THE CONTINUOUS STRENGTH METHOD FOR STRUCTURAL HIGH STRENGTH STEEL DESIGN

Man Wing Chan **Supervised by Prof. Leroy Gardner**

Department of Civil and Environmental Engineering, Imperial College London

INTRODUCTION

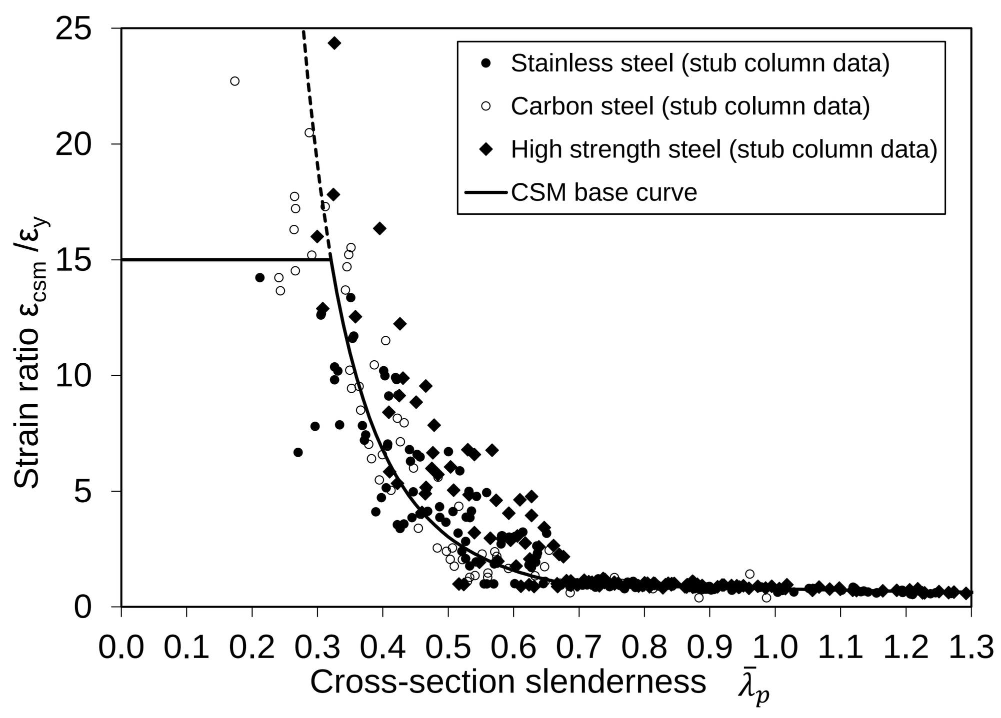
The current EC3 specifications for high strength steel (HSS) design employs elastic, perfectly plastic material model and cross-section classification to determine cross-section resistances, which are known to over-predicts for stocky section. The Continuous Strength Method (CSM) has been developed to reflect the actual behaviour of structural sections for different metallic material by allowing rational exploitation of strain hardening. This study extended the application of CSM to HSS design and showed that the CSM offers improved accuracy and reduced scatter relative to the existing design methods.

CONTINUOUS STRENGTH METHOD

The CSM is a strain based design approach consists of a base curve, that defines the relationship between the cross-section slenderness $\bar{\lambda}_p$ and the cross-section deformation capacity $\varepsilon_{csm}/\varepsilon_y$, and a material model, which allow stresses greater than the yield stress.

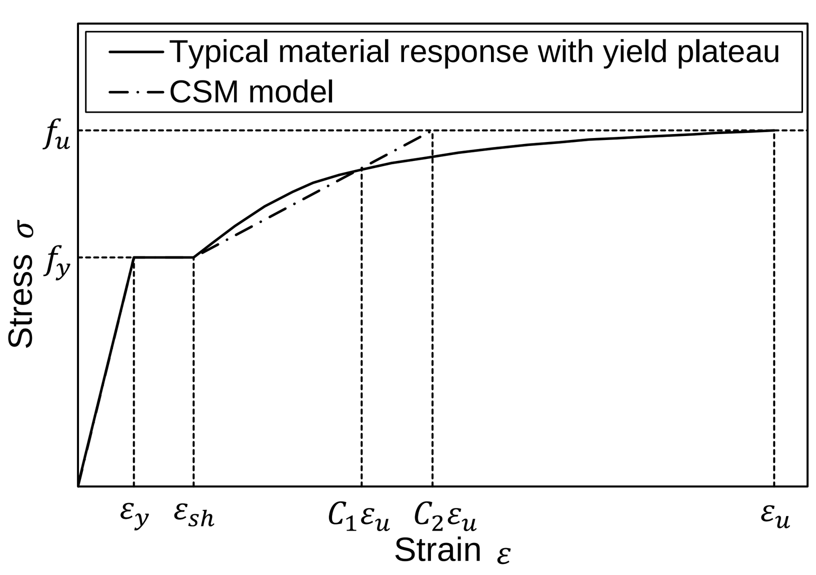
METHODOLOGY

Test data of HSS stub column and 4-point bending test were gathered and combined with stainless steels and other carbon steels for the development of design base curve.

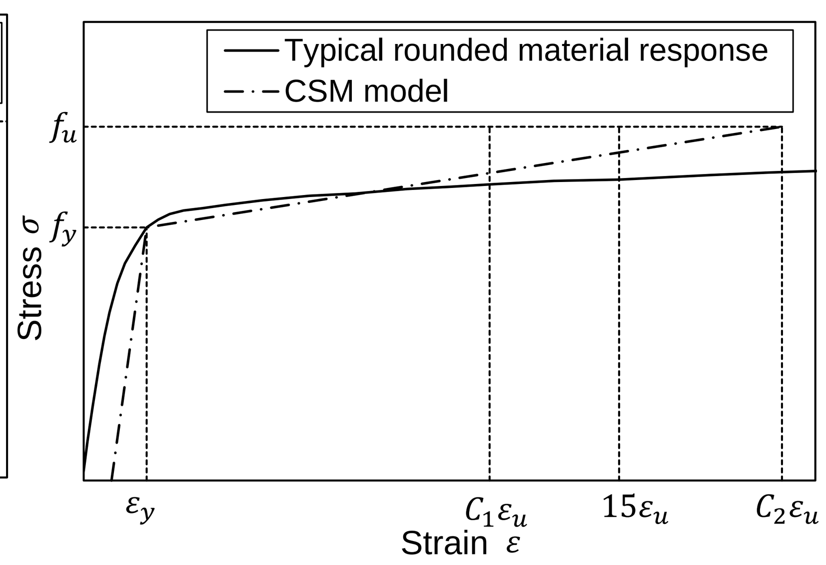


Base curve, based on stainless steel, carbon steel and high strength steel test data

The material response of HSS depends on the manufacturing process HSS (i.e. hot-finished, tempered and quenched (Q&T), normalised, cold-formed, thermo-mechanical rolled (TMCP)), two material models were proposed for corresponding material response.



A typical stress-strain curve with yield plateau and the proposed tri-linear model



A typical rounded stress-strain curve and the proposed bi-linear model

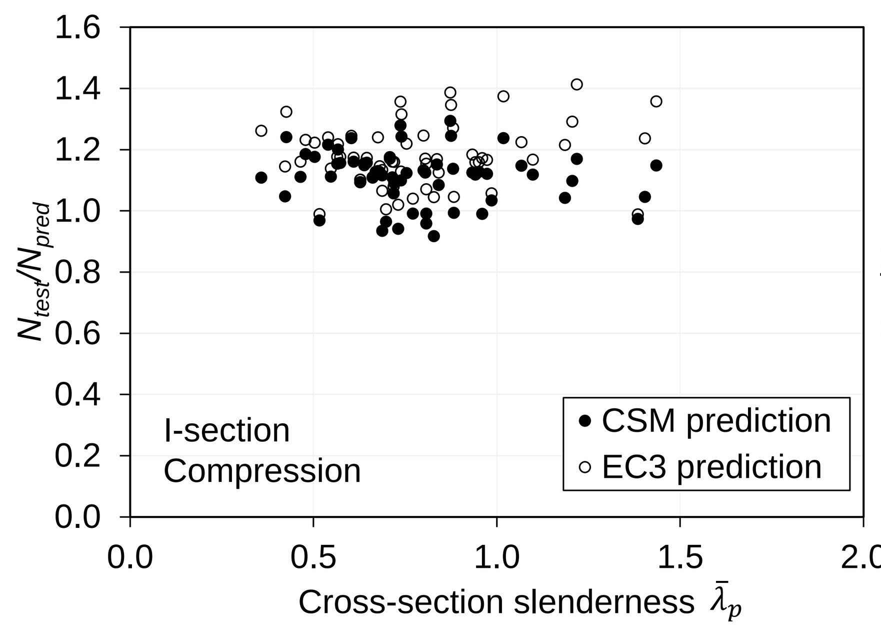
MATERIAL RESPONSE

The table below summarises the typical material response of different types of HSS sections, based on 193 coupon tests.

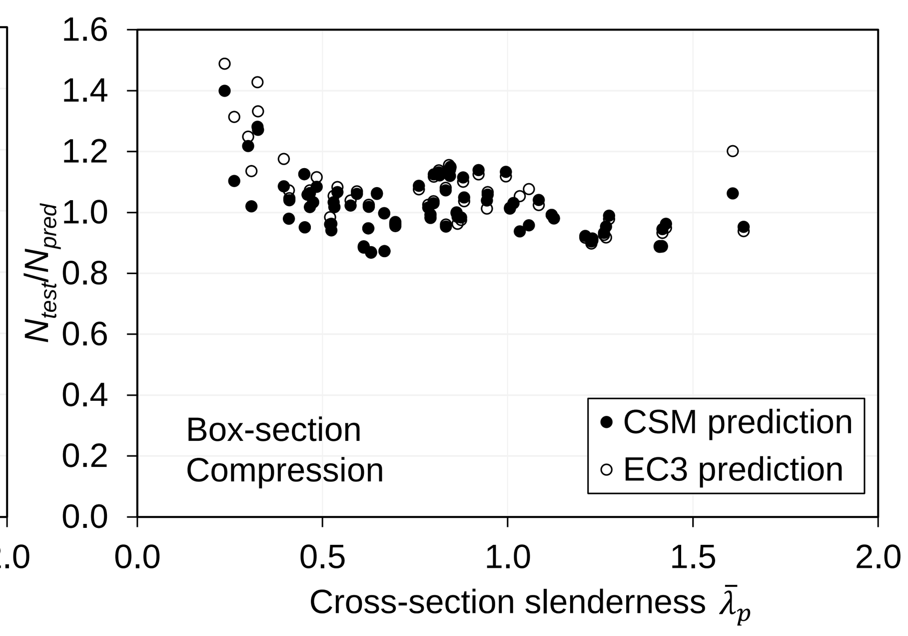
Material response	Material types
Rounded stress-strain behaviour	Hot-finished or welded sections with Q&T or TMCP HSS as base material Cold-formed section
Stress-strain behaviour with yield plateau	Hot-finished or welded sections with normalised HSS as base material

RESULTS AND CONCLUSIONS

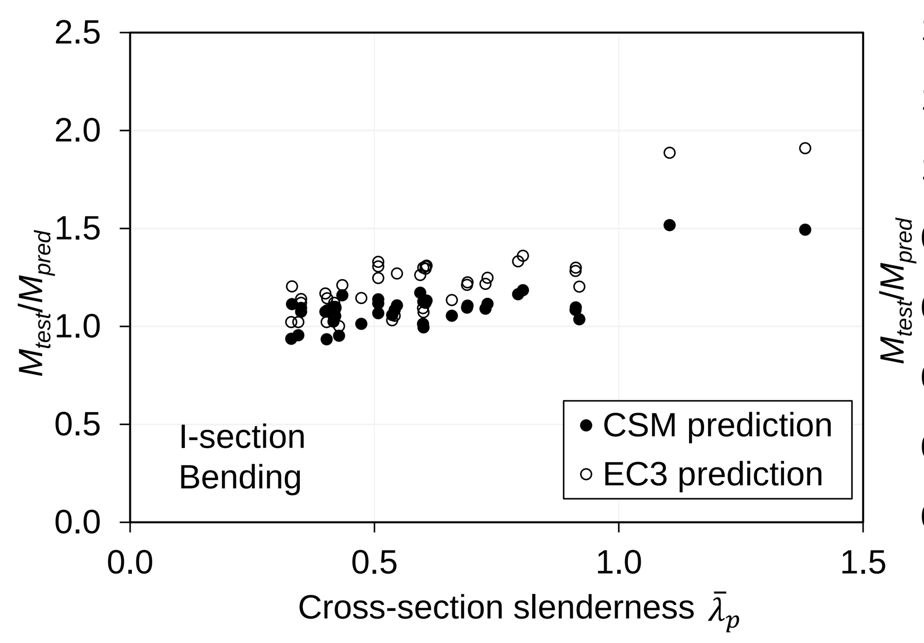
The predictions from the CSM (N_{pred}, M_{pred}) have been compared with the experimental results (N_{test}, M_{test}) on HSS I-section and Box-section stub columns and beams, and show that the CSM improved the mean resistance predictions and reduced scatter, as compared to the EN 1993-1-12 design rules.



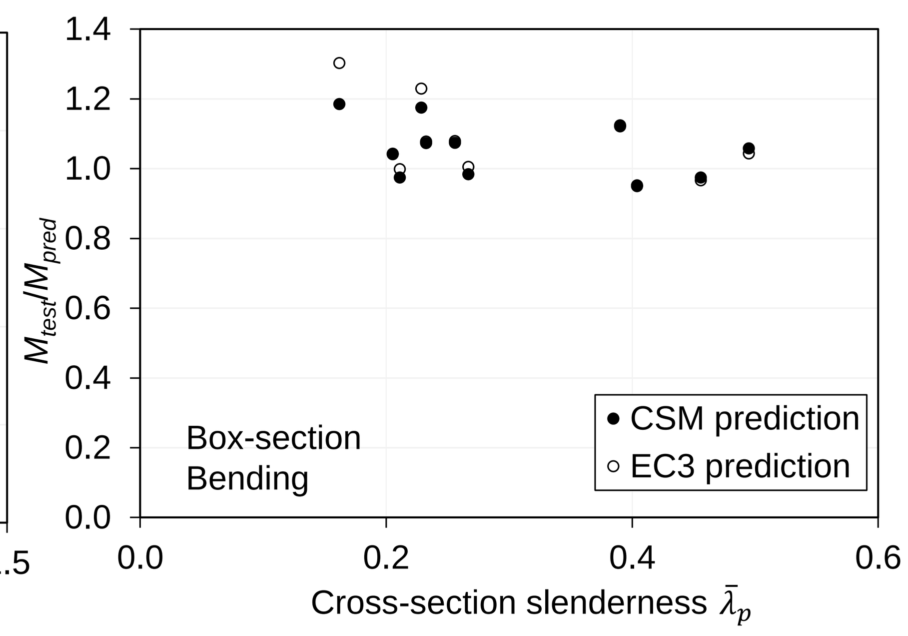
Comparison of the I-section stub column tests with the CSM and EC3 predictions



Comparison of the box-section stub column tests with the CSM and EC3 predictions



Comparison of the I-section beam tests with the CSM and EC3 predictions



Comparison of the box-section beam tests with the CSM and EC3 predictions

No. of tests: 21	N_{test}/N_{EC3}	N_{test}/N_{csm}	N_{csm}/N_{EC3}
Mean	1.177	1.140	1.062
COV	0.062	0.055	-

Comparison of the CSM and EC3 predictions with I-section stub column test results for $\bar{\lambda}_p \leq 0.68$

No. of tests: 21	N_{test}/N_{EC3}	N_{test}/N_{csm}	N_{csm}/N_{EC3}
Mean	1.090	1.053	1.032
COV	0.138	0.114	-

Comparison of the CSM and EC3 predictions with box-section stub column test results for $\bar{\lambda}_p \leq 0.68$

No. of tests: 11	M_{test}/M_{EC3}	M_{test}/M_{EC3}	M_{csm}/M_{EC3}
Mean	1.075	1.056	1.016
COV	0.101	0.077	-

Comparison of the CSM and EC3 predictions with I-section beam test results for $\bar{\lambda}_p \leq 0.68$

No. of tests: 22	M_{test}/M_{EC3}	M_{test}/M_{EC3}	M_{csm}/M_{EC3}
Mean	1.133	1.057	1.071
COV	0.084	0.060	-

Comparison of the CSM and EC3 predictions with box-section beam test results for $\bar{\lambda}_p \leq 0.68$

The importance of strain hardening in the design of HSS structures was highlighted. The CSM offers improved cross-section resistance predictions of up to 27% and lower scatter over traditional design methods, leading to more economical design.

ACKNOWLEDGEMENTS

I would like to express my gratitude to Professor Leroy Gardner for his continued patience and kind support, as well as his research associate, Jie Wang.

REFERENCES

Afshan, S. & Gardner, L. (2013) The continuous strength method for structural stainless steel design. *Thin-Walled Structures.* 6842-49.

Buchanan, C., Gardner, L. & Liew, A. (2016) The continuous strength method for the design of circular hollow sections. *Journal of Constructional Steel Research.* 118207-216.