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BUCKLING OF STAINLESS STEEL COLUMNS AT ELEVATED TEMPERATURE

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INTRODUCTION

Historically, the use of stainless steels was regarded as an extravagant solution because of its high initial costs. The inherent corrosion resistance and superior material strength and stiffness retention at elevated temperature of stainless steels accelerate its use in conventional structures. A comprehensive numerical modelling was conducted to investigate the structural performance at elevated temperatures and focused on the suitability of using two strength parameters, 0.2% proof stress, $f_{0.2}$ and stress at 2% total strain f_2.

STRESS-STRAIN BEHAVIOUR OF STAINLESS STEELS

The most significant difference between carbon steels and stainless steels is the stress-strain behaviour.

Carbon Steels	Stainless Steels
Linear elastic until yield	Rounded response
Sharp yield	No-well defined yield

The stress at 0.2% plastic strain (0.2% proof stress) is generally adopted for stainless steel design and analysis as the 'equivalent' yield.

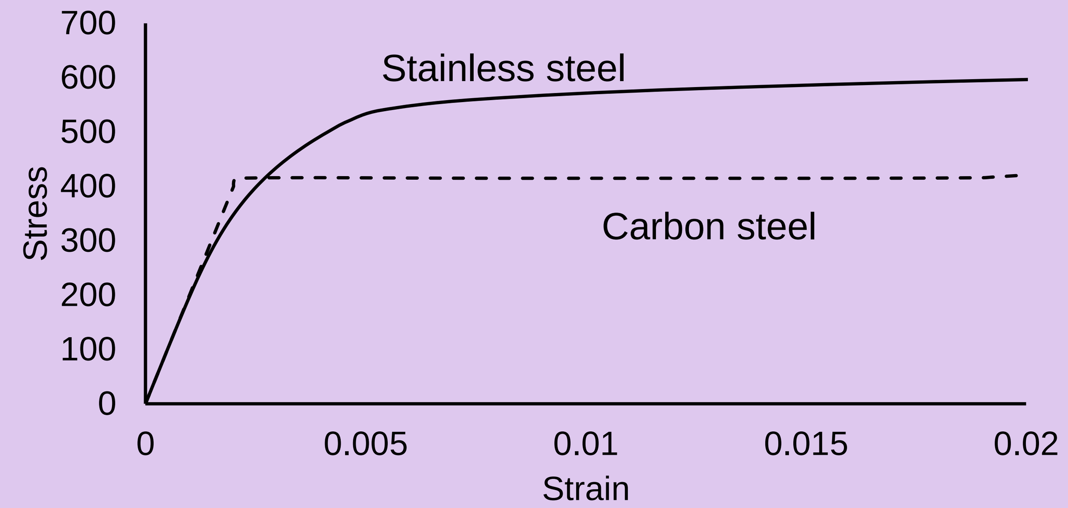

Figure 1: Stress-strain behaviour

STAINLESS STEELS AT ELEVATED TEMPERATURE

Stainless steel structural members had greater fire resistance compared to equivalent carbon steel members. Stainless steels offered better retention of strength and stiffness at elevated temperature from the beneficial effects of the alloying elements as shown in Figure 2 and 3.

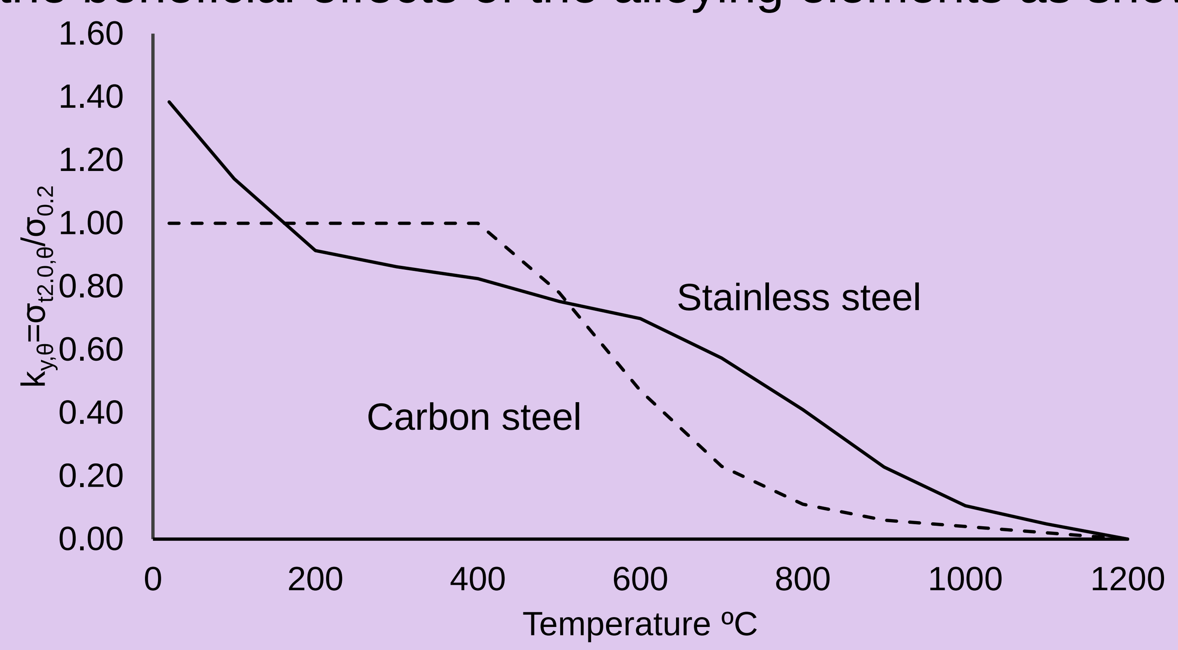

Figure 2: Strength reduction factors at elevated temperatures

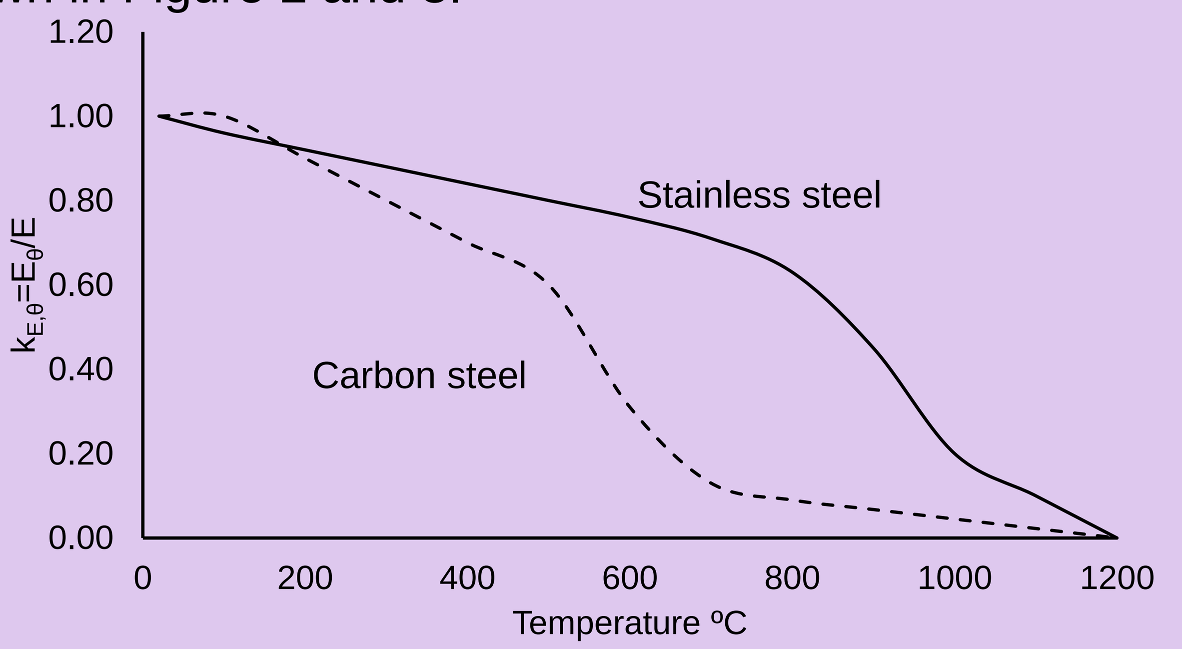

Figure 3: Stiffness reduction factor at elevated temperatures

FINITE ELEMENT MODELLING

The non-linear finite element analysis package ABAQUS (2015) was used to develop numerical models for predicting the fire resistance of stainless steel columns.

Validation against experimental results → Parametric studies with fixed cross-section but varying lengths at different temperatures → Elastic buckling analysis for local and global buckling mode → Non-linear stress analysis for ultimate loads

ACKNOWLEDGEMENTS

I would like to express my gratitude to Professor Leroy Gardner for his guidance and support, as well as Dr. Sheida Afshan.

FINITE ELEMENT MESH

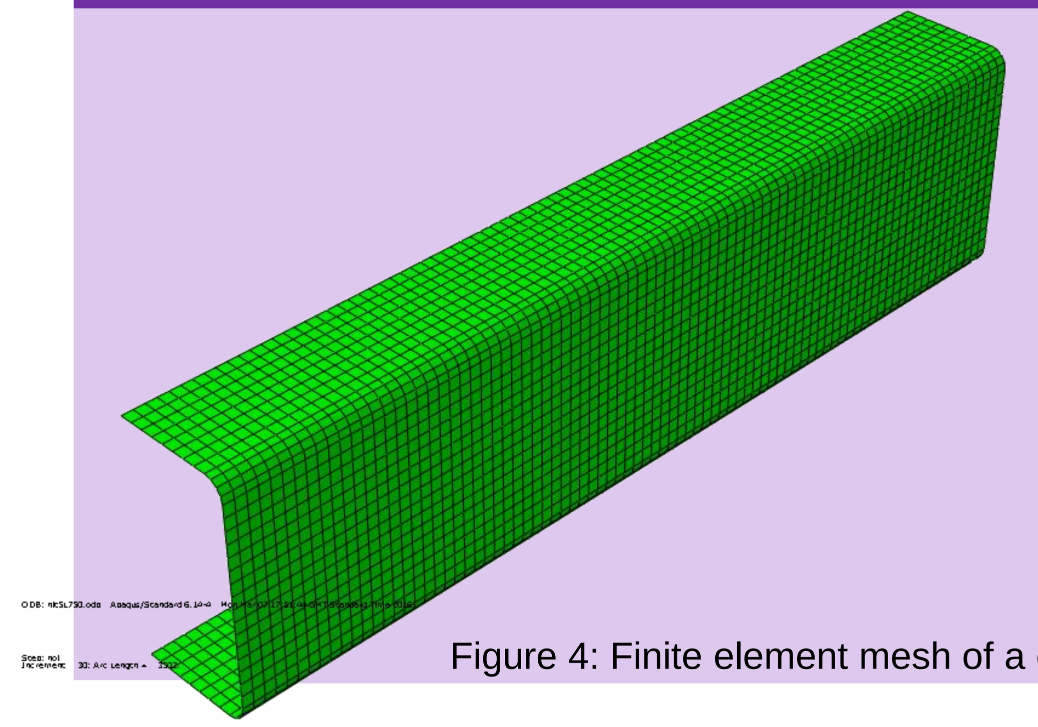
Figure 4: Finite element mesh of a column

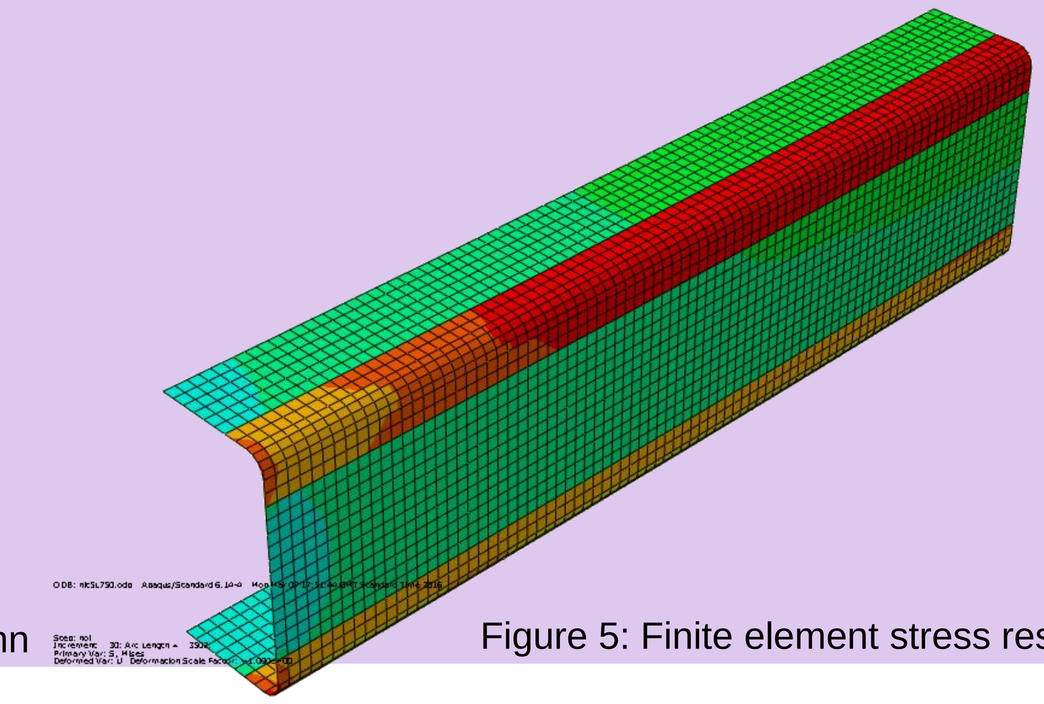
Figure 5: Finite element stress result of the column

RESULTS AND ANALYSIS

The ultimate loads over various lengths at different temperatures were obtained from the finite element results. The obtained ultimate loads were normalized by $A_{avg}f_{0.2}$ or $A_{avg}f_2$ squash loads to calculate χ to obtain buckling curves as shown in Figure 6 and 7.

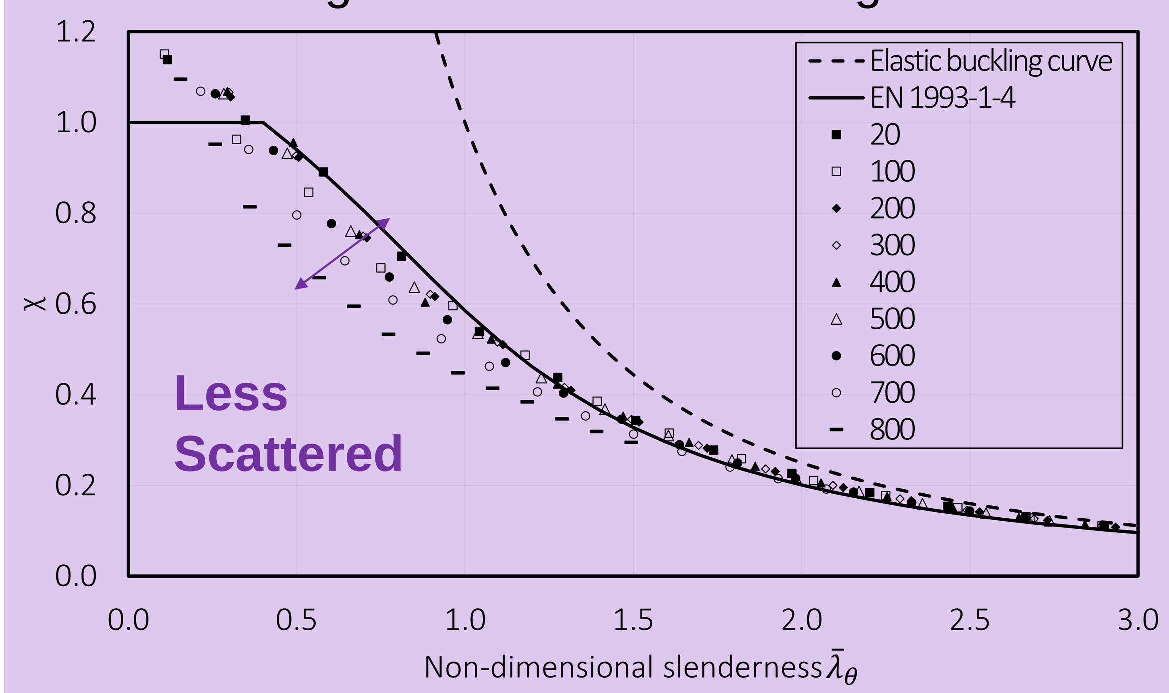

Figure 6: Flexural Buckling curve normalised by **0.2% proof stress**

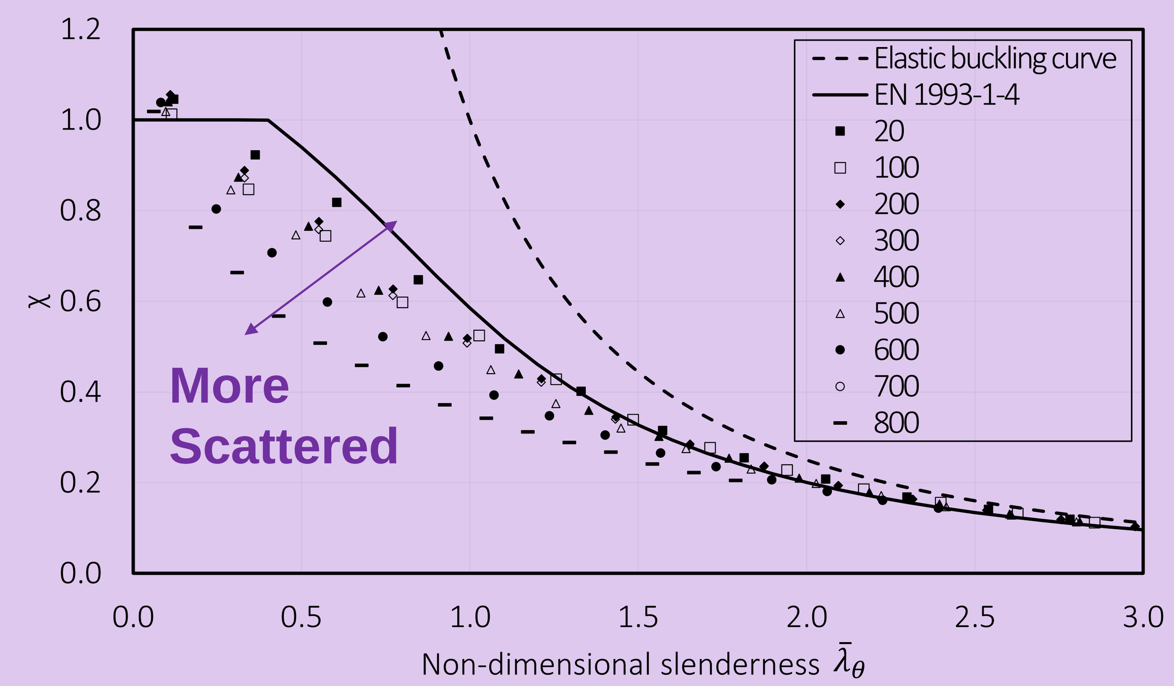

Figure 7: Flexural Buckling curve normalised by **stress at 2% total strain**

✓ **0.2% proof stress $f_{0.2}$**	X **Stress at 2% total strain f_2**
Points closer together	Points more scattered
Close to failure stress	Far away from failure stress

The failure stress is lower than the 0.2% proof stress because of the highly nonlinear stress-strain behaviour of stainless steels. The following methods can be adopted to account for the nonlinearity:

- Tangent modulus method
- Rasmussen-Rondal model

CONCLUSIONS

- 0.2% proof stress was more appropriate than stress at 2% total strain as basis for column design in fire
- Tangent modulus and Rasmussen-Rondal model accurately capture the buckling stress for columns of nonlinear stress-strain behaviour
- Rasmussen-Rondal model is rather complicated for practical design and simplified relationship was proposed

REFERENCES

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