Innovative strategies for the strengthening of railway metallic bridges using fibre reinforced polymers (FRPs) to improve the fatigue behaviour of connections between elements

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1. MOTIVATION

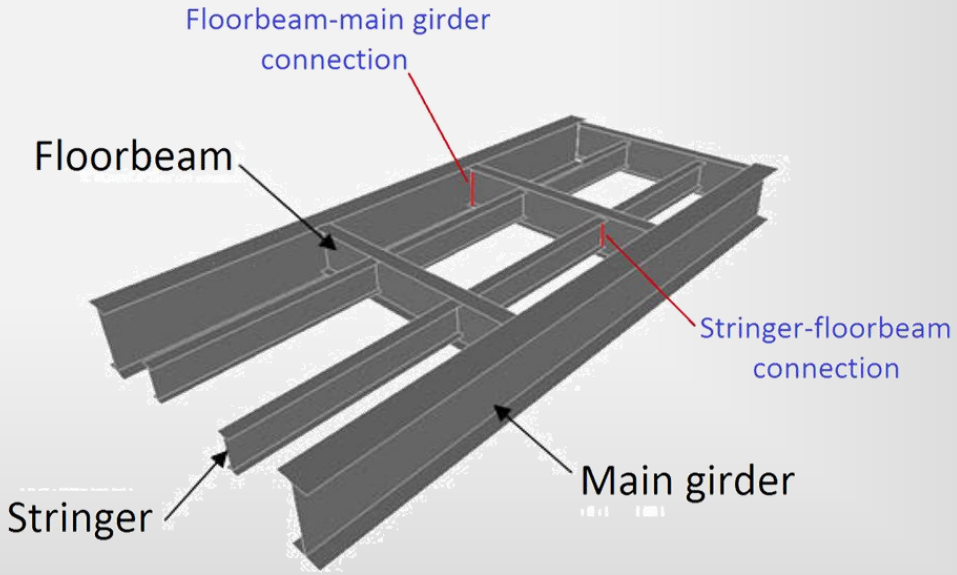
Problem: Existing railway metallic bridges are aging

70% more than 50 years and still in service!

Causes of degradation:

- Lack of maintenance
- Corrosion
- Traffic increase
- **Fatigue**

Distortion-induced **fatigue** in riveted steel truss bridges



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1. MOTIVATION

Distortion-induced **fatigue** in riveted steel truss bridges

Where?

Fatigue-prone details

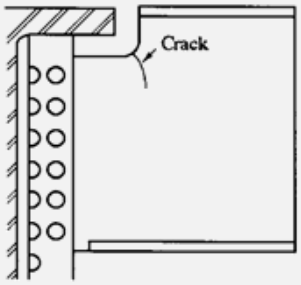
Connections between orthogonal elements:

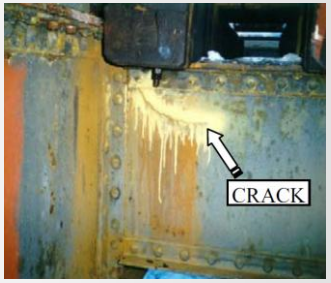
- Stringer-floorbeam connections
- Floorbeam-main girder connections

Why?

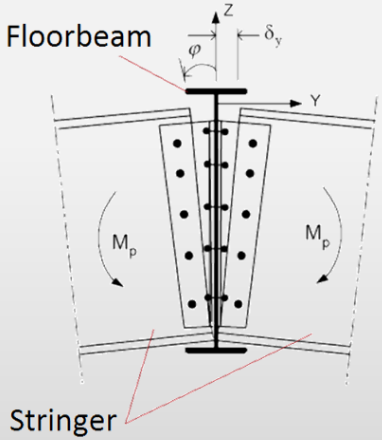
Result of secondary restraining forces between different elements in the bridge

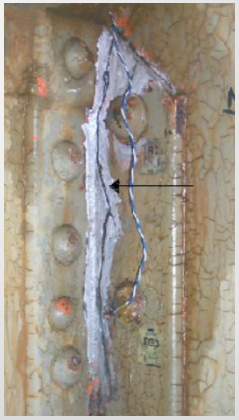
Example: Fatigue crack in **coped web** [1]





Example: Fatigue crack in **connecting angle** [2]





[1] *J. Gocál et al. 2010*

[2] R. *Haghani et al. 2012*

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2. OBJECTIVE

Main objective:

Extend the fatigue lifetime of **railway metallic bridges** through the development and validation of **FRP strengthening new solutions** for the wide implementation of the technique in full-scale field structures.

Fibre reinforced polymers (FRP)

- No corrosion
- Lightweight
- Bonded joints
- Rapid installation

Fibre + Resin

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3. WORK PLAN

1. Study of bond strength between steel and CFRP

A. *Selection of materials*: steel, CFRP, adhesive

B. *Material characterization*:

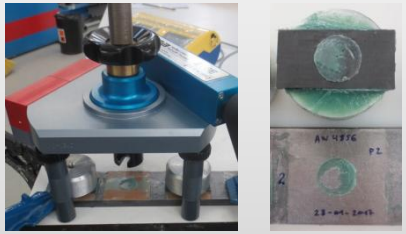
CFRP

- *Tensile tests*

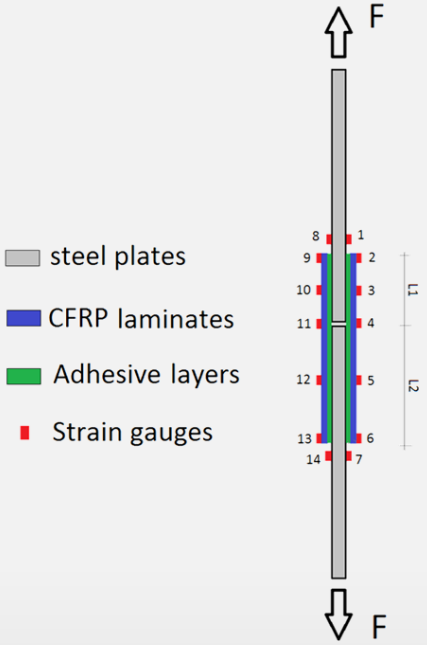
Adhesive

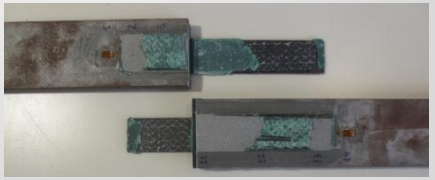
- *Single lap-shear tests*

- *Pull-off tests*



C. *Double-strap joint tests*





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3. WORK PLAN

1. Study of bond strength between steel and CFRP

Double-strap joint tests

Analytical evaluation

$$P_{ult} = b_p \min\{P_i, P_o\}$$

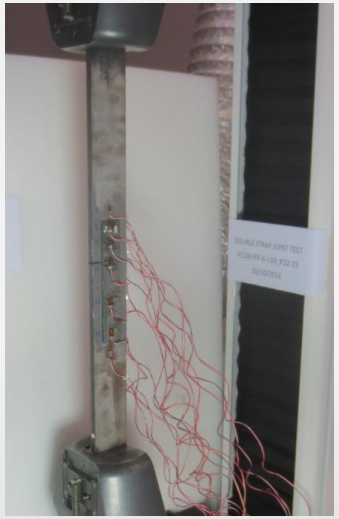
$$P_i = \sqrt{2\tau_f t_a \left(\frac{1}{2}\gamma_e + \gamma_p\right) 2E_{steel}t_{steel}\left(1 + \frac{E_{steel}t_{steel}}{2E_{CFRP}t_{CFRP}}\right)}$$

$$P_o = \sqrt{2\tau_f t_a \left(\frac{1}{2}\gamma_e + \gamma_p\right) 4E_{CFRP}t_{CFRP}\left(1 + \frac{2E_{CFRP}t_{CFRP}}{E_{steel}t_{steel}}\right)}$$

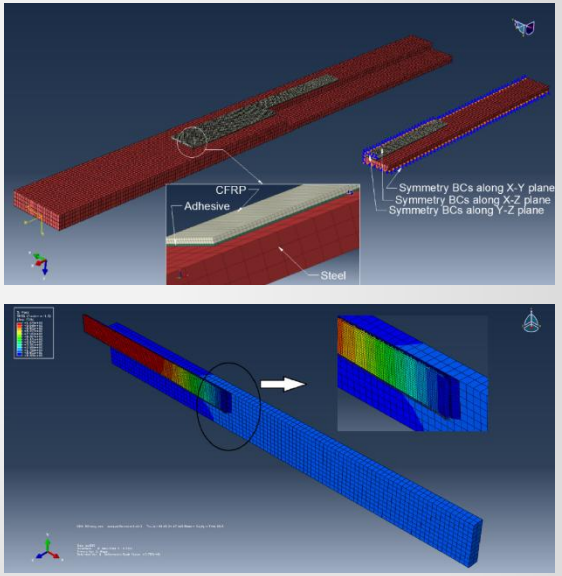
$$L_e = \frac{P_{ult}}{2\tau_f b_p} + \frac{2}{\lambda} \qquad \lambda = \sqrt{\frac{G_a}{t_a}\left(\frac{1}{E_{CFRP}t_{CFRP}} + \frac{2}{E_{steel}t_{steel}}\right)}$$

$$P_{ult,1} = P_{ult} L_1 / L_e \text{ for } L_1 < L_e$$

Experimental validation



Numerical simulation



[3] *A. Al-Mosawe et al. 2015*

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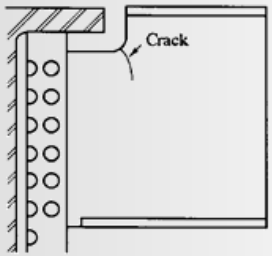
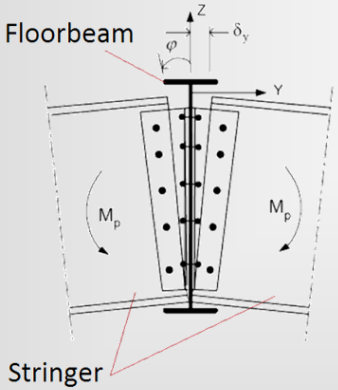
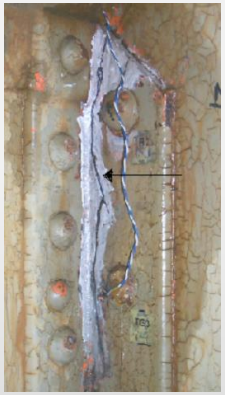
3. WORK PLAN

2. FRP strengthening strategy for the fatigue-prone detail *(next steps)*

Stress reduction in fatigue-prone detail







FRP strengthening of metallic railway bridge

Fibre + Resin

4. SCIENTIFIC ACTIVITY

Conference papers (2016-2017)

Jiménez-Vicaria, J. D., G. Pulido, M.D. and Castro-Fresno, D. *Numerical evaluation of the bond behaviour in CFRP-steel double-strap joints*. 4th International Conference on Mechanical Models in Structural Engineering (CMMoST 2017), 29 Nov - 01 Dec 2017, Madrid (Spain). Status: abstract accepted.

Jiménez-Vicaria, J. D., Sánchez-Sierra, P., Martínez Barriguete, E. y Paulotto, C. *Numerical and experimental evaluation of the dynamic response of a fibre reinforced polymers (FRP) lighthouse*. VII Congreso de ACHE (Asociación Científico-Técnica del Hormigón Estructural), 20-22 June 2017, A Coruña (Spain). Status: Accepted. Publication in journal: *Hormigón y Acero*. Status: Accepted (publication pending).

4. SCIENTIFIC ACTIVITY

Seminars (2016-2017)

JEC World 2017 Composites & Conferences. JEC Group, 14-16 March 2017, Paris (France).

Moving Bridges: Collaboration and Design, by David Knight (Flint & Neill, London), 17 Nov. 2016, EPS Universidad CEU San Pablo (Madrid).

Training courses (2016-2017)

Execution of bridges (17 Oct – 19 Dic 2016). Duration: 45 hours (on-line). Organiser: Structuralia S.A. Qualification: Distinction.

Research Projects (2016-2017)

In2Track Project: Research into enhanced tracks, switches and structures.
Participation as research engineer. Project duration: from 01/09/2016 to 28/02/2019.

One of main objectives: Investigate novel ways of extending the life of bridges through new approaches to maintain, repair and upgrade these structures.

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5. EVALUATION GUIDE

Basic competences	Science and Technique	Technology	Training courses	Results	SWOT analysis	Work plan	Mobility	Funding	Ethics
CB11	X	X	X						
CB12				x		X	x		
CB13				x					
CB14					X				
CB15				x			x		
CB16				x					X

Capacities and personal skills	Science and Technique	Technology	Training courses	Results	SWOT analysis	Work plan	Mobility	Funding	Ethics
CA01	X	X	X						
CA02				x					
CA03						X		X	
CA04			X				x		
CA05	X	X	X						
CA06					X				

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