Numerical study of the structural response of S460 & S690 beams

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1. Introduction

Increasing demands for sustainable and light structures together with the technological advances in material science brought high strength steel (HSS) into the construction market over the past decades. The principal benefit that HSS offers is the weight reduction which is achieved thanks to its high yield capacity. Apart from that, benefits by the use of HSS in building applications include more elegant and iconic solutions as well as more sustainable design due to reduced raw material, energy use and carbon emissions. Applications of HSS in building engineering are depicted in Figure 1.1.

Figure 1.1 Application of HSS at the Friends Arena Stadium in Sweden and at the Airbus Hangar in Frankfurt, Germany

2. Methodology

The aim of the current study is to investigate the structural response of HSS beams. To achieve this, the following methodology is adopted:

- ❖ Development of finite element (FE) model
- ❖ Validation of the FE model against the experimental results of HILONG project
- ❖ Execution of parametric studies
- ❖ Evaluation of the results
- ❖ Assessment of Eurocode 3

The general purpose FE software ABAQUS [1] is utilized for the fulfilment of the aforementioned steps. Both linear (Eigenbuckling) and non-linear (Riks) analysis are performed during the research, whereas the 4-noded elements (S4R) with material properties from HILONG project [2] are incorporated in the models.

3. Development of FE model and validation against 11 & 11 bending tests

- ❖ 11 (3 point, L/H=10) & 11 (4point, L/H=20) bending tests were validated
- ❖ 5 imperfection magnitudes were assessed

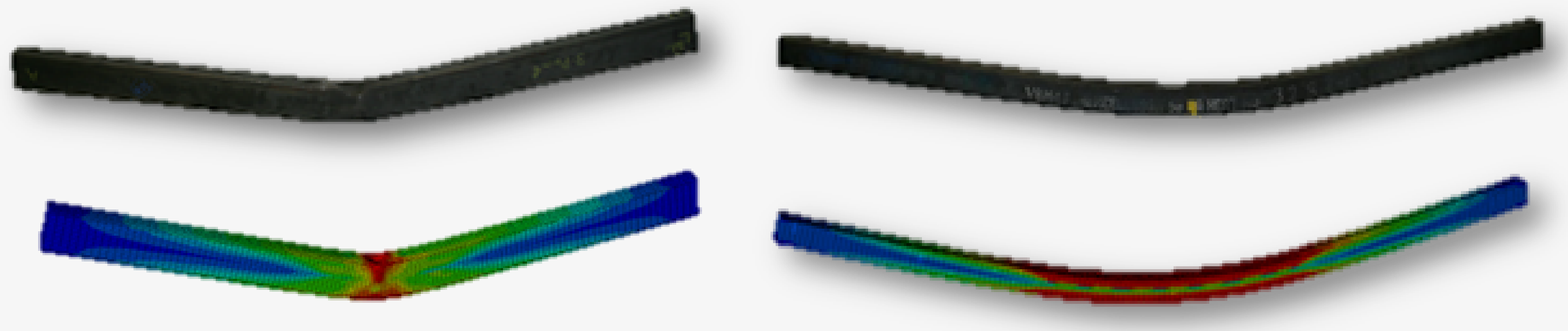


Figure 3.1 Typical experimental and numerical failure modes of RHS and SHS 3pt and 4pt bending beams respectively

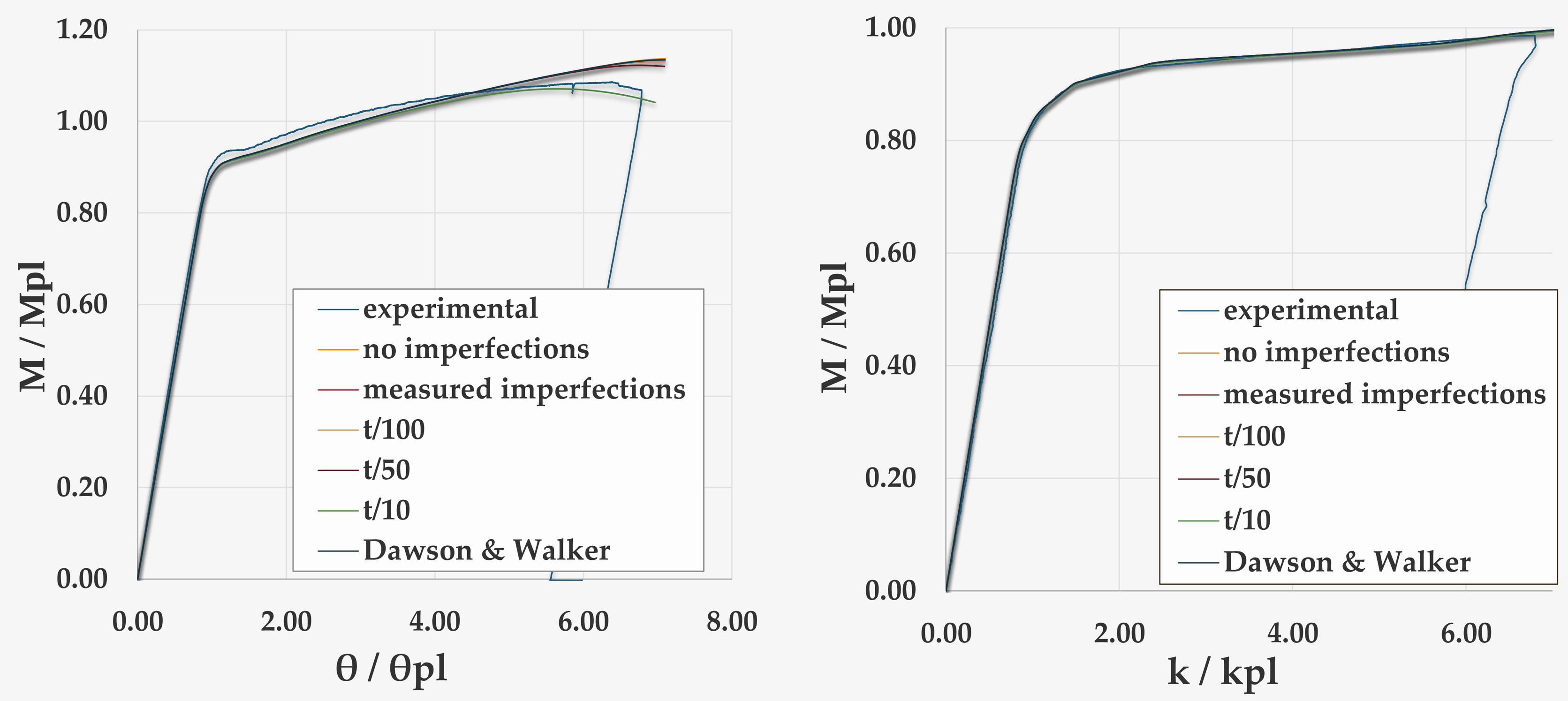


Figure 3.2 Typical experimental and numerical curves - moment-rotation for 3point bending and moment-curvature for 4point bending

4. Parametric studies

Varying thickness to provide cross-sectional slenderness ct/ε = 10÷90

- ❖ t = 1.52÷10.03mm for steel grade S460
- ❖ t = 1.89÷11.71mm for steel grade S690

Three testing configurations

- ❖ 3pt bending test with beam span of L=10xH
- ❖ 3pt bending test with beam span of L=20xH
- ❖ 4pt bending test with beam span of L=20xH

Three sections with aspect ratios 1.0, 2.0 and 2.44:

- ❖ SHS 100x100 (H/B=1)
- ❖ RHS 200x100 (H/B=2)
- ❖ RHS 200x100 (H/B=2.44)

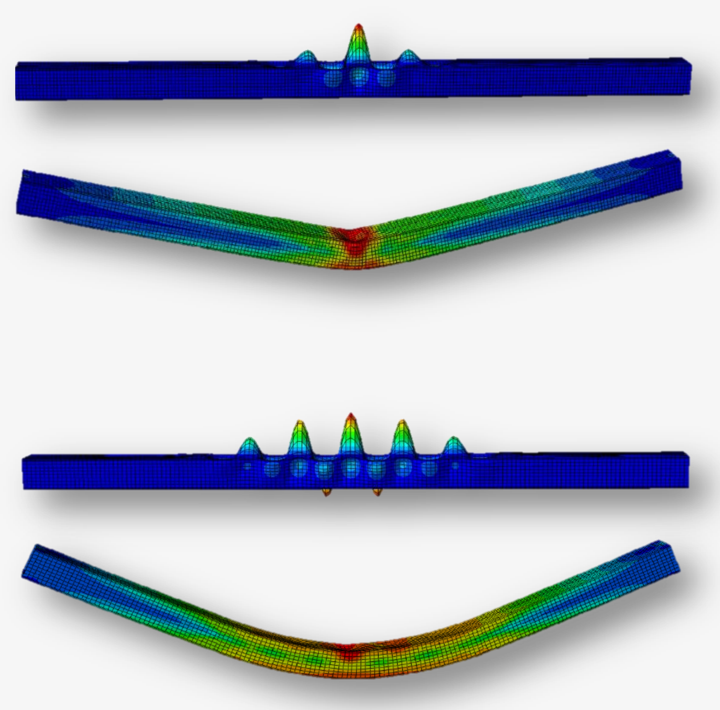
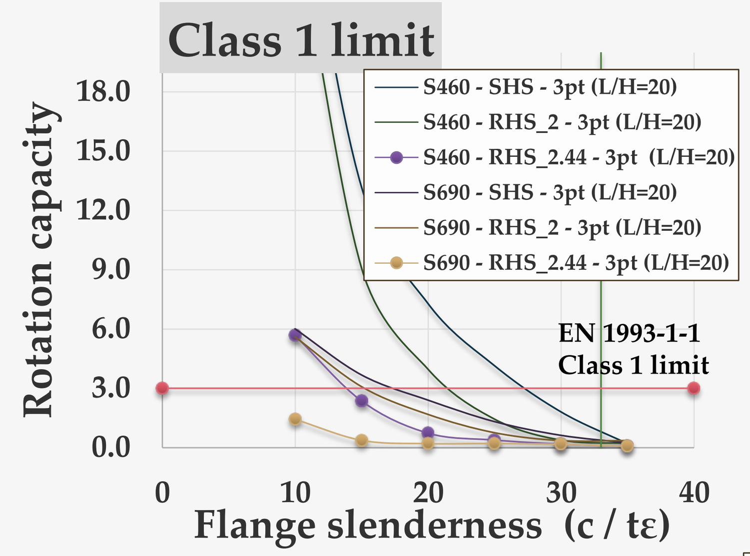
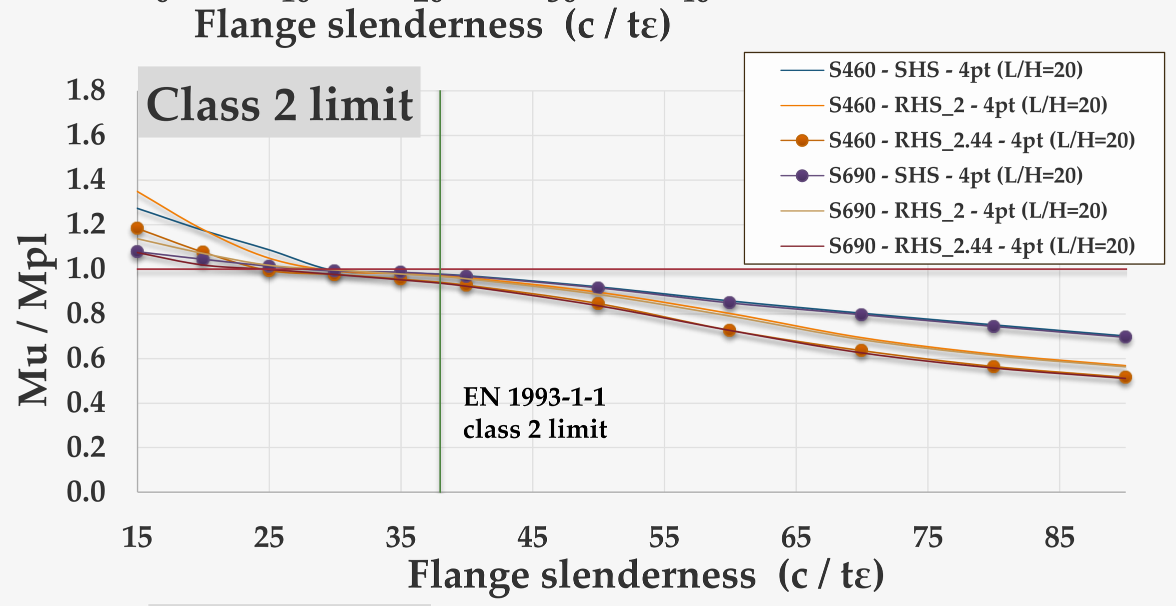


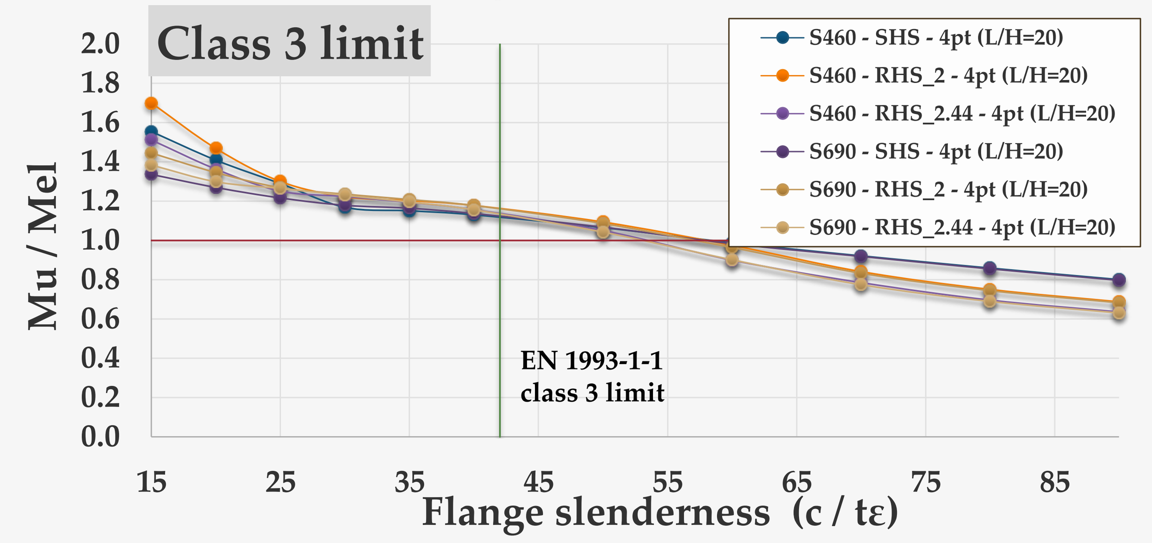
Figure 4.1: Typical linear and non-linear buckling for SHS 3pt and 4pt bending tests

5. Evalutaion of the results and assessment of Eurocode 3



- ❖ Slenderness limits=codified treatment of local buckling
- ❖ Depend on the support conditions of the constituent plate elements, the imposed stress distribution and the material yield strength





Figures 5.1, 5.2, 5.3: Assessment of Eurocode 3 slenderness limits

6. Conclusions

- ❖ Overall very good agreement between experimental and numerical results was achieved
- ❖ Conclusions regarding the applicability of slenderness limits for HSS
  - ❖ Class 1 limit not suitable for plastic design
  - ❖ Class 2 limit slightly unconservative
  - ❖ Class 3 limit non-economic

7. References

1. Hibbitt, Karlsson, Sorensen Inc. ABAQUS, (2010) ABAQUS/Standard user's manual volumes I–III and ABAQUS CAE manual. Version 6.10. USA: Pawtucket

2. Theofanous M, Gardner L. Report on tests (material, stub columns and beams). HILONG Background document D2.1, 2014: Pawtucket: 2010