Stainless Steel in Structures:
Fifth International Experts Seminar

Research on the Bearing Capacity of Lipped C-Section Stainless Steel Members Considering Local Buckling


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Outline

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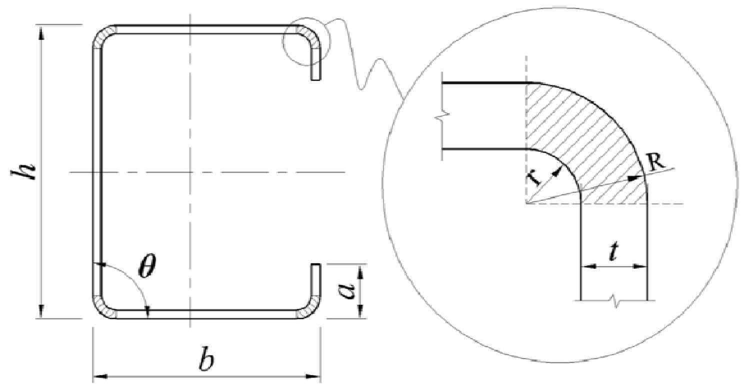
Introduction

Motivation

- Existing data generally focus on the carbon steel
- Limited research results on the local buckling of open-section beams, especially for stainless steel members with lipped C-sections
- No definitive evaluations of the design expressions

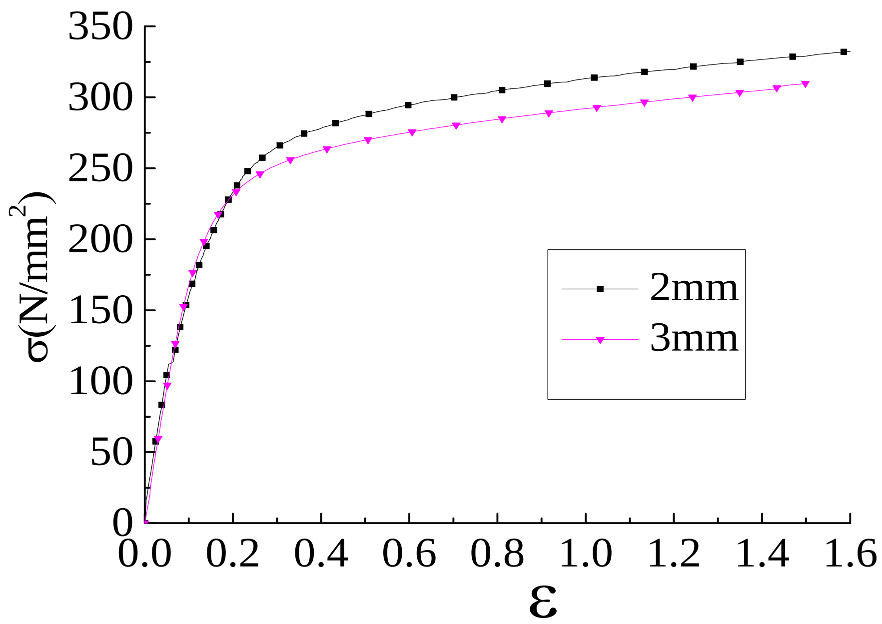
Objectives

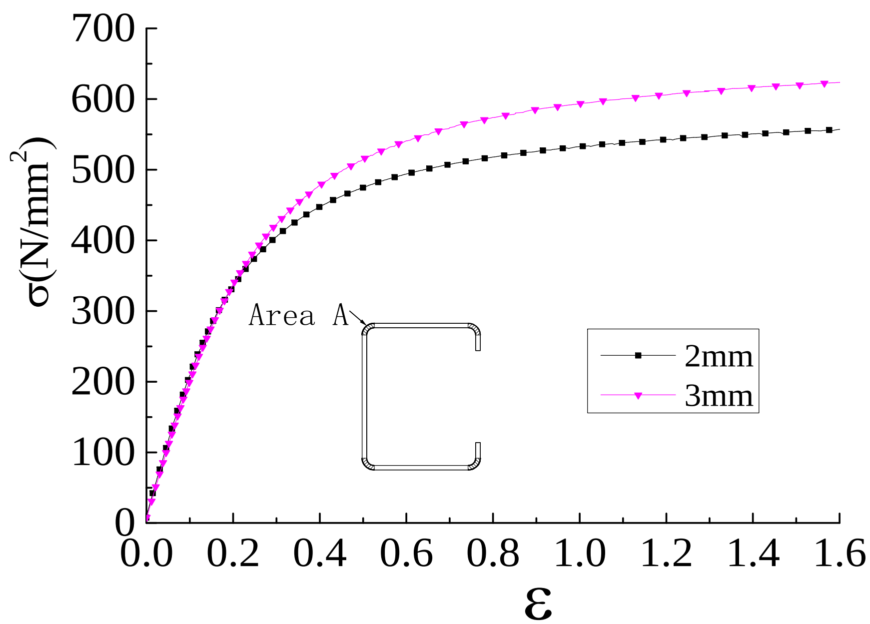
- Lipped C-section stainless steel beams tests was performed.
- Direct strength equations for bending lipped C-section stainless steel beams is proposed.



Experimental Investigation

Material Properties



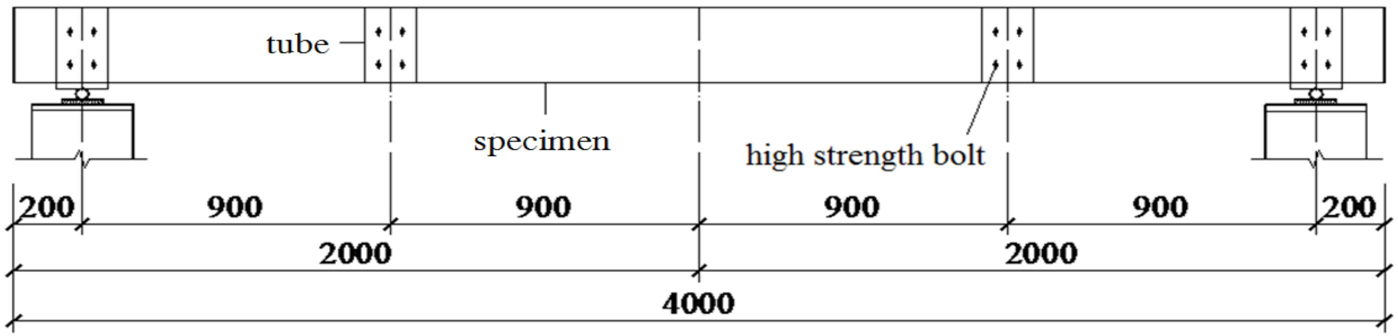


- Cold working can significantly improve the strength of stainless steel in the corner regions.

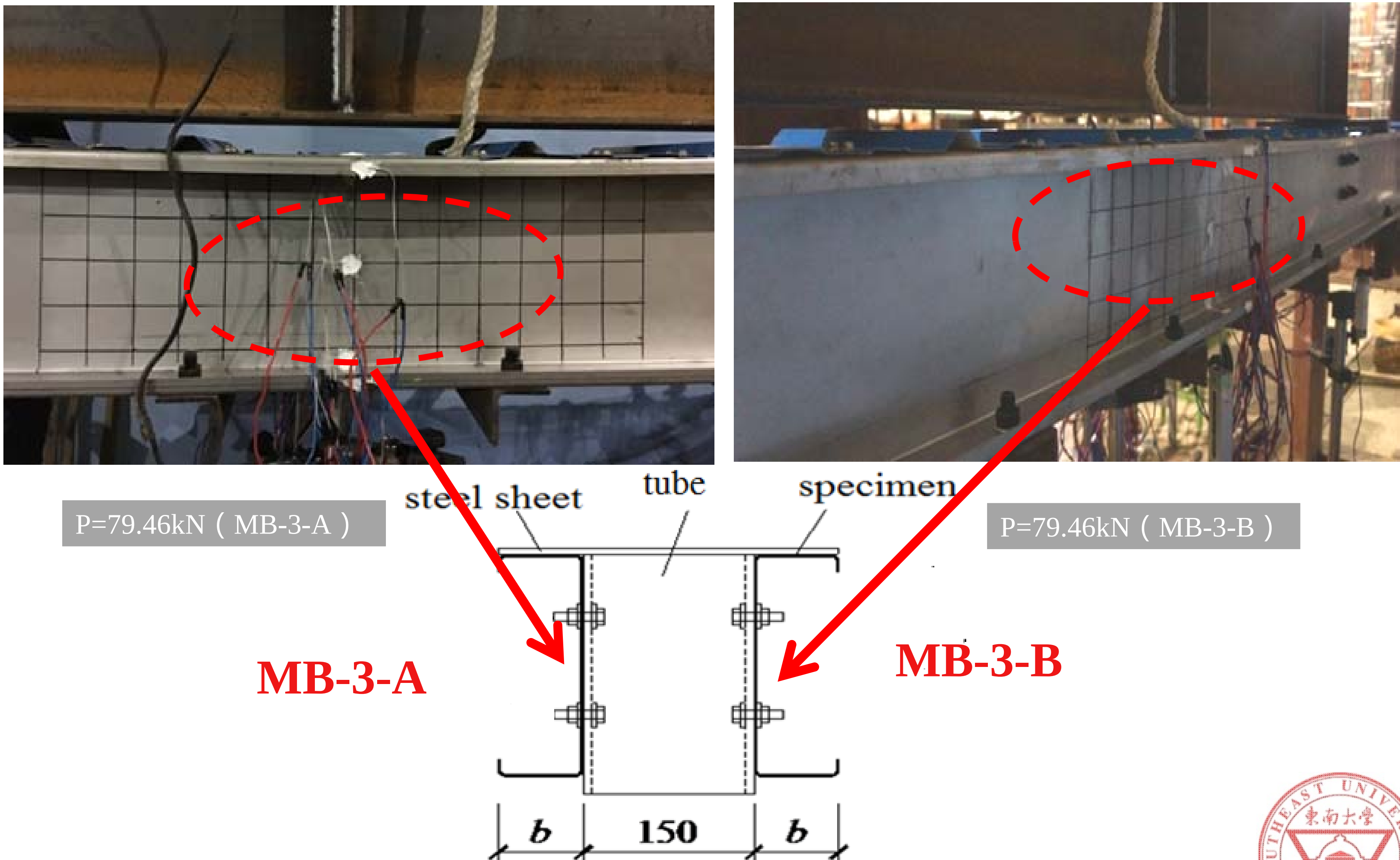
- Yield stress decreases slightly with increasing thickness of the specimens.

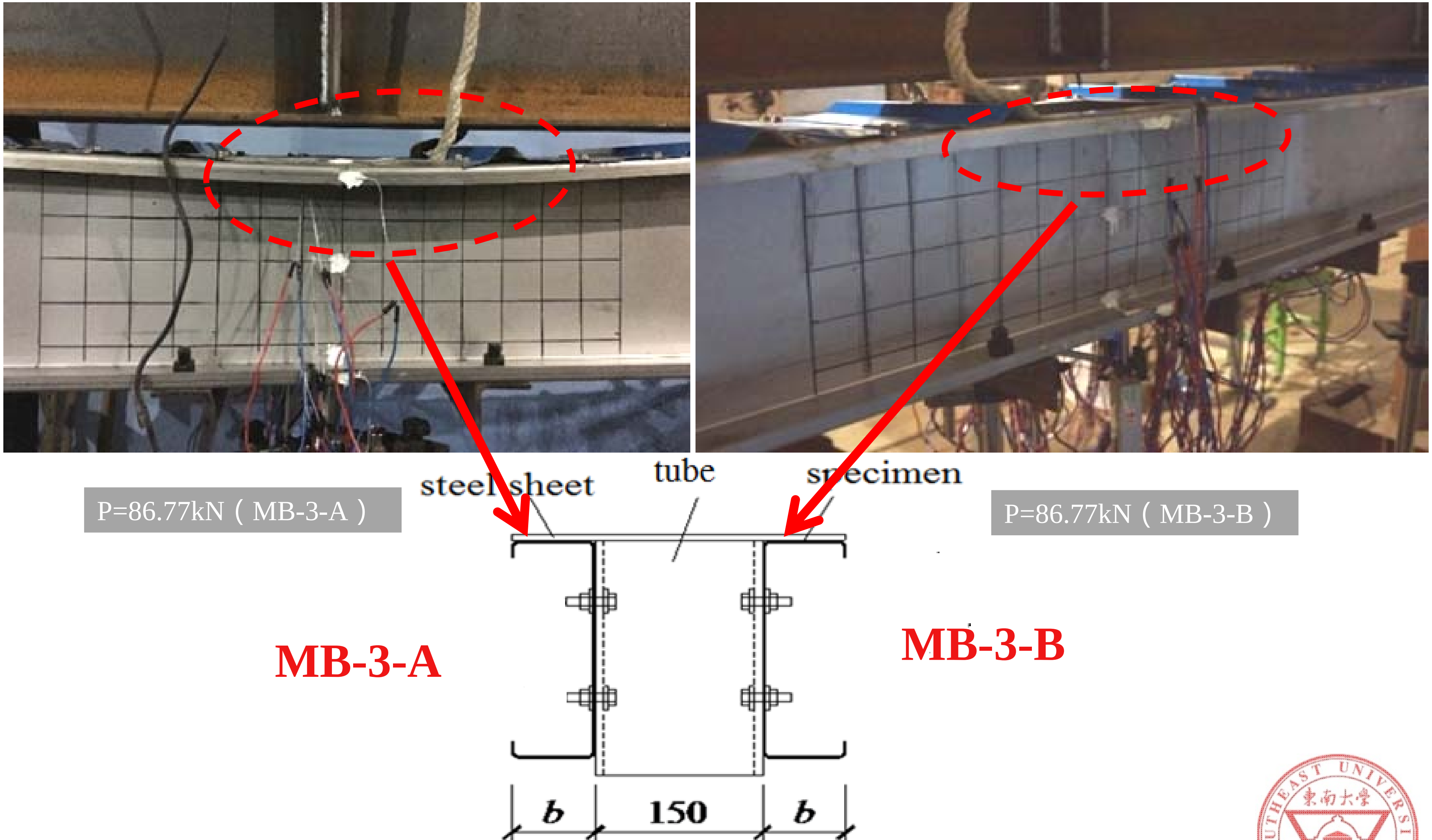
Specimen Design

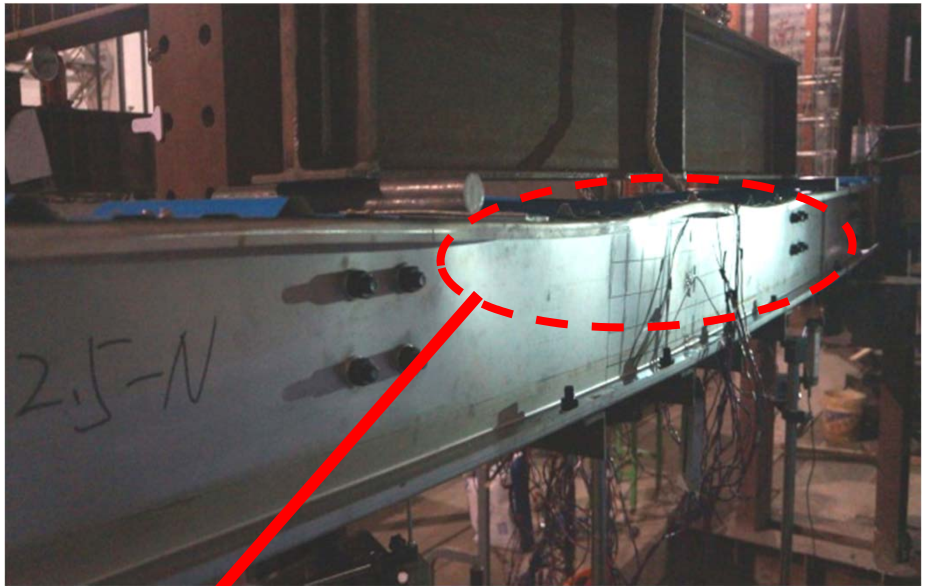
Group code	Section code	h/mm	b/mm	a/mm	r/mm	t/mm
SP-1	C150×60×20×2.0	150	60	20	2	2.0
SP-2	C250×50×20×2.0	250	50	20	2	2.0
SP-3	C250×75×20×2.0	250	75	20	2	2.0
SP-4	C250×75×20×2.5	250	75	20	2	2.5
SP-5	C300×80×20×2.0	300	80	20	2	2.0
SP-6	C400×90×20×2.0	400	90	20	2	2.0



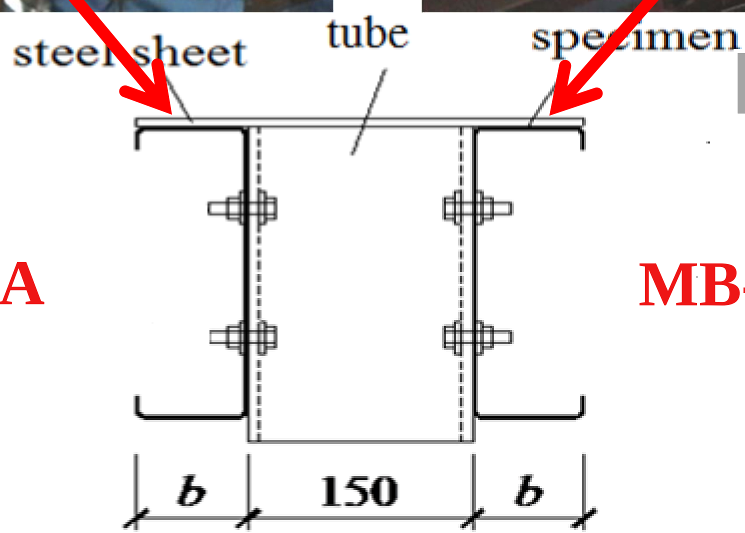

C400X90-S


P=79.46kN（MB-3-A）
P=79.46kN（MB-3-B）
steel sheet
tube
specimen
MB-3-A
MB-3-B
b
150
b


P=86.77kN（MB-3-A）
P=86.77kN（MB-3-B）
steel sheet
tube
specimen
MB-3-A
MB-3-B
b
150
b



P=70.41kN（MB-3-A）

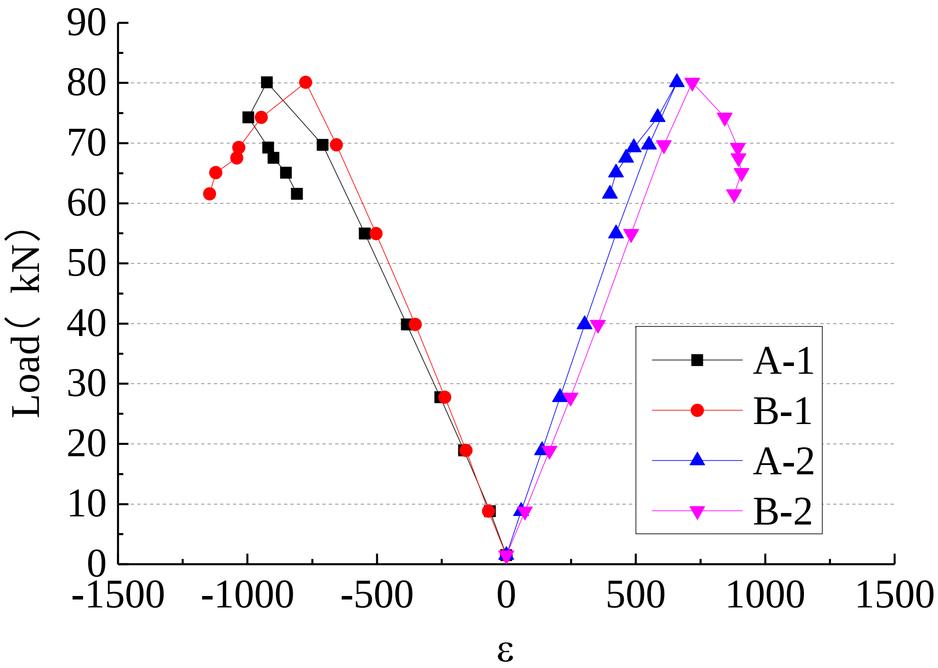


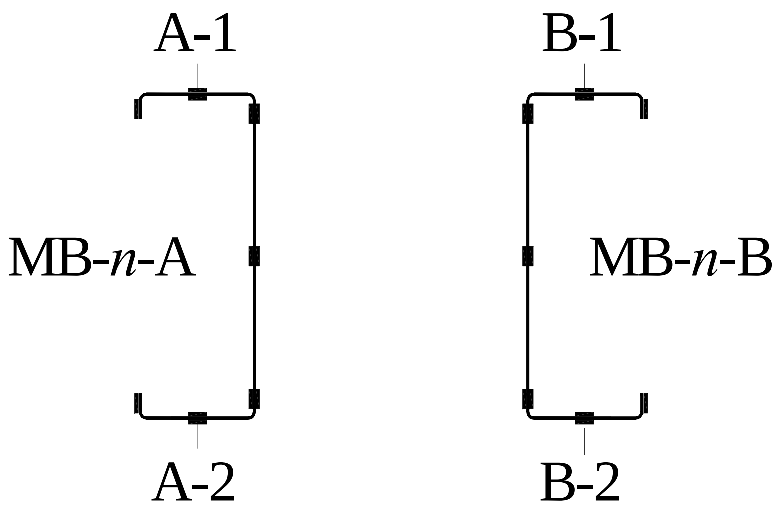
P=70.41kN（MB-3-B）

MB-3-A

MB-3-B

Experimental Result



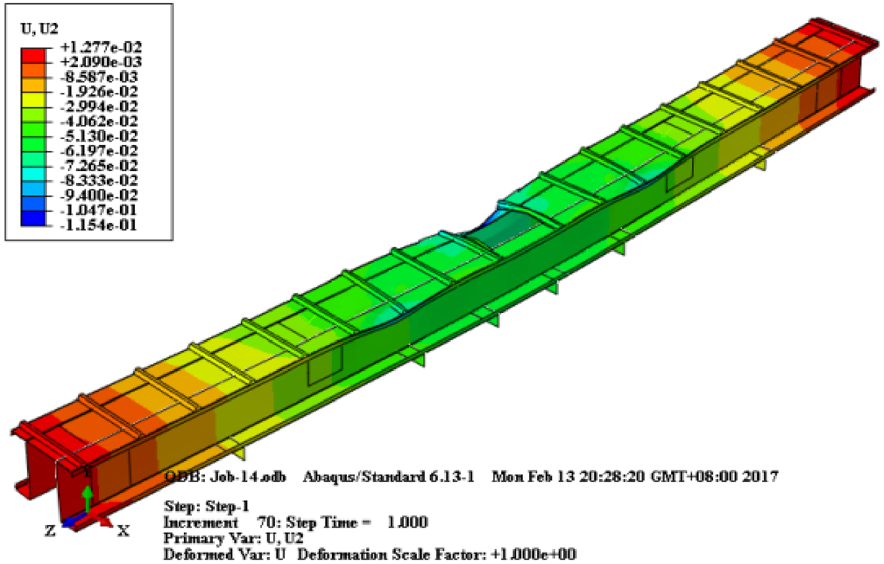


- At the initial stage, the beam at mid-span under pure bending. The two lipped C-section members that make up the specimen work well together.

Numerical Investigation

Comparison

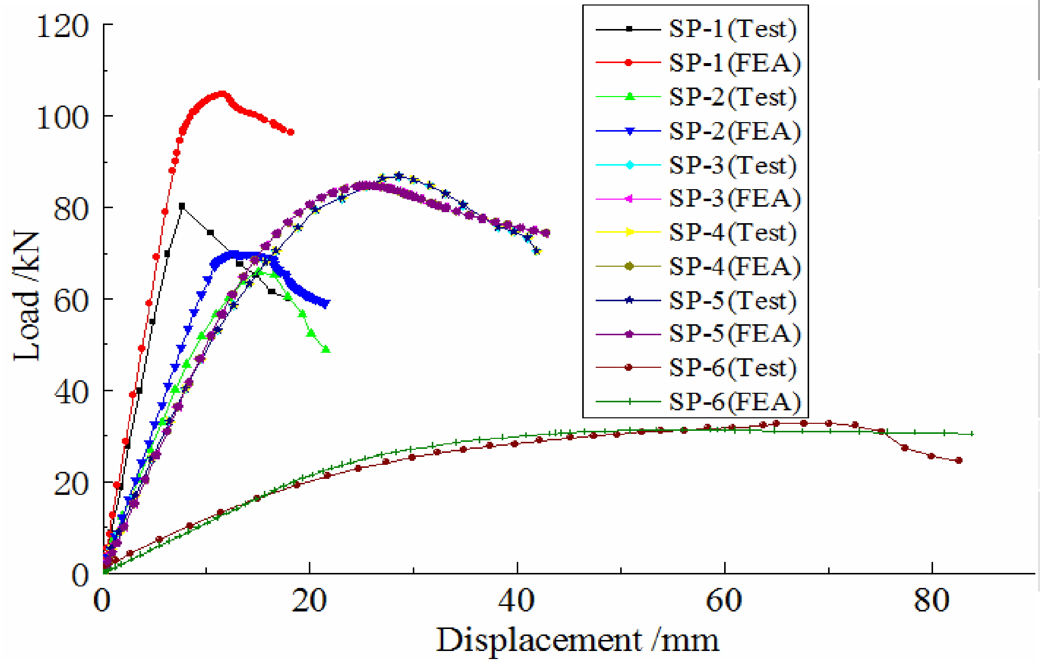
Test Failure Mode



FE Failure Mode

- The **failure modes** of specimens are consistent with the modes observed by the finite element analysis.

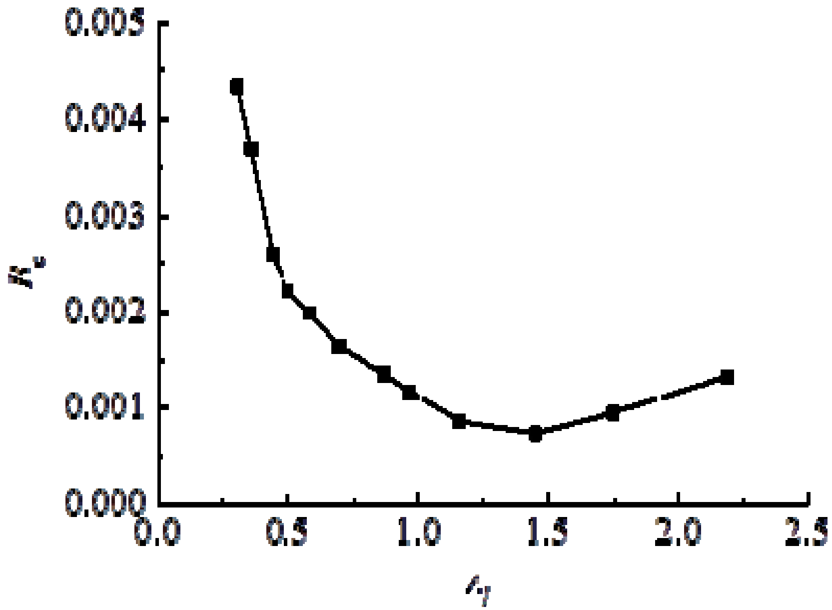
Comparison

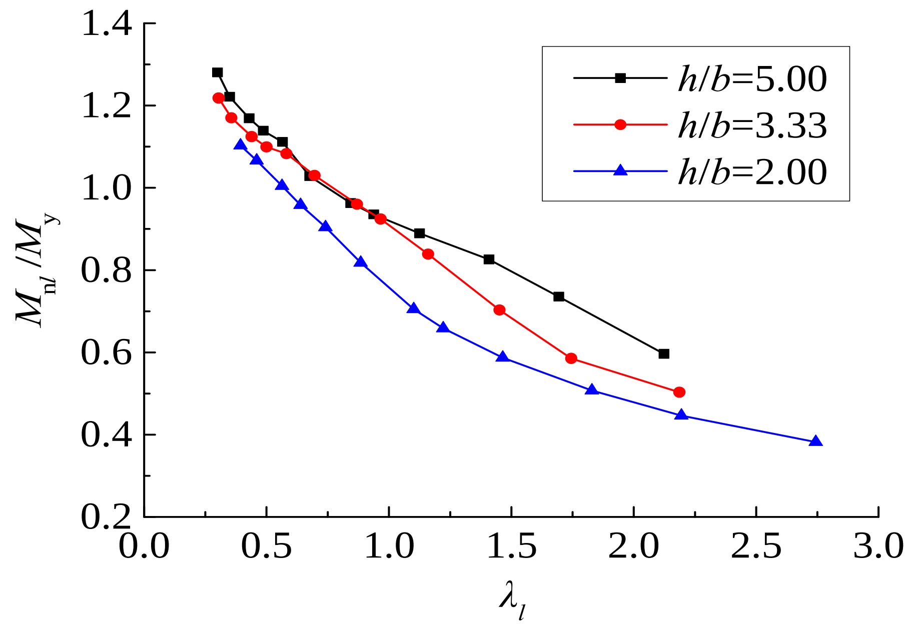


Specimen number	Deviation	P_{FE}/P_T
SP-1	30.52%	1.31
SP-2	6.68%	1.07
SP-3	-2.34%	0.98
SP-4	1.56%	1.02
SP-5	4.63%	1.05
SP-6	-4.34%	0.96
Average error	3.91%	1.01

- FE load–displacement curves of major axis bending specimen are generally in close agreement with the test.

Parameter Analysis





- The contribution of the **material hardening** to the increase of bearing capacity decreases first and then increases with the increase of slenderness.

- The ratio of the bearing capacity to the full cross section yield bearing capacity increases with the cross-section aspect ratio.

Direct Strength Method

Assumed Equation:

$$M_{nl} = \begin{cases} M_y & \lambda_l \le \lambda_{lim} \\ \frac{1}{\lambda_l^c} M_y \left(a - \frac{b}{\lambda_l^c} \right) & \lambda_l > \lambda_{lim} \end{cases}$$

Fitted Equation:

$$M_{nl} = \begin{cases} 1.66 M_y & \lambda_l \le 0.10 \\ \frac{1}{\lambda_l^{0.57}} M_y \left(0.93 - \frac{0.13}{\lambda_l^{0.57}} \right) & \lambda_l > 0.10 \end{cases}$$

- Based on the direct strength method (DSM) in North American Specification (NAS), the direct strength method equation of a stainless steel beam of lipped C-section is fitted.

Comparison

Specimen code	Specimen number	λ_l	Test result M_T/kN·m	North American Specification (AISI S100-07)			Fitting formula		
				M_{AISI}/kN·m	DEV_T	M_{AISI}/M_T	M_{cal}/kN·m	DEV_T	M_{cal}/M_T
SP-1	MB-1-A	1.53	18.02	20.84	15.59%	1.16	21.29	18.10%	1.18
	MB-1-B	1.52	18.02	21.09	16.99%	1.17	21.53	19.44%	1.19
SP-2	MB-2-A	1.16	14.82	16.08	8.54%	1.09	15.56	5.02%	1.05
	MB-2-B	1.14	14.82	16.39	10.59%	1.11	15.81	6.67%	1.07
SP-3	MB-3-A	0.76	19.52	20.18	3.38%	1.03	18.31	-6.19%	0.94
	MB-3-B	0.76	19.52	20.27	3.85%	1.04	18.43	-5.60%	0.94
SP-4	MB-4-A	0.95	13.59	14.12	3.84%	1.04	13.17	-3.10%	0.97
	MB-4-B	0.96	13.59	13.85	1.91%	1.02	12.95	-4.76%	0.95
SP-5	MB-5-A	0.94	11.67	11.29	-3.20%	0.97	10.51	-9.94%	0.90
	MB-5-B	0.94	11.67	11.26	-3.51%	0.96	10.48	-10.13%	0.90
SP-6	MB-6-A	0.63	7.38	7.04	-4.61%	0.95	6.96	-5.66%	0.94
	MB-6-B	0.64	7.38	6.94	-6.02%	0.94	6.81	-7.73%	0.92
				Average	1.48%	1.01	Average	-4.14%	0.96
				Standard deviation	0.003		Standard deviation	0.003	

Summary

- Cold working can significantly improve the strength of stainless steel in the corner regions.
- Yield stress decreases slightly with increasing thickness of the specimens
- The hardening index, the enhanced properties of the corner areas and the cross section aspect ratio all have effect on the capacity.
- The fitted formulas have high accuracy and reliability and can accurately calculate the bearing capacity of lipped C-section stainless steel beams.

Thank you for your attention!

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