Dynamics of FRP Bridges: Testing and Modal Properties

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Outline

- Overview of eight as-built (full or hybrid) FRP bridges
- Vibration testing methods
- Modal properties of eight bridges
- Conclusions

Eight as-built FRP bridges


Bridge 1


Bridge 2


Bridge 3


Bridge 4


Bridge 5


Bridge 6


Bridge 7


Bridge 8

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Modal testing methods

Impact hammer testing

- Bridge 1
- Bridge 2
- Bridge 3
- Bridge 4
- Bridge 5

Ambient vibration testing

- Bridge 6
- Bridge 7
- Bridge 8

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Bridge 1

A footbridge over the river Rheidol in a narrow valley in Wales.

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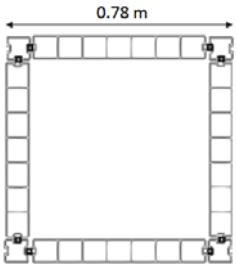
Bridge description

- 16.9 m long, 0.78 m wide; Opened in 1995.
- Advanced Composite Construction Systems (ACCS).
- Approximately 1.8 tonnes.



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Impact hammer testing



Input

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System identification

↑

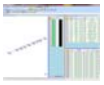
Output

Impact hammer

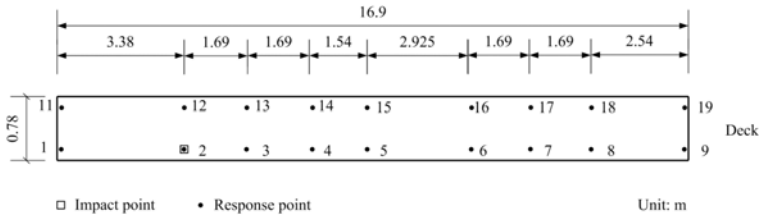
Data logger +
Spectrum analyser+
SI software

3 accelerometers



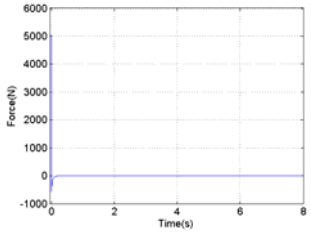



Measurement stations

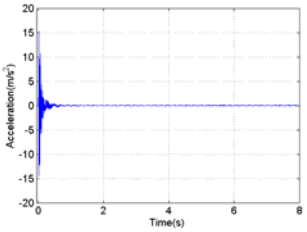


- 6 setups for vertical acceleration measurement.
- Measurement time : 6 × 6 × 8 s = 864 s.
- Actual testing time for experts: half a day.

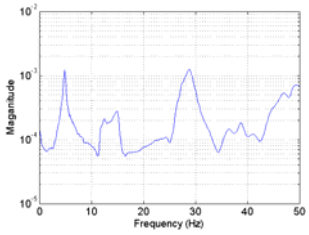
Measured signals



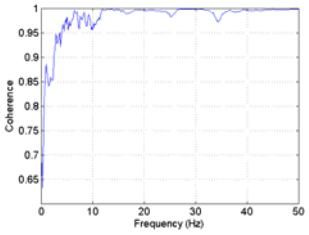
Vertical impact force at TP2



Vertical acceleration at TP5



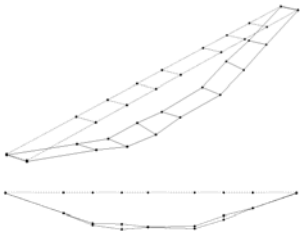
Frequency response function H52



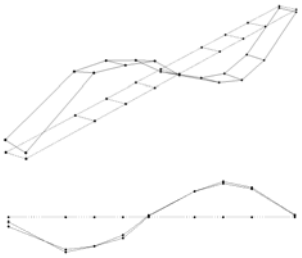
Coherence C52

Modal properties

Identify vertical vibration modes ≤20Hz.



V1: 4.9 Hz, 3.4%, 862 kg



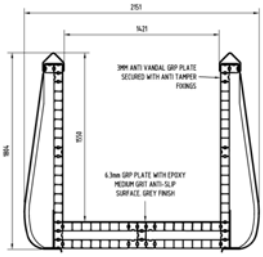
V2: 15.1 Hz, 2.9%

Bridge 2

- 5.0 + 14.0 + 6.0 m over the Paddington-Penzance Railway Line near St Austell station, Cornwall, Uk.
- Constructed in 2007.

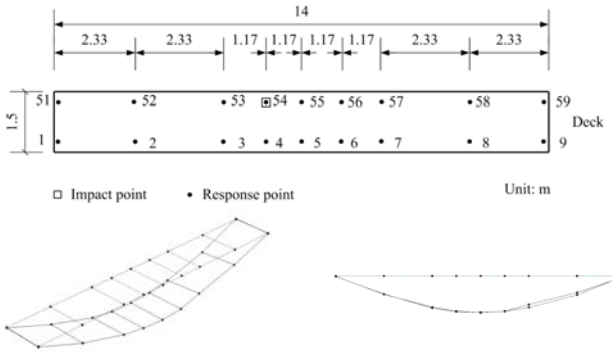
Bridge 2

- ACCS pultruded elements and moulded elements.
- ‘U’ shape cross-section.



Bridge 2

- Impact hammer tests conducted on the span of 14 m.
- Vertical modes <20 Hz.



V1: 11.9 Hz, 1.6%, 2674 kg

Bridge 3

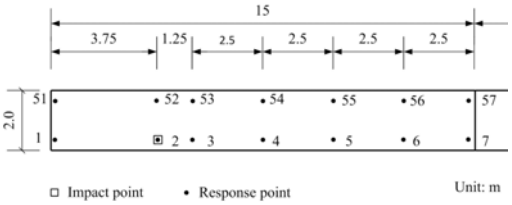
- 2 spans: 15.0 m + 10.0 m.
- Over a lake in Delft, Netherlands.

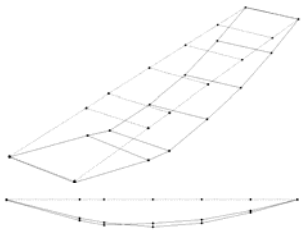
Bridge description

- 2 m wide deck; moulded together with two longitudinal beams underneath, made of vacuum infused FRPs with foam cores.
- 1 m high steel handrails.

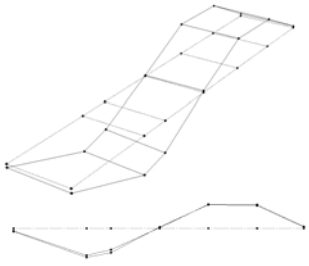
Modal analysis

- Impact hammer tests conducted on the span of 15 m.
- Vertical modes <20 Hz.





V1: 4.8 Hz, 1.2%, 3161kg



V2: 17.1 Hz, 1.2%

Bridge 4

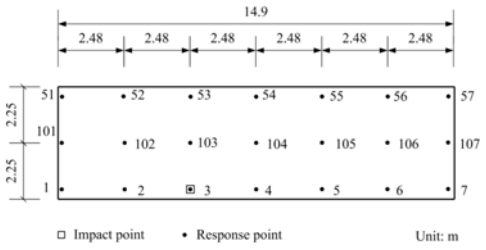
A footbridge over a canal in Delft, Netherlands.

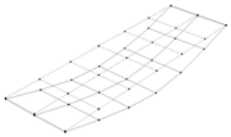
Bridge description

- 14.7 m long and 4.5 m wide.
- Four composite longitudinal beams connected into a whole structure by a composite cover.
- Weight 6600 kg.

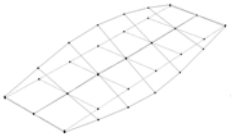
Modal analysis

- Impact hammer testing.
- Vertical modes <20 Hz.

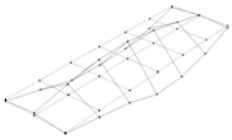




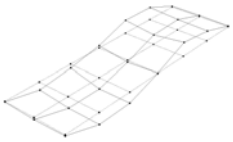
6.1 Hz, 7.9%, 3161kg



10.1 Hz, 4.4%



17.1 Hz, 1.0%



18.9 Hz, 2.1%

Bridge 5

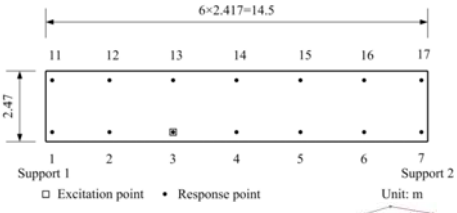
Two simply-supported truss footbridges over the Dover to Folkstone Railway Line.

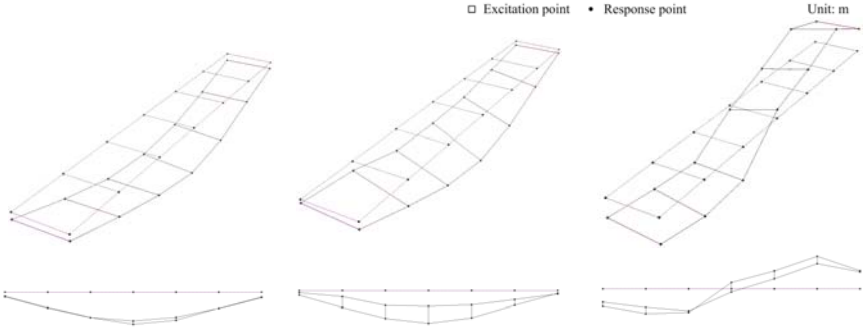
Bridge description

- Each span: 14 m long, 2.4m wide, 3.325 m high.
- pultruded and infused FRP sections.
- Total mass of each span is 5.5 tonnes.
- Opened in 2017.

Modal analysis

- Impact hammer testing.
- Vertical modes < 30 Hz.





V1: 15.1 Hz, 1.4%, 5261kg

V2: 16.7 Hz, 1.4%

V3: 26.9 Hz, 2.0%

Bridge 6

- A truss bridge for pedestrians and cyclists crosses a busy dual carriageway at the outskirts of Prato, Italy.
- It was open in 2008.

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Bridge description

- 25 m long, 2.6 m (3.9 m) wide at the middle (end).
- pultruded FRP channel sections, stainless bolts.
- Total mass: 8 tonnes.

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Ambient vibration testing

Output

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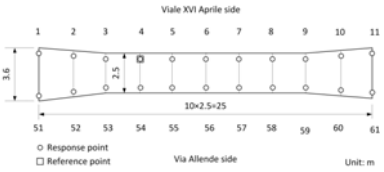
System identification

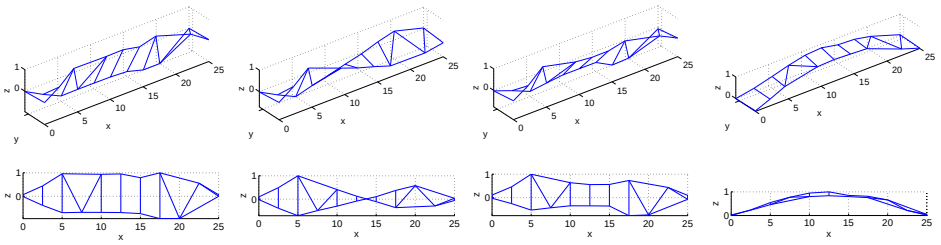
Accelerometers

Data logger
+
Spectrum analyser
+
SI software

Modal properties

- Ambient vibration testing.
- Vertical and torsional vibration modes < 8 Hz.





T1: 2.1 Hz, 1.6%

T2: 2.7 Hz, 1.3%

T3: 4.8 Hz, 1.4%

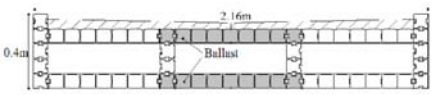
V1: 7.5 Hz, 2.6%

Bridge 7

A single span suspension footbridge over the Nesscliffe A5 bypass road, Shropshire, UK.

Bridge description

- 51.3 m long, 2.1 m wide.
- FRP deck: ACCS panels.
- 2 steel cables, 20 steel hangers, and 4 steel backstays.



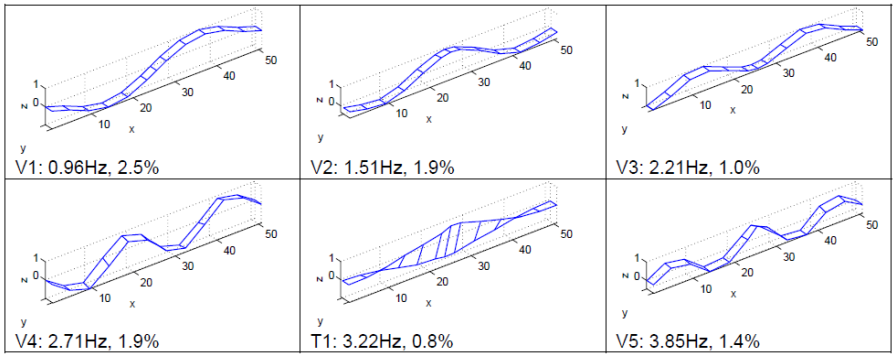
Dynamic assessment of a FRP suspension footbridge through field testing and finite element modelling

Renos A. Votsis[1a], Tim J. Stratford[2], Marios K. Chryssanthopoulos[3] and Ella A. Tantele[1]

Steel and Composite Structures.
Vol. 23, No. 2 (2017) 205-215

Modal properties

- Identify vertical and torsional vibration modes ≤5Hz.
- High density of vibration modes.

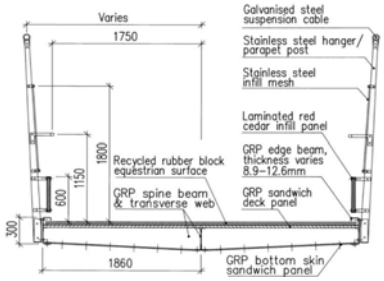


Bridge 8

A single span suspension footbridge over the A30 dual carriageway in the south of Bodmin, Cornwall, UK.

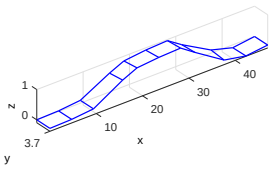
Bridge description

- 47 m long, 3.5 m wide.
- FRP deck: hand laid and vacuum infused FRP components.
- 2 steel cables, 20 steel hangers, and 4 steel backstays.

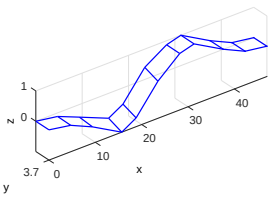


Modal properties

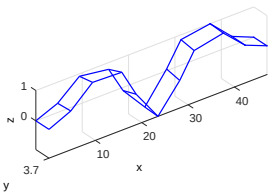
- Identify vertical and torsional vibration modes ≤4 Hz.
- High density of vibration modes.



V1: 1.91 Hz, 2.3%



V2: 1.99 Hz, 1.5%



V3: 3.29 Hz, 1.1%

Conclusions

- Modal tests and modal properties of eight as-built FRP bridges are presented.
- Two modal testing methods are introduced.
- The fundamental frequencies of the eight bridges are similar to those of conventional bridges of the same span.
- The damping ratios of the first two modes of the eight bridges are generally higher than those of conventional bridges.