Strengthening Steel Beams with Carbon Fibre Reinforced Thick Epoxy Coatings

by Karoline Horn Baksaas

Steel and CFRP

Steel structures may experience structural degradation over time. With loss of structural performance and capacity, for instance due to corrosion, strengthening of members may be required in order to continue to withstand the loads acting on the structure.

Carbon fibre reinforced polymers (CFRPs) are lightweight composite materials with high tensile strength and good corrosion and fatigue resistance [1]. With these characteristics the material can be highly preferable for structural strengthening purposes.

This project investigated the effect of strengthening steel I-beams with CFRP wrapping embedded in a 10mm thick epoxy coating serving as structural fire protection.

Beam Configuration

Five 3000mm simply supported UKB beam in four-point bending were used in the numerical analysis (Fig.1).

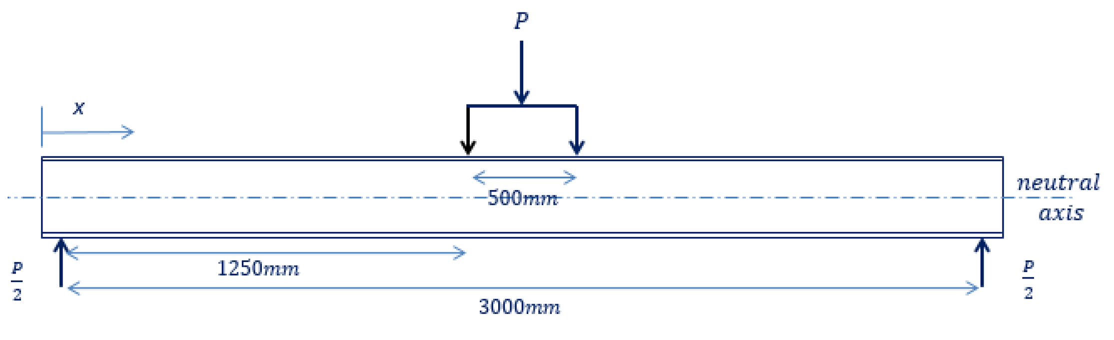

Figure 1 Beam configuration

Numerical Analysis

- Based on Euler-Bernoulli theory of layered beams
- Initial plane section analysis performed to determine moment-curvature relationship
- Load-displacement relationship derived from moment-curvature

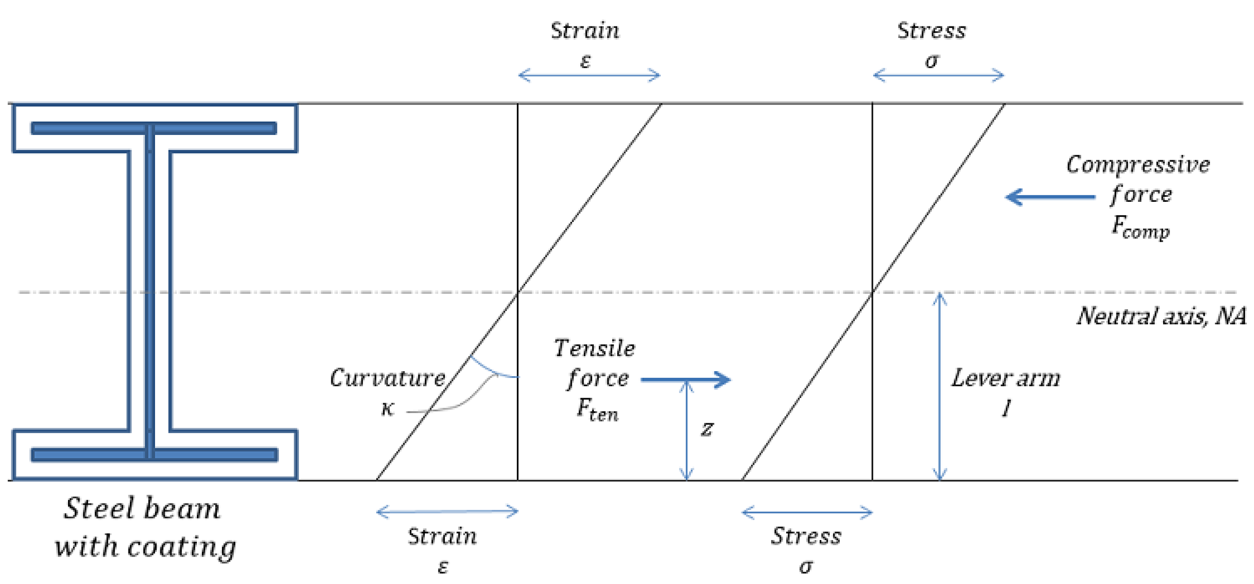

Figure 2 Plane section strain and stress distribution

- Bending moment (M) and curvature (κ)

$$\mathrm{M} = \int_A \sigma(\varepsilon) \times l_{PNA}\, dA \qquad \kappa = \frac{\varepsilon}{l}$$

- Vertical displacement (δ) and load carrying capacity (P)

$$\delta = \int_0^L m(x) \times \kappa(x) dx \qquad \mathrm{P} = \frac{\mathrm{M}}{x}$$

Results and Discussion

- Average increase in ultimate load carrying capacity was 24.2% at the lowest level of strengthening (carbon fibre volume fraction of 2%)
- An average 39.6% increase in ultimate load carrying capacity was found for the coating with a 4% carbon fibre volume fraction
- No correlation between strength increase and plastic modulus was found (Fig.3)

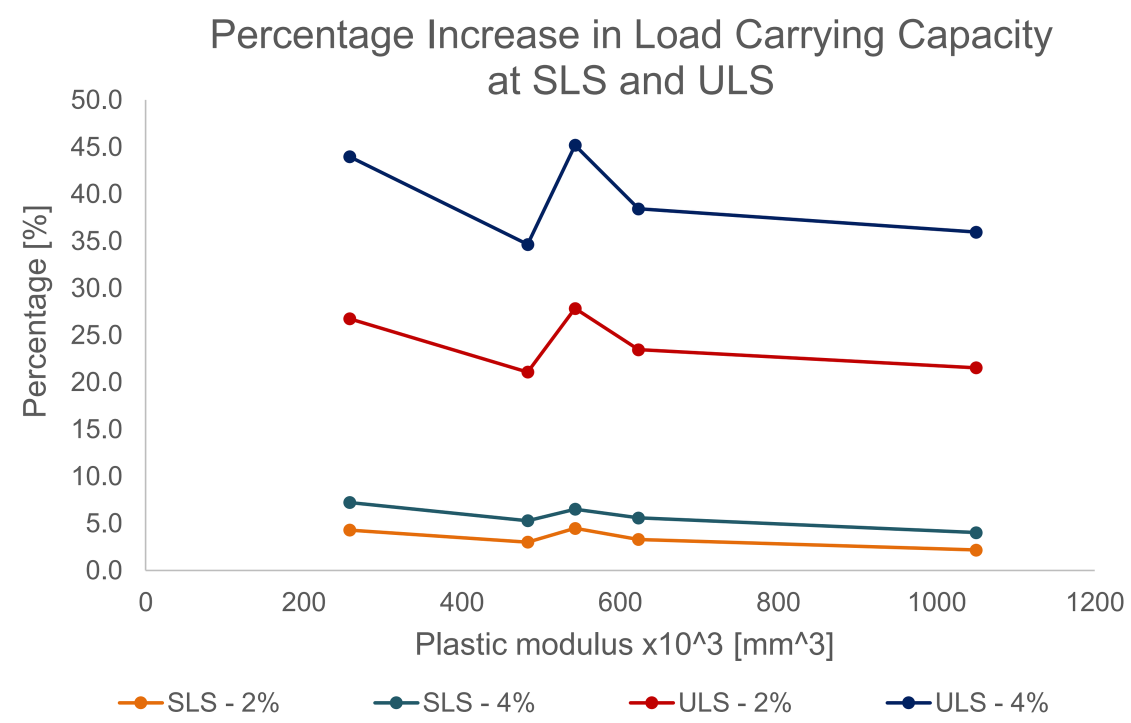

Figure 3 Percentage increase in strength vs plastic modulus

- Strengthening the corroded beams increased the strength by 21.9%, 22.8% and 26.0% (Fig.4)

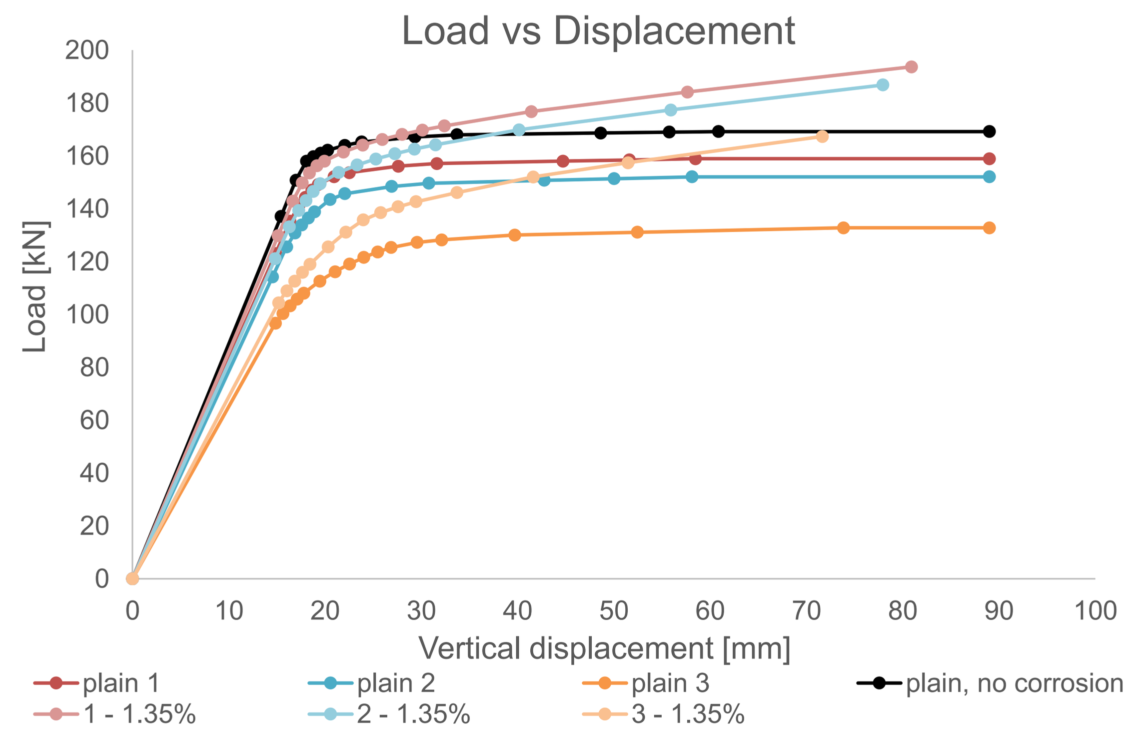

Figure 4 Load-displacement relationship of corroded beams

Conclusions

- Strengthening steel I-beams with carbon fibre reinforced coating effectively increases the strength of the member
- Increasing the amount of carbon fibres in the coating effectively increased the gain in strength
- Application of coating resulted in a more brittle behaviour after yielding of the steel
- Strengthening corroded beams restored their load carrying capacity to the load capacity of the uncorroded state

Reference

[1] Callister, W. and Rethwisch, D., *Material Science and Engineering: An Introduction*, 8th edition, John Wiley & Sons (2011).

Contact details:
karoline.horn.b@gmail.com