EVALUATION AND ASSESSMENT OF WIND EFFECTS ON BANAFJÄL BRIDGE (VÄSTERNORRLAND, SWEDEN) DURING ITS CONSTRUCTION

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1. Background

The developments in structural engineering are allowing the designers to make lighter and slenderer structures every year, which makes them vulnerable to dynamic loads.

During construction stages, some bridges are more flexible, so the dynamic effects of the wind can be a problem.

Simple girder bridges do not have budget to make a specific wind analysis, so they need to rely on analytical methods. Unfortunately, the codes do not provide the necessary aerodynamic parameters for every shape.

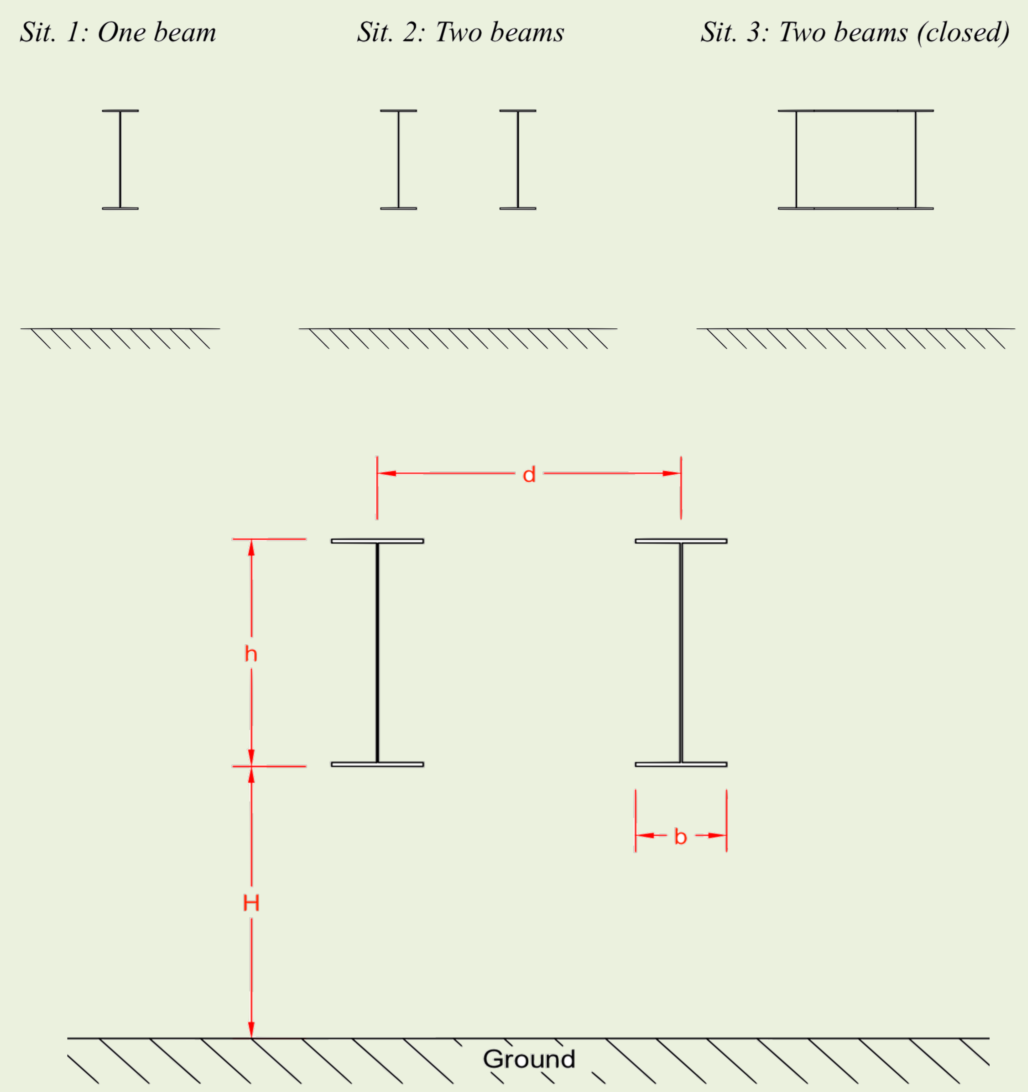
2. Project objectives

- Analyse the influence of the wind on simple girder bridges during construction stages, testing the different geometric parameters and how they affect the vortex shedding phenomenon.
- Propose some measures that can be taken to reduce the risk of incidents related to vortex shedding induced loads in the structure.
- Make an assessment of the Banafjäl Bridge vulnerability to vortex shedding induced loads, proposing measures to improve its behaviour if necessary.

3. Parametric study

Several Finite Volume Method simulations were made with the software Ansys-Fluent.

Three situations considered:
- **Sit. 1:** Only one beam
- **Sit. 2:** Two beams
- **Sit. 3:** Two beams with steel plates closing the section (alternative to situation 2)



Five parameters tested:
- $h = 2, 2.5, 3\ m$
- $\mathrm{d} = h, h + 0.5, h + 1\ m$
- $\mathrm{b} = 0.9\ m$
- $\mathrm{H} = 3, 5, 10, 120\ m$
- $\mathrm{U} = 5, 7.5, 10, 12.5, 15\ m/s$

Total n° of simulations: 456

4. Results

- Vortex shedding effects are more dangerous in the along-wind direction.
- Beams are less vulnerable to wind effects when both are located in their positions.
- Increasing beam distance reduces wind dynamic effects.
- The placement of steel slabs to close the section increases the critical wind speed, being less probable to find resonance.

5. Banafjäl Bridge response

Eurocode 1 analytical methods were applied to Banafjäl Bridge case. Four alternative designs were also tested to check if the vulnerability of the structure improves:
- **Alt. 1:** Increase beams' height by 10%.
- **Alt. 2:** Increase beams' width by 10%.
- **Alt. 3:** Increase beams' distance by 10%.
- **Alt. 4:** Placement of plates closing the space between beams (Sit. 3).

5.1. Buffeting response

- To create plastic behaviour in the beams, the wind speed needs to be quite high. Difficult to find these speeds in short periods.
- Increasing beams' height worsens the behaviour of the structure.
- Increasing flanges' width reduces structure's vulnerability.

	Maximum wind speed with elastic behaviour (m/s)				
	Banafjäl	Alt. 1	Alt. 2	Alt. 3	Alt. 4
Single beam	31.1	29.5	34.4	31.1	31.1
Two beams (free)	32.6	31.1	36.1	32.8	32.6
Two beams (joined)	48.11	45.5	52.8	49.5	47.9

5.1. Vortex shedding response

- No dangerous effects with Banafjäl Bridge geometry.
- With higher natural frequencies, the effects can be dangerous.
- The most effective measure is closing the section (Sit. 3).

		Vortex shedding response				
		Banafjäl	Alt. 1	Alt. 2	Alt. 3	Alt. 4
Single beam	Critical wind speed (m/s)	7.7	8.5	8.7	7.7	7.7
	Max stress (Mpa)	29.8	39.5	31.2	29.8	29.8
	Max displacement (mm)	60	80	57	60	60
	Max acceleration (m/s2)	1.95	2.49	2.36	1.95	1.95
Two beams (free)	Critical wind speed (m/s)	6.9	7.3	7.9	6.9	6.9
	Max stress (Mpa)	10.9	14.8	11.7	11	10.9
	Max displacement (mm)	22	30	21	22	22
	Max acceleration (m/s2)	0.71	0.93	0.88	0.72	0.71
Two beams (joined)	Critical wind speed (m/s)	7.0	7.4	8.0	7.1	10.3
	Max stress (Mpa)	12.9	16.7	14.1	12.1	3.6
	Max displacement (mm)	25	33	25	23	7
	Max acceleration (m/s2)	0.84	1.05	1.07	0.79	0.24

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