Imperial College London

HIGH SPEED RAILWAY BRIDGES WITH PRECAST-PRESTRESSED CONCRETE BEAMS

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INTRODUCTION

High speed railway (HSR) introduces very heavy load scenarios to bridges, which in turn leads to strong vertical accelerations, to the extent that vertical accelerations are often a limiting factor in design.

Adapting the geometry and properties of a 29.9m long HSR bridge from Spain, three base case models were created, as seen from Table 1. These were used as a basis for parametric analyses on the strength, and section properties to determine the change in response of the accelerations.

Loading was based on Eurocode 1 (BSI, 2010), using the HSLM A model, modelling the loads as pressures in ABAQUS, onto the top slab of the bridge. The ABAQUS model is seen in Figure 1c

Table 1: Outline of the base case models, with reference to the cross sections in Figure 1

Base Case	Cross section	Concrete Slab Strength [MPa]	Concrete beam strength [MPa]
Base Case 1 (BC1)	a	25	55
Base Case 2 (BC2)	a	55	55
Base Case 3 (BC3)	b	55	55

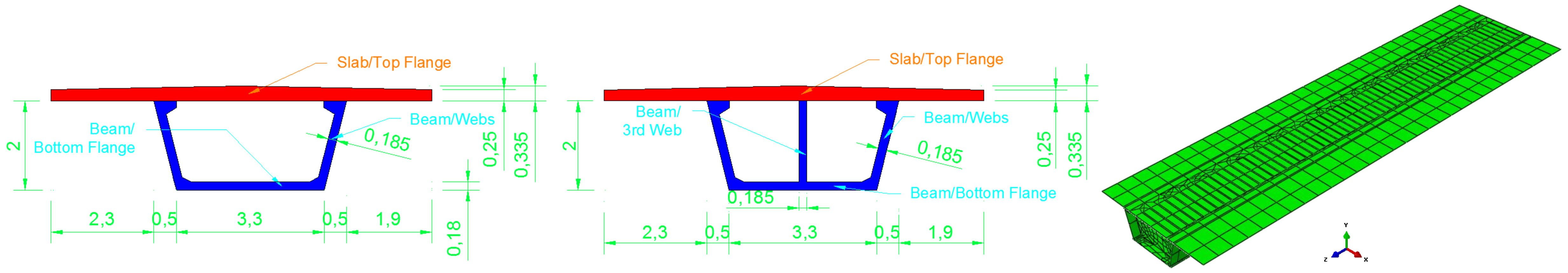

Figure 1: **(a)** Cross section for BC1 and BC2 (left), **(b)** cross section for BC3 (centre), and **(c)** ABAQUS model (right)

BASE CASE COMPARISON

Comparison of the three base cases showed that the accelerations experienced were highest in BC1 and lowest in BC3 as seen in Table 2. Interestingly the accelerations did not peak at midspan for BC1 and BC2 as seen in Figure 2. This showed an activation of bending modes beyond the first mode. BC3 had a variation of acceleration that matched what was expected of the first bending mode.

Table 2: Comparison of the results of the base case simulations

Base Case	Accelerations Experienced [m/s²]					
	½ Span		¼ span		¾ span	
	Peak	RMS	Peak	RMS	Peak	RMS
BC1	7.316	2.485	13.227	2.528	9.925	2.369
BC2	7.680	2.249	13.158	2.282	9.680	2.238
BC3	4.451	1.460	3.345	1.093	3.556	1.153

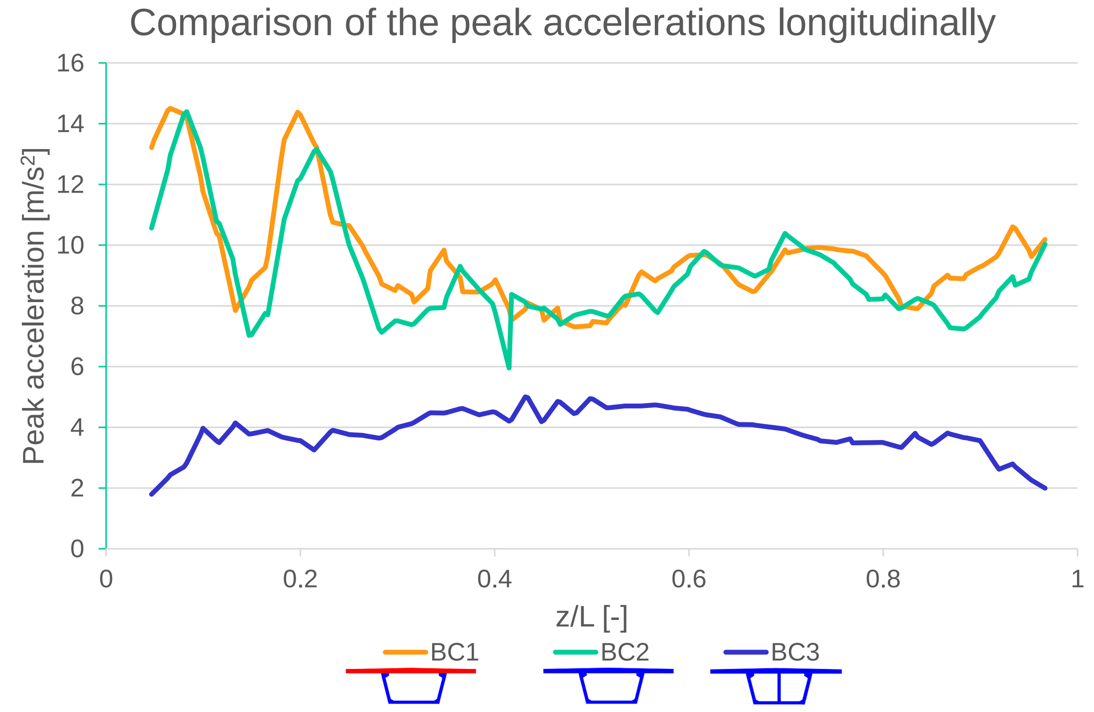

Figure 2: Variation of accelerations longitudinally along bridge for each Base Case

TIME HISTORY

A Fourier transform was performed on the signal, with the results in Figure 3 and Figure 4. The different locations show activation of different modes. Bending modes (V_i) showed the biggest contribution to accelerations, whereas torsional (T_i) and combined bending and torsional (C_i) appeared to not contribute to the vertical acceleration. Contributions also came from excitation frequency from the loading, as calculated by Equation 1

$$f_{S,n} = \frac{n \cdot v}{d}, \qquad (1)$$

where:
$f_{S,n}$ is the excitation frequency [Hz]
n is a constant 1,2,3,…
v is the velocity of the train [m/s]
d is the repeating distance between axles [m]

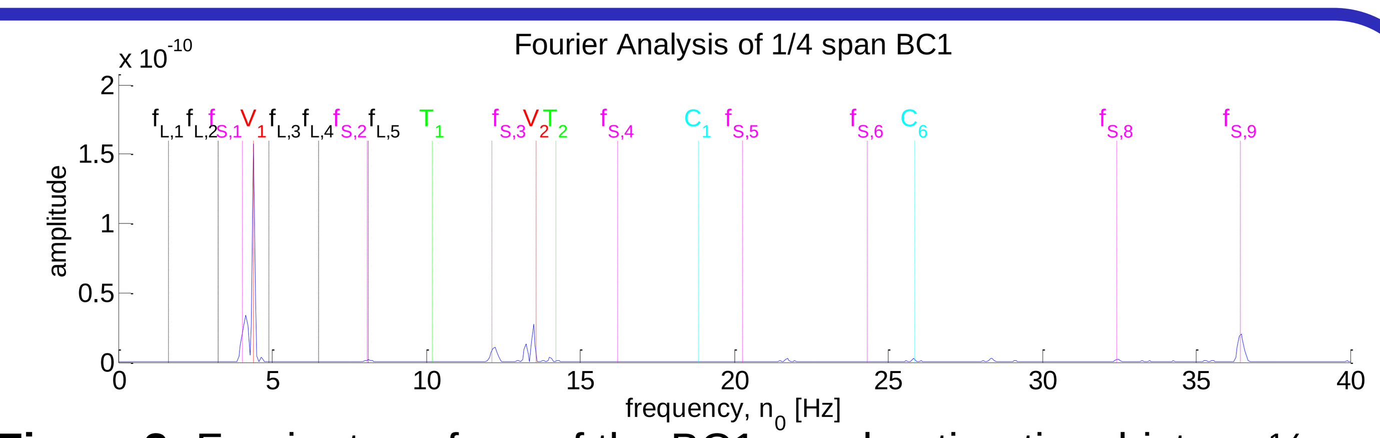

Figure 3: Fourier transform of the BC1 acceleration-time history, ¼ span

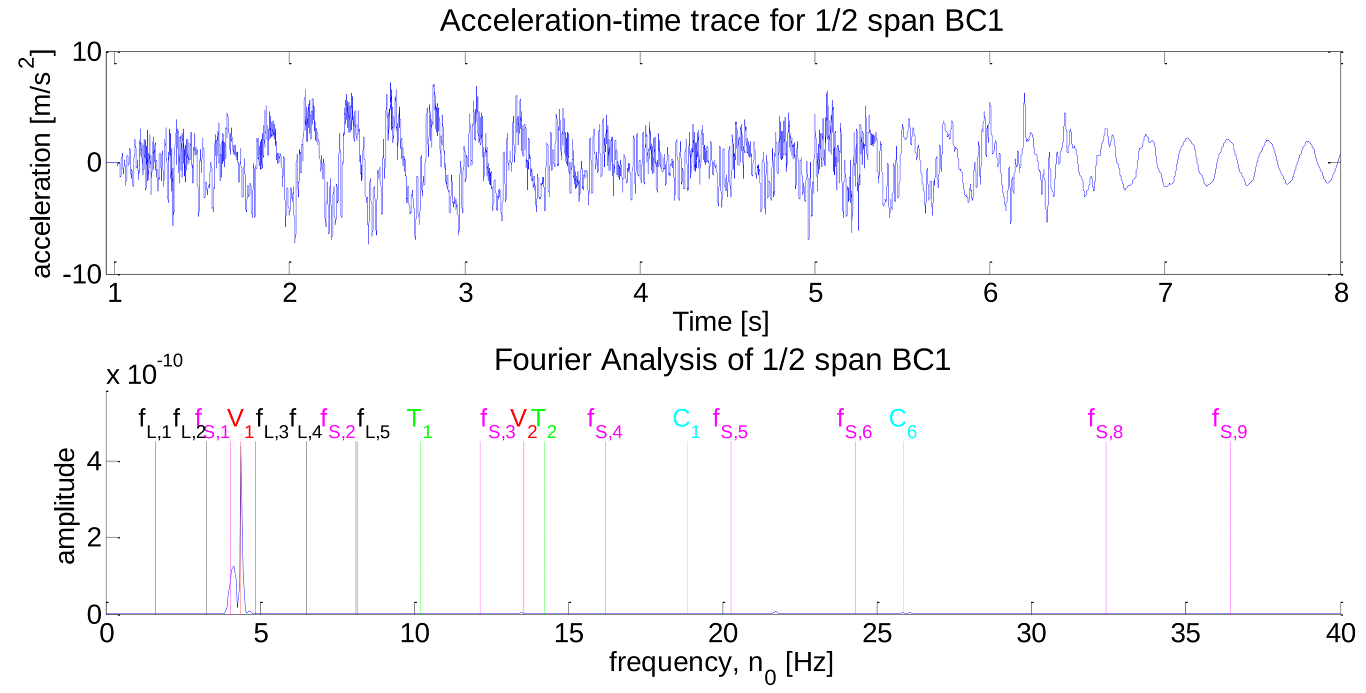

Figure 4: Time history and Fourier transform of the BC1 acceleration-time history, ½ span

PARAMETRIC ANALYSES

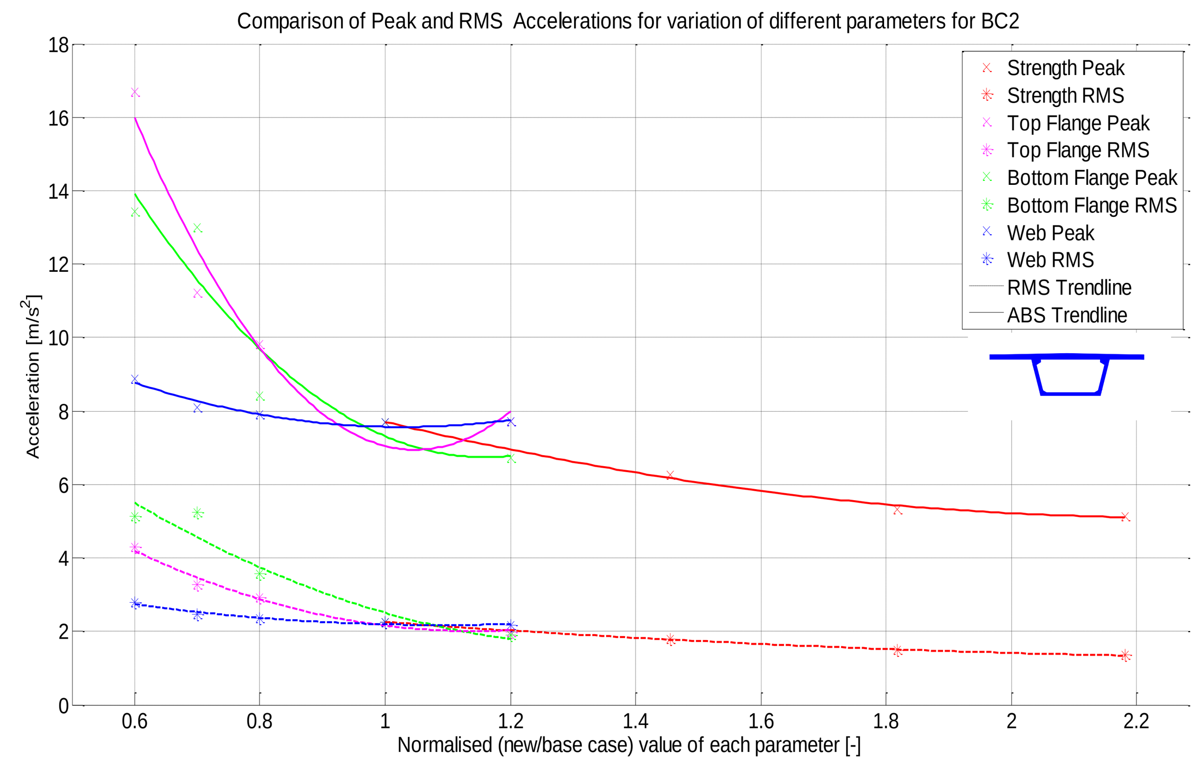

Figure 5: Comparison of parametric analyses on BC2.

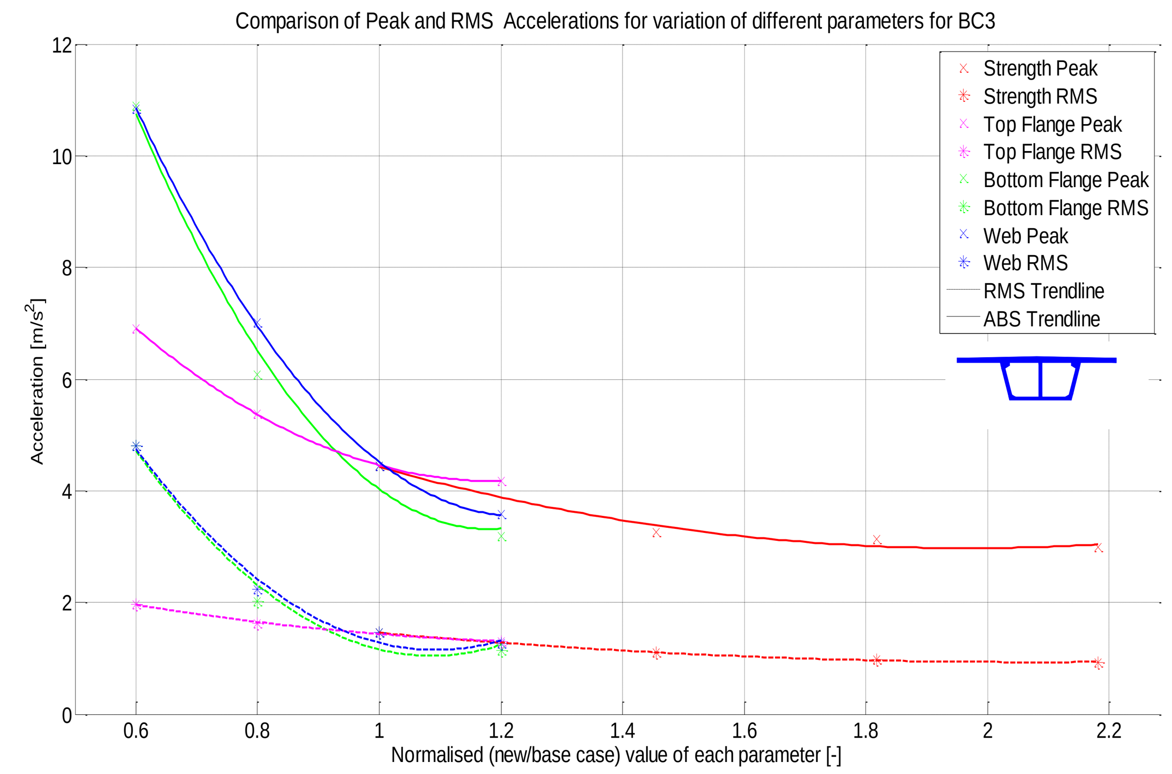

Figure 6: Comparison of parametric analyses on BC3.

CONCLUSIONS

- With increasing train velocities the accelerations increase, even more so near critical velocities.

For the two web case:

- Changes to webs had the smallest effect on accelerations; flange thickness was very sensitive.
- Similar gradients of strength and web changes allowing material usage reduction
- Changes could lead to shifting of the modal frequency to an excitation frequency

- Due to the width of the slab a small reduction in thickness would result in greater material savings.

For the three web case:

- The introduction of a third web reduced accelerations and sensitivity of the top flange.
- This allowed large savings in material due to the large width of the top flange.
- Accelerations were more sensitive to web changes than for BC2

ACKNOWLEDGEMENTS

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REFERENCES

BSI. 2010. BS EN 1991-2:2003 : Eurocode 1 : Actions on stuctures - Part 2 : Traffic loads on bridges. London, UK: BSI.