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WEB CRIPPLING STRENGTH OF MULTI-WEB STEEL DECK SECTIONS SUBJECTED TO END ONE FLANGE LOADING

Onur Avci[1] and W. Samuel Easterling[2]

Abstract

Cold-formed steel deck profiles are extensively used in building construction due to their versatility and economical considerations. Web crippling is one of the failure modes for these multi-web profiles. The *1996-AISI Specification for the Design of Cold-Formed Steel Structural Members* provisions for web crippling are believed to be conservative for multi-web deck sections. They are based on unfastened specimens and are limited to the use of decks with certain geometric parameters.

The unified web crippling equation of the *North American Specification for the Design of Cold-Formed Steel Structural Members (AISI 2001)* is also limited to certain geometric parameters. Although it has new web crippling coefficients for different load cases and different end conditions, in the *End One Flange Loading* case, coefficients for the unfastened configuration were used as a conservative solution for the fastened case because there was no directly applicable test data available in the literature.

This paper presents the results of an experimental study on web crippling strength of multiple-web cold-formed steel deck sections subjected to End One Flange (EOF) loading. A total of 78 tests were conducted on deck sections at Virginia Tech. Test specimens lying inside and outside of certain geometric parameters of the specifications were tested with both unrestrained and restrained end conditions. Test specimens lying inside the specification parameters have revealed conservative results in the prediction of web crippling strength using both the AISI(1996) and the draft of the North American Specification (AISI 2001.)

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1. Introduction

Web crippling is one of the failure modes that must be taken into consideration in cold-formed steel design. Cold-formed steel members experience web-crippling failure due to the high local intensity of loads and/or reactions. The web crippling strength of cold-formed steel sections is a function of many variables. Design equations in the specifications have always been empirical formulas developed by curve fitting of experimental data. While AISI(1996) has different design expressions for different type of cross sections and loading cases, the Canadian S136(1994) has one "Unified Design Expression" with different coefficients for different section types and loading. In both of the standards the web crippling calculations are based on unfastened specimens and are limited to the use of decks with certain geometric parameters. The unified design expression of S136(1994) was adopted by AISI in the North American Specification for the Design of Cold Formed Steel Structural Members (September 2001 Draft). In this specification, improved coefficients were developed for the unified web crippling design expression. Also, different coefficients were derived for fastened and unfastened end conditions. Web crippling capacity of a cold-formed steel section depends on many factors. Section type, cross sectional parameters, bearing length and loading conditions are the major factors that affect web crippling strength:

Section Type

There are many cold-formed steel section types being used in building construction. Although web crippling occurs in the webs of the members, the interaction of the web element with the flanges plays an important role in web crippling strength. The rotation of the web under loading depends on the degree of the restraint of the web provided by the flanges as illustrated in Fig.1. Because the web-flange interaction is one of the major factors affecting web crippling strength, different type of cross sections show different behaviors in web crippling failures. I-sections, Hat sections, Z-sections, C-sections and multi-web sections are the most common cross section types being used in cold-formed steel industry.

In this study, tests were performed for multi-web deck sections, as illustrated in Fig. 2. For web crippling calculations, sections are classified in the applicable specifications as either "Shapes Having Single Webs" and "I-Sections or Similar Sections". Additionally, both of the specifications classify some cross sections into stiffened and unstiffened sections.

Cross Sectional Parameters and Bearing Length

There are six major parameters used in web crippling strength calculations: thickness of the web (t), yield strength of the material (F_y), inside bend radius to thickness ratio (R/t), flat portion of the web to thickness ratio (h/t), bearing length to thickness ratio (N/t) and the inclination of the web element (θ). Cross sectional dimensions are illustrated in Fig. 3. Both specifications used herein contain web crippling equations that are functions of the parameters listed.

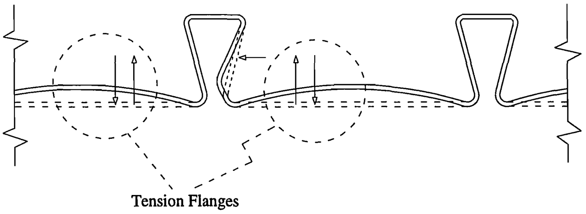

Fig.1 Web-flange Interaction

Fig. 2 Multi-web Deck Cross Section

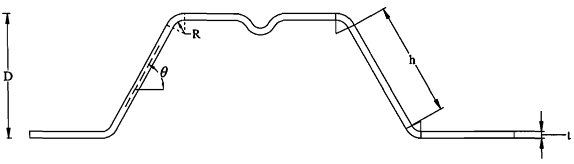

Fig. 3 Cross sectional dimensions

Loading Conditions

There are four different loading cases for web crippling. These cases are defined according to the number of flanges under loading (One Flange Loading or Two Flange Loading) and location of the load (Interior Loading or End Loading):

a) End One Flange Loading
b) Interior One Flange Loading
c) End Two Flange Loading
d) Interior Two Flange Loading

In this particular study all tests were done under End One Flange (EOF) Loading as illustrated in Fig. 4.

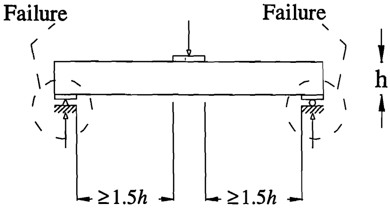

Fig. 4 EOF Loading

Flange Restraint

Beshara and Schuster (2000) improved the coefficients of the unified web crippling equation and derived new coefficients for different support conditions (fastened or unfastened). The restraining effect of the fasteners were not considered in S136 (1994) or in AISI (1996). Although fastening of the specimens to the supports was accepted as a factor affecting the web crippling strength, coefficients reflecting that influence have not appeared until the development of the North American Specification for the Design of Cold Formed Steel Structural Members (AISI 2001.) However, for multi-web deck sections subjected to end one flange loading, coefficients for the unfastened configuration were used as a conservative solution for the fastened case. This was because there were no directly applicable test data available in the literature.

2. Objective and Scope of Research

The web crippling strength of multiple-web cold-formed steel deck sections subjected to end one flange loading is reported. Further, the web crippling equations in AISI (1996) and recently accepted North American Specification (AISI 2001) of multiple-web cold formed steel deck sections subjected to end one flange (EOF) loading are evaluated. A total of 78 deck specimens were tested and the results were compared with different strength prediction approaches mentioned above. Half (39) of the specimens were fastened to the support locations while the remaining 39 were unfastened. In addition, the behavior of cross sections that did not fall into AISI (1996) or North American Specification parameters was investigated. The study resulted in a development and calibration of new web crippling coefficients for the unfastened and fastened multi-web deck sections subjected to end one flange (EOF) loading. Previous experimental studies on multi-web deck cross sections subjected to EOF loading are shown in Table 1.

Table 1 Experimental Studies on EOF Loading of Deck Sections

Support Condition	Name	University	Number of Data Points
Unfastened	Yu, 1981	University of Missouri- Rolla	18
	Bhakta, 1992	University of Missouri- Rolla	2
	Wu, 1997	University of Missouri- Rolla	16
	Avci, 2001	Virginia Tech	39
Fastened	Bhakta, 1992	University of Missouri- Rolla	2
	Avci, 2001	Virginia Tech	39

3. Experimental Study

3.1. Test Specimens

Two group of decks were tested. Group 1 (P1-P5) included five different types of plain (unembossed) decks while Group 2 (C1, C2) included 2 different composite decks with 4 different steel sheet thicknesses for each. Test specimens varied in thickness (t), yield strength (F_y), inside bend radius to thickness ratio (R/t) and web slenderness ratio (h/t). Tests were conducted with both unrestrained and restrained end conditions. Each specimen is given a designation based on the deck type, gage number and the support condition. The test designation is as follows:

"s-m-g-i"

"s" represents the support condition: Restrained by fastening (R) or Unrestrained (U).
"m" indicates the member type: P1, P2, P3, P4, P5, C1 or C2.
"g" designates the gage number of the steel: 16, 18, 20, 22, 26 or 28.
"i" shows order of the test (each test is repeated 3 times).

Tensile coupon tests were performed using an Instron-4468 testing machine with 10 kips (50kN) load capacity. The yield stress for each specimen is reported in Tables 2 and 3.

3.2. Test Setup and Operation

Each deck specimen was prepared in a similar manner and simulated a simple span arrangement. Deck specimens were cut such that they included three ribs (six webs.) The midspan region of the test specimens was strengthened using pieces of the same deck type to prevent a flexural failure. The end one flange loading condition is shown in Fig. 4. In the fastened tests, the ends of the specimens were connected to the supports by self-drilling screws through the tension flanges approximately every 12 in. The test setup used is shown in Fig. 5. A bearing length of 1.5in was used as illustrated in Fig. 6. Specimens were tied with straps to prevent spreading during loading. The deck pieces and tie straps were connected with self-drilling screws. An H-shape was used as a spreader beam to distribute the concentrated load applied by a hydraulic actuator to the entire deck as shown in Fig. 5. A load cell was placed between the actuator and the spreader beam.

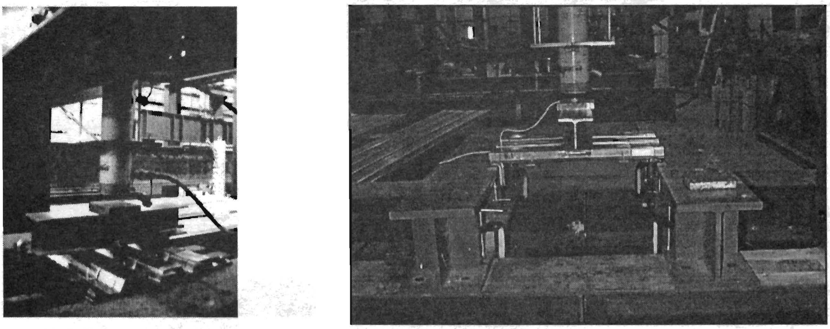

Fig. 5 Test Setup

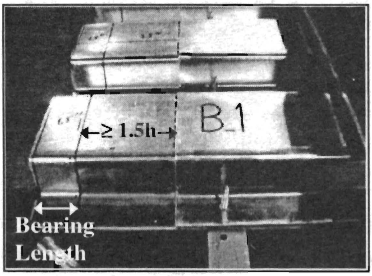

Fig. 6 Bearing Length at Supports

A two-phase loading was used for all tests. In the first phase, the deck specimens were loaded continuously until the allowable design load is reached. The allowable design load was taken as the smaller of the two web crippling strengths calculated by AISI (1996) and North American (AISI 2001) approaches. In the second phase, the load was increased monotonically by adding 20% of the allowable design load to the previous load. The loading was continued after five minute waiting periods until the web crippling failure was observed at exterior end flanges. The maximum recorded load was divided by the number of webs at each support, which was six for all specimens in this study, to find the web crippling strength per web. Example web-crippling failures are shown in Fig. 7.

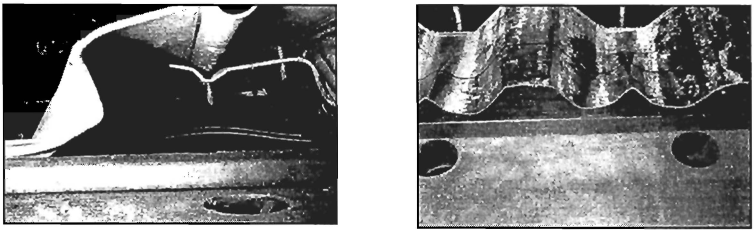

Fig. 7 Web Crippling Failures under EOF Loading

3.3. Test Results

The additional short steel deck pieces attached to the central portion of the specimens made the web crippling failure occur at both ends. Otherwise bending failures in the center of the span would have occurred. The progression of crippling on the webs of the specimens initiated on an interior web and followed by the outer webs as the load increased. The crippling of the webs caused deformation on the tension flanges of the specimens and moved the tension flanges upwards. Yu (1981) also observed this type of behavior. The redistribution of the forces enabled the deck specimens to carry load after the web crippling failure of the interior webs until all webs experience the failure. The amount of resistance provided by the outer webs to the inner webs is believed to be higher for the fastened specimens than for the unfastened ones. The results of the 78 tests are shown in Tables 5 and 6. The test results reveal that there is an increase in web crippling strength when the ends of the specimens are fastened to the supports. There were no failures of the screws connecting the deck to the supports.

4. Analytical Study

Five different types of plain (unembossed) decks and 8 different types of composite decks were analyzed using the AISI (1996) and North American (AISI 2001) procedures. Web crippling equations for these methods are not applicable to the decks whose inside bend radius to thickness ratios (R/t) greater than 7.0. Also, the equations were the same for unfastened and fastened specimens. Moreover, the effect of embossments on the webs of composite decks are not taken into consideration in either method. The test results for the specimens whose inside bend radius to thickness ratios exceed 7.0 are also reported herein to permit comparison to predicted values. (AISI 1996;

2001) The Following equation is used in AISI (1996) to calculate web crippling strength of multi-web deck sections subjected to end one flange loading:

$$P_n = t^2 k C_1 C_4 C_9 C_\theta [331 - 0.61(h/t)][1 + 0.01(N/t)] \qquad \text{Eq. 1}$$

where,
P_n = Nominal strength for concentrated load or reaction per web
t = Web thickness, in.
k = $894F_y/E$
F_y = Design yield stress of the web
$C_1 = 1.22-0.22k$
$C_4 = 1.15-0.15R/t \leq 1.0$ but no less than 0.50
$C_9 = 1.0$ for U.S. customary units
$C_\theta = 0.7+0.3(\theta/90)^2$
h = Depth of flat portion of the web measured along the plane of the web, in.
N = Actual length of bearing, in.
R = Inside bend radius
θ = Angle between the plane of the web and the plane of the bearing surface ≥ 45°, but <90°

The equation can be applied to decks when $R/t \leq 7$, $N/t \leq 210$ and $N/h \leq 3.5$. P_n represents the nominal strength for one solid web connecting top and bottom flanges. For two or more webs, P_n shall be computed for each individual web and the results added to obtain the nominal load or reaction for the multiple web. (AISI 1996.) The results of the analyses are summarized in Tables 2 and 3 and Figs 8 and 9.

Equation 2 is used to calculate the web crippling strength by the unified expression in North American Specification which and the Canadian standard (AISI 2001; S136 1994).

$$P_n = Ct^2 F_y Sin\theta \left(1 - C_R\sqrt{\frac{R}{t}}\right)\left(1 + C_N\sqrt{\frac{N}{t}}\right)\left(1 - C_h\sqrt{\frac{h}{t}}\right) \qquad \text{Eq. 2}$$

where C, C_R, C_N and C_h are coefficients varying with cross section type and loading condition. For both unfastened and fastened configurations, C=3.00, C_R=0.08, C_N=0.70 and C_h=0.055 when multi-web specimens are under EOF loading. The equation can be applied to decks when $R/t \leq 7$, $h/t \leq 200$, $N/t \leq 210$ and $N/h \leq 3.0$. P_n represents the nominal strength for one solid web connecting top and bottom flanges. For two or more webs, P_n is computed for each web and the results are added in order to find the web crippling load for the multiple web.

In Tables 2 and 3, the test results are compared to predicted values using the ratio P_t/P_n for unfastened and fastened cases. All 78 test specimens resulted in P_t/P_n values greater than unity for calculations based on AISI (1996). The North American Specification method resulted in P_t/P_n values greater than unity for all specimens that satisfied the specified R/t ratios. The AISI (1996) values are more conservative than North American Specification values (AISI 2001) for most of the specimens.

Comparisons show that the fastened cases, when compared to the unfastened cases, are more conservative.

5. Summary and Conclusions

An experimental study on web crippling capacity of cold formed steel deck sections subjected to end one flange (EOF) loading has been presented. Test results were compared with AISI (1996) and North American (2001) strength prediction methods. The study also focused on the effect of fastening through the supports of the members because the field practice can be represented better with the fastened test specimens than the unfastened ones.

Fastened specimens resulted in higher web crippling strengths than unfastened specimens. Calculation procedures (AISI 1996; 2001) were found to be conservative for the web crippling strength of deck sections under EOF loading when compared with the test results. AISI (1996) values are more conservative than North American Specification values (2001) for most of the specimens.

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Appendix - Notation

C	Coefficent depending on the section type
C_h	Web slenderness coefficient
C_N	Bearing length coefficient
C_R	Inside bend radius coefficient
E	Young's Modulus of steel
EOF	End One Flange Loading
ETF	End Two Flange Loading
F_y	Yield strength of steel
h	Flat dimension of web measured in plane of web
IOF	Interior One Flange Loading
ITF	Interior Two Flange Loading
N	Bearing length
P_n	Computed web crippling strength
P_t	Web crippling strength measured in the test
R	Inside bend radius
t	Thickness of the web
θ	Angle between the plane of the web and plane of bearing surface

Table 2 Multi-web Deck Sections, EOF Loading, Unfastened Tests

												AISI (1996)			North American (2001)		
Specimen	No	t		F_y		θ	R/t	N/t	h/t	P_t		P_n		P_t/P_n	P_n		P_t/P_n
		(in)	(mm)	(ksi)	(MPa)	(deg)				(kips)	(kN)	(kips)	(kN)		(kips)	(kN)	
U-P1-22-1	1	0.0295	0.749	45.8	316.0	70.0	6.9	50.8	42.7	0.34	1.53	0.22	1.00	1.53	0.34	1.52	1.01
U-P1-22-2	2	0.0295	0.749	45.8	316.0	70.0	6.9	50.8	42.7	0.34	1.52	0.22	1.00	1.52	0.34	1.52	1.00
U-P1-22-3	3	0.0295	0.749	45.8	316.0	70.0	6.9	50.8	42.7	0.35	1.54	0.22	1.00	1.54	0.34	1.52	1.01
U-P2-26-1	4	0.0182	0.462	95.4^{*}	657.4	58.0	14.6	82.4	42.8	0.18	0.81	0.11	0.50	1.60	0.17	0.74	1.09
U-P2-26-2	5	0.0182	0.462	95.4^{*}	657.4	58.0	14.6	82.4	42.8	0.19	0.84	0.11	0.50	1.66	0.17	0.74	1.14
U-P2-26-3	6	0.0182	0.462	95.4^{*}	657.4	58.0	14.6	82.4	42.8	0.18	0.81	0.11	0.50	1.62	0.17	0.74	1.11
U-P3-26-1	7	0.0183	0.465	103.9^{*}	716.5	50.0	17.1	82.0	75.9	0.16	0.72	0.10	0.46	1.57	0.12	0.53	1.36
U-P3-26-2	8	0.0183	0.465	103.9^{*}	716.5	50.0	17.1	82.0	75.9	0.16	0.70	0.10	0.46	1.54	0.12	0.53	1.34
U-P3-26-3	9	0.0183	0.465	103.9^{*}	716.5	50.0	17.1	82.0	75.9	0.17	0.75	0.10	0.46	1.64	0.12	0.53	1.42
U-P4-22-1	10	0.0300	0.762	48.0	330.9	75.5	6.8	50.0	56.6	0.39	1.72	0.24	1.06	1.62	0.35	1.54	1.11
U-P4-22-2	11	0.0300	0.762	48.0	330.9	75.5	6.8	50.0	56.6	0.39	1.74	0.24	1.06	1.64	0.35	1.54	1.13
U-P4-22-3	12	0.0300	0.762	48.0	330.9	75.5	6.8	50.0	56.6	0.39	1.75	0.24	1.06	1.65	0.35	1.54	1.13
U-P5-28-1	13	0.0153	0.389	105.2^{*}	725.6	58.0	11.2	98.0	29.2	0.20	0.90	0.09	0.40	2.27	0.15	0.65	1.39
U-P5-28-2	14	0.0153	0.389	105.2^{*}	725.6	58.0	11.2	98.0	29.2	0.20	0.90	0.09	0.40	2.27	0.15	0.65	1.39
U-P5-28-3	15	0.0153	0.389	105.2^{*}	725.6	58.0	11.2	98.0	29.2	0.20	0.89	0.09	0.40	2.24	0.15	0.65	1.37
U-C1-16-1	16	0.0598	1.519	46.5	320.6	63.0	3.1	25.1	31.8	1.37	6.11	1.03	4.59	1.33	1.19	5.28	1.16
U-C1-16-2	17	0.0598	1.519	46.5	320.6	63.0	3.1	25.1	31.8	1.32	5.88	1.03	4.59	1.28	1.19	5.28	1.11
U-C1-16-3	18	0.0598	1.519	46.5	320.6	63.0	3.1	25.1	31.8	1.39	6.18	1.03	4.59	1.35	1.19	5.28	1.17
U-C1-18-1	19	0.0474	1.204	49.5	341.3	63.0	4.0	31.6	40.6	1.00	4.45	0.57	2.54	1.75	0.80	3.57	1.25
U-C1-18-2	20	0.0474	1.204	49.5	341.3	63.0	4.0	31.6	40.6	0.96	4.25	0.57	2.54	1.67	0.80	3.57	1.19
U-C1-18-3	21	0.0474	1.204	49.5	341.3	63.0	4.0	31.6	40.6	1.01	4.50	0.57	2.54	1.77	0.80	3.57	1.26
U-C1-20-1	22	0.0358	0.909	52.0	358.5	63.0	5.2	41.9	54.3	0.63	2.80	0.32	1.41	1.99	0.48	2.13	1.31
U-C1-20-2	23	0.0358	0.909	52.0	358.5	63.0	5.2	41.9	54.3	0.61	2.72	0.32	1.41	1.93	0.48	2.13	1.28
U-C1-20-3	24	0.0358	0.909	52.0	358.5	63.0	5.2	41.9	54.3	0.58	2.60	0.32	1.41	1.85	0.48	2.13	1.22
U-C1-22-1	25	0.0295	0.749	54.0	372.3	63.0	6.4	50.8	66.2	0.42	1.85	0.23	1.01	1.83	0.33	1.48	1.26
U-C1-22-2	26	0.0295	0.749	54.0	372.3	63.0	6.4	50.8	66.2	0.46	2.03	0.23	1.01	2.00	0.33	1.48	1.37
U-C1-22-3	27	0.0295	0.749	54.0	372.3	63.0	6.4	50.8	66.2	0.44	1.98	0.23	1.01	1.95	0.33	1.48	1.34
U-C2-16-1	28	0.0598	1.519	35.0	241.3	67.0	3.1	25.1	48.4	1.10	4.89	0.83	3.70	1.32	0.83	3.67	1.33
U-C2-16-2	29	0.0598	1.519	35.0	241.3	67.0	3.1	25.1	48.4	1.12	4.99	0.83	3.70	1.35	0.83	3.67	1.36
U-C2-16-3	30	0.0598	1.519	35.0	241.3	67.0	3.1	25.1	48.4	1.03	4.56	0.83	3.70	1.23	0.83	3.67	1.24
U-C2-18-1	31	0.0474	1.204	48.0	330.9	67.0	4.0	31.6	61.5	0.98	4.37	0.55	2.44	1.79	0.70	3.13	1.40
U-C2-18-2	32	0.0474	1.204	48.0	330.9	67.0	4.0	31.6	61.5	0.96	4.25	0.55	2.44	1.74	0.70	3.13	1.36
U-C2-18-3	33	0.0474	1.204	48.0	330.9	67.0	4.0	31.6	61.5	0.97	4.30	0.55	2.44	1.76	0.70	3.13	1.37
U-C2-20-1	34	0.0358	0.909	53.5	368.9	67.0	5.2	41.9	82.1	0.65	2.89	0.31	1.38	2.09	0.43	1.91	1.51
U-C2-20-2	35	0.0358	0.909	53.5	368.9	67.0	5.2	41.9	82.1	0.63	2.80	0.31	1.38	2.03	0.43	1.91	1.47
U-C2-20-3	36	0.0358	0.909	53.5	368.9	67.0	5.2	41.9	82.1	0.63	2.82	0.31	1.38	2.04	0.43	1.91	1.48
U-C2-22-1	37	0.0295	0.749	52.5	362.0	67.0	6.4	50.8	100.0	0.39	1.73	0.21	0.95	1.83	0.27	1.21	1.44
U-C2-22-2	38	0.0295	0.749	52.5	362.0	67.0	6.4	50.8	100.0	0.36	1.62	0.21	0.95	1.71	0.27	1.21	1.34
U-C2-22-3	39	0.0295	0.749	52.5	362.0	67.0	6.4	50.8	100.0	0.38	1.68	0.21	0.95	1.77	0.27	1.21	1.39

Table 3 Multi-web Deck Sections, EOF Loading, Fastened Tests

												AISI (1996)			North American (2001)		
Specimen	No	t		F_y		θ	R/t	N/t	h/t	P_t		P_n		P_t/P_n	P_n		P_t/P_n
		(in)	(mm)	(ksi)	(MPa)	(deg)				(kips)	(kN)	(kips)	(kN)		(kips)	(kN)	
R-P1-22-1	1	0.0295	0.749	45.8	316.0	70.0	6.9	50.8	42.7	0.37	1.66	0.22	1.00	1.66	0.34	1.52	1.09
R-P1-22-2	2	0.0295	0.749	45.8	316.0	70.0	6.9	50.8	42.7	0.38	1.69	0.22	1.00	1.70	0.34	1.52	1.11
R-P1-22-3	3	0.0295	0.749	45.8	316.0	70.0	6.9	50.8	42.7	0.37	1.65	0.22	1.00	1.66	0.34	1.52	1.09
R-P2-26-1	4	0.0182	0.462	95.4*	657.4	58.0	14.6	82.4	42.8	0.20	0.90	0.11	0.50	1.79	0.17	0.74	1.23
R-P2-26-2	5	0.0182	0.462	95.4*	657.4	58.0	14.6	82.4	42.8	0.21	0.93	0.11	0.50	1.84	0.17	0.74	1.26
R-P2-26-3	6	0.0182	0.462	95.4*	657.4	58.0	14.6	82.4	42.8	0.20	0.90	0.11	0.50	1.78	0.17	0.74	1.22
R-P3-26-1	7	0.0183	0.465	103.9*	716.5	50.0	17.1	82.0	75.9	0.18	0.79	0.10	0.46	1.74	0.12	0.53	1.51
R-P3-26-2	8	0.0183	0.465	103.9*	716.5	50.0	17.1	82.0	75.9	0.18	0.81	0.10	0.46	1.79	0.12	0.53	1.55
R-P3-26-3	9	0.0183	0.465	103.9*	716.5	50.0	17.1	82.0	75.9	0.17	0.77	0.10	0.46	1.69	0.12	0.53	1.46
R-P4-22-1	10	0.0300	0.762	48.0	330.9	75.5	6.8	50.0	56.6	0.43	1.89	0.24	1.06	1.78	0.35	1.54	1.23
R-P4-22-2	11	0.0300	0.762	48.0	330.9	75.5	6.8	50.0	56.6	0.42	1.88	0.24	1.06	1.77	0.35	1.54	1.22
R-P4-22-3	12	0.0300	0.762	48.0	330.9	75.5	6.8	50.0	56.6	0.43	1.92	0.24	1.06	1.81	0.35	1.54	1.24
R-P5-28-1	13	0.0153	0.389	105.2*	725.6	58.0	11.2	98.0	29.2	0.22	0.98	0.09	0.40	2.46	0.15	0.65	1.51
R-P5-28-2	14	0.0153	0.389	105.2*	725.6	58.0	11.2	98.0	29.2	0.22	0.99	0.09	0.40	2.50	0.15	0.65	1.53
R-P5-28-3	15	0.0153	0.389	105.2*	725.6	58.0	11.2	98.0	29.2	0.23	1.02	0.09	0.40	2.57	0.15	0.65	1.57
R-C1-16-1	16	0.0598	1.519	46.5	320.6	63.0	3.1	25.1	31.8	1.59	7.07	1.03	4.59	1.54	1.19	5.28	1.34
R-C1-16-2	17	0.0598	1.519	46.5	320.6	63.0	3.1	25.1	31.8	1.62	7.22	1.03	4.59	1.57	1.19	5.28	1.37
R-C1-16-3	18	0.0598	1.519	46.5	320.6	63.0	3.1	25.1	31.8	1.58	7.03	1.03	4.59	1.53	1.19	5.28	1.33
R-C1-18-1	19	0.0474	1.204	49.5	341.3	63.0	4.0	31.6	40.6	1.18	5.24	0.57	2.54	2.06	0.80	3.57	1.47
R-C1-18-2	20	0.0474	1.204	49.5	341.3	63.0	4.0	31.6	40.6	1.23	5.49	0.57	2.54	2.16	0.80	3.57	1.54
R-C1-18-3	21	0.0474	1.204	49.5	341.3	63.0	4.0	31.6	40.6	1.24	5.54	0.57	2.54	2.18	0.80	3.57	1.55
R-C1-20-1	22	0.0358	0.909	52.0	358.5	63.0	5.2	41.9	54.3	0.78	3.46	0.32	1.41	2.46	0.48	2.13	1.62
R-C1-20-2	23	0.0358	0.909	52.0	358.5	63.0	5.2	41.9	54.3	0.74	3.31	0.32	1.41	2.35	0.48	2.13	1.56
R-C1-20-3	24	0.0358	0.909	52.0	358.5	63.0	5.2	41.9	54.3	0.75	3.35	0.32	1.41	2.38	0.48	2.13	1.57
R-C1-22-1	25	0.0295	0.749	54.0	372.3	63.0	6.4	50.8	66.2	0.59	2.60	0.23	1.01	2.57	0.33	1.48	1.76
R-C1-22-2	26	0.0295	0.749	54.0	372.3	63.0	6.4	50.8	66.2	0.57	2.55	0.23	1.01	2.52	0.33	1.48	1.73
R-C1-22-3	27	0.0295	0.749	54.0	372.3	63.0	6.4	50.8	66.2	0.56	2.51	0.23	1.01	2.48	0.33	1.48	1.70
R-C2-16-1	28	0.0598	1.519	35.0	241.3	67.0	3.1	25.1	48.4	1.46	6.48	0.83	3.70	1.75	0.83	3.67	1.77
R-C2-16-2	29	0.0598	1.519	35.0	241.3	67.0	3.1	25.1	48.4	1.47	6.52	0.83	3.70	1.76	0.83	3.67	1.78
R-C2-16-3	30	0.0598	1.519	35.0	241.3	67.0	3.1	25.1	48.4	1.49	6.61	0.83	3.70	1.78	0.83	3.67	1.80
R-C2-18-1	31	0.0474	1.204	48.0	330.9	67.0	4.0	31.6	61.5	1.31	5.83	0.55	2.44	2.39	0.70	3.13	1.86
R-C2-18-2	32	0.0474	1.204	48.0	330.9	67.0	4.0	31.6	61.5	1.34	5.94	0.55	2.44	2.43	0.70	3.13	1.90
R-C2-18-3	33	0.0474	1.204	48.0	330.9	67.0	4.0	31.6	61.5	1.33	5.93	0.55	2.44	2.43	0.70	3.13	1.90
R-C2-20-1	34	0.0358	0.909	53.5	368.9	67.0	5.2	41.9	82.1	0.88	3.90	0.31	1.38	2.83	0.43	1.91	2.04
R-C2-20-2	35	0.0358	0.909	53.5	368.9	67.0	5.2	41.9	82.1	0.85	3.80	0.31	1.38	2.75	0.43	1.91	1.99
R-C2-20-3	36	0.0358	0.909	53.5	368.9	67.0	5.2	41.9	82.1	0.86	3.83	0.31	1.38	2.77	0.43	1.91	2.00
R-C2-22-1	37	0.0295	0.749	52.5	362.0	67.0	6.4	50.8	100.0	0.49	2.18	0.21	0.95	2.30	0.27	1.21	1.80
R-C2-22-2	38	0.0295	0.749	52.5	362.0	67.0	6.4	50.8	100.0	0.48	2.15	0.21	0.95	2.27	0.27	1.21	1.78
R-C2-22-3	39	0.0295	0.749	52.5	362.0	67.0	6.4	50.8	100.0	0.47	2.08	0.21	0.95	2.20	0.27	1.21	1.72

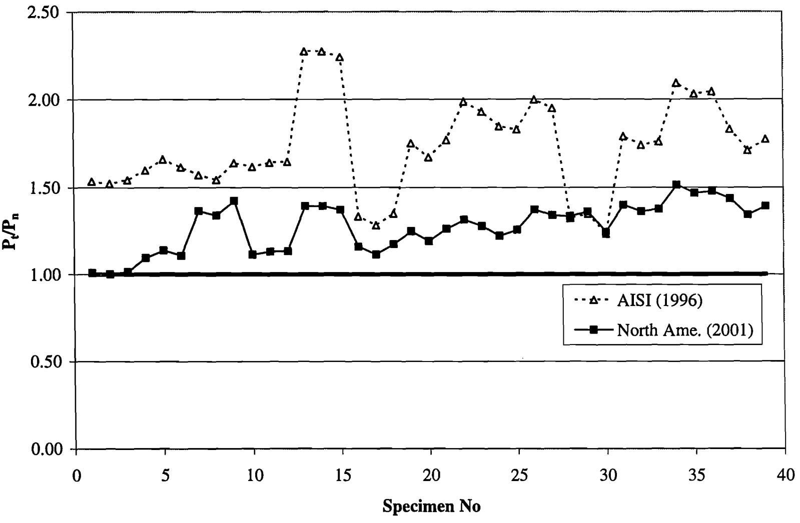

Figure 8 P_t/P_n for Multi-web Deck Sections, EOF Loading, Unfastened Tests

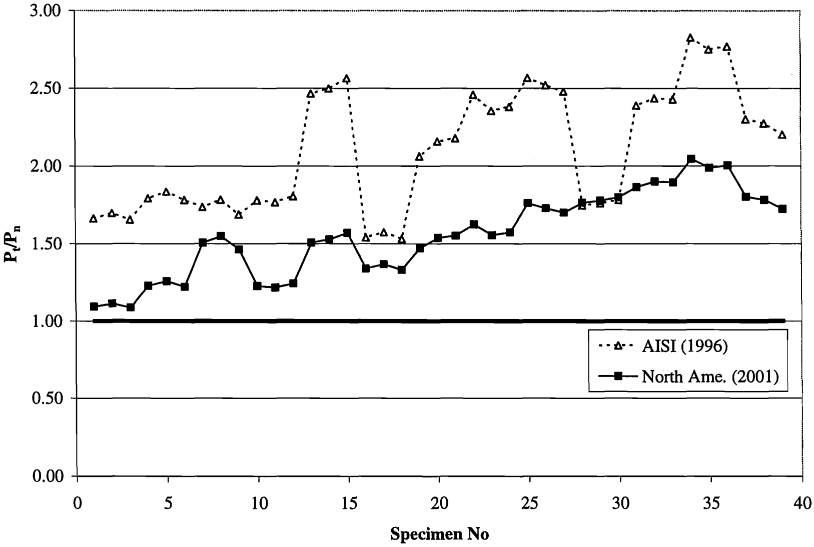

Figure 9 P_t/P_n for Multi-web Deck Sections, EOF Loading, Unfastened Tests