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Parametric studies and design recommendations of perforated cold-formed ferritic stainless steel unlipped channels subject to web crippling under interior-one-flange and end-one-flange loadings

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ABSTRACT

A finite element and parametric study evaluations into the web crippling strength of perforated cold-formed ferritic stainless steel unlipped channels with circular web perforations under interior-one-flange (IOF) and end-one-flange (EOF) loadings are presented in this paper. The cases of web perforations located offset to the load and reaction bearing plates, are considered. In order to take into account the effect of the circular web perforations, a parametric study involving 288 finite element analyses was performed; from the results of the parametric study, strength reduction factor equations are determined. The strength reduction factor equations are first compared to equations recently proposed for lipped cold-formed stainless steel channels. It is demonstrated that the strength reduction factor equations proposed for lipped cold-formed stainless steel are unreliable and unconservative for the unlipped stainless steel channels as much as 10%. New strength reduction factor equations are then proposed that can be applied to unlipped ferritic stainless steel grade.

1. INTRODUCTION

Cold-formed ferritic stainless steel channels are most often used for both architectural and structural applications in conditions characterised by high corrosion aggressiveness; not only because they are aesthetically pleasing, but they also have favourable characteristics in terms of strength, durability and formability (Zhao *et al.* 2016). To provide ease of access for services, the use of web perforations for such sections are also becoming popular in industry (Lawson *et al.* 2015). Such web

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perforations, however, result in the sections being more susceptible to web crippling, especially under concentrated loads in the vicinity of the perforations.

The authors have previously proposed unified strength reduction factor equations for the web crippling strength of cold-formed stainless steel lipped channel-sections with circular web perforations under the one- and two-flange loading conditions (Yousefi *et al.* 2016, 2017a,b,c). The equations covered three stainless steel grades: duplex grade EN 1.4462; austenitic grade EN 1.4404 and ferritic grade EN 1.4003. Similar equations for cold-formed carbon steel under end-one-flange loading condition have previously been proposed by Lian *et al.* (2016, 2017), which was a continuation of the work of Uzzaman *et al.* (2012, 2013) who had considered the two-flange loading conditions. When applied to the stainless steel grades, (Yousefi *et al.* 2017d-j) showed that the equations proposed by Lian *et al.* (2016) for the end-one-flange (EOF) loading condition were unconservative by up to 7%. Also, Yousefi *et al.* (2018a-e) showed that the equations proposed by Uzzaman *et al.* (2012, 2013) for the interior-two-flange (ITF) and end-two-flange loading conditions were unconservative for stainless steel channel-sections. Yousefi *et al. (2019a,b,c)* also conducted a series of test programme on unlipped cold-formed ferritic stainless steel channels under one-flange loadings and proposed strength reduction factors due to openins in web.

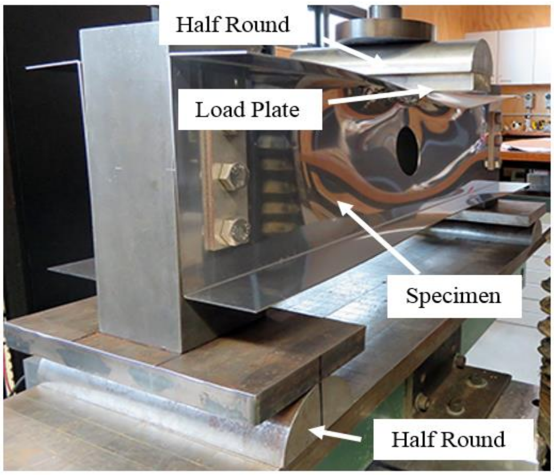
In the literature, for cold-formed stainless steel lipped channel-sections, only Krovink and van den Berg (1994) and Krovink *et al.* (1995) have considered web crippling strength, but limited to sections without perforations. Zhou and Young (2006, 2007, 2008, 2013) have considered the web crippling strength of cold-formed stainless steel tubular sections, again without perforations. Research by Lawson *et al.* (2015), while concerned with circular web perforations, focussed on the bending strength of the sections and not on the web crippling strength under concentrated loads. In terms of cold-formed carbon steel, Keerthan and Mahendran (2012) considered the web crippling strength of hollow flange channel beams. Gunalan and Mahendran (2015) have also considered a Direct Strength Method approach for the web crippling strength of channel sections, again without perforations. For cold-formed carbon steel lipped channel-sections, recent work has included Natario *et al.* (2014) and Gunalan and Mahendran (2015), all without perforations.

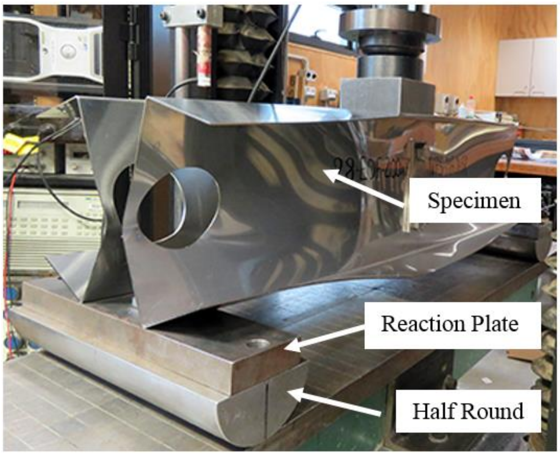
This paper considers the web crippling strength of unlipped cold-formed ferritic stainless steel channels with web perforations subject to one-flange loadings, known as interior-one-flange (IOF) and end-one-flange (EOF) loadings, as shown in Fig. 1. Design guidance against web crippling for such cold-formed stainless steel channels are found in SEI/ASCE 8-02, AS/NZS 4673 and EN 1993-1-4 (referring to EN 1993-1-3 for carbon steel). However, no cold-formed stainless steel standard provides strength reduction factor equations for channels having perforations in web. While AISI S136-16 does provide two equations, these equations were developed for cold-formed carbon steel channels.In this paper, the web crippling strength of unlipped cold-formed ferritic grade G430 stainless steel channels having perforations in web subject to interior-one-flange (IOF) and end-one-flange (EOF) loadings is considered, as shown in Fig. 1 and 3. A total of 288 results are presented, comprising 18 laboratory and 270 numerical results. The finite element analysis (FEA) models developed use quasi-static analyses with an implicit integration scheme in ABAQUS (2014). The quasi-static FE model is then used to conduct a parametric investigation to determine the web crippling strength of perforated unlipped channels having different section sizes, load and reaction plates lengths and thicknesses, as well as to examine the suitability of existing design equations recommended by Yousefi et al. (2018a,b). Finally, using laboratory and finite element results, new web crippling strength reduction factor equations are then proposed which are shown to be reliable when compared against laboratory and numerical results.

2. EXPERIMENTAL AND NUMERICAL INVESTIGATION

For cold-formed ferritic stainless steel, in previous study Yousefi *et al.* (2019d) conducted 18 one-flange laboratory tests on unlipped channel-sections with circular web perforations subjected to web crippling (see Fig. 1). Fig. 2 shows the definition of the symbols used to describe the dimensions of the cold-formed ferritic stainless steel unlipped channel-sections considered in the test programme. The size of the circular web perforations was varied in order to investigate the effect of the web perforations on the web crippling strength. All the test specimens were fabricated with web perforations located at the mid-depth of the webs with centred to the bearing plates.
The laboratory test results were used to validate a non-linear geometry elasto-plastic finite element model (details of the model can be found in Yousefi *et al.* (2019d)), which was then can be used for a parametric study to investigate the web crippling strength of cold-formed stainless steel unlipped channel-sections with circular web perforations under the interior-one-flange (IOF) and end-one-flange (EOF) loading conditions. In this research, recommendations are proposed in the form of strength reduction factor equations, relating the loss of strength due to the web perforations to the strength of the web without perforations. The size of the circular web perforations are varied in order to investigate the effect of the web perforation size on the web crippling strength. Full details of both the laboratory tests can be found in companion paper by Yousefi *et al.* (2019d).

In this study, the non-linear elasto-plastic general purpose finite element program ABAQUS (2014) was used to simulate the cold-formed ferritic stainless steel unlipped channels with circular web perforations subjected to web crippling. The bearing plates, the lipped channel-section with circular web perforations and the interfaces between the bearing plates and the unlipped-channel section were modelled. In the finite element model, the model was based on the centreline dimensions of the cross-sections. For the finite element model verification, the results of experimental study conducted in the companion study for the cases of web holes located centred to the bearing plates under IOF and EOF loading conditions conducted by Yousefi *et al.* (2019d) (see Fig. 1) were compared to the results obtained from the finite element analyses (Fig. 3).





(a) IOF loading **(b)** EOF loading

Fig. 1 Experimental analysis of cold-formed stainless steel channel sections under IOF and EOF loading conditions

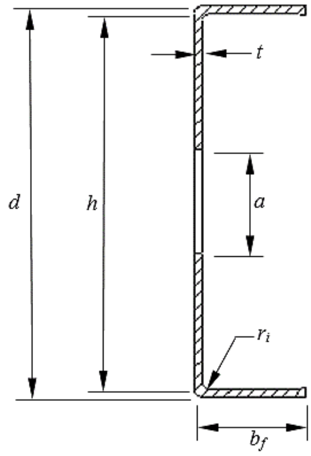
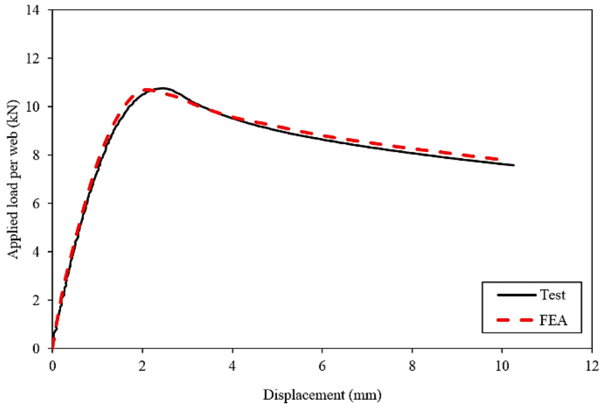
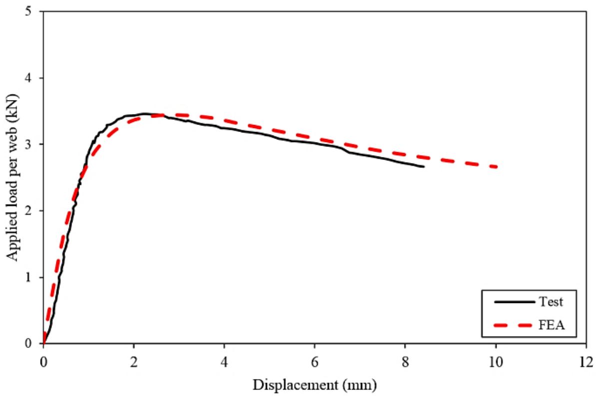


Fig. 2 Definition of symbols





a) IOF loading condition **b)** EOF loading condition

Fig. 3 Comparison of finite element results and experimental results by Yousefi et al. (2019d) for sections with centred circular web perforation

3. PARAMETRIC STUDY

The FE model was used so to complete an extensive study to determine the web crippling strength of channels with perforations in web subjected to the IOF and EOF load case. The parameters comprise of different lengths of load and reaction plates. The unlipped channels cross-section sizes and the web perforations diameters were varied so to investigate the effect of load and reaction plates lengths ratio *(B/h),* web perforations diameter ratio *(a/h)* and web perforations location ratio (*x/h)* on the web crippling strength of unlipped channels with web perforations under the IOF and EOF load cases. The unlipped channels had different depth sizes, with thicknesses (*t*) between 1.45 mm to 6.0 mm. The height-to thickness ratios (*h/t*) were between 148.9 to 232.6. The *a/h* ratios were 0.2, 0.4, 0.6 and 0.8. The length of load and reaction plates (*B*) were 50 mm, 75 mm and 100 mm. The load and reaction plates, applying the concentrated forces, were thus considered to cover the full flange widths of the unlipped channels.

The web bearing capacities of the unlipped channels with no perforations in web were also obtained from the literature [37] for each series of models. Hence, the strength reduction factor (*R*), which is the ratio of the web crippling capacities for unlipped channels with perforations in web over the web crippling capacities of channels with no perforations in web, was used as a degrading ratio to quantify the effect of perforations on the web crippling capacities of unlipped channels. The models have been coded so that the nominal model dimension, the length of the load or reaction plates and web perforations ratio (*A*) can be identified in Tables 1 and 2.

In terms of channels having perforations in web under IOF loading, 135 sections were considered to determine the effect of web perforations diameter ratio *(a/h)* as well as load and reaction plates lengths ratio *(B/h)*. Table 1 presents the web crippling capacities (P_{FEA}) per single web predicted from the FE analyses as well as cross-section dimensions. Fig. 4 demonstrates the effects of the web perforations diameter ratio (*a/h*) and load and reaction plates lengths ratio (*B/h)* on the web strength reduction factors of the C175 section. As can be seen from Fig. 4(a), the reduction factor decreases as the web perforations diameter ratio *(a/h)* increases from the ratio of 0.2 to the ratio of 0.8. Also, it is clear from Fig. 4(b) that the reduction factor is not sensitive to the load and reaction plates length ratio *(N/h).*

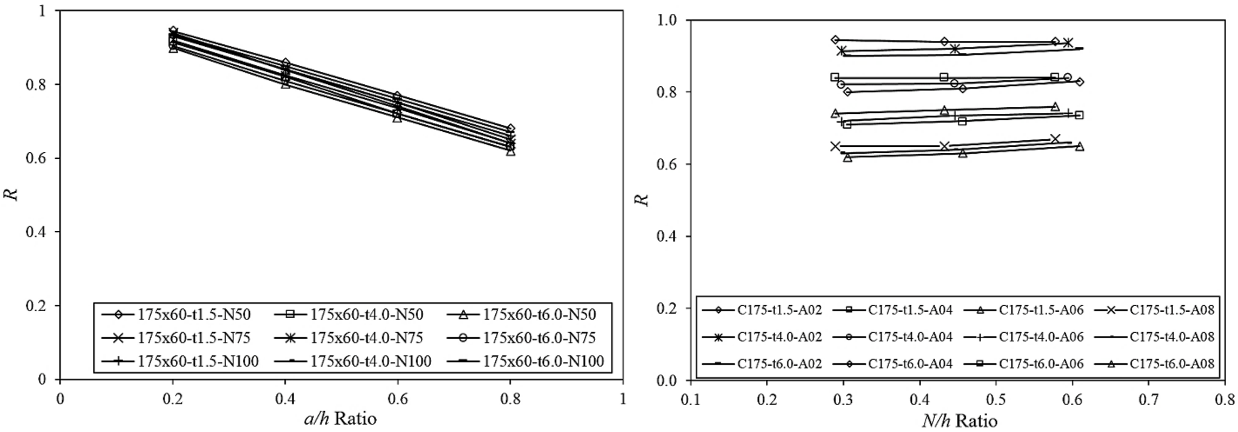
In terms of channels having perforations in web under EOF loading, 135 sections were modelled and analysed to determine the effects of web perforations diameter ratio *(a/h)* and as well as load and reaction plates lengths ratio *(B/h)*. The web crippling capacities (P_{FEA}) per single web predicted from the FE analyses as well as cross-section dimensions are presented in Table 2. Fig. 5 demonstrates the effects of the web perforations diameter ratio (*a/h)* and reaction plates lengths ratio (*B/h)* on the web crippling reduction factors of the C175 section. It can be deduced, from Fig. 5(a), that the strength reduction factor decreases as the web perforations diameter ratio *(a/h)* increases from the ratio of 0.2 to the ratio of 0.8. Also, it is evident from Fig. 5(b) that the reduction factor is more sensitive to the diameter of the perforation in the web than the reaction plates lengths ratio (*B/h).*

Table 1 Section details and web crippling strengths obtained from FEA for parametric study of *a/h* for channels with web perforation under IOF load case

Section	Web depth	Flange width	Web thickness	Length of channel	FEA ultimate load per single web, (P_{FEA})				
	d	b_f	t	L	(a/h=0)	(a/h=0.2)	(a/h=0.4)	(a/h=0.6)	(a/h=0.8)
	(mm)	(mm)	(mm)	(mm)	(kN)	(kN)	(kN)	(kN)	(kN)
175x60-t1.5-B50	176.09	59.74	1.50	775.00	10.16	9.85	8.21	7.93	7.51
175x60-t4.0-B50	176.09	59.74	4.00	775.00	66.18	60.52	54.37	49.82	42.86
175x60-t6.0-B50	176.09	59.74	6.00	775.00	134.80	121.12	99.64	88.17	79.32
175x60-t1.5-B75	176.30	59.69	1.50	800.00	11.32	10.91	9.54	8.87	8.03
175x60-t4.0-B75	176.30	59.69	4.00	800.00	75.19	69.72	61.92	55.27	49.69
175x60-t6.0-B75	176.30	59.69	6.00	800.00	146.21	132.18	121.16	107.29	95.02
175x60-t1.5-B100	176.15	59.81	1.50	824.92	12.20	11.37	10.26	9.42	8.37
175x60-t4.0-B100	176.15	59.81	4.00	824.92	80.34	75.26	68.73	59.14	54.50
175x60-t6.0-B100	176.15	59.81	6.00	824.92	152.29	142.51	129.36	117.91	107.38
200x75-t1.5-B50	200.76	74.85	1.49	850.00	9.96	9.21	8.36	7.93	7.30
200x75-t4.0-B50	200.76	74.85	4.00	850.00	69.99	61.98	52.39	48.82	45.60
200x75-t6.0-B50	200.76	74.85	6.00	850.00	147.77	129.65	115.28	99.67	84.69
200x75-t1.5-B75	200.80	74.89	1.49	874.83	11.27	10.56	9.16	8.13	7.69
200x75-t4.0-B75	200.80	74.89	4.00	874.83	75.69	70.19	67.24	58.37	51.80
200x75-t6.0-B75	200.80	74.89	6.00	874.83	158.38	145.28	127.16	116.37	99.91
200x75-t1.5-B100	201.14	74.76	1.50	900.08	12.40	11.59	10.26	9.11	8.20
200x75-t4.0-B100	201.14	74.76	4.00	900.08	84.23	76.91	69.72	63.24	56.50
200x75-t6.0-B100	201.14	74.76	6.00	900.08	168.79	151.67	130.52	121.12	114.05
250x75-t1.5-B50	251.05	76.67	1.48	999.83	9.80	9.05	8.36	7.29	6.55
250x75-t4.0-B50	251.05	76.67	4.00	999.83	69.55	62.09	57.62	51.37	46.00
250x75-t6.0-B50	251.05	76.67	6.00	999.83	151.68	140.26	122.59	101.19	87.98
250x75-t1.5-B75	251.55	75.08	1.50	1025.00	11.01	10.23	9.39	8.12	7.00
250x75-t4.0-B75	251.55	75.08	4.00	1025.00	74.96	66.92	60.28	54.29	49.90
250x75-t6.00-B75	251.55	75.08	6.00	1025.00	163.69	151.69	139.17	119.26	100.00
250x75-t1.5-B100	252.19	75.09	1.49	1049.67	11.84	10.24	9.63	8.16	7.20
250x75-t4.0-B100	252.19	75.09	4.00	1049.67	82.06	73.26	67.34	58.36	53.80
250x75-t6.0-B100	252.19	75.09	6.00	1049.67	177.26	161.94	139.41	127.69	111.90

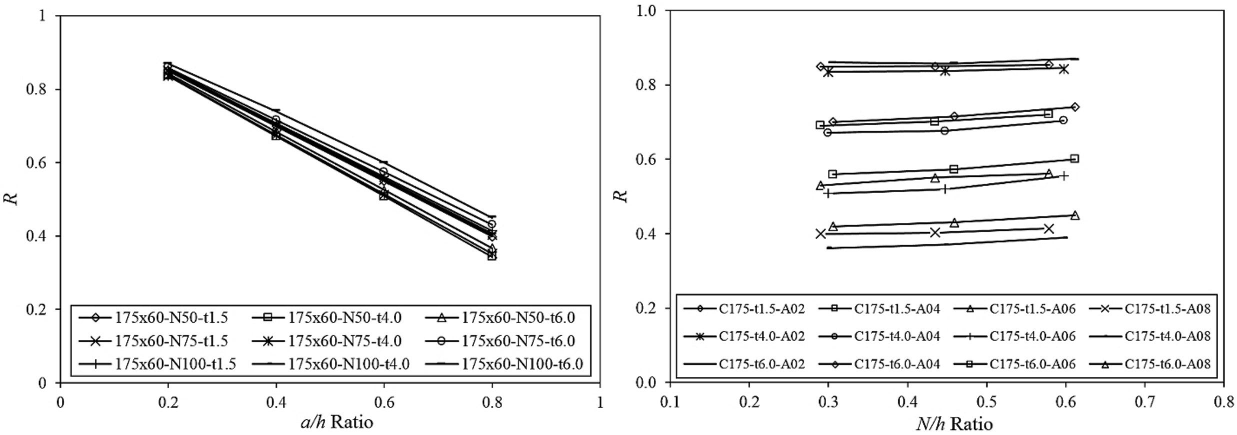
Table 2 Section details and web crippling capacities obtained from FEA for parametric study of *a/h* for channels with web perforation under EOF load case

Section	Web depth	Flange width	Web thickness	Length of channel	FEA ultimate load per single web, (P_{FEA})				
	d	b_f	t	L	(a/h=0)	(a/h=0.2)	(a/h=0.4)	(a/h=0.6)	(a/h=0.8)
	(mm)	(mm)	(mm)	(mm)	(kN)	(kN)	(kN)	(kN)	(kN)
175x60-t1.5-B50	175.51	59.99	1.41	725.00	4.54	3.86	3.18	2.49	1.81
175x60-t4.0-B50	175.51	59.99	4.00	725.00	40.29	33.68	27.07	20.45	13.84
175x60-t6.0-B50	175.51	59.99	6.00	725.00	74.92	63.06	51.21	39.35	27.49
175x60-t1.5-B75	175.48	60.03	1.44	775.00	4.95	4.21	3.47	2.73	1.99
175x60-t4.0-B75	175.48	60.03	4.00	775.00	44.26	37.09	29.92	22.74	15.57
175x60-t6.0-B75	175.48	60.03	6.00	775.00	73.24	62.83	52.42	42.01	31.60
175x60-t1.5-B100	175.53	60.02	1.41	825.00	5.38	4.59	3.81	3.02	2.23
175x60-t4.0-B100	175.53	60.02	4.00	825.00	44.16	37.61	31.06	24.50	17.95
175x60-t6.0-B100	175.53	60.02	6.00	825.00	71.29	62.78	54.27	45.76	37.25
200x75-t1.5-B50	200.54	75.03	1.44	800.00	4.35	3.71	3.06	2.42	1.77
200x75-t4.0-B50	200.54	75.03	4.00	800.00	40.73	33.80	26.87	19.93	13.00
200x75-t6.0-B50	200.54	75.03	6.00	800.00	85.81	71.18	56.55	41.92	27.29
200x75-t1.5-B75	200.50	75.00	1.44	850.00	4.72	4.03	3.33	2.64	1.94
200x75-t4.0-B75	200.50	75.00	4.00	850.00	45.81	38.03	30.25	22.46	14.68
200x75-t6.0-B75	200.50	75.00	6.00	850.00	86.45	72.67	58.90	45.12	31.34
200x75-t1.5-B100	200.55	75.01	1.42	900.00	5.06	4.33	3.60	2.87	2.14
200x75-t4.0-B100	200.55	75.01	4.00	900.00	53.63	44.38	35.14	25.89	16.64
200x75-t6.0-B100	200.55	75.01	6.00	900.00	84.30	72.24	60.18	48.12	36.06
250x75-t1.5-B50	250.61	75.01	1.43	950.00	3.82	3.26	2.71	2.15	1.59
250x75-t4.0-B50	250.61	75.01	4.00	950.00	37.74	30.84	23.94	17.04	10.14
250x75-t6.0-B50	250.61	75.01	6.00	950.00	86.07	70.66	55.24	39.83	24.41
250x75-t1.5-B75	250.46	75.00	1.43	1000.00	4.03	3.45	2.86	2.28	1.69
250x75-t4.0-B75	250.46	75.00	4.00	1000.00	41.41	34.03	26.65	19.26	11.88
250x75-t6.00-B75	250.46	75.00	6.00	1000.00	92.99	76.38	59.77	43.15	26.54
250x75-t1.5-B100	250.58	74.99	1.43	1050.00	4.34	3.72	3.10	2.48	1.86
250x75-t4.0-B100	250.58	74.99	4.00	1050.00	45.60	37.60	29.60	21.60	13.60
250x75-t6.0-B100	250.58	74.99	6.00	1050.00	95.04	78.98	62.92	46.85	30.79



(a) With *a/h* ratio **(b)** With *N/h* ratio

Fig. 4 Reduction factor Variations for C175 section with web perforation under IOF loading



(a) With *a/h* ratio **(b)** With *N/h* ratio

Fig. 5 Reduction factor Variations for C175 section with web perforation under EOF loading

Fig. 4 shows the ratio of the circular web perforation depth to the flat portion of the web (*a/h)* versus the strength reduction factor, for the three stainless steel grades. As can be seen, the reduction in strength increases as the parameter *a/h* increases for all three stainless steels, in particular for the ferritic grade with lower thickness (1.3mm). The reduction in strength of the ferritic grade 6 mm thick section is smallest and the reduction in strength increases as the section becomes thinner. It can be seen that when the *a/h* ratio increases from 0.2 to 0.6, the reduction in strength for the ferritic grade increases by 28%.

Fig. 5 shows the ratio of the bearing length to the flat portion of the web (*N/h)* versus the strength reduction factor, for the three stainless steel grades. As can be seen, the reduction in strength is not sensitive to the ratio *N/h* and the 6 mm thick sections have the smallest reduction in strength or the highest strength reduction factor.

4. PROPOSED STRENGTH REDUCTION FACTORS

As shown in Tables 1 and 2, the ultimate crippling strength increases as the circular web perforations diameter decreases. As expected, it is also evident from Tables 1 and 2 that the ultimate web crippling capacities are affected by the length of the load and reaction plates. It increases as the length of the load and reaction plates increases. Evaluating results from the laboratory and numerical analyses, it is shown that web perforations diameter ratio *(a/h),* load and reaction plates lengths ratio *(N/h)* can be the main factors affecting the web crippling strength of the unlipped channels having web perforations under the IOF and EOF load cases.

Hence, according to both the numerical and the laboratory results obtained from this study and upon performing bivariate regression analysis, two web crippling strength reduction factor equations (R_D) are proposed for the unlipped channels having perforations in web under the IOF and EOF load cases.

IOF loading:

$$R_D = 0.97 - 0.43(\frac{a}{h}) + 0.07(\frac{N}{h}) \le 1 \quad (1)$$

EOF loading:

$$R_D = 0.92 - 0.77(\frac{a}{h}) + 0.19(\frac{N}{h}) \le 1 \quad (2)$$

where the limitations for the two above equations are 0 < *a/h* ≤ 0.8, *N/h* ≤ 0.61, *h/t* ≤ 200, *N/t* ≤ 90.09 and θ =90º.

5. Comparison of the proposed reduction factors with laboratory and numerical analyses results

The calculated strength reduction factors from the proposed Eqs. (1) and (2), are compared to the obtained strength reduction factor values from the numerical and laboratory results, as depicted versus the web perforations diameter ratio *(a/h)* and web slenderness ratio (*h/t*) in Figs. 6 and 7. In order to show the reliability of the proposed reduction factors, a summary of statistical values for reliability analysis is presented in Tables 3 and 4. The proposed equations are evidently conservative and match well with the results for unlipped channels with perforations in web under IOF and EOF load cases.

In terms of channels having perforations in web under IOF loading, it is evident from Table 3 that the mean of the obtained strength reduction factor values from the numerical and the laboratory analyses results over the results from proposed strength reduction factor is 1.00, having the coefficient of variation of COV=0.05 and having the corresponding reliability index value of β=2.59. In regards to channels having perforations in web under EOF loading, it is clear from Table 4 that the mean ratio of the obtained strength reduction factor values from the numerical and the laboratory analyses results over the results from proposed strength reduction factor is also 1.00, having the coefficient of variation of COV=0.06 and having the reliability index value of β=2.56.

Table 3: Statistical analysis of strength reduction factor for IOF loading condition

Statistical parameters	R (LAB & FEA) / R_D (0.97-0.43 (a/h)+0.07 (N/h))
Number of data	108
Mean value, (P_m)	1.00
Coefficient of variation, (V_p)	0.05
Reliability index, (β)	2.59
Resistance factor, (ϕ)	0.85

Table 4: Statistical analysis of strength reduction factor for EOF loading condition

Statistical parameters	R (LAB & FEA) / R_D (0.92-0.77 (a/h)+0.19 (N/h))
Number of data	97
Mean value, (P_m)	1.00
Coefficient of variation, (V_p)	0.06
Reliability index, (β)	2.56
Resistance factor, (ϕ)	0.85

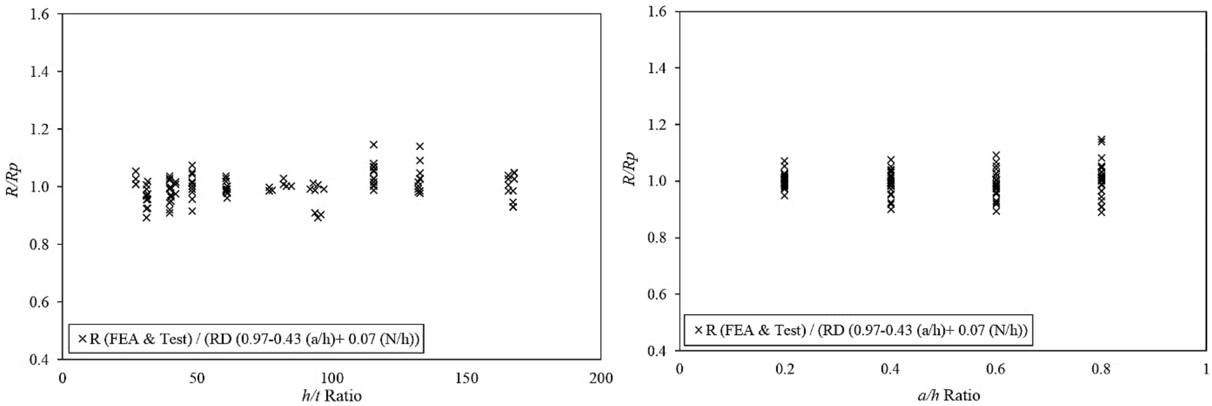


Fig. 6 Strength reduction factor comparison for C175 section with web perforation under IOF loading

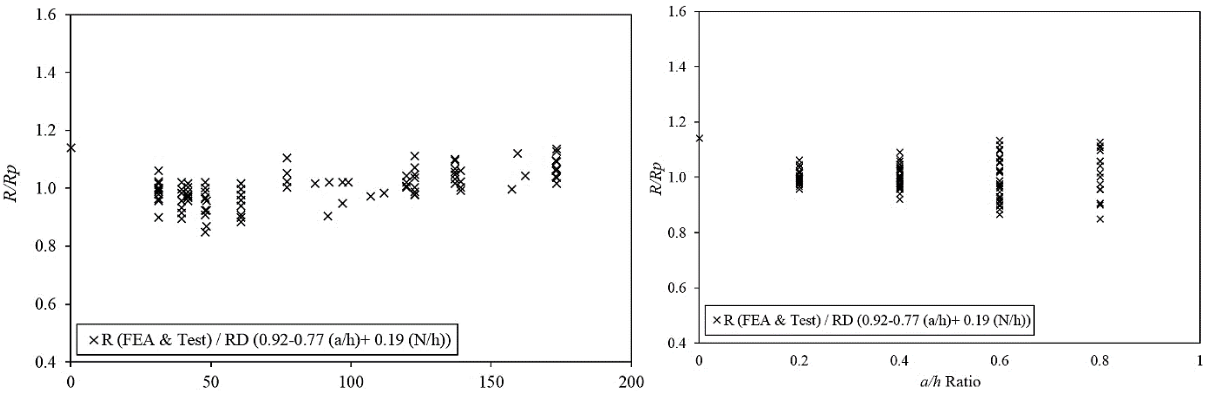


Fig. 7 Strength reduction factor comparison for C175 section with web perforation under EOF loading

Thus, the equations proposed for ferritic stainless steel unlipped channels having perforations in web can well predict the web crippling strength reduction factor of such channels under the IOF and EOF load cases.

6. CONCLUSIONS

This paper considered the use of cold-formed ferritic stainless steel unlipped channels with web perforations subject to interior-one-flange and end-one-flange loading, the benefit of perforations being ease of service integration. A total of 288 results were presented, comprising 18 laboratory and 270 numerical results. The numerical analysis in this paper used nonlinear quasi-static finite element analysis with an implicit integration scheme. An extensive parametric study was described to determine web crippling strength reduction factors for different sizes of web perforations and cross-section dimensions. It was noted that no cold-formed stainless steel standard provides strength reduction factors for any one-flange load case. The strength reduction factors were first compared to reduction factors previously recommended for lipped cold-formed stainless steel channels. It was found that these existing equations were unreliable and unconservative for unlipped channels by as much as 16%. From both laboratory and finite element results, web crippling design equations were proposed for channels with perforations in the web under one-flange loadings; the proposed equations were shown to be reliable when compared against laboratory and numerical results.

REFERENCES

ABAQUS. (2014), Analysis User's Manual-Version 6.14-2 ABAQUS Inc., USA.

AS/NZS 4600 (2005), Cold-formed steel structures: AS/NZS 4600:2005, Standards Australia, Sydney, Australia.

ASCE 8-02 (2002), Specification for the Design of Cold-Formed Stainless Steel Structural Members: SEI/ASCE 8-02, Reston, VA.

Cashell, K. A., and Baddoo, N. R. (2014). "Ferritic stainless steels in structural applications." Thin-Wall. Struct., 83, 169-181.

Gunalan, S., M. Mahendran (2015), "Web crippling tests of cold-formed steel channels under two flange load cases", Journal of Constructional Steel Research, 110, 1-15.

Eurocode-3 (2006), Design of steel structures: Part 1.3: General rules — Supplementary rules for cold-formed thin gauge members and sheeting, in: ENV 1993-1-3, European Committee for Standardization, Brussels, Belgium.

ISO E. 6892-1. (2009). "Metallic Materials: Tensile Testing: Part 1: Method of Test at Room Temperature" ISO E. 6892-1, International Standard, Geneva.

Korvink, S. A., Van den Berg, G. J., and Van der Merwe, P. (1995). "Web crippling of stainless steel cold-formed beams." J. Constr. Steel Res., 34(2-3), 225-248.

Korvink, S. A., Van den Berg, G. J. (1994). "Web crippling of stainless steel cold-formed beams."Proc., 12th Int. Specialty Conf. on Cold-Formed Steel Structures, University of Missouri-Rolla, St. Louis, 551-569.

Lawson, R. M., Antonio Basta, Assraf Uzzaman (2015), "Design of stainless steel sections with circular perforations in shear", Journal of Constructional Steel Research, 112, 228-241.

Lian, Y., Uzzaman, A., Lim, J. B., Abdelal, G., Nash, D., and Young, B. (2017a). "Web crippling behaviour of cold-formed steel channel sections with web holes subjected to Interior-one-flange loading condition-part I: experimental and numerical investigation." Thin-Wall. Struct., 111, 103-112.

Lian, Y., Uzzaman, A., Lim, J. B., Abdelal, G., Nash, D., and Young, B. (2016a). "Effect of web holes on web crippling strength of cold-formed steel channel sections under end-one-flange loading condition–Part I: Tests and finite element analysis." Thin-Wall. Struct., 107, 443-452.

Mohammadjani, C., Yousefi, A. M., Cai, S. Q., Clifton, G. C., and Lim, J. B. P. (2017). "Strength and stiffness of cold-formed steel portal frame joints using quasi-static finite element analysis." Steel Compos. Struct., Int. J., 25(6), 727-734.

NAS (2007), North American Specification for the Design of Cold-Formed Steel Structural Members: American Iron and Steel Institute, AISI S100-2007, AISI Standard.

Natário, P., N. Silvestre, D. Camotim (2014), "Web crippling failure using quasi-static FE models", Thin-Walled Structures, 84, 34-49.

Rezvani, F. H., Yousefi, A. M., and Ronagh, H. R. (2015), "Effect of span length on progressive collapse behaviour of steel moment resisting frames". Structures, 3, 81-89.

Uzzaman, A., Lim, J. B., Nash, D., Rhodes, J., and Young, B. (2012c). "Cold-formed steel sections with web perforations subjected to web crippling under two-flange loading conditions—Part II: Parametric study and proposed design equations." Thin-Wall. Struct., 56, 79-87.

Uzzaman, A., Lim, J. B., Nash, D., Rhodes, J., and Young, B. (2013). "Effect of offset web holes on web crippling strength of cold-formed steel channel sections under end-two-flange loading condition." Thin-Wall. Struct., 65, 34-48.

Yousefi, A. M., Lim, J. B., Uzzaman, A., Lian, Y., Clifton, G. C., and Young, B. (2016). "Web crippling strength of cold-formed stainless steel lipped channel-sections with web perforations subjected to interior-one-flange loading condition.", Steel Compos. Struct., Int. J., 21(3), 629-659.

Yousefi, A. M., Lim, J. B., Uzzaman, A., Lian, Y., Clifton, G. C., and Young, B. (2017a). "Design of cold-formed stainless steel lipped channel sections with web perforations subjected to web crippling under end-one-flange loading condition." Adv. Struct. Eng., 20, 1024-1045.

Yousefi, A. M., Uzzaman, A., Lim, J. B. P., Clifton, G. C., and Young, B. (2017b). "Numerical investigation of web crippling strength in cold-formed stainless steel lipped channels with web perforations subjected to interior-two-flange loading condition." Steel Compos. Struct., Int. J., 23(4), 363-383.

Yousefi, A. M., Uzzaman, A., Lim, J. B. P., Clifton, G. C., and Young, B. (2017c). "Web crippling strength of cold-formed stainless-steel lipped channels with web perforations under end-two-flange loading." Adv. Struct. Eng., 20, 1845-1863.

Yousefi, A. M., Lim, J. B. P., and Clifton, G. C. (2017d). "Cold-formed ferritic stainless steel unlipped channels with web perforations subjected to web crippling under interior-two-flange loading condition–Part I: Tests and finite element model validation." Thin-Wall. Struct., 116, 333-341.

Yousefi, A. M., Lim, J. B. P., and Clifton, G. C. (2017e). "Cold-formed ferritic stainless steel unlipped channels with web perforations subjected to web crippling under interior-two-flange loading condition–Part II: Parametric study and design equations." Thin-Wall. Struct., 116, 342-356.

Yousefi, A. M., Lim, J. B. P., and Clifton, G. C. (2017f). "Web bearing strength of unlipped cold-formed ferritic stainless steel channels with perforated web subject to end-two-flange (ETF) loading.", Engineering Structures, 152, 804-818.

Yousefi, A., Lim, J., and Clifton, G. C. (2017g). "Experimental study of cold-formed ferritic stainless steel unlipped channels with web perforations subjected to web crippling under interior-two-flange loading.", proceeding of The 2017 International Conference on Steel and Composite Structures (ICSCS17), Ilsan (Seoul), Korea.

Yousefi, A., Lim, J. B. P., Clifton, G. C., and Young, B. (2017h). "Web crippling strength of cold-formed duplex stainless steel lipped channels with web perforations under end-two-flange loading.", proceeding of The 2017 International Conference on Steel and Composite Structures (ICSCS17), Ilsan (Seoul), Korea.

Yousefi, A. M., Lim, J. B. P., and Clifton, G. C. (2017i). "Web Crippling Design of Cold-formed Ferritic Stainless Steel Unlipped Channels with Web Holes and with Fastened Flanges Under End-two-flange loading Condition–Part I: Experimental Tests and Numerical Validation.", proceeding of The Fifth International Experts Seminar on Stainless Steel in Structures, London, UK.

Yousefi, A. M., Lim, J. B. P., and Clifton, G. C. (2017j). "Web crippling Design of Cold-formed Ferritic Stainless Steel Unlipped Channels with Web Holes and with Fastened Flanges under End-two-Flange Loading Condition-Part II: Parametric Study and Design Equations.", proceeding of The Fifth International Experts Seminar on Stainless Steel in Structures, London, UK.

Yousefi, A. M., Lim, J. B. P., and Clifton, G. C. (2018a). "Web crippling behaviour of unlipped cold-formed ferritic stainless steel channels subject to one-flange loading.", Journal of structural engineering, 144(8), 04018105.

Yousefi, A. M., Lim, J. B. P., and Clifton, G. C. (2018b). "Cold-formed ferritic stainless steel unlipped channels with web perforations subject to web crippling under one-flange.", Construction and Building Materials, 191, 713-725.

Yousefi, A. M., Lim, J. B., and Clifton, G. C. (2018c). "Web crippling design of G430 cold-formed stainless steel unlipped channels with web perforations under interior-two-flange loading", proceeding of The Australian Structural Engineering Conference: ASEC, p. 41, Engineers Australia.

Yousefi, A., Lim, J. B. P., and Clifton, G. C. (2018d). "Web Bearing Strength of Cold-Formed Ferritic Stainless Steel Unlipped Channels With Web perforations Under the End-Two-Flange (ETF) Loading", proceeding of The Wei-Wen Yu International Specialty Conference on Cold-Formed Steel Structures, St. Louis, Missouri, USA.

Yousefi, A., Lim, J. B. P., and Clifton, G. C. (2018e). "Web Crippling Behavior of Cold-Formed Ferritic Stainless Steel Unlipped Channels under Interior-One-Flange And End-One-Flange Loadings.", proceeding of The Wei-Wen Yu International Specialty Conference on Cold-Formed Steel Structures, St. Louis, Missouri, USA.

Yousefi, A. M., Lim, J. B. P., and Clifton, G. C. (2019a). "Web crippling design of cold-formed ferritic stainless steel unlipped channels with fastened flanges under end-two-flange loading", Journal of Constructional Steel Research, 152, 12-28.

Yousefi, A. M., Lim, J. B. P., and Clifton, G. C. (2019b). "Web crippling strength of perforated cold-formed ferritic stainless steel unlipped channels with restrained flanges under one-flange loadings." Thin-Wall. Struct., 137, 94-105.

Yousefi, A., Lim, J. B. P., and Clifton, G. C. (2019c). "Perforated cold-formed ferritic stainless steel unlipped channels with restrained flanges subject to web crippling under one-flange loadings", proceeding of 9th International Conference on Steel and Aluminium Structures (ICSAS19), Bradford, UK.

Yousefi, A., Lim, J. B. P., and Clifton, G. C. (2019d). "Experimental and numerical study of perforated cold-formed ferritic stainless steel unlipped channels subject to web crippling under interior-one-flange and end-one-flange loadings", proceeding of The 2019 International Conference on Steel and Composite Structures (ICSCS19), Jeju Island, Korea.

Zhao, O., Leroy Gardner, Ben Young, (2016), Buckling of ferritic stainless steel members under combined axial compression and bending, Journal of Constructional Steel Research, Vol. 117, pp. 35-48.

Zhou, F., and Ben Young (2007), "Cold-formed high-strength stainless steel tubular sections subjected to web crippling", Journal of structural engineering, 133(3), 368-377.

Zhou, F., and Ben Young (2013), "Web crippling behaviour of cold-formed duplex stainless steel tubular sections at elevated temperatures", Engineering Structures, 57, 51-62.