DYNAMIC RESPONSE OF FIBER REINFORCED POLYMER (FRP) COMPOSITE BRIDGES

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Outline

- FRP Bridge Decks
- FRP Bridge Construction
- Description of FRP Bridges Tested
- Importance of Dynamic Response
- Testing Procedure
- Results
- Conclusion

Acknowledgements

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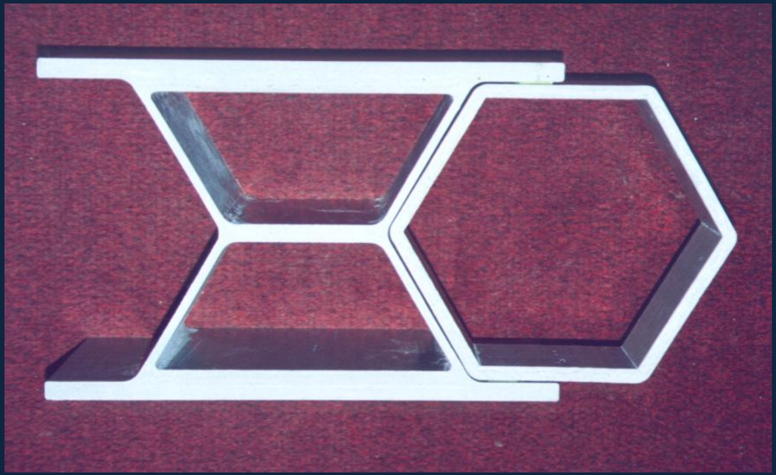
FRP BRIDGE DECKS



First Generation FRP Bridge Deck

Weight – 25 lb/ft^2 (122 kg/m^2)

Cost ~ $80 sq. ft (Rs.4000 sq.ft)

E-glass Fabrics & Vinyl Ester Resin

Trade Name: Superdeck™

FRP BRIDGE DECKS

Third Generation FRP Bridge Deck

Weight – 11 lb/ft^2 (~50 kg/m^2)

Cost ~ $30 sq. ft (Rs. 1650 sq.ft)

E-glass Fabrics & Vinyl Ester Resin

Trade Name: Prodeck 4

FRP BRIDGE CONSTRUCTION

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FRP BRIDGE CONSTRUCTION

FRP BRIDGE CONSTRUCTION

FRP Deck Modules being bonded together

FRP BRIDGE CONSTRUCTION

FRP Deck Modules connected to Girders using Spring Clips

FRP BRIDGE CONSTRUCTION

FRP Deck Joints Reinforced with Glass Fabric and Resin

FRP BRIDGE CONSTRUCTION

Completed Bridge

Bridge Descriptions – Market Street Bridge

- Located in Downtown Wheeling, WV, USA
- ADT of 6,900-10,000
- Span- 177'; Width –56'
- Design Load: HS-25

- Deck connected to steel plate girders using shear studs and concrete grout
- 3/8" Polymer Concrete used as wearing surface

Bridge Descriptions – Katy Truss Bridge

- Located in Marion County, WV, USA
- ADT of 700
- Span- 90'; Width –14'
- Design Load: HS-20

- Deck connected to girders/floor beams using mechanical connectors and adhesive bonding
- 3/8" Polymer Concrete used as wearing surface

Bridge Descriptions – Laurel Lick Bridge

- Located in WV, USA
- FRP deck and FRP stringer
- Six FRP girders (WF 12 x 12 x ½)
- Span- 19′; Width –15′
- Design Load: HS-25

Performance Evaluation – FRP Deck Bridges

Overall objective is to evaluate the structural response of the three FRP deck bridges. Specifically, the following parameters were evaluated:

DYNAMIC

1. Natural frequencies, damping ratios
2. Dynamic load allowance factor

Importance of Dynamics FRP Bridges

Vibration of bridges due to moving traffic has two potential problems

- Dynamic amplification of stresses/deflections
- Vibration Serviceability - Not accounted in design- No provisions in AASHTO LRFD Spec- AASHTO LRFD commentary refers to OHBDC.

Test Procedure for FRP Bridges

- Dynamic amplification of stresses/deflections

- Natural Frequencies/Acceleration

Dynamic Response of FRP Bridges

Dynamic Load Allowance ***(DLA)*** Factor or Impact Factor is determined by allowing a loaded truck to pass at 2 mph and at highway speeds and calculated using the formula below.

$$DLA = \left(\frac{\varepsilon_{dyn} - \varepsilon_{stat}}{\varepsilon_{stat}} \right)$$

ε_{dyn} = maximum strain as the vehicle travels at test speed

ε_{stat} = maximum strain as the vehicle travels at crawl speed

Dynamic Response of FRP Bridges

Maximum DLA Factors

Bridge	Katy Truss		Market Street	
Component	DLA	Truck Speed	DLA	Truck Speed
Deck	**6.8 %**	5 mph (8 kph)	**30%**	30 mph (48.3 kph)
Stringer	**9.4 %**	10 mph (16.1 kph)	**25%**	30 mph (48.3 kph)
Floor beams	**9.4 %**	5 mph (8 kph)	-	-

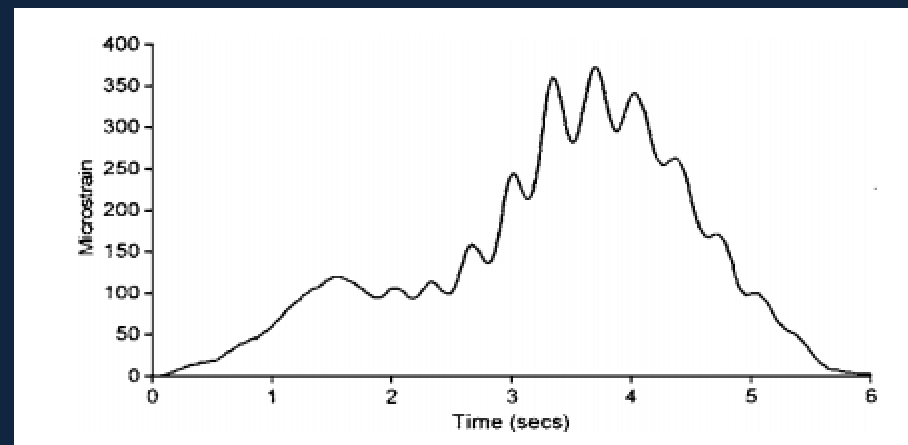
1998 AASHTO LFRD Specifications DLA – 33%

Dynamic Response of FRP Bridges

Maximum DLA Factors for Laurel Lick Bridge

	3.22 kph as baseline		Static test as baseline	
Components	DLA (%)	Truck speed (kph)	DLA (%)	Truck speed (kph)
Stringers	14	6.44	78	3.22
Deck	21	6.44	93	3.22

Maximum DLA Factors for Laurel Lick Bridge



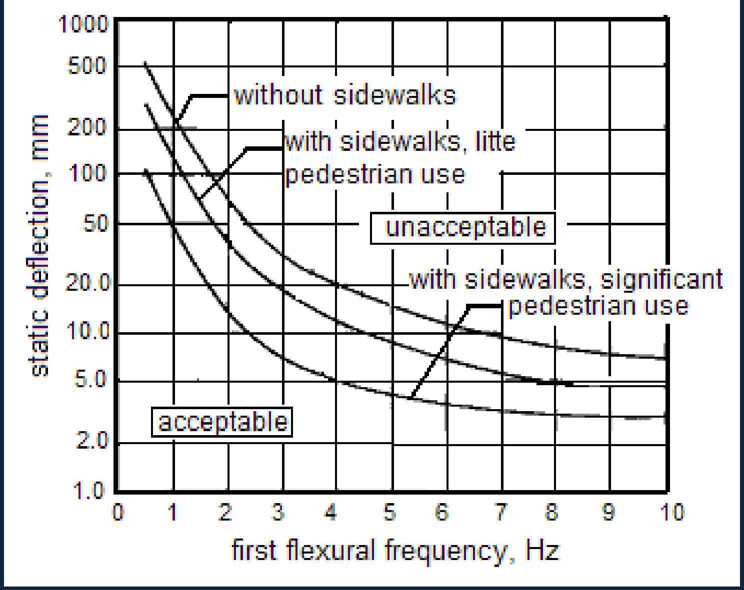
Strain Measurement at "Crawl Speed" of 3.22 kph (2mph) on Laurel

Lick Bridge

Dynamic Response of FRP Bridges

Vibration Serviceability

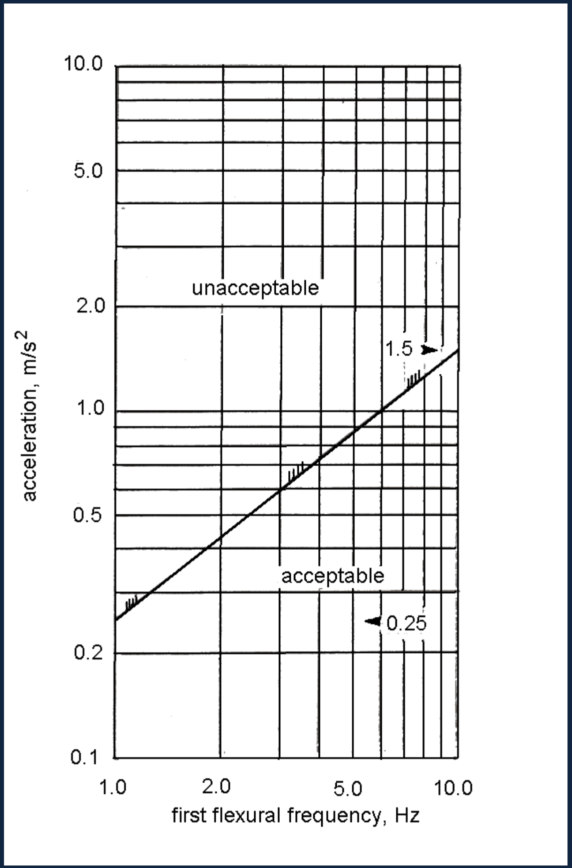
- No current provisions in AASHTO LRFD Specifications
- 1983/1991 Ontario Highway Bridge Design Code provides static deflection limits for bridges based on their natural frequency



Dynamic Response of FRP Bridges

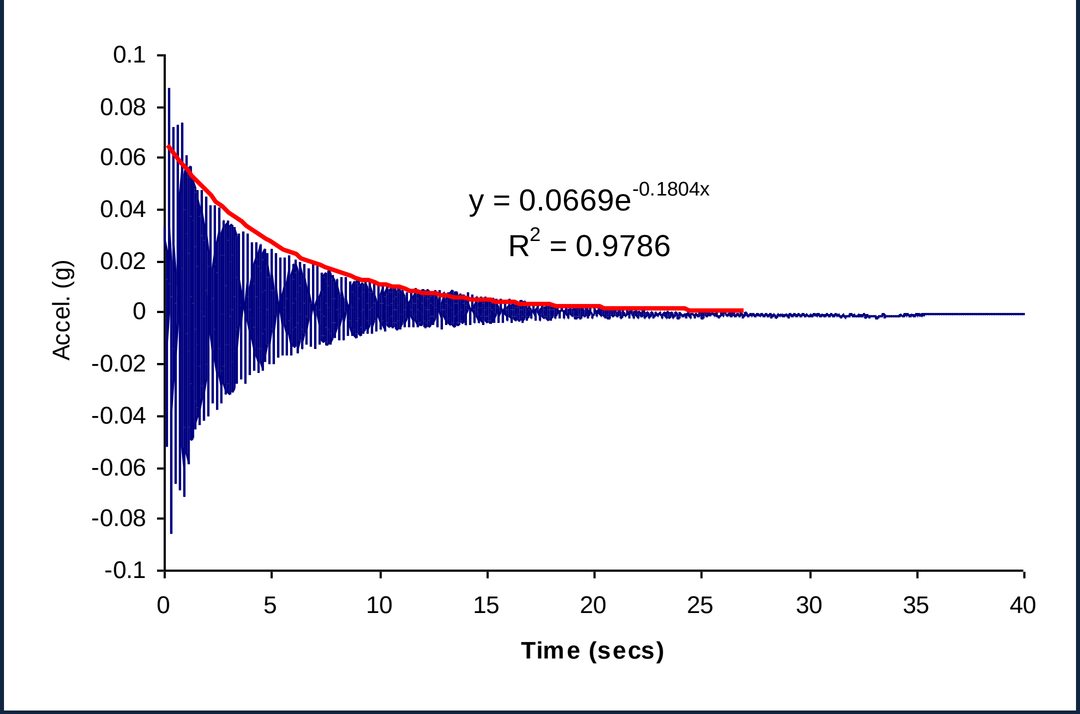
Vibration Serviceability

- Deflections are sometimes difficult to acquire due to accessibility reasons
- In that case, accelerations can be measured and compared against 1983 Ontario Highway Bridge Design Code (OHBDC) chart for pedestrian bridges
- This chart provides an indication whether traffic induced bridge vibrations are perceptible



Dynamic Response of FRP Bridges

Bridge parameters needed to check against OHBDC chart – First natural frequency and Amplitude of acceleration



Free Vibration Response of Katy Truss Bridge

Dynamic Response of FRP Bridges

KATY TRUSS BRIDGE

Bridge Frequency – **5.25 Hz**

Max. Allow. Acceleration using OHBDC Chart – **0.0972 g**

Acceleration values were close to or exceeded OHBDC limits in 5 out of 7 tests

MARKET STREET BRIDGE

Bridge Frequency - **3 Hz**

Max. Allow. Acceleration using OHBDC Chart – **0.0611 g**

Acceleration values were close to or exceeded OHBDC limits in 5 out of 6 tests

Dynamic Response of FRP Bridges

DAMPING

- Damping usually not measured for steel-concrete & concrete bridges. Since inherent damping of these bridges is sufficiently high enough to dissipate traffic induced vibrations

A study by Paultre et al., 1992 revealed the following

- Steel-Concrete Bridges – Avg. Damping for 12 bridges - 8.4%
- Concrete Bridges – Avg. Damping for 213 bridges –7.9 %

Dynamic Response of FRP Bridges

DAMPING

Damping for the two FRP bridges was evaluated by fitting an exponential curve to the measured free vibration response

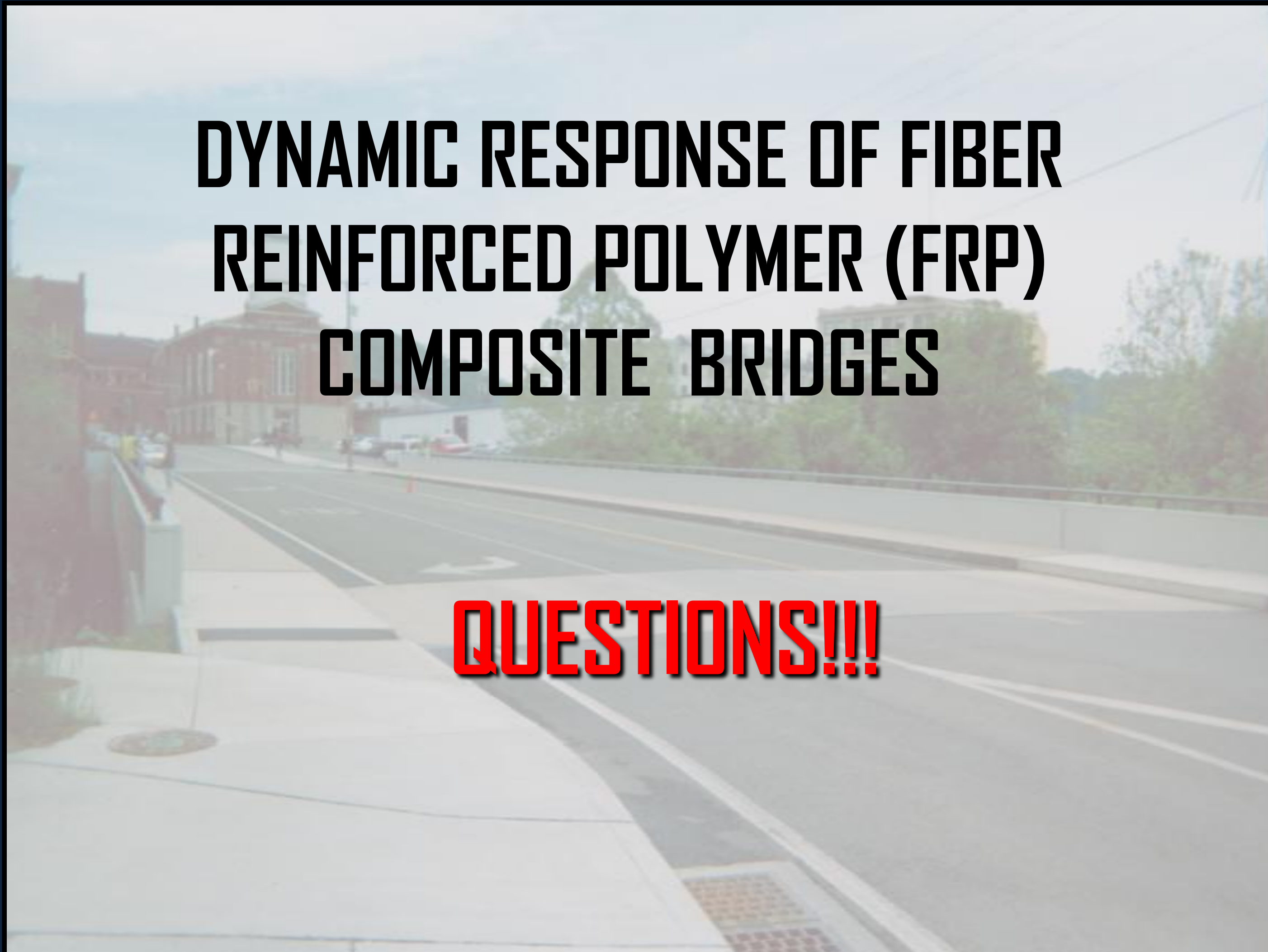
Average damping ratio for Katy Truss Bridge – **0.5%**

Average damping ratio for Market Street Bridge – **1.97%**

Performance Evaluation – FRP Deck Bridges

CONCLUSIONS

- Dynamic load allowance factors for the two bridges are within design code limits. The limits are exceeded for Laurel Lick Bridge.
- Traffic induced bridge vibrations are clearly perceptible in the two FRP bridges,
- Lack of inherent damping in these two bridges is the primary reason for high amplitudes of vibration.
- As a general takeaway, as Composites are primarily lightweight, dynamic issues need to be addressed during design stage.


DYNAMIC RESPONSE OF FIBER REINFORCED POLYMER (FRP) COMPOSITE BRIDGES
QUESTIONS!!!