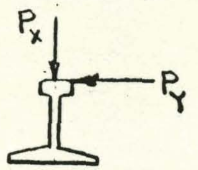


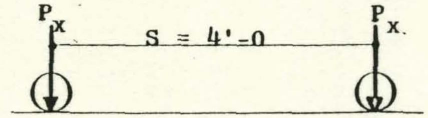
$P_y = 0.12P_x$ $F_y = 36$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	25.67	15.42	9.83	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	28.17	16.67	11.25	8.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	29.50	17.17	11.83	8.67	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	32.92	18.75	13.75	9.92	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	38.50	22.17	16.67	12.83	10.08	8.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	47.08	25.58	18.75	15.50	12.17	9.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	39.83	29.92	21.42	17.42	15.00	12.25	10.33	9.00	8.00	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C15X33.9	52.58	35.17	24.83	19.92	17.08	15.17	12.75	11.00	9.67	0.00	0.00	0.00	0.00	0.00	0.00
W21X 62-C12X20.7	41.58	33.33	25.67	20.50	17.58	15.67	13.50	11.67	10.25	9.17	8.33	8.00	0.00	0.00	0.00
W21X 62-C15X33.9	54.75	43.92	30.75	24.17	20.42	18.00	16.25	14.75	13.00	11.58	10.42	9.50	0.00	0.00	0.00
W21X 68-C12X20.7	41.83	33.58	27.75	22.00	18.67	16.50	14.83	12.75	11.25	10.00	9.08	8.25	8.00	0.00	0.00
W21X 68-C15X33.9	54.83	44.00	33.33	26.00	21.83	19.08	17.25	15.83	14.25	12.67	11.42	10.42	9.58	0.00	0.00
W24X 68-C12X20.7	43.00	34.58	27.67	22.08	18.83	16.75	15.25	13.17	11.58	10.42	9.42	8.58	8.00	8.00	0.00
W24X 68-C15X33.9	56.42	45.25	33.92	26.50	22.25	19.58	17.67	16.25	15.00	13.33	12.08	11.00	10.17	9.33	0.00
W24X 84-C12X20.7	43.83	35.25	30.67	26.25	21.92	19.25	17.33	15.92	14.42	12.83	11.58	10.58	9.67	9.00	8.33
W24X 84-C15X33.9	56.75	45.58	39.67	31.75	26.25	22.67	20.25	18.50	17.08	16.00	15.00	13.58	12.50	11.50	10.67
W27X 84-C12X20.7	45.25	36.33	31.58	25.83	21.75	19.17	17.33	16.00	14.58	13.00	11.75	10.75	9.92	9.17	8.50
W27X 84-C15X33.9	58.42	46.83	40.75	31.58	26.25	22.83	20.42	18.67	17.25	16.25	15.33	14.00	12.83	11.92	11.08
W27X 94-C12X20.7	46.00	36.92	32.25	28.50	23.75	20.75	18.67	17.08	15.92	14.67	13.25	12.08	11.08	10.25	9.50
W27X 94-C15X33.9	58.75	47.08	41.17	34.92	28.75	24.75	22.08	20.08	18.50	17.33	16.33	15.50	14.33	13.25	12.33
W30X 99-C15X33.9	58.75	47.08	41.17	34.00	28.08	24.33	21.75	19.83	18.33	17.17	16.17	15.42	14.17	13.17	12.25
W30X 99-C18X42.7	70.17	56.17	49.00	38.58	31.67	27.25	24.25	22.00	20.25	18.83	17.75	16.83	16.00	15.33	14.33
W30X116-C15X33.9	60.50	48.50	42.58	38.42	34.25	29.17	25.75	23.17	21.25	19.75	18.50	17.50	16.67	15.92	15.25
W30X116-C18X42.7	71.83	57.50	50.50	45.42	39.08	33.17	29.00	26.00	23.75	22.00	20.58	19.33	18.33	17.50	16.75
W33X118-C15X33.9	62.25	49.83	43.75	39.50	34.17	29.25	25.83	23.42	21.50	20.00	18.75	17.75	16.92	16.17	15.50
W33X118-C18X42.7	73.67	58.92	51.75	46.58	39.33	33.42	29.33	26.42	24.17	22.33	20.92	19.75	18.75	17.83	17.08
W33X141-C15X33.9	63.58	50.83	44.58	40.58	37.25	34.42	30.17	27.00	24.58	22.75	21.25	20.00	18.92	18.00	17.25
W33X141-C18X42.7	74.42	59.50	52.25	47.42	43.42	39.58	34.42	30.67	27.75	25.58	23.75	22.25	21.08	20.00	19.08
W36X150-C15X33.9	64.83	51.83	45.50	41.42	38.17	35.33	31.50	28.17	25.67	23.67	22.08	20.75	19.67	18.67	17.52
W36X150-C18X42.7	75.75	60.50	53.08	48.33	44.42	41.00	36.08	32.08	29.08	26.75	24.83	23.25	22.00	20.83	19.92

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



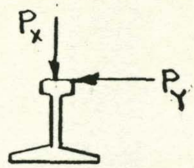


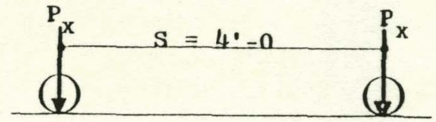
$P_y = 0.08P_x$ $F_y = 50$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	29.08	16.50	11.83	9.58	8.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	34.67	17.92	12.67	10.25	8.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	30.17	19.42	13.58	10.92	9.33	8.25	7.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	36.92	21.33	14.83	11.83	10.00	8.83	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	38.42	26.92	18.33	14.33	12.00	10.50	9.42	8.58	8.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	50.83	30.83	20.92	16.17	13.42	11.58	10.33	9.42	8.75	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	40.08	32.00	26.17	19.92	16.33	14.00	12.42	11.17	10.25	9.58	8.92	8.42	0.00	0.00	0.00
W18X 50-C15X33.9	53.00	42.33	30.33	22.92	18.67	15.92	14.00	12.58	11.50	10.67	9.92	9.33	0.00	0.00	0.00
W21X 62-C12X20.7	42.17	33.67	29.50	25.33	20.50	17.42	15.25	13.67	12.50	11.50	10.75	10.08	9.58	9.08	8.67
W21X 62-C15X33.9	55.58	44.33	38.83	30.00	24.17	20.33	17.75	15.83	14.33	13.25	12.25	11.50	10.83	10.25	9.83
W21X 68-C12X20.7	42.42	33.83	29.67	26.75	22.33	18.83	16.50	14.67	13.33	12.33	11.42	10.75	10.17	9.67	9.17
W21X 68-C15X33.9	55.75	44.42	39.00	32.92	26.33	22.17	19.25	17.08	15.42	14.17	13.17	12.25	11.58	10.92	10.42
W24X 68-C12X20.7	43.92	35.00	30.67	27.67	22.83	19.33	16.92	15.17	13.75	12.67	11.83	11.08	10.50	9.92	9.50
W24X 68-C15X33.9	57.58	45.92	40.25	34.25	27.42	23.08	20.08	17.83	16.17	14.83	13.75	12.83	12.08	11.42	10.92
W24X 84-C12X20.7	44.83	35.75	31.25	28.50	26.17	23.67	20.50	18.17	16.33	15.00	13.83	12.92	12.17	11.50	10.92
W24X 84-C15X33.9	58.08	46.33	40.58	36.92	34.00	28.33	24.42	21.50	19.33	17.58	16.25	15.08	14.17	13.33	12.67
W27X 84-C12X20.7	46.50	37.00	32.42	29.50	27.08	23.75	20.67	18.33	16.58	15.25	14.08	13.17	12.42	11.75	11.17
W27X 84-C15X33.9	60.00	47.75	41.83	38.08	34.58	28.83	24.92	22.00	19.83	18.08	16.67	15.50	14.58	13.75	13.00
W27X 94-C12X20.7	47.33	37.58	32.92	30.00	27.67	25.75	23.00	20.33	18.33	16.75	15.42	14.42	13.50	12.75	12.08
W27X 94-C15X33.9	60.42	48.08	42.08	38.33	35.50	32.25	27.67	24.42	21.83	19.92	18.33	17.00	15.92	15.00	14.17
W30X 99-C15X33.9	60.42	48.08	42.08	38.33	35.50	31.58	27.17	24.00	21.58	19.67	18.08	16.83	15.75	14.83	14.08
W30X 99-C18X42.7	72.17	57.42	50.25	45.75	42.33	35.42	30.42	26.83	24.00	21.83	20.08	18.67	17.42	16.42	15.50
W30X116-C15X33.9	62.67	49.83	43.58	39.67	36.92	34.58	32.58	30.17	26.92	24.33	22.25	20.58	19.17	17.92	16.92
W30X116-C18X42.7	74.33	59.17	51.75	47.08	43.83	41.08	38.58	34.00	30.25	27.33	24.92	23.00	21.42	20.00	18.83
W33X118-C15X33.9	64.67	51.42	45.00	40.92	38.00	35.75	33.67	30.75	27.50	24.92	22.83	21.08	19.67	18.50	17.42
W33X118-C18X42.7	76.50	60.83	53.25	48.42	45.00	42.25	39.83	35.00	31.17	28.17	25.75	23.75	22.17	20.75	19.58
W33X141-C15X33.9	66.17	52.50	45.92	41.75	38.83	36.58	34.67	32.92	31.33	29.83	27.25	25.08	23.25	21.75	20.42
W33X141-C18X42.7	77.42	61.58	53.83	49.00	45.50	42.83	40.58	38.58	36.67	33.83	30.75	28.25	26.17	24.42	22.92
W36X150-C15X33.9	67.75	53.75	47.00	42.67	39.67	37.33	35.50	33.83	32.25	30.75	28.92	26.58	24.67	23.08	21.67
W36X150-C18X42.7	79.08	62.83	54.92	49.92	46.42	43.67	41.50	39.50	37.58	35.92	32.92	30.17	28.0C	26.08	24.50

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



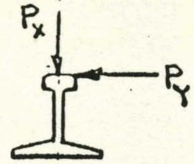


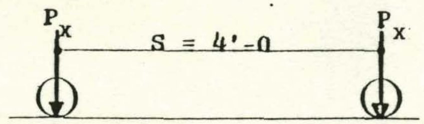
$P_y' = 0.10P_x$ $F_y = 50$ ksi

[illegible]	WH LOAD P_x (kips)													
	[illegible]	1).	1 .0	).:	25.	3Ω0	35 .	4 C.9	4 .0	50.	.0	.0	65		.0
W12X 25-C10X15.3	2850	15.50	11.08	9..0	7.8)	0.00	0 .00	0.00	0.00	0.00	0.00	0.90	0 .00	0.00	0.00
W12X 25-C12X20.7	3325	17.00	12.08	9 .7	8.42	0.00	0 .00	0.00	0.00	0.00	0.00	0..0	0 .00	0.00	0.00
W14X 30-C10X15.3	2950	18.00	12.75	10 .2	8.75	7.83	7 .08	0.00	0.00	0.00	0.00	0..0	0 .CC	0.0C	0.00
W14X 30-C12X20.7	3625	20.17	14.00	11..1	9.5)	8.42	7 .67	0.00	0.00	0.00	0.00	0..0	0 .00	0.0C	0.00
W16X 35-C12X20.7	3758	25.25	17.17	13..4	11.33	9.92	8 .92	8.17	7.58	0.00	0.00	0..0	0 .00	0.00	0.00
W16X 35-C15X33.9	5000	29.58	15.92	15..3	12.75	11.08	9 .92	9.C0	8.33	0.00	0.00	0..0	0 .00	0.00	0.00
W18X 50-C12X20.7	3900	31.17	24.33	18..4	15.17	13.00	11 .58	10.50	5.67	9.00	8.42	8..0	0 .0C	0.00	0.C0
W18X 50-C15X33.9	5192	41.50	28.83	21..6	17.67	15.00	13 .25	11.92	10.92	10.08	9.42	8..2	0 .00	0.00	0.C0
W21X 62-C12X20.7	4092	32.67	28.50	23..2	18.83	16.0C	14 .08	12.67	11.58	10.75	10.00	9..2	8 .92	8.50	8.17
W21X 62-C15X33.9	5417	43.25	37.83	29..1	22.53	19.08	16 .67	14.83	13.50	12.42	11.58	10..3	10 .25	9.75	9.25
W21X 63-C12X20.7	4117	32.83	28.75	25..4	20.42	17.33	15 .17	13.58	12.33	11.42	10.58	10..0	9 .42	9.00	8.58
W21X 63-C15X33.9	5433	43.33	38.00	30..8	24.67	20.67	18 .00	16.C0	14.50	13.33	12.33	11.58	10 .92	10.33	9.83
W24X 63-C12X20.7	4250	33.83	29.67	25..6	20.75	17.67	15 .50	13.92	12.67	11.67	10.92	10.25	9 .75	9.25	8.83
W24X 63-C15X33.9	5600	44.67	39.17	31..8	25.5)	21.42	18 .67	16.58	15.08	13.83	12.83	12.00	11.33	10.75	10.25
W24X 84-C12X20.7	4333	34.50	30.25	27..4	25.0)	21.42	18 .58	16.50	14.92	13.67	12.67	11.83	11.17	10.58	10.08
W24X 84-C15X33.9	5650	45.00	39.42	35..8	31.5)	26.25	22 .58	19.92	17.92	16.33	15.08	14.08	13.17	12.42	11.83
W27X 84-C12X20.7	4492	35.67	31.25	28..3	25.33	21.33	18 .58	16.58	15.08	13.83	12.83	12..0	11.33	10.75	10.25
W27X 84-C15X33.9	5825	46.33	40.58	36..9	31.67	26.42	22 .83	20.25	18.25	16.67	15.42	14..2	13.50	12.75	12.C8
W27X 94-C12X20.7	4567	36.25	31.75	28..8	26.5)	23.83	20 .67	18.33	16.50	15.17	14.00	13.08	12.33	11.67	11.C8
W27X 94-C15X33.9	5858	46.58	40.83	37..1	34.25	29.58	25 .42	22.33	20.08	18.33	16.83	15.67	14.67	13.83	13.C8
W30X 99-C15X33.9	5858	46.58	40.83	37..1	34.17	28.83	24 .92	22.00	19.83	18.08	16.67	15.50	14.58	13.75	13.00
W30X 99-C18X42.7	7017	55.83	48.92	44..5	39.53	32.92	28 .25	24.92	22.33	20.33	18.75	17.42	16.25	15.33	14.50
W30X115-C15X33.9	6058	48.17	42.08	38..3	35.53	33.25	31 .08	27.33	24.42	22.08	20.25	18.75	17.50	16.42	15.50
W30X115-C18X42.7	7208	57.33	50.17	45..6	42.42	39.58	35 .92	31.33	27.83	25.17	23.00	21.25	19.75	18.50	17.42
W33X118-C15X33.9	6242	49.58	43.42	39..5	36.67	34.25	31 .58	27.67	24.75	22.50	20.67	19..7	17.83	16.83	15.83
W33X118-C18X42.7	7408	58.92	51.50	46..8	43.53	40.67	36 .50	31.92	28.50	25.75	23.58	21..3	20.33	19.08	18.00
W33X141-C15X33.9	6383	50.67	44.25	40..2	37.42	35.17	33 .17	31.42	29.75	26.83	24.50	22..8	21.00	19.58	18.50
W33X141-C18X42.7	7492	59.50	52.00	47..3	44.0)	41.33	39 .00	36.83	34.25	30.83	28.00	25..5	23.92	22.33	21.00
W36X150-C15X33.9	6525	51.75	45.17	41..0	38.17	35.92	34 .00	32.25	30.58	28.33	25.83	23..3	22.08	20.67	19.50
W36X150-C18X42.7	7633	60.58	53.00	48..1	44.75	42.17	39 .83	37.75	35.83	32.75	29.75	27..3	25.33	23.67	22.25

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



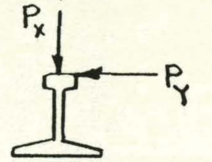


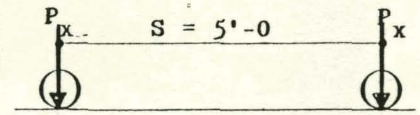
$P_y = 0.12P_x$ $F_y = 50$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	28.00	14.58	10.50	8.58	7.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	32.00	16.17	11.50	9.33	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	28.83	16.83	11.92	9.67	8.33	7.42	6.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	35.58	19.08	13.25	10.58	9.08	8.00	7.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	36.75	23.75	16.17	12.67	10.67	9.42	8.50	7.75	7.25	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	49.17	28.42	19.00	14.67	12.17	10.58	9.50	8.67	8.00	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	38.08	30.42	22.58	17.17	14.17	12.25	10.83	9.83	9.08	8.50	8.00	7.58	0.00	0.00	0.00
W18X 50-C15X33.9	50.92	40.67	27.42	20.58	16.75	14.25	12.58	11.33	10.42	9.67	9.00	8.50	0.00	0.00	0.00
W21X 62-C12X20.7	39.83	31.75	27.58	21.42	17.42	14.83	13.08	11.83	10.83	10.00	9.42	8.83	8.42	8.00	7.67
W21X 62-C15X33.9	53.00	42.25	35.75	26.42	21.25	17.92	15.67	14.00	12.75	11.75	10.92	10.25	9.75	9.25	8.83
W21X 68-C12X20.7	40.00	31.92	27.83	23.42	18.83	16.00	14.00	12.58	11.50	10.67	9.92	9.33	8.83	8.42	8.08
W21X 68-C15X33.9	53.08	42.33	37.08	29.00	23.17	19.42	16.92	15.00	13.67	12.50	11.67	10.92	10.33	9.75	9.33
W24X 68-C12X20.7	41.25	32.83	28.67	23.42	19.00	16.25	14.25	12.83	11.75	10.92	10.17	9.58	9.08	8.67	8.25
W24X 68-C15X33.9	54.67	43.58	38.17	29.67	23.75	20.00	17.42	15.58	14.08	13.00	12.08	11.33	10.67	10.17	9.67
W24X 84-C12X20.7	42.08	33.50	29.33	26.33	23.33	19.58	17.00	15.17	13.75	12.67	11.75	11.00	10.42	9.83	9.42
W24X 84-C15X33.9	55.00	43.83	38.42	34.75	29.33	24.33	21.00	18.58	16.75	15.25	14.08	13.17	12.33	11.67	11.08
W27X 84-C12X20.7	43.50	34.58	30.25	27.25	23.00	19.42	17.00	15.25	13.83	12.75	11.83	11.17	10.50	10.00	9.50
W27X 84-C15X33.9	56.58	45.08	39.50	35.75	29.25	24.42	21.17	18.75	16.92	15.50	14.33	13.42	12.58	11.92	11.33
W27X 94-C12X20.7	44.17	35.08	30.75	27.83	25.33	21.67	18.75	16.75	15.17	13.92	12.92	12.08	11.33	10.75	10.25
W27X 94-C15X33.9	56.92	45.33	39.67	36.00	32.83	27.25	23.42	20.67	18.58	17.00	15.67	14.58	13.67	12.92	12.25
W30X 99-C15X33.9	56.92	45.33	39.67	36.00	31.83	26.58	23.00	20.33	18.33	16.75	15.50	14.42	13.58	12.83	12.17
W30X 99-C18X42.7	68.42	54.42	47.67	43.25	36.92	30.67	26.33	23.25	20.92	19.08	17.58	16.33	15.25	14.42	13.67
W30X116-C15X33.9	58.75	46.67	40.83	37.17	34.33	31.92	28.50	25.00	22.33	20.25	18.58	17.25	16.08	15.17	14.33
W30X116-C18X42.7	70.08	55.75	48.83	44.42	41.08	38.17	33.17	28.92	25.75	23.33	21.33	19.75	18.42	17.25	16.25
W33X118-C15X33.9	60.42	48.00	42.00	38.17	35.42	32.92	28.67	25.17	22.58	20.58	18.92	17.58	16.42	15.42	14.58
W33X118-C18X42.7	71.92	57.17	50.00	45.50	42.17	39.17	33.58	29.42	26.25	23.75	21.83	20.17	18.83	17.67	16.67
W33X141-C15X33.9	61.75	49.00	42.83	38.92	36.17	33.92	31.83	29.92	27.00	24.33	22.25	20.50	19.08	17.92	16.92
W33X141-C18X42.7	72.67	57.67	50.42	45.92	42.67	39.92	37.50	35.25	31.42	28.25	25.75	23.67	22.00	20.58	19.33
W36X150-C15X33.9	63.00	50.00	43.67	39.67	36.83	34.67	32.58	30.75	28.33	25.58	23.42	21.58	20.08	18.83	17.75
W36X150-C18X42.7	73.92	58.67	51.33	46.67	43.33	40.67	38.33	36.08	33.25	29.83	27.17	25.00	23.25	21.75	20.42

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



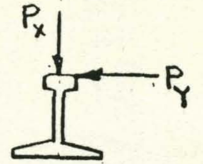


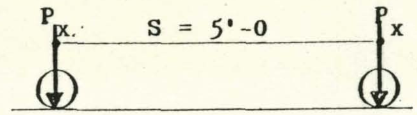
$P_y = 0.08P_x$ $F_y = 50$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	29.42	17.50	12.67	10.42	9.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	35.75	18.92	13.58	11.08	9.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	30.50	20.42	14.58	11.75	10.17	9.08	8.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	37.25	22.42	15.83	12.67	10.83	9.67	8.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	38.75	28.08	19.33	15.25	12.92	11.33	10.25	9.42	8.83	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	51.17	31.92	21.92	17.08	14.33	12.50	11.25	10.25	9.50	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	40.42	32.33	27.33	20.92	17.25	14.92	13.25	12.08	11.17	10.42	9.75	9.25	0.00	0.00	0.00
W18X 50-C15X33.9	53.33	42.67	31.42	24.00	19.67	16.83	14.92	13.50	12.42	11.50	10.75	10.17	0.00	0.00	0.00
W21X 62-C12X20.7	42.50	34.00	29.83	26.42	21.58	18.42	16.25	14.58	13.42	12.42	11.58	11.00	10.42	9.92	9.50
W21X 62-C15X33.9	55.92	44.67	39.25	31.17	25.17	21.42	18.75	16.75	15.33	14.08	13.17	12.33	11.67	11.17	10.67
W21X 68-C12X20.7	42.83	34.17	30.00	27.17	23.42	19.92	17.42	15.67	14.25	13.17	12.33	11.58	11.00	10.50	10.00
W21X 68-C15X33.9	56.08	44.83	39.33	34.00	27.42	23.17	20.25	18.08	16.42	15.08	14.00	13.17	12.42	11.83	11.25
W24X 68-C12X20.7	44.25	35.33	31.00	28.08	23.92	20.33	17.92	16.08	14.67	13.58	12.67	11.92	11.33	10.83	10.33
W24X 68-C15X33.9	57.92	46.25	40.58	35.42	28.50	24.08	21.08	18.83	17.08	15.75	14.67	13.75	13.00	12.33	11.75
W24X 84-C12X20.7	45.25	36.08	31.67	28.83	26.58	24.67	21.50	19.17	17.33	15.92	14.75	13.83	13.08	12.42	11.83
W24X 84-C15X33.9	58.50	46.67	40.92	37.33	34.42	29.42	25.42	22.58	20.33	18.58	17.17	16.08	15.08	14.25	13.58
W27X 84-C12X20.7	46.92	37.33	32.75	29.83	27.58	24.75	21.58	19.33	17.50	16.17	15.00	14.08	13.25	12.58	12.00
W27X 84-C15X33.9	60.33	48.17	42.17	38.42	35.58	29.92	25.92	23.00	20.75	19.00	17.58	16.42	15.50	14.67	13.92
W27X 94-C12X20.7	47.67	38.00	33.25	30.33	28.08	26.17	24.00	21.33	19.25	17.67	16.42	15.33	14.42	13.67	13.00
W27X 94-C15X33.9	60.75	48.42	42.50	38.67	35.92	33.42	28.75	25.42	22.83	20.83	19.25	17.92	16.83	15.92	15.08
W30X 99-C15X33.9	60.75	48.42	42.42	38.67	35.92	32.67	28.25	25.00	22.58	20.58	19.08	17.75	16.67	15.75	15.00
W30X 99-C18X42.7	72.50	57.75	50.67	46.08	42.75	36.50	31.50	27.83	25.00	22.83	21.08	19.58	18.33	17.33	16.42
W30X116-C15X33.9	63.00	50.17	43.92	40.00	37.25	35.00	33.00	31.25	27.92	25.33	23.25	21.58	20.08	18.92	17.92
W30X116-C18X42.7	74.67	59.50	52.17	47.50	44.17	41.50	39.08	35.08	31.33	28.33	26.00	24.00	22.42	21.00	19.83
W33X118-C15X33.9	65.08	51.75	45.33	41.25	38.42	36.17	34.08	31.83	28.50	25.92	23.83	22.08	20.67	19.42	18.33
W33X118-C18X42.7	76.83	61.17	53.58	48.75	45.33	42.67	40.25	36.08	32.17	29.17	26.75	24.75	23.08	21.67	20.50
W33X141-C15X33.9	66.50	52.92	46.25	42.08	39.17	36.92	35.08	33.33	31.83	30.33	28.33	26.08	24.25	22.75	21.42
W33X141-C18X42.7	77.75	61.92	54.17	49.33	45.83	43.25	41.00	39.00	37.08	34.92	31.83	29.33	27.25	25.50	23.92
W36X150-C15X33.9	68.08	54.08	47.33	43.08	40.00	37.75	35.83	34.25	32.67	31.25	29.92	27.67	25.67	24.08	22.67
W36X150-C18X42.7	79.42	63.17	55.25	50.25	46.75	44.08	41.83	39.92	38.08	36.33	34.00	31.25	29.00	27.08	25.50

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



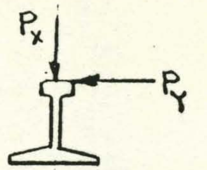


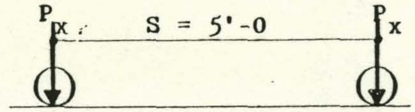
$P_y = 0.10P_x$ $F_y = 50$ ksi

SECTION	WHEEL LOAD P_x (kips) 5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	28.83	16.50	12.00	9.92	8.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	34.42	18.00	13.00	10.58	9.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	29.83	19.08	13.67	11.08	9.58	8.58	7.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	36.58	21.17	15.00	12.08	10.33	9.25	8.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	37.92	26.42	18.17	14.42	12.17	10.75	9.75	9.00	8.33	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	50.33	30.75	21.00	16.33	13.67	12.00	10.75	9.83	9.17	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	39.33	31.50	25.42	19.50	16.08	14.00	12.42	11.33	10.50	9.83	9.25	8.75	0.00	0.00	0.00
W18X 50-C15X33.9	52.25	41.83	29.92	22.75	18.67	16.00	14.17	12.83	11.75	11.00	10.33	9.75	0.00	0.00	0.00
W21X 62-C12X20.7	41.25	33.00	28.92	24.33	19.83	17.00	15.00	13.58	12.42	11.58	10.83	10.25	9.75	9.33	8.92
W21X 62-C15X33.9	54.58	43.58	38.25	29.25	23.67	20.08	17.58	15.83	14.42	13.33	12.42	11.67	11.08	10.58	10.08
W21X 68-C12X20.7	41.50	33.17	29.08	26.08	21.50	18.33	16.08	14.50	13.25	12.25	11.50	10.83	10.25	9.83	9.42
W21X 68-C15X33.9	54.67	43.67	38.33	32.00	25.75	21.75	19.00	17.00	15.42	14.25	13.25	12.42	11.75	11.17	10.67
W24X 68-C12X20.7	42.83	34.17	30.00	26.75	21.75	18.58	16.42	14.83	13.58	12.58	11.75	11.08	10.58	10.08	9.67
W24X 68-C15X33.9	56.42	45.00	39.50	33.00	26.58	22.42	19.67	17.58	16.00	14.75	13.75	12.92	12.17	11.58	11.08
W24X 84-C12X20.7	43.75	34.92	30.58	27.83	25.42	22.50	19.58	17.50	15.83	14.58	13.58	12.75	12.08	11.42	10.92
W24X 84-C15X33.9	56.83	45.33	39.75	36.17	32.67	27.33	23.67	20.92	18.92	17.33	16.00	15.00	14.08	13.33	12.67
W27X 84-C12X20.7	45.25	36.08	31.58	28.75	26.33	22.42	19.58	17.58	16.00	14.75	13.75	12.92	12.25	11.58	11.08
W27X 84-C15X33.9	58.58	46.67	40.92	37.25	32.83	27.50	23.92	21.25	19.25	17.67	16.33	15.25	14.42	13.67	13.00
W27X 94-C12X20.7	46.00	36.67	32.08	29.25	26.92	24.92	21.67	19.33	17.50	16.08	14.92	14.00	13.17	12.50	11.92
W27X 94-C15X33.9	58.92	47.00	41.17	37.50	34.67	30.67	26.42	23.42	21.08	19.25	17.83	16.58	15.58	14.75	14.00
W30X 99-C15X33.9	58.92	47.00	41.17	37.50	34.58	29.92	25.92	23.00	20.75	19.00	17.58	16.42	15.50	14.67	13.92
W30X 99-C18X42.7	70.50	56.17	49.25	44.83	40.75	34.00	29.33	25.92	23.33	21.33	19.67	18.33	17.17	16.25	15.42
W30X116-C15X33.9	60.92	48.50	42.50	38.67	36.00	33.67	31.58	28.42	25.42	23.08	21.25	19.67	18.42	17.33	16.42
W30X116-C18X42.7	72.42	57.67	50.58	46.00	42.75	40.00	37.00	32.42	28.92	26.17	24.00	22.25	20.75	19.50	18.42
W33X118-C15X33.9	62.75	49.92	43.75	39.83	37.00	34.67	32.58	28.75	25.83	23.50	21.58	20.08	18.83	17.75	16.83
W33X118-C18X42.7	74.42	59.25	51.83	47.25	43.92	41.08	37.67	33.00	29.50	26.83	24.58	22.83	21.33	20.00	18.92
W33X141-C15X33.9	64.17	51.00	44.67	40.58	37.75	35.58	33.67	31.83	30.25	27.92	25.50	23.58	22.00	20.58	19.42
W33X141-C18X42.7	75.25	59.83	52.42	47.67	44.33	41.75	39.42	37.33	35.42	31.92	29.08	26.83	24.92	23.33	22.00
W36X150-C15X33.9	65.58	52.08	45.58	41.42	38.50	36.33	34.42	32.67	31.08	29.42	26.92	24.83	23.08	21.67	20.42
W36X150-C18X42.7	76.67	61.00	53.33	49.50	45.08	42.50	40.25	38.17	36.33	33.83	30.83	28.42	26.42	24.67	23.25

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



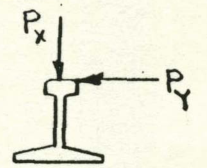


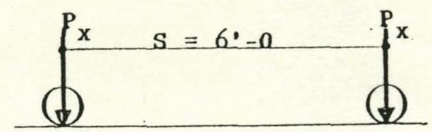
$P_y = 0.12P_x$ $F_y = 50$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	28.33	15.58	11.42	9.42	8.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	33.17	17.25	12.42	10.17	8.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	29.25	17.92	12.83	10.50	9.08	7.92	6.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	35.92	20.08	14.25	11.50	9.92	8.83	7.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	37.08	24.83	17.17	13.58	11.58	10.25	9.25	8.58	7.67	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	49.50	29.58	20.08	15.67	13.08	11.50	10.33	9.50	8.83	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	38.42	30.75	23.75	18.25	15.17	13.17	11.75	10.75	9.92	9.33	8.83	8.25	0.00	0.00	0.00
W18X 50-C15X33.9	51.25	41.00	28.50	21.67	17.75	15.25	13.50	12.25	11.25	10.50	9.83	9.33	0.00	0.00	0.00
W21X 62-C12X20.7	40.17	32.08	28.00	22.50	18.42	15.83	14.00	12.67	11.67	10.92	10.25	9.67	9.25	8.83	8.50
W21X 62-C15X33.9	53.33	42.58	36.92	27.58	22.25	18.92	16.58	14.92	13.67	12.67	11.83	11.17	10.58	10.08	9.67
W21X 68-C12X20.7	40.42	32.25	28.25	24.50	19.92	17.00	15.00	13.50	12.42	11.50	10.75	10.17	9.67	9.25	8.92
W21X 68-C15X33.9	53.42	42.67	37.42	30.17	24.25	20.50	17.92	16.00	14.58	13.42	12.58	11.83	11.17	10.67	10.17
W24X 68-C12X20.7	41.58	33.17	29.08	24.50	20.00	17.17	15.25	13.75	12.67	11.75	11.00	10.42	9.92	9.50	9.08
W24X 68-C15X33.9	55.00	43.92	38.50	30.83	24.83	21.00	18.42	16.50	15.08	13.92	13.00	12.17	11.58	11.00	10.50
W24X 84-C12X20.7	42.42	33.83	29.67	26.83	24.42	20.58	18.00	16.08	14.67	13.58	12.67	11.92	11.25	10.67	10.25
W24X 84-C15X33.9	55.33	44.17	38.75	35.17	30.50	25.50	22.08	19.58	17.67	16.25	15.08	14.08	13.25	12.58	12.00
W27X 84-C12X20.7	43.83	34.92	30.59	27.67	24.08	20.42	18.00	16.17	14.75	13.67	12.75	12.00	11.33	10.83	10.33
W27X 84-C15X33.9	57.00	45.42	39.83	36.17	30.33	25.50	22.17	19.75	17.92	16.42	15.25	14.33	13.50	12.83	12.25
W27X 94-C12X20.7	44.50	35.50	31.08	28.25	25.83	22.67	19.75	17.67	16.08	14.83	13.75	12.92	12.25	11.67	11.08
W27X 94-C15X33.9	57.33	45.67	40.00	36.42	33.50	28.33	24.50	21.67	19.58	17.92	16.58	15.50	14.58	13.83	13.17
W30X 99-C15X33.9	57.33	45.67	40.00	36.42	33.00	27.67	24.00	21.33	19.33	17.75	16.42	15.33	14.50	13.67	13.08
W30X 99-C18X42.7	68.75	54.83	48.00	43.67	38.08	31.75	27.42	24.25	21.92	20.00	18.50	17.25	16.17	15.33	14.58
W30X116-C15X33.9	59.08	47.00	41.17	37.50	34.75	32.42	29.67	26.08	23.33	21.25	19.58	18.17	17.08	16.08	15.25
W30X116-C18X42.7	70.42	56.08	49.17	44.75	41.50	38.58	34.33	30.08	26.83	24.33	22.33	20.75	19.33	18.17	17.25
W33X118-C15X33.9	60.83	48.33	42.33	38.58	35.75	33.33	29.75	26.25	23.58	21.50	19.83	18.50	17.33	16.33	15.50
W33X118-C18X42.7	72.25	57.50	50.33	45.83	42.58	39.67	34.67	30.50	27.25	24.83	22.83	21.17	19.83	18.67	17.67
W33X141-C15X33.9	62.08	49.33	43.17	39.25	36.50	34.33	32.25	30.50	28.08	25.42	23.25	21.58	20.08	18.92	17.83
W33X141-C18X42.7	73.00	58.08	50.83	46.25	43.00	40.33	37.92	35.75	32.50	29.33	26.83	24.75	23.00	21.58	20.33
W36X150-C15X33.9	63.42	50.33	44.00	40.08	37.25	35.00	33.08	31.25	29.50	26.67	24.42	22.58	21.08	19.75	18.67
W36X150-C18X42.7	74.25	59.08	51.67	47.00	43.67	41.08	38.75	36.58	34.33	31.00	28.25	26.08	24.25	22.75	21.42

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



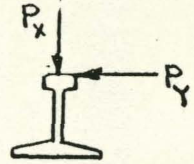


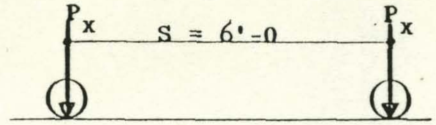
$P_y = 0.08P_x$ $F_y = 50$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	29.75	18.42	13.58	11.25	9.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	36.17	19.83	14.50	11.92	10.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	30.92	21.42	15.50	12.67	11.00	9.58	8.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	37.58	23.42	16.75	13.58	11.67	10.50	9.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	39.08	29.08	20.33	16.17	13.75	12.17	11.08	10.25	9.08	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	51.50	33.00	22.92	18.08	15.25	13.42	12.08	11.08	10.33	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	40.75	32.67	28.42	21.92	18.25	15.83	14.17	12.92	12.00	11.17	10.58	9.92	0.00	0.00	0.00
W18X 50-C15X33.9	53.67	43.00	32.50	25.00	20.67	17.83	15.83	14.33	13.25	12.33	11.58	11.00	0.00	0.00	0.00
W21X 62-C12X20.7	42.92	34.33	30.17	27.25	22.58	19.33	17.17	15.50	14.25	13.25	12.50	11.83	11.25	10.75	10.33
W21X 62-C15X33.9	56.25	45.00	39.58	32.25	26.25	22.42	19.67	17.75	16.17	15.00	14.00	13.25	12.58	12.00	11.50
W21X 68-C12X20.7	43.17	34.58	30.42	27.58	24.42	20.83	18.42	16.58	15.17	14.08	13.17	12.42	11.83	11.33	10.83
W21X 68-C15X33.9	56.42	45.17	39.67	35.17	28.50	24.17	21.17	19.00	17.33	16.00	14.92	14.00	13.33	12.67	12.08
W24X 68-C12X20.7	44.58	35.67	31.33	28.50	24.92	21.33	18.83	17.00	15.58	14.50	13.58	12.83	12.17	11.58	11.17
W24X 68-C15X33.9	58.25	46.58	40.92	36.50	29.58	25.08	22.00	19.75	18.00	16.67	15.50	14.58	13.83	13.17	12.58
W24X 84-C12X20.7	45.58	36.42	32.00	29.17	27.00	25.08	22.50	20.08	18.25	16.83	15.67	14.75	13.92	13.25	12.67
W24X 84-C15X33.9	58.83	47.00	41.25	37.67	34.83	30.50	26.50	23.58	21.33	19.58	18.17	16.92	16.00	15.17	14.42
W27X 84-C12X20.7	47.25	37.75	33.08	30.25	28.00	25.83	22.58	20.25	18.42	17.00	15.92	14.92	14.17	13.42	12.83
W27X 84-C15X33.9	60.75	48.50	42.58	38.83	36.00	31.00	26.92	24.00	21.75	20.00	18.50	17.33	16.33	15.50	14.75
W27X 94-C12X20.7	48.00	38.33	33.67	30.67	28.50	26.67	25.00	22.33	20.25	18.58	17.25	16.17	15.33	14.50	13.83
W27X 94-C15X33.9	61.17	48.83	42.83	39.08	36.33	33.92	29.83	26.42	23.83	21.83	20.25	18.83	17.75	16.75	15.92
W30X 99-C15X33.9	61.08	48.83	42.83	39.00	36.25	33.75	29.25	26.00	23.50	21.58	20.00	18.67	17.58	16.67	15.83
W30X 99-C18X42.7	72.83	58.08	51.00	46.50	43.17	37.58	32.50	28.83	26.00	23.83	22.00	20.50	19.25	18.25	17.33
W30X116-C15X33.9	63.33	50.50	44.33	40.42	37.58	35.42	33.50	31.67	29.00	26.33	24.25	22.50	21.08	19.83	18.83
W30X116-C18X42.7	75.00	59.83	52.50	47.83	44.50	41.83	39.50	36.17	32.42	29.42	27.00	25.00	23.33	22.00	20.75
W33X118-C15X33.9	65.42	52.08	45.67	41.58	38.75	36.50	34.50	32.75	29.50	26.92	24.75	23.00	21.58	20.33	19.25
W33X118-C18X42.7	77.25	61.50	53.92	49.17	45.75	43.08	40.67	37.17	33.25	30.17	27.75	25.75	24.08	22.67	21.42
W33X141-C15X33.9	66.92	53.25	46.67	42.50	39.50	37.25	35.42	33.75	32.25	30.83	29.33	27.08	25.25	23.75	22.42
W33X141-C18X42.7	78.17	62.25	54.50	49.67	46.17	43.58	41.42	39.42	37.58	35.92	32.92	30.33	28.25	26.50	24.92
W36X150-C15X33.9	68.42	54.50	47.67	43.42	40.42	38.08	36.25	34.58	33.17	31.75	30.50	28.67	26.75	25.08	23.58
W36X150-C18X42.7	79.75	63.50	55.58	50.67	47.08	44.42	42.25	40.33	38.50	36.83	35.08	32.33	30.00	28.08	26.50

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



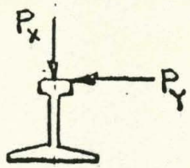


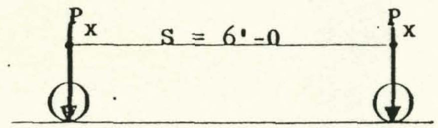
$P_y = 0.10P_x$ $F_y = 50$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	29.17	17.42	12.92	10.67	8.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	35.58	19.00	13.92	11.42	9.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	30.17	20.08	14.58	11.92	10.42	8.67	7.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	36.92	22.25	15.92	12.92	11.17	9.92	8.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	38.25	27.50	19.17	15.25	13.08	11.58	10.58	9.42	8.33	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	50.67	31.83	22.00	17.33	14.58	12.83	11.58	10.67	9.75	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	39.75	31.83	26.50	20.50	17.08	14.83	13.33	12.17	11.33	10.58	9.92	9.00	0.00	0.00	0.00
W18X 50-C15X33.9	52.58	42.17	31.00	23.83	19.67	16.92	15.08	13.67	12.67	11.83	11.08	10.58	0.00	0.00	0.00
W21X 62-C12X20.7	41.67	33.33	29.25	25.33	20.83	17.92	15.92	14.42	13.33	12.42	11.67	11.08	10.58	10.08	9.33
W21X 62-C15X33.9	54.92	43.92	38.58	30.42	24.75	21.08	18.58	16.75	15.33	14.17	13.33	12.58	11.92	11.42	10.92
W21X 68-C12X20.7	41.92	33.50	29.50	26.58	22.58	19.25	17.00	15.42	14.17	13.17	12.33	11.67	11.08	10.58	10.17
W21X 68-C15X33.9	55.00	44.00	38.67	33.17	26.83	22.75	20.00	17.92	16.33	15.08	14.08	13.33	12.58	12.00	11.50
W24X 68-C12X20.7	43.17	34.58	30.33	27.42	22.75	19.58	17.33	15.67	14.42	13.42	12.58	11.92	11.33	10.83	10.42
W24X 68-C15X33.9	56.75	45.33	39.83	34.08	27.58	23.42	20.58	18.50	16.92	15.67	14.58	13.75	13.08	12.42	11.92
W24X 84-C12X20.7	44.08	35.25	30.92	28.17	25.92	23.50	20.58	18.42	16.83	15.50	14.50	13.67	12.92	12.33	11.75
W24X 84-C15X33.9	57.17	45.67	40.08	36.58	33.67	28.42	24.67	21.92	19.92	18.25	17.00	15.92	15.00	14.25	13.58
W27X 84-C12X20.7	45.58	36.42	32.00	29.17	26.83	23.42	20.58	18.50	16.92	15.67	14.58	13.75	13.08	12.42	11.92
W27X 84-C15X33.9	58.92	47.08	41.25	37.67	33.92	28.58	24.92	22.17	20.17	18.58	17.25	16.17	15.25	14.50	13.83
W27X 94-C12X20.7	46.33	37.00	32.42	29.58	27.33	25.42	22.67	20.25	18.42	17.00	15.83	14.83	14.08	13.42	12.75
W27X 94-C15X33.9	59.25	47.33	41.50	37.83	35.08	31.75	27.50	24.42	22.08	20.25	18.75	17.50	16.50	15.67	14.92
W30X 99-C15X33.9	59.25	47.33	41.50	37.83	35.00	31.00	26.92	24.00	21.75	20.00	18.50	17.33	16.33	15.50	14.75
W30X 99-C18X42.7	70.83	56.58	49.58	45.25	41.75	35.08	30.33	26.92	24.33	22.25	20.58	19.25	18.08	17.17	16.33
W30X116-C15X33.9	61.25	48.83	42.83	39.00	36.33	34.08	32.08	29.50	26.50	24.08	22.25	20.67	19.42	18.25	17.33
W30X116-C18X42.7	72.83	58.08	50.92	46.42	43.17	40.42	38.00	33.50	30.00	27.25	25.00	23.25	21.75	20.42	19.33
W33X118-C15X33.9	63.17	50.33	44.08	40.17	37.42	35.08	33.08	29.83	26.83	24.50	22.58	21.00	19.75	18.67	17.67
W33X118-C18X42.7	74.75	59.58	52.25	47.58	44.25	41.50	38.75	34.08	30.58	27.83	25.58	23.75	22.25	21.00	19.83
W33X141-C15X33.9	64.50	51.33	45.00	41.00	38.08	35.92	34.08	32.33	30.75	29.00	26.58	24.58	22.92	21.58	20.42
W33X141-C18X42.7	75.58	60.25	52.75	48.00	44.67	42.08	39.83	37.75	35.92	33.00	30.17	27.83	25.92	24.33	22.92
W36X150-C15X33.9	65.92	52.42	45.92	41.83	38.92	36.67	34.83	33.08	31.58	30.17	27.92	25.83	24.08	22.67	21.42
W36X150-C18X42.7	77.00	61.33	53.67	48.92	45.50	42.83	40.67	38.67	36.75	34.92	31.92	29.50	27.42	25.67	24.25

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



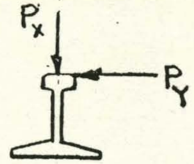


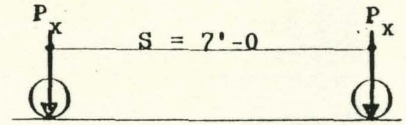
$P_y = 0.12P_x$ $F_y = 50$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	28.67	16.50	12.25	10.25	8.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	34.33	18.25	13.33	11.00	9.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	29.58	18.92	13.75	11.33	9.67	7.92	6.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	36.25	21.17	15.17	12.33	10.75	9.17	7.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	37.50	26.00	18.17	14.50	12.42	11.08	10.00	8.67	7.67	0.00	0.00	0.00	0.00	0.00	0.00
W16X 6-C15X33.9	49.83	30.75	21.08	16.58	14.00	12.33	11.17	10.33	9.17	0.00	0.00	0.00	0.00	0.00	0.00
W18X 0-C12X20.7	38.75	31.08	24.83	19.25	16.08	14.00	12.58	11.58	10.75	10.00	9.08	8.25	0.00	0.00	0.00
W18X 0-C15X33.9	51.58	41.33	29.67	22.67	18.75	16.17	14.42	13.08	12.08	11.33	10.67	10.08	0.00	0.00	0.00
W21X 62-C12X20.7	40.50	32.42	28.42	23.50	19.33	16.75	14.92	13.58	12.50	11.75	11.00	10.50	9.83	9.08	8.50
W21X 62-C15X33.9	53.67	43.00	37.67	28.67	23.33	19.92	17.58	15.83	14.50	13.50	12.67	12.00	11.42	10.92	10.42
W21X 68-C12X20.7	40.75	32.58	28.67	25.58	20.92	17.92	15.92	14.42	13.25	12.33	11.58	11.00	10.50	9.92	9.25
W21X 68-C15X33.9	53.75	43.00	37.83	31.33	25.33	21.50	18.83	16.92	15.50	14.33	13.42	12.67	12.00	11.42	11.00
W24X 68-C12X20.7	41.92	33.50	29.42	25.58	21.00	18.17	16.08	14.67	13.50	12.58	11.83	11.25	10.75	10.25	9.58
W24X 68-C15X33.9	55.33	44.25	38.83	31.92	25.83	22.00	19.33	17.42	15.92	14.75	13.83	13.08	12.42	11.83	11.33
W24X 84-C12X20.7	42.75	34.17	30.00	27.25	24.92	21.67	19.00	17.08	15.58	14.42	13.50	12.75	12.08	11.50	11.08
W24X 84-C15X33.9	55.67	44.50	39.08	35.50	31.67	26.58	23.08	20.58	18.67	17.17	16.00	15.00	14.17	13.42	12.83
W27X 84-C12X20.7	44.17	35.25	31.00	28.08	25.08	21.42	18.92	17.08	15.67	14.50	13.58	12.83	12.17	11.67	11.17
W27X 84-C15X33.9	57.33	45.75	40.17	36.50	31.42	26.50	23.17	20.67	18.83	17.33	16.17	15.17	14.33	13.67	13.08
W27X 94-C12X20.7	44.92	35.83	31.42	28.58	26.33	23.75	20.75	18.67	17.00	15.75	14.67	13.83	13.08	12.50	11.92
W27X 94-C15X33.9	57.67	46.00	40.33	36.75	33.92	29.42	25.50	22.67	20.58	18.83	17.50	16.42	15.50	14.67	14.00
W30X 99-C15X33.9	57.67	46.00	40.33	36.75	33.83	28.67	25.00	22.33	20.25	18.67	17.33	16.25	15.33	14.58	13.92
W30X 99-C18X42.7	69.08	55.17	48.33	44.08	39.25	32.83	28.42	25.25	22.83	21.00	19.42	18.17	17.08	16.17	15.42
W30X116-C15X33.9	59.42	47.42	41.58	37.83	35.17	32.83	30.75	27.17	24.42	22.25	20.58	19.17	18.00	17.00	16.17
W30X116-C18X42.7	70.83	56.50	49.50	45.08	41.92	39.08	35.50	31.17	27.92	25.42	23.33	21.67	20.33	19.17	18.17
W33X118-C15X33.9	61.17	48.75	42.67	38.92	36.17	33.83	30.83	27.25	24.58	22.50	20.83	19.42	18.25	17.25	16.42
W33X118-C18X42.7	72.67	57.83	50.75	46.17	42.92	40.08	35.83	31.50	28.33	25.83	23.75	22.08	20.75	19.58	18.58
W33X141-C15X33.9	62.50	49.75	43.50	39.67	36.92	34.67	32.75	31.00	29.17	26.42	24.33	22.50	21.08	19.83	18.75
W33X141-C18X42.7	73.33	58.42	51.17	46.58	43.33	40.75	38.42	36.25	33.67	30.42	27.83	25.75	24.00	22.58	21.33
W36X150-C15X33.9	63.75	50.67	44.42	40.42	37.58	35.42	33.50	31.75	30.08	27.67	25.42	23.58	22.08	20.75	19.58
W36X150-C18X42.7	74.67	59.42	52.00	47.33	44.08	41.50	39.17	37.08	35.17	32.08	29.33	27.08	25.25	23.67	22.33

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



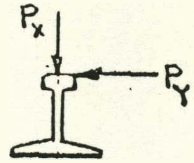


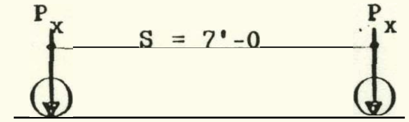
$P_y = 0.08P_x$ $F_y = 50$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	30.17	19.33	14.42	12.00	9.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	36.50	20.83	15.42	12.75	10.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	31.25	22.42	16.33	13.50	11.67	9.58	8.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	37.92	24.42	17.67	14.42	12.50	10.75	9.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	39.42	30.17	21.33	17.08	14.67	13.00	11.83	10.25	9.08	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	51.83	34.00	23.92	19.00	16.08	14.25	12.92	11.92	10.50	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	41.08	33.08	29.00	22.92	19.17	16.75	15.00	13.75	12.75	12.00	10.92	9.92	0.00	0.00	0.00
W18X 50-C15X33.9	54.00	43.33	33.50	26.00	21.58	18.75	16.75	15.25	14.08	13.17	12.42	11.75	0.00	0.00	0.00
W21X 62-C12X20.7	43.25	34.67	30.58	27.75	23.50	20.33	18.08	16.42	15.08	14.08	13.25	12.58	12.00	11.25	10.42
W21X 62-C15X33.9	56.58	45.33	39.92	33.25	27.25	23.33	20.67	18.58	17.08	15.83	14.92	14.08	13.33	12.75	12.25
W21X 68-C12X20.7	43.50	34.92	30.75	28.00	25.50	21.83	19.33	17.50	16.08	14.92	14.00	13.25	12.67	12.08	11.42
W21X 68-C15X33.9	56.75	45.50	40.00	36.25	29.50	25.17	22.17	19.92	18.25	16.92	15.83	14.92	14.17	13.50	12.92
W24X 68-C12X20.7	44.92	36.00	31.75	28.92	25.92	22.25	19.75	17.92	16.42	15.33	14.42	13.58	13.00	12.42	11.92
W24X 68-C15X33.9	58.58	46.92	41.25	37.58	30.58	26.08	23.00	20.67	18.92	17.50	16.42	15.42	14.67	14.00	13.42
W24X 84-C12X20.7	45.92	36.83	32.33	29.58	27.42	25.58	23.50	21.08	19.17	17.75	16.58	15.58	14.75	14.08	13.50
W24X 84-C15X33.9	59.17	47.33	41.58	38.00	35.25	31.58	27.50	24.50	22.25	20.50	19.08	17.83	16.83	16.00	15.25
W27X 84-C12X20.7	47.58	38.08	33.50	30.58	28.42	26.50	23.58	21.17	19.33	17.92	16.75	15.83	15.00	14.25	13.67
W27X 84-C15X33.9	61.08	48.83	42.92	39.17	36.42	32.00	27.92	24.92	22.67	20.92	19.42	18.25	17.25	16.42	15.67
W27X 94-C12X20.7	48.42	38.67	34.00	31.00	28.92	27.08	25.50	23.25	21.17	19.50	18.17	17.08	16.17	15.33	14.67
W27X 94-C15X33.9	61.50	49.17	43.17	39.42	36.67	34.33	30.83	27.42	24.83	22.75	21.17	19.75	18.67	17.67	16.83
W30X 99-C15X33.9	61.50	49.17	43.17	39.42	36.67	34.33	30.25	27.00	24.50	22.50	20.92	19.58	18.50	17.50	16.67
W30X 99-C18X42.7	73.17	58.50	51.33	46.83	43.50	38.67	33.58	29.83	27.00	24.75	22.92	21.42	20.17	19.08	18.17
W30X116-C15X33.9	63.75	50.92	44.67	40.75	37.92	35.75	33.92	32.17	30.00	27.33	25.25	23.50	22.00	20.75	19.75
W30X116-C18X42.7	75.42	60.17	52.83	48.17	44.83	42.25	39.92	37.25	33.42	30.42	28.00	26.00	24.33	22.92	21.67
W33X118-C15X33.9	65.75	52.50	46.00	42.00	39.08	36.92	34.92	33.25	30.58	27.92	25.75	24.00	22.50	21.25	20.17
W33X118-C18X42.7	77.58	61.92	54.25	49.50	46.08	43.42	41.08	38.17	34.25	31.25	28.75	26.75	25.00	23.58	22.33
W33X141-C15X33.9	67.25	53.58	47.00	42.83	39.92	37.58	35.83	34.17	32.75	31.33	30.08	28.17	26.25	24.67	23.33
W33X141-C18X42.7	78.50	62.58	54.92	50.00	46.58	43.92	41.75	39.83	38.00	36.42	33.92	31.42	29.25	27.42	25.92
W36X150-C15X33.9	68.83	54.83	48.08	43.75	40.75	38.42	36.58	35.00	33.58	32.17	30.92	29.75	27.75	26.00	24.58
W36X150-C18X42.7	80.08	63.83	56.00	51.00	47.42	44.75	42.58	40.67	38.92	37.33	35.83	33.33	31.08	29.08	27.42

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



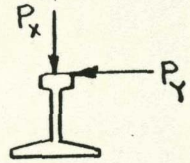


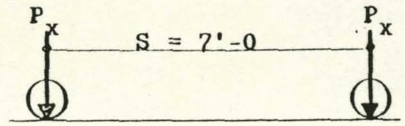
$P_y = 0.10P_x$ $F_Y = 50$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	[illegible]	[illegible]	15.0	[illegible]	75.1	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	29-58	18-33	13.75	11.17	8-75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	35.92	20.00	14.75	12-25	9-83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.C0	0.00
W14X 30-C10X15.3	30.58	21-08	15.42	12.75	10-58	8-67	7-42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.C0
W14X 30-C12X20.7	37-25	13-25	16.83	13-75	12-00	9-92	8-42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.C0
W16X 36-C12X20.7	38.58	28-58	20.17	16-11	13-92	12-42	10.83	9-42	8-33	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	51-00	32-92	23.00	18.25	15-50	13-67	12-42	11-08	9-75	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	40.08	32.25	27.58	21-50	18-00	15-75	14-17	13-00	12-08	11.00	9-92	9-00	0.00	0.00	0.00
W18X 50-C15X33.9	52-92	42-50	32-08	24.83	20.58	17.83	16.00	14-58	13.50	12-58	11-92	10.83	0.00	0.0C	0.C0
W21X 62-C12X20.7	42-00	33.67	29.67	26-42	21-83	18.83	16.83	15.33	14-17	13-25	12.50	11.83	10.92	10.08	9-33
W21X 62-C15X33.9	55.25	44-25	39-00	31.50	25.75	22-08	19-50	17-61	16-17	15-08	14.17	13-42	12-75	12-17	11.58
W21X 68-C12X20.7	42-25	33-92	29-83	27.00	23-58	20.25	17-92	16-25	15-00	14.00	13-17	12-50	11.92	11.0C	10.17
W21X 68-C15X33.9	55-33	44-42	39-00	34-25	27.92	23-75	20.92	18.83	17-25	16-00	15-00	14-17	13-42	12-83	12-33
W24X 68-C12X20.7	43-50	34-92	30.75	27-83	23.75	20.50	18.25	16-58	15-25	14-25	13-42	12-75	12-17	11-42	10.67
W24X 68-C15X33.9	57-08	45-75	40.17	35-17	28-67	24-42	21-58	19-42	17-83	16-50	15-50	14-58	13-83	13-25	12.75
W24X 84-C12X20.7	44-42	35-59	31-33	28-58	2633	24.50	21-58	19-33	17-75	16-42	15-33	14-50	13-75	13-08	12-58
W24X 84-C15X33.9	57-50	46.08	40.50	36.92	34.08	29-50	25-67	22-92	20.83	19-17	17-83	16-75	15-83	15.08	14.42
W27X 84-C12X20.7	46-00	36-15	32-33	29-50	27-25	24-33	21-50	19-42	17.75	16.50	15-50	14-58	13-92	13.25	12-75
W27X 84-C15X33.9	59-25	47-42	41-61	38-00	35-00	29-58	25-92	23-17	21-08	19-50	18-17	17-08	16.17	15-33	14.67
W27X 94-C12X20.7	46-75	37-33	32-83	30.00	27-83	25-92	23.67	21-25	19-33	17-92	16-75	15.75	11-92	14-25	13.58
W27X 94-C15X33.9	59.67	47-67	41-83	38-25	35.50	32-83	28-50	25-42	23-00	21-17	19-61	18-42	17-42	16-50	15.75
W30X 99-C15X33.9	59-67	47.67	41-83	38.17	35.42	32.08	27-92	24-92	22-67	20.92	19-42	18-25	17-25	16-42	15.67
W30X 99-C18X42.7	71-25	56-92	49-92	45.58	42-17	36.17	31-42	27-92	25-25	23-25	21-58	20.17	19-00	18-00	17.17
W30X116-C15X33.9	61-67	49-25	43-17	39.42	36-67	34-50	32-50	30.58	27.50	25-08	23-17	21-58	20.33	19.17	18-25
W30X116-C18X42.7	73.17	58-42	51-25	46.75	43.50	40.83	38-42	34.58	31-00	28-25	26-00	24-17	22-67	21-33	20.25
W33X118-C15X33.9	63-50	50.67	44-42	40.50	31-75	35-50	33.50	30.83	27-83	25.42	23-50	22-00	20.67	19-50	18-58
W33X118-C18X42.7	75.17	59-92	52-58	41-92	44.58	41-92	39.50	35.17	31.58	28.83	26-58	24.75	23-17	21-92	20.75
W33X141-C15X33.9	64-32	51-75	45-33	41.33	38-50	36.25	34.42	32.75	31.25	29-83	27-58	25-58	23-92	22.50	21-33
W33X141-C18X42.7	75-92	60.58	53.08	48-42	45-00	42-50	40.25	38.25	36-42	34.08	31-17	28-92	26.92	25-33	23-92
W36X150-C15X33.9	66-33	52-83	46.25	42-17	39-25	37-00	35.17	33-58	32-00	30.67	29-00	26.83	25-08	23-58	22-33
W36X150-C18X42.7	77-42	61-67	54.C8	49.25	45.83	43.25	41.08	39-08	31-25	35-58	33.00	30.50	28-42	26-67	25-17

Note: A value of 0.00 indicates allowable web shear strese exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



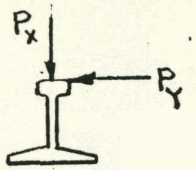


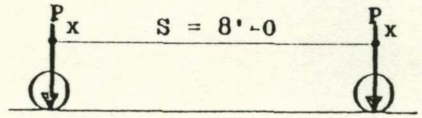
$P_y = 0.12P_x$ $F_y = 50$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	29.00	17.50	13.08	10.25	8.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	35.42	19.17	14.17	11.75	9.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	29.92	19.83	14.67	12.17	9.67	7.92	6.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	36.58	22.17	16.08	13.17	11.17	9.17	7.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	37.83	27.08	19.08	15.42	13.25	11.83	10.00	8.67	7.67	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	50.17	31.83	22.08	17.50	14.92	13.17	12.00	10.42	9.17	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	39.17	31.50	25.92	20.17	17.00	14.92	13.42	12.42	11.25	10.00	9.08	8.25	0.00	0.00	0.00
W18X 50-C15X33.9	51.92	41.67	30.75	23.75	19.67	17.08	15.25	13.92	12.92	12.17	11.08	10.08	0.00	0.00	0.00
W21X 62-C12X20.7	40.83	32.83	28.83	24.58	20.33	17.67	15.75	14.42	13.33	12.50	11.75	10.75	9.83	9.08	8.50
W21X 62-C15X33.9	54.00	43.33	38.08	29.75	24.33	20.92	18.50	16.75	15.42	14.33	13.50	12.75	12.17	11.50	10.67
W21X 68-C12X20.7	41.08	33.00	29.00	26.08	21.92	18.92	16.83	15.25	14.08	13.17	12.42	11.75	10.75	9.92	9.25
W21X 68-C15X33.9	54.08	43.42	38.17	32.42	26.33	22.50	19.83	17.83	16.42	15.25	14.25	13.50	12.83	12.25	11.67
W24X 68-C12X20.7	42.25	33.92	29.83	26.58	22.00	19.08	17.00	15.50	14.33	13.42	12.67	12.00	11.17	10.33	9.58
W24X 68-C15X33.9	55.67	44.58	39.25	33.08	26.92	23.00	20.33	18.33	16.83	15.67	14.67	13.92	13.17	12.58	12.08
W24X 84-C12X20.7	43.17	34.58	30.42	27.67	25.42	22.67	19.92	18.00	16.50	15.33	14.33	13.58	12.92	12.33	11.83
W24X 84-C15X33.9	56.08	44.92	39.42	35.92	32.75	27.58	24.08	21.50	19.58	18.08	16.83	15.83	15.00	14.25	13.67
W27X 84-C12X20.7	44.58	35.67	31.33	28.50	26.08	22.42	19.83	17.92	16.50	15.33	14.42	13.67	13.00	12.42	12.00
W27X 84-C15X33.9	57.67	46.17	40.50	36.92	32.50	27.58	24.17	21.67	19.75	18.25	17.08	16.08	15.25	14.50	13.92
W27X 94-C12X20.7	45.25	36.17	31.83	29.00	26.75	24.75	21.75	19.58	17.92	16.58	15.50	14.67	13.92	13.25	12.75
W27X 94-C15X33.9	58.00	46.33	40.75	37.17	34.33	30.50	26.50	23.67	21.50	19.83	18.42	17.25	16.33	15.50	14.83
W30X 99-C15X33.9	58.00	46.33	40.75	37.17	34.33	29.75	26.00	23.25	21.17	19.58	18.25	17.17	16.17	15.42	14.75
W30X 99-C18X42.7	69.42	55.50	48.75	44.42	40.33	33.92	29.50	26.25	23.83	21.92	20.33	19.08	18.00	17.08	16.25
W30X116-C15X33.9	59.83	47.75	41.92	38.25	35.58	33.25	31.25	28.17	25.42	23.25	21.50	20.08	18.92	17.92	17.00
W30X116-C18X42.7	71.17	56.83	49.83	45.42	42.25	39.50	36.58	32.25	28.92	26.42	24.33	22.67	21.25	20.08	19.00
W33X118-C15X33.9	61.50	49.08	43.08	39.25	36.58	34.25	31.92	28.25	25.58	23.42	21.75	20.33	19.17	18.17	17.25
W33X118-C18X42.7	73.00	58.25	51.08	46.58	43.33	40.50	36.92	32.58	29.33	26.75	24.75	23.08	21.67	20.50	19.42
W33X141-C15X33.9	62.83	50.08	43.92	40.00	37.25	35.08	33.17	31.42	29.83	27.50	25.33	23.50	22.00	20.75	19.67
W33X141-C18X42.7	73.67	58.75	51.50	46.92	43.67	41.17	38.83	36.75	34.75	31.50	28.92	26.75	25.00	23.50	22.25
W36X150-C15X33.9	64.17	51.08	44.75	40.75	37.92	35.75	33.92	32.17	30.67	28.75	26.42	24.58	23.00	21.67	20.58
W36X150-C18X42.7	75.00	59.75	52.42	47.75	44.42	41.83	39.58	37.58	35.67	33.08	30.33	28.08	26.25	24.67	23.33

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



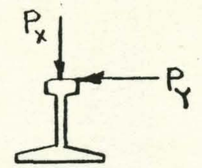


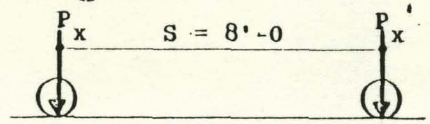
$P_y = 0.08P_x$ $\qquad F_y = 50$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	30.50	20.33	15.25	12.17	9.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	36.83	21.75	16.25	13.50	10.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	31.58	23.42	17.25	14.25	11.67	9.58	8.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	38.25	25.33	18.58	15.25	13.08	10.75	9.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	39.75	31.17	22.25	18.00	15.50	13.83	11.83	10.25	9.08	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	52.17	35.08	24.83	19.92	17.00	15.08	13.67	11.92	10.50	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	41.42	33.42	29.42	23.92	20.08	17.58	15.83	14.58	13.58	12.08	10.92	9.92	0.00	0.00	0.00
W18X 50-C15X33.9	54.33	43.67	34.58	27.00	22.50	19.67	17.58	16.08	14.92	14.00	12.92	11.75	0.00	0.00	0.00
W21X 62-C12X20.7	43.58	35.08	30.92	28.17	24.50	21.25	18.92	17.25	16.00	14.92	14.08	13.25	12.17	11.25	10.42
W21X 62-C15X33.9	56.92	45.67	40.25	34.33	28.25	24.33	21.58	19.50	17.92	16.75	15.75	14.92	14.17	13.58	12.58
W21X 68-C12X20.7	43.83	35.25	31.08	28.42	26.17	22.83	20.25	18.33	16.92	15.75	14.83	14.08	13.33	12.25	11.42
W21X 68-C15X33.9	57.08	45.83	40.33	36.83	30.58	26.17	23.08	20.83	19.08	17.75	16.67	15.75	14.92	14.33	13.75
W24X 68-C12X20.7	45.33	36.42	32.08	29.33	26.92	23.17	20.67	18.75	17.33	16.17	15.25	14.42	13.75	12.83	12.00
W24X 68-C15X33.9	59.00	47.25	41.58	38.00	31.67	27.08	23.92	21.58	19.83	18.42	17.25	16.25	15.50	14.83	14.17
W24X 84-C12X20.7	46.33	37.17	32.75	29.92	27.83	26.08	24.50	22.00	20.08	18.67	17.42	16.42	15.58	14.92	14.25
W24X 84-C15X33.9	59.50	47.67	42.00	38.33	35.67	32.58	28.50	25.50	23.17	21.42	19.92	18.75	17.75	16.83	16.08
W27X 84-C12X20.7	48.00	38.42	33.83	30.92	28.83	26.92	24.50	22.08	20.25	18.83	17.58	16.67	15.83	15.08	14.50
W27X 84-C15X33.9	61.42	49.17	43.25	39.50	36.75	33.00	28.92	25.92	23.58	21.83	20.33	19.08	18.08	17.25	16.50
W27X 94-C12X20.7	48.75	39.08	34.33	31.42	29.25	27.50	25.92	24.25	22.08	20.42	19.08	17.92	17.00	16.17	15.50
W27X 94-C15X33.9	61.83	49.50	43.50	39.75	37.08	34.83	31.92	28.42	25.83	23.75	22.08	20.67	19.50	18.50	17.67
W30X 99-C15X33.9	61.83	49.50	43.50	39.75	37.00	34.75	31.25	27.92	25.42	23.42	21.83	20.50	19.33	18.42	17.58
W30X 99-C18X42.7	73.50	58.83	51.67	47.17	43.92	39.67	34.58	30.83	27.92	25.67	23.83	22.33	21.08	20.00	19.08
W30X116-C15X33.9	64.08	51.25	45.00	41.08	38.33	36.17	34.33	32.58	31.08	28.33	26.17	24.42	22.92	21.67	20.58
W30X116-C18X42.7	75.75	60.58	53.17	48.50	45.17	42.67	40.33	38.33	34.42	31.42	29.00	26.92	25.25	23.83	22.58
W33X118-C15X33.9	66.08	52.83	46.42	42.33	39.42	37.25	35.33	33.67	31.58	28.83	26.67	24.92	23.42	22.17	21.08
W33X118-C18X42.7	77.92	62.25	54.67	49.83	46.42	43.83	41.50	39.25	35.25	32.17	29.75	27.67	25.92	24.50	23.25
W33X141-C15X33.9	67.58	54.00	47.33	43.17	40.25	38.00	36.17	34.58	33.17	31.83	30.58	29.17	27.25	25.67	24.25
W33X141-C18X42.7	78.83	63.00	55.25	50.42	46.92	44.25	42.17	40.25	38.50	36.83	35.00	32.42	30.25	28.42	26.83
W36X150-C15X33.9	69.17	55.17	48.42	44.17	41.08	38.75	36.92	35.42	34.00	32.67	31.42	30.33	28.67	27.00	25.50
W36X150-C18X42.7	80.50	64.25	56.33	51.33	47.83	45.08	42.92	41.08	39.42	37.75	36.33	34.33	32.08	30.08	28.42

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



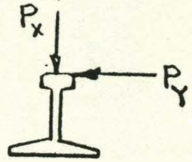


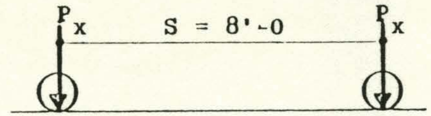
$P_y = 0.10P_x$ $F_y = 50$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	29.92	19.25	14.59	11.17	8.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	36.33	20.92	15.58	12.58	9.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	30.92	22.00	16.33	13.58	10.58	8.67	7.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	37.58	24.25	17.67	14.58	12.08	9.92	8.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	38.92	29.58	21.08	17.08	14.75	12.83	10.83	9.42	8.33	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	51.33	33.92	24.00	19.17	16.33	14.50	12.83	11.08	9.75	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	40.42	32.58	28.58	22.42	18.92	16.58	15.00	13.83	12.33	11.00	9.92	9.00	0.00	0.00	0.00
W18X 50-C15X33.9	53.25	42.83	33.17	25.83	21.50	18.75	16.83	15.42	14.33	13.25	11.92	10.83	0.00	0.00	0.00
W21X 62-C12X20.7	42.33	34.08	30.00	27.17	22.75	19.75	17.67	16.17	15.00	14.08	13.00	11.83	10.92	10.08	9.33
W21X 62-C15X33.9	55.58	44.67	39.33	32.50	26.75	23.00	20.42	18.50	17.08	15.92	15.00	14.17	13.50	12.42	11.58
W21X 68-C12X20.7	42.58	34.25	30.17	27.42	24.58	21.17	18.83	17.17	15.83	14.83	14.00	13.00	11.92	11.00	10.17
W21X 68-C15X33.9	55.75	44.75	39.42	35.33	28.92	24.75	21.83	19.75	18.17	16.83	15.83	15.00	14.25	13.67	12.67
W24X 68-C12X20.7	43.92	35.25	31.08	28.25	24.75	21.42	19.08	17.42	16.17	15.08	14.25	13.50	12.42	11.42	10.67
W24X 68-C15X33.9	57.42	46.08	40.50	36.25	29.67	25.42	22.50	20.33	18.67	17.33	16.33	15.42	14.67	14.08	13.42
W24X 84-C12X20.7	44.83	35.92	31.67	28.92	26.83	25.00	22.50	20.33	18.58	17.25	16.17	15.33	14.58	13.92	13.17
W24X 84-C15X33.9	57.83	46.42	40.83	37.33	34.50	30.50	26.67	23.92	21.75	20.08	18.75	17.67	16.75	15.92	15.25
W27X 84-C12X20.7	46.33	37.17	32.67	29.92	27.67	25.33	22.42	20.25	18.67	17.33	16.33	15.42	14.67	14.08	13.42
W27X 84-C15X33.9	59.67	47.75	42.00	38.33	35.58	30.58	26.83	24.08	22.00	20.33	19.00	17.92	17.00	16.17	15.50
W27X 94-C12X20.7	47.08	37.75	33.17	30.33	28.17	26.33	24.67	22.17	20.25	18.75	17.58	16.58	15.75	15.00	14.42
W27X 94-C15X33.9	60.00	48.00	42.25	38.58	35.92	33.50	29.58	26.42	24.00	22.08	20.58	19.33	18.25	17.33	16.58
W30X 99-C15X33.9	60.00	48.00	42.25	38.58	35.83	33.08	28.92	25.92	23.58	21.83	20.33	19.08	18.08	17.25	16.50
W30X 99-C18X42.7	71.58	57.25	50.33	45.92	42.58	37.17	32.42	28.92	26.25	24.17	22.42	21.08	19.92	18.92	18.00
W30X116-C15X33.9	62.00	49.58	43.58	39.75	37.08	34.92	33.00	31.25	28.50	26.08	24.17	22.58	21.25	20.08	19.08
W30X116-C18X42.7	73.50	58.75	51.58	47.08	43.83	41.25	38.92	35.67	32.08	29.25	27.00	25.17	23.58	22.25	21.17
W33X118-C15X33.9	63.83	51.00	44.83	40.92	38.08	35.92	33.92	31.83	28.75	26.42	24.50	22.92	21.58	20.42	19.42
W33X118-C18X42.7	75.50	60.33	52.92	48.25	45.00	42.33	40.00	36.17	32.58	29.75	27.50	25.67	24.08	22.83	21.67
W33X141-C15X33.9	65.25	52.08	45.67	41.67	38.83	36.67	34.83	33.25	31.75	30.33	28.58	26.58	24.92	23.42	22.25
W33X141-C18X42.7	76.33	60.92	53.42	48.75	45.42	42.83	40.67	38.67	36.92	35.08	32.25	29.92	27.92	26.25	24.83
W36X150-C15X33.9	66.67	53.17	46.67	42.50	39.58	37.42	35.58	34.00	32.50	31.17	29.83	27.83	26.08	24.58	23.25
W36X150-C18X42.7	77.75	62.00	54.42	49.58	46.17	43.58	41.42	39.50	37.75	36.08	34.00	31.50	29.42	27.67	26.17

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



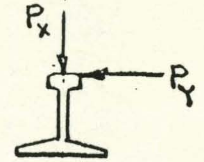


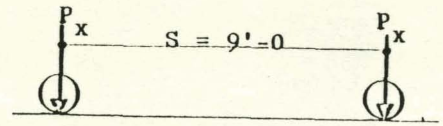
$P_y = 0.12P_x$ $F_y = 50$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	29.33	18.42	13.92	10.25	8.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	35.75	20.08	15.00	11.75	9.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	30.25	20.83	15.50	12.42	9.67	7.92	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	36.92	23.17	16.92	14.00	11.17	9.17	7.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	38.17	28.08	20.00	16.25	14.08	11.83	10.00	8.67	7.67	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	50.50	32.83	23.08	18.42	15.75	14.00	12.08	10.42	9.17	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	39.50	31.83	26.92	21.17	17.83	15.75	14.25	12.83	11.25	10.00	9.08	8.25	0.00	0.00	0.00
W18X 50-C15X33.9	52.25	42.08	31.83	24.75	20.58	18.00	16.17	14.75	13.75	12.33	11.08	10.08	0.00	0.00	0.00
W21X 62-C12X20.7	41.25	33.17	29.17	25.58	21.25	18.58	16.67	15.25	14.17	13.08	11.75	10.75	9.83	9.08	8.50
W21X 62-C15X33.9	54.33	43.67	38.42	30.83	25.33	21.83	19.42	17.67	16.25	15.17	14.33	13.58	12.42	11.50	10.67
W21X 68-C12X20.7	41.42	33.33	29.42	26.58	22.92	19.83	17.67	16.17	14.92	14.00	12.92	11.75	10.75	9.92	9.25
W21X 68-C15X33.9	54.50	43.75	38.50	33.50	27.42	23.50	20.75	18.75	17.25	16.08	15.08	14.33	13.67	12.58	11.67
W24X 68-C12X20.7	42.67	34.25	30.17	27.33	22.92	20.00	17.92	16.33	15.17	14.25	13.33	12.17	11.17	10.33	9.58
W24X 68-C15X33.9	56.00	44.92	39.58	34.17	27.92	23.92	21.25	19.25	17.67	16.50	15.50	14.67	14.00	13.25	12.33
W24X 84-C12X20.7	43.50	34.92	30.75	28.08	25.83	23.67	20.92	18.92	17.33	16.17	15.17	14.42	13.75	12.75	11.83
W24X 84-C15X33.9	56.42	45.25	39.83	36.33	33.50	28.67	25.08	22.50	20.50	19.00	17.75	16.75	15.83	15.08	14.50
W27X 84-C12X20.7	44.92	36.00	31.67	28.92	26.67	23.33	20.75	18.83	17.33	16.17	15.25	14.50	13.83	12.92	12.00
W27X 84-C15X33.9	58.00	46.50	40.83	37.33	33.58	28.58	25.08	22.58	20.67	19.17	17.92	16.92	16.08	15.33	14.67
W27X 94-C12X20.7	45.67	36.58	32.17	29.42	27.17	25.33	22.67	20.50	18.75	17.42	16.42	15.50	14.75	14.08	13.50
W27X 94-C15X33.9	58.33	46.75	41.08	37.50	34.75	31.58	27.50	24.67	22.42	20.67	19.33	18.17	17.17	16.42	15.67
W30X 99-C15X33.9	58.33	46.75	41.08	37.50	34.75	30.75	27.00	24.17	22.08	20.42	19.08	18.00	17.08	16.25	15.58
W30X 99-C18X42.7	69.83	55.83	49.08	44.75	41.42	34.92	30.50	27.25	24.75	22.83	21.25	19.92	18.83	17.92	17.17
W30X116-C15X33.9	60.17	48.08	42.25	38.58	35.92	33.67	31.75	29.25	26.42	24.17	22.42	21.00	19.75	18.75	17.92
W30X116-C18X42.7	71.50	57.17	50.17	45.83	42.67	39.92	37.50	33.33	30.00	27.42	25.33	23.58	22.17	21.00	19.92
W33X118-C15X33.9	61.92	49.42	43.42	39.58	36.92	34.67	32.67	29.25	26.50	24.42	22.67	21.25	20.00	19.00	18.17
W33X118-C18X42.7	73.33	58.58	51.42	46.92	43.67	40.92	38.00	33.58	30.33	27.75	25.67	24.00	22.58	21.33	20.33
W33X141-C15X33.9	63.17	50.42	44.25	40.33	37.58	35.50	33.58	31.92	30.42	28.50	26.25	24.50	23.00	21.67	20.58
W33X141-C18X42.7	74.08	59.17	51.92	47.33	44.08	41.50	39.25	37.25	35.42	32.50	29.92	27.75	26.00	24.50	23.17
W36X150-C15X33.9	64.50	51.42	45.08	41.17	38.33	36.17	34.33	32.67	31.08	29.75	27.42	25.50	23.92	22.58	21.42
W36X150-C18X42.7	75.33	60.17	52.75	48.08	44.75	42.25	40.00	38.00	36.17	34.17	31.33	29.08	27.25	25.58	24.25

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



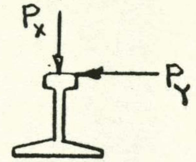


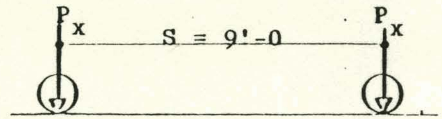
$P_y = 0.08P_x$ $F_y = 50$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	30.83	21.17	16.08	12.17	9.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	37.25	22.67	17.08	13.50	10.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	31.92	24.33	18.08	14.92	11.67	9.58	8.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	38.67	26.33	19.42	16.08	13.08	10.75	9.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	40.08	32.17	23.17	18.83	16.25	14.00	11.83	10.25	9.08	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	52.50	36.00	25.83	20.75	17.83	15.83	13.75	11.92	10.50	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	41.83	33.75	29.83	24.83	21.00	18.50	16.67	15.42	13.58	12.08	10.92	9.92	0.00	0.00	0.00
W18X 50-C15X33.9	54.67	44.08	35.58	27.92	23.42	20.50	18.42	16.92	15.75	14.33	12.92	11.75	0.00	0.00	0.00
W21X 62-C12X20.7	43.92	35.42	31.25	28.58	25.42	22.17	19.83	18.08	16.75	15.75	14.50	13.25	12.17	11.25	10.42
W21X 62-C15X33.9	57.25	46.08	40.58	35.33	29.25	25.25	22.42	20.42	18.83	17.58	16.50	15.67	14.67	13.58	12.58
W21X 68-C12X20.7	44.25	35.58	31.42	28.75	26.58	23.75	21.17	19.25	17.75	16.58	15.67	14.50	13.33	12.25	11.42
W21X 68-C15X33.9	57.42	46.17	40.67	37.17	31.58	27.17	24.00	21.75	20.00	18.58	17.50	16.58	15.75	14.92	13.83
W24X 68-C12X20.7	45.67	36.75	32.42	29.67	27.50	24.08	21.50	19.58	18.17	17.00	16.00	15.17	13.92	12.83	12.00
W24X 68-C15X33.9	59.33	47.67	42.00	38.33	32.67	28.08	24.83	22.50	20.67	19.25	18.08	17.08	16.33	15.58	14.75
W24X 84-C12X20.7	46.67	37.50	33.08	30.25	28.25	26.50	25.00	22.92	21.00	19.50	18.25	17.25	16.42	15.75	14.92
W24X 84-C15X33.9	59.83	48.08	42.33	38.67	36.08	33.58	29.50	26.42	24.17	22.33	20.83	19.58	18.58	17.67	16.92
W27X 84-C12X20.7	48.33	38.83	34.17	31.25	29.17	27.42	25.42	23.00	21.17	19.67	18.42	17.50	16.58	15.92	15.25
W27X 84-C15X33.9	61.75	49.50	43.58	39.83	37.17	34.00	29.92	26.83	24.50	22.67	21.17	20.00	18.92	18.08	17.25
W27X 94-C12X20.7	49.08	39.42	34.67	31.75	29.67	27.92	26.42	25.08	23.00	21.33	19.92	18.83	17.83	17.00	16.33
W27X 94-C15X33.9	62.17	49.83	43.92	40.08	37.42	35.17	32.92	29.42	26.75	24.67	22.92	21.58	20.42	19.42	18.50
W30X 99-C15X33.9	62.17	49.83	43.83	40.09	37.42	35.17	32.25	28.92	26.33	24.33	22.67	21.33	20.17	19.25	18.42
W30X 99-C18X42.7	73.83	59.17	52.00	47.50	44.25	40.75	35.58	31.75	28.92	26.58	24.75	23.25	21.92	20.83	19.92
W30X116-C15X33.9	64.42	51.58	45.33	41.42	38.67	36.50	34.67	33.08	31.58	29.33	27.17	25.33	23.83	22.58	21.50
W30X116-C18X42.7	76.08	60.92	53.50	48.83	45.58	43.00	40.75	38.75	35.50	32.42	29.92	27.92	26.17	24.75	23.50
W33X118-C15X33.9	66.50	53.17	46.75	42.67	39.75	37.58	35.75	34.08	32.50	29.83	27.67	25.83	24.33	23.08	21.92
W33X118-C18X42.7	78.25	62.58	55.00	50.17	46.75	44.17	41.92	39.92	36.25	33.17	30.67	28.58	26.92	25.42	24.17
W33X141-C15X33.9	67.92	54.33	47.75	43.58	40.58	38.33	36.50	35.00	33.58	32.25	31.08	29.92	28.17	26.58	25.17
W33X141-C18X42.7	79.17	63.33	55.58	50.75	47.25	44.58	42.50	40.67	38.92	37.33	35.83	33.42	31.25	29.33	27.83
W36X150-C15X33.9	69.50	55.58	48.75	44.50	41.50	39.17	37.33	35.75	34.42	33.08	31.92	30.75	29.67	27.92	26.42
W36X150-C18X42.7	80.93	64.58	56.67	51.67	48.17	45.50	43.33	41.50	39.83	38.25	36.75	35.42	33.00	31.08	29.33

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths



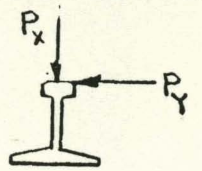


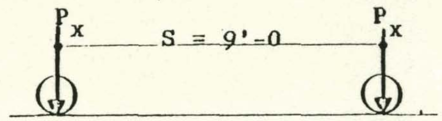
$P_y = 0.10P_x$ $F_y = 50$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	30.25	20.17	15.33	11.17	8.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	36.67	21.83	16.42	12.58	9.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	31.25	23.00	17.17	13.58	10.58	8.67	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	37.92	25.17	18.58	15.42	12.08	9.92	8.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	39.25	30.58	22.00	17.92	15.50	12.83	10.83	9.42	8.33	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	51.67	34.92	24.92	20.00	17.17	15.33	12.83	11.08	9.75	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	40.75	32.92	29.00	23.33	19.75	17.42	15.83	14.00	12.33	11.00	9.92	9.00	0.00	0.00	0.00
W18X 50-C15X33.9	53.58	43.17	34.17	26.75	22.42	19.67	17.67	16.25	14.92	13.25	11.92	10.83	0.00	0.00	0.00
W21X 62-C12X20.7	42.67	34.42	30.42	27.58	23.67	20.67	18.58	17.00	15.83	14.42	13.00	11.83	10.92	10.08	9.33
W21X 62-C15X33.9	55.92	45.00	39.67	33.50	27.75	23.92	21.33	19.42	17.92	16.75	15.75	14.75	13.50	12.42	11.58
W21X 68-C12X20.7	42.92	34.58	30.58	27.83	25.50	22.08	19.75	18.00	16.67	15.58	14.33	13.00	11.92	11.00	10.17
W21X 68-C15X33.9	56.08	45.08	39.75	36.25	29.92	25.75	22.75	20.67	19.00	17.67	16.67	15.75	14.83	13.67	12.67
W24X 68-C12X20.7	44.25	35.58	31.42	28.67	25.67	22.33	20.00	18.25	16.92	15.92	14.83	13.50	12.42	11.42	10.67
W24X 68-C15X33.9	57.75	46.42	40.92	37.33	30.67	26.33	23.42	21.25	19.50	18.25	17.17	16.25	15.50	14.42	13.42
W24X 84-C12X20.7	45.17	36.33	32.00	29.33	27.25	25.42	23.42	21.17	19.50	18.17	17.00	16.17	15.33	14.25	13.17
W24X 84-C15X33.9	58.25	46.75	41.17	37.67	34.92	31.50	27.67	24.83	22.67	21.00	19.67	18.50	17.58	16.75	16.08
W27X 84-C12X20.7	46.67	37.50	33.08	30.25	28.08	26.25	23.33	21.17	19.50	18.17	17.17	16.25	15.50	14.50	13.42
W27X 84-C15X33.9	60.00	48.08	42.33	38.75	36.00	31.58	27.83	25.00	22.92	21.25	19.92	18.75	17.83	17.00	16.33
W27X 94-C12X20.7	47.42	38.08	33.50	30.67	28.58	26.83	25.25	23.08	21.17	19.67	18.42	17.42	16.58	15.83	15.17
W27X 94-C15X33.9	60.33	48.42	42.58	38.92	36.25	34.00	30.58	27.33	24.92	23.00	21.42	20.17	19.08	18.17	17.42
W30X 99-C15X33.9	60.33	48.42	42.58	38.92	36.25	33.92	29.92	26.83	24.50	22.67	21.17	20.00	18.92	18.08	17.25
W30X 99-C18X42.7	71.92	57.58	50.67	46.25	43.00	38.25	33.42	29.83	27.17	25.08	23.33	21.92	20.75	19.75	18.83
W30X116-C15X33.9	62.33	49.92	43.92	40.08	37.42	35.25	33.42	31.75	29.50	27.08	25.08	23.50	22.08	21.00	20.00
W30X116-C18X42.7	73.83	59.08	51.92	47.42	44.25	41.67	39.33	36.67	33.08	30.25	27.92	26.08	24.50	23.17	22.08
W33X118-C15X33.9	64.25	51.42	45.17	41.25	38.42	36.25	34.42	32.67	29.75	27.33	25.42	23.75	22.42	21.33	20.33
W33X118-C18X42.7	75.83	60.67	53.25	48.67	45.33	42.75	40.42	37.25	33.58	30.75	28.50	26.58	25.00	23.67	22.50
W33X141-C15X33.9	65.58	52.42	46.00	42.00	39.17	37.00	35.25	33.67	32.17	30.83	29.58	27.50	25.83	24.42	23.17
W33X141-C18X42.7	76.67	61.25	53.83	49.08	45.75	43.17	41.08	39.08	37.33	35.75	33.25	30.83	28.92	27.25	25.75
W36X150-C15X33.9	67.00	53.50	47.00	42.92	40.00	37.75	35.92	34.42	32.92	31.58	30.42	28.83	27.00	25.50	24.17
W36X150-C18X42.7	78.08	62.42	54.75	49.92	46.50	43.92	41.83	39.92	38.17	36.58	35.00	32.50	30.42	28.58	27.08

Note: A value of 0.00 indicates allowable web shear stress exceeded.

TABLE 3-3 (cont.): Maximum allowable beam lengths





$P_y = 0.12P_x$ $F_y = 50$ ksi

SECTION	WHEEL LOAD P_x (kips)														
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0
W12X 26-C10X15.3	29.75	19.25	14.25	10.25	8.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W12X 26-C12X20.7	36.09	21.00	15.83	11.75	9.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C10X15.3	30.58	21.75	16.33	12.42	9.67	8.00	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W14X 30-C12X20.7	37.33	24.08	17.83	14.42	11.17	9.17	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C12X20.7	38.50	29.08	20.92	17.08	14.50	11.83	10.00	8.67	8.00	0.00	0.00	0.00	0.00	0.00	0.00
W16X 36-C15X33.9	50.83	33.92	24.08	19.33	16.58	14.33	12.08	10.42	9.17	0.00	0.00	0.00	0.00	0.00	0.00
W18X 50-C12X20.7	39.83	32.17	27.92	22.08	18.75	16.58	14.92	12.83	11.25	10.00	9.08	8.25	0.00	0.00	0.00
W18X 50-C15X33.9	52.58	42.42	32.83	25.67	21.50	18.83	17.00	15.58	13.92	12.33	11.08	10.08	0.00	0.00	0.00
W21X 62-C12X20.7	41.58	33.50	29.58	26.58	22.25	19.42	17.50	16.08	14.67	13.08	11.75	10.75	9.83	9.08	8.50
W21X 62-C15X33.9	54.75	44.00	38.83	31.92	26.33	22.75	20.33	18.50	17.08	16.00	14.92	13.58	12.42	11.50	10.67
W21X 68-C12X20.7	41.83	33.67	29.75	27.00	23.83	20.75	18.58	17.00	15.75	14.33	12.92	11.75	10.75	9.92	9.25
W21X 68-C15X33.9	54.83	44.08	38.83	34.58	28.42	24.42	21.67	19.67	18.08	16.92	15.92	14.92	13.67	12.58	11.67
W24X 68-C12X20.7	43.00	34.58	30.58	27.75	23.92	20.83	18.75	17.17	16.00	14.75	13.33	12.17	11.17	10.33	9.58
W24X 68-C15X33.9	56.42	45.33	39.92	35.17	28.92	24.92	22.17	20.08	18.58	17.33	16.33	15.50	14.33	13.25	12.33
W24X 84-C12X20.7	43.83	35.25	31.08	28.42	26.33	24.50	21.83	19.75	18.25	17.00	16.00	15.08	13.83	12.75	11.83
W24X 84-C15X33.9	56.75	45.58	40.17	36.67	33.92	29.67	26.08	23.42	21.42	19.83	18.58	17.58	16.67	15.92	15.25
W27X 84-C12X20.7	45.25	36.33	32.08	29.33	27.08	24.25	21.67	19.67	18.25	17.00	16.08	15.25	14.00	12.92	12.00
W27X 84-C15X33.9	58.42	46.83	41.25	37.67	34.67	29.58	26.08	23.50	21.58	20.00	18.75	17.75	16.83	16.17	15.50
W27X 94-C12X20.7	46.00	36.92	32.50	29.75	27.67	25.83	23.67	21.33	19.67	18.33	17.25	16.33	15.58	14.50	13.50
W27X 94-C15X33.9	58.75	47.08	41.42	37.83	35.17	32.58	28.50	25.58	23.33	21.58	20.17	19.00	18.00	17.17	16.50
W30X 99-C15X33.9	58.75	47.08	41.42	37.83	35.17	31.75	27.92	25.17	23.00	21.33	19.92	18.83	17.92	17.08	16.33
W30X 99-C18X42.7	70.17	56.17	49.42	45.17	41.83	36.00	31.50	28.17	25.67	23.75	22.17	20.83	19.75	18.75	17.92
W30X116-C15X33.9	60.50	48.50	42.58	38.92	36.33	34.17	32.17	30.25	27.33	25.17	23.33	21.92	20.67	19.67	18.75
W30X116-C18X42.7	71.83	57.50	50.58	46.17	43.00	40.33	38.00	34.33	31.00	28.33	26.25	24.50	23.08	21.83	20.83
W33X118-C15X33.9	62.25	49.83	43.75	40.00	37.25	35.08	33.08	30.25	27.50	25.33	23.58	22.08	20.92	19.92	19.00
W33X118-C18X42.7	73.67	58.92	51.75	47.25	44.00	41.33	39.00	34.67	31.33	28.67	26.58	24.92	23.50	22.25	21.17
W33X141-C15X33.9	63.58	50.83	44.58	40.75	38.00	35.83	34.00	32.33	30.83	29.50	27.25	25.42	23.92	22.58	21.50
W33X141-C18X42.7	74.42	59.50	52.25	47.67	44.42	41.92	39.67	37.67	35.92	33.58	30.92	28.75	26.92	25.42	24.08
W36X150-C15X33.9	64.83	51.83	45.50	41.50	38.67	36.50	34.75	33.08	31.58	30.25	28.42	26.50	24.83	23.50	22.33
W36X150-C18X42.7	75.75	60.50	53.08	48.42	45.08	42.58	40.42	38.50	36.67	35.00	32.42	30.08	28.17	26.58	25.17

Note: A value of 0.00 indicates allowable web shear stress exceeded.

are the same common sections listed in part one of the AISC Steel Manual.

To use the table as a design aid, it is first necessary to select the correct table. There are listings for wheelbases of 4'-0, 5'-0, 6'-0, 7'-0, 8'-0, and 9'-0. Also, the listings are repeated for varying lateral loads, P_y, which are expressed as functions of P_x, i.e. P_Y is either $0.08P_x$, $0.10P_x$, or $0.12P_x$. Thus, the designer must use the table with the wheelbase, lateral load, and grade of steel that corresponds to the design situation. Once the proper table is selected, the column for P_x the direct wheel load, must be selected so that it again corresponds to the design situation. The values of P_x range from a minimum of 5 kips to a maximum of 75 kips, with intermediate values of P_x in multiples of 5 kips. With the correct value for P_x selected, the designer must find the length in this column that is closest to the actual length used. Obviously, the length selected cannot be less than the design length needed. The combination section that corresponds to this length should be used.

In constructing these design tables, some simplifying assumptions were made. The first assumption made was that a constant rail height of five inches will be employed. The rail height has a direct effect on the torsional stresses since the torque increases or decreases with a change in wheel height. Crane rails are available in different sizes, with the heights varying from 3.5 in. to 6 in. The lengths in the tables, however, use only 5 in.

and differ by leas than ±5% for other actual rail heights. In most cases the error is about 2%, which is not too significant. This is demonstrated in Table 3-4.

P_x = 20 kips P_y = 2.0 kips Wheelbase = 4'-0					
SECTION	% DIFF. 4" to 5"	RAIL HEIGHT			% DIFF. 5" to 6"
		4.00"	5.00"	6.00"	
W12X50-C10X15.3	3.03%	11.33	11.00	10.75	2.27%
W18X50-C12X20.7	4.22%	14.42	13.83	13.42	4.22%
W24X84-C12X20.7	2.89%	23.75	23.08	22.42	2.89%
W30X99-C18X42.7	3.29%	36.67	35.50	34.42	3.05%

TABLE 3-4: Typical difference in maximum allowable lengths for varying rail heights.

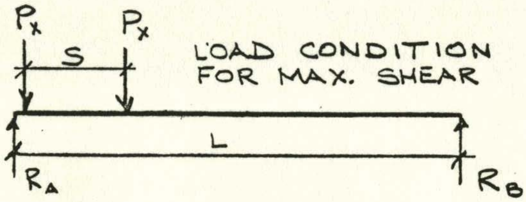
The use of 8%, 10%, or 12% of the vertical load for the lateral load applied at the top of the rail was another simplification used. It is neither feasible nor design expedient to try to use anything more precise. The lateral loads on a crane beam seldom fall below 8% or exceed 12%. Therefore, if "the lateral load lies between two percentages given in the tables, linear interpolation can be used to derive the maximum allowable length. This interpolation yields a length that is almost precisely the correct value with an error far below 1%. This is illustrated in Table 3-5 in which lengths are compared from interpolation and by actual calculation for a lateral load not included in the design table. The design tables can also be extended linearly past the 8% or 1296 range and still yield very satisfactory results.

P_x = 25 kips Wheelbase = 6'-0 Rail Height = 5.0"				
SECTION	$P_y = 0.09P_x$		$P_y = 0.11P_x$	
	Interp.	Calc.	Interp.	Calc.
W21X62-C12X20.7	16.63	16.58	15.50	15.50
W27X84-C15X33.9	26.08	26.08	24.21	24.17
W36X150-C18X42.7	45.83	45.83	43.88	43.83

Table 3-5: Comparison of allowable lengths obtained by calculation and by intarpolation of Table 3-3.

Using a similar simplifying assumption for the crane wheelbases, linear interpolation may again be used for an actual wheelbase that lies between the ones listed. Wheelbase dimensions vary from one manufacturer to another and it is not possible to even attempt to list all the different possible spacings that can be encountered. But, the ranges presented should be sufficient to cover most design situations that will occur. Linear interpolation between table8 can be used for a wheelbase not listed with a very insignificant error.

When using Table 3-38, if a length of 0.00 is listed, this signifies the shear stress in the beam web exceeds the allowable stress (as defined by AISC Section 1.5.1.2). In evaluating the actual Web shear stress in the beam, a value of' twice the vertical live load was always used to calculate the shear stress. While this is not .correct and is only approximate as shown by Fig. 3-4, the length of the beam in which shear controls is eo short that a beam of that length is not practical to use.



$$V_{max}\Big|_{net} = \frac{R}{dt_w} = \frac{P_x\left[1 + \frac{(L-S)}{L}\right]}{dt_w} \cong \frac{2P_x}{dt_w}$$

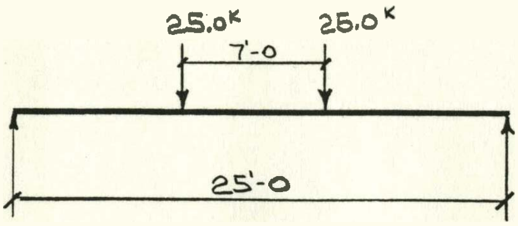
Figure 3-4: Approximation of web shear.

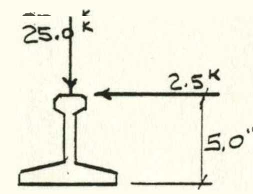
In Table 3-3, the lengths listed are the maximum lengths that can be used for that particular combination section. Therefore, the actual bending stress in the beam would be approximately the same as the allowable bending stress as defined by AISC Section 1.5.1.4.5. The allowable tensile stress is given as $0.60F_Y$ and the allowable compreesion stress is given by either eq(1.5-6a) or eq(1.5-6b) depending on the value of L/r_t for the combination section being used. The lengths listed are thus the maximum lengths that may be used for a simply-supported span.

The following examples will demonstrate the use of Table 3-3.

EXAMPLE 3-2:

GIVEN: The following crane load conditions,





TO FIND: Using Table 3-3, find the lightest suitable combination section for both 36 ksi and 50 ksi grade steels.

SOLUTION: 36 ksi steel:

Using Table 3-3 on page 45 , and using the column for P_x = 25 kips:

Select either

W24X84-C15X33.9   Allowable length= 26.08'

or W27X84-C15X33.9   Allowable length= 25.83'

While both sections are satisfactory and both have the same weight, it is advantageous to use the W27X84-C15X33.9. Since this section has a larger allowable length, it will have a lower bending stress. In addition, it will also deflect less..

Now, the stresses can be checked in the section using the torsional theory.

Tension stress:

f_{bT} = 21.4 ksi F_{bT} = 22.0 ksi   O.K.

Compression stress:

f_{bC} = 12.8 ksi F_{bC} = 20.3 ksi   O.K.

Thus, the section is adequate.

50 ksi steel:

Use Fable 3-3 on page63 and the column for P_x = 25 kips.

Select:

W21X62-C15X33.9   Allowable length = 25.75'

A check of the bending stress yields:

Tension stress:

f_{bT} = 29.5 ksi F_{bT} = 30.0 ksi   O.K.

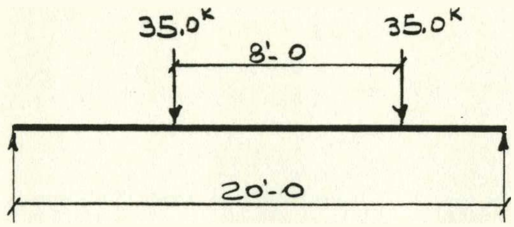
Compression stress:

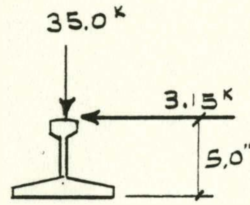
f_{bC} = 16.2 ksi F_{bC} = 26.5 ksi   O.K.

Therefore, a W21X62-C15X33.9 section of 50 ksi grade steel is adequate for the load condition.

EXAMPLE 3-3:

GIVEN: The following crane load conditions!





TO FIND: Using Table **3-3**, find the lightest suitable combination section for 36 ksi grade steel.

SOLUTION: For this load condition

$$\frac{P_y}{P_x} = 0.09$$

Therefore, it will be necessary to interpolate between the tables for $P_y = 0.08P_x$ and $P_y = 0.10P_x$.

Select:

W27X84-C15X33.9 Allowable length = **21.50'**

A check of the bending stresses yields:

Tension stress:

f_{bT} = **20.4** ksi F_{bT} = **22.0** ksi **O.K.**

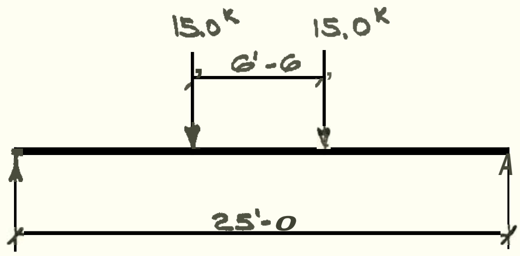
Compression stress:

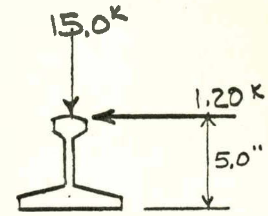
f_{bC} = **12.0** ksi F_{bC} = **22.0** ksi **O.K.**

Thus, a W27X84-C15X33.9 section is adequate.

EXAMPLE 3-4:

GIVEN: The following crane load conditions:





TO FIND: Using Table 3-3, find the lightest suitable combination of 36 ksi steel.

SOLUTION:

$$\frac{P_y}{P_x} = 0.08$$

For this load condition, the wheelbase is 6'-6". Therefore, it will be necessary to interpolate between the tables for S = 6'-0 and S = 7'-0. Select:

W21X62-C12X20.7 Allowable length = 27.04'

A check of the bending stresses for this selection using the torsional theory yields:

Tension stress:

f_{bT} = 20.1 ksi F_{bT} = 22.0 ksi O.K.

Compression stress:

f_{bC} = 13.2 ksi F_{bC} = 18.1 ksi O.K.

Thus, this section is adequate for the load condition given,

Chapter 4

DISCUSSIONS AND CONCLUSIONS

By making a comparison of the torsional theory of combination sections and the so-called "conservative" method, a very interesting point was observed. It appears the "conservative" method is not always conservative. This is dramatically shown in Example 3.1. In the conservative method, the top flange of the combination section is assumed to carry the entire lateral force while in the torsional theory, the entire cross-section resists the lateral load. Since the first method overestimates the compressive stress in the top flange, the method is considered to be conservative.

When a channel is mounted to the top flange of a wide-flange shape, which, in turn, is to be unsymmetrically loaded, three things are accomplished. First, the stresses in the top flange due to the vertical load are reduced since the neutral axis is shifted closer to the top. Second, the bending stress in the top flange due to the lateral load is also reduced since there is a greater section modulus in that direction. And third, the radius of gyration of the built-up top flange is increased and thus, the member is less likely to fail by lateral torsional buckling. Also, the AISC specifications address this by permitting a larger allowable compressive stress. The resulting built-up wide-flange shape is also more effective because the shear center is shifted toward the top flange, thereby making the torque on the section smaller so the warping stresses are, in turn, lower.

While the addition of the channel is beneficial for the top flange, it is detrimental to the tension flange. Since the neutral axis is shifted toward the top, the section modulus for the tension flange is reduced, often by a very significant amount. This will, in turn, yield a higher bending stress in the bottom flange. This fact was highly evident when Table 3-2 was initially developed. Obviously, the permissible length of a beam is at an optimum when the bending stress in either the compression or tension flange has reached its allowable stress. In the vast majority of the cases for sections listed in Table 3-2, the allowable tension stress in the bottom flange was reached before the allowable compressive stress in the top flange.

It should be noted that it is perhaps preferable that the tension flange reach its maximum allowable stress first. Since, if the compression flange controlled the design, the beam could eventually fail much more suddenly due to lateral-torsional buckling. Local buckling problems are also minimized. As with any. type of buckling failure, the failure is usually sudden and catastrophic as compared to a tension failure in which the steel would first begin to yield, going from an elastic state to a plastic state at a progressive rate. All engineers have seen stress-strain curve for a tensil specimen of steel. The steel must yield considerably before rupture will occur.

Although Table 3-2 is very useful in the design of crane beams, it is subject, to a few shortcomings. The first being that the maximum lengths listed in the table do not take into account the beam weight or the crane rail weight. This dead weight can be considered by merely increasing the value of P_x by a very small percentage, for example, an equivalent concentrated load procedure could be easily developed. In any case, the bending stresses arising from the beam dead weight in this instance will be very small considering the magnitudes of the live loads involved.

Another limitation of the tables is that the sections listed were not checked for compliance to Section 1.9 of the AISC Steel Code Specifications. This section deals with the width-to-thickness ratios of elements under compression. Usually, for hot-rolled shapes, this is not a controlling factor for the grades of steel considered.

Finally, the members in Table 3.2 are not loaded in such a way as to produce a fatigue failure. Obviously, for a beam that has a large number of loading cycles, Table 3-2 cannot be used and the design of the beam must be handled by a long-handled solution.

Even with these shortfalls, the design tables still provide a very useful aid for the design of crane beams. Table 3-1, the table of section properties, is extremely useful in that it provides properties for over 150 possible combination sections. Even though Table 3-2 has a maximum wheel load of 75 kips, it is still useful for the structural engineer who only occasionally designs beams for medium-sized cranes. Obviously, for a heavy duty crane, such as in a steel mill, a built-up plate girder will most likely be used. For occasional use, however, and especially for purposes of quickly estimating a crane runway, this design aid is extremely useful.

LIST OF REFERENCES CITED

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2. Heins, C. P. and Seaburg, P. A.,"Torsional Analysis of Rolled Steel Sections", Bethlehem Steel Corp. (1963).

3. Seely, F., Smith, J., et al, "Advanced Mechanics of Materials", John Wiley and Sons (1978).

4. Heins, C. P., "Bending and Torsional Design in Structural Members", D.C. Heath and Co.(1975).

5. Roark, R. J. and Young, W.C., "Formulas for Stress and Strain", McGraw-Hill Book Co.(1975).

6. Kitipornchai, S. and Trahair, N.S.,"Buckling Properties of Monosymmetric I-Beams", Journal of the Structural Division, ASCE(May, 1980).

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8. Galambos, T.V., "Structural Members and Frames", Prentice-Hall (1968).

APPENDIX A

This program has two main functions. First, for a given wide-flange shape and channel section, the program will calculate the elastic.,torsional, and warping properties for the resulting combination section. Second, for this combination section, the propgram will give the maximum allowable length of a crane beam for a given two-wheel crane loading condition and grade of steel.using the torsional theory developed in Chapter 2.

INPUT

To use this program, the crane loading conditions and steel grade must first be entered. Using a format of (5F10.3), the first line contains:

P_x, P_y, S, RH, F_y

where P_x = Vertical wheel load(kips)

P_y = Lateral wheel load (kips)

S = Crane wheelbase (in.)

RH = Crane rail Height (in)

Fy = Steel yield stress (ksi)

Next, it is necessary to input the dimensions and properties of the individual wide-flange shape and channel section, in that order. First for the wide-flange shape, using a format of (2I5,7F10.3), the dimensions and properties needed are entered in the following order:

HGTW,WTW,AWF,DW,BFW,TF,TW,IXWF,IYWF

where HGTW = Nominal height of the wide-flange (in.)

WTW = Weight of the wide-flange (lbs)

AWF = Area of the section (in^2)

DW = Depth of the wide-flange (in.)

BFW = Flange width (in,)

TF = Flange thickness (in.)

TW = Web thickness (in.)

IXWF = Moment of inertia about X-axis (in^4)

IYWF = Moment of inertia about Y-axis ($in.^4$)

Next, for the channel, using a FORMAT of (I5,F5.1, 7F10.3) the dimensions and properties needed are entered in the following order:

HGTC,WTC,AC,BFC,TFC,TWC,IXC,IYC,XBAR

HGTC = Nominal height of channel (in.)

WTC = Weight of the channel

AC = Area of channel (in.)

BFC = Channel flange width (in.)

TWC = Channel flange thickness (in.)

IXC = Moment of inertia about the X-axis (in^4)

IYC = Moment of inertia about the Y-axis (in^4)

XBAR = Distance from neutral axis to the back of the channel, (in.)

This program is designed to handle any quantity of combination sections for the one set of given loading conditions that were entered on the first line. Therefore, it is only necessary to enter additional dimensions and properties of individual wide-flanges and channels, as before.

When the desired combination sections have been entered, the program is halted by the insertion of a blank card as input.

OUTPUT

The first line of output gives:

AREA, Y1, IX, IY, RT, EB

where AREA = Area of the combination section (in^2)

Y1 = Distance from the neutral axis to the bottom flange of combination section (in)

IX = Moment of inertia about X-axis (in^4)

IY = Moment of inertia about Y-axis (in^4)

RT = Radius of gyration of top flange (in)

EB = Distance from shear center to the bottom flange (in)

The second line of output gives:

K, A, CW, WNA, WNB

whrer K = Torsional constant (in^4)

A = $1/\lambda = (EC_W/GK)^{\frac{1}{2}}$

CW = Warping constant (in^6)

WNA = Normalized warping function at point on the top flange (in^2)

WNB = Normalized warping function at point on the bottom flange (in^2)

The third line of output merely gives the loading conditions that were entered The last line of output prints the maximum allowable length for the combination section and indicates whether the tension flange or compression flange has the larger stress. The following example will illustrate the use of the program.

EXAMPLE:

GIVEN: P_x =20.0, P_y = 2.0, S= 60.0 in., RH = 4.0 in.,

F_y = 36 ksi

FIND: Using tho program given, calculate the section properties for a combination section consisting of a W18X50-C12X20.7 and calculate the maximum allowable length ~~it~~ that may be used for the given loading conditions.

SOLUTION:

The individual section properties and loading conditions must be entered using the formats stated previously. So, the following is entered:

```
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
   20.0            2.0          60.0          4.00        36.0
 18   50         14.7          17.99         7.495        0.570        0.355      800.0        40.1
 12 20.7          6.09          2.942        0.501        0.282      129.0          3.88        0.699
```

and the results follow with a maximum allowable length of 15.33 ft. and the maximum bending stress occuring in the bottom flange.

```
$JCB
      INTEGER WTW, HGTW, HGTC
      REAL IXWF, IYWF, IXC, IYC, IX, IY,IYCF
      REAL L, LFINAL, INCR, LA, LB, MX
C     THIS FRCGRAM CALCULATES SECTION PRCPERTIES AND TCRSICNAL
C     PRCPERTIES CF CCMBINEC WICE-FLANGE ANC CHANNEL SECTICNS.
      REAC(5,290)PX,PY,S,RH,FY
  290 FCRMAT(5F10.3)
  200 CCNTINUE
      REAC(5,1C0) HGTW,WTW, AWF, CW, BFW, TF, TW, IXWF, IYWF
      IF(HGTW.EQ.0) GC TC 10CC
      REAC(5,233)HGTC,WTC,AC,BFC,TFC,TWC,IXC,IYC,XBAR
  233 FCRMAT(I5,F5.1,7F1C.3)
      AYBAR=.5*AWF*CW+AC*(CW+TWC-XBAR)
      AREA= AWF+AC
      Y1 = AYBAR/AREA
      Y2 = CW+TWC-Y1
      IX= IXWF+AWF*(Y1-.5*CW)**2+IYC+AC*(Y2-XBAR)**2
      IY=IYWF+IXC
      B1=BFC-TWC/2.
      B3=BFW/2.
      HC=HGTC
      CC=HC-TFC
      B2=.5*CC-B3
      T1=TFC
      T2=TWC
      T3=TF
      CT=CW+(T2-T3)/2.
      EB=(B1*T1*CC**2*(B1/4.+DT/2.)+T2*CC**3*DT/12.+2./3.*T3*B3**3*(DT-
     1T2/2.-T3/2.))/IY
      ET=CT-EB
      B4=B3+B2
      AN=B3**3*T3*EB**2
      B=B3**3*(T2+T3)*(ET-T3/2.)**2
      C=3.*B3**2*(ET-T3/2.)**2+3.*ET*B2*B3*(ET-T3/2.)+(ET*B2)**2
      D=3.*(ET*B4-B3*T3/2.)**2+B1*B4*(3.*ET*B4-3./2.*B3*T3+B1*B4)
      CW=2./3.*(AN+B+B2*T2*C+B1*T1*D)
      XK=(2.*(BFW*TF**3+B1*T1**3)+(DW-TF)*TW**3+CC*TWC**3)/3.
      A=SCRT(2.6*CW/XK)
      WNA=B3*(T3/2.-ET)-ET*B2
      WNB=EB*B3
      IYCF=IXC+TF*BFW**3/12.
      RT=SCRT(IYCF/(AC+BFW*TF+TW*(Y2-TWC-TF)/3.))
      CCT=PY/PX
      CLB=Y1/IX+BFW*CCT/(2.*IY)
      CLA=-Y2/IX-HC*CCT/(2.*IY)
      CLB=WNB*A/CW
      CLA=WNA*A/CW
       BETA=1./A
       FALL=0.60*FY
       FV=2.*PX/(DW*TW)
       FVALL=0.40*FY
       IF(FV.GT.FVALL)GC TC 3000
       T=PY*(RH+ET)
      L=S
      INCR=12.0
      NN=0
      KK=0
      GC TC 460
 3000 JJ=0
```

```
      LFINAL=C.00
      GC TC 4CC2
 46C  CCNTINUE
      IF(NN-1)422,423,423
 422  CL=CLE
      CL=CLE
      GC TC 421
 423  CL=CLA
      CL=CLA
 922  IF(S-C.586*L)420,42C,520
 42C  MX=PX*((L-S/2.)**2)/(2.*L
      B=L/2.-S/4.
      C1=SINH(BETA*B)/SINH(BETA*L)
      C2=SINH(BETA*(L-B))+SINH(BETA*(L-B-S))
      C=C1*C2
      FACT=ABS(MX*CL+C*CL*T)
      IF(NN.EC.0)GC TC 8CC
      EL=L
      CALL STRESS(EL,RT,FY,FALL)
      IF(KK.EC.1)GC TC 911
      GC TC 80C
 520  MX=PX*L/4.
      FACT=ABS(MX*CL + T*CL/2.*TANH(BETA*L/2.))
      IF(NN.EC.0)GC TC PCC
      EL=L
      CALL STRESS(EL,RT,FY,FALL)
      IF(KK.EC.1)GC TC 911
 8CC  IF(FACT-FALL)43C,2CCC,440
 430  L=L+INCR
      GC TC 46C
 440  L=L-INCR
      IF(INCR-1.0)2000,2CCC,45C
 45C  INCR=INCR/12.
      GC TC 43C
 2000 IF(NN-1)9CC,9C1,901
 9CC  LB=L
      NN=1
      KK=1
      GC TC 46C
 911  IF(FACT-FALL)9C2,9C2,913
 913  L=S
      KK=C
      INCR=12.C
      GC TC 46C
 901  LA=L
      GC TC 9C3
 9C2  LFINAL=LB/12.
      JJ=1
      GC TC 4CC2
 9C3  LFINAL=LA/12.
      JJ=2
 4002 CCNTINUE
 1CC  FCRMAT(2I5,7F10.3)
      WRITE(6,102)
 102  FCRMAT(4X,' SECTICN',8X,'AREA',5X,'Y1',7X,'IX',5X,'IY',5X,'RT',
     14X,'EB')
 300  WRITE(6,103)HGTW,WTW,HGTC,WTC,AREA,Y1,IX,IY,RT,EB
 103  FCRMAT(' W',I2,'X',I3,'-C',I2,'X',F4.1,F8.2,F7.2,F1C.1,F7.1,F6.2,
     1F7.2
      WRITE(6,104)
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      1C4  FCRMAT(1H0,20X,' ***** TCRSICNAL  PRCPERTIES *****')
           WRITE(6,105)
           FCRMAT(4X,' SECTICN',10X,'K',8X,'A',9X,'CW',7X,'WNA',5X,'WNB')
           WRITE(6,106)HGTW,WTW,HGTC,WTC,XK,A,CW,WNA,WNB
      1C6  FCRMAT(' W',I2,'X',I3,'-C',I2,'X',F4.1,F8.3,F8.2,F1C.1,2F9.2)
           WRITE(6,13C)PX,PY,S,RH,FY
      13C  FCRMAT(1H0/2X,' PX=',F5.1,4X,'PY=',F5.2,4X,'WHEELBASE=',F5.1,4X,
          1'RAIL HEIGHT=',F6.3,4X,'FY=',F5.1/1HC)
      SC4  IF(JJ-1)9C9,9C5,9C8
      9C5  WRITE(6,131)HGTW,WTW,HGTC,WTC,LFINAL
      131  FCRMAT(' W',I2,'X',I3,'-C',I2,'X',F4.1,5X,'MAXIMUM SPAN=',F7.2,
          1'  FT.',5X,'TENSICN STRESS CCNTRCLS'/1H1)
           GC TC 907
      9C8  WRITE(6,132)HGTW,WTW,HGTC,WTC,LFINAL
      132  FCRMAT(' W',I2,'X',I3,'-C',I2,'X',F4.1,5X,'MAXIMUM SPAN=',F7.2,
          1'  FT.',5X,'CCMPRESSICN STRESS CCNTRCLS'/1H1)
           GC TC 907
      9C9  WRITE(6,133)HGTW,WTW,HGTC,WTC
      133  FCRMAT(' W',I2,'X',I3,'-C',I2,'X',F4.1,5X,'ALLCWABLE        SPEAR
          1          STRESS        EXCEEDED'/1H1)
      SC7  CCNTINUE
           GC TC 2CC
      1CCC CCNTINUE
           STCP
           END

           SUBRCUTINE STRESS(EL,RT,FY,FALL)
           R=EL/RT
           XL1=SQRT(102000/FY)
           XL2=SQRT(51C0C0/FY)
           IF(R.GE.XL1)GC TC 51C
           FALL=C.6C*FY
           RETURN
      51C  IF(R.GT.XL2)GC TC 52C
           FALL=FY*(2./3.-FY*R**2/153000C)
           RETURN
      52C  FALL=17CC0C/R**2
           RETURN
           END

      $ENTRY
     SECTICN              AREA       YL         IX        IY       RT      EE
 W18X 5C-C12X20.7       2C.79     11.51     1120.8    169.1    3.67    16.39

                    ***** TCRSICNAL  PRCPERTIES *****
     SECTICN               K          A           CW          WNA        WNB
 W18X 5C-C12X20.7      1.5C6      1C3.26      6175.2      -7.30      61.42


   PX= 2C.C     PY= 2.CC     WHEELBASE= 60.C     RAIL HEIGHT= 4.0CC     FY= 36.C


 W18X 5C-C12X2C.7      MAXIMUM SPAN=  15.33  FT.     TENSICN STRESS CCNTRCLS
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