Design of direct- and indirect-formed rectangular hollow section beam-columns

by

Farbod Tahbazzadeh
Bachelor of Science, University of Tehran, 2020

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We acknowledge and respect the Lək̓ʷəŋən (Songhees and Esquimalt) peoples on whose territory the university stands, and the Lək̓ʷəŋən and W̱SÁNEĆ peoples whose historical relationships with the land continue to this day.

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Supervisory Committee

Dr. Min Sun, Supervisor
Department of Civil Engineering

Dr. Cheng Lin, Departmental Member
Department of Civil Engineering

Abstract

Hollow structural sections (HSS) are tubular steel profiles commonly produced by cold-forming for various engineering applications. Square and rectangular hollow sections—referred to as SHS and RHS, and collectively termed RHS hereinafter—are extensively used as structural members, including braces, beams, columns, and beam-columns. In North America, cold-formed RHS are primarily manufactured using two techniques: (1) direct-forming and (2) indirect-forming. In direct-forming, cold work is concentrated at the corners of RHS, while in indirect-forming, it is applied across the entire perimeter; thus, each technique results in different levels of residual stresses and distinct stress distributions across the cross-section, potentially influencing the mechanical behaviour of the members.

Several studies by other researchers have indicated that, on average, direct-forming induces smaller and more localized residual stresses on the RHS cross-sections than indirect-forming. As a result, direct-formed RHS beams and columns have demonstrated relatively higher flexural and axial compressive capacities compared to their indirect-formed counterparts. However, the existing provisions of the Canadian and American steel design standards (CSA S16:19 and AISC 360-22) for RHS members do not account for mechanical differences resulting from different cold-forming techniques (i.e., direct-forming and indirect-forming). Despite these findings, a comparative study on direct- and indirect-formed RHS beam-columns (i.e., members subjected to combined axial compression and flexure) is still lacking. The purpose of this research was to compare the mechanical behaviour and load-bearing capacity of cold-formed, untreated RHS beam-columns, made from different steel grades and fabricated using these two forming techniques.

A comprehensive finite element (FE)-based parametric investigation was conducted on a total of 1040 RHS beam-columns in each of Chapters 1 and 2, with Chapter 1 focusing on stub members and Chapter 2 on long members, to evaluate their ultimate axial compressive and flexural load-bearing capacities. In both chapters, several tensile coupon test data from previous experimental studies were collected and used to create a variety of steel material groups, covering a range of

nominal yield strengths from 350 MPa to 700 MPa. To validate the FE modeling, 53 stub and 36 long beam-column models were generated to replicate actual specimens, boundary conditions, and loading configurations. The developed material groups were subsequently implemented in the FE models to define the corresponding material properties, without explicitly modeling residual stresses. Geometric and material nonlinearities, as well as initial geometric imperfections, were incorporated to enhance the accuracy of the analyses. The models were subjected to static axial compressive loading, applied either concentrically or with varying eccentricities, resulting in combined axial compression and flexure. Their load-deformation responses and ultimate load-bearing capacities were then compared to experimental results, as presented in Chapters 1 and 2.

In each chapter, a series of reliability analyses were conducted to assess the safety and adequacy of CSA S16:19 and AISC 360-22 in the design of RHS beam-columns. Based on the findings in Chapter 1 on stub members, the CSA S16:19 provisions were, in general, reasonably reliable, whereas those in AISC 360-22 were excessively conservative. As for the findings in Chapter 2 regarding long members, CSA S16:19 was found to be overly conservative for members with more slender sidewalls (Classes 3 and 4), yet less reliable for those with stockier sidewalls (Classes 1 and 2). Additionally, AISC 360-22 was observed to be slightly conservative for direct-formed members and comparatively less reliable for indirect-formed ones. According to both chapters, direct-formed members were mechanically advantageous over their indirect-formed counterparts, exhibiting higher ultimate load-bearing capacities. A set of modifications was proposed for the cross-section slenderness limits of direct-formed members in AISC 360-22, as well as for the coefficients of the axial compression-flexure interaction formulas for both direct-formed and indirect-formed members in both standards, to ensure appropriate reliability levels.

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Acknowledgements

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Finally, I would like to convey my heartfelt thanks to my family, especially my parents, for their boundless love, care, and belief in me, and to all my friends and colleagues for their constant motivation and encouragement throughout this journey.

Dedication

This thesis is dedicated to my beloved parents, Banafsheh and Shahrokh, and to the memory of a dear and inspirational friend, Shahab Amanat.

Chapter 1 Design of direct- and indirect-formed RHS stub beam-columns

1.1 Abstract

Square and rectangular hollow sections (collectively referred to as RHS) are commonly produced through cold-forming, using both direct- and indirect-forming techniques. A number of prior studies by other researchers on direct-formed RHS beams and stub columns have demonstrated that these members exhibit lower residual stress levels, leading to higher expected load-bearing capacities compared to their indirect-formed counterparts. However, the current provisions in the Canadian and American steel design standards (CSA S16:19 and AISC 360-22) do not distinguish between them. Moreover, a comparative study on direct- and indirect-formed RHS beam-columns has yet to be conducted. In this study, test data from several prior investigations were used to replicate 53 nonlinear finite element (FE) models of RHS stub beam-columns, subjected to concentric or eccentric static axial loading. Their load-deformation responses and ultimate capacities were compared to experimental results to validate the FE models. A subsequent parametric investigation was conducted on 1040 RHS stub beam-column FE models, including both direct- and indirect-formed members made from normal- and high-strength steel (with nominal yield strengths ranging from 350 MPa to 700 MPa). The models were subjected to static axial loading, either concentrically or eccentrically, and their ultimate axial compressive and flexural capacities were evaluated. Multiple reliability analyses were performed on CSA S16:19 and AISC 360-22 to assess their adequacy. Based on these analyses, modifications to the provisions were proposed to meet target reliability levels.

1.2 Introduction

1.2.1 Background

There has been an increasing global demand for Hollow structural sections (HSS) in the steel industry over the past few decades. The combination of aesthetic appeal and favourable mechanical properties, such as high moments of inertia about both axes and high torsional rigidity, has made them preferred choices. Among the various HSS shapes including elliptical, circular, multi-sided, rectangular, and square sections, rectangular and square sections (collectively referred to as RHS) are the most frequently used due to their ease of production.

The manufacturing process of RHS steel members follows two major methods in the North American industry: (1) hot-rolling, which is designated as Class H in the Canadian Standard for the Design of Steel Structures (CSA S16:19 [1]), and (2) cold-forming, which is generally designated as Class C (for untreated members, on which cold-forming is typically performed at room temperature or at slightly elevated temperatures) in the same standard. Both methods utilize a set of rollers to shape steel materials into the desired profiles. In hot-rolling, temperatures can reach up to 925 °C, whereas in cold-forming, which conforms to the ASTM A500 [2] or ASTM A1085 [3] standards, the temperature is generally limited to 450 °C, even with post-production processes such as heat treatment or hot-dip galvanizing. Hot-rolling results in comparatively lower cross-sectional residual stresses, which in turn leads to higher ductility and more consistent material properties throughout the section in RHS members. However, cold-forming is more commonly used due to its lower manufacturing costs.

In North America, cold-forming consists of two main techniques: (1) direct-forming and (2) indirect-forming. In both techniques, a steel strip is cold-bent and passed through a set of pressure rollers to form the desired shapes. In direct-forming, steel strips are directly roll-formed into RHS sections using localized cold work around the section corners. The seam is then welded using the Electric Resistance Welding (ERW) procedure. In indirect-forming, steel strips are first roll-formed into cylinders and welded using the same procedure, then transformed into RHS sections. (see Fig. 1.1 [4] for a brief overview).

A series of studies has investigated the steel material properties, along with the measurement of longitudinal residual stress across the cross-section, in several direct- and indirect-formed RHS specimens [5–18]. As a result of these studies, it was found that direct-formed RHS specimens generally exhibited smaller, more concentrated residual stresses at the corners, due to the localized cold work applied in these regions during the fabrication process. In contrast, indirect-formed RHS specimens overall showed higher and more distributed residual stresses across their entire cross-section. Furthermore, based on the findings in [8, 19, 20] for hot-rolled RHS and [7, 12, 13, 15–19] for cold-formed, heat-treated or hot-dip galvanized RHS, it was observed that members exposed to higher temperatures experienced a reduction in residual stresses (i.e., stress relief). Comparative studies on direct- and indirect-formed RHS stub columns by Sun and Packer [7], and by Tayyebi and Sun [21], found that direct-formed RHS stub columns exhibited higher axial compressive capacities compared to indirect-formed ones, attributed to lower residual stresses. In addition, several experimental and finite element (FE)-based comparative studies on cold-formed RHS—whether untreated, heat-treated, or hot-dip galvanized—[7, 12, 13, 16–19, 21] reported that heat-treated and hot-dip galvanized RHS beams and stub columns demonstrated higher load-bearing capacities than untreated members, due to stress relief. The same studies also indicated that variations in residual stress levels and distribution can significantly influence local buckling behaviour, which may result in overly conservative designs for members with lower residual stresses.

Several studies on direct-formed RHS beams and stub columns by Tayyebi et al. [16–18] and the study in [21] investigated the behaviour and load-bearing performance of these members. Both normal- and high-strength steel materials with nominal yield strengths of 350 MPa and 690 MPa were included. The effects of heat-treatment and hot-dip galvanizing were also studied. The provisions of CSA S16:19 [1], AISC 360-16 (which, in this context, aligns with AISC 360-22 [22]), and AISI S100-16 [23] were examined, and modifications to the cross-section slenderness limits for direct-formed RHS members were proposed to reduce excessive design conservatism.

Multiple studies were conducted on indirect-formed RHS members made from normal-strength steel. Key et al. [24] experimentally investigated the behaviour and axial compressive capacity of several cold-formed, untreated columns. Sun and Ma [12] conducted an experimental study on the effects of heat treatment and hot-dip galvanizing on the mechanical properties of RHS. Poursadrollah et al. [25] carried out both experimental and numerical investigations on cold-formed, untreated RHS columns, focusing on the influence of material properties on their buckling resistance and behaviour. Similarly, Hayeck et al. [26, 27] examined the stability and resistance of cold-formed, untreated, and hot-rolled RHS beam-columns. Various research studies explored indirect-formed RHS members made from high-strength steel. In a series of studies by Ma et al. [28-32], several experimental tests and FE simulations were performed on RHS beams, columns, and beam-columns made of steel with nominal yield strengths ranging from 700 MPa to 1100 MPa. The ultimate load-bearing capacities were evaluated and compared to the predictions in various design standards, and design revisions were proposed. The studies in [33–35] investigated the behaviour and design of several indirect-formed RHS columns and beam-columns made from either normal- or high-strength steel. In a recent study by Yin et al. [36], a number of indirect-formed square hollow section (SHS) columns made of high-strength steel were investigated, and their flexural buckling behaviour was reported. The research studies in [20, 26–29, 31, 33] further explored a range of circular hollow section (CHS) beams, columns, and beam-columns. The complementary research in [37–44] also studied the behaviour and design of a series of stainless steel columns and beam-columns, primarily focusing on RHS and CHS.

The design provisions in CSA S16:19 [1] and AISC 360-22 [22] do not account for the effects of cold-forming techniques (i.e., direct-forming and indirect-forming) on the mechanical behaviour of RHS beam-columns. The studies in [16–18, 21] on direct-formed RHS have focused on either beams or stub columns but have not addressed beam-columns. Moreover, the studies in [28–32] on indirect-formed RHS have focused only on high-strength steel materials and have not provided axial compression-flexure interaction formulas for beam-columns separately, considering their material grade or cold-forming technique. Hence, a comparative study on direct- and indirect-formed RHS beam-columns made of both normal- and high-strength steel is essential.

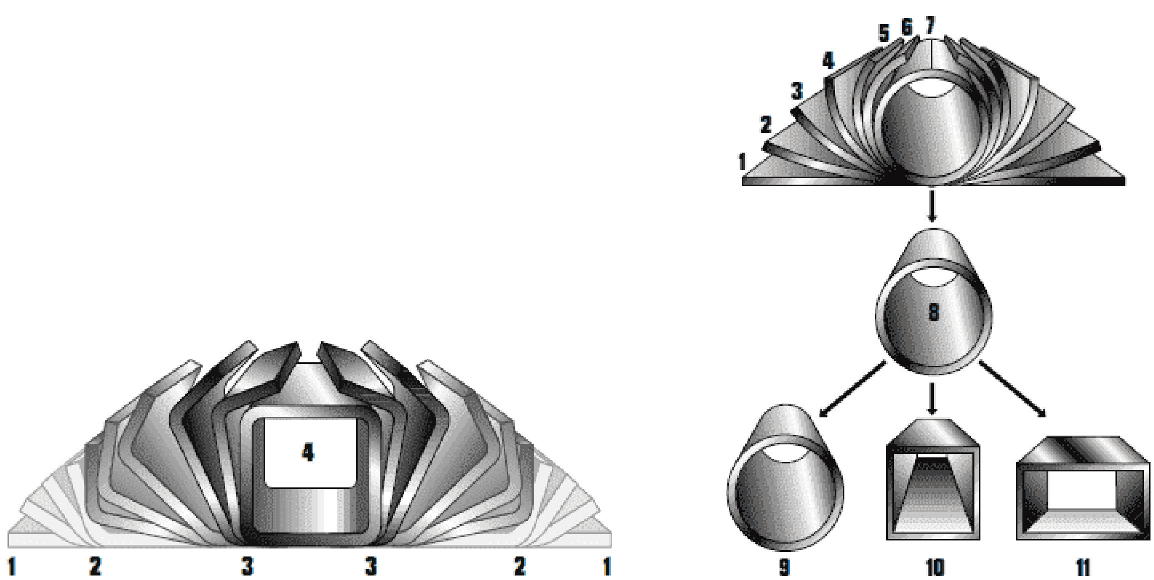
1.2.2 Scope of research

This research mainly aims to evaluate how different cold-forming techniques (direct-forming vs. indirect-forming) influence the static load-bearing capacity of cold-formed, untreated RHS stub beam-columns. For this purpose, a combination of previously published experimental investigations and a finite element (FE) simulation approach has been employed. No original experimental work has been carried out as part of this research; all experimental data have been obtained from prior studies conducted by other researchers.

The experimental investigation involved using tensile coupon test data from several previous studies on both direct- and indirect-formed RHS specimens to establish a set of steel material groups, mechanical parameters, and stress-strain curves, without directly incorporating residual stress measurements. Instead, residual stress effects were indirectly considered by assigning different steel material properties to the flat faces and corner regions of the RHS cross-section, based on the observed differences in the tensile test results.

53 nonlinear FE models were developed to simulate actual RHS stub beam-column specimens, taking into account their geometric dimensions and imperfections, material properties, boundary conditions, and loading configurations. The models were subjected to static axial compressive loading, applied either concentrically or eccentrically, resulting in a combination of axial compression and flexure. The ultimate load-bearing capacity and load-deformation response of the FE models were validated against real test results. A comprehensive finite element (FE)-based parametric study was conducted on a total of 1040 RHS stub beam-column models to determine their ultimate axial compressive and flexural capacities. The models covered a broad range of cross-section sizes, aspect ratios, and slenderness ratios, including both direct- and indirect-formed members made from normal- and high-strength steel. For each member, several load cases with varying load eccentricities were considered.

The ultimate load-bearing capacities of RHS beam-columns were compared to the predictions of CSA S16:19 [1] and AISC 360-22 [22] separately for direct-formed and indirect-formed members. The reliability and safety margins of these standards were assessed through a series of reliability analyses in accordance with the provisions of AISI S100-16 [23]. A set of targeted revisions were proposed to improve design efficiency and safety margins, particularly for members with sections belonging to the highest slenderness class (i.e, Class 4 in CSA S16:19 [1], and slender in AISC 360-22 [22]). These revisions included defining modified cross-section slenderness limits for direct-formed members with slender sidewalls in AISC 360-22 [22], as well as applying modified coefficients in the axial compression-flexure interaction formulas for both direct- and indirect-formed members in CSA S16:19 [1] and AISC 360-22 [22].



(a) (b)

Figure 1.1 Different cold-forming techniques: (a) direct-forming; (b) indirect-forming [4]

1.3 Experimental investigation

1.3.1 RHS specimens

A series of cold-formed, untreated RHS stub specimens, including both direct-formed and indirect-formed types, were collected and tested in several previous studies [12, 16, 21, 30, 32]. These specimens covered a range of steel material grades, including normal-strength steel (with nominal yield strengths of 350 MPa for direct-formed RHS and 355 MPa for indirect-formed RHS) and high-strength steel (with nominal yield strengths of 690 MPa for direct-formed RHS and 700 MPa for indirect-formed RHS). Comprehensive geometric measurements were conducted on each specimen, including the outer cross-section dimensions—the depth (h), measured along the loading eccentricity (i.e., web direction), and the width (b), measured perpendicular to it (i.e., flange direction), regardless of which side is longer—as well as the wall thickness (t), length (L), inner and outer corner radii (r_i and r_o), and maximum local imperfection of the sidewalls (δ_l). According to the approach used in [16, 21, 30, 32], the maximum local imperfection of the sidewalls was assumed to be proportional to the thickness. Due to the lack of consistent measurements in some studies, an average ratio of local imperfection to thickness (i.e., δ_l/t = 0.05) was adopted and applied to determine δ_l in Table 1.1.

Each specimen is assigned a unique identification (ID) consisting of six components. The first component indicates the cross-section shape, either square (SHS) or rectangular (RHS). The second specifies the cold-forming technique used in fabrication, denoted as D for direct-formed or I for indirect-formed. The third component represents the steel grade, with N for normal-strength and H for high-strength steel. The final three numerical components correspond to the nominal outer depth (h) and width (b), as well as the wall thickness (t) in millimeters. A total of 53 specimens were subjected to axial compressive load tests: 12 direct-formed and 41 indirect-formed. These tests were either concentrically applied (21 cases) or with varying eccentricities (32 cases), as shown in Table 1.1. The experimental results are presented in more detail in Section 1.4.4.

Table 1.1 Measured geometric parameters and eccentricities of stub beam-column specimens

Specimen ID	e (mm)	h (mm)	b (mm)	t (mm)	L (mm)	r_i (mm)	r_o (mm)	δ_l (mm)
SHS-DN-102×102×3.2	0	101.1	101.9	3.03	402	3.4	6.4	0.15
SHS-DN-102×102×4.8	0	101.6	102.1	4.40	403	5.6	10.0	0.22
SHS-DN-127×127×4.8	0	127.0	127.6	4.40	403	6.6	11.0	0.22
RHS-DN-76×102×3.2	0	76.5	101.9	3.03	402	2.4	5.4	0.15
RHS-DN-76×102×4.8	0	76.4	101.9	4.36	404	3.4	7.8	0.22
SHS-DH-76×76×4.8	0	76.3	76.6	4.81	352	8.5	13.3	0.24
RHS-DH-76×102×3.2	0	76.9	102.6	3.02	403	2.6	5.6	0.15
RHS-DH-76×102×3.2*	0	76.9	102.6	3.02	403	2.6	5.6	0.15
RHS-DH-76×102×4.1	0	76.3	101.8	4.06	402	4.8	8.9	0.20
RHS-DH-76×102×4.8	0	76.6	102.0	4.82	402	8.9	13.7	0.24
RHS-DH-76×152×4.1	0	77.2	153.1	4.04	503	5.1	9.1	0.20
RHS-DH-76×152×4.1*	0	77.2	153.1	4.04	503	5.1	9.1	0.20
SHS-IN-102×102×6.4	0	102.1	102.2	6.41	350	8.0	14.4	0.32
SHS-IN-102×102×7.9	0	101.9	102.1	7.83	350	11.7	19.5	0.39
SHS-IH-80×80×4	0.10	80.1	80.4	3.92	220	5.0	9.5	0.20
SHS-IH-80×80×4	10.07	80.1	80.4	3.92	220	5.0	9.5	0.20
SHS-IH-80×80×4	18.67	80.1	80.4	3.92	220	5.0	9.5	0.20
SHS-IH-80×80×4	40.33	80.1	80.4	3.92	220	5.0	9.5	0.20
SHS-IH-80×80×4	80.45	80.1	80.4	3.92	220	5.0	9.5	0.20
SHS-IH-120×120×4	0.19	120.9	120.9	3.92	310	4.0	8.0	0.20
SHS-IH-120×120×4	4.31	120.9	120.9	3.92	310	4.0	8.0	0.20
SHS-IH-120×120×4	11.91	120.9	120.9	3.92	310	4.0	8.0	0.20
SHS-IH-120×120×4	29.62	120.9	120.9	3.92	310	4.0	8.0	0.20
SHS-IH-120×120×4	57.91	120.9	120.9	3.92	310	4.0	8.0	0.20
SHS-IH-120×120×4	118.63	120.9	120.9	3.92	310	4.0	8.0	0.20
SHS-IH-140×140×6	0.27	141.1	140.8	5.90	310	7.0	13.0	0.30
SHS-IH-140×140×6	13.27	141.1	140.8	5.90	310	7.0	13.0	0.30

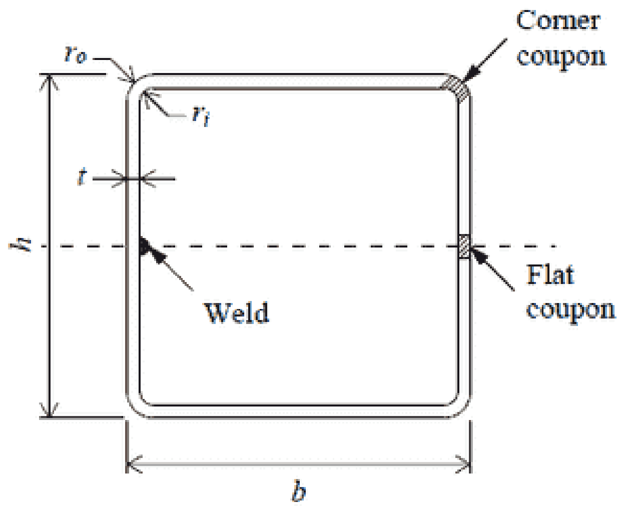
SHS-IH-140×140×6	35.55	141.1	140.8	5.90	310	7.0	13.0	0.30
SHS-IH-140×140×6	68.64	141.1	140.8	5.90	310	7.0	13.0	0.30
SHS-IH-140×140×6	100.87	141.1	140.8	5.90	310	7.0	13.0	0.30
RHS-IH-50×100×4	0.06	50.5	100.2	3.94	220	3.5	8.5	0.20
RHS-IH-50×100×4	3.71	50.5	100.2	3.94	220	3.5	8.5	0.20
RHS-IH-50×100×4	8.86	50.5	100.2	3.94	220	3.5	8.5	0.20
RHS-IH-50×100×4	23.06	50.5	100.2	3.94	220	3.5	8.5	0.20
RHS-IH-50×100×4	49.28	50.5	100.2	3.94	220	3.5	8.5	0.20
RHS-IH-50×100×4*	49.54	50.5	100.2	3.94	220	3.5	8.5	0.20
RHS-IH-120×200×5	0.22	120.4	200.4	4.95	490	7.5	13.0	0.25
RHS-IH-120×200×5	15.43	120.4	200.4	4.95	490	7.5	13.0	0.25
RHS-IH-120×200×5	28.80	120.4	200.4	4.95	490	7.5	13.0	0.25
RHS-IH-120×200×5	59.14	120.4	200.4	4.95	490	7.5	13.0	0.25
RHS-IH-120×200×5*	60.10	120.4	200.4	4.95	490	7.5	13.0	0.25
RHS-IH-120×200×5	120.06	120.4	200.4	4.95	490	7.5	13.0	0.25
RHS-IH-100×50×4	0.17	100.2	50.6	3.94	220	3.5	8.5	0.20
RHS-IH-100×50×4	7.91	100.2	50.6	3.94	220	3.5	8.5	0.20
RHS-IH-100×50×4	19.00	100.2	50.6	3.94	220	3.5	8.5	0.20
RHS-IH-100×50×4	39.70	100.2	50.6	3.94	220	3.5	8.5	0.20
RHS-IH-100×50×4	99.09	100.2	50.6	3.94	220	3.5	8.5	0.20
RHS-IH-200×120×5	1.08	200.3	120.6	4.93	490	7.5	13.0	0.25
RHS-IH-200×120×5	15.60	200.3	120.6	4.93	490	7.5	13.0	0.25
RHS-IH-200×120×5	30.72	200.3	120.6	4.93	490	7.5	13.0	0.25
RHS-IH-200×120×5	59.90	200.3	120.6	4.93	490	7.5	13.0	0.25
RHS-IH-200×120×5	111.86	200.3	120.6	4.93	490	7.5	13.0	0.25
RHS-IH-200×120×5*	110.58	200.3	120.6	4.93	490	7.5	13.0	0.25

*Repeated test

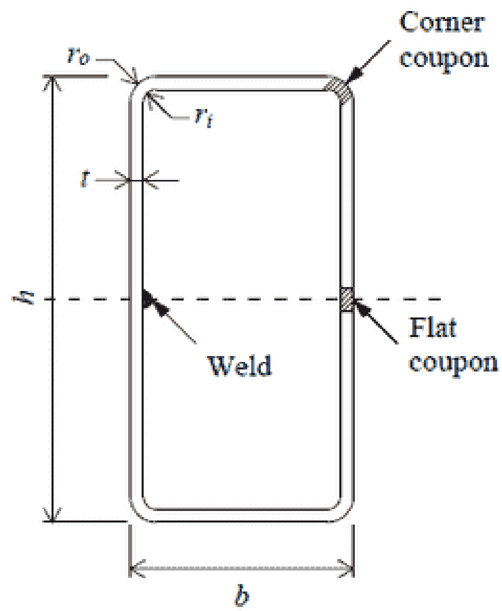
1.3.2 Tensile coupon tests

To determine the stress-strain relationship of the steel materials, several coupons were machined from the flat faces and corners of RHS specimens and were used in tensile tests reported in previous studies [12, 15–18, 21, 28–32]. The mechanical behavior of the steel varied depending on the cold-forming technique (direct-forming vs. indirect-forming), the steel grade (normal-strength vs. high-strength), and the coupon location (flat faces vs. corners, as shown in Fig. 1.2). As a result, eight distinct material groups were identified, each labeled with three components. The first component indicates the cold-forming technique used in fabricating the member from which the coupon was machined (D = direct-formed, I = indirect-formed). The second component indicates the steel grade (N = normal-strength, H = high-strength), and the third component specifies the coupon location (Flat = flat face, Corner = corner region).

For each material group associated with direct-forming (D-N-Flat, D-N-Corner, D-H-Flat, and D-H-Corner), averaged parameters from five tensile coupon test results were used, based on data from [15–18, 21]. Similarly, for the indirect-formed normal-strength steel groups (I-N-Flat and I-N-Corner), averaged parameters were obtained from the tensile test results of six flat face and twelve corner coupons reported in [12]. Additionally, for each of the indirect-formed high-strength steel groups (I-H-Flat and I-H-Corner), averaged parameters were derived from eight tensile coupon tests presented in [28–32]. In total, the averaged parameters of 54 tensile coupon tests were used to define the eight material groups.



(a)



(b)

Figure 1.2 Cross-sectional parameters and coupon locations for: (a) SHS; (b) RHS

Based on the tensile coupon test results, two distinct stress-strain patterns were identified. The first pattern, observed in the flat-face coupons of the direct-formed RHS (D-N-Flat and D-H-Flat), exhibited higher ductility and a noticeable yield plateau. Conversely, the second pattern, found in the remaining material groups, showed lower ductility with early and continuous yielding (see Figs. 1.3 and 1.4).

1.3.3 Material constitutive models

Material constitutive models describe stress-strain relationships using key parameters derived from tensile coupon test results. These models establish numerical relationships between stress and strain, allowing for the development of stress-strain curves that represent the averaged properties of the steel materials.

In a study on hot-rolled steels by Yun and Gardner [45], a quad-linear constitutive model was proposed, where stress is defined as a function of strain (Eqs. 1.1–1.3), encompassing four phases:

(1) linear elasticity, (2) sudden yielding plateau, (3) initial strain hardening, and (4) secondary strain hardening (with a gentler slope than the initial strain hardening phase). This model was applied to the D-N-Flat and D-H-Flat material groups, which align with the first pattern as discussed in Section 1.3.2. The experimental observations from [15–18, 21] confirm that the flat face coupons of the direct-formed RHS exhibit stress-strain curves with a more abrupt yielding transition, attributed to minimal cold work and correspondingly low levels of residual stress. These characteristics result in a well-defined yield point and support the use of the quad-linear model, which captures the sudden yield plateau typical of hot-rolled steels.

In contrast, Gardner and Yun [48], building on the work of Ramberg and Osgood [46] and Hill [47], proposed a two-phase, rounded constitutive model for cold-formed steels, where strain is expressed as a nonlinear function of stress (Eqs. 1.4–1.7), reflecting a more gradual yielding response. This model was applied to the remaining material groups that follow the second pattern in Section 1.3.2, including all the corners of the direct-formed RHS and all the flat faces and corners of the indirect-formed RHS. The experimental results from [12, 15–18, 21, 28–32] demonstrate that coupons sectioned from these regions exhibit lower ductility and feature rounded stress-strain curves without a sharply defined yield point, attributed to more intensive cold work that causes relatively higher levels of residual stress. A 0.2% proof stress ($\sigma_{0.2}$) was accordingly suggested to serve as the yield stress (f_y) in Eqs. 1.4–1.7 to account for the absence of a distinct yield point. A summary of the steel material groups is provided in Table 1.2.

$$f(\varepsilon) = \begin{cases} E\varepsilon & \varepsilon < \varepsilon_y \\ f_y & \varepsilon_y < \varepsilon \le \varepsilon_{sh} \\ f_y + E_{sh}(\varepsilon - \varepsilon_{sh}) & \varepsilon_{sh} < \varepsilon \le C_1\varepsilon_u \\ f_{C_1\varepsilon_u} + \dfrac{f_u - f_{C_1\varepsilon_u}}{\varepsilon_u - C_1\varepsilon_u}(\varepsilon - C_1\varepsilon_u) & C_1\varepsilon_u < \varepsilon \le \varepsilon_u \end{cases} \tag{1.1}$$

$$C_1 = \frac{\varepsilon_{sh} + 0.25(\varepsilon_u - \varepsilon_{sh})}{\varepsilon_u} \tag{1.2}$$

$$E_{sh} = \frac{f_u - f_y}{0.4(\varepsilon_u - \varepsilon_{sh})} \tag{1.3}$$

$$\varepsilon = \begin{cases} \dfrac{f}{E} + 0.002\left(\dfrac{f}{f_y}\right)^n & f < f_y \\ \dfrac{f - f_y}{E_{0.2}} + \left(\varepsilon_u - \varepsilon_{0.2} - \dfrac{f_u - f_y}{E_{0.2}}\right)\left(\dfrac{f - f_y}{f_u - f_y}\right)^m + \varepsilon_{0.2} & f_y < f \leq f_u \end{cases} \tag{1.4}$$

$$n = \frac{\ln(4)}{\ln\left(f_y / \sigma_{0.05}\right)} \tag{1.5}$$

$$E_{0.2} = \frac{E}{1 + 0.002n\frac{E}{f_y}} \tag{1.6}$$

$$m = 1 + 1.33\frac{f_y}{f_u} \tag{1.7}$$

Table 1.2 Description of steel material groups

Material ID	Cold-forming technique	Steel grade	Coupon location	Stress-strain model	Data source
D-N-Flat	Direct-forming	Normal-strength	Flat face	Quad-linear	[15–18, 21]
D-N-Corner	Direct-forming	Normal-strength	Corner region	Rounded	[15–18, 21]
D-H-Flat	Direct-forming	High-strength	Flat face	Quad-linear	[15–18, 21]
D-H-Corner	Direct-forming	High-strength	Corner region	Rounded	[15–18, 21]
I-N-Flat	Indirect-forming	Normal-strength	Flat face	Rounded	[12]
I-N-Corner	Indirect-forming	Normal-strength	Corner region	Rounded	[12]
I-H-Flat	Indirect-forming	High-strength	Flat face	Rounded	[28–32]
I-H-Corner	Indirect-forming	High-strength	Corner region	Rounded	[28–32]

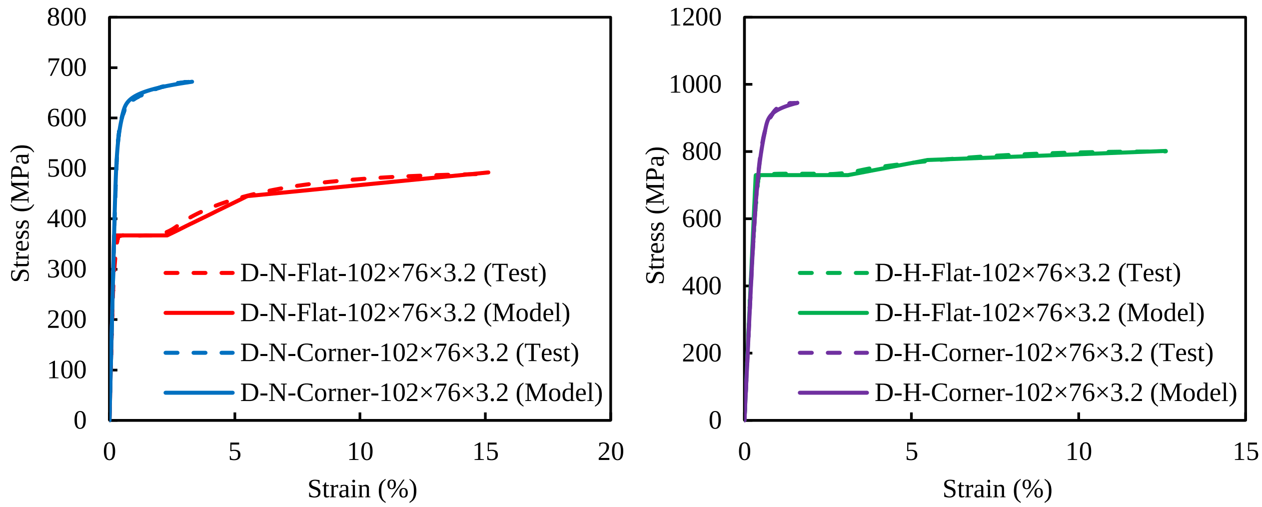
The averaged key parameters of the material groups, obtained from digitized stress-strain curves from [12, 15–18, 21, 28–32], are summarized in Tables 1.3 and 1.4. Since the data were digitized using WebPlotDigitizer (Automeris, https://automeris.io/WebPlotDigitizer), slight deviations from the reported values may occur, which are minimal and do not significantly affect the results. A comparison of several tensile coupon test results and material constitutive models is illustrated in Figs. 1.3 and 1.4.

Table 1.3 Averaged key parameters for quad-linear stress-strain models

Material ID	E (MPa)	f_y (MPa)	f_u (MPa)	ε_y	ε_{sh}	ε_u	E_{sh} (MPa)	C_1	$C_1\varepsilon_u$	$f_{C1\varepsilon u}$ (MPa)
D-N-Flat	202,500	383	475	0.0019	0.0258	0.1622	1687	0.369	0.0599	441
D-H-Flat	202,100	708	784	0.0035	0.0244	0.1184	2021	0.405	0.0479	756

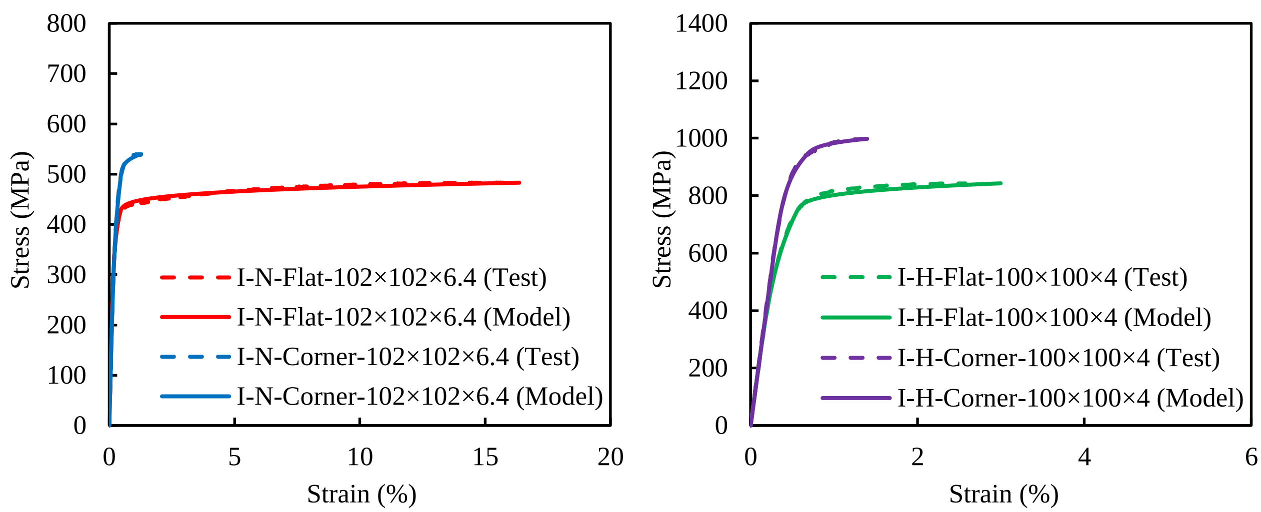
Table 1.4 Averaged key parameters for rounded stress-strain models

Material ID	E (MPa)	f_y (MPa)	f_u (MPa)	$\sigma_{0.05}$ (MPa)	$\varepsilon_{0.2}$	ε_u	$E_{0.2}$ (MPa)	n	m
D-N-Corner	211,200	573	621	471	0.0047	0.0174	33,992	7.07	4.04
D-H-Corner	203,400	862	950	700	0.0062	0.0159	49,099	6.66	3.99
I-N-Flat	199,000	456	513	359	0.0044	0.1075	32,844	5.8	3.93
I-N-Corner	200,000	514	561	433	0.0045	0.0139	27,431	8.08	4.02
I-H-Flat	211,093	739	845	575	0.0055	0.0439	50,790	5.52	3.89
I-H-Corner	211,282	907	986	777	0.0063	0.0160	40,866	8.96	4.04



(a) (b)

Figure 1.3 Comparison of stress-strain curves from tensile coupon tests and corresponding material constitutive models for: (a) DN; (b) DH



(a) (b)

Figure 1.4 Comparison of stress-strain curves from tensile coupon tests and corresponding material constitutive models for: (a) IN; (b) IH

1.4 Finite element analysis

1.4.1 Elements, meshing, and boundary conditions

The finite element software package Abaqus [49] was utilized to simulate multiple RHS stub beam-column models. The RHS members were modeled using four-node shell elements with reduced integration (S4R) from the Abaqus element library. Based on mesh sensitivity analyses reported in [29–32], a mesh size of (h+b)/30 was adopted for the flat face elements, where h and b denote the outer cross-section depth and width, respectively. Furthermore, to more accurately model the curved surfaces at the corners, each corner was discretized into five elements, resulting in a refined mesh. The selected mesh configuration provided a reasonable balance between analysis accuracy and computational efficiency. A reference point was assigned at each end cross-section, positioned at a distance corresponding to the eccentricity of the load application and support location (e), with all cross-section nodes tied to it. Each reference point was restrained from displacement but allowed to rotate freely. However, the top end was permitted to move freely in the axial direction, enabling the application of the axial compressive load and the resulting deformation.

1.4.2 Material properties

The averaged key material parameters from Tables 1.3 and 1.4 and the material constitutive models discussed in Section 1.3.3 were used to create a series of engineering stress-strain data covering all eight material groups. The data were then converted to true stress-strain values, as shown in Eqs. 1.8 and 1.9.

$$\sigma_{true} = \sigma(1+\varepsilon) \tag{1.8}$$

$$\varepsilon_{true} = \ln(1+\varepsilon) \tag{1.9}$$

In accordance with the material definition approach used in Abaqus [49], the elastic-region parameters, including Young's modulus (*E*) as indicated in Tables 1.3 and 1.4, and a Poisson's ratio (*v*) of 0.3, were selected. The true strain data was converted into logarithmic true plastic strain, as shown in Eq. 1.10, and used alongside the true stress values to characterize the steel material behaviour in the plastic region.

$$\varepsilon_{true,\,pl} = \varepsilon_{true} - \sigma_{true}/E \tag{1.10}$$

To account for the residual stress effects in the proximity of the corners, these regions were extended into the adjacent flat faces. The study in [38] explored extensions of *t*, 2*t*, and 3*t* (where *t* is the wall thickness), reporting an average variation of approximately 4% in the axial compressive capacity of stub columns. Sensitivity analyses conducted in [18, 32] also identified 2*t* as the most appropriate extension among the three. Similarly, studies in [29–31] found 2*t* to be the most suitable choice. Accordingly, an extension of 2*t* (i.e., equal to the outer corner radius) was applied, and these regions were assigned the same material properties as the corners (see Fig. 1.5).

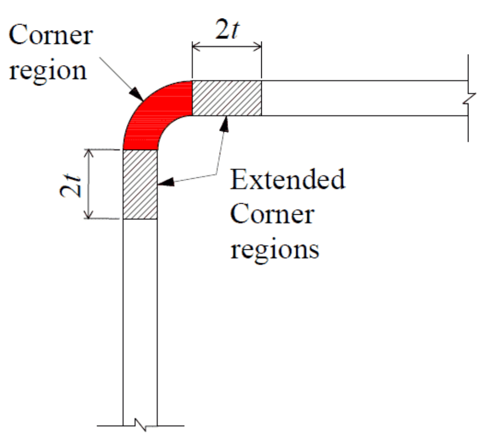
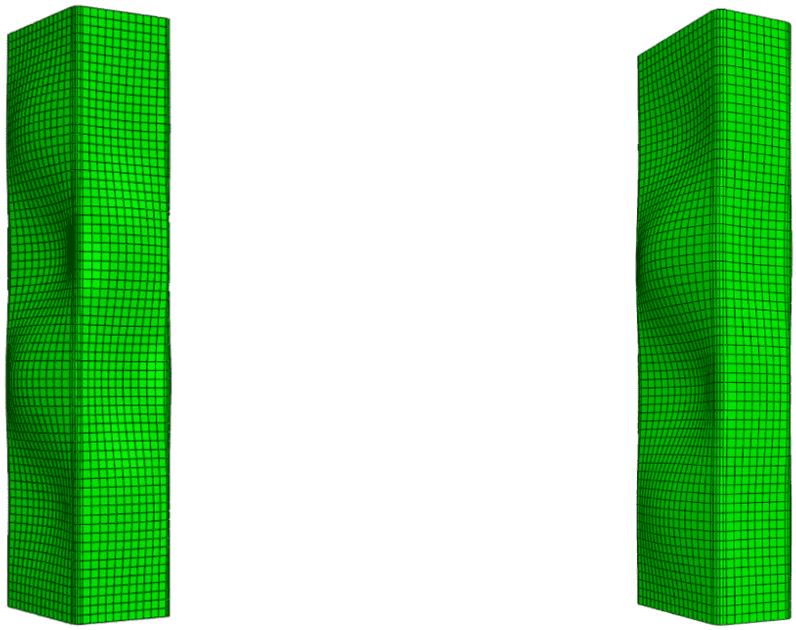


Figure 1.5 Extension of corner regions into flat faces in the FE models

1.4.3 Initial geometric imperfections

Initial local geometric imperfections were incorporated into the models to enhance the accuracy of simulations and analyses. However, global geometric imperfections were disregarded due to their negligible impact on the mechanical behavior of RHS stub members. However, this assumption does not hold for long beam-columns, which are addressed in Chapter 2. In line with the approach in [16, 21, 30, 32], the maximum local imperfections were considered proportional to the wall thickness. Using the data summarized in Table 1.1, the ratios of maximum measured local imperfections (δ_l) to the wall thickness (t) were calculated and averaged. Consequently, an average value of $0.05t$ was adopted as the maximum initial local imperfection for all FE models. To incorporate these imperfections into the models, a series of elastic buckling analyses were conducted in Abaqus [49]. The first buckling mode shapes were extracted, scaled to $0.05t$, and then applied to the FE models as initial geometric imperfections. The resulting imperfections are displayed in Figs. 1.6 and 1.7, with the deformations magnified to enhance visual clarity.



(a) (b)

Figure 1.6 Initial geometric imperfections applied to the FE models before loading:
(a) RHS-DN-76×102×3.2 (magnified ×100); (b) RHS-DH-76×152×4.1 (magnified ×100)

(a) (b)

Figure 1.7 Initial geometric imperfections applied to the FE models before loading:
(a) SHS-IN-102×102×6.4 (magnified ×50); (b) SHS-IH-120×120×4 (magnified ×100)

1.4.4 Validation of the FE modeling

Using the geometric data from Table 1.1, the material properties outlined in Sections 1.3.2 and 1.3.3, and the modeling details discussed in Sections 1.4.1–1.4.3, a total of 53 RHS stub beam-column specimens were simulated. Based on data from [16, 21], five direct-formed normal-strength steel (DN) models and seven direct-formed high-strength steel (DH) models were generated. Additionally, two indirect-formed normal-strength steel (IN) models were created using data from [12], and 39 indirect-formed high-strength steel (IH) models were simulated according to [30, 32]. The models were subjected to axial compressive static loads, either concentrically or eccentrically, replicating real test loading conditions until reaching their ultimate load-bearing capacities (i.e., the maximum axial compressive force and bending moment at the mid-height section). The ultimate capacities from the FE models were compared with the experimental results, and tabulated along with the associated failure patterns (i.e., cross-sectional yielding or local buckling), as displayed in Table 1.5. Furthermore, several failure patterns and load-deformation diagrams from the FE models were illustrated and validated against experimental results (see Figs. 1.8–1.15).

Table 1.5 Comparison of the stub beam-column FE and test results

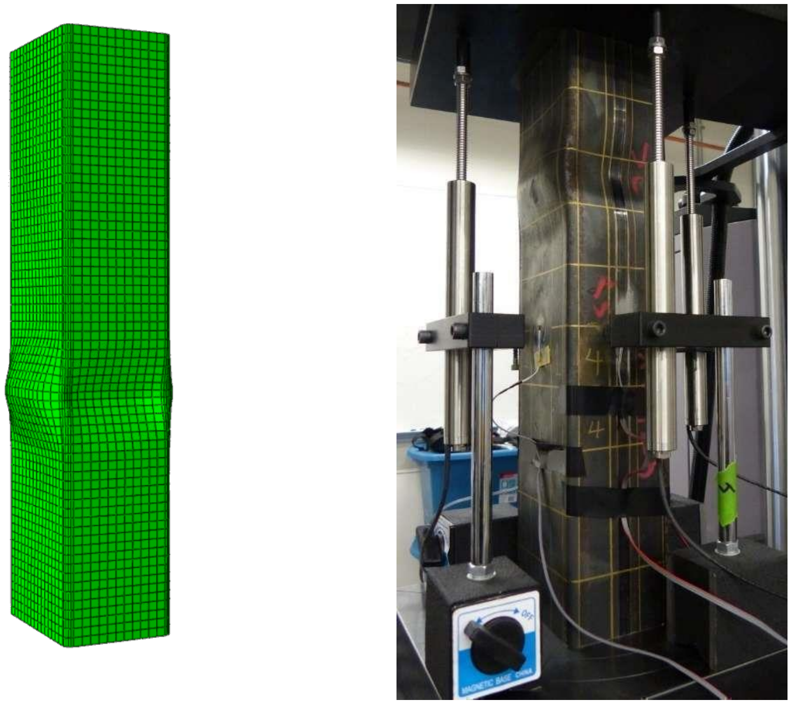
Specimen ID	e (mm)	$P_{u, FE}$ (kN)	$P_{u, test}$ (kN)	$P_{u, FE}$/ $P_{u, test}$	*Failure pattern*
SHS-DN-102×102×3.2	0	466	478	0.97	CY
SHS-DN-102×102×4.8	0	781	839	0.93	CY
SHS-DN-127×127×4.8	0	913	969	0.94	CY
RHS-DN-76×102×3.2	0	426	459	0.93	CY
RHS-DN-76×102×4.8	0	689	679	1.01	CY
SHS-DH-76×76×4.8	0	1155	1116	1.03	CY
RHS-DH-76×102×3.2	0	653	666	0.98	LB
RHS-DH-76×102×3.2*	0	653	678	0.96	LB
RHS-DH-76×102×4.1	0	1036	1052	0.98	CY
RHS-DH-76×102×4.8	0	1308	1276	1.02	CY
RHS-DH-76×152×4.1	0	1114	1043	1.07	LB
RHS-DH-76×152×4.1*	0	1114	1052	1.06	LB
SHS-IN-102×102×6.4	0	1305	1143	1.14	CY
SHS-IN-102×102×7.9	0	1616	1532	1.05	CY
SHS-IH-80×80×4	0.10	1010	976	1.03	CY
SHS-IH-80×80×4	10.07	773	755	1.02	CY
SHS-IH-80×80×4	18.67	647	618	1.05	CY
SHS-IH-80×80×4	40.33	457	435	1.05	CY
SHS-IH-80×80×4	80.45	293	283	1.04	CY
SHS-IH-120×120×4	0.19	1243	1211	1.03	LB
SHS-IH-120×120×4	4.31	1189	1200	0.99	LB
SHS-IH-120×120×4	11.91	1050	1036	1.01	LB
SHS-IH-120×120×4	29.62	830	788	1.05	LB
SHS-IH-120×120×4	57.91	606	576	1.05	LB
SHS-IH-120×120×4	118.63	379	366	1.03	LB
SHS-IH-140×140×6	0.27	2556	2434	1.05	CY
SHS-IH-140×140×6	13.27	2125	2035	1.04	CY
SHS-IH-140×140×6	35.55	1630	1612	1.01	CY
SHS-IH-140×140×6	68.64	1200	1141	1.05	CY

SHS-IH-140×140×6	100.87	951	824	1.15	CY
RHS-IH-50×100×4	0.06	929	879	1.06	CY
RHS-IH-50×100×4	3.71	760	738	1.03	CY
RHS-IH-50×100×4	8.86	625	608	1.03	CY
RHS-IH-50×100×4	23.06	423	412	1.03	CY
RHS-IH-50×100×4	49.28	265	252	1.05	CY
RHS-IH-50×100×4*	49.54	264	255	1.03	CY
RHS-IH-120×200×5	0.22	1854	1745	1.06	LB
RHS-IH-120×200×5	15.43	1453	1388	1.05	LB
RHS-IH-120×200×5	28.80	1208	1149	1.05	LB
RHS-IH-120×200×5	59.14	871	822	1.06	LB
RHS-IH-120×200×5*	60.10	864	826	1.05	LB
RHS-IH-120×200×5	120.06	560	509	1.10	LB
RHS-IH-100×50×4	0.17	942	903	1.04	CY
RHS-IH-100×50×4	7.91	813	768	1.06	CY
RHS-IH-100×50×4	19.00	670	632	1.06	CY
RHS-IH-100×50×4	39.70	504	473	1.07	CY
RHS-IH-100×50×4	99.09	285	257	1.11	CY
RHS-IH-200×120×5	1.08	1884	1701	1.11	LB
RHS-IH-200×120×5	15.60	1718	1603	1.07	LB
RHS-IH-200×120×5	30.72	1544	1451	1.06	LB
RHS-IH-200×120×5	59.90	1269	1243	1.02	LB
RHS-IH-200×120×5	111.86	948	931	1.02	LB
RHS-IH-200×120×5*	110.58	956	945	1.01	LB
Mean				1.04	
COV				0.04	

*Repeated test

CY: Cross-sectional yielding

LB: Local buckling



(a) (b)

Figure 1.8 Comparison of the failure pattern between the FE model and test specimen for RHS-DN-76×102×3.2-e0 [16]: (a) FE model; (b) Test specimen

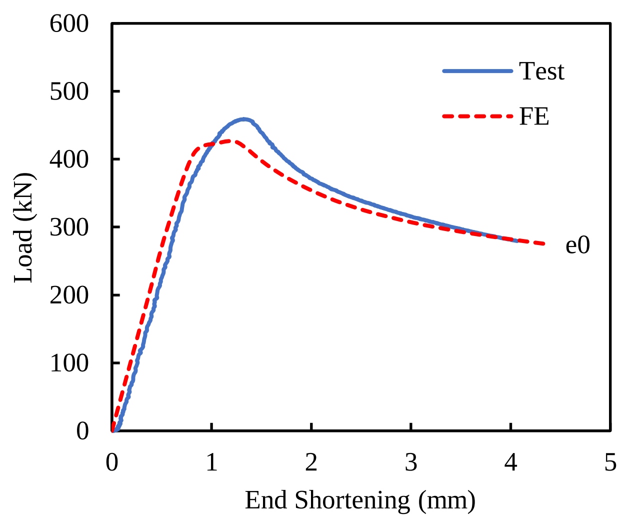
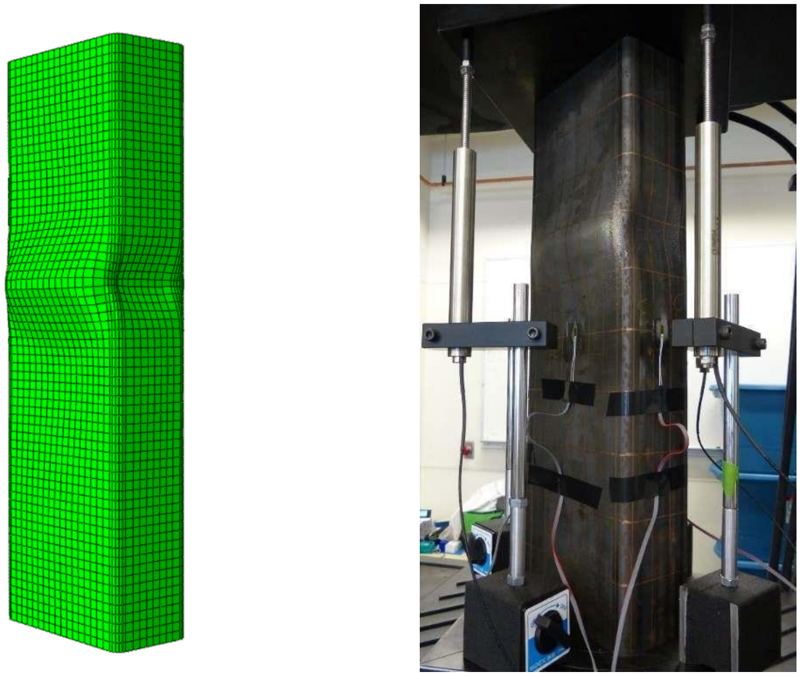


Figure 1.9 Comparison of the End Shortening–Load diagram between the FE model and test specimen for RHS-DN-76×102×3.2-e0



(a) (b)

Figure 1.10 Comparison of the failure pattern between the FE model and test specimen for RHS-DH-76×152×4.1-e0 [16]: (a) FE model; (b) Test specimen

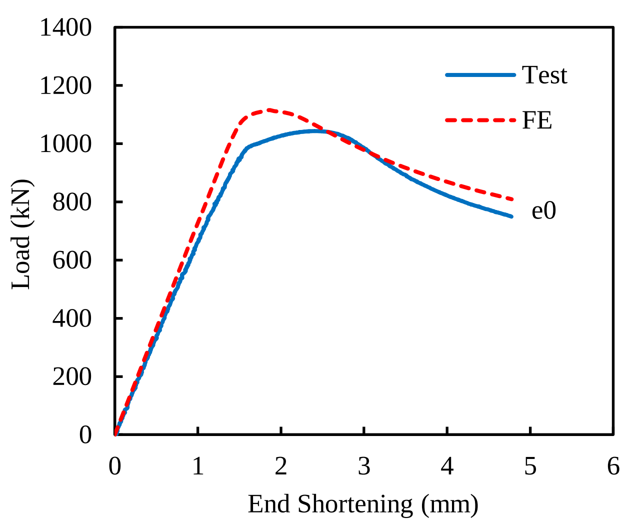
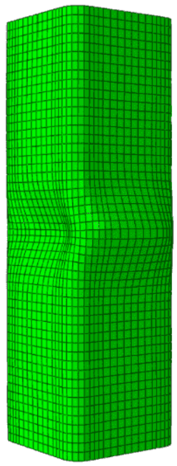
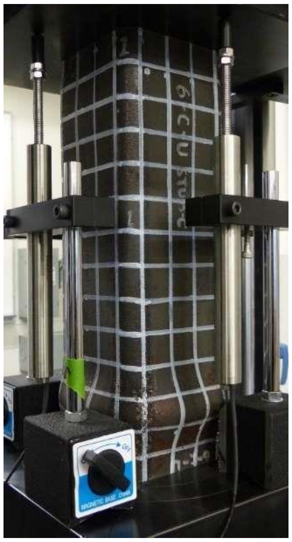


Figure 1.11 Comparison of the End Shortening–Load diagram between the FE model and test specimen for RHS-DH-76×152×4.1-e0





(a) (b)

Figure 1.12 Comparison of the failure pattern between the FE model and test specimen for SHS-IN-102×102×6.4-e0 [12]: (a) FE model; (b) Test specimen

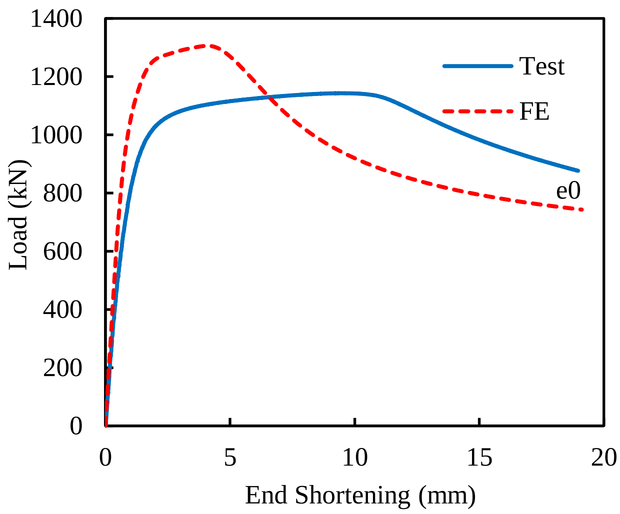


Figure 1.13 Comparison of the End Shortening–Load diagram between the FE model and test specimen for SHS-IN-102×102×6.4-e0

(a) (b)

Figure 1.14 Comparison of the failure pattern between the FE model and test specimen for SHS-IH-120×120×4-e30 [30, 32]: (a) FE model; (b) Test specimen

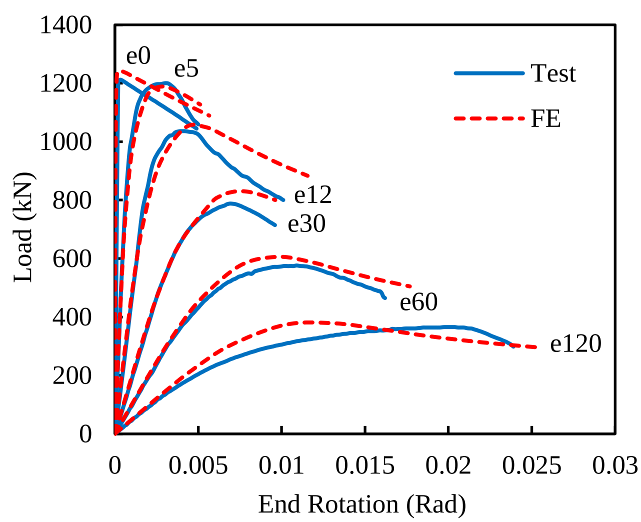


Figure 1.15 Comparison of the End Rotation–Load diagram between the FE model and test specimen for SHS-IH-120×120×4-e0, e5, e12, e30, e60, e120

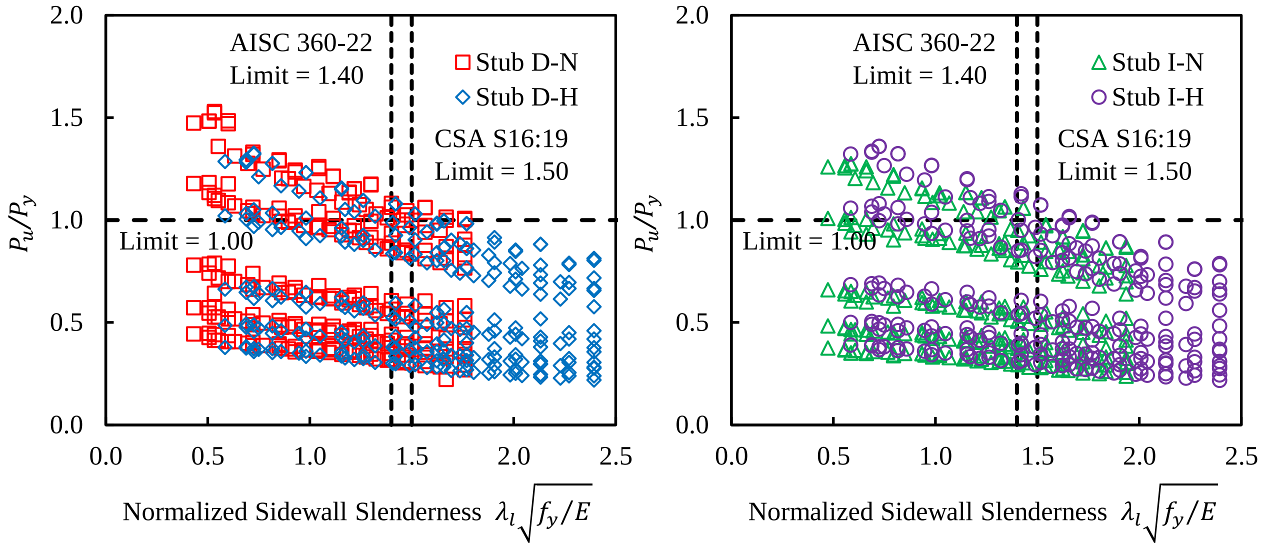
1.4.5 Parametric investigation

A parametric study was conducted on RHS stub beam-columns using the FE modeling approach discussed in Sections 1.4.1–1.4.3, which was validated in Section 1.4.4. A total of 1040 FE models were generated to evaluate the load-bearing capacity of the beam-columns. Identical sets of cross-sections were used across all models, corresponding to both direct- and indirect-formed members, and to steel materials of either normal- or high-strength, as outlined in Sections 1.3.1 and 1.3.2 and shown in Table 1.6. The study considered 20 distinct square hollow sections (SHS) and 16 rectangular hollow sections (RHS), with external dimensions (h and b) ranging from 50 mm to 500 mm and aspect ratios between 1.00 and 2.50. The inner and outer corner radii (r_i and r_o) were defined as the wall thickness (t) and twice the wall thickness ($2t$), respectively. A wide range of cross-section slenderness (λ_l), varying from 9.88 to 40.44, was included to cover all section classes according to CSA S16:19 [1] and AISC 360-22 [22]. To ensure stub behavior and prevent global buckling, each beam-column was assigned a length (L) equal to three times the greater outer cross-sectional dimension. This configuration resulted in global slenderness values lower than the critical limits for global buckling and also lower than those of all specimens listed in Table 1.5, where failure was governed by either cross-sectional yielding or local buckling. Local geometric imperfections (δ_l) of $0.05t$ were introduced in the FE models following the approach described in Section 1.4.3.

To model stub beam-columns under axial compression as well as combined axial compression and uniaxial bending, each square hollow section (SHS) member was subjected to five different loading eccentricities (e) applied along one of its principal axes. In contrast, each rectangular hollow section (RHS) member was subjected to five distinct loading eccentricities along both its major and minor bending axes separately, resulting in a total of 10 loading cases per member (a summary is provided in Table 1.6). Using the same range and number of eccentricities as in [30–32], the applied values were chosen as 0, 0.1, 0.4, 0.7, and 1.0 times the outer dimension of the cross-section along the direction of eccentricity. Each FE beam-column model was statically loaded until failure. The second-order effects (P-Delta) were accounted for by activating geometric nonlinearity (NLGEOM) in Abaqus [49], allowing for the consideration of large deformations and rotations in the analysis. The ultimate load-bearing capacity—defined by the maximum axial compressive load (P_u) and the corresponding bending moment (M_u) at the mid-height section—was then determined by extracting these values from the axial reaction at the support and a section cut at the mid-height of the deformed model, respectively. The corresponding results are presented in Table A.1. Figs. 1.16–1.20 present various normalized cross-section slenderness values plotted versus normalized actions (axial compressive force and bending moment), including the specified slenderness limits according to CSA S16:19 [1] and AISC 360-22 [22].

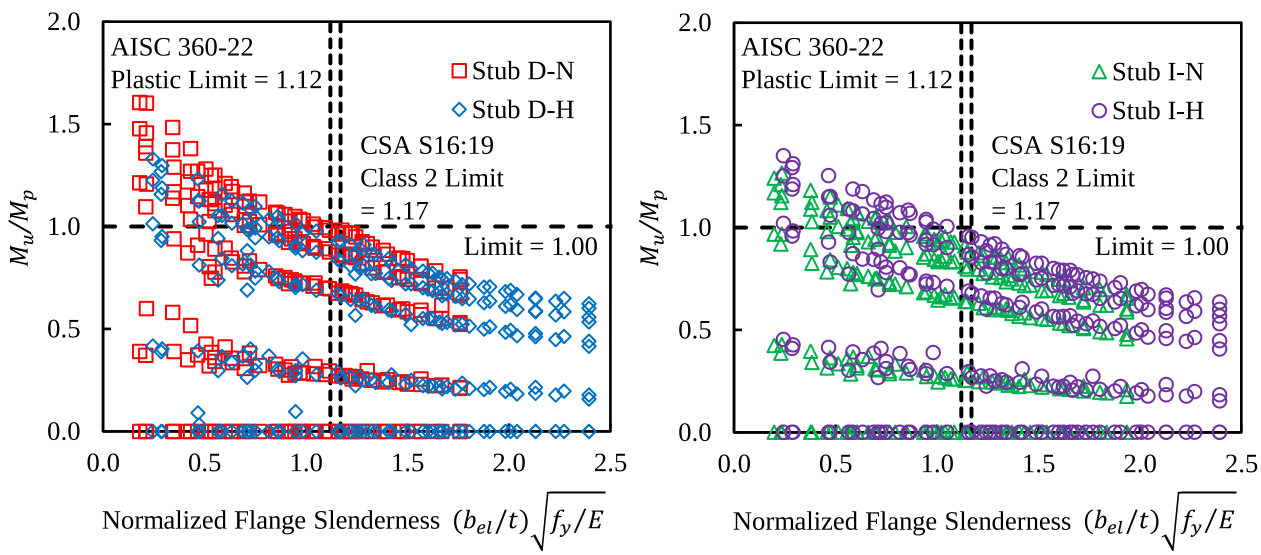
Table 1.6 Description of stub beam-column section groups in the parametric study

Section ID	Cross-section shape	Cold-forming technique	Steel grade	Number of sections	Load cases per section	Total load cases
SHS-DN	Square	Direct-forming	Normal-strength	20	5	100
SHS-DH	Square	Direct-forming	High-strength	20	5	100
SHS-IN	Square	Indirect-forming	Normal-strength	20	5	100
SHS-IH	Square	Indirect-forming	High-strength	20	5	100
RHS-DN	Rectangular	Direct-forming	Normal-strength	16	10	160
RHS-DH	Rectangular	Direct-forming	High-strength	16	10	160
RHS-IN	Rectangular	Indirect-forming	Normal-strength	16	10	160
RHS-IH	Rectangular	Indirect-forming	High-strength	16	10	160
						1040



(a) (b)

Figure 1.16 Normalized sidewall slenderness versus normalized ultimate axial compressive load for different material groups: (a) DN and DH; (b) IN and IH



(a) (b)

Figure 1.17 Normalized flange slenderness versus normalized ultimate bending moment for different material groups: (a) DN and DH; (b) IN and IH

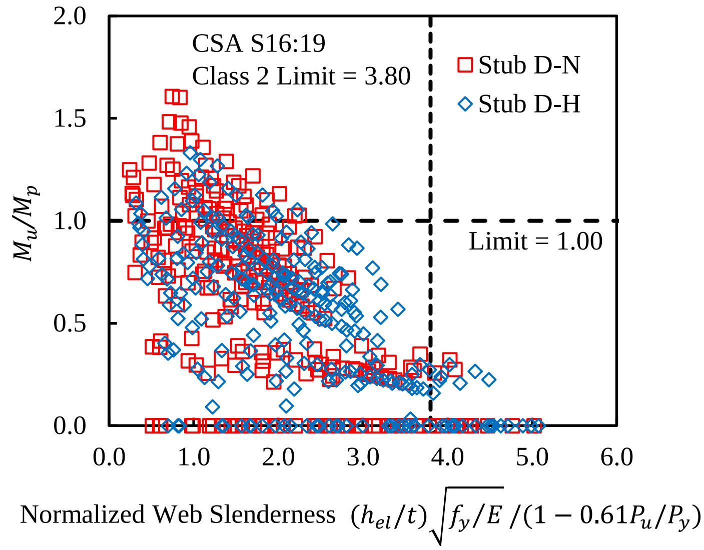


Figure 1.18 Normalized web slenderness versus normalized ultimate bending moment for DN and DH material groups according to CSA S16:19 [1]

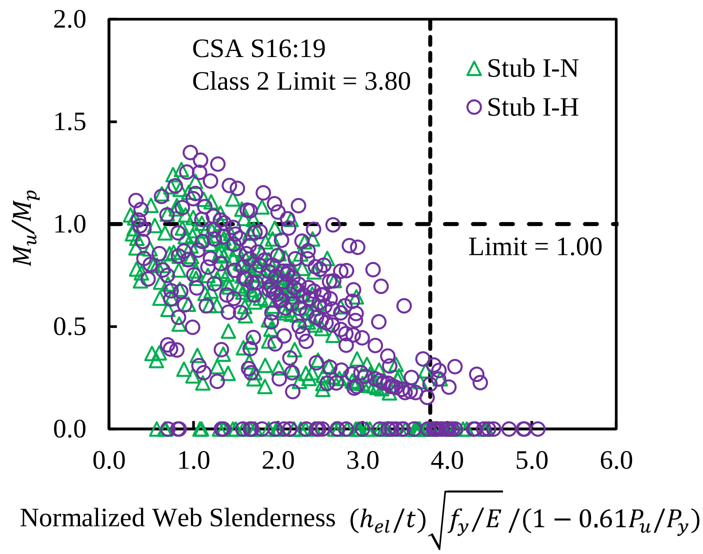


Figure 1.19 Normalized web slenderness versus normalized ultimate bending moment for IN and IH material groups according to CSA S16:19 [1]

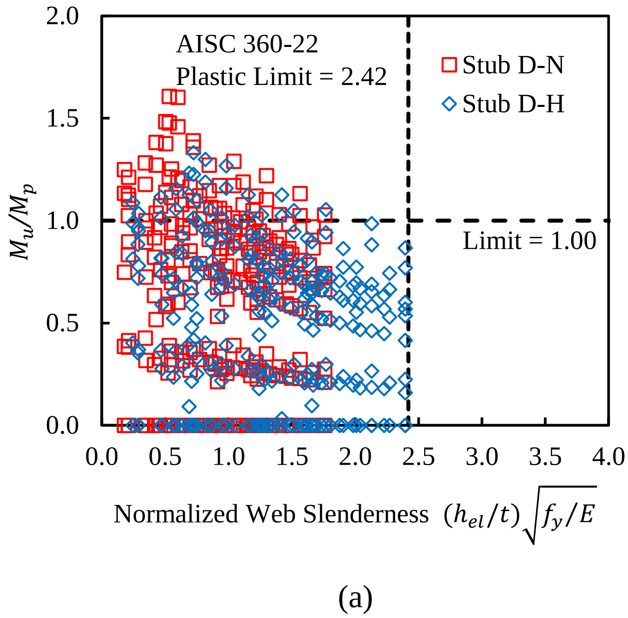
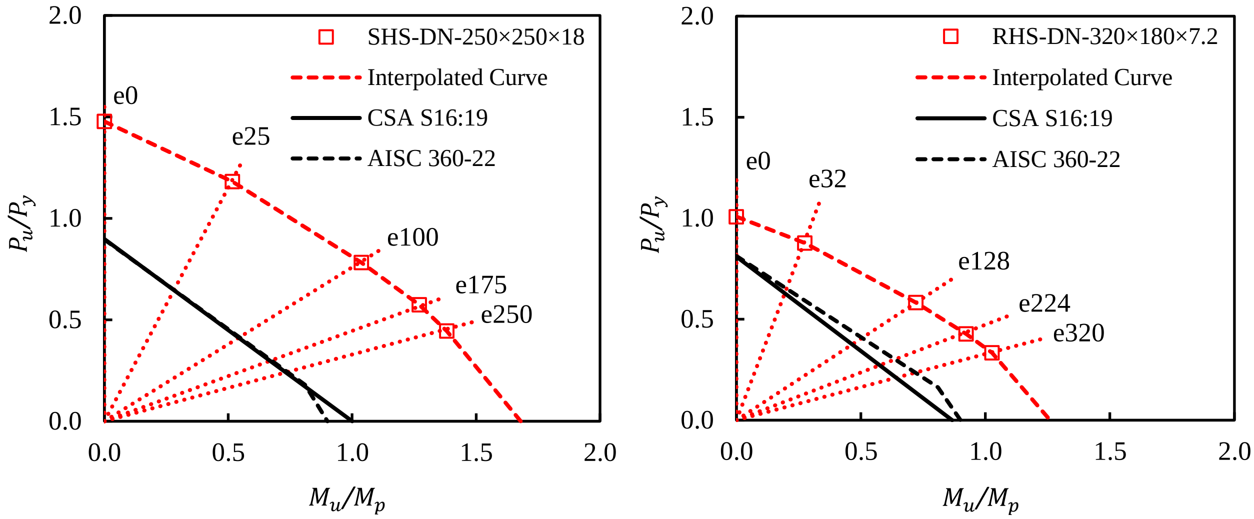


Figure 1.20 Normalized web slenderness versus normalized ultimate bending moment for different material groups according to AISC 360-22 [22]: (a) DN and DH; (b) IN and IH

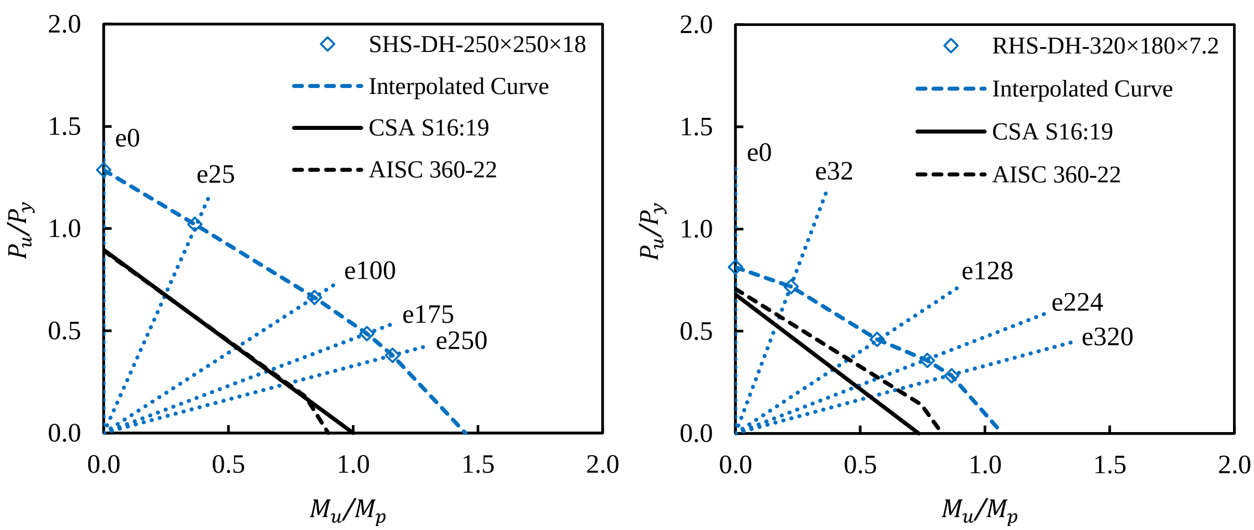
As shown in Figs. 1.16–1.20, a wide range of plate slenderness values was considered for the sidewalls of RHS under axial compression and for the flanges and webs under combined axial compression and flexure. The pattern in all the diagrams indicated a decrease in both axial compressive and flexural capacities as the cross-section slenderness increased. As observed in Fig. 1.16 and consistent with the findings in [16], the capacities of all members with normalized sidewall slenderness values exceeding 1.50—matching the limit specified by CSA S16:19 [1]—were governed by local buckling. Furthermore, as evident from the comparison of Fig. 1.17 with Figs. 1.18–1.20, the flexural capacity of the stub beam-columns was primarily governed by the flanges. This observation aligns with the design provisions of CSA S16:19 [1] and AISC 360-22 [22], which impose considerably more stringent slenderness limits on flanges than on webs. Further discussion is provided in Section 1.5. A series of interaction curves illustrating the relationship between the normalized flexural and axial compressive capacities of the stub beam-columns is presented in Figs. 1.21–1.24 for different material groups. These include a series of discrete data points corresponding to specific eccentricity values, as well as interpolated interaction curves—constructed using line segments—for members with the lowest and highest sidewall slenderness values (i.e., λ_l = 9.88 and λ_l = 40.44), along with the corresponding design interaction curves from CSA S16:19 [1] and AISC 360-22 [22] for comparison.



(a) (b)

Figure 1.21 Interaction curves for DN stub beam-columns:

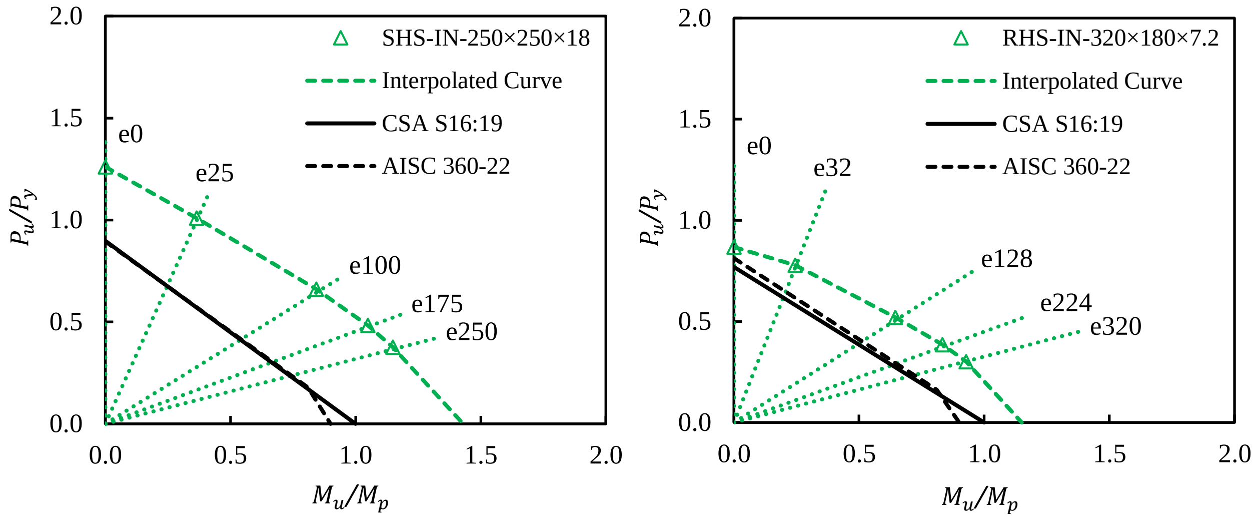
(a) with the lowest sidewall slenderness; (b) with the highest sidewall slenderness



(a) (b)

Figure 1.22 Interaction curves for DH stub beam-columns:

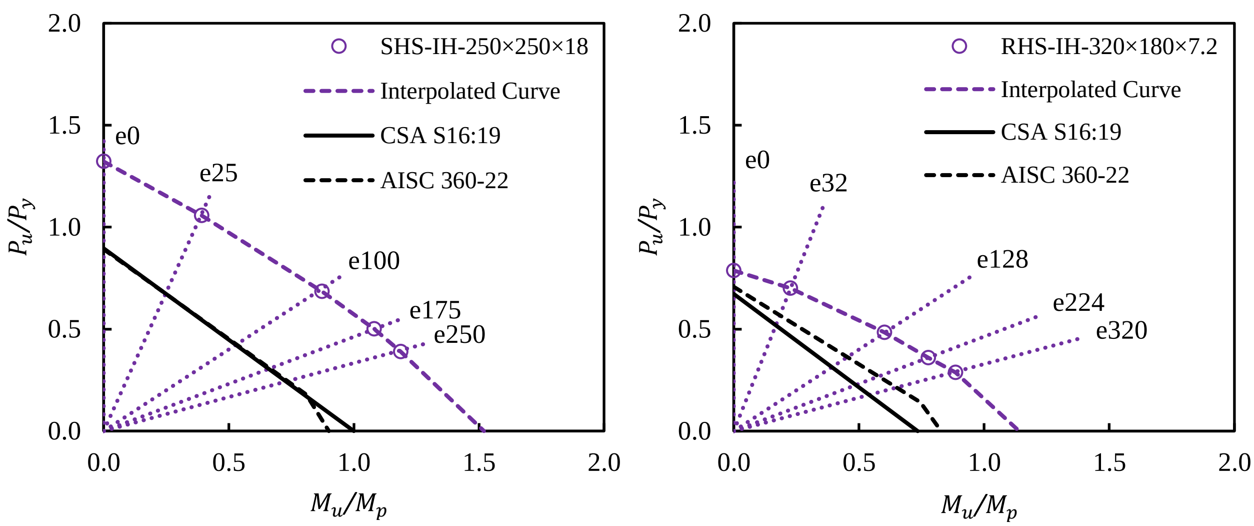
(a) with the lowest sidewall slenderness; (b) with the highest sidewall slenderness



(a) (b)

Figure 1.23 Interaction curves for IN stub beam-columns:

(a) with the lowest sidewall slenderness; (b) with the highest sidewall slenderness



(a) (b)

Figure 1.24 Interaction curves for IH stub beam-columns:

(a) with the lowest sidewall slenderness; (b) with the highest sidewall slenderness

As shown in Figs. 1.21–1.24, an increase in normalized axial compressive capacity (P_u/P_y) was accompanied by a decrease in normalized flexural capacity (M_u/M_p), and vice versa. Additionally, as cross-section slenderness increased within each material group, both normalized pure axial compressive and flexural capacities decreased, leading to curves with lower maximum P_u/P_y and M_u/M_p values. The actual interaction behaviour was inherently nonlinear but was approximated using piecewise linear interpolation between discrete data points. CSA S16:19 [1] and AISC 360-22 [22] employ formulations corresponding to linear and bilinear interaction patterns, respectively, when explicitly accounting for P-Delta effects, as detailed in Sections 1.5.1 to 1.5.3. As part of these formulations, the maximum axial compression is limited to the cross-section yield load (P_y), and the maximum flexural capacity to the plastic moment (M_p). These limit values are typically calculated using the flat face yield strength (f_y) applied uniformly across the entire section—an approach commonly adopted by both standards. However, in practice, cold-formed sections often exhibit elevated yield strengths at the corners due to residual stresses, which can lead to ultimate axial compressive loads (P_u) and bending moments (M_u) exceeding the nominal limits defined by the standards (P_y and M_p). As a result, the interpolated interaction curves indicated enhanced capacities compared to those prescribed by the standards.

1.5 Existing design provisions

1.5.1 Background

Unlike beams and columns, stub beam-columns are often subjected to significant levels of both axial compression and bending simultaneously. As a result, these members do not achieve the ultimate load-bearing capacity of beams and columns. Due to the complexity of predicting the combined capacity, design standards typically suggest a simplified approach based on a set of interaction relations between axial compression and flexure. Both CSA S16:19 [1] and AISC 360-22 [22] employ the interaction format shown in Eq. 1.11. While CSA S16:19 [1] adopts it as a consistently single-phase formulation, AISC 360-22 [22] incorporates it into a two-phase design approach, as detailed in Sections 1.5.2 and 1.5.3.

$$\alpha_1 \frac{P_f}{P_r} + \alpha_2 \frac{M_f}{M_r} \leq 1.0 \tag{1.11}$$

α_1 and α_2 are the coefficients of axial compression and flexure, respectively, and vary between the two standards. P_f and M_f represent the factored axial compressive load and the factored uniaxial bending moment. Similarly, P_r and M_r denote the factored nominal axial compressive and flexural capacities, corresponding to pure column and beam behaviour, respectively. These are calculated by multiplying the corresponding unfactored capacities by a resistance factor ($P_r = \phi P_n$ and $M_r = \phi M_n$). By substituting the factored axial compressive load and the factored uniaxial bending moment with their corresponding ultimate values (P_u and M_u), the inequality in Eq. 1.11 is ideally transformed into an equation where the right-hand side equals 1.0 (see Eq. 1.12).

$$\alpha_1 \frac{P_u}{P_r} + \alpha_2 \frac{M_u}{M_r} = 1.0 \tag{1.12}$$

1.5.2 CSA S16:19

The factored nominal axial compressive capacity ($P_{r,\ CSA}$) is determined by multiplying the unfactored nominal axial compressive capacity ($P_{n,\ CSA}$) by the resistance factor (ϕ) of 0.90, in accordance with Clause 13.3 of CSA S16:19 [1]. Similarly, the factored nominal flexural capacity ($M_{r, CSA}$) is calculated by multiplying the unfactored nominal flexural capacity ($M_{n, CSA}$) by the same resistance factor, following the provisions of Clauses 13.5 and 13.6. For RHS members subjected to axial compression and biaxial bending, a set of interaction equations is provided in Clauses 13.8.3 and 13.8.4. The members were classified into two categories: (1) those with sidewalls classified as Classes 1 and 2, and (2) those with sidewalls classified as Classes 3 and 4. To simplify the formulation while maintaining consistency with the scope of this study, the interaction of axial compression and biaxial bending was reduced to axial compression and uniaxial bending by assuming the out-of-plane bending component to be zero. Eq. 1.13 presents the interaction relation for members with sidewalls of Classes 1 and 2, while Eq. 1.14 applies to those with sidewalls of Classes 3 and 4. In Eqs. 1.13 and 1.14, the bending moment is treated as a first-order action, which is subsequently adjusted to a second-order action (considering P-Delta effects) using the U_1 coefficient specified in Clause 13.8.5. However, in the parametric investigation presented in Section 1.4.5, the second-order bending moment was directly obtained by accounting for geometric nonlinearity and using the deformed shape to extract the bending moment values, with U_1 set to 1.0.

$$\frac{P_f}{P_{r,\ CSA}} + \frac{0.85 U_1 M_f}{M_{r,\ CSA}} \leq 1.0 \tag{1.13}$$

$$\frac{P_f}{P_{r,\ CSA}} + \frac{U_1 M_f}{M_{r,\ CSA}} \leq 1.0 \tag{1.14}$$

1.5.3 AISC 360-22

The factored nominal axial compressive capacity ($P_{r,\ AISC}$) and the factored nominal flexural capacity ($M_{r,\ AISC}$) of RHS members are determined from their corresponding unfactored capacities ($P_{n,\ AISC}$ and $M_{n,\ AISC}$) using a resistance factor of 0.90, as per Chapters E and F of AISC 360-22 [22]. The design standard employs the Load and Resistance Factor Design (LRFD) approach, which defines a set of limit states. The design is governed by the limit state with the lowest load-bearing capacity. For RHS members, the axial compression limit states generally include flexural, torsional, and flexural-torsional buckling. Likewise, the flexural limit states involve yielding (plastic moment), flange local buckling, web local buckling, and lateral-torsional buckling. Section H1 of AISC 360-22 [22] provides a two-phase interaction equation based on the ratio of the factored axial compressive load (P_f) to the factored nominal axial compressive capacity ($P_{r,\ AISC} = \phi P_{n,\ AISC}$). The original interaction equations consider axial compression and biaxial bending. However, to maintain simplicity and ensure consistency with the scope of this study, the formulation was reduced to axial compression and uniaxial bending by assuming the out-of-plane bending component to be zero. Accordingly, members are divided into two groups based on their axial compression ratios: (1) those with ratios equal to or greater than 0.2, which follow the relationship in Eq. 1.15; and (2) those with ratios less than 0.2, which follow the relationship in

Eq. 1.16. This formulation reflects a simplified bilinear approximation of the interaction curves, directly accounting for P-Delta effects, as discussed in Section 1.4.5. The 0.2 threshold marks a shift in beam-column behaviour, below which the slope of the second line segment increases noticeably, and flexural effects become more prominent (see Figs. 1.21–1.24).

$$\text{When } \frac{P_f}{P_{r,\,AISC}} \geq 0.2 \qquad \frac{P_f}{P_{r,\,AISC}} + \frac{8}{9}\frac{M_f}{M_{r,\,AISC}} \leq 1.0 \tag{1.15}$$

$$\text{When } \frac{P_f}{P_{r,\,AISC}} < 0.2 \qquad \frac{P_f}{2P_{r,\,AISC}} + \frac{M_f}{M_{r,\,AISC}} \leq 1.0 \tag{1.16}$$

1.5.4 Cross-section slenderness limits

To determine the cross-section slenderness of RHS members (λ_l), the flat face dimensions excluding the outer corner radii (h_{el} and b_{el}) and sidewall thickness (t) are considered. Cross-section slenderness is defined as the ratio of the flat face dimensions to the wall thickness ($\lambda_l = h_{el}/t$ and $\lambda_l = b_{el}/t$). In cases where corner radii measurements are unavailable, CSA S16:19 [1] recommends approximating the flat face dimensions as the external dimensions minus three times the wall thickness ($h_{el} = h$-$3t$ and $b_{el} = b$-$3t$), whereas AISC 360-22 [22] suggests using four times the wall thickness ($h_{el} = h$-$4t$ and $b_{el} = b$-$4t$).

Both CSA S16:19 [1] and AISC 360-22 [22] establish cross-section limits for members under axial compression, and for members subjected to flexure or combined axial compression and flexure. For pure axial compression, both standards classify the entire RHS section (i.e., non-slender or slender) based on the dimension of its larger flat face. Sidewalls with slenderness values less than or equal to λ_r are categorized as non-slender, while those exceeding this limit are considered slender. For members subjected to flexure or combined axial compression and flexure, flanges and webs are classified separately, and the higher classification governs the overall section class. CSA S16:19 [1] defines three slenderness limits (λ_{C1}, λ_{C2}, λ_{C3}) and four section classes (Classes 1, 2, 3, 4). In contrast, AISC 360-22 [22] specifies two slenderness limits (λ_p, λ_r) and three section classes (compact, non-compact, and slender). In AISC 360-22 [22], the slenderness limits for both flanges and webs of members under flexure or combined loading are independent of the applied axial load. However, in CSA S16:19 [1], while flange slenderness limits remain unaffected by axial load, web slenderness limits depend on axial load values. The normalized slenderness limits outlined in both standards are summarized in Tables 1.7–1.9 (overview provided in Figs. 1.16–1.20).

Table 1.7 Slenderness limits for RHS sidewalls subjected to axial compression in the existing standards

Design standard	Element description	Normalized slenderness $\bar{\lambda}_l$	Normalized slenderness limit $\bar{\lambda}_r$
CSA S16:19 [1]	Flanges of RHS	$(b_{el}/t)\sqrt{f_y/E}$	1.50
	Webs of RHS	$(h_{el}/t)\sqrt{f_y/E}$	1.50
AISC 360-22 [22]	Flanges of RHS	$(b_{el}/t)\sqrt{f_y/E}$	1.40
	Webs of RHS	$(h_{el}/t)\sqrt{f_y/E}$	1.40

Table 1.8 Slenderness limits for RHS flanges and webs subjected to axial compression and flexure in CSA S16:19 [1]

Element description	Normalized slenderness	Normalized slenderness limits		
	$\bar{\lambda}_l$	$\bar{\lambda}_{C1}$	$\bar{\lambda}_{C2}$	$\bar{\lambda}_{C3}$
Flanges of RHS	$(b_{el}/t)\sqrt{f_y/E}$	0.94	1.17	1.50
Webs of RHS, Class 1	$(h_{el}/t)\sqrt{f_y/E}\,/(1-0.39P_u/P_y)$	2.46	—	—
Webs of RHS, Class 2	$(h_{el}/t)\sqrt{f_y/E}\,/(1-0.61P_u/P_y)$	—	3.80	—
Webs of RHS, Class 3	$(h_{el}/t)\sqrt{f_y/E}\,/(1-0.65P_u/P_y)$	—	—	4.25

Table 1.9 Slenderness limits for RHS flanges and webs subjected to axial compression and flexure in AISC 360-22 [22]

Element description	Normalized slenderness	Normalized slenderness limits	
	$\bar{\lambda}_l$	$\bar{\lambda}_p$	$\bar{\lambda}_r$
Flanges of RHS	$(b_{el}/t)\sqrt{f_y/E}$	1.12	1.40
Webs of RHS	$(h_{el}/t)\sqrt{f_y/E}$	2.42	5.70

As shown in Table 1.7, CSA S16:19 [1] specifies a higher cross-section slenderness limit for members under axial compression compared to AISC 360-22 [22] ($\bar{\lambda}_r$ = 1.50 vs. $\bar{\lambda}_r$ = 1.40). Additionally, as presented in Tables 1.8 and 1.9, both standards specify similar flange slenderness limits for the highest slenderness class—Class 4 in CSA S16:19 [1] and slender in AISC 360-22 [22]—where local buckling governs ($\bar{\lambda}_{C3}$ = 1.50 vs. $\bar{\lambda}_r$ = 1.40). Under the combined effects of axial compression and flexure due to eccentric loading, the compressive flanges of RHS experience the highest compressive stresses. Hence, the mechanical behaviour of the models is predominantly governed by the compressive flanges. Consequently, both standards specify higher slenderness limits on the webs than for flanges. However, CSA S16:19 [1] imposes a lower and stricter slenderness limit on the webs of the highest slenderness class than AISC 360-22 [22] ($\bar{\lambda}_{C3}$ = 4.25 vs. $\bar{\lambda}_r$ = 5.70), resulting in more conservative capacity predictions. Studies on direct-formed [16–18, 21] and indirect-formed RHS members [28–32] indicated that the existing cross-section slenderness limits in these standards may be overly conservative in predicting the load-bearing capacities, particularly for direct-formed beams with flanges classified as Class 4 or slender when flange buckling governs.

1.5.5 Effective width method

Cross-section slenderness significantly influences the axial compressive and flexural capacities of RHS stub beam-columns. As cross-section slenderness increases, members become less capable of achieving their full cross-section yield capacity, and the local buckling effects become more prominent. According to existing design standards, stub columns with non-slender sidewalls subjected to axial compression reach the full cross-section yield capacity (P_y). For stub beams with stocky elements—where flanges and webs are classified as Class 1 or 2 in CSA S16:19 [1] and as compact in AISC 360-22 [22]—the plastic moment capacity ($M_p = Zf_y$, where Z is the plastic section modulus) is fully developed under flexure. Additionally, CSA S16:19 [1] specifies that beams with Class 3 elements have a flexural capacity equal to the yield moment capacity ($M_y = Sf_y$, where S is the elastic section modulus). In contrast, AISC 360-22 [22] applies a linear interpolation between the plastic and yield moment capacities for beams with flanges or webs classified as non-compact, as shown in Eq. 1.17.

$$M_{n,\,AISC} = M_p - \left(M_p - M_y\right)\left(\frac{\lambda_l - \lambda_p}{\lambda_r - \lambda_p}\right) \le M_p \tag{1.17}$$

In this equation, λ_l denotes the flange or web slenderness; λ_p and λ_r represent the compact/non-compact and non-compact/slender limits, respectively, as defined in AISC 360-22 [22].

The load-bearing capacity of stub beam-columns with flanges or webs classified as Class 4 or slender is primarily governed by local buckling. These members are unable to develop their full cross-sectional yield or yield moment capacities. Accurately predicting the axial compressive or flexural capacity of these members demands a detailed understanding of the complex mechanism of local buckling, which becomes particularly challenging under combined loading. Therefore, design standards such as CSA S16:19 [1] and AISC 360-22 [22] recommend a simplified approach known as the effective width method. This method accounts for local buckling effects by reducing the dimensions of slender sidewalls to effective values, indirectly lowering the section's axial compressive and flexural capacities in a way that reflects the actual reductions caused by local buckling. The method is typically applied separately for members subjected to pure axial compression (columns) or pure flexure (beams). However, for beam-columns, a mixed application is used to evaluate their axial compressive and flexural capacities (P_n and M_n, respectively) under combined loading: first using the column provisions to determine P_n, and then using the beam provisions to determine M_n.

According to the provisions of CSA S16:19 [1], the dimensions of all slender sidewalls of members under pure axial compression are reduced to effective widths (b_e) and depths (h_e), ensuring that the new sidewall slenderness is reduced to the specified slenderness limit (λ_r). In the case of flexure, compressive flanges and webs classified as Class 4 are reduced to effective widths and heights to achieve slenderness values equal to the specified Class 3 limit (λ_{C3}). The effective cross-section parameters are then used to calculate the axial compressive and flexural capacities of the member, following the same procedure as for Class 3 elements (e.g, for flexural capacity, $M_{n,\,CSA} = S_e f_y$, where S_e is the effective elastic section modulus). Alternatively, AISC 360-22 [22] adopts a different approach for determining effective widths. In accordance with Section E7 of AISC 360-22 [22], which addresses the design of members with slender elements under axial compression, the effective width of RHS sidewalls is determined using Eqs. 1.18 and 1.19.

$$\text{When } \lambda_l \le \lambda_r \sqrt{\frac{f_y}{f_n}} \qquad b_e = b_{el} \tag{1.18}$$

$$\text{When } \lambda_l > \lambda_r \sqrt{\frac{f_y}{f_n}} \qquad b_e = b_{el}\left(1 - 0.20\sqrt{\frac{f_{el}}{f_n}}\right)\sqrt{\frac{f_{el}}{f_n}} \tag{1.19}$$

In the above equations, b_e and b_{el} denote the effective width and the internal flange width, excluding the corner portions, respectively. Similarly, h_e and h_{el} can be used when webs are considered, representing the effective depth and internal web depth, excluding the corner portions, correspondingly. λ_l denotes the sidewall slenderness, λ_r represents the non-slender/slender limit, f_{el} indicates the elastic local buckling stress determined in Section E7, and f_n corresponds to the nominal stress determined in Section E3. In accordance with Section F7 of AISC 360-22 [22], which covers the design of RHS members under flexure, the effective width of slender compression flanges is calculated using Eq. 1.20.

$$b_e = 1.92t\sqrt{\frac{E}{f_y}}\left(1 - \frac{0.38}{b_{el}/t}\sqrt{\frac{E}{f_y}}\right) \le b_{el} \tag{1.20}$$

The flexural capacity of the RHS beam is then determined using the effective elastic section modulus (i.e., $M_{n, AISC} = S_e f_y$).

According to Section 1.4.5 and as shown in Figs. 1.16–1.20, although a wide range of sections and sidewall slenderness values were considered, all the webs of the RHS members were classified as compact according to the definitions in AISC 360-22 [22]. The findings of this study suggested that the flexural behavior of the beam-columns was predominantly governed by the flanges. Therefore, no conclusions can be drawn regarding the effects of the webs on the behavior of RHS beam-columns in this research. The study in [18] investigated a variety of direct-formed RHS beams, including those with non-compact webs. The studies in [16, 50] also examined the safety and reliability of the existing effective width method in CSA S16:19 [1] and AISC 360-22 [22], proposing some modifications to the effective width method formulas.

1.5.6 Reliability analysis

To assess the reliability of the current Canadian and American design standards, a series of reliability analyses was conducted based on the North American Specification for the Design of Cold-Formed Steel Structural Members (AISI S100-16) [23]. These analyses were performed for both CSA S16:19 [1] and AISC 360-22 [22] by calculating a reliability index (β_0) in accordance with AISI S100-16 [23], as shown in Eq. 1.21.

$$\beta_0 = \frac{\ln(C_\phi M_m F_m P_m / \phi)}{\sqrt{V_M^2 + V_F^2 + C_P V_P^2 + V_Q^2}} \tag{1.21}$$

In Eq. 1.21, the calibration coefficient (C_ϕ) was set to 1.42 for the reliability analysis in CSA S16:19 [1], as recommended by AISI S100-16 [23] for the Limit State Design (LSD) approach. For AISC 360-22 [22], this value was taken as 1.52, reflecting the recommendation for the Load and Resistance Factor Design (LRFD) approach. In line with the same reference, the mean and coefficient of variation (COV) of the material factors, denoted as M_m and V_M, were assumed to be 1.10 and 0.10, respectively. For fabrication effects, the mean and COV of the fabrication factor, denoted as F_m and V_F, were assumed to be 1.00 and 0.05. The mean and COV of the axial compression and flexure interaction term, presented on the left side of Eq. 1.12 ($\alpha_1 P_u/P_n$ + $\alpha_2 M_u/M_n$), were calculated to represent the mean (P_m) and COV (V_P) of the FE capacities relative to the code-predicted capacities. A correction factor, noted as C_P, was used to account for the effects of data size, as recommended by AISI S100-16 [23], shown in Eq. 1.22. The resistance factor (ϕ) was taken as 0.90 in both standards to convert unfactored nominal capacities to the corresponding factored capacities. Furthermore, to account for the COV of load effects, the parameter V_Q was introduced. This parameter depends solely on the applied loads, which can vary across different load combinations. CSA S16:19 [1] adopts the load combination 1.25DL + 1.5LL, while AISC 360-22 [22] specifies 1.2DL + 1.6LL, where DL and LL represent dead loads and live loads, respectively. The differences can influence the value of V_Q, which in turn impacts the safety margins and reliability. However, in line with the recommendation in AISI S100-16 [23], V_Q was taken as 0.21 for both CSA S16:19 [1] (LSD) and AISC 360-22 [22] (LRFD). The target reliability index (β_0) serves as a measure of safety, reliability, and performance of structural elements and can vary depending on the standard provisions and applications. As per the recommendations of AISI S100-16 [23], the target reliability indices were assumed to be 3.00 for CSA S16:19 [1] and 2.60 for AISC 360-22 [22]. Tables 1.10 and 1.11 present these values for each of the existing design standards.

$$C_P = (1 + 1/n')m'/(m' - 2) \qquad \text{for } n' \geq 4 \tag{1.22}$$

In Eq. 1.22, C_P is the correction factor, n' represents the data size, and m' denotes the degrees of freedom which is equal to $n' - 1$.

Table 1.10 Reliability analysis parameters for CSA S16:19 [1] and AISC 360-22 [22] for all material groups and categories

Design standard	Parameters						
	C_ϕ	M_m	F_m	V_M	V_F	V_Q	ϕ
CSA S16:19 [1]	1.42	1.10	1.00	0.10	0.05	0.21	0.90
AISC 360-22 [22]	1.52	1.10	1.00	0.10	0.05	0.21	0.90

Table 1.11 Reliability analysis parameters for CSA S16:19 [1] and AISC 360-22 [22] for different material groups and categories

Design standard	Material	Category	Parameters for the linear interaction: $\alpha_1 P_u/P_n + \alpha_2 M_u/M_n$							
			α_1	α_2	n'	m'	C_P	P_m	V_P	β_0
CSA S16:19 [1]	All	Class 1, 2	1.00	0.85	512	511	1.01	1.29	0.11	3.07
	All	Class 3, 4	1.00	1.00	528	527	1.01	1.20	0.10	2.86
	DN, DH	Class 1, 2	1.00	0.85	266	265	1.01	1.32	0.13	3.09
	DN, DH	Class 3, 4	1.00	1.00	254	253	1.01	1.21	0.09	2.91
	IN, IH	Class 1, 2	1.00	0.85	246	245	1.01	1.26	0.09	3.08
	IN, IH	Class 3, 4	1.00	1.00	274	273	1.01	1.20	0.10	2.81
AISC 360-22 [22]	All	$P_u/(\phi P_n) \geq 0.2$	1.00	0.89	1040	1039	1.00	1.22	0.13	3.02
	DN, DH	$P_u/(\phi P_n) \geq 0.2$	1.00	0.89	520	519	1.01	1.25	0.14	3.04
	IN, IH	$P_u/(\phi P_n) \geq 0.2$	1.00	0.89	520	519	1.01	1.20	0.11	3.03

As evident by the reliability indices (β_0), the current design provisions in both codes ensure conservative levels of reliability for most materials and categories. For CSA S16:19 [1], the indirect-formed members with sidewalls of Classes 3 and 4 exhibited the lowest reliability index of 2.81. In contrast, the direct-formed members with sidewalls of Classes 1 and 2 achieved the highest reliability index of 3.09, exceeding the proposed target of 3.00. For AISC 360-22 [22], all the analyses yielded excessively conservative results, with reliability indices slightly above 3.00, surpassing the target value of 2.60. Overall, direct-formed RHS stub beam-columns exhibited slightly higher reliability indices compared to their indirect-formed counterparts, demonstrating a marginally greater actual load-bearing capacity. Moreover, the current interaction formulas in CSA S16:19 [1] proved less reliable for members with sidewalls of Classes 3 and 4, compared to those with sidewalls of Classes 1 and 2. Additionally, the interaction formula for beam-columns with an axial compressive utilization of 20% or greater—applicable to all stub beam-column models in this study due to the absence of sufficiently large eccentricities—was found to be highly conservative in AISC 360-22 [22].

1.6 Proposed design modifications

1.6.1 Modification of the slenderness limits

The study in [16] showed that the cross-section slenderness limit for RHS members under axial compression in CSA S16:19 [1] provides a more accurate prediction of the behavior of direct-formed, untreated RHS members than that in AISC 360-22 [22]. In line with the findings of [16], and consistent with the current practice in both CSA S16:19 [1] and AISC 360-22 [22]—where the same slenderness limit is applied to both the flanges of the highest slenderness class and the sidewalls under pure axial compression—it is proposed that the corresponding CSA S16:19 [1] limit ($\bar{\lambda}_r$ = 1.50) also be adopted in AISC 360-22 [22] for direct-formed RHS members. Table 1.12 presents the proposed modified slenderness limits for the sidewalls of direct-formed RHS under axial compression, as well as for the flanges under combined axial compression and flexure, in AISC 360-22 [22].

Table 1.12 Proposed modified slenderness limits for the sidewalls and flanges of direct-formed RHS in AISC 360-22 [22]

Element description	Normalized slenderness	Normalized slenderness limits	
	$\bar{\lambda}_l$	$\bar{\lambda}_p$	$\bar{\lambda}_r$
Sidewalls of RHS	$(b_{el}/t)\sqrt{f_y/E}$	—	1.50
Sidewalls of RHS	$(h_{el}/t)\sqrt{f_y/E}$	—	1.50
Flanges of RHS	$(b_{el}/t)\sqrt{f_y/E}$	1.12	1.50

1.6.2 Modification of the interaction coefficients

As discussed in Sections 1.5.1–1.5.3, the general procedure for determining the load-bearing capacity of stub beam-columns involves the use of coefficients (α_1 and α_2) in the interaction formulas shown in Eqs. 1.11–1.16 and Table 1.11. Reliability analyses of the existing standards, presented in Table 1.11, yielded a series of reliability indices (β_0) that differed from the target reliability indices recommended by CSA S16:19 [1] (β_0 = 3.00) and AISC 360-22 [22] (β_0 = 2.60). To achieve the recommended target reliability indices, a set of modified interaction coefficients is proposed (see Table 1.13), along with the modified cross-section slenderness limits discussed in Section 1.6.1. The coefficient for the axial compression term (α_1) is assumed to be 1.00 to meet the design requirements when the axial load is applied concentrically. A series of reliability analyses is conducted for the FE models with the proposed modifications in Section 1.6.3.

1.6.3 Reliability analysis

Following the general procedure discussed in Section 1.5.6 and using the same parameter values presented in Table 1.10, a series of reliability analyses is carried out for the FE models with the modified design provisions discussed in Sections 1.6.1 and 1.6.2. The modified interaction coefficients were set to achieve reliability indices that meet or slightly exceed the target values, avoiding excessive design conservatism. Table 1.13 presents the corresponding results, including the modified interaction coefficient values (α_1 and α_2) and target reliability indices (β_0).

Table 1.13 Reliability analysis results for the proposed modifications in CSA S16:19 [1] and AISC 360-22 [22]

Design standard	Material	Category	Parameters for the linear interaction: $\alpha_1 P_u/P_n + \alpha_2 M_u/M_n$							
			α_1	α_2	n'	m'	C_P	P_m	V_P	β_0
CSA S16:19 [1]	DN, DH	Class 1, 2	1.00	0.80	266	265	1.01	1.29	0.12	3.02
	DN, DH	Class 3, 4	1.00	1.15	254	253	1.01	1.30	0.13	3.00
	IN, IH	Class 1, 2	1.00	0.81	246	245	1.01	1.24	0.09	3.01
	IN, IH	Class 3, 4	1.00	1.50	274	273	1.01	1.47	0.20	3.01
AISC 360-22 [22]	DN, DH	$P_u/(\phi P_n) \geq 0.2$	1.00	0.66	520	519	1.01	1.10	0.14	2.62
	IN, IH	$P_u/(\phi P_n) \geq 0.2$	1.00	0.67	520	519	1.01	1.07	0.11	2.60

1.7 Conclusions

The existing North American steel design standards (CSA S16:19 [1] and AISC 360-22 [22]) do not account for the differences between the RHS stub members manufactured through different cold-forming techniques (i.e., direct-forming and indirect-forming). In this study, a comprehensive finite element (FE)-based numerical investigation was conducted on a total of 1040 cold-formed, untreated RHS stub beam-columns. A wide range of cross-sectional geometries and slenderness levels was considered, with nominal steel yield strengths ranging from 350 MPa to 700 MPa, involving both direct- and indirect-forming techniques. The ultimate axial compressive and flexural load-bearing capacities of the members were extracted and assessed using the interaction formulations specified in CSA S16:19 [1] and AISC 360-22 [22]. Several reliability analyses were carried out to evaluate the safety and adequacy of the existing design formulas.

As a result of this study, it was found that both CSA S16:19 [1] and AISC 360-22 [22] provided reliable predictions for direct-formed and indirect-formed RHS stub beam-columns. However, members produced through direct-forming were slightly more advantageous than their indirect-formed counterparts, exhibiting higher ultimate combined axial compressive and flexural capacities, reflected by higher reliability indices. This difference was more pronounced in members with slender sidewalls (Classes 3 and 4 in CSA S16:19 [1]). The approach adopted by AISC 360-22 [22] was overall found to be more conservative compared to CSA S16:19 [1], as indicated by the relatively higher reliability indices. Additionally, the existing formulation in CSA S16:19 [1] was observed to be more conservative for members with stockier sidewall elements (Classes 1 and 2) than for those with more slender sidewalls (Classes 3 and 4), assuming similar material and cold-forming technique.

To achieve the target reliability indices suggested by AISI S100-16 [23] in both standards, while minimizing excessive conservatism, a series of modifications were proposed. Based on the findings from [16], a higher non-slender/slender cross-section slenderness limit was proposed for the sidewalls of direct-formed members under axial compression in AISC 360-22 [22], aligning it with the corresponding limit in CSA S16:19 [1]. Similarly, a revised non-compact/slender limit was proposed in AISC 360-22 [22] for the flanges of direct-formed members subjected to combined axial compression and flexure, bringing it in line with the Class 3 limit specified in CSA S16:19 [1]. A series of modifications was also proposed to the coefficients of the interaction formulas for various RHS stub beam-columns in both CSA S16:19 [1] and AISC 360-22 [22], depending on the cold-forming technique (i.e., direct- or indirect-forming), steel grade (i.e., normal- or high-strength), and cross-section classification.

Nomenclature

b	External flange width of RHS
b_e	Effective internal flange width
b_{el}	Internal flange width excluding the corner portions
C_1	Material coefficient
C_P	Correction factor in reliability analysis
C_ϕ	Calibration coefficient in reliability analysis
E	Young's modulus
$E_{0.2}$	Tangent modulus of elasticity at the 0.2% proof stress
E_{sh}	Tangent modulus of elasticity during the first strain hardening
e	Load eccentricity
F_m	Mean value of the fabrication factor in reliability analysis
f	Steel stress
$f_{C1\varepsilon u}$	Steel stress at the onset of the second strain hardening
f_{el}	Elastic local buckling stress according to AISC 360-22
f_n	Nominal stress according to AISC 360-22
f_u	Steel ultimate tensile strength
f_y	Steel yield strength or 0.2% proof stress
h	External web depth of RHS

h_e	Effective internal web depth
h_{el}	Internal web depth excluding the corner portions
L	Length of RHS
M_f	Factored uniaxial bending moment
M_m	Mean value of the material factor in reliability analysis
M_n	Unfactored nominal flexural capacity
$M_{n, AISC}$	Unfactored nominal flexural capacity according to AISC 360-22
$M_{n, CSA}$	Unfactored nominal flexural capacity according to CSA S16:19
M_p	Plastic moment
M_r	Factored nominal flexural capacity
$M_{r, AISC}$	Factored nominal flexural capacity according to AISC 360-22
$M_{r, CSA}$	Factored nominal flexural capacity according to CSA S16:19
M_u	Ultimate second-order bending moment
M_y	Yield moment
m	Second strain hardening exponent
m'	Degrees of freedom in reliability analysis
n	First strain hardening exponent
n'	Number of data in reliability analysis
P_f	Factored axial compressive load

P_m — Mean value of the ratio of FE ultimate combined loads to unfactored nominal capacities in reliability analysis

P_n — Unfactored nominal axial compressive capacity

$P_{n,\ AISC}$ — Unfactored nominal axial compressive capacity according to AISC 360-22

$P_{n,\ CSA}$ — Unfactored nominal axial compressive capacity according to CSA S16:19

P_r — Factored nominal axial compressive capacity

$P_{r,\ AISC}$ — Factored nominal axial compressive capacity according to AISC 360-22

$P_{r,\ CSA}$ — Factored nominal axial compressive capacity according to CSA S16:19

P_u — Ultimate axial compressive load

$P_{u,\ FE}$ — Ultimate axial compressive load based on finite element analysis

$P_{u,\ test}$ — Ultimate axial compressive load based on experimental tests

P_y — Cross-section yield load based on the flat face material

r_i — Inner corner radius of RHS

r_o — Outer corner radius of RHS

S — Elastic section modulus

S_e — Effective elastic section modulus

t — Wall thickness of RHS

U_1 — Factor for second-order effects of axial compressive load on a deformed member according to CSA S16:19

V_F — Coefficient of variation of the fabrication factor in reliability analysis

V_M Coefficient of variation of the material factor in reliability analysis

V_P Coefficient of variation of the ratio of FE ultimate combined loads to unfactored nominal capacities in reliability analysis

V_Q Coefficient of variation of the load effect in reliability analysis

Z Plastic section modulus

α_1 Coefficient of axial compression in the interaction formulation

α_2 Coefficient of flexure in the interaction formulation

β_0 Reliability index

δ_l Maximum local imperfection of RHS sidewalls

ε Steel engineering strain

$\varepsilon_{0.2}$ Steel strain at the 0.2% proof stress

ε_{sh} Steel strain at the onset of the first strain hardening

ε_{true} Steel true strain

$\varepsilon_{true,\,pl}$ Steel logarithmic true plastic strain

ε_u Steel ultimate strain

ε_y Steel yield strain

λ_{C1} Class 1 slenderness limit according to CSA S16:19

λ_{C2} Class 2 slenderness limit according to CSA S16:19

λ_{C3} Class 3 slenderness limit according to CSA S16:19

λ_l Cross-sectional slenderness of RHS sidewalls

λ_p Compact/non-compact slenderness limit according to AISC 360-22

λ_r Non-slender/slender and non-compact/slender slenderness limits according to CSA S16:19 and AISC 360-22

$\bar{\lambda}_{C1}$ Normalized Class 1 slenderness limit

$\bar{\lambda}_{C2}$ Normalized Class 2 slenderness limit

$\bar{\lambda}_{C3}$ Normalized Class 3 slenderness limit

$\bar{\lambda}_l$ Normalized cross-sectional slenderness of RHS sidewalls

$\bar{\lambda}_p$ Normalized compact/non-compact slenderness limit

$\bar{\lambda}_r$ Normalized non-slender/slender and non-compact/slender slenderness limits

v Poisson's ratio

σ Steel engineering stress

$\sigma_{0.05}$ 0.05% proof stress for steel material

$\sigma_{0.2}$ 0.2% proof stress for steel material

σ_{true} Steel true stress

ϕ Resistance factor

Chapter 2 Design of direct- and indirect-formed RHS long beam-columns

2.1 Abstract

Complementary research on direct- and indirect-formed square and rectangular hollow section (collectively known as RHS) members has shown that the resulting residual stress levels and distributions differ between the two manufacturing techniques. Investigations into direct- and indirect-formed RHS beams and stub columns have indicated that these members generally experience lower residual stress levels, concentrated at the corners, which results in direct-formed members exhibiting higher load-bearing capacity. Previous studies on direct-formed RHS have only focused on beams and stub columns, while investigations on long beam-columns have been limited to those made through indirect-forming. Furthermore, the current provisions in the Canadian and American steel design standards (CSA S16:19 and AISC 360-22) do not differentiate between the two forming techniques. As a result, a study comparing direct- and indirect-formed RHS long beam-columns has yet to be performed. In this study, experimental data from prior research were gathered to simulate 36 nonlinear finite element (FE) models of RHS long beam-columns for validation purposes. A parametric study was conducted on 1040 models, incorporating both direct- and indirect-formed members made from normal- and high-strength steel (with nominal yield strengths ranging from 350 MPa to 700 MPa), to determine the axial compressive and flexural capacities of the models. Several reliability analyses were performed on CSA S16:19 and AISC 360-22 to evaluate their adequacy. Based on these analyses, modifications to the provisions were proposed to reach the target reliability levels.

2.2 Introduction

2.2.1 Background

Hollow Structural Sections (HSS) are tubular profiles produced in various geometric shapes, widely used in the engineering and construction industries to form structural members such as beam-columns. Among the different HSS shapes, square and rectangular hollow sections (collectively known as RHS) are the most widely utilized. These sections are available in a range of sizes and are used to form members of varying lengths, from stub to long. In North America, cold-formed RHS—designated as Class C in the Canadian Standard for the Design of Steel Structures (CSA S16:19 [1])—are manufactured using two primary techniques: (1) direct-forming and (2) indirect-forming, also known as continuous forming, which has traditionally been used. Indirect-forming involves severe cold working applied to a circular hollow section (CHS) to transform it into an RHS. In contrast, direct-forming produces RHS by cold-bending a flat strip of steel into the desired profile, with less severe cold work at the flat faces and more intense cold working concentrated at the corners.

The findings of several studies [5–18] on residual stress measurements and mechanical properties of steel in RHS specimens, obtained through tensile coupon tests, have revealed significant differences between direct- and indirect-formed members. As a result, direct-formed members were found to show relatively less residual stress levels. Research by Sun and Packer [7] and Tayyebi and Sun [21] on direct- and indirect-formed RHS stub columns has highlighted the mechanical advantages of direct-formed members, which exhibited higher axial compressive capacities due to differences in residual stress levels. Additionally, studies in [7, 12, 13, 16–19, 21] have suggested that variations in the magnitude and distribution of residual stresses can significantly influence local buckling behavior in RHS members, leading to overly conservative designs for those with lower residual stresses. Accordingly, the provisions of CSA S16:19 [1], AISC 360-16 (which aligns with AISC 360-22 [22] in this context), and AISI S100-16 [23] were assessed, and adjustments to the cross-section slenderness limits for direct-formed RHS members were proposed to reduce excessive design conservatism. However, these effects have not been sufficiently investigated in long RHS members. A variety of studies have investigated indirect-formed RHS through experimental or numerical methods. Key et al. [24] experimentally assessed the behavior and axial compressive strength of various cold-formed, untreated columns. Poursadrollah et al. [25] and Hayeck et al. [26, 27] employed both experimental and numerical methods to study cold-formed, untreated RHS columns and beam-columns. A series of studies by Ma et al. [28–32] was performed on cold-formed, untreated RHS members made from high-strength steel. Studies in [28, 29] examined the behaviour and design of RHS beams, while those in [30–32] explored RHS beam-columns, including both stub and long members. As a result, the load-bearing capacities of the members were compared to the provisions of various standards, leading to proposed design modifications. The studies in [33–35] examined the behavior and design of various indirect-formed RHS columns and beam-columns fabricated from either normal- or high-strength steel. Yin et al. [36] recently studied several indirect-formed square hollow section (SHS) columns made from high-strength steel, focusing on their flexural buckling behaviour. The studies in [37–44] also investigated the behavior and design of a series of stainless steel columns and beam-columns, with an emphasis on RHS and CHS.

The design provisions in CSA S16:19 [1] and AISC 360-22 [22] do not account for the impact of cold-forming techniques (i.e., direct-forming and indirect-forming) on the mechanical behaviour of RHS beam-columns. They also do not address the differences in axial compression-flexure interaction between stub and long beam-columns. As a result, the combined effects of local and global buckling on long beam-columns are not fully appreciated, with the same interaction formulas applied as for stub columns. The studies in [16–18, 21] on direct-formed RHS have primarily focused on beams or stub columns, without considering beam-columns. Additionally, the studies in [28–32] have exclusively examined indirect-formed high-strength RHS, without separately considering axial compression-flexure interaction formulas for beam-columns based on material grade or cold-forming technique. Thus, a comparative study has yet to be conducted to examine direct- and indirect-formed RHS long beam-columns made from both normal- and high-strength steel.

2.2.2 Scope of research

As outlined earlier in Chapter 1, Section 1.2.2, this research focuses on evaluating the ultimate static load-bearing capacity of cold-formed, untreated RHS beam-columns fabricated via direct- and indirect-forming. This chapter, in particular, has aimed to comparatively assess the influence of these two cold-forming techniques on the behaviour and design of RHS long beam-columns. To this end, both experimental data from previous studies and a finite element-based numerical investigation have been employed. This research does not include original experimental work; all experimental data were sourced from previously published studies by other researchers.

The experimental investigation included a series of tensile coupon tests from Chapter 1, Sections 1.3.2 and 1.3.3, along with additional tensile coupon tests reported in other studies, where the coupons were machined from a set of indirect-formed RHS specimens. To account for the residual stress effects, different steel material properties were assigned to the flat faces and corner regions of the RHS cross-section, based on the tensile test results, without directly including residual stress measurements. Six steel material groups were developed based on the test results, specifically for validation of the FE results.

36 nonlinear FE long beam-column models were generated using actual test geometrical dimensions, local and global geometric imperfections, material properties, boundary conditions, and loading configuration. The models were subjected to static axial compressive loads, applied concentrically or eccentrically, leading to a combined effect of axial compression and bending. The load-deformation responses, along with the ultimate axial compressive and flexural capacities, were validated against real test results, as reported in several previous studies. A finite element parametric study was performed on 1040 RHS long beam-column models, using the same material groups and cross-sections as in the previous chapter. The models spanned a wide range of section sizes, aspect ratios, slenderness ratios, and lengths, and included both direct- and indirect-formed members made from normal- and high-strength steel. Each model was subjected to the same set of load cases with varying eccentricities as used in the stub beam-column parametric study in the previous chapter, to determine its ultimate axial compressive and flexural capacities.

Consistent with the approach outlined in Chapter 1, Section 1.5, the ultimate long beam-column capacities were compared to the existing provisions of CSA S16:19 [1] and AISC 360-22 [22]. The safety and reliability of these standards were evaluated through a series of reliability analyses conducted separately for direct- and indirect-formed members, in accordance with AISI S100-16 [23]. As a result, a series of modifications were proposed to the cross-section slenderness limits for those direct-formed long beam-columns with sections belonging to the highest slenderness class (i.e., Class 4 in CSA S16:19 [1] and slender sections in AISC 360-22 [22]). Adjustments were made to the coefficients of the axial compression-flexure interaction formulas for both direct- and indirect-formed members in CSA S16:19 [1] and AISC 360-22 [22].

2.3 Experimental investigation

2.3.1 RHS specimens

A set of data from several indirect-formed RHS long beam-column specimens made of a normal-strength steel grade (with a nominal yield strength of 355 MPa, denoted as N2) and two high-strength steel grades (with nominal yield strengths of 700 MPa, denoted as H and H2, respectively) was collected. Since no experimental investigation has been conducted regarding the axial compression test of direct-formed RHS long beam-columns yet, no data for these specimens were presented up to Section 2.4.5. However, data from the previous chapter concerning direct-formed RHS stub beam-columns were utilized in the parametric study, which is discussed in more detail in Section 2.4.5.

Relevant geometric measurements were taken, including the outer cross-section dimensions—the depth (h), measured along the loading eccentricity (i.e., web direction), and the width (b), measured perpendicular to it (i.e., flange direction), regardless of which side is longer— as well as wall thickness (t), length (L), inner and outer corner radii (r_i and r_o), maximum local imperfection of the sidewalls (δ_l), and maximum global imperfection of the members (δ_g). However, due to the lack of consistent measurements of the local and global imperfections (δ_l and δ_g) in some cases, these imperfections were assumed to be proportional to the wall thickness (t) and member length

(L), respectively, following the approach used in [16, 21, 30–32]. Average imperfection-to-dimension ratios derived from available data were used to determine the corresponding imperfection magnitudes. Correspondingly, an average local imperfection-to-thickness ratio of 0.05 (δ_l/t = 0.05) was applied to all specimens. For global imperfections, average δ_g/L ratios of 0.0003, 0.0010, and 0.0005 were applied for the members with H, N2, and H2 steel material groups, respectively. These ratios were then used to calculate the values of δ_l and δ_g.

Each specimen is given a distinct identification (ID) consisting of six components. The first component indicates the cross-section shape, either square (SHS) or rectangular (RHS). The second component shows the cold-forming technique used in the production of the specimens (i.e., I = indirect-forming for all). The third component indicates the steel material grade, with H representing the high-strength steel used in Chapter 1, Sections 1.3.2 and 1.3.3, and N2 and H2 indicating the normal- and high-strength steels, respectively, as explained in this section. This naming convention is intended to distinguish these steel grades from those referred to as N and H in the previous chapter. The last three numerical components indicate the nominal outer depth (h), width (b), and wall thickness (t), all measured in millimeters. A total of 36 specimens were tested under axial compressive loads. The loads were applied either concentrically (11 cases) or with diverse eccentricities (25 cases), as outlined in Table 2.1. A more detailed discussion of the experimental results is provided in Section 2.4.4.

Table 2.1 Geometrical parameters of long beam-columns

Specimen ID	e (mm)	h (mm)	b (mm)	t (mm)	L (mm)	r_i (mm)	r_o (mm)	δ_l (mm)	δ_g (mm)
SHS-IH-80×80×4	-0.18	80.1	80.3	3.94	1480	5.0	9.5	0.20	0.44
SHS-IH-80×80×4	5.45	80.1	80.3	3.94	1480	5.0	9.5	0.20	0.44
SHS-IH-80×80×4	12.24	80.1	80.3	3.94	1480	5.0	9.5	0.20	0.44
SHS-IH-80×80×4	19.81	80.1	80.3	3.94	1480	5.0	9.5	0.20	0.44
SHS-IH-80×80×4*	21.56	80.1	80.3	3.94	1480	5.0	9.5	0.20	0.44
SHS-IH-80×80×4	39.19	80.1	80.3	3.94	1480	5.0	9.5	0.20	0.44
SHS-IH-80×80×4	79.87	80.1	80.3	3.94	1480	5.0	9.5	0.20	0.44
SHS-IH-80×80×4	151.58	80.1	80.3	3.94	1480	5.0	9.5	0.20	0.44
RHS-IH-50×100×4	0.36	50.6	100.2	3.97	1480	3.5	8.5	0.20	0.44
RHS-IH-50×100×4	5.30	50.6	100.2	3.97	1480	3.5	8.5	0.20	0.44
RHS-IH-50×100×4	14.92	50.6	100.2	3.97	1480	3.5	8.5	0.20	0.44
RHS-IH-50×100×4	27.08	50.6	100.2	3.97	1480	3.5	8.5	0.20	0.44
RHS-IH-50×100×4	48.73	50.6	100.2	3.97	1480	3.5	8.5	0.20	0.44
RHS-IH-50×100×4*	47.31	50.6	100.2	3.97	1480	3.5	8.5	0.20	0.44
RHS-IH-50×100×4	79.47	50.6	100.2	3.97	1480	3.5	8.5	0.20	0.44
RHS-IH-50×100×4	129.30	50.6	100.2	3.97	1480	3.5	8.5	0.20	0.44
RHS-IH-100×50×4	-0.12	100.2	50.3	3.98	1480	3.5	8.5	0.20	0.44
RHS-IH-100×50×4	2.50	100.2	50.3	3.98	1480	3.5	8.5	0.20	0.44
RHS-IH-100×50×4	9.54	100.2	50.3	3.98	1480	3.5	8.5	0.20	0.44
RHS-IH-100×50×4*	10.47	100.2	50.3	3.98	1480	3.5	8.5	0.20	0.44
RHS-IH-100×50×4	18.38	100.2	50.3	3.98	1480	3.5	8.5	0.20	0.44
RHS-IH-100×50×4	39.05	100.2	50.3	3.98	1480	3.5	8.5	0.20	0.44
RHS-IH-100×50×4	80.85	100.2	50.3	3.98	1480	3.5	8.5	0.20	0.44
RHS-IH-100×50×4	150.30	100.2	50.3	3.98	1480	3.5	8.5	0.20	0.44
RHS-IN2-200×100×4	84.60	200.1	100.3	4.00	4001	4.0	8.0	0.20	4.00
RHS-IN2-200×100×4	141.00	198.7	99.9	3.85	4000	3.9	7.7	0.19	4.00
RHS-IN2-220×120×6	72.20	220.1	119.8	5.90	4000	5.9	11.8	0.30	4.00

RHS-IN2-220×120×6	120.30	219.9	119.8	5.83	3999	5.8	11.6	0.29	4.00
SHS-IH2-80×80×3 T1	0	80.2	80.1	2.83	1017	3.6	6.4	0.14	0.51
SHS-IH2-80×80×3 T2	0	80.1	80.1	2.81	1268	3.6	6.4	0.14	0.63
SHS-IH2-80×80×3 T3	0	80.2	80.1	2.89	1508	3.6	6.5	0.14	0.75
SHS-IH2-80×80×3 T4	0	80.2	80.2	2.84	1818	3.6	6.4	0.14	0.91
SHS-IH2-100×100×3 T1	0	100.0	100.3	3.08	1118	2.8	5.9	0.15	0.56
SHS-IH2-100×100×3 T2	0	99.9	100.3	3.10	1314	2.8	5.9	0.16	0.66
SHS-IH2-100×100×3 T3	0	100.0	100.4	3.19	1510	2.8	6.0	0.16	0.76
SHS-IH2-100×100×3 T4	0	100.0	100.3	3.08	1818	2.8	5.9	0.15	0.91

*Repeated test

T1: Test 1

T2: Test 2

T3: Test 3

T4: Test 4

2.3.2 Tensile coupon tests

Several steel coupons from the flat face and corner regions of the sidewalls of the indirect-formed RHS specimens were extracted and used in tensile coupon tests conducted in [26–32, 36]. Based on the cold-forming technique (i.e., indirect-forming, denoted as I, for the specimens considered), steel grade (H, N2, and H2), and the coupon location (Flat = flat face; Corner = corner region), six distinct steel material groups were established, following the same naming convention introduced in Chapter 1, Section 1.3.2.

The relevant details of two of these groups—corresponding to the flat face and corner regions of one of the two high-strength steel grades (I-H-Flat and I-H-Corner)—were provided in Chapter 1, Sections 1.3.2 and 1.3.3. The stress-strain relationship for each indirect-formed normal-strength material group (I-N-2-Flat and I-N-2-Corner) was derived from the average parameters of 12 tensile coupon tests conducted in [26, 27]. Similarly, the stress-strain relationship for each indirect-formed high-strength material group (I-H-2-Flat and I-H-2-Corner) was established from the average parameters of two tensile coupon tests carried out in [36]. Overall, the averaged parameters from 44 tensile coupon tests were used to define the six material groups. All tests exhibited early and continuous yielding without a distinct yield plateau, as shown in Fig. 2.1. This pattern was similar to that observed in the coupons of the indirect-formed RHS stub members presented in the previous chapter (see Figs. 1.3 and 1.4 for comparison).

2.3.3 Material constitutive models

As previously explained in Chapter 1, Section 1.3.3, material constitutive models are used to derive stress-strain numerical relationships from key parameters obtained through tensile coupon test results. The rounded stress-strain constitutive model for cold-formed steel proposed by Yun and Gardner [48], which was developed based on the earlier works of Ramberg and Osgood [46] and Hill [47], was applied to all six material groups introduced in Sections 2.3.1 and 2.3.2. The same parameters and formulations presented in Eqs. 1.4–1.7 are adopted here and relabeled as Eqs. 2.1–2.4. A summary of the steel material groups is provided in Table 2.2.

$$\varepsilon = \begin{cases} \dfrac{f}{E} + 0.002\left(\dfrac{f}{f_y}\right)^n & f < f_y \\ \dfrac{f-f_y}{E_{0.2}} + \left(\varepsilon_u - \varepsilon_{0.2} - \dfrac{f_u - f_y}{E_{0.2}}\right)\left(\dfrac{f-f_y}{f_u-f_y}\right)^m + \varepsilon_{0.2} & f_y < f \le f_u \end{cases} \tag{2.1}$$

$$n = \frac{\ln(4)}{\ln\left(f_y/\sigma_{0.05}\right)} \tag{2.2}$$

$$E_{0.2} = \frac{E}{1 + 0.002n\frac{E}{f_y}} \tag{2.3}$$

$$m = 1 + 1.33\frac{f_y}{f_u} \tag{2.4}$$

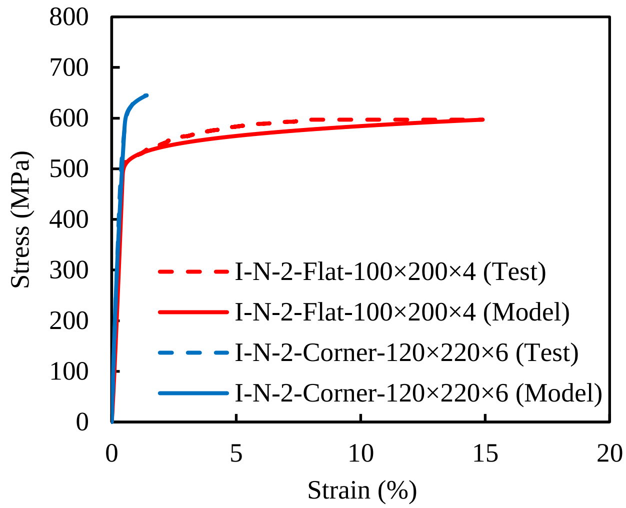
Table 2.2 Description of steel material groups

Material ID	Cold-forming technique	Steel grade	Coupon location	Stress-strain model	Data source
I-H-Flat	Indirect-forming	High-strength	Flat face	Rounded	[28–32]
I-H-Corner	Indirect-forming	High-strength	Corner region	Rounded	[28–32]
I-N-2-Flat	Indirect-forming	Normal-strength	Flat face	Rounded	[26, 27]
I-N-2-Corner	Indirect-forming	Normal-strength	Corner region	Rounded	[26, 27]
I-H-2-Flat	Indirect-forming	High-strength	Flat face	Rounded	[36]
I-H-2-Corner	Indirect-forming	High-strength	Corner region	Rounded	[36]

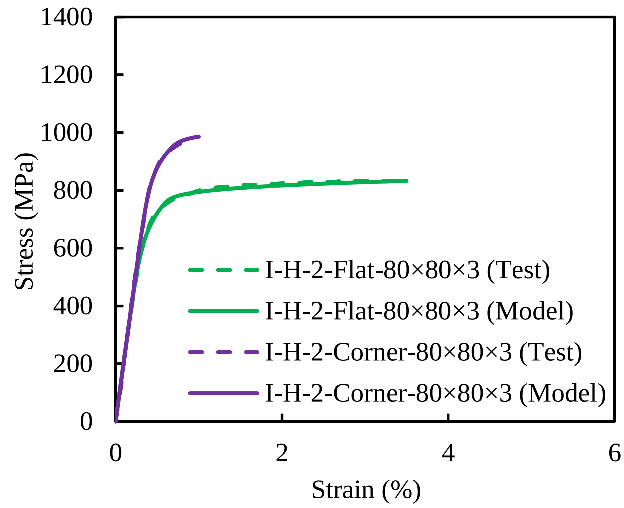
The averaged key parameters for the material groups, extracted from digitized stress-strain curves in [26–32, 36], are presented in Table 2.3. Since the data were digitized using WebPlotDigitizer (Automeris, https://automeris.io/WebPlotDigitizer), minor discrepancies from the original reported values may exist. However, such deviations are minimal and do not significantly affect the results. Fig. 2.1 presents a comparison of tensile coupon test results with their corresponding material constitutive models (see Fig. 1.4 for the I-H-Flat and I-H-Corner material groups).

Table 2.3 Averaged key parameters for rounded stress-strain models

Material ID	E (MPa)	f_y (MPa)	f_u (MPa)	$\sigma_{0.05}$ (MPa)	$\varepsilon_{0.2}$	ε_u	$E_{0.2}$ (MPa)	n	m
I-H-Flat	211,093	739	845	575	0.0055	0.0439	50,790	5.52	3.89
I-H-Corner	211,282	907	986	777	0.0063	0.0160	40,866	8.96	4.04
I-N-2-Flat	199,368	410	566	155	0.0041	0.1550	83,557	1.43	3.39
I-N-2-Corner	197,059	556	619	310	0.0048	0.0166	73,472	2.37	3.96
I-H-2-Flat	206,550	743	831	634	0.0056	0.0353	35,257	8.74	3.95
I-H-2-Corner	210,000	864	915	741	0.0061	0.0094	38,975	9.03	4.12



(a)



(b)

Figure 2.1 Comparison of stress-strain curves from tensile coupon tests and corresponding material constitutive models for: (a) IN2; (b) IH2

2.4 Finite element analysis

2.4.1 Elements, meshing, and boundary conditions

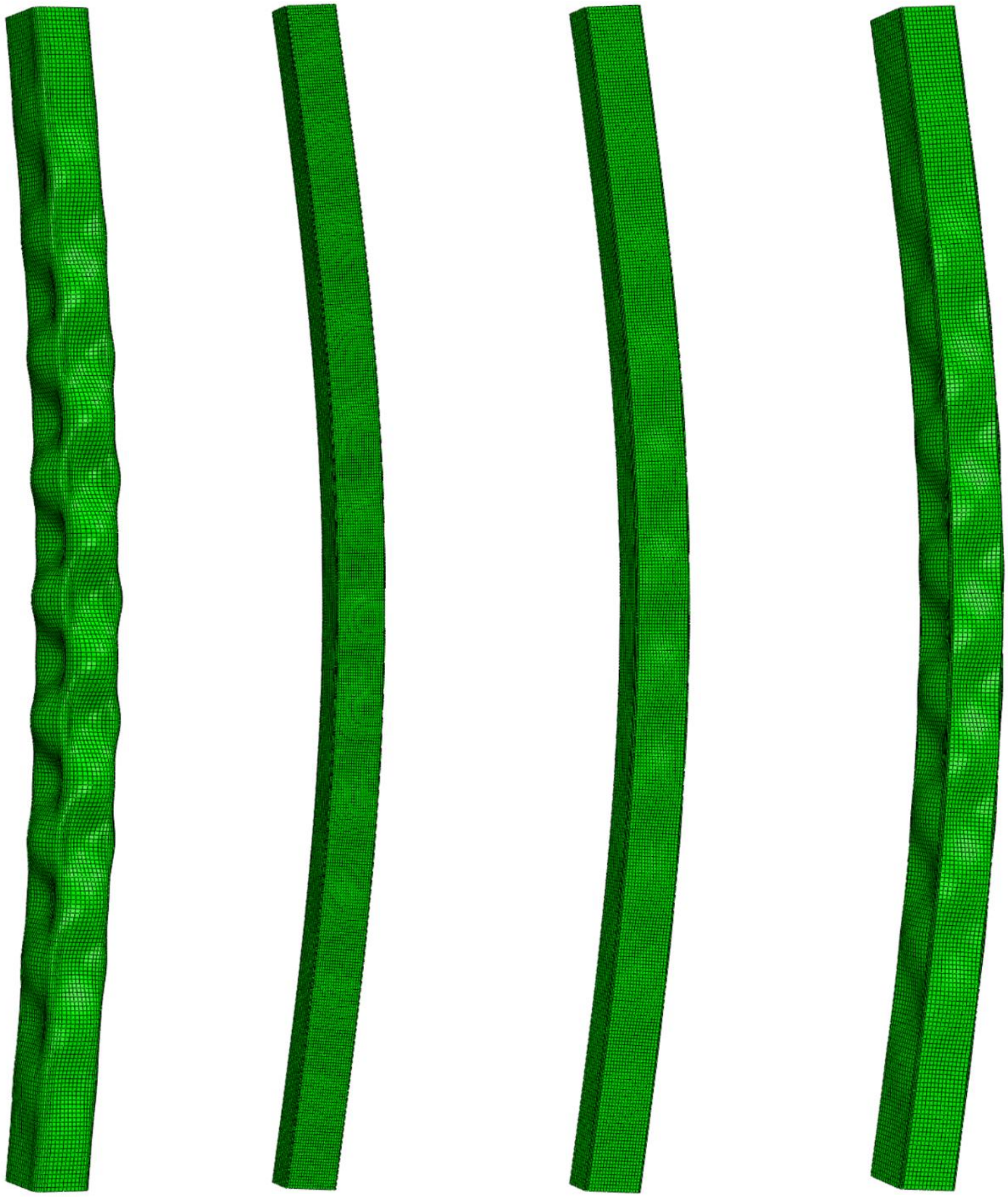
Similar as introduced in Chapter 1, Section 1.4.1, four-node shell elements with reduced integration (S4R) were to create the RHS long beam-column models in Abaqus [49]. Based on the mesh sensitivity analysis presented in [29–32], a mesh size of (h+b)/30 was employed for the flat faces, with h and b denoting the outer cross-section depth and width, respectively. To achieve a refined mesh at the curved surfaces of each corner, five elements were assigned to those regions. A reference point was defined at each end of the member, located at an offset from the cross-section centroid corresponding to the specified eccentricity for load application and support location (e). All nodes at the end cross-sections were tied to their respective reference points. Each reference point was fixed against translation but remained free to rotate. However, the top end (i.e., the end where the axial load is applied) was allowed to translate axially, facilitating the application of the compressive load and the resulting deformation.

2.4.2 Material properties

A similar approach, as explained in Chapter 1, Section 1.4.2, was taken. The averaged key material parameters for the I-H-Flat and I-H-Corner material groups from Table 1.4, along with the remaining parameters for the other groups from Table 2.3, were used to generate engineering stress-strain datasets for all six material groups. The engineering stress and strain values were then converted to the true values as shown in Eqs. 1.8 and 1.9. The elastic-region parameters, including Young's modulus (E), as listed in Table 2.3, and a Poisson's ratio (v) of 0.3, were adopted. True strain values were converted to logarithmic true plastic strain, as shown in Eq. 1.10, and were used in conjunction with the true stress values for defining the plastic-region material behaviour. All the material data were then introduced into Abaqus [49]. An extension equal to twice the wall thickness ($2t$) was assigned to the corner regions, in accordance with the studies in [18, 29–32, 38] and the approach used in the previous chapter (see Fig. 1.5).

2.4.3 Initial geometric imperfections

In contrast to the previous chapter, where only initial local imperfections were included in the stub models, both local and global imperfections were incorporated in the analysis of RHS long beam-column models to account for their considerable influence on the mechanical behaviour of the models and to improve the accuracy of the results. To implement the imperfections into the models, several elastic buckling analyses were performed to determine the buckling mode shapes. The first mode shapes corresponding to each of the local and global buckling were considered separately. The maximum local and global deformations were then scaled to their corresponding values (δ_l and δ_g), as shown in Table 2.1, and simultaneously applied as initial geometric imperfections to the FE models. The resulting imperfections are illustrated in Fig. 2.2, with the deformations magnified to improve visual clarity.



(a) (b) (c) (d)

Figure 2.2 Initial geometric imperfections applied to the FE models before loading:
(a) SHS-IH-80×80×4 (magnified ×100); (b) RHS-IN2-200×100×4 (magnified ×50);
(c) RHS-IN2-220×120×6 (magnified ×50); (d) SHS-IH2-100×100×3 (magnified ×100)

2.4.4 Validation of the FE modeling

Based on the geometric data from Table 2.1, the material properties outlined in Sections 2.3.2 and 2.3.3, and the modeling details described in Sections 2.4.1–2.4.3, simulations were conducted for a total of 36 RHS long beam-column specimens. 24 simulations of indirect-formed high-strength steel (IH) specimens were conducted based on data from [31, 32]. Four simulations of indirect-formed normal-strength steel (IN2) members were performed using data from [26, 27]. Moreover, eight simulations were carried out for indirect-formed high-strength steel (IH2) members according to data from [36]. Axial compressive static loads, applied concentrically or eccentrically as specified in Table 2.1, were gradually increased until the ultimate load-bearing capacities were reached, defined by the peak axial compressive force and bending moment at the mid-height section. The ultimate axial compressive loads obtained from the FE analysis results ($P_{u,\ FE}$) are compared with the experimental results ($P_{u,\ test}$) in Table 2.4. Global buckling was the failure pattern observed consistently across all the FE models. Several load-deformation diagrams from these models are presented and validated against the experimental results in Figs. 2.3–2.8.

Table 2.4 Comparison of the long beam-column FE and test results

Specimen ID	e (mm)	$P_{u, FE}$ (kN)	$P_{u, test}$ (kN)	$P_{u, FE}$/ $P_{u, test}$	*Failure pattern*
SHS-IH-80×80×4	-0.18	648	582	1.11	GB
SHS-IH-80×80×4	5.45	496	512	0.97	GB
SHS-IH-80×80×4	12.24	421	422	1.00	GB
SHS-IH-80×80×4	19.81	367	352	1.04	GB
SHS-IH-80×80×4*	21.56	358	342	1.05	GB
SHS-IH-80×80×4	39.19	285	270	1.06	GB
SHS-IH-80×80×4	79.87	198	186	1.06	GB
SHS-IH-80×80×4	151.58	131	127	1.03	GB
RHS-IH-50×100×4	0.36	325	307	1.06	GB
RHS-IH-50×100×4	5.30	266	242	1.10	GB
RHS-IH-50×100×4	14.92	215	194	1.11	GB
RHS-IH-50×100×4	27.08	179	159	1.12	GB
RHS-IH-50×100×4	48.73	141	128	1.10	GB
RHS-IH-50×100×4*	47.31	143	129	1.11	GB
RHS-IH-50×100×4	79.47	111	99	1.12	GB
RHS-IH-50×100×4	129.30	83	76	1.09	GB
RHS-IH-100×50×4	-0.12	698	642	1.09	GB
RHS-IH-100×50×4	2.50	608	532	1.14	GB
RHS-IH-100×50×4	9.54	500	433	1.16	GB
RHS-IH-100×50×4*	10.47	490	427	1.15	GB
RHS-IH-100×50×4	18.38	423	365	1.16	GB
RHS-IH-100×50×4	39.05	322	274	1.18	GB
RHS-IH-100×50×4	80.85	222	195	1.14	GB
RHS-IH-100×50×4	150.30	148	133	1.11	GB
RHS-IN2-200×100×4	84.60	328	352	0.93	GB
RHS-IN2-200×100×4	141.00	243	365	0.67	GB
RHS-IN2-220×120×6	72.20	667	700	0.95	GB

RHS-IN2-220×120×6	120.30	524	691	0.76	GB
SHS-IH2-80×80×3 T1	0	584	632	0.92	GB
SHS-IH2-80×80×3 T2	0	531	565	0.94	GB
SHS-IH2-80×80×3 T3	0	495	488	1.01	GB
SHS-IH2-80×80×3 T4	0	414	425	0.97	GB
SHS-IH2-100×100×3 T1	0	745	748	1.00	GB
SHS-IH2-100×100×3 T2	0	736	738	1.00	GB
SHS-IH2-100×100×3 T3	0	751	699	1.07	GB
SHS-IH2-100×100×3 T4	0	668	688	0.97	GB
Mean				1.04	
COV				0.10	

*Repeated test

GB: Global buckling

T1: Test 1

T2: Test 2

T3: Test 3

T4: Test 4

(a) (b) (c) (d)

Figure 2.3 Comparison of the failure pattern between the FE model and test specimen:
(a) SHS-IH-80×80×4-e40 FE model; (b) SHS-IH-80×80×4-e40 Test specimen [31, 32]
(c) RHS-IN2-200×100×4-e85 FE model; (d) RHS-IN2-200×100×4-e85 Test specimen [26, 27]

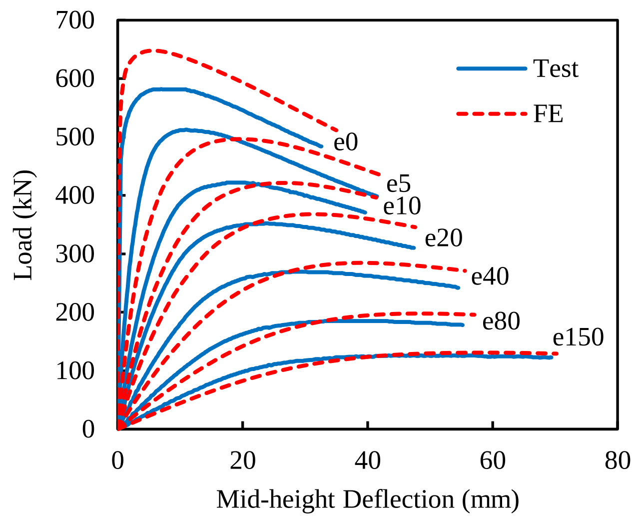


Figure 2.4 Comparison of the Mid-height Deflection–Load diagram between the FE model and test specimen for SHS-IH-80×80×4-e0, e5, e10, e20, e40, e80, e150

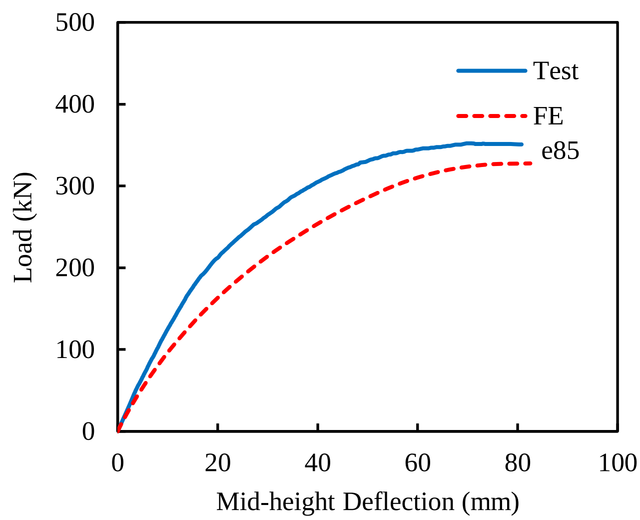


Figure 2.5 Comparison of the Mid-height Deflection–Load diagram between the FE model and test specimen for RHS-IN2-200×100×4-e85

(a) (b) (c) (d)

Figure 2.6 Comparison of the failure pattern between the FE model and test specimen:
(a) RHS-IN2-220×120×6-e70 FE model; (b) RHS-IN2-220×120×6-e70 Test specimen [26, 27]
(c) SHS-IH2-100×100×3-e0 FE model; (d) SHS-IH2-100×100×3-e0 Test specimen [36]

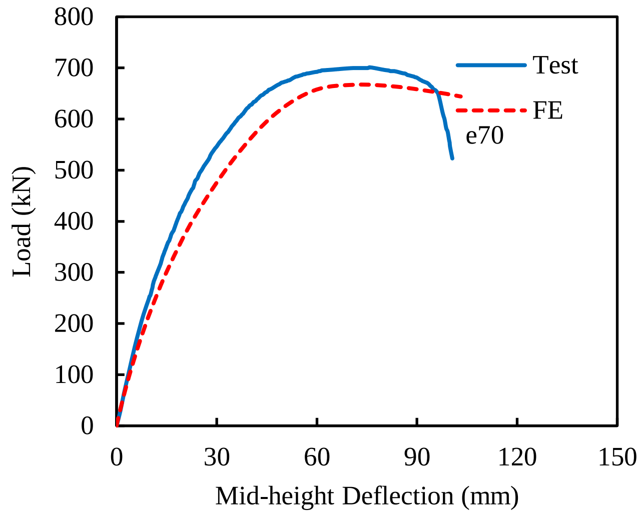


Figure 2.7 Comparison of the Mid-height Deflection–Load diagram between the FE model and test specimen for RHS-IN2-220×120×6-e70

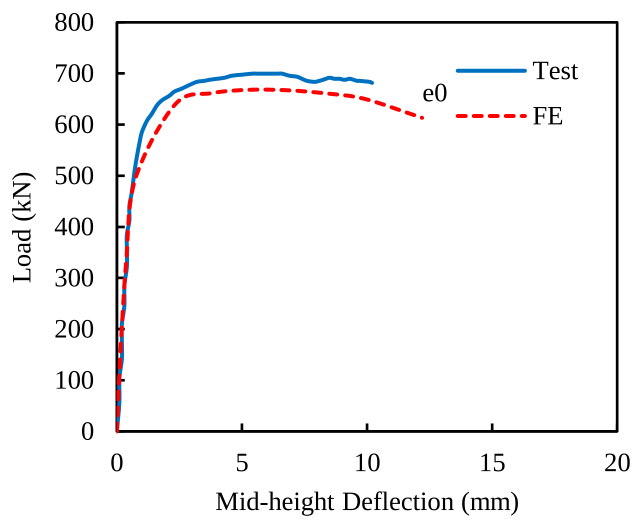


Figure 2.8 Comparison of the Mid-height Deflection–Load diagram between the FE model and test specimen for SHS-IH2-100×100×3-e0

2.4.5 Parametric investigation

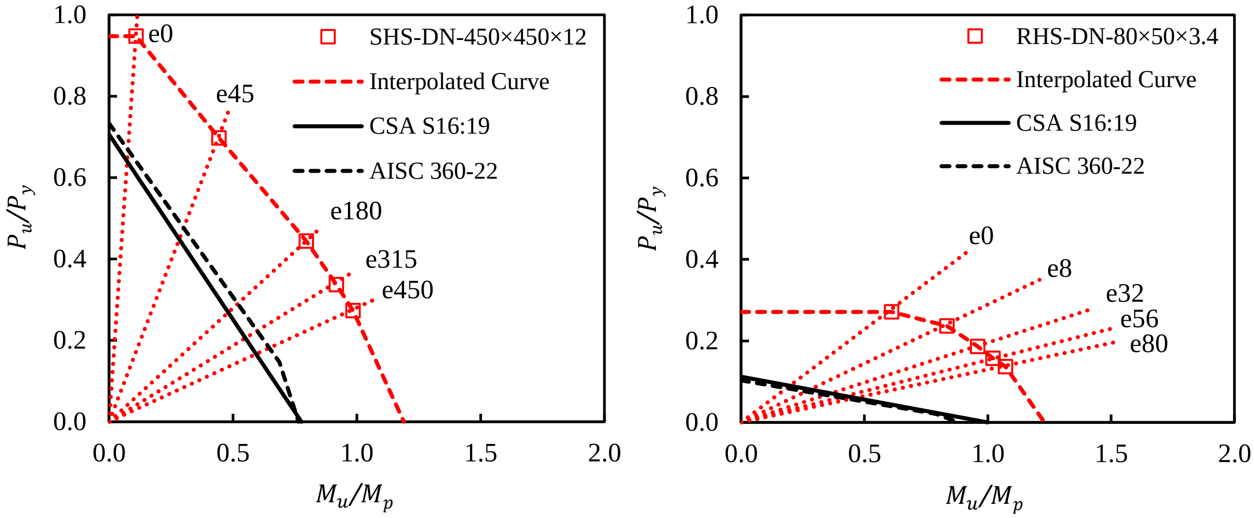
Implementing the general FE modeling procedure discussed in Sections 2.4.1–2.4.3, and validated against real test results in Section 2.4.4, a parametric study was carried out on RHS long beam-columns. A total of 1040 FE models were considered, comprising direct- and indirect-formed members made of normal- and high-strength steel. The same cross-sections and material properties as those in the parametric study of RHS stub beam-columns in Chapter 1, Section 1.4.5, were adopted to ensure broad coverage of geometric and material parameters. A total of 20 distinct square hollow sections (SHS) and 16 rectangular hollow sections (RHS), with external dimensions (h and b) ranging from 50 mm to 500 mm and aspect ratios between 1.00 and 2.50 were involved. The inner and outer corner radii (r_i and r_o) were taken as equal to the wall thickness (t) and twice the wall thickness ($2t$), respectively. To encompass all section classifications defined in CSA S16:19 [1] and AISC 360-22 [22], a broad range of cross-section slenderness (λ_l) from 9.88 to 40.44, was included. In contrast to the length (L) assignment for stub members in the previous chapter (i.e., setting L to three times the greater of h and b), a similar set of lengths, varying between 2700 mm to 12000 mm, was assigned to each material group. This resulted in global slenderness values (λ_g) ranging from 50.56 to 199.78, all of which are higher than those of the corresponding members in Table 2.1, ensuring the inclusion of global buckling effects. In line with Section 2.3.1, typical local imperfections (δ_l) of $0.05t$ and global imperfections (δ_g) of $0.001L$ were introduced to all FE models.

Each model with a square hollow section (SHS) was subjected to five different static load cases with varying eccentricities (e) along one of its principal axes. On the other hand, each model with a rectangular hollow section (RHS) underwent five distinct load cases with different eccentricities along both its major and minor bending axes separately, resulting in a total of 10 loading cases per member (see Table 2.5 for a summary). Following the same range and number of eccentricities used in [30–32], the applied values were defined as 0, 0.1, 0.4, 0.7, and 1.0 times the outer dimension of the cross-section along the direction of eccentricity. Each FE beam-column model was statically loaded until failure. The second-order effects (P-Delta) were incorporated by enabling geometric nonlinearity (NLGEOM) in Abaqus [49], which facilitated the inclusion of large deformations and rotations in the analysis. The ultimate load-bearing capacity—characterized by the peak axial compressive load (P_u) and the corresponding bending moment (M_u) at the mid-height section—was subsequently obtained by extracting these values from the axial reaction at the support and the section cut at the mid-height of the deformed model, respectively. The results are presented in Table B.1.

Table 2.5 Description of long beam-column section groups in the parametric study

Section ID	Cross-section shape	Cold-forming technique	Steel grade	Number of sections	Load cases per section	Total load cases
SHS-DN	Square	Direct-forming	Normal-strength	20	5	100
SHS-DH	Square	Direct-forming	High-strength	20	5	100
SHS-IN	Square	Indirect-forming	Normal-strength	20	5	100
SHS-IH	Square	Indirect-forming	High-strength	20	5	100
RHS-DN	Rectangular	Direct-forming	Normal-strength	16	10	160
RHS-DH	Rectangular	Direct-forming	High-strength	16	10	160
RHS-IN	Rectangular	Indirect-forming	Normal-strength	16	10	160
RHS-IH	Rectangular	Indirect-forming	High-strength	16	10	160
						1040

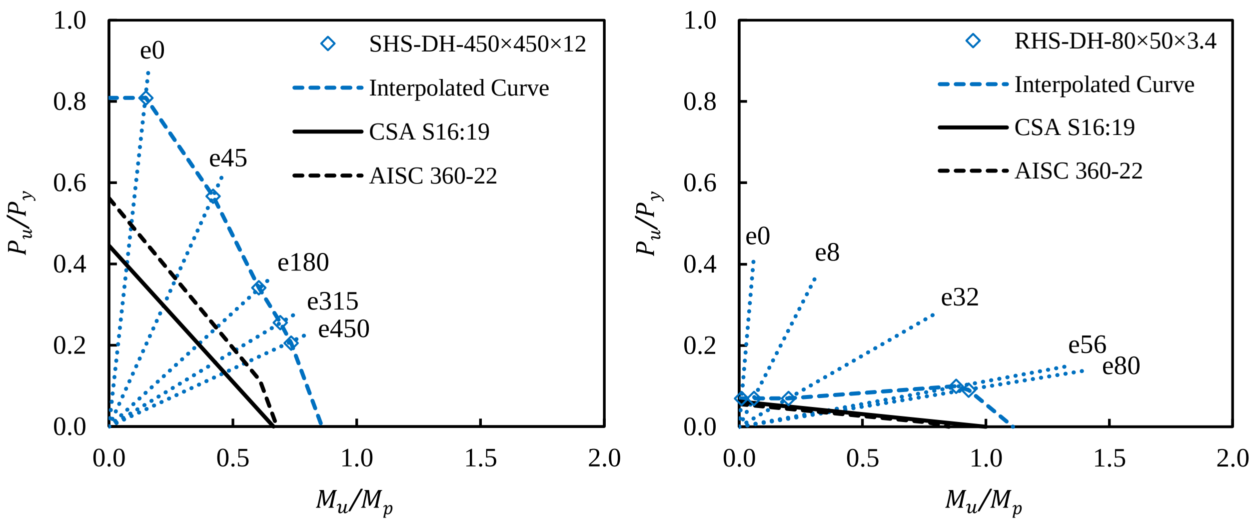
Figs. 2.9–2.12 illustrate several sets of interaction curves for the normalized flexural and axial compressive capacities of the long beam-columns across different material groups. These figures feature a set of discrete data points linked to specific eccentricity levels, along with interpolated interaction curves—constructed using line segments—for members with the minimum and maximum global slenderness values (i.e., λ_g = 50.56 and λ_g = 199.78). Additionally, the plots include the corresponding design interaction curves from CSA S16:19 [1] and AISC 360-22 [22] for comparison.



(a) (b)

Figure 2.9 Interaction curves for DN long beam-columns:

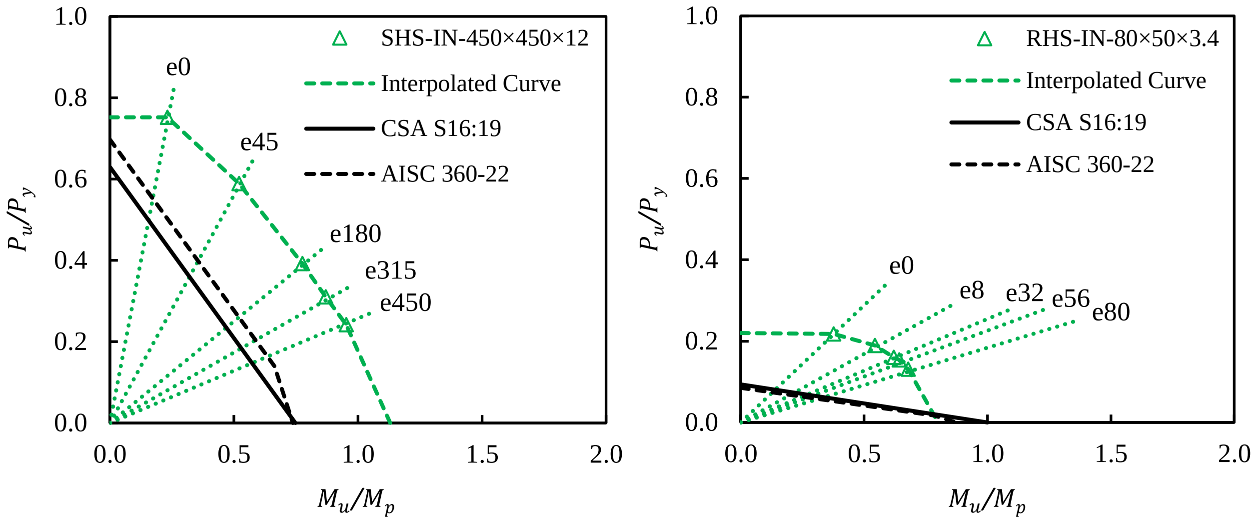
(a) with the lowest global slenderness; (b) with the highest global slenderness



(a) (b)

Figure 2.10 Interaction curves for DH long beam-columns:

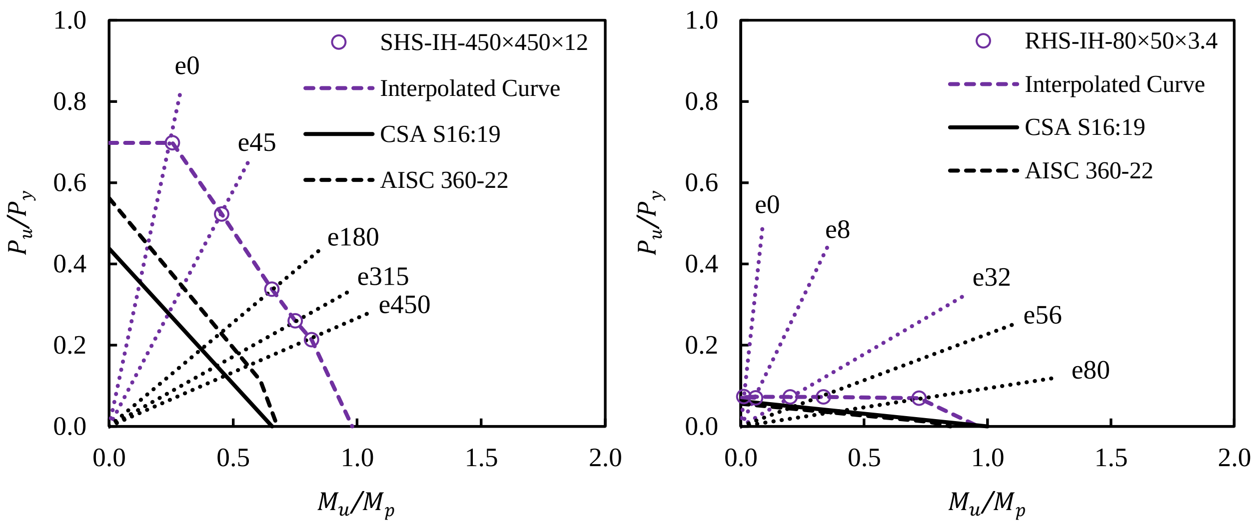
(a) with the lowest global slenderness; (b) with the highest global slender



(a) (b)

Figure 2.11 Interaction curves for IN long beam-columns:

(a) with the lowest global slenderness; (b) with the highest global slenderness



(a) (b)

Figure 2.12 Interaction curves for IH long beam-columns:

(a) with the lowest global slenderness; (b) with the highest global slenderness

As depicted in Figs. 2.9–2.12, an increase in normalized axial compressive capacity (P_u/P_y) corresponded to a reduction in normalized flexural capacity (M_u/M_p), and conversely, a decrease in axial capacity was associated with an increase in flexural capacity. Contrary to the observations for stub beam-columns in the previous chapter—where cross-section slenderness and local buckling demonstrated a dominant influence on the mechanical behaviour and interaction curve patterns—global slenderness played a central role in the behaviour and load-bearing capacity of long beam-columns. Global buckling was primarily the governing limit state, while local buckling had secondary, less significant effects. As the gap between global and local slenderness values widened, the distinction in their effects became more pronounced. The inclusion of P-Delta effects resulted in the development of bending moments in all models, including those with zero load eccentricity. As global slenderness increased within each material group, peak normalized axial compressive and flexural capacities (i.e., P_u/P_y and M_u/M_p) decreased. The actual interaction behaviour was nonlinear but was approximated using piecewise linear interpolation. For cases with zero eccentricity, initial shifts occurred due to the presence of flexure induced by the explicit consideration of P-Delta effects. This resulted in a constant ratio of P_u/P_y in the initial segment. The formulations in CSA S16:19 [1] and AISC 360-22 [22] align with linear and bilinear interaction patterns, respectively, when explicitly considering P-Delta effects, as explained in Sections 2.5.1 to 2.5.3. The values of P_y and M_p were calculated using the flat face yield strength (f_y) uniformly applied across the entire cross-section, following a commonly adopted approach in both standards. In practice, however, cold-formed sections exhibit higher yield strengths and altered Young's moduli at the corners due to residual stress effects. This can result in greater maximum axial compressive loads (P_u) and bending moments (M_u) than those predicted by the standards. Accordingly, the interpolated interaction curves demonstrated higher capacities than those predicted by the standards.

2.5 Existing design provisions

2.5.1 Background

As earlier discussed in Chapter 1, Section 2.5.1, beam-columns are typically subjected to substantial combined axial compression and bending, making it impossible for them to achieve the ultimate load-bearing capacities of beams and columns (i.e., the full flexural capacity in beams and axial compressive capacity in columns) concurrently. Therefore, interaction relationships between axial compression and bending actions are commonly proposed and adopted in design standards. Despite the behavioural and failure pattern differences between stub and long beam-columns, particularly due to the increasing influence of global buckling as the global slenderness increases, the existing design provisions of CSA S16:19 [1] and AISC 360-22 [22] apply the same interaction relationships and coefficients to long beam-columns as they do to stub ones. The general formulation of these standards, defining the beam-column capacity region, is shown in Eq. 2.5.

$$\alpha_1 \frac{P_f}{P_r} + \alpha_2 \frac{M_f}{M_r} \leq 1.0 \tag{2.5}$$

The coefficients α_1 and α_2, representing axial compression and flexure, respectively, are the same as those used for stub beam-columns and vary between CSA S16:19 [1] and AISC 360-22 [22], as introduced in Chapter 1, Section 1.5.1. P_f and M_f refer to the factored axial compressive load and the factored uniaxial bending moment. P_r and M_r denote the factored nominal axial compressive and flexural capacities. These capacities are calculated by multiplying the corresponding unfactored values by a resistance factor (i.e., $P_r = \phi P_n$ and $M_r = \phi M_n$, where $\phi = 0.90$). By replacing the factored axial compressive load and the factored uniaxial bending moment with their corresponding ultimate values (P_u and M_u), the inequality in Eq. 2.5 is changed into the equation shown in Eq. 2.6.

$$\alpha_1 \frac{P_u}{P_r} + \alpha_2 \frac{M_u}{M_r} = 1.0 \tag{2.6}$$

2.5.2 CSA S16:19

Consistent with the discussion in Chapter 1, Section 1.5.2 on stub beam-columns, the provisions in Clauses 13.8.3 and 13.8.4 classify RHS long beam-columns into two categories: (1) those with sidewalls classified as Classes 1 and 2, and (2) those with sidewalls classified as Classes 3 and 4. To simplify the formulation and align with the scope of this study, the interaction between axial compression and biaxial bending was reduced to a case of axial compression and uniaxial bending by neglecting the out-of-plane bending component. The corresponding interaction equations for these two categories are presented in Eqs. 2.7 and 2.8, respectively.

$$\frac{P_f}{P_{r,\ CSA}} + \frac{0.85 U_1 M_f}{M_{r,\ CSA}} \leq 1.0 \tag{2.7}$$

$$\frac{P_f}{P_{r,\ CSA}} + \frac{U_1 M_f}{M_{r,\ CSA}} \leq 1.0 \tag{2.8}$$

$P_{r,\ CSA}$ and $M_{r,\ CSA}$ represent the factored nominal axial compressive and flexural capacities, respectively ($P_{r,\ CSA} = \phi P_{n,\ CSA}$ and $M_{r,\ CSA} = \phi M_{n,\ CSA}$), as determined in accordance with Clauses 13.3, 13.5, and 13.6 of CSA S16:19 [1]. U_1, as defined in Clause 13.8.5, is the coefficient used to amplify the first-order bending moment to account for second-order effects (P-Delta) in the deformed configuration. However, in the parametric investigation described in Section 2.4.5, the second-order bending moment was directly extracted at the mid-height sections of the deformed beam-columns. Therefore, U_1 was taken as 1.0.

2.5.3 AISC 360-22

The interaction formulation for RHS long beam-columns follows the same provisions as Section H1 of AISC 360-22 [22], which was previously discussed in Chapter 1, Section 1.5.3 in the context of RHS stub beam-columns. The design provisions adopt a two-phase interaction expression based on the ratio of the factored axial compressive load (P_f) to the factored nominal axial compressive capacity ($P_{r,\ AISC} = \phi P_{n,\ AISC}$). Although the original formulation accounts for axial compression combined with biaxial bending, it was simplified in line with the scope of this study by assuming the out-of-plane bending component to be zero, reducing the formulation to axial compression and uniaxial bending. Members are divided into two categories based on their axial compression ratios: (1) those with ratios greater than or equal to 0.2, governed by the interaction formulation in Eq. 2.9, and (2) those with ratios less than 0.2, governed by Eq. 2.10. This represents a simplified bilinear approximation of the interaction curves, as outlined in Section 2.4.5. The 0.2 threshold signifies a transition in beam-column behavior, below which the slope of the second segment increases significantly, and flexural effects become more pronounced (see Figs. 2.9–2.12).

$$\text{When } \frac{P_f}{P_{r,\,AISC}} \geq 0.2 \qquad \frac{P_f}{P_{r,\,AISC}} + \frac{8}{9}\frac{M_f}{M_{r,\,AISC}} \leq 1.0 \tag{2.9}$$

$$\text{When } \frac{P_f}{P_{r,\,AISC}} < 0.2 \qquad \frac{P_f}{2P_{r,\,AISC}} + \frac{M_f}{M_{r,\,AISC}} \leq 1.0 \tag{2.10}$$

$P_{r,\,AISC}$ and $M_{r,\,AISC}$ denote the factored nominal axial compressive and flexural capacities, respectively ($P_{r,\,AISC} = \phi P_{n,\,AISC}$ and $M_{r,\,AISC} = \phi M_{n,\,AISC}$), as determined per Chapters E and F of AISC 360-22 [22]. The design standard adopts the Load and Resistance Factor Design (LRFD) methodology, which is based on a series of defined limit states. The governing design criterion is the limit state associated with the lowest load-bearing capacity. For RHS members under axial compression, typical limit states include flexural buckling (predominantly governing in long members), torsional buckling, and flexural-torsional buckling. Similarly, in flexure, the relevant limit states consist of yielding (plastic moment), flange local buckling, web local buckling, and lateral-torsional buckling.

2.5.4 Cross-section slenderness limits

Cross-section slenderness of RHS members (λ_l) is defined as the ratio of the flat face dimensions excluding the outer corner radii to the wall thickness (i.e., $\lambda_l = h_{el}/t$ and $\lambda_l = b_{el}/t$). In the absence of corner radius measurements, CSA S16:19 [1] recommends approximating the flat face dimensions as the external dimensions minus three times the wall thickness (i.e., $h_{el} = h\text{-}3t$ and b_{el}

= b-3t), whereas AISC 360-22 [22] suggests subtracting four times the wall thickness (i.e., h_{el} = h-4t and b_{el} = b-4t).

As previously discussed in Chapter 1, Section 1.5.4, both standards specify cross-section slenderness limits for members under axial compression, as well as for those subjected to flexure or combined axial compression and flexure. For pure axial compression, the sidewalls with the greater slenderness determine the classification of the entire RHS section (i.e., non-slender or slender). In contrast, for pure flexure or combined loading, flanges and webs are classified independently, with the higher classification governing the overall section class. CSA S16:19 [1] defines three slenderness limits (λ_{C1}, λ_{C2}, λ_{C3}) and four section classes (Classes 1, 2, 3, 4), while AISC 360-22 [22] adopts two slenderness limits (λ_p, λ_r) and three section classes (compact, non-compact, and slender). CSA S16:19 [1] treats flange slenderness limits as independent of axial load, but considers web slenderness limits to be load-dependent, accounting for the varying local buckling effects induced by different load magnitudes. In contrast, AISC 360-22 [22] assumes all flange and web slenderness limits are load-independent, relying solely on steel properties. In both standards, all cross-section slenderness limits are independent of cross-section geometry or member length. Accordingly, the same normalized slenderness limits specified for RHS stub members—outlined in Tables 1.7–1.9—are also applied to long members and are summarized in Tables 2.6–2.8.

Table 2.6 Slenderness limits for RHS sidewalls subjected to axial compression in the existing standards

Design standard	Element description	Normalized slenderness $\bar{\lambda}_l$	Normalized slenderness limit $\bar{\lambda}_r$
CSA S16:19 [1]	Flanges of RHS	$(b_{el}/t)\sqrt{f_y/E}$	1.50
	Webs of RHS	$(h_{el}/t)\sqrt{f_y/E}$	1.50
AISC 360-22 [22]	Flanges of RHS	$(b_{el}/t)\sqrt{f_y/E}$	1.40
	Webs of RHS	$(h_{el}/t)\sqrt{f_y/E}$	1.40

Table 2.7 Slenderness limits for RHS flanges and webs subjected to axial compression and flexure in CSA S16:19 [1]

Element description	Normalized slenderness	Normalized slenderness limits		
	$\bar{\lambda}_l$	$\bar{\lambda}_{C1}$	$\bar{\lambda}_{C2}$	$\bar{\lambda}_{C3}$
Flanges of RHS	$(b_{el}/t)\sqrt{f_y/E}$	0.94	1.17	1.50
Webs of RHS, Class 1	$(h_{el}/t)\sqrt{f_y/E}/(1-0.39P_u/P_y)$	2.46	—	—
Webs of RHS, Class 2	$(h_{el}/t)\sqrt{f_y/E}/(1-0.61P_u/P_y)$	—	3.80	—
Webs of RHS, Class 3	$(h_{el}/t)\sqrt{f_y/E}/(1-0.65P_u/P_y)$	—	—	4.25

Table 2.8 Slenderness limits for RHS flanges and webs subjected to axial compression and flexure in AISC 360-22 [22]

Element description	Normalized slenderness	Normalized slenderness limits	
	$\bar{\lambda}_l$	$\bar{\lambda}_p$	$\bar{\lambda}_r$
Flanges of RHS	$(b_{el}/t)\sqrt{f_y/E}$	1.12	1.40
Webs of RHS	$(h_{el}/t)\sqrt{f_y/E}$	2.42	5.70

As displayed in Table 2.6, CSA S16:19 [1] considers a higher normalized slenderness limit for members subjected to pure axial compression compared to AISC 360-22 [22] ($\bar{\lambda}_r$ = 1.50 vs. $\bar{\lambda}_r$ = 1.40). Both standards define similar flange slenderness limits for the highest slenderness class—Class 4 in CSA S16:19 [1] and slender in AISC 360-22 [22]—($\bar{\lambda}_{C3}$ = 1.50 vs. $\bar{\lambda}_r$ = 1.40). As previously discussed in Section 2.4.5, the mechanical behavior of long beam-columns is mainly governed by global buckling; however, local buckling effects may still have an impact. Under the combined effects of axial compression and flexure, the compressive flanges experience the highest stresses, making them the primary elements controlling the mechanical behavior of the models. Consequently, both standards set higher slenderness limits for webs than for flanges ($\bar{\lambda}_{C3}$ = 4.25 in CSA S16:19 [1] and $\bar{\lambda}_r$ = 5.70 in AISC 360-22 [22]). As discussed earlier in Chapter 1, Section

1.5.4, studies on direct-formed [16–18, 21] and indirect-formed RHS members [28–32] suggested that the existing cross-section slenderness limits in CSA S16:19 [1] and AISC 360-22 [22] may be excessively conservative in predicting load-bearing capacities, particularly for direct-formed beams with flanges classified as Class 4 or slender, where flange local buckling is the governing limit state.

2.5.5 Effective width method

The mechanical behaviour and load-bearing capacity of RHS long members with non-slender sidewalls under axial compression are primarily governed by global buckling, leading to ultimate axial loads below the cross-section yield load (P_y). For long members subjected to flexure and composed of stocky elements—i.e., flanges and webs classified as Class 1 or 2 in CSA S16:19 [1]—the standard assumes that the full plastic moment capacity ($M_p = Zf_y$) is achieved. In contrast, AISC 360-22 [22] indicates that, depending on the member length, long members with compact flanges may either achieve the full plastic moment capacity or be governed by lateral-torsional buckling. Furthermore, CSA S16:19 [1] specifies that long beam-columns composed of Class 3 elements are limited to a flexural capacity equal to the yield moment ($M_y = Sf_y$). Conversely, AISC 360-22 [22] adopts a linear interpolation between the plastic and yield moment capacities for members with non-compact flanges or webs (see Eq. 2.11).

$$M_{n,\,AISC} = M_p - \left(M_p - M_y\right)\left(\frac{\lambda_l - \lambda_p}{\lambda_r - \lambda_p}\right) \le M_p \tag{2.11}$$

In the above equation, λ_l represents the flange or web slenderness; λ_p and λ_r correspond to the compact/non-compact and non-compact/slender limits, respectively, as defined in AISC 360-22 [22].

Local buckling effects become most significant in long members with Class 4 or slender elements, resulting in lower load-bearing capacities compared to members of other classes with the same outer dimensions. To account for these effects, both CSA S16:19 [1] and AISC 360-22 [22] recommend a simplified approach known as the effective width method for calculating the axial compressive and flexural capacities of such members. In this method, instead of directly accounting for local buckling, the dimensions of slender sidewalls are reduced to effective values, which in turn lowers the axial and flexural capacities to reflect the actual impact of local buckling. The approach is typically applied separately to members under pure axial compression (columns) and pure flexure (beams). However, for beam-columns subjected to combined loading, a hybrid application is used. The axial compressive capacity (P_n) is determined using column provisions, while the flexural capacity (M_n) is evaluated using beam provisions. According to CSA S16:19 [1], the dimensions of slender sidewalls in members subjected to pure axial compression are adjusted to effective widths (b_e) and depths (h_e) to ensure that their slenderness is reduced to the specified limit (λ_r). For members subjected to flexure, compressive flanges and webs classified as Class 4 are similarly adjusted to effective widths and depths, ensuring their slenderness meets the specified Class 3 limit (λ_{C3}). These effective cross-sectional parameters are then used to calculate the axial compressive and flexural capacities of the member, following the same approach used for Class 3 elements (e.g, for flexural capacity, $M_{n,\,CSA} = S_e f_y$, where S_e is the effective elastic section modulus). In contrast, AISC 360-22 [22] adopts a different method for determining effective widths, wherein the values are dependent on both cross-sectional and global slenderness. As per Section E7 of AISC 360-22 [22], which pertains to the design of members with slender elements subjected to axial compression, the effective width of RHS sidewalls is determined using Eqs. 2.12 and 2.13.

$$\text{When } \lambda_l \le \lambda_r \sqrt{\frac{f_y}{f_n}} \qquad b_e = b_{el} \tag{2.12}$$

$$\text{When } \lambda_l > \lambda_r \sqrt{\frac{f_y}{f_n}} \qquad b_e = b_{el}\left(1 - 0.20\sqrt{\frac{f_{el}}{f_n}}\right)\sqrt{\frac{f_{el}}{f_n}} \tag{2.13}$$

In the above equations, b_e and b_{el} are the effective width and the internal flange width, excluding the corner regions, respectively. Likewise, h_e and h_{el} can be used when webs are concerned, denoting the effective depth and internal web depth, excluding the corners, correspondingly. λ_l represents the sidewall slenderness, λ_r denotes the non-slender/slender limit, f_{el} corresponds to the elastic local buckling stress determined in Section E7, and f_n indicates the nominal stress determined in Section E3, which is influenced by the global slenderness of the member. As specified in Section F7 of AISC 360-22 [22], which outlines the flexural design provisions for RHS members, the effective width of slender compression flanges is determined using Equation 2.14.

$$b_e = 1.92t\sqrt{\frac{E}{f_y}}\left(1 - \frac{0.38}{b_{el}/t}\sqrt{\frac{E}{f_y}}\right) \le b_{el} \tag{2.14}$$

The flexural capacity of the RHS beam is subsequently calculated using the effective elastic section modulus (i.e., $M_{n,\,AISC} = S_e f_y$).

2.5.6 Reliability analysis

A similar series of reliability analyses as discussed in Chapter 1, Section 1.5.6, was carried out on RHS long beam-columns to evaluate the reliability of the existing design standards (i.e., CSA S16:19 [1] and AISC 360-22 [22]). Corresponding reliability indices (β_0) were determined according to AISI S100-16 [23] provisions, as shown in Eq. 2.15.

$$\beta_0 = \frac{\ln(C_\phi M_m F_m P_m / \phi)}{\sqrt{V_M^2 + V_F^2 + C_P V_P^2 + V_Q^2}} \tag{2.15}$$

Consistent with the values used for RHS stub beam-columns in the previous chapter, the calibration coefficient (C_ϕ) was set to 1.42 for the reliability analyses related to CSA S16:19 [1], and 1.52 for AISC 360-22 [22], as recommended by AISI S100-16 [23]. Following additional recommendations from AISI S100-16 [23], the mean and coefficient of variation (COV) of the material factors (M_m and V_M) were taken as 1.10 and 0.10, respectively. Moreover, the fabrication factor was assigned a mean value (F_m) of 1.00 and a COV (V_F) of 0.05. The mean and COV of the axial compression and flexure interaction term, shown on the left side of Eq. 2.6 ($\alpha_1 P_u/P_n$ + $\alpha_2 M_u/M_n$), were calculated to represent the mean (P_m) and COV (V_P) of the FE capacities relative to the code-predicted capacities. The correction factor (C_P), which accounts for the influence of data size, was calculated using the formula provided in Eq. 2.16, as recommended by AISI S100-16 [23]. According to the provisions of both CSA S16:19 [1] and AISC 360-22 [22], a resistance factor (ϕ) of 0.90 was applied to convert the nominal unfactored capacities into the corresponding factored values. Based on AISI S100-16 [23], the COV of load effects (V_Q) was taken as 0.21 in both standards. The target reliability indices were set to 3.00 for CSA S16:19 [1] and 2.60 for AISC 360-22 [22], as suggested by AISI S100-16 [23], reflecting the respective design philosophies of each standard.

$$C_P = (1 + 1/n')m'/(m' - 2) \qquad \text{for } n' \geq 4 \tag{2.16}$$

In Eq. 2.16, C_P stands for the correction factor, n' indicates the data size, and m' corresponds to the degrees of freedom, which is equal to $n' - 1$.

Table 2.9 Reliability analysis parameters for CSA S16:19 [1] and AISC 360-22 [22] for all material groups and categories

Design standard	Parameters						
	C_ϕ	M_m	F_m	V_M	V_F	V_Q	ϕ
CSA S16:19 [1]	1.42	1.10	1.00	0.10	0.05	0.21	0.90
AISC 360-22 [22]	1.52	1.10	1.00	0.10	0.05	0.21	0.90

Table 2.10 Reliability analysis parameters for CSA S16:19 [1] and AISC 360-22 [22] for different material groups and categories

Design standard	Material	Category	Parameters for the linear interaction: $\alpha_1 P_u/P_n + \alpha_2 M_u/M_n$							
			α_1	α_2	n'	m'	C_P	P_m	V_P	β_0
CSA S16:19 [1]	All	Class 1, 2	1.00	0.85	520	519	1.01	1.68	0.34	2.57
	All	Class 3, 4	1.00	1.00	520	519	1.01	1.77	0.14	4.09
	DN, DH	Class 1, 2	1.00	0.85	270	269	1.01	1.77	0.33	2.75
	DN, DH	Class 3, 4	1.00	1.00	250	249	1.01	1.83	0.13	4.27
	IN, IH	Class 1, 2	1.00	0.85	250	249	1.01	1.57	0.34	2.41
	IN, IH	Class 3, 4	1.00	1.00	270	269	1.01	1.71	0.13	3.97
AISC 360-22 [22]	All	$P_u/(\phi P_n) \geq 0.2$	1.00	0.89	1040	1039	1.00	1.71	0.41	2.45
	DN, DH	$P_u/(\phi P_n) \geq 0.2$	1.00	0.89	520	519	1.01	1.77	0.35	2.81
	IN, IH	$P_u/(\phi P_n) \geq 0.2$	1.00	0.89	520	519	1.01	1.65	0.46	2.15

Based on the results of the reliability analyses and the calculated reliability indices (β_0), the design provisions for RHS long beam-columns in CSA S16:19 [1] were found to provide varying levels of reliability. The provisions were noticeably more conservative for members with sidewalls belonging to higher cross-section slenderness classes (i.e., Classes 3 and 4) compared to those with lower slenderness classes (i.e., Classes 1 and 2), as reflected in the higher reliability indices for the former. The reason lies in the fact that CSA S16:19 [1], in contrast to AISC 360-22 [22], does not account for the variations in the combined effect of global and local buckling in the effective width method. As a result, excessive cross-section penalties are applied to members with relatively higher global slenderness in longer members. Among all categories considered for CSA S16:19 [1], indirect-formed members with sidewalls of Classes 1 and 2 exhibited the lowest reliability, with a reliability index of 2.41. In contrast, direct-formed members with sidewalls of Classes 3 and 4 demonstrated the highest reliability, with a reliability index of 4.27, surpassing the target reliability index of 3.00.

For the AISC 360-22 [22] design provisions, the overall reliability was observed to be relatively lower compared to the CSA S16:19 [1] results, with a corresponding reliability index of 2.45, marginally below the target value of 2.60. While the direct-formed RHS long beam-columns showed a higher reliability index of 2.81, the indirect-formed members, with a reliability index of 2.15, did not meet the target value of 2.60.

In contrast to the findings for RHS stub beam-columns in Chapter 1, Section 1.5.6, where the design provisions in CSA S16:19 [1] were generally found to be less conservative than those in AISC 360-22 [22], the provisions for RHS long beam-columns in CSA S16:19 [1] overall proved to be more conservative than those in AISC 360-22 [22]. Similar to the findings for stub members in the previous chapter, direct-formed RHS long beam-columns exhibited higher reliability indices than their indirect-formed counterparts, indicating greater actual load-bearing capacities. However, the most notable differences in reliability indices (i.e., the disparity between code predictions and actual load-bearing capacities) were linked to the cross-section slenderness classes in CSA S16:19 [1]. Specifically, the actual load-bearing capacity of RHS long beam-columns with sidewalls of higher slenderness classes (i.e., Classes 3 and 4) was most significantly underestimated. This is because the design provisions in CSA S16:19 [1] specify the effective depth (h_e) and width (b_e) for members with sidewalls of Class 4, regardless of the global slenderness. Overall, RHS long beam-columns exhibited relatively higher mean and COV values for the ratio of FE capacities to code-predicted capacities (i.e., P_m and V_P, respectively), compared to their stub counterparts.

2.6 Proposed design modifications

2.6.1 Modification of the slenderness limits

A detailed discussion on the parametric investigation and proposed modifications to the slenderness limits for RHS stub beam-columns was presented in Chapter 1, Sections 1.4.5 and 1.6.1. Consistent with CSA S16:19 [1] and AISC 360-22 [22], which define cross-section slenderness limits regardless of member length, similar slenderness modifications as those recommended for stub members are suggested for long members. Accordingly, it is proposed that the current CSA S16:19 [1] limit for sidewalls under axial compression (i.e., $\bar{\lambda}_r$ = 1.50) be adopted in AISC 360-22 [22] for direct-formed RHS long beam-columns. The same limit is also recommended for the slender flanges of direct-formed RHS long members subjected to flexure or combined axial compression and flexure, to be incorporated into AISC 360-22 [22]. A summary of these modifications is provided in Table 2.11.

Table 2.11 Proposed modified slenderness limits for the sidewalls and flanges of direct-formed RHS in AISC 360-22 [22]

Element description	Normalized slenderness	Normalized slenderness limits	
	$\bar{\lambda}_l$	$\bar{\lambda}_p$	$\bar{\lambda}_r$
Sidewalls of RHS	$(b_{el}/t)\sqrt{f_y/E}$	—	1.50
Sidewalls of RHS	$(h_{el}/t)\sqrt{f_y/E}$	—	1.50
Flanges of RHS	$(b_{el}/t)\sqrt{f_y/E}$	1.12	1.50

2.6.2 Modification of the interaction coefficients

As outlined in Sections 2.5.1–2.5.3, both CSA S16:19 [1] and AISC 360-22 [22] evaluate the load-bearing capacity of RHS long beam-columns using a similar interaction formulation, with coefficients α_1 and α_2 in the same way as for stub members in each standard (see Eqs. 2.5–2.10). The reliability analyses conducted on the existing interaction formulas, as shown in Table 2.10, resulted in a series of reliability indices (β_0) that deviated from the target values suggested by CSA S16:19 [1] (β_0 = 3.00) and AISC 360-22 [22] (β_0 = 2.60). To reach the recommended target reliability indices, a set of revised coefficients, along with the adjusted cross-section slenderness limits outlined in Section 2.6.1, is proposed. The coefficient for the axial compression term (α_1) is assumed to be 1.00 to meet the design requirements when the axial load is applied concentrically.

A series of reliability analyses is performed on the FE models incorporating the proposed changes, as detailed in Section 2.6.3.

2.6.3 Reliability analysis

According to the procedure outlined in Section 2.5.6 and using the parameter values provided in Table 2.9, a series of reliability analyses is conducted for the FE models, incorporating the modified design provisions from Sections 2.6.1 and 2.6.2. The modified interaction coefficients (α_1 and α_2) were set to achieve reliability indices (β_0) that meet or slightly exceed the target values, avoiding excessive design conservatism. The results are summarized in Table 2.12.

Table 2.12 Reliability analysis results for the proposed modifications in CSA S16:19 [1] and AISC 360-22 [22]

Design standard	Material	Category	Parameters for the linear interaction: $\alpha_1 P_u/P_n + \alpha_2 M_u/M_n$							
			α_1	α_2	n'	m'	C_P	P_m	V_P	β_0
CSA S16:19 [1]	DN, DH	Class 1, 2	1.00	1.00	270	269	1.01	1.89	0.31	3.00
	DN, DH	Class 3, 4	1.00	0.52	250	249	1.01	1.40	0.17	3.03
	IN, IH	Class 1, 2	1.00	1.33	250	249	1.01	1.87	0.31	3.00
	IN, IH	Class 3, 4	1.00	0.58	270	269	1.01	1.36	0.16	3.00
AISC 360-22 [22]	DN, DH	$P_u/(\phi P_n) \geq 0.2$	1.00	0.78	520	519	1.01	1.68	0.37	2.60
	IN, IH	$P_u/(\phi P_n) \geq 0.2$	1.00	1.20	520	519	1.01	1.87	0.41	2.60

2.7 Conclusions

Despite the mechanical differences among RHS long members produced through different cold-forming techniques (i.e., direct-forming and indirect-forming), such distinctions are not reflected in the current Canadian and American steel design standards (CSA S16:19 [1] and AISC 360-22 [22]). Furthermore, the behavioural differences between RHS stub and long beam-columns, stemming from varying levels of combined cross-section and global slenderness effects, are not fully recognized, since no distinct formulas are used for their combined axial compressive and flexural load-bearing capacities in these standards. In this study, a comprehensive numerical investigation was conducted on a total of 1040 finite element models simulating cold-formed, untreated RHS long beam-columns. The models included a broad range of cross-section slenderness and global slenderness values, along with yield steel strengths ranging from 350 MPa to 700 MPa, considering both direct- and indirect-formed members. The ultimate combined axial compressive and flexural capacities were obtained and compared to the interaction equations provided in CSA S16:19 [1] and AISC 360-22 [22]. A series of reliability analyses were conducted to assess the safety and reliability of the existing interaction formulas in these standards.

The findings of this study indicated that the current CSA S16:19 [1] provisions for the design of RHS long beam-columns provided varying levels of reliability. However, the design formula applied to members with more slender sidewalls, classified as Classes 3 and 4, was found to be overly conservative compared to those with Classes 1 and 2 sidewalls, leading to significant underestimation of their load-bearing capacities. This conservatism is primarily attributed to the limited consideration of the variation in combined cross-section and global slenderness effects, particularly in Class 4 members. In such cases, the effective width method imposes unnecessary reductions in sidewall dimensions, even though the behaviour of these members is mainly governed by global buckling. On the other hand, AISC 360-22 [22] generally resulted in relatively lower design conservatism and reliability, particularly for indirect-formed members. Similar to the findings for RHS stub members, direct-formed RHS long members were found to be mechanically superior to their indirect-formed counterparts, exhibiting greater ultimate capacities under combined axial compression and flexure.

Several modifications were proposed for the design of RHS long beam-columns in both CSA S16:19 [1] and AISC 360-22 [22] to achieve target reliability levels while avoiding over-conservatism. In line with the modification of the cross-section slenderness limits proposed for the RHS stub beam-columns in the previous chapter, the same higher non-slender/slender cross-section slenderness limit was proposed for direct-formed RHS long members under axial compression in AISC 360-22 [22], matching it with CSA S16:19 [1]. A similar modification was proposed for the non-compact/slender limit of the flanges in direct-formed members subjected to combined axial compression and flexure, aligning it with the Class 3 limit specified in CSA S16:19 [1]. Several adjustments were also made to the interaction coefficients in both CSA S16:19 [1] and AISC 360-22 [22], taking into account factors such as cold-forming technique (i.e., direct or indirect forming), steel grade (i.e., normal or high strength), and cross-section classification, which resulted in modified design formulas.

Nomenclature

b	External flange width of RHS
b_e	Effective internal flange width
b_{el}	Internal flange width excluding the corner portions
C_P	Correction factor in reliability analysis
C_ϕ	Calibration coefficient in reliability analysis
E	Young's modulus
$E_{0.2}$	Tangent modulus of elasticity at the 0.2% proof stress
e	Load eccentricity
F_m	Mean value of the fabrication factor in reliability analysis
f	Steel stress
f_{el}	Elastic local buckling stress according to AISC 360-22
f_n	Nominal stress according to AISC 360-22
f_u	Steel ultimate tensile strength
f_y	Steel yield strength or 0.2% proof stress
h	External web depth of RHS
h_e	Effective internal web depth
h_{el}	Internal web depth excluding the corner portions
L	Length of RHS

M_f Factored uniaxial bending moment

M_m Mean value of the material factor in reliability analysis

M_n Unfactored nominal flexural capacity

$M_{n,\,AISC}$ Unfactored nominal flexural capacity according to AISC 360-22

$M_{n,\,CSA}$ Unfactored nominal flexural capacity according to CSA S16:19

M_p Plastic moment

M_r Factored nominal flexural capacity

$M_{r,\,AISC}$ Factored nominal flexural capacity according to AISC 360-22

$M_{r,\,CSA}$ Factored nominal flexural capacity according to CSA S16:19

M_u Ultimate second-order bending moment

M_y Yield moment

m Second strain hardening exponent

m' Degrees of freedom in reliability analysis

n First strain hardening exponent

n' Number of data in reliability analysis

P_f Factored axial compressive load

P_m Mean value of the ratio of FE ultimate combined loads to unfactored nominal capacities in reliability analysis

P_n Unfactored nominal axial compressive capacity

$P_{n,\,AISC}$ Unfactored nominal axial compressive capacity according to AISC 360-22

$P_{n,\,CSA}$ Unfactored nominal axial compressive capacity according to CSA S16:19

P_r Factored nominal axial compressive capacity

$P_{r,\,AISC}$ Factored nominal axial compressive capacity according to AISC 360-22

$P_{r,\,CSA}$ Factored nominal axial compressive capacity according to CSA S16:19

P_u Ultimate axial compressive load

$P_{u,\,FE}$ Ultimate axial compressive load based on finite element analysis

$P_{u,\,test}$ Ultimate axial compressive load based on experimental tests

P_y Cross-section yield load based on the flat face material

r_i Inner corner radius of RHS

r_o Outer corner radius of RHS

S Elastic section modulus

S_e Effective elastic section modulus

t Wall thickness of RHS

U_1 Factor for second-order effects of axial compressive load on a deformed member according to CSA S16:19

V_F Coefficient of variation of the fabrication factor in reliability analysis

V_M Coefficient of variation of the material factor in reliability analysis

V_P Coefficient of variation of the ratio of FE ultimate combined loads to unfactored nominal capacities in reliability analysis

V_Q	Coefficient of variation of the load effect in reliability analysis
Z	Plastic section modulus
α_1	Coefficient of axial compression in the interaction formulation
α_2	Coefficient of flexure in the interaction formulation
β_0	Reliability index
δ_l	Maximum local imperfection of RHS sidewalls
δ_g	Maximum global imperfection of RHS members
ε	Steel engineering strain
$\varepsilon_{0.2}$	Steel strain at the 0.2% proof stress
ε_u	Steel ultimate strain
λ_{C1}	Class 1 slenderness limit according to CSA S16:19
λ_{C2}	Class 2 slenderness limit according to CSA S16:19
λ_{C3}	Class 3 slenderness limit according to CSA S16:19
λ_g	Global slenderness of RHS members
λ_l	Cross-sectional slenderness of RHS sidewalls
λ_p	Compact/non-compact slenderness limit according to AISC 360-22
λ_r	Non-slender/slender and non-compact/slender slenderness limits according to CSA S16:19 and AISC 360-22
$\bar{\lambda}_{C1}$	Normalized Class 1 slenderness limit

$\bar{\lambda}_{C2}$	Normalized Class 2 slenderness limit
$\bar{\lambda}_{C3}$	Normalized Class 3 slenderness limit
$\bar{\lambda}_{l}$	Normalized cross-sectional slenderness of RHS sidewalls
$\bar{\lambda}_{p}$	Normalized compact/non-compact slenderness limit
$\bar{\lambda}_{r}$	Normalized non-slender/slender and non-compact/slender slenderness limits
v	Poisson's ratio
$\sigma_{0.05}$	0.05% proof stress for steel material
ϕ	Resistance factor

Chapter 3 Future work

This thesis provided insights into the behaviour and design of cold-formed, untreated RHS beam-columns, presenting a comparative study on direct- and indirect-formed members. Advancements were made by highlighting the structural and mechanical advantages of direct-formed RHS beam-columns, as well as by improving design formulas. Future studies may be conducted on the topics outlined below:

(1) Experimental investigation on direct-formed RHS long beam-columns

(2) Design of direct- and indirect-formed RHS beam-columns with slender webs

(3) Design of direct- and indirect-formed RHS beam-columns under axial compression and biaxial bending

(4) Comparative study on the design of hot-rolled and cold-formed, heat-treated RHS beam-columns

(5) Behaviour and design of cold-formed, hot-dip galvanized circular hollow section (CHS) beam-columns

(6) Developing nonlinear axial compression-flexure interaction formulations for (2–5)

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Appendices

Appendix A Stub beam-column parametric study

Table A.1 Stub beam-column parametric study results

Model ID	e (mm)	h (mm)	b (mm)	t (mm)	L (mm)	δ_l (mm)	P_u (kN)	M_u (kN.m)
SHS-DN-50×50×2.5	0	50	50	2.5	150	0.13	224.5	0
SHS-DN-50×50×2.5	5	50	50	2.5	150	0.13	183.8	1.1
SHS-DN-50×50×2.5	20	50	50	2.5	150	0.13	120.5	2.5
SHS-DN-50×50×2.5	35	50	50	2.5	150	0.13	89.1	3.2
SHS-DN-50×50×2.5	50	50	50	2.5	150	0.13	70.1	3.6
SHS-DN-50×50×3	0	50	50	3.0	150	0.15	281.8	0
SHS-DN-50×50×3	5	50	50	3.0	150	0.15	226.9	1.3
SHS-DN-50×50×3	20	50	50	3.0	150	0.15	148.6	3.2
SHS-DN-50×50×3	35	50	50	3.0	150	0.15	109.3	4.0
SHS-DN-50×50×3	50	50	50	3.0	150	0.15	85.6	4.5
SHS-DN-100×100×2.8	0	100	100	2.8	300	0.14	413.8	0
SHS-DN-100×100×2.8	10	100	100	2.8	300	0.14	352.1	3.6
SHS-DN-100×100×2.8	40	100	100	2.8	300	0.14	222.9	9.1
SHS-DN-100×100×2.8	70	100	100	2.8	300	0.14	162.4	11.5
SHS-DN-100×100×2.8	100	100	100	2.8	300	0.14	129.4	13.1
SHS-DN-100×100×4.2	0	100	100	4.2	300	0.21	722.0	0
SHS-DN-100×100×4.2	10	100	100	4.2	300	0.21	595.8	6.5
SHS-DN-100×100×4.2	40	100	100	4.2	300	0.21	386.9	15.9
SHS-DN-100×100×4.2	70	100	100	4.2	300	0.21	286.2	20.4
SHS-DN-100×100×4.2	100	100	100	4.2	300	0.21	223.9	22.7
SHS-DN-150×150×3.9	0	150	150	3.9	450	0.20	856.9	0
SHS-DN-150×150×3.9	15	150	150	3.9	450	0.20	716.5	10.8
SHS-DN-150×150×3.9	60	150	150	3.9	450	0.20	452.8	27.3
SHS-DN-150×150×3.9	105	150	150	3.9	450	0.20	329.3	34.7

SHS-DN-150×150×3.9	150	150	150	3.9	450	0.20	259.3	39.0
SHS-DN-150×150×4.6	0	150	150	4.6	450	0.23	1079.4	0
SHS-DN-150×150×4.6	15	150	150	4.6	450	0.23	917.8	14.5
SHS-DN-150×150×4.6	60	150	150	4.6	450	0.23	590.7	36.2
SHS-DN-150×150×4.6	105	150	150	4.6	450	0.23	432.9	46.1
SHS-DN-150×150×4.6	150	150	150	4.6	450	0.23	340.8	51.6
SHS-DN-200×200×4.5	0	200	200	4.5	600	0.23	1203.7	0
SHS-DN-200×200×4.5	20	200	200	4.5	600	0.23	1016.8	20.4
SHS-DN-200×200×4.5	80	200	200	4.5	600	0.23	631.9	50.7
SHS-DN-200×200×4.5	140	200	200	4.5	600	0.23	458.3	64.3
SHS-DN-200×200×4.5	200	200	200	4.5	600	0.23	358.2	71.8
SHS-DN-200×200×7.6	0	200	200	7.6	600	0.38	2541.8	0
SHS-DN-200×200×7.6	20	200	200	7.6	600	0.38	2126.4	44.9
SHS-DN-200×200×7.6	80	200	200	7.6	600	0.38	1382.7	113.2
SHS-DN-200×200×7.6	140	200	200	7.6	600	0.38	1018.3	144.6
SHS-DN-200×200×7.6	200	200	200	7.6	600	0.38	798.9	161.7
SHS-DN-250×250×11.5	0	250	250	11.5	750	0.58	5085.6	0
SHS-DN-250×250×11.5	25	250	250	11.5	750	0.58	4165.7	115.8
SHS-DN-250×250×11.5	100	250	250	11.5	750	0.58	2731.6	284.5
SHS-DN-250×250×11.5	175	250	250	11.5	750	0.58	2024.0	363.2
SHS-DN-250×250×11.5	250	250	250	11.5	750	0.58	1582.8	403.5
SHS-DN-250×250×18	0	250	250	18.0	750	0.90	8962.2	0
SHS-DN-250×250×18	25	250	250	18.0	750	0.90	7165.7	268.2
SHS-DN-250×250×18	100	250	250	18.0	750	0.90	4740.1	537.7
SHS-DN-250×250×18	175	250	250	18.0	750	0.90	3478.6	659.1
SHS-DN-250×250×18	250	250	250	18.0	750	0.90	2701.0	716.7
SHS-DN-300×300×9.8	0	300	300	9.8	900	0.49	4637.6	0
SHS-DN-300×300×9.8	30	300	300	9.8	900	0.49	3959.0	125.0
SHS-DN-300×300×9.8	120	300	300	9.8	900	0.49	2536.9	310.4
SHS-DN-300×300×9.8	210	300	300	9.8	900	0.49	1862.6	396.2

SHS-DN-300×300×9.8	300	300	300	9.8	900	0.49	1465.8	443.9
SHS-DN-300×300×12.2	0	300	300	12.2	900	0.61	6289.9	0
SHS-DN-300×300×12.2	30	300	300	12.2	900	0.61	5179.2	167.6
SHS-DN-300×300×12.2	120	300	300	12.2	900	0.61	3391.0	420.5
SHS-DN-300×300×12.2	210	300	300	12.2	900	0.61	2502.2	536.9
SHS-DN-300×300×12.2	300	300	300	12.2	900	0.61	1944.4	592.0
SHS-DN-350×350×10.5	0	350	350	10.5	1050	0.53	5632.3	0
SHS-DN-350×350×10.5	35	350	350	10.5	1050	0.53	4767.0	173.0
SHS-DN-350×350×10.5	140	350	350	10.5	1050	0.53	3063.6	435.6
SHS-DN-350×350×10.5	245	350	350	10.5	1050	0.53	2244.5	556.5
SHS-DN-350×350×10.5	350	350	350	10.5	1050	0.53	1776.4	627.1
SHS-DN-350×350×12	0	350	350	12.0	1050	0.60	6859.0	0
SHS-DN-350×350×12	35	350	350	12.0	1050	0.60	5792.8	211.9
SHS-DN-350×350×12	140	350	350	12.0	1050	0.60	3746.6	533.9
SHS-DN-350×350×12	245	350	350	12.0	1050	0.60	2748.5	681.1
SHS-DN-350×350×12	350	350	350	12.0	1050	0.60	2152.9	759.8
SHS-DN-400×400×10	0	400	400	10.0	1200	0.50	5720.8	0
SHS-DN-400×400×10	40	400	400	10.0	1200	0.50	4771.6	196.1
SHS-DN-400×400×10	160	400	400	10.0	1200	0.50	2997.9	486.8
SHS-DN-400×400×10	280	400	400	10.0	1200	0.50	2176.6	616.3
SHS-DN-400×400×10	400	400	400	10.0	1200	0.50	1706.5	688.8
SHS-DN-400×400×11.6	0	400	400	11.6	1200	0.58	6976.6	0
SHS-DN-400×400×11.6	40	400	400	11.6	1200	0.58	5909.6	245.2
SHS-DN-400×400×11.6	160	400	400	11.6	1200	0.58	3783.6	615.1
SHS-DN-400×400×11.6	280	400	400	11.6	1200	0.58	2755.6	781.2
SHS-DN-400×400×11.6	400	400	400	11.6	1200	0.58	2184.5	881.6
SHS-DN-450×450×10.8	0	450	450	10.8	1350	0.54	6797.9	0
SHS-DN-450×450×10.8	45	450	450	10.8	1350	0.54	5666.5	261.7
SHS-DN-450×450×10.8	180	450	450	10.8	1350	0.54	3530.8	645.7
SHS-DN-450×450×10.8	315	450	450	10.8	1350	0.54	2576.3	820.6

SHS-DN-450×450×10.8	450	450	450	10.8	1350	0.54	2022.9	917.9
SHS-DN-450×450×12	0	450	450	12.0	1350	0.60	7914.8	0
SHS-DN-450×450×12	45	450	450	12.0	1350	0.60	6658.6	309.3
SHS-DN-450×450×12	180	450	450	12.0	1350	0.60	4184.6	766.3
SHS-DN-450×450×12	315	450	450	12.0	1350	0.60	3041.6	969.1
SHS-DN-450×450×12	450	450	450	12.0	1350	0.60	2408.0	1093.1
SHS-DN-500×500×18	0	500	500	18.0	1500	0.90	14853.9	0
SHS-DN-500×500×18	50	500	500	18.0	1500	0.90	12484.4	653.7
SHS-DN-500×500×18	200	500	500	18.0	1500	0.90	8076.7	1649.0
SHS-DN-500×500×18	350	500	500	18.0	1500	0.90	5922.1	2098.3
SHS-DN-500×500×18	500	500	500	18.0	1500	0.90	4663.4	2355.4
SHS-DN-500×500×27	0	500	500	27.0	1500	1.35	24746.2	0
SHS-DN-500×500×27	50	500	500	27.0	1500	1.35	20141.2	1178.2
SHS-DN-500×500×27	200	500	500	27.0	1500	1.35	13209.1	2794.5
SHS-DN-500×500×27	350	500	500	27.0	1500	1.35	9763.3	3557.5
SHS-DN-500×500×27	500	500	500	27.0	1500	1.35	7659.8	3943.0
SHS-DH-50×50×2.5	0	50	50	2.5	150	0.13	370.8	0
SHS-DH-50×50×2.5	5	50	50	2.5	150	0.13	307.6	1.7
SHS-DH-50×50×2.5	20	50	50	2.5	150	0.13	198.1	4.1
SHS-DH-50×50×2.5	35	50	50	2.5	150	0.13	145.3	5.2
SHS-DH-50×50×2.5	50	50	50	2.5	150	0.13	114.0	5.8
SHS-DH-50×50×3	0	50	50	3.0	150	0.15	463.7	0
SHS-DH-50×50×3	5	50	50	3.0	150	0.15	378.8	2.2
SHS-DH-50×50×3	20	50	50	3.0	150	0.15	245.5	5.2
SHS-DH-50×50×3	35	50	50	3.0	150	0.15	181.0	6.6
SHS-DH-50×50×3	50	50	50	3.0	150	0.15	141.6	7.3
SHS-DH-100×100×2.8	0	100	100	2.8	300	0.14	626.4	0
SHS-DH-100×100×2.8	10	100	100	2.8	300	0.14	533.8	5.6
SHS-DH-100×100×2.8	40	100	100	2.8	300	0.14	334.8	13.7
SHS-DH-100×100×2.8	70	100	100	2.8	300	0.14	241.9	17.2

SHS-DH-100×100×2.8	100	100	100	2.8	300	0.14	190.3	19.3
SHS-DH-100×100×4.2	0	100	100	4.2	300	0.21	1165.3	0
SHS-DH-100×100×4.2	10	100	100	4.2	300	0.21	988.9	10.3
SHS-DH-100×100×4.2	40	100	100	4.2	300	0.21	635.2	26.0
SHS-DH-100×100×4.2	70	100	100	4.2	300	0.21	459.6	32.7
SHS-DH-100×100×4.2	100	100	100	4.2	300	0.21	361.5	36.6
SHS-DH-150×150×3.9	0	150	150	3.9	450	0.20	1211.6	0
SHS-DH-150×150×3.9	15	150	150	3.9	450	0.20	1050.7	15.8
SHS-DH-150×150×3.9	60	150	150	3.9	450	0.20	668.0	40.3
SHS-DH-150×150×3.9	105	150	150	3.9	450	0.20	487.5	51.4
SHS-DH-150×150×3.9	150	150	150	3.9	450	0.20	383.5	57.7
SHS-DH-150×150×4.6	0	150	150	4.6	450	0.23	1673.9	0
SHS-DH-150×150×4.6	15	150	150	4.6	450	0.23	1402.5	22.0
SHS-DH-150×150×4.6	60	150	150	4.6	450	0.23	873.3	53.6
SHS-DH-150×150×4.6	105	150	150	4.6	450	0.23	631.7	67.5
SHS-DH-150×150×4.6	150	150	150	4.6	450	0.23	494.0	75.0
SHS-DH-200×200×4.5	0	200	200	4.5	600	0.23	1613.7	0
SHS-DH-200×200×4.5	20	200	200	4.5	600	0.23	1416.0	28.3
SHS-DH-200×200×4.5	80	200	200	4.5	600	0.23	927.5	74.4
SHS-DH-200×200×4.5	140	200	200	4.5	600	0.23	682.4	95.8
SHS-DH-200×200×4.5	200	200	200	4.5	600	0.23	537.3	107.7
SHS-DH-200×200×7.6	0	200	200	7.6	600	0.38	4111.4	0
SHS-DH-200×200×7.6	20	200	200	7.6	600	0.38	3445.6	73.2
SHS-DH-200×200×7.6	80	200	200	7.6	600	0.38	2165.8	177.8
SHS-DH-200×200×7.6	140	200	200	7.6	600	0.38	1562.1	222.1
SHS-DH-200×200×7.6	200	200	200	7.6	600	0.38	1229.5	249.2
SHS-DH-250×250×11.5	0	250	250	11.5	750	0.58	8347.0	0
SHS-DH-250×250×11.5	25	250	250	11.5	750	0.58	6951.8	184.2
SHS-DH-250×250×11.5	100	250	250	11.5	750	0.58	4458.5	458.2
SHS-DH-250×250×11.5	175	250	250	11.5	750	0.58	3260.6	582.3

SHS-DH-250×250×11.5	250	250	250	11.5	750	0.58	2563.9	651.0
SHS-DH-250×250×18	0	250	250	18.0	750	0.90	14452.0	0
SHS-DH-250×250×18	25	250	250	18.0	750	0.90	11471.9	350.0
SHS-DH-250×250×18	100	250	250	18.0	750	0.90	7452.9	810.7
SHS-DH-250×250×18	175	250	250	18.0	750	0.90	5463.6	1012.1
SHS-DH-250×250×18	250	250	250	18.0	750	0.90	4262.9	1110.0
SHS-DH-300×300×9.8	0	300	300	9.8	900	0.49	7430.5	0
SHS-DH-300×300×9.8	30	300	300	9.8	900	0.49	6233.9	189.6
SHS-DH-300×300×9.8	120	300	300	9.8	900	0.49	3874.3	469.7
SHS-DH-300×300×9.8	210	300	300	9.8	900	0.49	2817.3	596.4
SHS-DH-300×300×9.8	300	300	300	9.8	900	0.49	2205.8	665.9
SHS-DH-300×300×12.2	0	300	300	12.2	900	0.61	10076.9	0
SHS-DH-300×300×12.2	30	300	300	12.2	900	0.61	8525.1	274.5
SHS-DH-300×300×12.2	120	300	300	12.2	900	0.61	5383.2	665.4
SHS-DH-300×300×12.2	210	300	300	12.2	900	0.61	3918.1	837.4
SHS-DH-300×300×12.2	300	300	300	12.2	900	0.61	3093.2	941.8
SHS-DH-350×350×10.5	0	350	350	10.5	1050	0.53	8749.4	0
SHS-DH-350×350×10.5	35	350	350	10.5	1050	0.53	7326.1	259.0
SHS-DH-350×350×10.5	140	350	350	10.5	1050	0.53	4607.0	650.1
SHS-DH-350×350×10.5	245	350	350	10.5	1050	0.53	3344.2	824.5
SHS-DH-350×350×10.5	350	350	350	10.5	1050	0.53	2612.5	919.0
SHS-DH-350×350×12	0	350	350	12.0	1050	0.60	10809.8	0
SHS-DH-350×350×12	35	350	350	12.0	1050	0.60	9137.9	325.6
SHS-DH-350×350×12	140	350	350	12.0	1050	0.60	5698.4	807.3
SHS-DH-350×350×12	245	350	350	12.0	1050	0.60	4112.0	1016.3
SHS-DH-350×350×12	350	350	350	12.0	1050	0.60	3255.0	1147.8
SHS-DH-400×400×10	0	400	400	10.0	1200	0.50	7962.7	0
SHS-DH-400×400×10	40	400	400	10.0	1200	0.50	6928.6	293.7
SHS-DH-400×400×10	160	400	400	10.0	1200	0.50	4454.5	729.4
SHS-DH-400×400×10	280	400	400	10.0	1200	0.50	3236.1	921.9

SHS-DH-400×400×10	400	400	400	10.0	1200	0.50	2542.4	1029.8
SHS-DH-400×400×11.6	0	400	400	11.6	1200	0.58	10683.3	0
SHS-DH-400×400×11.6	40	400	400	11.6	1200	0.58	9124.5	380.2
SHS-DH-400×400×11.6	160	400	400	11.6	1200	0.58	5662.2	929.5
SHS-DH-400×400×11.6	280	400	400	11.6	1200	0.58	4111.8	1170.7
SHS-DH-400×400×11.6	400	400	400	11.6	1200	0.58	3218.2	1303.2
SHS-DH-450×450×10.8	0	450	450	10.8	1350	0.54	9244.6	0
SHS-DH-450×450×10.8	45	450	450	10.8	1350	0.54	8132.9	386.5
SHS-DH-450×450×10.8	180	450	450	10.8	1350	0.54	5261.0	971.1
SHS-DH-450×450×10.8	315	450	450	10.8	1350	0.54	3839.9	1230.7
SHS-DH-450×450×10.8	450	450	450	10.8	1350	0.54	3022.8	1376.9
SHS-DH-450×450×12	0	450	450	12.0	1350	0.60	11524.9	0
SHS-DH-450×450×12	45	450	450	12.0	1350	0.60	9909.2	467.5
SHS-DH-450×450×12	180	450	450	12.0	1350	0.60	6276.7	1157.0
SHS-DH-450×450×12	315	450	450	12.0	1350	0.60	4555.7	1458.0
SHS-DH-450×450×12	450	450	450	12.0	1350	0.60	3574.5	1628.5
SHS-DH-500×500×18	0	500	500	18.0	1500	0.90	23704.5	0
SHS-DH-500×500×18	50	500	500	18.0	1500	0.90	20076.0	1027.1
SHS-DH-500×500×18	200	500	500	18.0	1500	0.90	12571.0	2549.3
SHS-DH-500×500×18	350	500	500	18.0	1500	0.90	9082.1	3211.4
SHS-DH-500×500×18	500	500	500	18.0	1500	0.90	7194.6	3629.1
SHS-DH-500×500×27	0	500	500	27.0	1500	1.35	40672.2	0
SHS-DH-500×500×27	50	500	500	27.0	1500	1.35	33612.0	1851.3
SHS-DH-500×500×27	200	500	500	27.0	1500	1.35	21766.2	4546.6
SHS-DH-500×500×27	350	500	500	27.0	1500	1.35	16012.6	5773.6
SHS-DH-500×500×27	500	500	500	27.0	1500	1.35	12513.0	6401.7
SHS-IN-50×50×2.5	0	50	50	2.5	150	0.13	242.0	0
SHS-IN-50×50×2.5	5	50	50	2.5	150	0.13	199.2	1.1
SHS-IN-50×50×2.5	20	50	50	2.5	150	0.13	129.5	2.7
SHS-IN-50×50×2.5	35	50	50	2.5	150	0.13	95.0	3.4

SHS-IN-50×50×2.5	50	50	50	2.5	150	0.13	74.3	3.8
SHS-IN-50×50×3	0	50	50	3.0	150	0.15	296.7	0
SHS-IN-50×50×3	5	50	50	3.0	150	0.15	240.7	1.4
SHS-IN-50×50×3	20	50	50	3.0	150	0.15	156.2	3.3
SHS-IN-50×50×3	35	50	50	3.0	150	0.15	114.6	4.2
SHS-IN-50×50×3	50	50	50	3.0	150	0.15	89.8	4.6
SHS-IN-100×100×2.8	0	100	100	2.8	300	0.14	435.1	0
SHS-IN-100×100×2.8	10	100	100	2.8	300	0.14	370.0	3.9
SHS-IN-100×100×2.8	40	100	100	2.8	300	0.14	239.7	9.8
SHS-IN-100×100×2.8	70	100	100	2.8	300	0.14	172.7	12.2
SHS-IN-100×100×2.8	100	100	100	2.8	300	0.14	136.5	13.8
SHS-IN-100×100×4.2	0	100	100	4.2	300	0.21	795.8	0
SHS-IN-100×100×4.2	10	100	100	4.2	300	0.21	650.6	6.9
SHS-IN-100×100×4.2	40	100	100	4.2	300	0.21	423.7	17.4
SHS-IN-100×100×4.2	70	100	100	4.2	300	0.21	310.2	22.1
SHS-IN-100×100×4.2	100	100	100	4.2	300	0.21	242.9	24.6
SHS-IN-150×150×3.9	0	150	150	3.9	450	0.20	864.9	0
SHS-IN-150×150×3.9	15	150	150	3.9	450	0.20	743.4	11.7
SHS-IN-150×150×3.9	60	150	150	3.9	450	0.20	473.2	29.0
SHS-IN-150×150×3.9	105	150	150	3.9	450	0.20	344.8	36.7
SHS-IN-150×150×3.9	150	150	150	3.9	450	0.20	271.5	41.1
SHS-IN-150×150×4.6	0	150	150	4.6	450	0.23	1142.7	0
SHS-IN-150×150×4.6	15	150	150	4.6	450	0.23	964.2	15.1
SHS-IN-150×150×4.6	60	150	150	4.6	450	0.23	614.2	37.5
SHS-IN-150×150×4.6	105	150	150	4.6	450	0.23	456.4	48.5
SHS-IN-150×150×4.6	150	150	150	4.6	450	0.23	355.2	53.8
SHS-IN-200×200×4.5	0	200	200	4.5	600	0.23	1150.9	0
SHS-IN-200×200×4.5	20	200	200	4.5	600	0.23	1011.9	20.3
SHS-IN-200×200×4.5	80	200	200	4.5	600	0.23	656.8	52.7
SHS-IN-200×200×4.5	140	200	200	4.5	600	0.23	482.7	67.8

SHS-IN-200×200×4.5	200	200	200	4.5	600	0.23	376.9	75.5
SHS-IN-200×200×7.6	0	200	200	7.6	600	0.38	2815.5	0
SHS-IN-200×200×7.6	20	200	200	7.6	600	0.38	2316.2	48.6
SHS-IN-200×200×7.6	80	200	200	7.6	600	0.38	1494.4	121.9
SHS-IN-200×200×7.6	140	200	200	7.6	600	0.38	1089.1	154.5
SHS-IN-200×200×7.6	200	200	200	7.6	600	0.38	855.0	172.9
SHS-IN-250×250×11.5	0	250	250	11.5	750	0.58	5494.0	0
SHS-IN-250×250×11.5	25	250	250	11.5	750	0.58	4544.0	123.9
SHS-IN-250×250×11.5	100	250	250	11.5	750	0.58	2946.4	304.8
SHS-IN-250×250×11.5	175	250	250	11.5	750	0.58	2162.4	386.8
SHS-IN-250×250×11.5	250	250	250	11.5	750	0.58	1693.7	430.6
SHS-IN-250×250×18	0	250	250	18.0	750	0.90	9122.1	0
SHS-IN-250×250×18	25	250	250	18.0	750	0.90	7302.0	225.7
SHS-IN-250×250×18	100	250	250	18.0	750	0.90	4776.1	520.9
SHS-IN-250×250×18	175	250	250	18.0	750	0.90	3495.8	648.4
SHS-IN-250×250×18	250	250	250	18.0	750	0.90	2722.1	709.3
SHS-IN-300×300×9.8	0	300	300	9.8	900	0.49	5145.8	0
SHS-IN-300×300×9.8	30	300	300	9.8	900	0.49	4236.9	134.7
SHS-IN-300×300×9.8	120	300	300	9.8	900	0.49	2675.1	328.5
SHS-IN-300×300×9.8	210	300	300	9.8	900	0.49	1951.4	415.4
SHS-IN-300×300×9.8	300	300	300	9.8	900	0.49	1546.7	468.7
SHS-IN-300×300×12.2	0	300	300	12.2	900	0.61	6767.1	0
SHS-IN-300×300×12.2	30	300	300	12.2	900	0.61	5648.7	182.6
SHS-IN-300×300×12.2	120	300	300	12.2	900	0.61	3612.3	445.2
SHS-IN-300×300×12.2	210	300	300	12.2	900	0.61	2633.5	562.2
SHS-IN-300×300×12.2	300	300	300	12.2	900	0.61	2064.9	627.7
SHS-IN-350×350×10.5	0	350	350	10.5	1050	0.53	6059.5	0
SHS-IN-350×350×10.5	35	350	350	10.5	1050	0.53	5067.6	180.4
SHS-IN-350×350×10.5	140	350	350	10.5	1050	0.53	3227.6	456.3
SHS-IN-350×350×10.5	245	350	350	10.5	1050	0.53	2379.5	587.1

SHS-IN-350×350×10.5	350	350	350	10.5	1050	0.53	1871.4	658.9
SHS-IN-350×350×12	0	350	350	12.0	1050	0.60	7521.2	0
SHS-IN-350×350×12	35	350	350	12.0	1050	0.60	6204.1	224.3
SHS-IN-350×350×12	140	350	350	12.0	1050	0.60	4021.9	572.5
SHS-IN-350×350×12	245	350	350	12.0	1050	0.60	2919.4	723.2
SHS-IN-350×350×12	350	350	350	12.0	1050	0.60	2258.5	797.4
SHS-IN-400×400×10	0	400	400	10.0	1200	0.50	5682.2	0
SHS-IN-400×400×10	40	400	400	10.0	1200	0.50	4913.4	206.2
SHS-IN-400×400×10	160	400	400	10.0	1200	0.50	3161.6	515.8
SHS-IN-400×400×10	280	400	400	10.0	1200	0.50	2316.8	656.9
SHS-IN-400×400×10	400	400	400	10.0	1200	0.50	1773.0	717.5
SHS-IN-400×400×11.6	0	400	400	11.6	1200	0.58	7449.6	0
SHS-IN-400×400×11.6	40	400	400	11.6	1200	0.58	6245.2	266.3
SHS-IN-400×400×11.6	160	400	400	11.6	1200	0.58	3998.2	653.0
SHS-IN-400×400×11.6	280	400	400	11.6	1200	0.58	2956.4	838.7
SHS-IN-400×400×11.6	400	400	400	11.6	1200	0.58	2268.1	915.5
SHS-IN-450×450×10.8	0	450	450	10.8	1350	0.54	6616.7	0
SHS-IN-450×450×10.8	45	450	450	10.8	1350	0.54	5775.1	273.5
SHS-IN-450×450×10.8	180	450	450	10.8	1350	0.54	3725.9	684.7
SHS-IN-450×450×10.8	315	450	450	10.8	1350	0.54	2707.4	865.3
SHS-IN-450×450×10.8	450	450	450	10.8	1350	0.54	2140.0	972.1
SHS-IN-450×450×12	0	450	450	12.0	1350	0.60	8078.6	0
SHS-IN-450×450×12	45	450	450	12.0	1350	0.60	6932.5	326.7
SHS-IN-450×450×12	180	450	450	12.0	1350	0.60	4475.1	820.4
SHS-IN-450×450×12	315	450	450	12.0	1350	0.60	3215.2	1027.1
SHS-IN-450×450×12	450	450	450	12.0	1350	0.60	2527.7	1148.3
SHS-IN-500×500×18	0	500	500	18.0	1500	0.90	16091.1	0
SHS-IN-500×500×18	50	500	500	18.0	1500	0.90	13525.5	703.1
SHS-IN-500×500×18	200	500	500	18.0	1500	0.90	8678.8	1765.8
SHS-IN-500×500×18	350	500	500	18.0	1500	0.90	6331.3	2241.5

SHS-IN-500×500×18	500	500	500	18.0	1500	0.90	4986.4	2517.5
SHS-IN-500×500×27	0	500	500	27.0	1500	1.35	26550.4	0
SHS-IN-500×500×27	50	500	500	27.0	1500	1.35	21546.2	1217.4
SHS-IN-500×500×27	200	500	500	27.0	1500	1.35	14020.2	2943.7
SHS-IN-500×500×27	350	500	500	27.0	1500	1.35	10271.6	3700.7
SHS-IN-500×500×27	500	500	500	27.0	1500	1.35	8028.4	4104.4
SHS-IH-50×50×2.5	0	50	50	2.5	150	0.13	405.4	0
SHS-IH-50×50×2.5	5	50	50	2.5	150	0.13	332.7	1.8
SHS-IH-50×50×2.5	20	50	50	2.5	150	0.13	213.1	4.4
SHS-IH-50×50×2.5	35	50	50	2.5	150	0.13	156.3	5.6
SHS-IH-50×50×2.5	50	50	50	2.5	150	0.13	121.9	6.2
SHS-IH-50×50×3	0	50	50	3.0	150	0.15	506.1	0
SHS-IH-50×50×3	5	50	50	3.0	150	0.15	411.6	2.4
SHS-IH-50×50×3	20	50	50	3.0	150	0.15	266.2	5.6
SHS-IH-50×50×3	35	50	50	3.0	150	0.15	195.2	7.1
SHS-IH-50×50×3	50	50	50	3.0	150	0.15	152.6	7.8
SHS-IH-100×100×2.8	0	100	100	2.8	300	0.14	622.6	0
SHS-IH-100×100×2.8	10	100	100	2.8	300	0.14	542.9	5.8
SHS-IH-100×100×2.8	40	100	100	2.8	300	0.14	351.8	14.5
SHS-IH-100×100×2.8	70	100	100	2.8	300	0.14	255.5	18.2
SHS-IH-100×100×2.8	100	100	100	2.8	300	0.14	200.0	20.2
SHS-IH-100×100×4.2	0	100	100	4.2	300	0.21	1282.9	0
SHS-IH-100×100×4.2	10	100	100	4.2	300	0.21	1053.1	11.0
SHS-IH-100×100×4.2	40	100	100	4.2	300	0.21	680.6	27.9
SHS-IH-100×100×4.2	70	100	100	4.2	300	0.21	494.7	35.2
SHS-IH-100×100×4.2	100	100	100	4.2	300	0.21	385.6	39.1
SHS-IH-150×150×3.9	0	150	150	3.9	450	0.20	1213.8	0
SHS-IH-150×150×3.9	15	150	150	3.9	450	0.20	1063.4	16.0
SHS-IH-150×150×3.9	60	150	150	3.9	450	0.20	694.2	41.9
SHS-IH-150×150×3.9	105	150	150	3.9	450	0.20	512.0	54.0

SHS-IH-150×150×3.9	150	150	150	3.9	450	0.20	403.0	60.7
SHS-IH-150×150×4.6	0	150	150	4.6	450	0.23	1675.1	0
SHS-IH-150×150×4.6	15	150	150	4.6	450	0.23	1451.8	23.4
SHS-IH-150×150×4.6	60	150	150	4.6	450	0.23	925.7	56.9
SHS-IH-150×150×4.6	105	150	150	4.6	450	0.23	677.1	72.4
SHS-IH-150×150×4.6	150	150	150	4.6	450	0.23	530.6	80.7
SHS-IH-200×200×4.5	0	200	200	4.5	600	0.23	1638.9	0
SHS-IH-200×200×4.5	20	200	200	4.5	600	0.23	1435.4	28.8
SHS-IH-200×200×4.5	80	200	200	4.5	600	0.23	946.9	76.0
SHS-IH-200×200×4.5	140	200	200	4.5	600	0.23	705.0	99.0
SHS-IH-200×200×4.5	200	200	200	4.5	600	0.23	559.5	112.2
SHS-IH-200×200×7.6	0	200	200	7.6	600	0.38	4415.0	0
SHS-IH-200×200×7.6	20	200	200	7.6	600	0.38	3654.6	77.6
SHS-IH-200×200×7.6	80	200	200	7.6	600	0.38	2306.0	189.4
SHS-IH-200×200×7.6	140	200	200	7.6	600	0.38	1683.8	240.5
SHS-IH-200×200×7.6	200	200	200	7.6	600	0.38	1328.0	269.4
SHS-IH-250×250×11.5	0	250	250	11.5	750	0.58	8741.6	0
SHS-IH-250×250×11.5	25	250	250	11.5	750	0.58	7473.2	199.6
SHS-IH-250×250×11.5	100	250	250	11.5	750	0.58	4806.3	495.2
SHS-IH-250×250×11.5	175	250	250	11.5	750	0.58	3502.7	626.5
SHS-IH-250×250×11.5	250	250	250	11.5	750	0.58	2749.0	698.8
SHS-IH-250×250×18	0	250	250	18.0	750	0.90	15502.7	0
SHS-IH-250×250×18	25	250	250	18.0	750	0.90	12403.8	392.5
SHS-IH-250×250×18	100	250	250	18.0	750	0.90	8029.6	873.3
SHS-IH-250×250×18	175	250	250	18.0	750	0.90	5869.7	1082.1
SHS-IH-250×250×18	250	250	250	18.0	750	0.90	4574.4	1188.7
SHS-IH-300×300×9.8	0	300	300	9.8	900	0.49	7594.4	0
SHS-IH-300×300×9.8	30	300	300	9.8	900	0.49	6520.3	199.7
SHS-IH-300×300×9.8	120	300	300	9.8	900	0.49	4145.4	503.5
SHS-IH-300×300×9.8	210	300	300	9.8	900	0.49	3011.3	637.9

SHS-IH-300×300×9.8	300	300	300	9.8	900	0.49	2352.2	710.6
SHS-IH-300×300×12.2	0	300	300	12.2	900	0.61	10913.2	0
SHS-IH-300×300×12.2	30	300	300	12.2	900	0.61	9183.6	297.1
SHS-IH-300×300×12.2	120	300	300	12.2	900	0.61	5806.7	718.8
SHS-IH-300×300×12.2	210	300	300	12.2	900	0.61	4167.8	894.0
SHS-IH-300×300×12.2	300	300	300	12.2	900	0.61	3293.9	1004.4
SHS-IH-350×350×10.5	0	350	350	10.5	1050	0.53	8765.4	0
SHS-IH-350×350×10.5	35	350	350	10.5	1050	0.53	7620.0	270.4
SHS-IH-350×350×10.5	140	350	350	10.5	1050	0.53	4902.9	693.1
SHS-IH-350×350×10.5	245	350	350	10.5	1050	0.53	3572.9	881.8
SHS-IH-350×350×10.5	350	350	350	10.5	1050	0.53	2800.0	985.7
SHS-IH-350×350×12	0	350	350	12.0	1050	0.60	11308.8	0
SHS-IH-350×350×12	35	350	350	12.0	1050	0.60	9641.1	346.1
SHS-IH-350×350×12	140	350	350	12.0	1050	0.60	6103.6	866.3
SHS-IH-350×350×12	245	350	350	12.0	1050	0.60	4434.9	1097.2
SHS-IH-350×350×12	350	350	350	12.0	1050	0.60	3445.0	1215.0
SHS-IH-400×400×10	0	400	400	10.0	1200	0.50	7993.6	0
SHS-IH-400×400×10	40	400	400	10.0	1200	0.50	7016.7	302.8
SHS-IH-400×400×10	160	400	400	10.0	1200	0.50	4581.6	757.0
SHS-IH-400×400×10	280	400	400	10.0	1200	0.50	3385.2	966.3
SHS-IH-400×400×10	400	400	400	10.0	1200	0.50	2656.7	1079.4
SHS-IH-400×400×11.6	0	400	400	11.6	1200	0.58	10644.5	0
SHS-IH-400×400×11.6	40	400	400	11.6	1200	0.58	9298.4	395.6
SHS-IH-400×400×11.6	160	400	400	11.6	1200	0.58	5970.5	979.7
SHS-IH-400×400×11.6	280	400	400	11.6	1200	0.58	4322.9	1235.8
SHS-IH-400×400×11.6	400	400	400	11.6	1200	0.58	3439.6	1394.9
SHS-IH-450×450×10.8	0	450	450	10.8	1350	0.54	9353.9	0
SHS-IH-450×450×10.8	45	450	450	10.8	1350	0.54	8190.4	401.6
SHS-IH-450×450×10.8	180	450	450	10.8	1350	0.54	5423.0	1005.3
SHS-IH-450×450×10.8	315	450	450	10.8	1350	0.54	3980.9	1279.7

SHS-IH-450×450×10.8	450	450	450	10.8	1350	0.54	3148.2	1437.5
SHS-IH-450×450×12	0	450	450	12.0	1350	0.60	11474.5	0
SHS-IH-450×450×12	45	450	450	12.0	1350	0.60	10045.2	482.1
SHS-IH-450×450×12	180	450	450	12.0	1350	0.60	6512.5	1209.7
SHS-IH-450×450×12	315	450	450	12.0	1350	0.60	4787.0	1537.6
SHS-IH-450×450×12	450	450	450	12.0	1350	0.60	3769.0	1719.8
SHS-IH-500×500×18	0	500	500	18.0	1500	0.90	25090.4	0
SHS-IH-500×500×18	50	500	500	18.0	1500	0.90	21294.4	1097.8
SHS-IH-500×500×18	200	500	500	18.0	1500	0.90	13465.8	2735.2
SHS-IH-500×500×18	350	500	500	18.0	1500	0.90	9761.6	3455.6
SHS-IH-500×500×18	500	500	500	18.0	1500	0.90	7670.0	3870.0
SHS-IH-500×500×27	0	500	500	27.0	1500	1.35	44480.5	0
SHS-IH-500×500×27	50	500	500	27.0	1500	1.35	36497.8	2055.3
SHS-IH-500×500×27	200	500	500	27.0	1500	1.35	23551.3	4928.1
SHS-IH-500×500×27	350	500	500	27.0	1500	1.35	17228.5	6205.5
SHS-IH-500×500×27	500	500	500	27.0	1500	1.35	13484.4	6904.9
RHS-DN-50×80×2.5	0	50	80	2.5	240	0.13	269.0	0
RHS-DN-50×80×2.5	5	50	80	2.5	240	0.13	220.8	1.2
RHS-DN-50×80×2.5	20	50	80	2.5	240	0.13	143.7	3.0
RHS-DN-50×80×2.5	35	50	80	2.5	240	0.13	104.7	3.8
RHS-DN-50×80×2.5	50	50	80	2.5	240	0.13	83.1	4.3
RHS-DN-50×80×3.4	0	50	80	3.4	240	0.17	400.7	0
RHS-DN-50×80×3.4	5	50	80	3.4	240	0.17	315.2	1.9
RHS-DN-50×80×3.4	20	50	80	3.4	240	0.17	204.7	4.4
RHS-DN-50×80×3.4	35	50	80	3.4	240	0.17	151.1	5.6
RHS-DN-50×80×3.4	50	50	80	3.4	240	0.17	119.8	6.2
RHS-DN-60×140×5	0	60	140	5.0	420	0.25	886.6	0
RHS-DN-60×140×5	6	60	140	5.0	420	0.25	679.5	5.2
RHS-DN-60×140×5	24	60	140	5.0	420	0.25	440.1	11.9
RHS-DN-60×140×5	42	60	140	5.0	420	0.25	325.9	14.7

RHS-DN-60×140×5	60	60	140	5.0	420	0.25	258.8	16.4
RHS-DN-60×140×6.8	0	60	140	6.8	420	0.34	1222.7	0
RHS-DN-60×140×6.8	6	60	140	6.8	420	0.34	955.3	8.0
RHS-DN-60×140×6.8	24	60	140	6.8	420	0.34	613.2	17.4
RHS-DN-60×140×6.8	42	60	140	6.8	420	0.34	453.6	21.4
RHS-DN-60×140×6.8	60	60	140	6.8	420	0.34	358.3	23.5
RHS-DN-80×200×5	0	80	200	5.0	600	0.25	1071.1	0
RHS-DN-80×200×5	8	80	200	5.0	600	0.25	860.2	8.3
RHS-DN-80×200×5	32	80	200	5.0	600	0.25	548.0	19.2
RHS-DN-80×200×5	56	80	200	5.0	600	0.25	399.6	23.7
RHS-DN-80×200×5	80	80	200	5.0	600	0.25	312.3	26.2
RHS-DN-80×200×5.9	0	80	200	5.9	600	0.30	1384.6	0
RHS-DN-80×200×5.9	8	80	200	5.9	600	0.30	1079.9	11.1
RHS-DN-80×200×5.9	32	80	200	5.9	600	0.30	684.7	23.7
RHS-DN-80×200×5.9	56	80	200	5.9	600	0.30	514.1	30.7
RHS-DN-80×200×5.9	80	80	200	5.9	600	0.30	407.6	34.3
RHS-DN-130×260×14.6	0	130	260	14.6	780	0.73	5627.2	0
RHS-DN-130×260×14.6	13	130	260	14.6	780	0.73	4151.7	75.6
RHS-DN-130×260×14.6	52	130	260	14.6	780	0.73	2679.4	164.0
RHS-DN-130×260×14.6	91	130	260	14.6	780	0.73	1978.2	202.1
RHS-DN-130×260×14.6	130	130	260	14.6	780	0.73	1555.9	221.8
RHS-DN-130×260×16	0	130	260	16.0	780	0.80	6300.2	0
RHS-DN-130×260×16	13	130	260	16.0	780	0.80	4569.4	75.4
RHS-DN-130×260×16	52	130	260	16.0	780	0.80	2658.8	146.2
RHS-DN-130×260×16	91	130	260	16.0	780	0.80	2177.7	221.4
RHS-DN-130×260×16	130	130	260	16.0	780	0.80	1708.9	244.2
RHS-DN-180×320×7.2	0	180	320	7.2	960	0.36	2633.8	0
RHS-DN-180×320×7.2	18	180	320	7.2	960	0.36	2145.8	39.8
RHS-DN-180×320×7.2	72	180	320	7.2	960	0.36	1346.5	98.8
RHS-DN-180×320×7.2	126	180	320	7.2	960	0.36	980.6	125.3

RHS-DN-180×320×7.2	180	180	320	7.2	960	0.36	769.6	140.1
RHS-DN-180×320×10.8	0	180	320	10.8	960	0.54	4659.0	0
RHS-DN-180×320×10.8	18	180	320	10.8	960	0.54	3726.2	78.4
RHS-DN-180×320×10.8	72	180	320	10.8	960	0.54	2420.4	185.3
RHS-DN-180×320×10.8	126	180	320	10.8	960	0.54	1779.8	233.1
RHS-DN-180×320×10.8	180	180	320	10.8	960	0.54	1407.7	261.2
RHS-DN-280×380×10.5	0	280	380	10.5	1140	0.53	5351.0	0
RHS-DN-280×380×10.5	28	280	380	10.5	1140	0.53	4466.1	134.7
RHS-DN-280×380×10.5	112	280	380	10.5	1140	0.53	2838.3	328.1
RHS-DN-280×380×10.5	196	280	380	10.5	1140	0.53	2075.2	414.5
RHS-DN-280×380×10.5	280	280	380	10.5	1140	0.53	1618.7	460.4
RHS-DN-280×380×15	0	280	380	15.0	1140	0.75	8733.0	0
RHS-DN-280×380×15	28	280	380	15.0	1140	0.75	7014.0	229.6
RHS-DN-280×380×15	112	280	380	15.0	1140	0.75	4570.7	538.3
RHS-DN-280×380×15	196	280	380	15.0	1140	0.75	3384.5	684.1
RHS-DN-280×380×15	280	280	380	15.0	1140	0.75	2503.3	710.5
RHS-DN-360×440×11.6	0	360	440	11.6	1320	0.58	6938.6	0
RHS-DN-360×440×11.6	36	360	440	11.6	1320	0.58	5782.9	220.6
RHS-DN-360×440×11.6	144	360	440	11.6	1320	0.58	3684.9	544.0
RHS-DN-360×440×11.6	252	360	440	11.6	1320	0.58	2683.6	687.7
RHS-DN-360×440×11.6	360	360	440	11.6	1320	0.58	2105.6	767.6
RHS-DN-360×440×14	0	360	440	14.0	1320	0.70	9194.2	0
RHS-DN-360×440×14	36	360	440	14.0	1320	0.70	7677.9	294.3
RHS-DN-360×440×14	144	360	440	14.0	1320	0.70	4946.0	731.1
RHS-DN-360×440×14	252	360	440	14.0	1320	0.70	3631.7	930.6
RHS-DN-360×440×14	360	360	440	14.0	1320	0.70	2869.7	1046.0
RHS-DN-380×500×11.8	0	380	500	11.8	1500	0.59	7594.4	0
RHS-DN-380×500×11.8	38	380	500	11.8	1500	0.59	6195.9	247.8
RHS-DN-380×500×11.8	152	380	500	11.8	1500	0.59	3864.6	603.3
RHS-DN-380×500×11.8	266	380	500	11.8	1500	0.59	2818.6	764.6

RHS-DN-380×500×11.8	380	380	500	11.8	1500	0.59	1687.0	672.6
RHS-DN-380×500×32	0	380	500	32.0	1500	1.60	28178.2	0
RHS-DN-380×500×32	38	380	500	32.0	1500	1.60	21543.4	1091.5
RHS-DN-380×500×32	152	380	500	32.0	1500	1.60	14067.5	2465.1
RHS-DN-380×500×32	266	380	500	32.0	1500	1.60	10371.0	3014.0
RHS-DN-380×500×32	380	380	500	32.0	1500	1.60	8101.8	3279.6
RHS-DN-80×50×2.5	0	80	50	2.5	240	0.13	268.7	0
RHS-DN-80×50×2.5	8	80	50	2.5	240	0.13	226.8	1.9
RHS-DN-80×50×2.5	32	80	50	2.5	240	0.13	147.8	4.8
RHS-DN-80×50×2.5	56	80	50	2.5	240	0.13	108.7	6.2
RHS-DN-80×50×2.5	80	80	50	2.5	240	0.13	84.7	6.9
RHS-DN-80×50×3.4	0	80	50	3.4	240	0.17	399.1	0
RHS-DN-80×50×3.4	8	80	50	3.4	240	0.17	327.4	3.0
RHS-DN-80×50×3.4	32	80	50	3.4	240	0.17	214.3	7.3
RHS-DN-80×50×3.4	56	80	50	3.4	240	0.17	157.9	9.2
RHS-DN-80×50×3.4	80	80	50	3.4	240	0.17	122.6	10.2
RHS-DN-140×60×5	0	140	60	5.0	420	0.25	880.0	0
RHS-DN-140×60×5	14	140	60	5.0	420	0.25	731.9	11.7
RHS-DN-140×60×5	56	140	60	5.0	420	0.25	478.0	28.2
RHS-DN-140×60×5	98	140	60	5.0	420	0.25	345.6	35.1
RHS-DN-140×60×5	140	140	60	5.0	420	0.25	268.3	38.7
RHS-DN-140×60×6.8	0	140	60	6.8	420	0.34	1231.5	0
RHS-DN-140×60×6.8	14	140	60	6.8	420	0.34	983.6	14.3
RHS-DN-140×60×6.8	56	140	60	6.8	420	0.34	683.7	42.2
RHS-DN-140×60×6.8	98	140	60	6.8	420	0.34	497.8	52.3
RHS-DN-140×60×6.8	140	140	60	6.8	420	0.34	373.9	53.5
RHS-DN-200×80×5	0	200	80	5.0	600	0.25	1071.1	0
RHS-DN-200×80×5	20	200	80	5.0	600	0.25	949.4	19.9
RHS-DN-200×80×5	80	200	80	5.0	600	0.25	610.6	49.9
RHS-DN-200×80×5	140	200	80	5.0	600	0.25	445.6	63.5

RHS-DN-200×80×5	200	200	80	5.0	600	0.25	346.2	70.2
RHS-DN-200×80×5.9	0	200	80	5.9	600	0.30	1380.1	0
RHS-DN-200×80×5.9	20	200	80	5.9	600	0.30	1170.8	25.1
RHS-DN-200×80×5.9	80	200	80	5.9	600	0.30	756.0	62.5
RHS-DN-200×80×5.9	140	200	80	5.9	600	0.30	550.0	79.1
RHS-DN-200×80×5.9	200	200	80	5.9	600	0.30	427.2	87.4
RHS-DN-260×130×14.6	0	260	130	14.6	780	0.73	5677.2	0
RHS-DN-260×130×14.6	26	260	130	14.6	780	0.73	4500.9	180.5
RHS-DN-260×130×14.6	104	260	130	14.6	780	0.73	2964.9	363.0
RHS-DN-260×130×14.6	182	260	130	14.6	780	0.73	2159.2	438.2
RHS-DN-260×130×14.6	260	260	130	14.6	780	0.73	1672.1	481.7
RHS-DN-260×130×16	0	260	130	16.0	780	0.80	6329.1	0
RHS-DN-260×130×16	26	260	130	16.0	780	0.80	4636.5	125.5
RHS-DN-260×130×16	104	260	130	16.0	780	0.80	3267.0	390.4
RHS-DN-260×130×16	182	260	130	16.0	780	0.80	2366.7	475.1
RHS-DN-260×130×16	260	260	130	16.0	780	0.80	1824.4	516.6
RHS-DN-320×180×7.2	0	320	180	7.2	960	0.36	2647.1	0
RHS-DN-320×180×7.2	32	320	180	7.2	960	0.36	2303.6	75.9
RHS-DN-320×180×7.2	128	320	180	7.2	960	0.36	1528.4	199.0
RHS-DN-320×180×7.2	224	320	180	7.2	960	0.36	1123.0	254.7
RHS-DN-320×180×7.2	320	320	180	7.2	960	0.36	876.5	283.3
RHS-DN-320×180×10.8	0	320	180	10.8	960	0.54	4669.7	0
RHS-DN-320×180×10.8	32	320	180	10.8	960	0.54	3872.2	135.9
RHS-DN-320×180×10.8	128	320	180	10.8	960	0.54	2368.1	308.1
RHS-DN-320×180×10.8	224	320	180	10.8	960	0.54	1849.6	427.0
RHS-DN-320×180×10.8	320	320	180	10.8	960	0.54	1440.0	470.6
RHS-DN-380×280×10.5	0	380	280	10.5	1140	0.53	5445.1	0
RHS-DN-380×280×10.5	38	380	280	10.5	1140	0.53	4701.2	186.6
RHS-DN-380×280×10.5	152	380	280	10.5	1140	0.53	3056.8	474.1
RHS-DN-380×280×10.5	266	380	280	10.5	1140	0.53	2227.9	600.0

RHS-DN-380×280×10.5	380	380	280	10.5	1140	0.53	1753.9	673.9
RHS-DN-380×280×15	0	380	280	15.0	1140	0.75	8668.1	0
RHS-DN-380×280×15	38	380	280	15.0	1140	0.75	7163.9	302.2
RHS-DN-380×280×15	152	380	280	15.0	1140	0.75	4703.9	743.6
RHS-DN-380×280×15	266	380	280	15.0	1140	0.75	3466.5	951.0
RHS-DN-380×280×15	380	380	280	15.0	1140	0.75	2692.3	1051.3
RHS-DN-440×360×11.6	0	440	360	11.6	1320	0.58	7077.4	0
RHS-DN-440×360×11.6	44	440	360	11.6	1320	0.58	6151.6	281.4
RHS-DN-440×360×11.6	176	440	360	11.6	1320	0.58	3992.0	714.6
RHS-DN-440×360×11.6	308	440	360	11.6	1320	0.58	2893.2	900.4
RHS-DN-440×360×11.6	440	440	360	11.6	1320	0.58	2306.0	1024.7
RHS-DN-440×360×14	0	440	360	14.0	1320	0.70	9164.7	0
RHS-DN-440×360×14	44	440	360	14.0	1320	0.70	7681.3	352.2
RHS-DN-440×360×14	176	440	360	14.0	1320	0.70	5033.6	906.9
RHS-DN-440×360×14	308	440	360	14.0	1320	0.70	3710.4	1161.6
RHS-DN-440×360×14	440	440	360	14.0	1320	0.70	2909.9	1296.5
RHS-DN-500×380×11.8	0	500	380	11.8	1500	0.59	7708.4	0
RHS-DN-500×380×11.8	50	500	380	11.8	1500	0.59	6623.9	338.7
RHS-DN-500×380×11.8	200	500	380	11.8	1500	0.59	4350.9	881.3
RHS-DN-500×380×11.8	350	500	380	11.8	1500	0.59	3227.8	1141.1
RHS-DN-500×380×11.8	500	500	380	11.8	1500	0.59	2534.7	1276.9
RHS-DN-500×380×32	0	500	380	32.0	1500	1.60	28178.2	0
RHS-DN-500×380×32	50	500	380	32.0	1500	1.60	22483.2	1798.8
RHS-DN-500×380×32	200	500	380	32.0	1500	1.60	14910.2	3526.7
RHS-DN-500×380×32	350	500	380	32.0	1500	1.60	10885.1	4260.1
RHS-DN-500×380×32	500	500	380	32.0	1500	1.60	8491.5	4596.0
RHS-DH-50×80×2.5	0	50	80	2.5	240	0.13	429.2	0
RHS-DH-50×80×2.5	5	50	80	2.5	240	0.13	345.6	1.8
RHS-DH-50×80×2.5	20	50	80	2.5	240	0.13	213.2	4.4
RHS-DH-50×80×2.5	35	50	80	2.5	240	0.13	155.0	5.6

RHS-DH-50×80×2.5	50	50	80	2.5	240	0.13	122.2	6.2
RHS-DH-50×80×3.4	0	50	80	3.4	240	0.17	658.1	0
RHS-DH-50×80×3.4	5	50	80	3.4	240	0.17	527.4	3.1
RHS-DH-50×80×3.4	20	50	80	3.4	240	0.17	335.4	7.2
RHS-DH-50×80×3.4	35	50	80	3.4	240	0.17	245.6	9.0
RHS-DH-50×80×3.4	50	50	80	3.4	240	0.17	192.2	9.9
RHS-DH-60×140×5	0	60	140	5.0	420	0.25	1401.4	0
RHS-DH-60×140×5	6	60	140	5.0	420	0.25	1093.0	8.4
RHS-DH-60×140×5	24	60	140	5.0	420	0.25	671.8	17.9
RHS-DH-60×140×5	42	60	140	5.0	420	0.25	487.6	22.4
RHS-DH-60×140×5	60	60	140	5.0	420	0.25	389.3	24.8
RHS-DH-60×140×6.8	0	60	140	6.8	420	0.34	2105.9	0
RHS-DH-60×140×6.8	6	60	140	6.8	420	0.34	1557.0	13.7
RHS-DH-60×140×6.8	24	60	140	6.8	420	0.34	983.6	27.7
RHS-DH-60×140×6.8	42	60	140	6.8	420	0.34	724.3	34.1
RHS-DH-60×140×6.8	60	60	140	6.8	420	0.34	572.5	37.3
RHS-DH-80×200×5	0	80	200	5.0	600	0.25	1645.0	0
RHS-DH-80×200×5	8	80	200	5.0	600	0.25	1291.9	12.9
RHS-DH-80×200×5	32	80	200	5.0	600	0.25	800.4	28.7
RHS-DH-80×200×5	56	80	200	5.0	600	0.25	582.5	35.3
RHS-DH-80×200×5	80	80	200	5.0	600	0.25	458.3	38.8
RHS-DH-80×200×5.9	0	80	200	5.9	600	0.30	2139.5	0
RHS-DH-80×200×5.9	8	80	200	5.9	600	0.30	1671.3	16.3
RHS-DH-80×200×5.9	32	80	200	5.9	600	0.30	1024.2	36.2
RHS-DH-80×200×5.9	56	80	200	5.9	600	0.30	741.5	44.8
RHS-DH-80×200×5.9	80	80	200	5.9	600	0.30	585.4	49.6
RHS-DH-130×260×14.6	0	130	260	14.6	780	0.73	9027.6	0
RHS-DH-130×260×14.6	13	130	260	14.6	780	0.73	6740.6	124.9
RHS-DH-130×260×14.6	52	130	260	14.6	780	0.73	4293.4	263.7
RHS-DH-130×260×14.6	91	130	260	14.6	780	0.73	3165.7	321.3

RHS-DH-130×260×14.6	130	130	260	14.6	780	0.73	2497.1	350.4
RHS-DH-130×260×16	0	130	260	16.0	780	0.80	10148.2	0
RHS-DH-130×260×16	13	130	260	16.0	780	0.80	7411.3	145.5
RHS-DH-130×260×16	52	130	260	16.0	780	0.80	4719.6	293.7
RHS-DH-130×260×16	91	130	260	16.0	780	0.80	3477.5	356.8
RHS-DH-130×260×16	130	130	260	16.0	780	0.80	2743.7	392.4
RHS-DH-180×320×7.2	0	180	320	7.2	960	0.36	3899.7	0
RHS-DH-180×320×7.2	18	180	320	7.2	960	0.36	3232.2	61.3
RHS-DH-180×320×7.2	72	180	320	7.2	960	0.36	2033.4	151.4
RHS-DH-180×320×7.2	126	180	320	7.2	960	0.36	1481.6	191.3
RHS-DH-180×320×7.2	180	180	320	7.2	960	0.36	1166.4	214.0
RHS-DH-180×320×10.8	0	180	320	10.8	960	0.54	7316.1	0
RHS-DH-180×320×10.8	18	180	320	10.8	960	0.54	5914.6	123.2
RHS-DH-180×320×10.8	72	180	320	10.8	960	0.54	3415.5	256.1
RHS-DH-180×320×10.8	126	180	320	10.8	960	0.54	2672.8	353.6
RHS-DH-180×320×10.8	180	180	320	10.8	960	0.54	2095.2	391.0
RHS-DH-280×380×10.5	0	280	380	10.5	1140	0.53	8512.0	0
RHS-DH-280×380×10.5	28	280	380	10.5	1140	0.53	6904.9	212.4
RHS-DH-280×380×10.5	112	280	380	10.5	1140	0.53	4267.3	502.1
RHS-DH-280×380×10.5	196	280	380	10.5	1140	0.53	3093.9	625.5
RHS-DH-280×380×10.5	280	280	380	10.5	1140	0.53	2425.5	694.0
RHS-DH-280×380×15	0	280	380	15.0	1140	0.75	14220.1	0
RHS-DH-280×380×15	28	280	380	15.0	1140	0.75	11671.6	356.4
RHS-DH-280×380×15	112	280	380	15.0	1140	0.75	7378.7	861.5
RHS-DH-280×380×15	196	280	380	15.0	1140	0.75	5346.8	1076.4
RHS-DH-280×380×15	280	280	380	15.0	1140	0.75	4202.7	1202.0
RHS-DH-360×440×11.6	0	360	440	11.6	1320	0.58	10684.5	0
RHS-DH-360×440×11.6	36	360	440	11.6	1320	0.58	8908.2	348.2
RHS-DH-360×440×11.6	144	360	440	11.6	1320	0.58	5543.0	830.5
RHS-DH-360×440×11.6	252	360	440	11.6	1320	0.58	4023.4	1040.1

RHS-DH-360×440×11.6	360	360	440	11.6	1320	0.58	3155.4	1158.4
RHS-DH-360×440×14	0	360	440	14.0	1320	0.70	14658.4	0
RHS-DH-360×440×14	36	360	440	14.0	1320	0.70	11996.7	443.1
RHS-DH-360×440×14	144	360	440	14.0	1320	0.70	7459.4	1094.1
RHS-DH-360×440×14	252	360	440	14.0	1320	0.70	5369.1	1370.7
RHS-DH-360×440×14	360	360	440	14.0	1320	0.70	4231.6	1539.5
RHS-DH-380×500×11.8	0	380	500	11.8	1500	0.59	11092.9	0
RHS-DH-380×500×11.8	38	380	500	11.8	1500	0.59	9360.6	396.8
RHS-DH-380×500×11.8	152	380	500	11.8	1500	0.59	5899.0	939.2
RHS-DH-380×500×11.8	266	380	500	11.8	1500	0.59	4302.7	1179.5
RHS-DH-380×500×11.8	380	380	500	11.8	1500	0.59	3381.0	1314.7
RHS-DH-380×500×32	0	380	500	32.0	1500	1.60	45409.0	0
RHS-DH-380×500×32	38	380	500	32.0	1500	1.60	35310.5	1734.8
RHS-DH-380×500×32	152	380	500	32.0	1500	1.60	22734.7	3862.7
RHS-DH-380×500×32	266	380	500	32.0	1500	1.60	16760.3	4793.3
RHS-DH-380×500×32	380	380	500	32.0	1500	1.60	13163.5	5276.3
RHS-DH-80×50×2.5	0	80	50	2.5	240	0.13	430.0	0
RHS-DH-80×50×2.5	8	80	50	2.5	240	0.13	373.0	3.1
RHS-DH-80×50×2.5	32	80	50	2.5	240	0.13	243.1	8.0
RHS-DH-80×50×2.5	56	80	50	2.5	240	0.13	179.0	10.2
RHS-DH-80×50×2.5	80	80	50	2.5	240	0.13	138.4	1.1
RHS-DH-80×50×3.4	0	80	50	3.4	240	0.17	661.9	0
RHS-DH-80×50×3.4	8	80	50	3.4	240	0.17	549.9	5.0
RHS-DH-80×50×3.4	32	80	50	3.4	240	0.17	356.5	12.0
RHS-DH-80×50×3.4	56	80	50	3.4	240	0.17	259.4	15.1
RHS-DH-80×50×3.4	80	80	50	3.4	240	0.17	202.3	16.7
RHS-DH-140×60×5	0	140	60	5.0	420	0.25	1402.8	0
RHS-DH-140×60×5	14	140	60	5.0	420	0.25	1202.3	1.8
RHS-DH-140×60×5	56	140	60	5.0	420	0.25	773.0	45.0
RHS-DH-140×60×5	98	140	60	5.0	420	0.25	561.9	56.7

RHS-DH-140×60×5	140	140	60	5.0	420	0.25	434.9	62.4
RHS-DH-140×60×6.8	0	140	60	6.8	420	0.34	2105.9	0
RHS-DH-140×60×6.8	14	140	60	6.8	420	0.34	1727.5	27.7
RHS-DH-140×60×6.8	56	140	60	6.8	420	0.34	1107.2	66.4
RHS-DH-140×60×6.8	98	140	60	6.8	420	0.34	799.3	82.4
RHS-DH-140×60×6.8	140	140	60	6.8	420	0.34	615.8	90.2
RHS-DH-200×80×5	0	200	80	5.0	600	0.25	1645.1	0
RHS-DH-200×80×5	20	200	80	5.0	600	0.25	1456.9	30.3
RHS-DH-200×80×5	80	200	80	5.0	600	0.25	967.0	79.1
RHS-DH-200×80×5	140	200	80	5.0	600	0.25	710.2	101.1
RHS-DH-200×80×5	200	200	80	5.0	600	0.25	556.4	112.9
RHS-DH-200×80×5.9	0	200	80	5.9	600	0.30	2137.4	0
RHS-DH-200×80×5.9	20	200	80	5.9	600	0.30	1876.3	39.4
RHS-DH-200×80×5.9	80	200	80	5.9	600	0.30	1193.9	98.0
RHS-DH-200×80×5.9	140	200	80	5.9	600	0.30	873.8	124.8
RHS-DH-200×80×5.9	200	200	80	5.9	600	0.30	686.3	139.8
RHS-DH-260×130×14.6	0	260	130	14.6	780	0.73	9029.2	0
RHS-DH-260×130×14.6	26	260	130	14.6	780	0.73	7318.8	223.7
RHS-DH-260×130×14.6	104	260	130	14.6	780	0.73	4708.2	528.7
RHS-DH-260×130×14.6	182	260	130	14.6	780	0.73	3412.8	660.6
RHS-DH-260×130×14.6	260	260	130	14.6	780	0.73	2633.6	721.6
RHS-DH-260×130×16	0	260	130	16.0	780	0.80	10103.1	0
RHS-DH-260×130×16	26	260	130	16.0	780	0.80	8028.1	248.3
RHS-DH-260×130×16	104	260	130	16.0	780	0.80	5161.1	602.6
RHS-DH-260×130×16	182	260	130	16.0	780	0.80	3729.7	728.9
RHS-DH-260×130×16	260	260	130	16.0	780	0.80	2851.7	791.7
RHS-DH-320×180×7.2	0	320	180	7.2	960	0.36	3947.2	0
RHS-DH-320×180×7.2	32	320	180	7.2	960	0.36	3486.6	114.1
RHS-DH-320×180×7.2	128	320	180	7.2	960	0.36	2232.0	289.6
RHS-DH-320×180×7.2	224	320	180	7.2	960	0.36	1731.1	392.4

RHS-DH-320×180×7.2	320	320	180	7.2	960	0.36	1368.0	442.0
RHS-DH-320×180×10.8	0	320	180	10.8	960	0.54	7316.1	0
RHS-DH-320×180×10.8	32	320	180	10.8	960	0.54	6418.9	218.6
RHS-DH-320×180×10.8	128	320	180	10.8	960	0.54	4141.1	547.8
RHS-DH-320×180×10.8	224	320	180	10.8	960	0.54	3020.7	692.0
RHS-DH-320×180×10.8	320	320	180	10.8	960	0.54	2356.3	768.5
RHS-DH-380×280×10.5	0	380	280	10.5	1140	0.53	8305.5	0
RHS-DH-380×280×10.5	38	380	280	10.5	1140	0.53	7365.7	289.4
RHS-DH-380×280×10.5	152	380	280	10.5	1140	0.53	4765.1	738.9
RHS-DH-380×280×10.5	266	380	280	10.5	1140	0.53	3463.2	934.9
RHS-DH-380×280×10.5	380	380	280	10.5	1140	0.53	2720.3	1045.0
RHS-DH-380×280×15	0	380	280	15.0	1140	0.75	14220.1	0
RHS-DH-380×280×15	38	380	280	15.0	1140	0.75	12004.5	488.3
RHS-DH-380×280×15	152	380	280	15.0	1140	0.75	7720.3	1214.4
RHS-DH-380×280×15	266	380	280	15.0	1140	0.75	5657.6	1543.8
RHS-DH-380×280×15	380	380	280	15.0	1140	0.75	4403.6	1703.2
RHS-DH-440×360×11.6	0	440	360	11.6	1320	0.58	10608.4	0
RHS-DH-440×360×11.6	44	440	360	11.6	1320	0.58	9360.3	424.9
RHS-DH-440×360×11.6	176	440	360	11.6	1320	0.58	5930.4	1063.4
RHS-DH-440×360×11.6	308	440	360	11.6	1320	0.58	4292.4	1339.9
RHS-DH-440×360×11.6	440	440	360	11.6	1320	0.58	3346.9	1488.9
RHS-DH-440×360×14	0	440	360	14.0	1320	0.70	14718.6	0
RHS-DH-440×360×14	44	440	360	14.0	1320	0.70	12574.2	569.7
RHS-DH-440×360×14	176	440	360	14.0	1320	0.70	8200.0	1472.0
RHS-DH-440×360×14	308	440	360	14.0	1320	0.70	5918.9	1847.7
RHS-DH-440×360×14	440	440	360	14.0	1320	0.70	4683.9	2084.1
RHS-DH-500×380×11.8	0	500	380	11.8	1500	0.59	11020.2	0
RHS-DH-500×380×11.8	50	500	380	11.8	1500	0.59	9785.0	505.8
RHS-DH-500×380×11.8	200	500	380	11.8	1500	0.59	6325.0	1286.4
RHS-DH-500×380×11.8	350	500	380	11.8	1500	0.59	4550.4	1614.1

RHS-DH-500×380×11.8	500	500	380	11.8	1500	0.59	3584.6	1809.5
RHS-DH-500×380×32	0	500	380	32.0	1500	1.60	44969.6	0
RHS-DH-500×380×32	50	500	380	32.0	1500	1.60	36239.1	2259.5
RHS-DH-500×380×32	200	500	380	32.0	1500	1.60	23630.9	520.8
RHS-DH-500×380×32	350	500	380	32.0	1500	1.60	17294	6451.2
RHS-DH-500×380×32	500	500	380	32.0	1500	1.60	13413.1	7058.0
RHS-IN-50×80×2.5	0	50	80	2.5	240	0.13	295.6	0
RHS-IN-50×80×2.5	5	50	80	2.5	240	0.13	236.5	1.3
RHS-IN-50×80×2.5	20	50	80	2.5	240	0.13	152.3	3.2
RHS-IN-50×80×2.5	35	50	80	2.5	240	0.13	109.6	3.9
RHS-IN-50×80×2.5	50	50	80	2.5	240	0.13	86.4	4.4
RHS-IN-50×80×3.4	0	50	80	3.4	240	0.17	425.3	0
RHS-IN-50×80×3.4	5	50	80	3.4	240	0.17	340.3	2.1
RHS-IN-50×80×3.4	20	50	80	3.4	240	0.17	220.1	4.7
RHS-IN-50×80×3.4	35	50	80	3.4	240	0.17	161.9	5.9
RHS-IN-50×80×3.4	50	50	80	3.4	240	0.17	127.9	6.6
RHS-IN-60×140×5	0	60	140	5.0	420	0.25	949.6	0
RHS-IN-60×140×5	6	60	140	5.0	420	0.25	732.3	5.7
RHS-IN-60×140×5	24	60	140	5.0	420	0.25	468.5	12.5
RHS-IN-60×140×5	42	60	140	5.0	420	0.25	345.5	15.6
RHS-IN-60×140×5	60	60	140	5.0	420	0.25	270.7	17.2
RHS-IN-60×140×6.8	0	60	140	6.8	420	0.34	1347.2	0
RHS-IN-60×140×6.8	6	60	140	6.8	420	0.34	995.8	8.3
RHS-IN-60×140×6.8	24	60	140	6.8	420	0.34	639.6	18.0
RHS-IN-60×140×6.8	42	60	140	6.8	420	0.34	471.5	22.0
RHS-IN-60×140×6.8	60	60	140	6.8	420	0.34	372.4	24.3
RHS-IN-80×200×5	0	80	200	5.0	600	0.25	1140.6	0
RHS-IN-80×200×5	8	80	200	5.0	600	0.25	893.2	8.7
RHS-IN-80×200×5	32	80	200	5.0	600	0.25	568.4	19.8
RHS-IN-80×200×5	56	80	200	5.0	600	0.25	415.7	24.6

RHS-IN-80×200×5	80	80	200	5.0	600	0.25	328.6	27.3
RHS-IN-80×200×5.9	0	80	200	5.9	600	0.30	1484.7	0
RHS-IN-80×200×5.9	8	80	200	5.9	600	0.30	1161.3	11.5
RHS-IN-80×200×5.9	32	80	200	5.9	600	0.30	743.3	26.0
RHS-IN-80×200×5.9	56	80	200	5.9	600	0.30	539.0	31.9
RHS-IN-80×200×5.9	80	80	200	5.9	600	0.30	425.0	35.6
RHS-IN-130×260×14.6	0	130	260	14.6	780	0.73	5651.7	0
RHS-IN-130×260×14.6	13	130	260	14.6	780	0.73	4243.7	81.0
RHS-IN-130×260×14.6	52	130	260	14.6	780	0.73	2733.1	166.0
RHS-IN-130×260×14.6	91	130	260	14.6	780	0.73	2014.0	202.9
RHS-IN-130×260×14.6	130	130	260	14.6	780	0.73	1588.9	224.6
RHS-IN-130×260×16	0	130	260	16.0	780	0.80	6274.9	0
RHS-IN-130×260×16	13	130	260	16.0	780	0.80	4638.1	85.6
RHS-IN-130×260×16	52	130	260	16.0	780	0.80	2978.4	181.6
RHS-IN-130×260×16	91	130	260	16.0	780	0.80	2189.8	221.5
RHS-IN-130×260×16	130	130	260	16.0	780	0.80	1724.5	243.0
RHS-IN-180×320×7.2	0	180	320	7.2	960	0.36	2731.8	0
RHS-IN-180×320×7.2	18	180	320	7.2	960	0.36	2188.0	46.0
RHS-IN-180×320×7.2	72	180	320	7.2	960	0.36	1391.0	105.7
RHS-IN-180×320×7.2	126	180	320	7.2	960	0.36	1019.9	133.2
RHS-IN-180×320×7.2	180	180	320	7.2	960	0.36	803.8	148.8
RHS-IN-180×320×10.8	0	180	320	10.8	960	0.54	5073.0	0
RHS-IN-180×320×10.8	18	180	320	10.8	960	0.54	4012.1	85.8
RHS-IN-180×320×10.8	72	180	320	10.8	960	0.54	2501.4	192.5
RHS-IN-180×320×10.8	126	180	320	10.8	960	0.54	1866.9	245.4
RHS-IN-180×320×10.8	180	180	320	10.8	960	0.54	1467.2	272.9
RHS-IN-280×380×10.5	0	280	380	10.5	1140	0.53	5822.7	0
RHS-IN-280×380×10.5	28	280	380	10.5	1140	0.53	4778.2	147.4
RHS-IN-280×380×10.5	112	280	380	10.5	1140	0.53	3021.8	349.4
RHS-IN-280×380×10.5	196	280	380	10.5	1140	0.53	2185.2	438.8

RHS-IN-280×380×10.5	280	280	380	10.5	1140	0.53	1712.8	487.5
RHS-IN-280×380×15	0	280	380	15.0	1140	0.75	9470.9	0
RHS-IN-280×380×15	28	280	380	15.0	1140	0.75	7620.7	238.0
RHS-IN-280×380×15	112	280	380	15.0	1140	0.75	4906.6	573.4
RHS-IN-280×380×15	196	280	380	15.0	1140	0.75	3612.2	728.8
RHS-IN-280×380×15	280	280	380	15.0	1140	0.75	2837.0	812.8
RHS-IN-360×440×11.6	0	360	440	11.6	1320	0.58	7394.4	0
RHS-IN-360×440×11.6	36	360	440	11.6	1320	0.58	6059.4	240.3
RHS-IN-360×440×11.6	144	360	440	11.6	1320	0.58	3890.3	576.5
RHS-IN-360×440×11.6	252	360	440	11.6	1320	0.58	2865.0	735.0
RHS-IN-360×440×11.6	360	360	440	11.6	1320	0.58	2209.6	808.2
RHS-IN-360×440×14	0	360	440	14.0	1320	0.70	10078.2	0
RHS-IN-360×440×14	36	360	440	14.0	1320	0.70	8307.2	315.9
RHS-IN-360×440×14	144	360	440	14.0	1320	0.70	5221.1	767.9
RHS-IN-360×440×14	252	360	440	14.0	1320	0.70	3795.6	969.7
RHS-IN-360×440×14	360	360	440	14.0	1320	0.70	2996.3	1091.2
RHS-IN-380×500×11.8	0	380	500	11.8	1500	0.59	7831.1	0
RHS-IN-380×500×11.8	38	380	500	11.8	1500	0.59	6497.7	251.9
RHS-IN-380×500×11.8	152	380	500	11.8	1500	0.59	4119.4	633.8
RHS-IN-380×500×11.8	266	380	500	11.8	1500	0.59	3008.4	807.7
RHS-IN-380×500×11.8	380	380	500	11.8	1500	0.59	2373.0	908.5
RHS-IN-380×500×32	0	380	500	32.0	1500	1.60	28620.4	0
RHS-IN-380×500×32	38	380	500	32.0	1500	1.60	22270.1	1092.0
RHS-IN-380×500×32	152	380	500	32.0	1500	1.60	14456.9	2431.4
RHS-IN-380×500×32	266	380	500	32.0	1500	1.60	10638.6	3025.6
RHS-IN-380×500×32	380	380	500	32.0	1500	1.60	8345.5	3327.5
RHS-IN-80×50×2.5	0	80	50	2.5	240	0.13	295.6	0
RHS-IN-80×50×2.5	8	80	50	2.5	240	0.13	247.9	2.1
RHS-IN-80×50×2.5	32	80	50	2.5	240	0.13	160.8	5.3
RHS-IN-80×50×2.5	56	80	50	2.5	240	0.13	118.0	6.7

RHS-IN-80×50×2.5	80	80	50	2.5	240	0.13	92.0	7.5
RHS-IN-80×50×3.4	0	80	50	3.4	240	0.17	426.2	0
RHS-IN-80×50×3.4	8	80	50	3.4	240	0.17	352.6	3.2
RHS-IN-80×50×3.4	32	80	50	3.4	240	0.17	229.4	7.7
RHS-IN-80×50×3.4	56	80	50	3.4	240	0.17	166.3	9.6
RHS-IN-80×50×3.4	80	80	50	3.4	240	0.17	128.6	10.6
RHS-IN-140×60×5	0	140	60	5.0	420	0.25	949.6	0
RHS-IN-140×60×5	14	140	60	5.0	420	0.25	783.7	12.2
RHS-IN-140×60×5	56	140	60	5.0	420	0.25	504.6	29.5
RHS-IN-140×60×5	98	140	60	5.0	420	0.25	363.0	36.7
RHS-IN-140×60×5	140	140	60	5.0	420	0.25	278.4	40.1
RHS-IN-140×60×6.8	0	140	60	6.8	420	0.34	1338.6	0
RHS-IN-140×60×6.8	14	140	60	6.8	420	0.34	1082.3	17.7
RHS-IN-140×60×6.8	56	140	60	6.8	420	0.34	695.1	42.1
RHS-IN-140×60×6.8	98	140	60	6.8	420	0.34	495.4	51.4
RHS-IN-140×60×6.8	140	140	60	6.8	420	0.34	377.6	55.4
RHS-IN-200×80×5	0	200	80	5.0	600	0.25	1135.9	0
RHS-IN-200×80×5	20	200	80	5.0	600	0.25	998.1	21.0
RHS-IN-200×80×5	80	200	80	5.0	600	0.25	653.0	53.5
RHS-IN-200×80×5	140	200	80	5.0	600	0.25	472.4	67.4
RHS-IN-200×80×5	200	200	80	5.0	600	0.25	371.4	75.5
RHS-IN-200×80×5.9	0	200	80	5.9	600	0.30	1484.9	0
RHS-IN-200×80×5.9	20	200	80	5.9	600	0.30	1248.1	26.9
RHS-IN-200×80×5.9	80	200	80	5.9	600	0.30	807.7	66.9
RHS-IN-200×80×5.9	140	200	80	5.9	600	0.30	583.2	83.7
RHS-IN-200×80×5.9	200	200	80	5.9	600	0.30	451.7	92.5
RHS-IN-260×130×14.6	0	260	130	14.6	780	0.73	5738.5	0
RHS-IN-260×130×14.6	26	260	130	14.6	780	0.73	4570.1	153.4
RHS-IN-260×130×14.6	104	260	130	14.6	780	0.73	2955.2	346.0
RHS-IN-260×130×14.6	182	260	130	14.6	780	0.73	2107.7	413.4

RHS-IN-260×130×14.6	260	260	130	14.6	780	0.73	1608.9	453.2
RHS-IN-260×130×16	0	260	130	16.0	780	0.80	6279.8	0
RHS-IN-260×130×16	26	260	130	16.0	780	0.80	4989.7	162.6
RHS-IN-260×130×16	104	260	130	16.0	780	0.80	3209.6	370.6
RHS-IN-260×130×16	182	260	130	16.0	780	0.80	2292.2	447.6
RHS-IN-260×130×16	260	260	130	16.0	780	0.80	1730.5	475.1
RHS-IN-320×180×7.2	0	320	180	7.2	960	0.36	2714.3	0
RHS-IN-320×180×7.2	32	320	180	7.2	960	0.36	2433.8	80.6
RHS-IN-320×180×7.2	128	320	180	7.2	960	0.36	1628.3	212.0
RHS-IN-320×180×7.2	224	320	180	7.2	960	0.36	1205.6	273.6
RHS-IN-320×180×7.2	320	320	180	7.2	960	0.36	942.3	304.7
RHS-IN-320×180×10.8	0	320	180	10.8	960	0.54	5080.6	0
RHS-IN-320×180×10.8	32	320	180	10.8	960	0.54	4210.5	148.8
RHS-IN-320×180×10.8	128	320	180	10.8	960	0.54	2744.6	366.1
RHS-IN-320×180×10.8	224	320	180	10.8	960	0.54	1994.6	460.4
RHS-IN-320×180×10.8	320	320	180	10.8	960	0.54	1541.4	505.9
RHS-IN-380×280×10.5	0	380	280	10.5	1140	0.53	5859.5	0
RHS-IN-380×280×10.5	38	380	280	10.5	1140	0.53	5076.3	202.1
RHS-IN-380×280×10.5	152	380	280	10.5	1140	0.53	3310.7	513.9
RHS-IN-380×280×10.5	266	380	280	10.5	1140	0.53	2411.8	650.9
RHS-IN-380×280×10.5	380	380	280	10.5	1140	0.53	1882.3	723.3
RHS-IN-380×280×15	0	380	280	15.0	1140	0.75	9355.3	0
RHS-IN-380×280×15	38	380	280	15.0	1140	0.75	7809.6	326.0
RHS-IN-380×280×15	152	380	280	15.0	1140	0.75	5086.5	802.9
RHS-IN-380×280×15	266	380	280	15.0	1140	0.75	3725.3	1019.0
RHS-IN-380×280×15	380	380	280	15.0	1140	0.75	2900.6	1126.9
RHS-IN-440×360×11.6	0	440	360	11.6	1320	0.58	7411.3	0
RHS-IN-440×360×11.6	44	440	360	11.6	1320	0.58	6502.1	299.2
RHS-IN-440×360×11.6	176	440	360	11.6	1320	0.58	4231.5	757.6
RHS-IN-440×360×11.6	308	440	360	11.6	1320	0.58	3110.5	969.9

RHS-IN-440×360×11.6	440	440	360	11.6	1320	0.58	2392.7	1062.1
RHS-IN-440×360×14	0	440	360	14.0	1320	0.70	10061.3	0
RHS-IN-440×360×14	44	440	360	14.0	1320	0.70	8514.5	394.4
RHS-IN-440×360×14	176	440	360	14.0	1320	0.70	5500.5	989.0
RHS-IN-440×360×14	308	440	360	14.0	1320	0.70	4040.5	1264.4
RHS-IN-440×360×14	440	440	360	14.0	1320	0.70	3154.5	1405.6
RHS-IN-500×380×11.8	0	500	380	11.8	1500	0.59	7818.0	0
RHS-IN-500×380×11.8	50	500	380	11.8	1500	0.59	6979.0	361.7
RHS-IN-500×380×11.8	200	500	380	11.8	1500	0.59	4589.5	934.3
RHS-IN-500×380×11.8	350	500	380	11.8	1500	0.59	3395.1	1201.9
RHS-IN-500×380×11.8	500	500	380	11.8	1500	0.59	2655.8	1340.3
RHS-IN-500×380×32	0	500	380	32.0	1500	1.60	28366.0	0
RHS-IN-500×380×32	50	500	380	32.0	1500	1.60	22681.9	1460.9
RHS-IN-500×380×32	200	500	380	32.0	1500	1.60	14819.4	3295.3
RHS-IN-500×380×32	350	500	380	32.0	1500	1.60	10740.2	4018.0
RHS-IN-500×380×32	500	500	380	32.0	1500	1.60	8294.0	4361.2
RHS-IH-50×80×2.5	0	50	80	2.5	240	0.13	458.2	0
RHS-IH-50×80×2.5	5	50	80	2.5	240	0.13	366.8	2.1
RHS-IH-50×80×2.5	20	50	80	2.5	240	0.13	228.3	4.9
RHS-IH-50×80×2.5	35	50	80	2.5	240	0.13	166.7	6.1
RHS-IH-50×80×2.5	50	50	80	2.5	240	0.13	132.2	6.8
RHS-IH-50×80×3.4	0	50	80	3.4	240	0.17	715.1	0
RHS-IH-50×80×3.4	5	50	80	3.4	240	0.17	566.1	3.3
RHS-IH-50×80×3.4	20	50	80	3.4	240	0.17	359.0	7.7
RHS-IH-50×80×3.4	35	50	80	3.4	240	0.17	263.5	9.7
RHS-IH-50×80×3.4	50	50	80	3.4	240	0.17	206.7	10.7
RHS-IH-60×140×5	0	60	140	5.0	420	0.25	1530.2	0
RHS-IH-60×140×5	6	60	140	5.0	420	0.25	1158.6	9.8
RHS-IH-60×140×5	24	60	140	5.0	420	0.25	739.1	20.1
RHS-IH-60×140×5	42	60	140	5.0	420	0.25	540.5	24.6

RHS-IH-60×140×5	60	60	140	5.0	420	0.25	425.9	27.1
RHS-IH-60×140×6.8	0	60	140	6.8	420	0.34	2261.2	0
RHS-IH-60×140×6.8	6	60	140	6.8	420	0.34	1669.1	15.7
RHS-IH-60×140×6.8	24	60	140	6.8	420	0.34	1051.8	29.5
RHS-IH-60×140×6.8	42	60	140	6.8	420	0.34	776.5	36.9
RHS-IH-60×140×6.8	60	60	140	6.8	420	0.34	611.3	40.0
RHS-IH-80×200×5	0	80	200	5.0	600	0.25	1737.9	0
RHS-IH-80×200×5	8	80	200	5.0	600	0.25	1333.1	14.6
RHS-IH-80×200×5	32	80	200	5.0	600	0.25	842.5	31.1
RHS-IH-80×200×5	56	80	200	5.0	600	0.25	615.4	37.9
RHS-IH-80×200×5	80	80	200	5.0	600	0.25	488.3	42.0
RHS-IH-80×200×5.9	0	80	200	5.9	600	0.30	2247.9	0
RHS-IH-80×200×5.9	8	80	200	5.9	600	0.30	1734.5	19.8
RHS-IH-80×200×5.9	32	80	200	5.9	600	0.30	1091.8	39.3
RHS-IH-80×200×5.9	56	80	200	5.9	600	0.30	801.2	48.7
RHS-IH-80×200×5.9	80	80	200	5.9	600	0.30	630.7	54.1
RHS-IH-130×260×14.6	0	130	260	14.6	780	0.73	9768.7	0
RHS-IH-130×260×14.6	13	130	260	14.6	780	0.73	7247.3	136.2
RHS-IH-130×260×14.6	52	130	260	14.6	780	0.73	4619.0	283.8
RHS-IH-130×260×14.6	91	130	260	14.6	780	0.73	3395.2	344.9
RHS-IH-130×260×14.6	130	130	260	14.6	780	0.73	2677.8	378.6
RHS-IH-130×260×16	0	130	260	16.0	780	0.80	10851.6	0
RHS-IH-130×260×16	13	130	260	16.0	780	0.80	7952.9	154.8
RHS-IH-130×260×16	52	130	260	16.0	780	0.80	5064.6	313.7
RHS-IH-130×260×16	91	130	260	16.0	780	0.80	3726.6	384.6
RHS-IH-130×260×16	130	130	260	16.0	780	0.80	2937.0	420.6
RHS-IH-180×320×7.2	0	180	320	7.2	960	0.36	3960.2	0
RHS-IH-180×320×7.2	18	180	320	7.2	960	0.36	3340.7	65.6
RHS-IH-180×320×7.2	72	180	320	7.2	960	0.36	2131.1	160.2
RHS-IH-180×320×7.2	126	180	320	7.2	960	0.36	1568.0	203.4

RHS-IH-180×320×7.2	180	180	320	7.2	960	0.36	1237.8	228.1
RHS-IH-180×320×10.8	0	180	320	10.8	960	0.54	7963.0	0
RHS-IH-180×320×10.8	18	180	320	10.8	960	0.54	6322.7	140.7
RHS-IH-180×320×10.8	72	180	320	10.8	960	0.54	3983.8	308.5
RHS-IH-180×320×10.8	126	180	320	10.8	960	0.54	2907.8	385.5
RHS-IH-180×320×10.8	180	180	320	10.8	960	0.54	2262.2	423.6
RHS-IH-280×380×10.5	0	280	380	10.5	1140	0.53	8684.7	0
RHS-IH-280×380×10.5	28	280	380	10.5	1140	0.53	7176.9	229.6
RHS-IH-280×380×10.5	112	280	380	10.5	1140	0.53	4510.3	536.2
RHS-IH-280×380×10.5	196	280	380	10.5	1140	0.53	3296.2	670.7
RHS-IH-280×380×10.5	280	280	380	10.5	1140	0.53	2606.1	749.1
RHS-IH-280×380×15	0	280	380	15.0	1140	0.75	15079.2	0
RHS-IH-280×380×15	28	280	380	15.0	1140	0.75	12482.9	386.3
RHS-IH-280×380×15	112	280	380	15.0	1140	0.75	7853.0	918.8
RHS-IH-280×380×15	196	280	380	15.0	1140	0.75	5774.3	1167.4
RHS-IH-280×380×15	280	280	380	15.0	1140	0.75	4479.4	1284.7
RHS-IH-360×440×11.6	0	360	440	11.6	1320	0.58	10632.3	0
RHS-IH-360×440×11.6	36	360	440	11.6	1320	0.58	9129.4	365.0
RHS-IH-360×440×11.6	144	360	440	11.6	1320	0.58	5807.0	878.4
RHS-IH-360×440×11.6	252	360	440	11.6	1320	0.58	4237.8	1101.7
RHS-IH-360×440×11.6	360	360	440	11.6	1320	0.58	3319.4	1224.4
RHS-IH-360×440×14	0	360	440	14.0	1320	0.70	15117.1	0
RHS-IH-360×440×14	36	360	440	14.0	1320	0.70	12538.5	467.5
RHS-IH-360×440×14	144	360	440	14.0	1320	0.70	8010.3	1177.8
RHS-IH-360×440×14	252	360	440	14.0	1320	0.70	5807.3	1484.8
RHS-IH-360×440×14	360	360	440	14.0	1320	0.70	4513.9	1643.2
RHS-IH-380×500×11.8	0	380	500	11.8	1500	0.59	11177.2	0
RHS-IH-380×500×11.8	38	380	500	11.8	1500	0.59	9585.3	420.5
RHS-IH-380×500×11.8	152	380	500	11.8	1500	0.59	6140.6	977.1
RHS-IH-380×500×11.8	266	380	500	11.8	1500	0.59	4521.7	1245.7

RHS-IH-380×500×11.8	380	380	500	11.8	1500	0.59	3552.6	1386.5
RHS-IH-380×500×32	0	380	500	32.0	1500	1.60	48985.8	0
RHS-IH-380×500×32	38	380	500	32.0	1500	1.60	38091.3	1911.3
RHS-IH-380×500×32	152	380	500	32.0	1500	1.60	24477.7	4171.5
RHS-IH-380×500×32	266	380	500	32.0	1500	1.60	18019.0	5154.3
RHS-IH-380×500×32	380	380	500	32.0	1500	1.60	14141.8	5602.6
RHS-IH-80×50×2.5	0	80	50	2.5	240	0.13	455.1	0
RHS-IH-80×50×2.5	8	80	50	2.5	240	0.13	398.4	3.4
RHS-IH-80×50×2.5	32	80	50	2.5	240	0.13	260.6	8.6
RHS-IH-80×50×2.5	56	80	50	2.5	240	0.13	190.1	10.9
RHS-IH-80×50×2.5	80	80	50	2.5	240	0.13	150.0	12.2
RHS-IH-80×50×3.4	0	80	50	3.4	240	0.17	718.0	0
RHS-IH-80×50×3.4	8	80	50	3.4	240	0.17	596.9	5.5
RHS-IH-80×50×3.4	32	80	50	3.4	240	0.17	386.5	13.1
RHS-IH-80×50×3.4	56	80	50	3.4	240	0.17	282.7	16.5
RHS-IH-80×50×3.4	80	80	50	3.4	240	0.17	219.6	18.2
RHS-IH-140×60×5	0	140	60	5.0	420	0.25	1511.5	0
RHS-IH-140×60×5	14	140	60	5.0	420	0.25	1289.3	19.8
RHS-IH-140×60×5	56	140	60	5.0	420	0.25	824.7	48.1
RHS-IH-140×60×5	98	140	60	5.0	420	0.25	605.4	61.3
RHS-IH-140×60×5	140	140	60	5.0	420	0.25	465.1	66.7
RHS-IH-140×60×6.8	0	140	60	6.8	420	0.34	2264.3	0
RHS-IH-140×60×6.8	14	140	60	6.8	420	0.34	1853.2	30.4
RHS-IH-140×60×6.8	56	140	60	6.8	420	0.34	1185.7	71.2
RHS-IH-140×60×6.8	98	140	60	6.8	420	0.34	854.5	88.2
RHS-IH-140×60×6.8	140	140	60	6.8	420	0.34	655.6	96.0
RHS-IH-200×80×5	0	200	80	5.0	600	0.25	1737.9	0
RHS-IH-200×80×5	20	200	80	5.0	600	0.25	1529.1	32.0
RHS-IH-200×80×5	80	200	80	5.0	600	0.25	1014.1	83.3
RHS-IH-200×80×5	140	200	80	5.0	600	0.25	750.5	107.0

RHS-IH-200×80×5	200	200	80	5.0	600	0.25	587.3	119.2
RHS-IH-200×80×5.9	0	200	80	5.9	600	0.30	2237.3	0
RHS-IH-200×80×5.9	20	200	80	5.9	600	0.30	1985.1	42.1
RHS-IH-200×80×5.9	80	200	80	5.9	600	0.30	1293.5	106.9
RHS-IH-200×80×5.9	140	200	80	5.9	600	0.30	940.9	134.9
RHS-IH-200×80×5.9	200	200	80	5.9	600	0.30	739.0	150.8
RHS-IH-260×130×14.6	0	260	130	14.6	780	0.73	9775.6	0
RHS-IH-260×130×14.6	26	260	130	14.6	780	0.73	7829.4	247.6
RHS-IH-260×130×14.6	104	260	130	14.6	780	0.73	5034.5	570.1
RHS-IH-260×130×14.6	182	260	130	14.6	780	0.73	3627.6	701.9
RHS-IH-260×130×14.6	260	260	130	14.6	780	0.73	2785.2	760.8
RHS-IH-260×130×16	0	260	130	16.0	780	0.80	10844.0	0
RHS-IH-260×130×16	26	260	130	16.0	780	0.80	8615.2	281.7
RHS-IH-260×130×16	104	260	130	16.0	780	0.80	5531.4	632.9
RHS-IH-260×130×16	182	260	130	16.0	780	0.80	3977.6	776.9
RHS-IH-260×130×16	260	260	130	16.0	780	0.80	3048.4	837.7
RHS-IH-320×180×7.2	0	320	180	7.2	960	0.36	3991.1	0
RHS-IH-320×180×7.2	32	320	180	7.2	960	0.36	3550.5	120.4
RHS-IH-320×180×7.2	128	320	180	7.2	960	0.36	2454.0	320.4
RHS-IH-320×180×7.2	224	320	180	7.2	960	0.36	1822.0	414.2
RHS-IH-320×180×7.2	320	320	180	7.2	960	0.36	1458.1	472.0
RHS-IH-320×180×10.8	0	320	180	10.8	960	0.54	7963.0	0
RHS-IH-320×180×10.8	32	320	180	10.8	960	0.54	6904.5	238.1
RHS-IH-320×180×10.8	128	320	180	10.8	960	0.54	4478.8	596.0
RHS-IH-320×180×10.8	224	320	180	10.8	960	0.54	3261.7	749.6
RHS-IH-320×180×10.8	320	320	180	10.8	960	0.54	2566.0	840.0
RHS-IH-380×280×10.5	0	380	280	10.5	1140	0.53	8681.0	0
RHS-IH-380×280×10.5	38	380	280	10.5	1140	0.53	7640.1	308.1
RHS-IH-380×280×10.5	152	380	280	10.5	1140	0.53	5055.1	786.9
RHS-IH-380×280×10.5	266	380	280	10.5	1140	0.53	3742.2	1010.8

RHS-IH-380×280×10.5	380	380	280	10.5	1140	0.53	2854.5	1098.6
RHS-IH-380×280×15	0	380	280	15.0	1140	0.75	14778.3	0
RHS-IH-380×280×15	38	380	280	15.0	1140	0.75	12913.3	531.3
RHS-IH-380×280×15	152	380	280	15.0	1140	0.75	8409.7	1331.6
RHS-IH-380×280×15	266	380	280	15.0	1140	0.75	6111.7	1668.5
RHS-IH-380×280×15	380	380	280	15.0	1140	0.75	4772.4	1850.3
RHS-IH-440×360×11.6	0	440	360	11.6	1320	0.58	10741.7	0
RHS-IH-440×360×11.6	44	440	360	11.6	1320	0.58	9470.3	440.1
RHS-IH-440×360×11.6	176	440	360	11.6	1320	0.58	6287.7	1133.0
RHS-IH-440×360×11.6	308	440	360	11.6	1320	0.58	4631.4	1448.3
RHS-IH-440×360×11.6	440	440	360	11.6	1320	0.58	3582.6	1593.0
RHS-IH-440×360×14	0	440	360	14.0	1320	0.70	15216.2	0
RHS-IH-440×360×14	44	440	360	14.0	1320	0.70	13119.0	598.2
RHS-IH-440×360×14	176	440	360	14.0	1320	0.70	8681.7	1561.6
RHS-IH-440×360×14	308	440	360	14.0	1320	0.70	6331.7	1980.6
RHS-IH-440×360×14	440	440	360	14.0	1320	0.70	4931.1	2196.0
RHS-IH-500×380×11.8	0	500	380	11.8	1500	0.59	11159.5	0
RHS-IH-500×380×11.8	50	500	380	11.8	1500	0.59	9831.5	520.1
RHS-IH-500×380×11.8	200	500	380	11.8	1500	0.59	6510.7	1327.6
RHS-IH-500×380×11.8	350	500	380	11.8	1500	0.59	4857.8	1726.7
RHS-IH-500×380×11.8	500	500	380	11.8	1500	0.59	3873.1	1957.8
RHS-IH-500×380×32	0	500	380	32.0	1500	1.60	48811.4	0
RHS-IH-500×380×32	50	500	380	32.0	1500	1.60	39103.3	2479.9
RHS-IH-500×380×32	200	500	380	32.0	1500	1.60	25297.2	5546.7
RHS-IH-500×380×32	350	500	380	32.0	1500	1.60	18527.3	6871.6
RHS-IH-500×380×32	500	500	380	32.0	1500	1.60	14340.3	7496.1

Appendix B   Long beam-column parametric study

Table B.1 Long beam-column parametric study results

Model ID	e (mm)	h (mm)	b (mm)	t (mm)	L (mm)	δ_l (mm)	δ_g (mm)	P_u (kN)	M_u (kN.m)
SHS-DN-50×50×2.5	0	50	50	2.5	3300	0.13	3.30	31.2	2.3
SHS-DN-50×50×2.5	5	50	50	2.5	3300	0.13	3.30	28.5	2.8
SHS-DN-50×50×2.5	20	50	50	2.5	3300	0.13	3.30	24.1	2.9
SHS-DN-50×50×2.5	35	50	50	2.5	3300	0.13	3.30	20.9	3.2
SHS-DN-50×50×2.5	50	50	50	2.5	3300	0.13	3.30	18.1	3.5
SHS-DN-50×50×3	0	50	50	3.0	2700	0.15	2.70	54.1	2.4
SHS-DN-50×50×3	5	50	50	3.0	2700	0.15	2.70	48.5	2.8
SHS-DN-50×50×3	20	50	50	3.0	2700	0.15	2.70	38.3	3.5
SHS-DN-50×50×3	35	50	50	3.0	2700	0.15	2.70	32.6	3.5
SHS-DN-50×50×3	50	50	50	3.0	2700	0.15	2.70	28.7	3.8
SHS-DN-100×100×2.8	0	100	100	2.8	7800	0.14	7.80	57.6	8.8
SHS-DN-100×100×2.8	10	100	100	2.8	7800	0.14	7.80	54.2	12.1
SHS-DN-100×100×2.8	40	100	100	2.8	7800	0.14	7.80	47.7	12.6
SHS-DN-100×100×2.8	70	100	100	2.8	7800	0.14	7.80	42.6	14.0
SHS-DN-100×100×2.8	100	100	100	2.8	7800	0.14	7.80	38.8	14.1
SHS-DN-100×100×4.2	0	100	100	4.2	6500	0.21	6.50	113.4	12.5
SHS-DN-100×100×4.2	10	100	100	4.2	6500	0.21	6.50	104.9	15.6
SHS-DN-100×100×4.2	40	100	100	4.2	6500	0.21	6.50	87.4	19.1
SHS-DN-100×100×4.2	70	100	100	4.2	6500	0.21	6.50	76.2	19.5
SHS-DN-100×100×4.2	100	100	100	4.2	6500	0.21	6.50	68.0	22.0
SHS-DN-150×150×3.9	0	150	150	3.9	10500	0.20	10.50	144.9	28.0
SHS-DN-150×150×3.9	15	150	150	3.9	10500	0.20	10.50	135.6	33.7
SHS-DN-150×150×3.9	60	150	150	3.9	10500	0.20	10.50	115.7	41.0
SHS-DN-150×150×3.9	105	150	150	3.9	10500	0.20	10.50	101.7	44.0
SHS-DN-150×150×3.9	150	150	150	3.9	10500	0.20	10.50	91.5	45.7

SHS-DN-150×150×4.6	0	150	150	4.6	11000	0.23	11.00	149.0	37.9
SHS-DN-150×150×4.6	15	150	150	4.6	11000	0.23	11.00	139.7	44.5
SHS-DN-150×150×4.6	60	150	150	4.6	11000	0.23	11.00	119.6	48.4
SHS-DN-150×150×4.6	105	150	150	4.6	11000	0.23	11.00	106.0	51.2
SHS-DN-150×150×4.6	150	150	150	4.6	11000	0.23	11.00	96.1	52.3
SHS-DN-200×200×4.5	0	200	200	4.5	9500	0.23	9.50	473.1	43.6
SHS-DN-200×200×4.5	20	200	200	4.5	9500	0.23	9.50	408.8	65.3
SHS-DN-200×200×4.5	80	200	200	4.5	9500	0.23	9.50	303.8	80.3
SHS-DN-200×200×4.5	140	200	200	4.5	9500	0.23	9.50	250.9	89.5
SHS-DN-200×200×4.5	200	200	200	4.5	9500	0.23	9.50	216.0	93.2
SHS-DN-200×200×7.6	0	200	200	7.6	12000	0.38	12.00	494.2	101.3
SHS-DN-200×200×7.6	20	200	200	7.6	12000	0.38	12.00	450.5	116.6
SHS-DN-200×200×7.6	80	200	200	7.6	12000	0.38	12.00	365.0	129.1
SHS-DN-200×200×7.6	140	200	200	7.6	12000	0.38	12.00	314.1	148.0
SHS-DN-200×200×7.6	200	200	200	7.6	12000	0.38	12.00	278.1	161.6
SHS-DN-250×250×11.5	0	250	250	11.5	11000	0.58	11.00	1544.5	207.0
SHS-DN-250×250×11.5	25	250	250	11.5	11000	0.58	11.00	1308.7	235.3
SHS-DN-250×250×11.5	100	250	250	11.5	11000	0.58	11.00	964.8	303.6
SHS-DN-250×250×11.5	175	250	250	11.5	11000	0.58	11.00	799.7	362.5
SHS-DN-250×250×11.5	250	250	250	11.5	11000	0.58	11.00	685.7	375.2
SHS-DN-250×250×18	0	250	250	18.0	12000	0.90	12.00	1893.0	371.0
SHS-DN-250×250×18	25	250	250	18.0	12000	0.90	12.00	1655.9	364.1
SHS-DN-250×250×18	100	250	250	18.0	12000	0.90	12.00	1275.5	468.5
SHS-DN-250×250×18	175	250	250	18.0	12000	0.90	12.00	1074.0	542.4
SHS-DN-250×250×18	250	250	250	18.0	12000	0.90	12.00	931.1	576.8
SHS-DN-300×300×9.8	0	300	300	9.8	11200	0.49	11.20	2242.4	163.7
SHS-DN-300×300×9.8	30	300	300	9.8	11200	0.49	11.20	1773.1	263.4
SHS-DN-300×300×9.8	120	300	300	9.8	11200	0.49	11.20	1233.1	387.6
SHS-DN-300×300×9.8	210	300	300	9.8	11200	0.49	11.20	986.5	437.0
SHS-DN-300×300×9.8	300	300	300	9.8	11200	0.49	11.20	831.7	456.6

SHS-DN-300×300×12.2	0	300	300	12.2	11500	0.61	11.50	2544.9	238.7
SHS-DN-300×300×12.2	30	300	300	12.2	11500	0.61	11.50	2038.9	381.2
SHS-DN-300×300×12.2	120	300	300	12.2	11500	0.61	11.50	1451.5	509.2
SHS-DN-300×300×12.2	210	300	300	12.2	11500	0.61	11.50	1172.9	541.7
SHS-DN-300×300×12.2	300	300	300	12.2	11500	0.61	11.50	993.9	572.0
SHS-DN-350×350×10.5	0	350	350	10.5	11000	0.53	11.00	3639.1	160.5
SHS-DN-350×350×10.5	35	350	350	10.5	11000	0.53	11.00	2717.8	377.0
SHS-DN-350×350×10.5	140	350	350	10.5	11000	0.53	11.00	1799.6	563.5
SHS-DN-350×350×10.5	245	350	350	10.5	11000	0.53	11.00	1412.6	648.8
SHS-DN-350×350×10.5	350	350	350	10.5	11000	0.53	11.00	1174.7	681.4
SHS-DN-350×350×12	0	350	350	12.0	11500	0.60	11.50	3779.8	305.3
SHS-DN-350×350×12	35	350	350	12.0	11500	0.60	11.50	2862.5	487.4
SHS-DN-350×350×12	140	350	350	12.0	11500	0.60	11.50	1946.2	639.4
SHS-DN-350×350×12	245	350	350	12.0	11500	0.60	11.50	1538.7	753.8
SHS-DN-350×350×12	350	350	350	12.0	11500	0.60	11.50	1282.6	788.0
SHS-DN-400×400×10	0	400	400	10.0	11200	0.50	11.20	4545.6	160.1
SHS-DN-400×400×10	40	400	400	10.0	11200	0.50	11.20	3328.2	438.7
SHS-DN-400×400×10	160	400	400	10.0	11200	0.50	11.20	2153.2	680.8
SHS-DN-400×400×10	280	400	400	10.0	11200	0.50	11.20	1672.2	826.4
SHS-DN-400×400×10	400	400	400	10.0	11200	0.50	11.20	1380.1	858.9
SHS-DN-400×400×11.6	0	400	400	11.6	12000	0.58	12.00	4969.5	280.9
SHS-DN-400×400×11.6	40	400	400	11.6	12000	0.58	12.00	3587.6	475.6
SHS-DN-400×400×11.6	160	400	400	11.6	12000	0.58	12.00	2369.1	806.6
SHS-DN-400×400×11.6	280	400	400	11.6	12000	0.58	12.00	1851.8	957.8
SHS-DN-400×400×11.6	400	400	400	11.6	12000	0.58	12.00	1535.2	993.3
SHS-DN-450×450×10.8	0	450	450	10.8	12000	0.54	12.00	5887.8	256.3
SHS-DN-450×450×10.8	45	450	450	10.8	12000	0.54	12.00	4207.2	571.0
SHS-DN-450×450×10.8	180	450	450	10.8	12000	0.54	12.00	2694.2	948.9
SHS-DN-450×450×10.8	315	450	450	10.8	12000	0.54	12.00	2085.1	1103.8
SHS-DN-450×450×10.8	450	450	450	10.8	12000	0.54	12.00	1716.0	1172.2

SHS-DN-450×450×12	0	450	450	12.0	9000	0.60	9.00	7495.1	141.2
SHS-DN-450×450×12	45	450	450	12.0	9000	0.60	9.00	5519.5	572.1
SHS-DN-450×450×12	180	450	450	12.0	9000	0.60	9.00	3510.4	1027.4
SHS-DN-450×450×12	315	450	450	12.0	9000	0.60	9.00	2664.7	1185.7
SHS-DN-450×450×12	450	450	450	12.0	9000	0.60	9.00	2160.3	1272.1
SHS-DN-500×500×18	0	500	500	18.0	12000	0.90	12.00	11637.6	347.1
SHS-DN-500×500×18	50	500	500	18.0	12000	0.90	12.00	8268.0	1144.6
SHS-DN-500×500×18	200	500	500	18.0	12000	0.90	12.00	5324.2	2065.9
SHS-DN-500×500×18	350	500	500	18.0	12000	0.90	12.00	4112.1	2316.4
SHS-DN-500×500×18	500	500	500	18.0	12000	0.90	12.00	3348.0	2420.2
SHS-DN-500×500×27	0	500	500	27.0	10500	1.35	10.50	17607.9	674.9
SHS-DN-500×500×27	50	500	500	27.0	10500	1.35	10.50	13118.1	1798.5
SHS-DN-500×500×27	200	500	500	27.0	10500	1.35	10.50	8551.0	3061.9
SHS-DN-500×500×27	350	500	500	27.0	10500	1.35	10.50	6534.3	3448.8
SHS-DN-500×500×27	500	500	500	27.0	10500	1.35	10.50	5256.6	3574.6
SHS-DH-50×50×2.5	0	50	50	2.5	3300	0.13	3.30	32.1	2.8
SHS-DH-50×50×2.5	5	50	50	2.5	3300	0.13	3.30	30.8	4.0
SHS-DH-50×50×2.5	20	50	50	2.5	3300	0.13	3.30	27.7	4.7
SHS-DH-50×50×2.5	35	50	50	2.5	3300	0.13	3.30	25.4	5.1
SHS-DH-50×50×2.5	50	50	50	2.5	3300	0.13	3.30	23.4	5.2
SHS-DH-50×50×3	0	50	50	3.0	2700	0.15	2.70	54.9	3.2
SHS-DH-50×50×3	5	50	50	3.0	2700	0.15	2.70	51.7	4.9
SHS-DH-50×50×3	20	50	50	3.0	2700	0.15	2.70	44.4	5.9
SHS-DH-50×50×3	35	50	50	3.0	2700	0.15	2.70	39.4	5.8
SHS-DH-50×50×3	50	50	50	3.0	2700	0.15	2.70	35.6	6.0
SHS-DH-100×100×2.8	0	100	100	2.8	7800	0.14	7.80	57.2	10.8
SHS-DH-100×100×2.8	10	100	100	2.8	7800	0.14	7.80	55.4	16.2
SHS-DH-100×100×2.8	40	100	100	2.8	7800	0.14	7.80	51.3	22.2
SHS-DH-100×100×2.8	70	100	100	2.8	7800	0.14	7.80	48.1	23.7
SHS-DH-100×100×2.8	100	100	100	2.8	7800	0.14	7.80	45.2	24.8

SHS-DH-100×100×4.2	0	100	100	4.2	6500	0.21	6.50	114.6	19.9
SHS-DH-100×100×4.2	10	100	100	4.2	6500	0.21	6.50	109.3	26.9
SHS-DH-100×100×4.2	40	100	100	4.2	6500	0.21	6.50	97.9	31.9
SHS-DH-100×100×4.2	70	100	100	4.2	6500	0.21	6.50	89.4	34.7
SHS-DH-100×100×4.2	100	100	100	4.2	6500	0.21	6.50	82.3	36.8
SHS-DH-150×150×3.9	0	150	150	3.9	10500	0.20	10.50	147.9	38.7
SHS-DH-150×150×3.9	15	150	150	3.9	10500	0.20	10.50	142.2	58.0
SHS-DH-150×150×3.9	60	150	150	3.9	10500	0.20	10.50	129.8	71.7
SHS-DH-150×150×3.9	105	150	150	3.9	10500	0.20	10.50	119.5	78.0
SHS-DH-150×150×3.9	150	150	150	3.9	10500	0.20	10.50	110.9	80.2
SHS-DH-150×150×4.6	0	150	150	4.6	11000	0.23	11.00	157.0	42.8
SHS-DH-150×150×4.6	15	150	150	4.6	11000	0.23	11.00	151.7	62.9
SHS-DH-150×150×4.6	60	150	150	4.6	11000	0.23	11.00	139.5	82.5
SHS-DH-150×150×4.6	105	150	150	4.6	11000	0.23	11.00	129.4	87.5
SHS-DH-150×150×4.6	150	150	150	4.6	11000	0.23	11.00	120.8	91.4
SHS-DH-200×200×4.5	0	200	200	4.5	9500	0.23	9.50	479.4	84.3
SHS-DH-200×200×4.5	20	200	200	4.5	9500	0.23	9.50	445.1	123.9
SHS-DH-200×200×4.5	80	200	200	4.5	9500	0.23	9.50	368.6	142.1
SHS-DH-200×200×4.5	140	200	200	4.5	9500	0.23	9.50	316.6	144.6
SHS-DH-200×200×4.5	200	200	200	4.5	9500	0.23	9.50	279.2	147.1
SHS-DH-200×200×7.6	0	200	200	7.6	12000	0.38	12.00	492.2	135.2
SHS-DH-200×200×7.6	20	200	200	7.6	12000	0.38	12.00	467.4	210.2
SHS-DH-200×200×7.6	80	200	200	7.6	12000	0.38	12.00	411.6	239.2
SHS-DH-200×200×7.6	140	200	200	7.6	12000	0.38	12.00	369.6	258.5
SHS-DH-200×200×7.6	200	200	200	7.6	12000	0.38	12.00	338.0	263.7
SHS-DH-250×250×11.5	0	250	250	11.5	11000	0.58	11.00	1630.2	338.8
SHS-DH-250×250×11.5	25	250	250	11.5	11000	0.58	11.00	1483.1	449.0
SHS-DH-250×250×11.5	100	250	250	11.5	11000	0.58	11.00	1204.4	553.0
SHS-DH-250×250×11.5	175	250	250	11.5	11000	0.58	11.00	1032.0	598.4
SHS-DH-250×250×11.5	250	250	250	11.5	11000	0.58	11.00	912.8	632.3

SHS-DH-250×250×18	0	250	250	18.0	12000	0.90	12.00	1957.7	500.7
SHS-DH-250×250×18	25	250	250	18.0	12000	0.90	12.00	1800.9	684.4
SHS-DH-250×250×18	100	250	250	18.0	12000	0.90	12.00	1509.3	841.9
SHS-DH-250×250×18	175	250	250	18.0	12000	0.90	12.00	1319.4	912.0
SHS-DH-250×250×18	250	250	250	18.0	12000	0.90	12.00	1182.5	939.4
SHS-DH-300×300×9.8	0	300	300	9.8	11200	0.49	11.20	2410.5	495.5
SHS-DH-300×300×9.8	30	300	300	9.8	11200	0.49	11.20	2109.0	596.9
SHS-DH-300×300×9.8	120	300	300	9.8	11200	0.49	11.20	1599.5	652.9
SHS-DH-300×300×9.8	210	300	300	9.8	11200	0.49	11.20	1337.5	797.0
SHS-DH-300×300×9.8	300	300	300	9.8	11200	0.49	11.20	1162.3	819.6
SHS-DH-300×300×12.2	0	300	300	12.2	11500	0.61	11.50	2707.8	414.6
SHS-DH-300×300×12.2	30	300	300	12.2	11500	0.61	11.50	2411.2	758.4
SHS-DH-300×300×12.2	120	300	300	12.2	11500	0.61	11.50	1870.2	893.3
SHS-DH-300×300×12.2	210	300	300	12.2	11500	0.61	11.50	1570.0	998.4
SHS-DH-300×300×12.2	300	300	300	12.2	11500	0.61	11.50	1365.4	1031.9
SHS-DH-350×350×10.5	0	350	350	10.5	11000	0.53	11.00	4173.9	629.5
SHS-DH-350×350×10.5	35	350	350	10.5	11000	0.53	11.00	3442.1	779.9
SHS-DH-350×350×10.5	140	350	350	10.5	11000	0.53	11.00	2462.6	1040.7
SHS-DH-350×350×10.5	245	350	350	10.5	11000	0.53	11.00	2000.5	1120.9
SHS-DH-350×350×10.5	350	350	350	10.5	11000	0.53	11.00	1705.2	1191.4
SHS-DH-350×350×12	0	350	350	12.0	11500	0.60	11.50	4323.4	723.4
SHS-DH-350×350×12	35	350	350	12.0	11500	0.60	11.50	3604.5	829.2
SHS-DH-350×350×12	140	350	350	12.0	11500	0.60	11.50	2648.0	1190.2
SHS-DH-350×350×12	245	350	350	12.0	11500	0.60	11.50	2161.3	1369.8
SHS-DH-350×350×12	350	350	350	12.0	11500	0.60	11.50	1860.1	1381.6
SHS-DH-400×400×10	0	400	400	10.0	11200	0.50	11.20	5530.1	471.1
SHS-DH-400×400×10	40	400	400	10.0	11200	0.50	11.20	4432.5	937.6
SHS-DH-400×400×10	160	400	400	10.0	11200	0.50	11.20	2957.3	1048.0
SHS-DH-400×400×10	280	400	400	10.0	11200	0.50	11.20	2310.7	1148.1
SHS-DH-400×400×10	400	400	400	10.0	11200	0.50	11.20	1903.7	1194.8

SHS-DH-400×400×11.6	0	400	400	11.6	12000	0.58	12.00	5795.6	888.6
SHS-DH-400×400×11.6	40	400	400	11.6	12000	0.58	12.00	4643.8	1110.6
SHS-DH-400×400×11.6	160	400	400	11.6	12000	0.58	12.00	3273.2	1476.9
SHS-DH-400×400×11.6	280	400	400	11.6	12000	0.58	12.00	2634.2	1612.2
SHS-DH-400×400×11.6	400	400	400	11.6	12000	0.58	12.00	2219.5	1647.0
SHS-DH-450×450×10.8	0	450	450	10.8	12000	0.54	12.00	7480.5	840.4
SHS-DH-450×450×10.8	45	450	450	10.8	12000	0.54	12.00	5690.6	1115.6
SHS-DH-450×450×10.8	180	450	450	10.8	12000	0.54	12.00	3757.4	1427.3
SHS-DH-450×450×10.8	315	450	450	10.8	12000	0.54	12.00	2855.7	1513.0
SHS-DH-450×450×10.8	450	450	450	10.8	12000	0.54	12.00	2375.8	1621.5
SHS-DH-450×450×12	0	450	450	12.0	9000	0.60	9.00	11826.7	354.5
SHS-DH-450×450×12	45	450	450	12.0	9000	0.60	9.00	8296.5	1003.2
SHS-DH-450×450×12	180	450	450	12.0	9000	0.60	9.00	5001.0	1442.8
SHS-DH-450×450×12	315	450	450	12.0	9000	0.60	9.00	3746.2	1649.4
SHS-DH-450×450×12	450	450	450	12.0	9000	0.60	9.00	3006.8	1755.5
SHS-DH-500×500×18	0	500	500	18.0	12000	0.90	12.00	15573.3	1236.0
SHS-DH-500×500×18	50	500	500	18.0	12000	0.90	12.00	11529.2	2511.9
SHS-DH-500×500×18	200	500	500	18.0	12000	0.90	12.00	7704.6	3456.4
SHS-DH-500×500×18	350	500	500	18.0	12000	0.90	12.00	6056.8	4108.7
SHS-DH-500×500×18	500	500	500	18.0	12000	0.90	12.00	5047.4	4274.4
SHS-DH-500×500×27	0	500	500	27.0	10500	1.35	10.50	26114.4	1812.0
SHS-DH-500×500×27	50	500	500	27.0	10500	1.35	10.50	18815.4	3437.7
SHS-DH-500×500×27	200	500	500	27.0	10500	1.35	10.50	12454.1	5470.8
SHS-DH-500×500×27	350	500	500	27.0	10500	1.35	10.50	9713.1	5991.4
SHS-DH-500×500×27	500	500	500	27.0	10500	1.35	10.50	7998.6	6346.3
SHS-IN-50×50×2.5	0	50	50	2.5	3300	0.13	3.30	30.6	1.4
SHS-IN-50×50×2.5	5	50	50	2.5	3300	0.13	3.30	27.9	1.9
SHS-IN-50×50×2.5	20	50	50	2.5	3300	0.13	3.30	23.3	2.7
SHS-IN-50×50×2.5	35	50	50	2.5	3300	0.13	3.30	20.4	2.8
SHS-IN-50×50×2.5	50	50	50	2.5	3300	0.13	3.30	18.3	3.1

SHS-IN-50×50×3	0	50	50	3.0	2700	0.15	2.70	51.0	1.9
SHS-IN-50×50×3	5	50	50	3.0	2700	0.15	2.70	45.0	2.7
SHS-IN-50×50×3	20	50	50	3.0	2700	0.15	2.70	35.9	3.2
SHS-IN-50×50×3	35	50	50	3.0	2700	0.15	2.70	30.5	3.4
SHS-IN-50×50×3	50	50	50	3.0	2700	0.15	2.70	26.9	3.7
SHS-IN-100×100×2.8	0	100	100	2.8	7800	0.14	7.80	55.4	7.1
SHS-IN-100×100×2.8	10	100	100	2.8	7800	0.14	7.80	51.3	8.4
SHS-IN-100×100×2.8	40	100	100	2.8	7800	0.14	7.80	44.2	11.5
SHS-IN-100×100×2.8	70	100	100	2.8	7800	0.14	7.80	39.4	13.2
SHS-IN-100×100×2.8	100	100	100	2.8	7800	0.14	7.80	35.9	13.3
SHS-IN-100×100×4.2	0	100	100	4.2	6500	0.21	6.50	106.2	12.6
SHS-IN-100×100×4.2	10	100	100	4.2	6500	0.21	6.50	96.7	13.1
SHS-IN-100×100×4.2	40	100	100	4.2	6500	0.21	6.50	80.1	18.3
SHS-IN-100×100×4.2	70	100	100	4.2	6500	0.21	6.50	70.0	19.5
SHS-IN-100×100×4.2	100	100	100	4.2	6500	0.21	6.50	62.6	20.9
SHS-IN-150×150×3.9	0	150	150	3.9	10500	0.20	10.50	135.3	20.2
SHS-IN-150×150×3.9	15	150	150	3.9	10500	0.20	10.50	124.0	26.8
SHS-IN-150×150×3.9	60	150	150	3.9	10500	0.20	10.50	103.9	34.1
SHS-IN-150×150×3.9	105	150	150	3.9	10500	0.20	10.50	91.4	41.2
SHS-IN-150×150×3.9	150	150	150	3.9	10500	0.20	10.50	82.3	42.7
SHS-IN-150×150×4.6	0	150	150	4.6	11000	0.23	11.00	144.5	23.5
SHS-IN-150×150×4.6	15	150	150	4.6	11000	0.23	11.00	133.6	33.8
SHS-IN-150×150×4.6	60	150	150	4.6	11000	0.23	11.00	113.1	40.2
SHS-IN-150×150×4.6	105	150	150	4.6	11000	0.23	11.00	100.2	47.9
SHS-IN-150×150×4.6	150	150	150	4.6	11000	0.23	11.00	90.7	49.1
SHS-IN-200×200×4.5	0	200	200	4.5	9500	0.23	9.50	429.5	34.9
SHS-IN-200×200×4.5	20	200	200	4.5	9500	0.23	9.50	372.1	65.7
SHS-IN-200×200×4.5	80	200	200	4.5	9500	0.23	9.50	285.3	87.1
SHS-IN-200×200×4.5	140	200	200	4.5	9500	0.23	9.50	238.0	93.6
SHS-IN-200×200×4.5	200	200	200	4.5	9500	0.23	9.50	206.2	98.2

SHS-IN-200×200×7.6	0	200	200	7.6	12000	0.38	12.00	451.2	90.9
SHS-IN-200×200×7.6	20	200	200	7.6	12000	0.38	12.00	405.0	112.2
SHS-IN-200×200×7.6	80	200	200	7.6	12000	0.38	12.00	327.4	141.6
SHS-IN-200×200×7.6	140	200	200	7.6	12000	0.38	12.00	283.0	150.9
SHS-IN-200×200×7.6	200	200	200	7.6	12000	0.38	12.00	251.5	157.9
SHS-IN-250×250×11.5	0	250	250	11.5	11000	0.58	11.00	1475.1	128.9
SHS-IN-250×250×11.5	25	250	250	11.5	11000	0.58	11.00	1244.7	269.6
SHS-IN-250×250×11.5	100	250	250	11.5	11000	0.58	11.00	937.1	312.2
SHS-IN-250×250×11.5	175	250	250	11.5	11000	0.58	11.00	774.1	379.3
SHS-IN-250×250×11.5	250	250	250	11.5	11000	0.58	11.00	667.2	396.6
SHS-IN-250×250×18	0	250	250	18.0	12000	0.90	12.00	1785.1	185.5
SHS-IN-250×250×18	25	250	250	18.0	12000	0.90	12.00	1568.4	335.6
SHS-IN-250×250×18	100	250	250	18.0	12000	0.90	12.00	1222.1	484.7
SHS-IN-250×250×18	175	250	250	18.0	12000	0.90	12.00	1026.0	520.7
SHS-IN-250×250×18	250	250	250	18.0	12000	0.90	12.00	893.9	557.0
SHS-IN-300×300×9.8	0	300	300	9.8	11200	0.49	11.20	2041.6	153.6
SHS-IN-300×300×9.8	30	300	300	9.8	11200	0.49	11.20	1642.3	300.3
SHS-IN-300×300×9.8	120	300	300	9.8	11200	0.49	11.20	1182.9	421.5
SHS-IN-300×300×9.8	210	300	300	9.8	11200	0.49	11.20	955.1	480.1
SHS-IN-300×300×9.8	300	300	300	9.8	11200	0.49	11.20	810.4	503.0
SHS-IN-300×300×12.2	0	300	300	12.2	11500	0.61	11.50	2389.9	206.7
SHS-IN-300×300×12.2	30	300	300	12.2	11500	0.61	11.50	1942.5	387.5
SHS-IN-300×300×12.2	120	300	300	12.2	11500	0.61	11.50	1409.1	535.2
SHS-IN-300×300×12.2	210	300	300	12.2	11500	0.61	11.50	1143.1	558.0
SHS-IN-300×300×12.2	300	300	300	12.2	11500	0.61	11.50	971.0	633.4
SHS-IN-350×350×10.5	0	350	350	10.5	11000	0.53	11.00	3188.0	199.9
SHS-IN-350×350×10.5	35	350	350	10.5	11000	0.53	11.00	2547.3	426.5
SHS-IN-350×350×10.5	140	350	350	10.5	11000	0.53	11.00	1785.7	643.2
SHS-IN-350×350×10.5	245	350	350	10.5	11000	0.53	11.00	1417.1	729.1
SHS-IN-350×350×10.5	350	350	350	10.5	11000	0.53	11.00	1182.9	738.4

SHS-IN-350×350×12	0	350	350	12.0	11500	0.60	11.50	3476.4	286.2
SHS-IN-350×350×12	35	350	350	12.0	11500	0.60	11.50	2746.8	526.7
SHS-IN-350×350×12	140	350	350	12.0	11500	0.60	11.50	1938.4	738.2
SHS-IN-350×350×12	245	350	350	12.0	11500	0.60	11.50	1546.4	814.9
SHS-IN-350×350×12	350	350	350	12.0	11500	0.60	11.50	1293.5	819.3
SHS-IN-400×400×10	0	400	400	10.0	11200	0.50	11.20	3978.2	237.2
SHS-IN-400×400×10	40	400	400	10.0	11200	0.50	11.20	3136.4	510.9
SHS-IN-400×400×10	160	400	400	10.0	11200	0.50	11.20	2167.9	819.1
SHS-IN-400×400×10	280	400	400	10.0	11200	0.50	11.20	1699.6	901.7
SHS-IN-400×400×10	400	400	400	10.0	11200	0.50	11.20	1404.6	932.2
SHS-IN-400×400×11.6	0	400	400	11.6	12000	0.58	12.00	4309.1	328.2
SHS-IN-400×400×11.6	40	400	400	11.6	12000	0.58	12.00	3354.9	640.3
SHS-IN-400×400×11.6	160	400	400	11.6	12000	0.58	12.00	2329.8	905.5
SHS-IN-400×400×11.6	280	400	400	11.6	12000	0.58	12.00	1838.8	1016.3
SHS-IN-400×400×11.6	400	400	400	11.6	12000	0.58	12.00	1530.2	1074.4
SHS-IN-450×450×10.8	0	450	450	10.8	12000	0.54	12.00	5119.1	375.1
SHS-IN-450×450×10.8	45	450	450	10.8	12000	0.54	12.00	3986.5	794.1
SHS-IN-450×450×10.8	180	450	450	10.8	12000	0.54	12.00	2736.0	1086.5
SHS-IN-450×450×10.8	315	450	450	10.8	12000	0.54	12.00	2129.5	1186.9
SHS-IN-450×450×10.8	450	450	450	10.8	12000	0.54	12.00	1750.1	1239.8
SHS-IN-450×450×12	0	450	450	12.0	9000	0.60	9.00	7081.7	356.3
SHS-IN-450×450×12	45	450	450	12.0	9000	0.60	9.00	5548.9	800.6
SHS-IN-450×450×12	180	450	450	12.0	9000	0.60	9.00	3697.3	1192.5
SHS-IN-450×450×12	315	450	450	12.0	9000	0.60	9.00	2752.6	1242.8
SHS-IN-450×450×12	450	450	450	12.0	9000	0.60	9.00	2279.9	1463.8
SHS-IN-500×500×18	0	500	500	18.0	12000	0.90	12.00	10132.8	567.9
SHS-IN-500×500×18	50	500	500	18.0	12000	0.90	12.00	7990.9	1626.4
SHS-IN-500×500×18	200	500	500	18.0	12000	0.90	12.00	5426.7	2254.8
SHS-IN-500×500×18	350	500	500	18.0	12000	0.90	12.00	4193.7	2537.7
SHS-IN-500×500×18	500	500	500	18.0	12000	0.90	12.00	3396.5	2513.1

SHS-IN-500×500×27	0	500	500	27.0	10500	1.35	10.50	16737.8	947.3
SHS-IN-500×500×27	50	500	500	27.0	10500	1.35	10.50	12927.4	2145.9
SHS-IN-500×500×27	200	500	500	27.0	10500	1.35	10.50	8607.0	3288.7
SHS-IN-500×500×27	350	500	500	27.0	10500	1.35	10.50	6578.3	3659.2
SHS-IN-500×500×27	500	500	500	27.0	10500	1.35	10.50	5298.3	3736.9
SHS-IH-50×50×2.5	0	50	50	2.5	3300	0.13	3.30	33.4	2.9
SHS-IH-50×50×2.5	5	50	50	2.5	3300	0.13	3.30	31.4	3.9
SHS-IH-50×50×2.5	20	50	50	2.5	3300	0.13	3.30	27.6	4.6
SHS-IH-50×50×2.5	35	50	50	2.5	3300	0.13	3.30	25.1	5.1
SHS-IH-50×50×2.5	50	50	50	2.5	3300	0.13	3.30	23.2	5.2
SHS-IH-50×50×3	0	50	50	3.0	2700	0.15	2.70	56.8	3.7
SHS-IH-50×50×3	5	50	50	3.0	2700	0.15	2.70	52.3	4.2
SHS-IH-50×50×3	20	50	50	3.0	2700	0.15	2.70	44.5	5.7
SHS-IH-50×50×3	35	50	50	3.0	2700	0.15	2.70	39.5	6.2
SHS-IH-50×50×3	50	50	50	3.0	2700	0.15	2.70	35.8	6.5
SHS-IH-100×100×2.8	0	100	100	2.8	7800	0.14	7.80	59.3	10.5
SHS-IH-100×100×2.8	10	100	100	2.8	7800	0.14	7.80	56.8	14.7
SHS-IH-100×100×2.8	40	100	100	2.8	7800	0.14	7.80	51.2	20.3
SHS-IH-100×100×2.8	70	100	100	2.8	7800	0.14	7.80	47.2	21.9
SHS-IH-100×100×2.8	100	100	100	2.8	7800	0.14	7.80	44.0	23.0
SHS-IH-100×100×4.2	0	100	100	4.2	6500	0.21	6.50	118.6	17.7
SHS-IH-100×100×4.2	10	100	100	4.2	6500	0.21	6.50	110.0	22.4
SHS-IH-100×100×4.2	40	100	100	4.2	6500	0.21	6.50	97.3	30.7
SHS-IH-100×100×4.2	70	100	100	4.2	6500	0.21	6.50	88.1	33.1
SHS-IH-100×100×4.2	100	100	100	4.2	6500	0.21	6.50	81.0	35.0
SHS-IH-150×150×3.9	0	150	150	3.9	10500	0.20	10.50	154.2	32.2
SHS-IH-150×150×3.9	15	150	150	3.9	10500	0.20	10.50	145.4	45.9
SHS-IH-150×150×3.9	60	150	150	3.9	10500	0.20	10.50	128.4	63.1
SHS-IH-150×150×3.9	105	150	150	3.9	10500	0.20	10.50	116.9	67.3
SHS-IH-150×150×3.9	150	150	150	3.9	10500	0.20	10.50	108.1	71.9

SHS-IH-150×150×4.6	0	150	150	4.6	11000	0.23	11.00	162.8	38.7
SHS-IH-150×150×4.6	15	150	150	4.6	11000	0.23	11.00	154.9	61.5
SHS-IH-150×150×4.6	60	150	150	4.6	11000	0.23	11.00	138.4	74.9
SHS-IH-150×150×4.6	105	150	150	4.6	11000	0.23	11.00	126.7	82.3
SHS-IH-150×150×4.6	150	150	150	4.6	11000	0.23	11.00	117.7	86.4
SHS-IH-200×200×4.5	0	200	200	4.5	9500	0.23	9.50	488.3	66.0
SHS-IH-200×200×4.5	20	200	200	4.5	9500	0.23	9.50	440.2	106.6
SHS-IH-200×200×4.5	80	200	200	4.5	9500	0.23	9.50	357.9	142.2
SHS-IH-200×200×4.5	140	200	200	4.5	9500	0.23	9.50	309.1	158.7
SHS-IH-200×200×4.5	200	200	200	4.5	9500	0.23	9.50	274.8	162.5
SHS-IH-200×200×7.6	0	200	200	7.6	12000	0.38	12.00	503.4	116.2
SHS-IH-200×200×7.6	20	200	200	7.6	12000	0.38	12.00	468.9	173.0
SHS-IH-200×200×7.6	80	200	200	7.6	12000	0.38	12.00	403.7	227.3
SHS-IH-200×200×7.6	140	200	200	7.6	12000	0.38	12.00	361.3	245.5
SHS-IH-200×200×7.6	200	200	200	7.6	12000	0.38	12.00	329.4	268.5
SHS-IH-250×250×11.5	0	250	250	11.5	11000	0.58	11.00	1662.2	274.7
SHS-IH-250×250×11.5	25	250	250	11.5	11000	0.58	11.00	1490.4	436.1
SHS-IH-250×250×11.5	100	250	250	11.5	11000	0.58	11.00	1200.0	581.0
SHS-IH-250×250×11.5	175	250	250	11.5	11000	0.58	11.00	1031.1	634.2
SHS-IH-250×250×11.5	250	250	250	11.5	11000	0.58	11.00	913.1	667.7
SHS-IH-250×250×18	0	250	250	18.0	12000	0.90	12.00	2005.2	465.1
SHS-IH-250×250×18	25	250	250	18.0	12000	0.90	12.00	1830.4	675.8
SHS-IH-250×250×18	100	250	250	18.0	12000	0.90	12.00	1522.3	909.8
SHS-IH-250×250×18	175	250	250	18.0	12000	0.90	12.00	1334.3	980.9
SHS-IH-250×250×18	250	250	250	18.0	12000	0.90	12.00	1200.1	999.8
SHS-IH-300×300×9.8	0	300	300	9.8	11200	0.49	11.20	2412.4	297.6
SHS-IH-300×300×9.8	30	300	300	9.8	11200	0.49	11.20	2060.2	507.9
SHS-IH-300×300×9.8	120	300	300	9.8	11200	0.49	11.20	1580.6	769.2
SHS-IH-300×300×9.8	210	300	300	9.8	11200	0.49	11.20	1325.2	826.3
SHS-IH-300×300×9.8	300	300	300	9.8	11200	0.49	11.20	1152.7	862.1

SHS-IH-300×300×12.2	0	300	300	12.2	11500	0.61	11.50	2778.6	376.2
SHS-IH-300×300×12.2	30	300	300	12.2	11500	0.61	11.50	2392.6	747.0
SHS-IH-300×300×12.2	120	300	300	12.2	11500	0.61	11.50	1855.3	862.5
SHS-IH-300×300×12.2	210	300	300	12.2	11500	0.61	11.50	1557.7	933.3
SHS-IH-300×300×12.2	300	300	300	12.2	11500	0.61	11.50	1362.8	1036.2
SHS-IH-350×350×10.5	0	350	350	10.5	11000	0.53	11.00	3994.3	331.4
SHS-IH-350×350×10.5	35	350	350	10.5	11000	0.53	11.00	3333.5	805.4
SHS-IH-350×350×10.5	140	350	350	10.5	11000	0.53	11.00	2455.2	1106.2
SHS-IH-350×350×10.5	245	350	350	10.5	11000	0.53	11.00	2006.8	1213.2
SHS-IH-350×350×10.5	350	350	350	10.5	11000	0.53	11.00	1712.8	1272.9
SHS-IH-350×350×12	0	350	350	12.0	11500	0.60	11.50	4289.3	585.0
SHS-IH-350×350×12	35	350	350	12.0	11500	0.60	11.50	3552.6	919.6
SHS-IH-350×350×12	140	350	350	12.0	11500	0.60	11.50	2637.3	1290.1
SHS-IH-350×350×12	245	350	350	12.0	11500	0.60	11.50	2169.4	1336.5
SHS-IH-350×350×12	350	350	350	12.0	11500	0.60	11.50	1858.8	1387.7
SHS-IH-400×400×10	0	400	400	10.0	11200	0.50	11.20	5280.4	445.1
SHS-IH-400×400×10	40	400	400	10.0	11200	0.50	11.20	4249.4	983.4
SHS-IH-400×400×10	160	400	400	10.0	11200	0.50	11.20	3035.0	1328.9
SHS-IH-400×400×10	280	400	400	10.0	11200	0.50	11.20	2380.3	1316.4
SHS-IH-400×400×10	400	400	400	10.0	11200	0.50	11.20	1978.3	1357.3
SHS-IH-400×400×11.6	0	400	400	11.6	12000	0.58	12.00	5540.4	583.6
SHS-IH-400×400×11.6	40	400	400	11.6	12000	0.58	12.00	4484.2	1194.5
SHS-IH-400×400×11.6	160	400	400	11.6	12000	0.58	12.00	3257.8	1595.7
SHS-IH-400×400×11.6	280	400	400	11.6	12000	0.58	12.00	2644.9	1750.3
SHS-IH-400×400×11.6	400	400	400	11.6	12000	0.58	12.00	2241.5	1892.2
SHS-IH-450×450×10.8	0	450	450	10.8	12000	0.54	12.00	6928.6	618.5
SHS-IH-450×450×10.8	45	450	450	10.8	12000	0.54	12.00	5472.6	1421.5
SHS-IH-450×450×10.8	180	450	450	10.8	12000	0.54	12.00	3862.3	1781.7
SHS-IH-450×450×10.8	315	450	450	10.8	12000	0.54	12.00	2944.1	1686.9
SHS-IH-450×450×10.8	450	450	450	10.8	12000	0.54	12.00	2500.8	1871.5

SHS-IH-450×450×12	0	450	450	12.0	9000	0.60	9.00	10654.2	636.5
SHS-IH-450×450×12	45	450	450	12.0	9000	0.60	9.00	7976.6	1132.0
SHS-IH-450×450×12	180	450	450	12.0	9000	0.60	9.00	5157.7	1635.5
SHS-IH-450×450×12	315	450	450	12.0	9000	0.60	9.00	4069.9	1974.9
SHS-IH-450×450×12	450	450	450	12.0	9000	0.60	9.00	3256.7	2034.2
SHS-IH-500×500×18	0	500	500	18.0	12000	0.90	12.00	14425.8	1129.3
SHS-IH-500×500×18	50	500	500	18.0	12000	0.90	12.00	11297.1	2567.3
SHS-IH-500×500×18	200	500	500	18.0	12000	0.90	12.00	7855.6	3841.8
SHS-IH-500×500×18	350	500	500	18.0	12000	0.90	12.00	6200.3	4276.3
SHS-IH-500×500×18	500	500	500	18.0	12000	0.90	12.00	5163.6	4562.6
SHS-IH-500×500×27	0	500	500	27.0	10500	1.35	10.50	24899.0	1802.1
SHS-IH-500×500×27	50	500	500	27.0	10500	1.35	10.50	19009.4	4214.7
SHS-IH-500×500×27	200	500	500	27.0	10500	1.35	10.50	12874.6	5714.6
SHS-IH-500×500×27	350	500	500	27.0	10500	1.35	10.50	10020.8	6320.2
SHS-IH-500×500×27	500	500	500	27.0	10500	1.35	10.50	8267.0	6723.5
RHS-DN-50×80×2.5	0	50	80	2.5	3600	0.13	3.60	38.4	2.8
RHS-DN-50×80×2.5	5	50	80	2.5	3600	0.13	3.60	36.0	3.3
RHS-DN-50×80×2.5	20	50	80	2.5	3600	0.13	3.60	30.8	3.9
RHS-DN-50×80×2.5	35	50	80	2.5	3600	0.13	3.60	27.2	3.9
RHS-DN-50×80×2.5	50	50	80	2.5	3600	0.13	3.60	24.5	4.1
RHS-DN-50×80×3.4	0	50	80	3.4	4000	0.17	4.00	40.8	4.6
RHS-DN-50×80×3.4	5	50	80	3.4	4000	0.17	4.00	38.3	5.2
RHS-DN-50×80×3.4	20	50	80	3.4	4000	0.17	4.00	33.7	5.5
RHS-DN-50×80×3.4	35	50	80	3.4	4000	0.17	4.00	30.1	5.8
RHS-DN-50×80×3.4	50	50	80	3.4	4000	0.17	4.00	27.1	6.1
RHS-DN-60×140×5	0	60	140	5.0	3200	0.25	3.20	208.7	10.6
RHS-DN-60×140×5	6	60	140	5.0	3200	0.25	3.20	185.4	11.9
RHS-DN-60×140×5	24	60	140	5.0	3200	0.25	3.20	143.2	14.7
RHS-DN-60×140×5	42	60	140	5.0	3200	0.25	3.20	121.8	14.6
RHS-DN-60×140×5	60	60	140	5.0	3200	0.25	3.20	106.0	16.0

RHS-DN-60×140×6.8	0	60	140	6.8	3300	0.34	3.30	245.8	13.6
RHS-DN-60×140×6.8	6	60	140	6.8	3300	0.34	3.30	218.2	17.6
RHS-DN-60×140×6.8	24	60	140	6.8	3300	0.34	3.30	174.2	19.8
RHS-DN-60×140×6.8	42	60	140	6.8	3300	0.34	3.30	148.6	21.0
RHS-DN-60×140×6.8	60	60	140	6.8	3300	0.34	3.30	129.1	22.6
RHS-DN-80×200×5	0	80	200	5.0	5000	0.25	5.00	228.5	23.9
RHS-DN-80×200×5	8	80	200	5.0	5000	0.25	5.00	209.2	25.0
RHS-DN-80×200×5	32	80	200	5.0	5000	0.25	5.00	169.9	27.6
RHS-DN-80×200×5	56	80	200	5.0	5000	0.25	5.00	147.3	28.1
RHS-DN-80×200×5	80	80	200	5.0	5000	0.25	5.00	129.8	29.2
RHS-DN-80×200×5.9	0	80	200	5.9	6500	0.30	6.50	158.8	25.4
RHS-DN-80×200×5.9	8	80	200	5.9	6500	0.30	6.50	150.7	27.9
RHS-DN-80×200×5.9	32	80	200	5.9	6500	0.30	6.50	133.5	32.6
RHS-DN-80×200×5.9	56	80	200	5.9	6500	0.30	6.50	118.0	36.1
RHS-DN-80×200×5.9	80	80	200	5.9	6500	0.30	6.50	107.6	37.1
RHS-DN-130×260×14.6	0	130	260	14.6	7800	0.73	7.80	836.9	106.3
RHS-DN-130×260×14.6	13	130	260	14.6	7800	0.73	7.80	769.0	136.8
RHS-DN-130×260×14.6	52	130	260	14.6	7800	0.73	7.80	631.4	155.5
RHS-DN-130×260×14.6	91	130	260	14.6	7800	0.73	7.80	545.4	166.8
RHS-DN-130×260×14.6	130	130	260	14.6	7800	0.73	7.80	485.6	184.3
RHS-DN-130×260×16	0	130	260	16.0	8500	0.80	8.50	749.1	114.0
RHS-DN-130×260×16	13	130	260	16.0	8500	0.80	8.50	695.7	141.3
RHS-DN-130×260×16	52	130	260	16.0	8500	0.80	8.50	586.0	191.3
RHS-DN-130×260×16	91	130	260	16.0	8500	0.80	8.50	507.7	210.1
RHS-DN-130×260×16	130	130	260	16.0	8500	0.80	8.50	457.3	213.9
RHS-DN-180×320×7.2	0	180	320	7.2	12000	0.36	12.00	517.8	128.0
RHS-DN-180×320×7.2	18	180	320	7.2	12000	0.36	12.00	477.9	141.2
RHS-DN-180×320×7.2	72	180	320	7.2	12000	0.36	12.00	394.3	154.9
RHS-DN-180×320×7.2	126	180	320	7.2	12000	0.36	12.00	344.9	155.9
RHS-DN-180×320×7.2	180	180	320	7.2	12000	0.36	12.00	306.9	156.9

RHS-DN-180×320×10.8	0	180	320	10.8	8500	0.54	8.50	1404.9	127.3
RHS-DN-180×320×10.8	18	180	320	10.8	8500	0.54	8.50	1216.9	174.4
RHS-DN-180×320×10.8	72	180	320	10.8	8500	0.54	8.50	905.5	202.0
RHS-DN-180×320×10.8	126	180	320	10.8	8500	0.54	8.50	748.1	253.0
RHS-DN-180×320×10.8	180	180	320	10.8	8500	0.54	8.50	645.8	269.5
RHS-DN-280×380×10.5	0	280	380	10.5	11500	0.53	11.50	2400.0	255.6
RHS-DN-280×380×10.5	28	280	380	10.5	11500	0.53	11.50	1920.1	358.3
RHS-DN-280×380×10.5	112	280	380	10.5	11500	0.53	11.50	1372.6	438.7
RHS-DN-280×380×10.5	196	280	380	10.5	11500	0.53	11.50	1111.2	500.1
RHS-DN-280×380×10.5	280	280	380	10.5	11500	0.53	11.50	945.7	527.1
RHS-DN-280×380×15	0	280	380	15.0	12000	0.75	12.00	2963.8	415.7
RHS-DN-280×380×15	28	280	380	15.0	12000	0.75	12.00	2455.6	496.6
RHS-DN-280×380×15	112	280	380	15.0	12000	0.75	12.00	1785.9	624.4
RHS-DN-280×380×15	196	280	380	15.0	12000	0.75	12.00	1462.8	719.9
RHS-DN-280×380×15	280	280	380	15.0	12000	0.75	12.00	1252.5	758.4
RHS-DN-360×440×11.6	0	360	440	11.6	12000	0.58	12.00	4402.1	273.7
RHS-DN-360×440×11.6	36	360	440	11.6	12000	0.58	12.00	3280.9	549.1
RHS-DN-360×440×11.6	144	360	440	11.6	12000	0.58	12.00	2215.8	737.4
RHS-DN-360×440×11.6	252	360	440	11.6	12000	0.58	12.00	1743.3	817.3
RHS-DN-360×440×11.6	360	360	440	11.6	12000	0.58	12.00	1454.8	870.1
RHS-DN-360×440×14	0	360	440	14.0	9500	0.70	9.50	5548.0	607.3
RHS-DN-360×440×14	36	360	440	14.0	9500	0.70	9.50	4735.0	635.8
RHS-DN-360×440×14	144	360	440	14.0	9500	0.70	9.50	3124.2	854.1
RHS-DN-360×440×14	252	360	440	14.0	9500	0.70	9.50	2421.9	1066.4
RHS-DN-360×440×14	360	360	440	14.0	9500	0.70	9.50	1997.3	1090.1
RHS-DN-380×500×11.8	0	380	500	11.8	11500	0.59	11.50	5772.9	278.5
RHS-DN-380×500×11.8	38	380	500	11.8	11500	0.59	11.50	4141.8	566.3
RHS-DN-380×500×11.8	152	380	500	11.8	11500	0.59	11.50	2713.9	830.8
RHS-DN-380×500×11.8	266	380	500	11.8	11500	0.59	11.50	2109.5	954.6
RHS-DN-380×500×11.8	380	380	500	11.8	11500	0.59	11.50	1749.9	1050.0

RHS-DN-380×500×32	0	380	500	32.0	12000	1.60	12.00	12539.5	984.1
RHS-DN-380×500×32	38	380	500	32.0	12000	1.60	12.00	9452.0	1540.5
RHS-DN-380×500×32	152	380	500	32.0	12000	1.60	12.00	6503.2	2545.5
RHS-DN-380×500×32	266	380	500	32.0	12000	1.60	12.00	5172.9	2852.7
RHS-DN-380×500×32	380	380	500	32.0	12000	1.60	12.00	4312.3	2930.1
RHS-DN-80×50×2.5	0	80	50	2.5	3600	0.13	3.60	77.5	3.1
RHS-DN-80×50×2.5	8	80	50	2.5	3600	0.13	3.60	66.4	4.4
RHS-DN-80×50×2.5	32	80	50	2.5	3600	0.13	3.60	49.7	6.0
RHS-DN-80×50×2.5	56	80	50	2.5	3600	0.13	3.60	40.9	6.4
RHS-DN-80×50×2.5	80	80	50	2.5	3600	0.13	3.60	34.9	6.7
RHS-DN-80×50×3.4	0	80	50	3.4	4000	0.17	4.00	83.9	4.9
RHS-DN-80×50×3.4	8	80	50	3.4	4000	0.17	4.00	73.3	6.7
RHS-DN-80×50×3.4	32	80	50	3.4	4000	0.17	4.00	57.6	7.7
RHS-DN-80×50×3.4	56	80	50	3.4	4000	0.17	4.00	48.6	8.2
RHS-DN-80×50×3.4	80	80	50	3.4	4000	0.17	4.00	42.3	8.6
RHS-DN-140×60×5	0	140	60	5.0	3200	0.25	3.20	590.4	8.6
RHS-DN-140×60×5	14	140	60	5.0	3200	0.25	3.20	426.5	19.0
RHS-DN-140×60×5	56	140	60	5.0	3200	0.25	3.20	277.7	31.2
RHS-DN-140×60×5	98	140	60	5.0	3200	0.25	3.20	210.4	33.4
RHS-DN-140×60×5	140	140	60	5.0	3200	0.25	3.20	169.8	34.7
RHS-DN-140×60×6.8	0	140	60	6.8	3300	0.34	3.30	763.5	13.3
RHS-DN-140×60×6.8	14	140	60	6.8	3300	0.34	3.30	562.4	30.9
RHS-DN-140×60×6.8	56	140	60	6.8	3300	0.34	3.30	370.2	43.5
RHS-DN-140×60×6.8	98	140	60	6.8	3300	0.34	3.30	281.3	46.2
RHS-DN-140×60×6.8	140	140	60	6.8	3300	0.34	3.30	228.0	47.9
RHS-DN-200×80×5	0	200	80	5.0	5000	0.25	5.00	769.9	17.9
RHS-DN-200×80×5	20	200	80	5.0	5000	0.25	5.00	551.2	38.0
RHS-DN-200×80×5	80	200	80	5.0	5000	0.25	5.00	358.1	59.5
RHS-DN-200×80×5	140	200	80	5.0	5000	0.25	5.00	273.0	64.8
RHS-DN-200×80×5	200	200	80	5.0	5000	0.25	5.00	222.0	68.5

RHS-DN-200×80×5.9	0	200	80	5.9	6500	0.30	6.50	624.9	31.8
RHS-DN-200×80×5.9	20	200	80	5.9	6500	0.30	6.50	485.3	52.2
RHS-DN-200×80×5.9	80	200	80	5.9	6500	0.30	6.50	334.9	72.2
RHS-DN-200×80×5.9	140	200	80	5.9	6500	0.30	6.50	263.9	77.3
RHS-DN-200×80×5.9	200	200	80	5.9	6500	0.30	6.50	219.7	79.9
RHS-DN-260×130×14.6	0	260	130	14.6	7800	0.73	7.80	2351.7	136.5
RHS-DN-260×130×14.6	26	260	130	14.6	7800	0.73	7.80	1829.4	264.3
RHS-DN-260×130×14.6	104	260	130	14.6	7800	0.73	7.80	1266.2	350.3
RHS-DN-260×130×14.6	182	260	130	14.6	7800	0.73	7.80	998.7	379.1
RHS-DN-260×130×14.6	260	260	130	14.6	7800	0.73	7.80	830.5	386.3
RHS-DN-260×130×16	0	260	130	16.0	8500	0.80	8.50	2202.4	183.5
RHS-DN-260×130×16	26	260	130	16.0	8500	0.80	8.50	1762.3	280.3
RHS-DN-260×130×16	104	260	130	16.0	8500	0.80	8.50	1257.5	387.4
RHS-DN-260×130×16	182	260	130	16.0	8500	0.80	8.50	1006.5	414.4
RHS-DN-260×130×16	260	260	130	16.0	8500	0.80	8.50	847.4	432.3
RHS-DN-320×180×7.2	0	320	180	7.2	12000	0.36	12.00	1196.6	128.6
RHS-DN-320×180×7.2	32	320	180	7.2	12000	0.36	12.00	955.6	185.8
RHS-DN-320×180×7.2	128	320	180	7.2	12000	0.36	12.00	672.4	257.5
RHS-DN-320×180×7.2	224	320	180	7.2	12000	0.36	12.00	539.5	275.2
RHS-DN-320×180×7.2	320	320	180	7.2	12000	0.36	12.00	453.5	281.8
RHS-DN-320×180×10.8	0	320	180	10.8	8500	0.54	8.50	2869.7	114.5
RHS-DN-320×180×10.8	32	320	180	10.8	8500	0.54	8.50	2090.3	245.5
RHS-DN-320×180×10.8	128	320	180	10.8	8500	0.54	8.50	1381.6	393.4
RHS-DN-320×180×10.8	224	320	180	10.8	8500	0.54	8.50	1067.2	419.9
RHS-DN-320×180×10.8	320	320	180	10.8	8500	0.54	8.50	871.8	441.7
RHS-DN-380×280×10.5	0	380	280	10.5	11500	0.53	11.50	3365.6	220.5
RHS-DN-380×280×10.5	38	380	280	10.5	11500	0.53	11.50	2484.0	396.6
RHS-DN-380×280×10.5	152	380	280	10.5	11500	0.53	11.50	1647.2	606.2
RHS-DN-380×280×10.5	266	380	280	10.5	11500	0.53	11.50	1295.1	651.4
RHS-DN-380×280×10.5	380	380	280	10.5	11500	0.53	11.50	1067.6	661.4

RHS-DN-380×280×15	0	380	280	15.0	12000	0.75	12.00	4397.7	330.6
RHS-DN-380×280×15	38	380	280	15.0	12000	0.75	12.00	3314.8	586.6
RHS-DN-380×280×15	152	380	280	15.0	12000	0.75	12.00	2259.3	837.2
RHS-DN-380×280×15	266	380	280	15.0	12000	0.75	12.00	1784.2	935.6
RHS-DN-380×280×15	380	380	280	15.0	12000	0.75	12.00	1477.7	979.3
RHS-DN-440×360×11.6	0	440	360	11.6	12000	0.58	12.00	5186.0	252.6
RHS-DN-440×360×11.6	44	440	360	11.6	12000	0.58	12.00	3716.7	515.8
RHS-DN-440×360×11.6	176	440	360	11.6	12000	0.58	12.00	2432.0	899.5
RHS-DN-440×360×11.6	308	440	360	11.6	12000	0.58	12.00	1892.9	1025.8
RHS-DN-440×360×11.6	440	440	360	11.6	12000	0.58	12.00	1549.0	1061.2
RHS-DN-440×360×14	0	440	360	14.0	9500	0.70	9.50	7287.9	213.0
RHS-DN-440×360×14	44	440	360	14.0	9500	0.70	9.50	5315.1	618.2
RHS-DN-440×360×14	176	440	360	14.0	9500	0.70	9.50	3423.5	1077.1
RHS-DN-440×360×14	308	440	360	14.0	9500	0.70	9.50	2615.8	1214.6
RHS-DN-440×360×14	440	440	360	14.0	9500	0.70	9.50	2113.9	1287.0
RHS-DN-500×380×11.8	0	500	380	11.8	11500	0.59	11.50	6551.1	251.2
RHS-DN-500×380×11.8	50	500	380	11.8	11500	0.59	11.50	4531.3	840.1
RHS-DN-500×380×11.8	200	500	380	11.8	11500	0.59	11.50	3017.2	1077.5
RHS-DN-500×380×11.8	350	500	380	11.8	11500	0.59	11.50	2310.9	1257.1
RHS-DN-500×380×11.8	500	500	380	11.8	11500	0.59	11.50	1873.8	1315.0
RHS-DN-500×380×32	0	500	380	32.0	12000	1.60	12.00	16200.9	1089.4
RHS-DN-500×380×32	50	500	380	32.0	12000	1.60	12.00	12033.2	2179.5
RHS-DN-500×380×32	200	500	380	32.0	12000	1.60	12.00	7997.9	3376.4
RHS-DN-500×380×32	350	500	380	32.0	12000	1.60	12.00	6133.9	3603.8
RHS-DN-500×380×32	500	500	380	32.0	12000	1.60	12.00	4988.5	3757.8
RHS-DH-50×80×2.5	0	50	80	2.5	3600	0.13	3.60	39.8	5.6
RHS-DH-50×80×2.5	5	50	80	2.5	3600	0.13	3.60	38.3	6.2
RHS-DH-50×80×2.5	20	50	80	2.5	3600	0.13	3.60	34.7	6.6
RHS-DH-50×80×2.5	35	50	80	2.5	3600	0.13	3.60	32.1	7.5
RHS-DH-50×80×2.5	50	50	80	2.5	3600	0.13	3.60	29.4	8.0

RHS-DH-50×80×3.4	0	50	80	3.4	4000	0.17	4.00	42.1	7.5
RHS-DH-50×80×3.4	5	50	80	3.4	4000	0.17	4.00	40.8	8.7
RHS-DH-50×80×3.4	20	50	80	3.4	4000	0.17	4.00	37.8	9.2
RHS-DH-50×80×3.4	35	50	80	3.4	4000	0.17	4.00	35.3	9.4
RHS-DH-50×80×3.4	50	50	80	3.4	4000	0.17	4.00	33.2	9.5
RHS-DH-60×140×5	0	60	140	5.0	3200	0.25	3.20	215.4	23.1
RHS-DH-60×140×5	6	60	140	5.0	3200	0.25	3.20	201.5	22.8
RHS-DH-60×140×5	24	60	140	5.0	3200	0.25	3.20	172.9	25.9
RHS-DH-60×140×5	42	60	140	5.0	3200	0.25	3.20	151.9	27.8
RHS-DH-60×140×5	60	60	140	5.0	3200	0.25	3.20	137.1	28.4
RHS-DH-60×140×6.8	0	60	140	6.8	3300	0.34	3.30	254.9	21.3
RHS-DH-60×140×6.8	6	60	140	6.8	3300	0.34	3.30	238.5	26.2
RHS-DH-60×140×6.8	24	60	140	6.8	3300	0.34	3.30	208.1	33.9
RHS-DH-60×140×6.8	42	60	140	6.8	3300	0.34	3.30	185.5	34.3
RHS-DH-60×140×6.8	60	60	140	6.8	3300	0.34	3.30	168.2	36.3
RHS-DH-80×200×5	0	80	200	5.0	5000	0.25	5.00	234.4	34.9
RHS-DH-80×200×5	8	80	200	5.0	5000	0.25	5.00	222.7	46.6
RHS-DH-80×200×5	32	80	200	5.0	5000	0.25	5.00	196.9	50.9
RHS-DH-80×200×5	56	80	200	5.0	5000	0.25	5.00	178.4	51.0
RHS-DH-80×200×5	80	80	200	5.0	5000	0.25	5.00	163.4	51.2
RHS-DH-80×200×5.9	0	80	200	5.9	6500	0.30	6.50	162.3	56.3
RHS-DH-80×200×5.9	8	80	200	5.9	6500	0.30	6.50	157.8	57.6
RHS-DH-80×200×5.9	32	80	200	5.9	6500	0.30	6.50	146.6	61.3
RHS-DH-80×200×5.9	56	80	200	5.9	6500	0.30	6.50	137.4	61.6
RHS-DH-80×200×5.9	80	80	200	5.9	6500	0.30	6.50	129.6	63.2
RHS-DH-130×260×14.6	0	130	260	14.6	7800	0.73	7.80	874.2	210.0
RHS-DH-130×260×14.6	13	130	260	14.6	7800	0.73	7.80	829.8	262.2
RHS-DH-130×260×14.6	52	130	260	14.6	7800	0.73	7.80	731.7	308.2
RHS-DH-130×260×14.6	91	130	260	14.6	7800	0.73	7.80	656.6	330.2
RHS-DH-130×260×14.6	130	130	260	14.6	7800	0.73	7.80	601.6	338.3

RHS-DH-130×260×16	0	130	260	16.0	8500	0.80	8.50	772.6	223.0
RHS-DH-130×260×16	13	130	260	16.0	8500	0.80	8.50	738.8	269.3
RHS-DH-130×260×16	52	130	260	16.0	8500	0.80	8.50	664.0	314.7
RHS-DH-130×260×16	91	130	260	16.0	8500	0.80	8.50	604.8	338.7
RHS-DH-130×260×16	130	130	260	16.0	8500	0.80	8.50	558.9	347.6
RHS-DH-180×320×7.2	0	180	320	7.2	12000	0.36	12.00	536.4	232.3
RHS-DH-180×320×7.2	18	180	320	7.2	12000	0.36	12.00	513.0	279.2
RHS-DH-180×320×7.2	72	180	320	7.2	12000	0.36	12.00	459.9	288.4
RHS-DH-180×320×7.2	126	180	320	7.2	12000	0.36	12.00	418.6	288.4
RHS-DH-180×320×7.2	180	180	320	7.2	12000	0.36	12.00	386.6	296.0
RHS-DH-180×320×10.8	0	180	320	10.8	8500	0.54	8.50	1485.6	253.5
RHS-DH-180×320×10.8	18	180	320	10.8	8500	0.54	8.50	1370.0	378.1
RHS-DH-180×320×10.8	72	180	320	10.8	8500	0.54	8.50	1127.3	404.3
RHS-DH-180×320×10.8	126	180	320	10.8	8500	0.54	8.50	973.3	413.5
RHS-DH-180×320×10.8	180	180	320	10.8	8500	0.54	8.50	861.5	452.3
RHS-DH-280×380×10.5	0	280	380	10.5	11500	0.53	11.50	2508.6	632.6
RHS-DH-280×380×10.5	28	280	380	10.5	11500	0.53	11.50	2234.9	698.3
RHS-DH-280×380×10.5	112	280	380	10.5	11500	0.53	11.50	1746.9	752.4
RHS-DH-280×380×10.5	196	280	380	10.5	11500	0.53	11.50	1462.6	783.6
RHS-DH-280×380×10.5	280	280	380	10.5	11500	0.53	11.50	1272.1	808.2
RHS-DH-280×380×15	0	280	380	15.0	12000	0.75	12.00	3135.7	866.7
RHS-DH-280×380×15	28	280	380	15.0	12000	0.75	12.00	2797.9	872.5
RHS-DH-280×380×15	112	280	380	15.0	12000	0.75	12.00	2255.6	1068.0
RHS-DH-280×380×15	196	280	380	15.0	12000	0.75	12.00	1911.7	1228.8
RHS-DH-280×380×15	280	280	380	15.0	12000	0.75	12.00	1676.9	1322.6
RHS-DH-360×440×11.6	0	360	440	11.6	12000	0.58	12.00	4894.5	971.4
RHS-DH-360×440×11.6	36	360	440	11.6	12000	0.58	12.00	4107.1	1073.6
RHS-DH-360×440×11.6	144	360	440	11.6	12000	0.58	12.00	2951.2	1180.4
RHS-DH-360×440×11.6	252	360	440	11.6	12000	0.58	12.00	2362.1	1246.2
RHS-DH-360×440×11.6	360	360	440	11.6	12000	0.58	12.00	2003.0	1309.8

RHS-DH-360×440×14	0	360	440	14.0	9500	0.70	9.50	8783.7	764.6
RHS-DH-360×440×14	36	360	440	14.0	9500	0.70	9.50	6627.1	1143.4
RHS-DH-360×440×14	144	360	440	14.0	9500	0.70	9.50	4496.0	1570.0
RHS-DH-360×440×14	252	360	440	14.0	9500	0.70	9.50	3575.3	1837.7
RHS-DH-360×440×14	360	360	440	14.0	9500	0.70	9.50	3005.0	1924.0
RHS-DH-380×500×11.8	0	380	500	11.8	11500	0.59	11.50	6738.3	945.9
RHS-DH-380×500×11.8	38	380	500	11.8	11500	0.59	11.50	5401.0	1173.9
RHS-DH-380×500×11.8	152	380	500	11.8	11500	0.59	11.50	3664.5	1328.0
RHS-DH-380×500×11.8	266	380	500	11.8	11500	0.59	11.50	2928.7	1475.9
RHS-DH-380×500×11.8	380	380	500	11.8	11500	0.59	11.50	2393.9	1491.6
RHS-DH-380×500×32	0	380	500	32.0	12000	1.60	12.00	14044.7	2173.7
RHS-DH-380×500×32	38	380	500	32.0	12000	1.60	12.00	11630.9	2902.6
RHS-DH-380×500×32	152	380	500	32.0	12000	1.60	12.00	8471.9	3900.0
RHS-DH-380×500×32	266	380	500	32.0	12000	1.60	12.00	6945.6	4605.0
RHS-DH-380×500×32	380	380	500	32.0	12000	1.60	12.00	5914.6	5007.8
RHS-DH-80×50×2.5	0	80	50	2.5	3600	0.13	3.60	39.6	0.2
RHS-DH-80×50×2.5	8	80	50	2.5	3600	0.13	3.60	39.5	0.9
RHS-DH-80×50×2.5	32	80	50	2.5	3600	0.13	3.60	39.3	2.8
RHS-DH-80×50×2.5	56	80	50	2.5	3600	0.13	3.60	38.9	4.7
RHS-DH-80×50×2.5	80	80	50	2.5	3600	0.13	3.60	38.1	6.3
RHS-DH-80×50×3.4	0	80	50	3.4	4000	0.17	4.00	41.9	0.2
RHS-DH-80×50×3.4	8	80	50	3.4	4000	0.17	4.00	41.9	0.9
RHS-DH-80×50×3.4	32	80	50	3.4	4000	0.17	4.00	41.8	3.0
RHS-DH-80×50×3.4	56	80	50	3.4	4000	0.17	4.00	59.8	13.0
RHS-DH-80×50×3.4	80	80	50	3.4	4000	0.17	4.00	53.8	13.8
RHS-DH-140×60×5	0	140	60	5.0	3200	0.25	3.20	220.9	0.7
RHS-DH-140×60×5	14	140	60	5.0	3200	0.25	3.20	220.9	5.1
RHS-DH-140×60×5	56	140	60	5.0	3200	0.25	3.20	382.9	52.2
RHS-DH-140×60×5	98	140	60	5.0	3200	0.25	3.20	214.6	30.1
RHS-DH-140×60×5	140	140	60	5.0	3200	0.25	3.20	204.4	40.4

RHS-DH-140×60×6.8	0	140	60	6.8	3300	0.34	3.30	259.9	0.9
RHS-DH-140×60×6.8	14	140	60	6.8	3300	0.34	3.30	259.7	6.0
RHS-DH-140×60×6.8	56	140	60	6.8	3300	0.34	3.30	257.7	21.0
RHS-DH-140×60×6.8	98	140	60	6.8	3300	0.34	3.30	252.6	35.1
RHS-DH-140×60×6.8	140	140	60	6.8	3300	0.34	3.30	242.9	47.5
RHS-DH-200×80×5	0	200	80	5.0	5000	0.25	5.00	239.9	1.3
RHS-DH-200×80×5	20	200	80	5.0	5000	0.25	5.00	239.3	7.8
RHS-DH-200×80×5	80	200	80	5.0	5000	0.25	5.00	236.4	27.0
RHS-DH-200×80×5	140	200	80	5.0	5000	0.25	5.00	231.8	45.1
RHS-DH-200×80×5	200	200	80	5.0	5000	0.25	5.00	224.9	61.6
RHS-DH-200×80×5.9	0	200	80	5.9	6500	0.30	6.50	164.5	1.0
RHS-DH-200×80×5.9	20	200	80	5.9	6500	0.30	6.50	164.5	5.5
RHS-DH-200×80×5.9	80	200	80	5.9	6500	0.30	6.50	432.5	121.0
RHS-DH-200×80×5.9	140	200	80	5.9	6500	0.30	6.50	353.0	134.3
RHS-DH-200×80×5.9	200	200	80	5.9	6500	0.30	6.50	299.0	146.0
RHS-DH-260×130×14.6	0	260	130	14.6	7800	0.73	7.80	884.0	8.3
RHS-DH-260×130×14.6	26	260	130	14.6	7800	0.73	7.80	883.3	44.0
RHS-DH-260×130×14.6	104	260	130	14.6	7800	0.73	7.80	878.8	150.1
RHS-DH-260×130×14.6	182	260	130	14.6	7800	0.73	7.80	867.4	252.0
RHS-DH-260×130×14.6	260	260	130	14.6	7800	0.73	7.80	844.5	343.8
RHS-DH-260×130×16	0	260	130	16.0	8500	0.80	8.50	2303.2	320.7
RHS-DH-260×130×16	26	260	130	16.0	8500	0.80	8.50	1958.4	494.5
RHS-DH-260×130×16	104	260	130	16.0	8500	0.80	8.50	1494.1	594.9
RHS-DH-260×130×16	182	260	130	16.0	8500	0.80	8.50	1242.9	638.0
RHS-DH-260×130×16	260	260	130	16.0	8500	0.80	8.50	1076.0	669.2
RHS-DH-320×180×7.2	0	320	180	7.2	12000	0.36	12.00	537.6	8.6
RHS-DH-320×180×7.2	32	320	180	7.2	12000	0.36	12.00	537.0	39.9
RHS-DH-320×180×7.2	128	320	180	7.2	12000	0.36	12.00	533.4	132.1
RHS-DH-320×180×7.2	224	320	180	7.2	12000	0.36	12.00	525.8	219.5
RHS-DH-320×180×7.2	320	320	180	7.2	12000	0.36	12.00	513.7	298.7

RHS-DH-320×180×10.8	0	320	180	10.8	8500	0.54	8.50	1518.9	16.6
RHS-DH-320×180×10.8	32	320	180	10.8	8500	0.54	8.50	1514.6	104.3
RHS-DH-320×180×10.8	128	320	180	10.8	8500	0.54	8.50	1472.1	351.1
RHS-DH-320×180×10.8	224	320	180	10.8	8500	0.54	8.50	1369.6	542.4
RHS-DH-320×180×10.8	320	320	180	10.8	8500	0.54	8.50	1215.3	659.0
RHS-DH-380×280×10.5	0	380	280	10.5	11500	0.53	11.50	2581.6	63.7
RHS-DH-380×280×10.5	38	380	280	10.5	11500	0.53	11.50	2556.0	348.2
RHS-DH-380×280×10.5	152	380	280	10.5	11500	0.53	11.50	2237.3	947.2
RHS-DH-380×280×10.5	266	380	280	10.5	11500	0.53	11.50	1822.9	1103.7
RHS-DH-380×280×10.5	380	380	280	10.5	11500	0.53	11.50	1541.8	1181.5
RHS-DH-380×280×15	0	380	280	15.0	12000	0.75	12.00	3232.1	74.4
RHS-DH-380×280×15	38	380	280	15.0	12000	0.75	12.00	3211.7	430.2
RHS-DH-380×280×15	152	380	280	15.0	12000	0.75	12.00	2938.0	1271.1
RHS-DH-380×280×15	266	380	280	15.0	12000	0.75	12.00	2439.8	1674.7
RHS-DH-380×280×15	380	380	280	15.0	12000	0.75	12.00	2086.4	1684.5
RHS-DH-440×360×11.6	0	440	360	11.6	12000	0.58	12.00	5151.2	186.8
RHS-DH-440×360×11.6	44	440	360	11.6	12000	0.58	12.00	4877.9	990.6
RHS-DH-440×360×11.6	176	440	360	11.6	12000	0.58	12.00	3442.8	1546.7
RHS-DH-440×360×11.6	308	440	360	11.6	12000	0.58	12.00	2739.9	1746.9
RHS-DH-440×360×11.6	440	440	360	11.6	12000	0.58	12.00	2302.6	1834.8
RHS-DH-440×360×14	0	440	360	14.0	9500	0.70	9.50	9619.8	283.0
RHS-DH-440×360×14	44	440	360	14.0	9500	0.70	9.50	7715.3	1260.0
RHS-DH-440×360×14	176	440	360	14.0	9500	0.70	9.50	5041.1	1919.3
RHS-DH-440×360×14	308	440	360	14.0	9500	0.70	9.50	3929.7	2188.8
RHS-DH-440×360×14	440	440	360	14.0	9500	0.70	9.50	3232.2	2243.1
RHS-DH-500×380×11.8	0	500	380	11.8	11500	0.59	11.50	7201.4	176.2
RHS-DH-500×380×11.8	50	500	380	11.8	11500	0.59	11.50	6775.4	1181.0
RHS-DH-500×380×11.8	200	500	380	11.8	11500	0.59	11.50	4499.5	1984.9
RHS-DH-500×380×11.8	350	500	380	11.8	11500	0.59	11.50	3524.8	2298.1
RHS-DH-500×380×11.8	500	500	380	11.8	11500	0.59	11.50	2911.7	2362.9

RHS-DH-500×380×32	0	500	380	32.0	12000	1.60	12.00	14910.6	415.0
RHS-DH-500×380×32	50	500	380	32.0	12000	1.60	12.00	14182.0	2457.3
RHS-DH-500×380×32	200	500	380	32.0	12000	1.60	12.00	10735.2	5528.9
RHS-DH-500×380×32	350	500	380	32.0	12000	1.60	12.00	8523.4	6145.6
RHS-DH-500×380×32	500	500	380	32.0	12000	1.60	12.00	7086.3	6283.5
RHS-IN-50×80×2.5	0	50	80	2.5	3600	0.13	3.60	36.9	2.4
RHS-IN-50×80×2.5	5	50	80	2.5	3600	0.13	3.60	34.0	2.7
RHS-IN-50×80×2.5	20	50	80	2.5	3600	0.13	3.60	28.7	3.4
RHS-IN-50×80×2.5	35	50	80	2.5	3600	0.13	3.60	25.4	3.9
RHS-IN-50×80×2.5	50	50	80	2.5	3600	0.13	3.60	22.9	4.2
RHS-IN-50×80×3.4	0	50	80	3.4	4000	0.17	4.00	39.9	2.7
RHS-IN-50×80×3.4	5	50	80	3.4	4000	0.17	4.00	37.3	4.2
RHS-IN-50×80×3.4	20	50	80	3.4	4000	0.17	4.00	32.3	4.4
RHS-IN-50×80×3.4	35	50	80	3.4	4000	0.17	4.00	29.1	5.0
RHS-IN-50×80×3.4	50	50	80	3.4	4000	0.17	4.00	26.5	5.1
RHS-IN-60×140×5	0	60	140	5.0	3200	0.25	3.20	197.2	7.6
RHS-IN-60×140×5	6	60	140	5.0	3200	0.25	3.20	172.6	10.8
RHS-IN-60×140×5	24	60	140	5.0	3200	0.25	3.20	135.4	15.0
RHS-IN-60×140×5	42	60	140	5.0	3200	0.25	3.20	115.3	16.1
RHS-IN-60×140×5	60	60	140	5.0	3200	0.25	3.20	101.2	17.1
RHS-IN-60×140×6.8	0	60	140	6.8	3300	0.34	3.30	233.0	11.5
RHS-IN-60×140×6.8	6	60	140	6.8	3300	0.34	3.30	205.6	16.1
RHS-IN-60×140×6.8	24	60	140	6.8	3300	0.34	3.30	165.1	18.8
RHS-IN-60×140×6.8	42	60	140	6.8	3300	0.34	3.30	141.4	20.1
RHS-IN-60×140×6.8	60	60	140	6.8	3300	0.34	3.30	124.6	22.0
RHS-IN-80×200×5	0	80	200	5.0	5000	0.25	5.00	219.2	16.9
RHS-IN-80×200×5	8	80	200	5.0	5000	0.25	5.00	196.9	20.3
RHS-IN-80×200×5	32	80	200	5.0	5000	0.25	5.00	160.2	25.8
RHS-IN-80×200×5	56	80	200	5.0	5000	0.25	5.00	138.5	27.6
RHS-IN-80×200×5	80	80	200	5.0	5000	0.25	5.00	123.1	29.0

RHS-IN-80×200×5.9	0	80	200	5.9	6500	0.30	6.50	154.1	19.6
RHS-IN-80×200×5.9	8	80	200	5.9	6500	0.30	6.50	143.8	22.1
RHS-IN-80×200×5.9	32	80	200	5.9	6500	0.30	6.50	124.4	27.8
RHS-IN-80×200×5.9	56	80	200	5.9	6500	0.30	6.50	111.5	29.8
RHS-IN-80×200×5.9	80	80	200	5.9	6500	0.30	6.50	101.9	31.5
RHS-IN-130×260×14.6	0	130	260	14.6	7800	0.73	7.80	797.5	82.9
RHS-IN-130×260×14.6	13	130	260	14.6	7800	0.73	7.80	719.3	121.8
RHS-IN-130×260×14.6	52	130	260	14.6	7800	0.73	7.80	586.3	144.1
RHS-IN-130×260×14.6	91	130	260	14.6	7800	0.73	7.80	508.0	183.8
RHS-IN-130×260×14.6	130	130	260	14.6	7800	0.73	7.80	453.7	173.8
RHS-IN-130×260×16	0	130	260	16.0	8500	0.80	8.50	721.4	90.9
RHS-IN-130×260×16	13	130	260	16.0	8500	0.80	8.50	661.9	127.6
RHS-IN-130×260×16	52	130	260	16.0	8500	0.80	8.50	553.9	180.0
RHS-IN-130×260×16	91	130	260	16.0	8500	0.80	8.50	484.7	201.4
RHS-IN-130×260×16	130	130	260	16.0	8500	0.80	8.50	435.3	213.2
RHS-IN-180×320×7.2	0	180	320	7.2	12000	0.36	12.00	496.0	92.7
RHS-IN-180×320×7.2	18	180	320	7.2	12000	0.36	12.00	450.0	119.4
RHS-IN-180×320×7.2	72	180	320	7.2	12000	0.36	12.00	371.4	135.9
RHS-IN-180×320×7.2	126	180	320	7.2	12000	0.36	12.00	324.5	155.4
RHS-IN-180×320×7.2	180	180	320	7.2	12000	0.36	12.00	290.5	169.7
RHS-IN-180×320×10.8	0	180	320	10.8	8500	0.54	8.50	1330.1	108.8
RHS-IN-180×320×10.8	18	180	320	10.8	8500	0.54	8.50	1129.6	157.5
RHS-IN-180×320×10.8	72	180	320	10.8	8500	0.54	8.50	865.0	226.3
RHS-IN-180×320×10.8	126	180	320	10.8	8500	0.54	8.50	720.4	243.8
RHS-IN-180×320×10.8	180	180	320	10.8	8500	0.54	8.50	625.2	261.6
RHS-IN-280×380×10.5	0	280	380	10.5	11500	0.53	11.50	2165.3	212.0
RHS-IN-280×380×10.5	28	280	380	10.5	11500	0.53	11.50	1777.5	369.6
RHS-IN-280×380×10.5	112	280	380	10.5	11500	0.53	11.50	1312.1	484.2
RHS-IN-280×380×10.5	196	280	380	10.5	11500	0.53	11.50	1071.3	496.1
RHS-IN-280×380×10.5	280	280	380	10.5	11500	0.53	11.50	919.7	555.9

RHS-IN-280×380×15	0	280	380	15.0	12000	0.75	12.00	2771.3	357.8
RHS-IN-280×380×15	28	280	380	15.0	12000	0.75	12.00	2317.1	493.5
RHS-IN-280×380×15	112	280	380	15.0	12000	0.75	12.00	1725.4	621.4
RHS-IN-280×380×15	196	280	380	15.0	12000	0.75	12.00	1424.7	714.4
RHS-IN-280×380×15	280	280	380	15.0	12000	0.75	12.00	1222.1	740.2
RHS-IN-360×440×11.6	0	360	440	11.6	12000	0.58	12.00	3865.5	277.9
RHS-IN-360×440×11.6	36	360	440	11.6	12000	0.58	12.00	3062.1	588.2
RHS-IN-360×440×11.6	144	360	440	11.6	12000	0.58	12.00	2167.1	833.8
RHS-IN-360×440×11.6	252	360	440	11.6	12000	0.58	12.00	1731.6	952.6
RHS-IN-360×440×11.6	360	360	440	11.6	12000	0.58	12.00	1455.1	981.3
RHS-IN-360×440×14	0	360	440	14.0	9500	0.70	9.50	5961.4	323.2
RHS-IN-360×440×14	36	360	440	14.0	9500	0.70	9.50	4633.0	690.0
RHS-IN-360×440×14	144	360	440	14.0	9500	0.70	9.50	3176.3	1045.6
RHS-IN-360×440×14	252	360	440	14.0	9500	0.70	9.50	2472.7	1094.1
RHS-IN-360×440×14	360	360	440	14.0	9500	0.70	9.50	2026.4	1131.0
RHS-IN-380×500×11.8	0	380	500	11.8	11500	0.59	11.50	4926.5	362.5
RHS-IN-380×500×11.8	38	380	500	11.8	11500	0.59	11.50	3854.6	660.6
RHS-IN-380×500×11.8	152	380	500	11.8	11500	0.59	11.50	2689.9	1012.6
RHS-IN-380×500×11.8	266	380	500	11.8	11500	0.59	11.50	2123.4	1090.7
RHS-IN-380×500×11.8	380	380	500	11.8	11500	0.59	11.50	1766.9	1145.6
RHS-IN-380×500×32	0	380	500	32.0	12000	1.60	12.00	11568.9	1053.5
RHS-IN-380×500×32	38	380	500	32.0	12000	1.60	12.00	9043.7	1647.7
RHS-IN-380×500×32	152	380	500	32.0	12000	1.60	12.00	6349.2	2567.9
RHS-IN-380×500×32	266	380	500	32.0	12000	1.60	12.00	5034.7	2704.5
RHS-IN-380×500×32	380	380	500	32.0	12000	1.60	12.00	4231.1	3005.7
RHS-IN-80×50×2.5	0	80	50	2.5	3600	0.13	3.60	39.2	0.2
RHS-IN-80×50×2.5	8	80	50	2.5	3600	0.13	3.60	38.6	0.9
RHS-IN-80×50×2.5	32	80	50	2.5	3600	0.13	3.60	39.3	2.9
RHS-IN-80×50×2.5	56	80	50	2.5	3600	0.13	3.60	39.1	5.8
RHS-IN-80×50×2.5	80	80	50	2.5	3600	0.13	3.60	33.8	6.3

RHS-IN-80×50×3.4	0	80	50	3.4	4000	0.17	4.00	80.2	3.6
RHS-IN-80×50×3.4	8	80	50	3.4	4000	0.17	4.00	69.9	5.2
RHS-IN-80×50×3.4	32	80	50	3.4	4000	0.17	4.00	40.8	3.0
RHS-IN-80×50×3.4	56	80	50	3.4	4000	0.17	4.00	39.7	4.8
RHS-IN-80×50×3.4	80	80	50	3.4	4000	0.17	4.00	37.3	6.2
RHS-IN-140×60×5	0	140	60	5.0	3200	0.25	3.20	543.4	9.6
RHS-IN-140×60×5	14	140	60	5.0	3200	0.25	3.20	407.7	21.8
RHS-IN-140×60×5	56	140	60	5.0	3200	0.25	3.20	267.3	29.6
RHS-IN-140×60×5	98	140	60	5.0	3200	0.25	3.20	205.4	35.0
RHS-IN-140×60×5	140	140	60	5.0	3200	0.25	3.20	163.2	33.3
RHS-IN-140×60×6.8	0	140	60	6.8	3300	0.34	3.30	250.7	0.7
RHS-IN-140×60×6.8	14	140	60	6.8	3300	0.34	3.30	249.9	5.6
RHS-IN-140×60×6.8	56	140	60	6.8	3300	0.34	3.30	245.2	19.8
RHS-IN-140×60×6.8	98	140	60	6.8	3300	0.34	3.30	218.5	29.7
RHS-IN-140×60×6.8	140	140	60	6.8	3300	0.34	3.30	193.3	36.8
RHS-IN-200×80×5	0	200	80	5.0	5000	0.25	5.00	240.4	1.1
RHS-IN-200×80×5	20	200	80	5.0	5000	0.25	5.00	235.1	7.5
RHS-IN-200×80×5	80	200	80	5.0	5000	0.25	5.00	226.3	25.6
RHS-IN-200×80×5	140	200	80	5.0	5000	0.25	5.00	207.9	39.8
RHS-IN-200×80×5	200	200	80	5.0	5000	0.25	5.00	186.2	50.0
RHS-IN-200×80×5.9	0	200	80	5.9	6500	0.30	6.50	161.6	1.0
RHS-IN-200×80×5.9	20	200	80	5.9	6500	0.30	6.50	459.1	51.8
RHS-IN-200×80×5.9	80	200	80	5.9	6500	0.30	6.50	320.3	73.1
RHS-IN-200×80×5.9	140	200	80	5.9	6500	0.30	6.50	159.0	31.2
RHS-IN-200×80×5.9	200	200	80	5.9	6500	0.30	6.50	154.3	42.6
RHS-IN-260×130×14.6	0	260	130	14.6	7800	0.73	7.80	2201.1	130.4
RHS-IN-260×130×14.6	26	260	130	14.6	7800	0.73	7.80	1704.1	222.3
RHS-IN-260×130×14.6	104	260	130	14.6	7800	0.73	7.80	1177.9	335.9
RHS-IN-260×130×14.6	182	260	130	14.6	7800	0.73	7.80	930.9	356.6
RHS-IN-260×130×14.6	260	260	130	14.6	7800	0.73	7.80	775.7	375.8

RHS-IN-260×130×16	0	260	130	16.0	8500	0.80	8.50	2074.7	139.2
RHS-IN-260×130×16	26	260	130	16.0	8500	0.80	8.50	1645.8	273.1
RHS-IN-260×130×16	104	260	130	16.0	8500	0.80	8.50	1162.8	356.6
RHS-IN-260×130×16	182	260	130	16.0	8500	0.80	8.50	928.7	379.1
RHS-IN-260×130×16	260	260	130	16.0	8500	0.80	8.50	779.2	410.6
RHS-IN-320×180×7.2	0	320	180	7.2	12000	0.36	12.00	524.2	8.1
RHS-IN-320×180×7.2	32	320	180	7.2	12000	0.36	12.00	522.3	38.1
RHS-IN-320×180×7.2	128	320	180	7.2	12000	0.36	12.00	503.5	122.1
RHS-IN-320×180×7.2	224	320	180	7.2	12000	0.36	12.00	462.7	185.8
RHS-IN-320×180×7.2	320	320	180	7.2	12000	0.36	12.00	415.5	230.6
RHS-IN-320×180×10.8	0	320	180	10.8	8500	0.54	8.50	1484.3	15.0
RHS-IN-320×180×10.8	32	320	180	10.8	8500	0.54	8.50	1449.6	97.8
RHS-IN-320×180×10.8	128	320	180	10.8	8500	0.54	8.50	1221.1	282.0
RHS-IN-320×180×10.8	224	320	180	10.8	8500	0.54	8.50	1013.5	375.7
RHS-IN-320×180×10.8	320	320	180	10.8	8500	0.54	8.50	853.5	433.3
RHS-IN-380×280×10.5	0	380	280	10.5	11500	0.53	11.50	2390.9	57.5
RHS-IN-380×280×10.5	38	380	280	10.5	11500	0.53	11.50	2200.2	283.3
RHS-IN-380×280×10.5	152	380	280	10.5	11500	0.53	11.50	1615.6	566.8
RHS-IN-380×280×10.5	266	380	280	10.5	11500	0.53	11.50	1285.8	693.5
RHS-IN-380×280×10.5	380	380	280	10.5	11500	0.53	11.50	1067.8	709.9
RHS-IN-380×280×15	0	380	280	15.0	12000	0.75	12.00	4046.5	310.7
RHS-IN-380×280×15	38	380	280	15.0	12000	0.75	12.00	3144.0	663.0
RHS-IN-380×280×15	152	380	280	15.0	12000	0.75	12.00	2170.9	891.5
RHS-IN-380×280×15	266	380	280	15.0	12000	0.75	12.00	1741.0	979.8
RHS-IN-380×280×15	380	380	280	15.0	12000	0.75	12.00	1454.6	1017.6
RHS-IN-440×360×11.6	0	440	360	11.6	12000	0.58	12.00	4264.5	150.4
RHS-IN-440×360×11.6	44	440	360	11.6	12000	0.58	12.00	3559.0	612.8
RHS-IN-440×360×11.6	176	440	360	11.6	12000	0.58	12.00	2449.2	1016.3
RHS-IN-440×360×11.6	308	440	360	11.6	12000	0.58	12.00	1906.9	1069.4
RHS-IN-440×360×11.6	440	440	360	11.6	12000	0.58	12.00	1573.2	1129.6

RHS-IN-440×360×14	0	440	360	14.0	9500	0.70	9.50	6493.2	194.6
RHS-IN-440×360×14	44	440	360	14.0	9500	0.70	9.50	5251.7	824.5
RHS-IN-440×360×14	176	440	360	14.0	9500	0.70	9.50	3506.2	1199.6
RHS-IN-440×360×14	308	440	360	14.0	9500	0.70	9.50	2632.6	1232.3
RHS-IN-440×360×14	440	440	360	14.0	9500	0.70	9.50	2164.3	1374.2
RHS-IN-500×380×11.8	0	500	380	11.8	11500	0.59	11.50	5401.4	133.4
RHS-IN-500×380×11.8	50	500	380	11.8	11500	0.59	11.50	4599.3	717.4
RHS-IN-500×380×11.8	200	500	380	11.8	11500	0.59	11.50	3127.3	1278.5
RHS-IN-500×380×11.8	350	500	380	11.8	11500	0.59	11.50	2396.3	1434.9
RHS-IN-500×380×11.8	500	500	380	11.8	11500	0.59	11.50	1936.7	1421.3
RHS-IN-500×380×32	0	500	380	32.0	12000	1.60	12.00	13058.8	300.5
RHS-IN-500×380×32	50	500	380	32.0	12000	1.60	12.00	11128.6	1696.3
RHS-IN-500×380×32	200	500	380	32.0	12000	1.60	12.00	7683.0	3315.0
RHS-IN-500×380×32	350	500	380	32.0	12000	1.60	12.00	5834.7	3356.0
RHS-IN-500×380×32	500	500	380	32.0	12000	1.60	12.00	4843.3	3862.5
RHS-IH-50×80×2.5	0	50	80	2.5	3600	0.13	3.60	40.6	4.0
RHS-IH-50×80×2.5	5	50	80	2.5	3600	0.13	3.60	38.4	4.7
RHS-IH-50×80×2.5	20	50	80	2.5	3600	0.13	3.60	34.0	6.3
RHS-IH-50×80×2.5	35	50	80	2.5	3600	0.13	3.60	31.1	6.8
RHS-IH-50×80×2.5	50	50	80	2.5	3600	0.13	3.60	28.7	7.4
RHS-IH-50×80×3.4	0	50	80	3.4	4000	0.17	4.00	43.3	5.4
RHS-IH-50×80×3.4	5	50	80	3.4	4000	0.17	4.00	41.4	6.5
RHS-IH-50×80×3.4	20	50	80	3.4	4000	0.17	4.00	37.5	8.0
RHS-IH-50×80×3.4	35	50	80	3.4	4000	0.17	4.00	34.7	8.9
RHS-IH-50×80×3.4	50	50	80	3.4	4000	0.17	4.00	32.5	9.0
RHS-IH-60×140×5	0	60	140	5.0	3200	0.25	3.20	219.7	11.5
RHS-IH-60×140×5	6	60	140	5.0	3200	0.25	3.20	200.5	16.8
RHS-IH-60×140×5	24	60	140	5.0	3200	0.25	3.20	168.3	24.3
RHS-IH-60×140×5	42	60	140	5.0	3200	0.25	3.20	148.0	24.9
RHS-IH-60×140×5	60	60	140	5.0	3200	0.25	3.20	133.2	29.3

RHS-IH-60×140×6.8	0	60	140	6.8	3300	0.34	3.30	256.8	17.6
RHS-IH-60×140×6.8	6	60	140	6.8	3300	0.34	3.30	236.7	24.9
RHS-IH-60×140×6.8	24	60	140	6.8	3300	0.34	3.30	201.2	30.0
RHS-IH-60×140×6.8	42	60	140	6.8	3300	0.34	3.30	178.6	32.5
RHS-IH-60×140×6.8	60	60	140	6.8	3300	0.34	3.30	162.0	34.4
RHS-IH-80×200×5	0	80	200	5.0	5000	0.25	5.00	240.7	25.9
RHS-IH-80×200×5	8	80	200	5.0	5000	0.25	5.00	223.0	31.4
RHS-IH-80×200×5	32	80	200	5.0	5000	0.25	5.00	191.4	40.6
RHS-IH-80×200×5	56	80	200	5.0	5000	0.25	5.00	171.1	45.8
RHS-IH-80×200×5	80	80	200	5.0	5000	0.25	5.00	156.0	48.1
RHS-IH-80×200×5.9	0	80	200	5.9	6500	0.30	6.50	168.1	28.4
RHS-IH-80×200×5.9	8	80	200	5.9	6500	0.30	6.50	160.3	40.0
RHS-IH-80×200×5.9	32	80	200	5.9	6500	0.30	6.50	144.7	45.6
RHS-IH-80×200×5.9	56	80	200	5.9	6500	0.30	6.50	133.6	51.4
RHS-IH-80×200×5.9	80	80	200	5.9	6500	0.30	6.50	124.8	55.7
RHS-IH-130×260×14.6	0	130	260	14.6	7800	0.73	7.80	898.4	184.6
RHS-IH-130×260×14.6	13	130	260	14.6	7800	0.73	7.80	836.4	194.4
RHS-IH-130×260×14.6	52	130	260	14.6	7800	0.73	7.80	727.1	295.5
RHS-IH-130×260×14.6	91	130	260	14.6	7800	0.73	7.80	654.8	318.0
RHS-IH-130×260×14.6	130	130	260	14.6	7800	0.73	7.80	600.7	326.8
RHS-IH-130×260×16	0	130	260	16.0	8500	0.80	8.50	794.7	196.2
RHS-IH-130×260×16	13	130	260	16.0	8500	0.80	8.50	747.2	199.9
RHS-IH-130×260×16	52	130	260	16.0	8500	0.80	8.50	660.6	302.0
RHS-IH-130×260×16	91	130	260	16.0	8500	0.80	8.50	601.4	325.3
RHS-IH-130×260×16	130	130	260	16.0	8500	0.80	8.50	556.2	334.5
RHS-IH-180×320×7.2	0	180	320	7.2	12000	0.36	12.00	550.3	139.0
RHS-IH-180×320×7.2	18	180	320	7.2	12000	0.36	12.00	514.0	202.1
RHS-IH-180×320×7.2	72	180	320	7.2	12000	0.36	12.00	447.0	243.6
RHS-IH-180×320×7.2	126	180	320	7.2	12000	0.36	12.00	402.8	261.5
RHS-IH-180×320×7.2	180	180	320	7.2	12000	0.36	12.00	369.3	272.2

RHS-IH-180×320×10.8	0	180	320	10.8	8500	0.54	8.50	1509.1	247.2
RHS-IH-180×320×10.8	18	180	320	10.8	8500	0.54	8.50	1350.7	318.9
RHS-IH-180×320×10.8	72	180	320	10.8	8500	0.54	8.50	1095.8	423.3
RHS-IH-180×320×10.8	126	180	320	10.8	8500	0.54	8.50	949.3	454.6
RHS-IH-180×320×10.8	180	180	320	10.8	8500	0.54	8.50	845.4	477.8
RHS-IH-280×380×10.5	0	280	380	10.5	11500	0.53	11.50	2498.4	334.4
RHS-IH-280×380×10.5	28	280	380	10.5	11500	0.53	11.50	2177.2	635.3
RHS-IH-280×380×10.5	112	280	380	10.5	11500	0.53	11.50	1704.9	836.3
RHS-IH-280×380×10.5	196	280	380	10.5	11500	0.53	11.50	1444.9	913.1
RHS-IH-280×380×10.5	280	280	380	10.5	11500	0.53	11.50	1267.9	954.7
RHS-IH-280×380×15	0	280	380	15.0	12000	0.75	12.00	3147.1	550.0
RHS-IH-280×380×15	28	280	380	15.0	12000	0.75	12.00	2772.2	831.1
RHS-IH-280×380×15	112	280	380	15.0	12000	0.75	12.00	2205.0	1206.9
RHS-IH-280×380×15	196	280	380	15.0	12000	0.75	12.00	1891.1	1235.6
RHS-IH-280×380×15	280	280	380	15.0	12000	0.75	12.00	1668.1	1283.8
RHS-IH-360×440×11.6	0	360	440	11.6	12000	0.58	12.00	4781.6	622.9
RHS-IH-360×440×11.6	36	360	440	11.6	12000	0.58	12.00	3956.5	1069.6
RHS-IH-360×440×11.6	144	360	440	11.6	12000	0.58	12.00	2941.8	1415.4
RHS-IH-360×440×11.6	252	360	440	11.6	12000	0.58	12.00	2421.1	1553.3
RHS-IH-360×440×11.6	360	360	440	11.6	12000	0.58	12.00	2079.4	1655.4
RHS-IH-360×440×14	0	360	440	14.0	9500	0.70	9.50	8160.2	608.8
RHS-IH-360×440×14	36	360	440	14.0	9500	0.70	9.50	6425.1	1171.5
RHS-IH-360×440×14	144	360	440	14.0	9500	0.70	9.50	4550.6	1791.7
RHS-IH-360×440×14	252	360	440	14.0	9500	0.70	9.50	3634.2	1945.6
RHS-IH-360×440×14	360	360	440	14.0	9500	0.70	9.50	3051.0	2020.1
RHS-IH-380×500×11.8	0	380	500	11.8	11500	0.59	11.50	6388.3	642.6
RHS-IH-380×500×11.8	38	380	500	11.8	11500	0.59	11.50	5152.9	1201.6
RHS-IH-380×500×11.8	152	380	500	11.8	11500	0.59	11.50	3608.2	1363.8
RHS-IH-380×500×11.8	266	380	500	11.8	11500	0.59	11.50	2882.8	1503.5
RHS-IH-380×500×11.8	380	380	500	11.8	11500	0.59	11.50	2313.9	1556.3

RHS-IH-380×500×32	0	380	500	32.0	12000	1.60	12.00	14144.3	2101.6
RHS-IH-380×500×32	38	380	500	32.0	12000	1.60	12.00	11697.9	3072.4
RHS-IH-380×500×32	152	380	500	32.0	12000	1.60	12.00	8718.7	4535.3
RHS-IH-380×500×32	266	380	500	32.0	12000	1.60	12.00	7131.6	4602.9
RHS-IH-380×500×32	380	380	500	32.0	12000	1.60	12.00	6147.8	5073.3
RHS-IH-80×50×2.5	0	80	50	2.5	3600	0.13	3.60	41.2	0.2
RHS-IH-80×50×2.5	8	80	50	2.5	3600	0.13	3.60	41.1	0.9
RHS-IH-80×50×2.5	32	80	50	2.5	3600	0.13	3.60	40.8	2.9
RHS-IH-80×50×2.5	56	80	50	2.5	3600	0.13	3.60	40.1	4.8
RHS-IH-80×50×2.5	80	80	50	2.5	3600	0.13	3.60	39.0	6.5
RHS-IH-80×50×3.4	0	80	50	3.4	4000	0.17	4.00	43.6	0.2
RHS-IH-80×50×3.4	8	80	50	3.4	4000	0.17	4.00	43.5	0.9
RHS-IH-80×50×3.4	32	80	50	3.4	4000	0.17	4.00	43.4	3.1
RHS-IH-80×50×3.4	56	80	50	3.4	4000	0.17	4.00	43.3	5.2
RHS-IH-80×50×3.4	80	80	50	3.4	4000	0.17	4.00	54.6	14.6
RHS-IH-140×60×5	0	140	60	5.0	3200	0.25	3.20	230.3	0.7
RHS-IH-140×60×5	14	140	60	5.0	3200	0.25	3.20	571.0	36.9
RHS-IH-140×60×5	56	140	60	5.0	3200	0.25	3.20	391.8	55.2
RHS-IH-140×60×5	98	140	60	5.0	3200	0.25	3.20	221.7	31.1
RHS-IH-140×60×5	140	140	60	5.0	3200	0.25	3.20	208.2	40.9
RHS-IH-140×60×6.8	0	140	60	6.8	3300	0.34	3.30	270.7	0.9
RHS-IH-140×60×6.8	14	140	60	6.8	3300	0.34	3.30	274.0	6.3
RHS-IH-140×60×6.8	56	140	60	6.8	3300	0.34	3.30	268.2	21.7
RHS-IH-140×60×6.8	98	140	60	6.8	3300	0.34	3.30	263.4	36.5
RHS-IH-140×60×6.8	140	140	60	6.8	3300	0.34	3.30	253.1	49.3
RHS-IH-200×80×5	0	200	80	5.0	5000	0.25	5.00	250.3	1.3
RHS-IH-200×80×5	20	200	80	5.0	5000	0.25	5.00	249.3	8.1
RHS-IH-200×80×5	80	200	80	5.0	5000	0.25	5.00	245.0	27.8
RHS-IH-200×80×5	140	200	80	5.0	5000	0.25	5.00	238.3	46.1
RHS-IH-200×80×5	200	200	80	5.0	5000	0.25	5.00	228.3	62.0

RHS-IH-200×80×5.9	0	200	80	5.9	6500	0.30	6.50	171.8	1.1
RHS-IH-200×80×5.9	20	200	80	5.9	6500	0.30	6.50	584.1	93.4
RHS-IH-200×80×5.9	80	200	80	5.9	6500	0.30	6.50	436.5	118.5
RHS-IH-200×80×5.9	140	200	80	5.9	6500	0.30	6.50	360.1	133.1
RHS-IH-200×80×5.9	200	200	80	5.9	6500	0.30	6.50	309.2	138.3
RHS-IH-260×130×14.6	0	260	130	14.6	7800	0.73	7.80	2685.0	299.1
RHS-IH-260×130×14.6	26	260	130	14.6	7800	0.73	7.80	2223.6	425.3
RHS-IH-260×130×14.6	104	260	130	14.6	7800	0.73	7.80	1640.0	598.6
RHS-IH-260×130×14.6	182	260	130	14.6	7800	0.73	7.80	1343.1	599.6
RHS-IH-260×130×14.6	260	260	130	14.6	7800	0.73	7.80	1150.0	652.0
RHS-IH-260×130×16	0	260	130	16.0	8500	0.80	8.50	813.8	7.6
RHS-IH-260×130×16	26	260	130	16.0	8500	0.80	8.50	2095.0	417.8
RHS-IH-260×130×16	104	260	130	16.0	8500	0.80	8.50	811.9	138.3
RHS-IH-260×130×16	182	260	130	16.0	8500	0.80	8.50	1330.9	655.3
RHS-IH-260×130×16	260	260	130	16.0	8500	0.80	8.50	811.3	333.5
RHS-IH-320×180×7.2	0	320	180	7.2	12000	0.36	12.00	574.0	8.9
RHS-IH-320×180×7.2	32	320	180	7.2	12000	0.36	12.00	565.1	41.9
RHS-IH-320×180×7.2	128	320	180	7.2	12000	0.36	12.00	551.4	139.1
RHS-IH-320×180×7.2	224	320	180	7.2	12000	0.36	12.00	711.2	468.2
RHS-IH-320×180×7.2	320	320	180	7.2	12000	0.36	12.00	618.3	484.5
RHS-IH-320×180×10.8	0	320	180	10.8	8500	0.54	8.50	1573.0	16.9
RHS-IH-320×180×10.8	32	320	180	10.8	8500	0.54	8.50	1565.2	106.3
RHS-IH-320×180×10.8	128	320	180	10.8	8500	0.54	8.50	1500.7	355.0
RHS-IH-320×180×10.8	224	320	180	10.8	8500	0.54	8.50	1360.7	533.6
RHS-IH-320×180×10.8	320	320	180	10.8	8500	0.54	8.50	1208.4	648.5
RHS-IH-380×280×10.5	0	380	280	10.5	11500	0.53	11.50	2661.1	64.3
RHS-IH-380×280×10.5	38	380	280	10.5	11500	0.53	11.50	2606.8	349.5
RHS-IH-380×280×10.5	152	380	280	10.5	11500	0.53	11.50	2191.7	904.3
RHS-IH-380×280×10.5	266	380	280	10.5	11500	0.53	11.50	1819.9	1131.5
RHS-IH-380×280×10.5	380	380	280	10.5	11500	0.53	11.50	1541.5	1153.7

RHS-IH-380×280×15	0	380	280	15.0	12000	0.75	12.00	3342.6	75.5
RHS-IH-380×280×15	38	380	280	15.0	12000	0.75	12.00	3319.6	440.5
RHS-IH-380×280×15	152	380	280	15.0	12000	0.75	12.00	2937.4	1263.4
RHS-IH-380×280×15	266	380	280	15.0	12000	0.75	12.00	2475.1	1630.6
RHS-IH-380×280×15	380	380	280	15.0	12000	0.75	12.00	2120.7	1730.4
RHS-IH-440×360×11.6	0	440	360	11.6	12000	0.58	12.00	5172.0	183.5
RHS-IH-440×360×11.6	44	440	360	11.6	12000	0.58	12.00	4698.3	923.9
RHS-IH-440×360×11.6	176	440	360	11.6	12000	0.58	12.00	3445.9	1697.3
RHS-IH-440×360×11.6	308	440	360	11.6	12000	0.58	12.00	2750.2	1946.0
RHS-IH-440×360×11.6	440	440	360	11.6	12000	0.58	12.00	2322.3	1980.6
RHS-IH-440×360×14	0	440	360	14.0	9500	0.70	9.50	8729.5	256.2
RHS-IH-440×360×14	44	440	360	14.0	9500	0.70	9.50	7518.0	1287.9
RHS-IH-440×360×14	176	440	360	14.0	9500	0.70	9.50	5152.6	2023.6
RHS-IH-440×360×14	308	440	360	14.0	9500	0.70	9.50	4015.1	2335.8
RHS-IH-440×360×14	440	440	360	14.0	9500	0.70	9.50	3316.2	2433.9
RHS-IH-500×380×11.8	0	500	380	11.8	11500	0.59	11.50	7224.1	185.6
RHS-IH-500×380×11.8	50	500	380	11.8	11500	0.59	11.50	6646.6	1467.8
RHS-IH-500×380×11.8	200	500	380	11.8	11500	0.59	11.50	4567.4	2182.4
RHS-IH-500×380×11.8	350	500	380	11.8	11500	0.59	11.50	3579.3	2410.6
RHS-IH-500×380×11.8	500	500	380	11.8	11500	0.59	11.50	2965.2	2549.2
RHS-IH-500×380×32	0	500	380	32.0	12000	1.60	12.00	15251.4	412.7
RHS-IH-500×380×32	50	500	380	32.0	12000	1.60	12.00	14523.6	2484.1
RHS-IH-500×380×32	200	500	380	32.0	12000	1.60	12.00	11095.1	5516.7
RHS-IH-500×380×32	350	500	380	32.0	12000	1.60	12.00	8826.8	6549.7
RHS-IH-500×380×32	500	500	380	32.0	12000	1.60	12.00	7363.9	6954.9