North American Pultrusion Conference

Discovering the World’s Longest Pultruded Bridge in Bermuda

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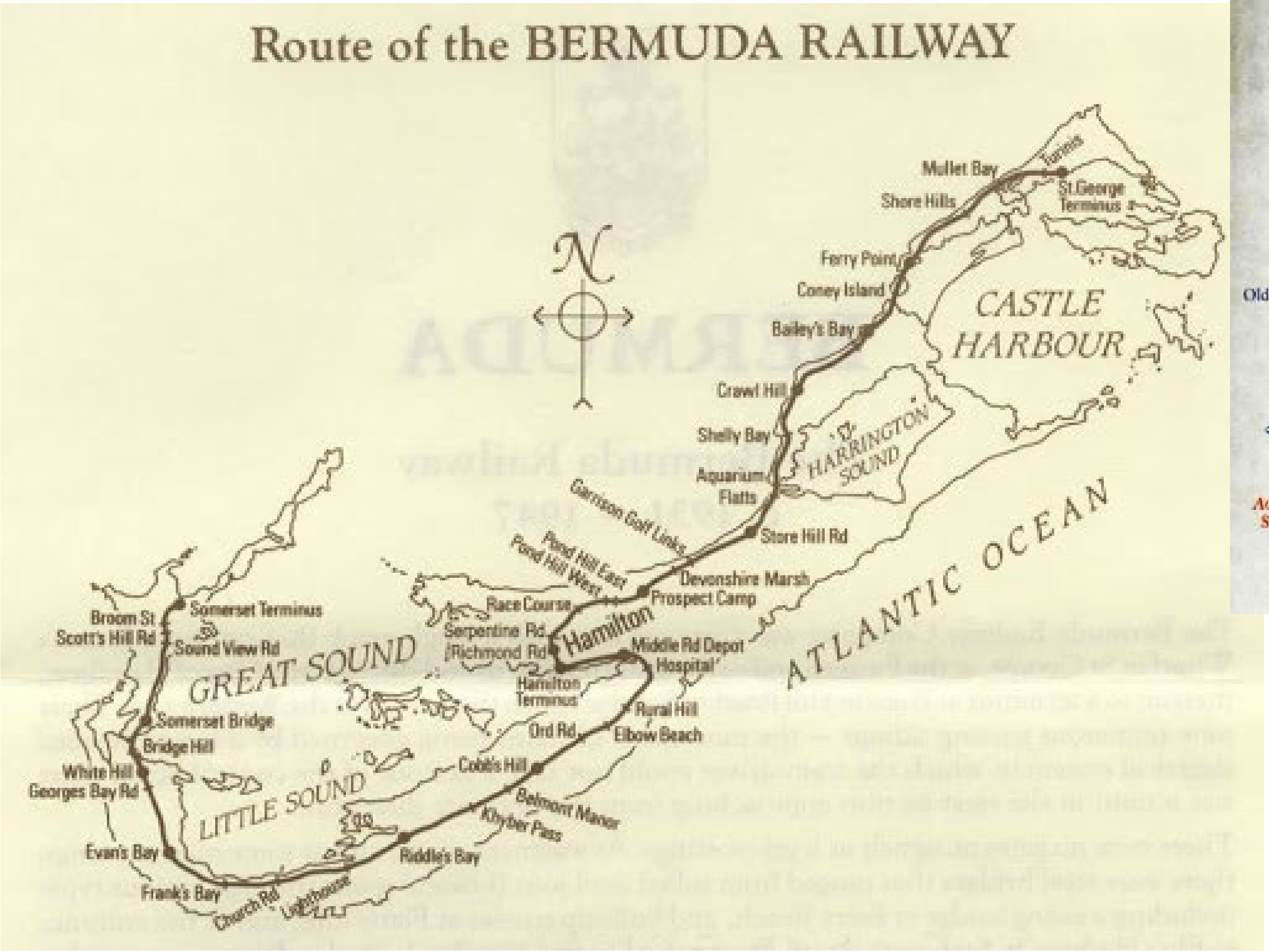
ACMA American Composites Manufacturers Association | EPTA

BERMUDA'S ENVIRONMENTAL CONSTRAINTS

- 2nd most isolated island in the world
- 3rd most densely populated country on earth
- 3rd most urbanized environment in the world
- 100% of the Bermuda population lives in an urban area

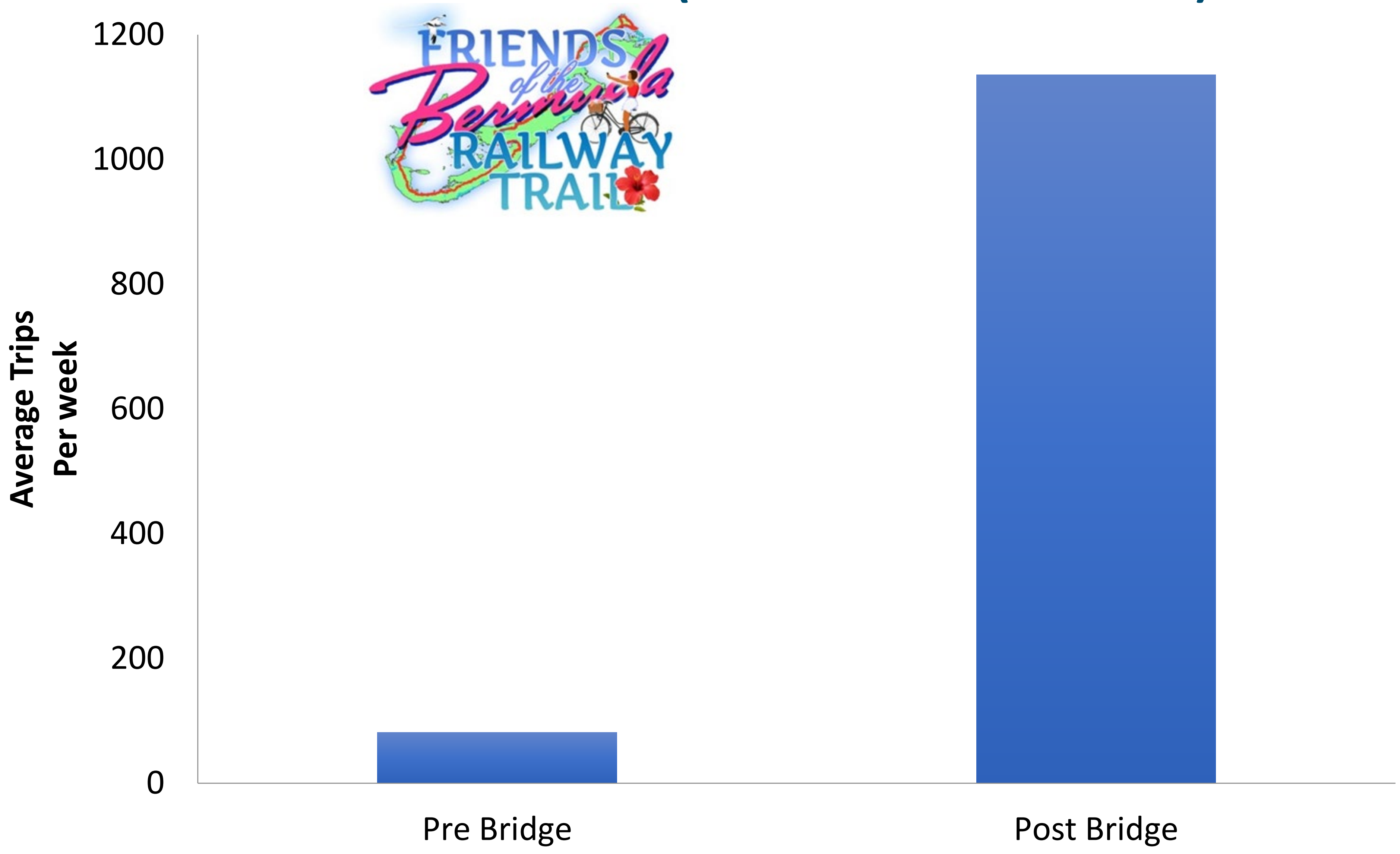
Story of the Longest Bridge BEGINS with Connecting the Bermuda Railway Trail

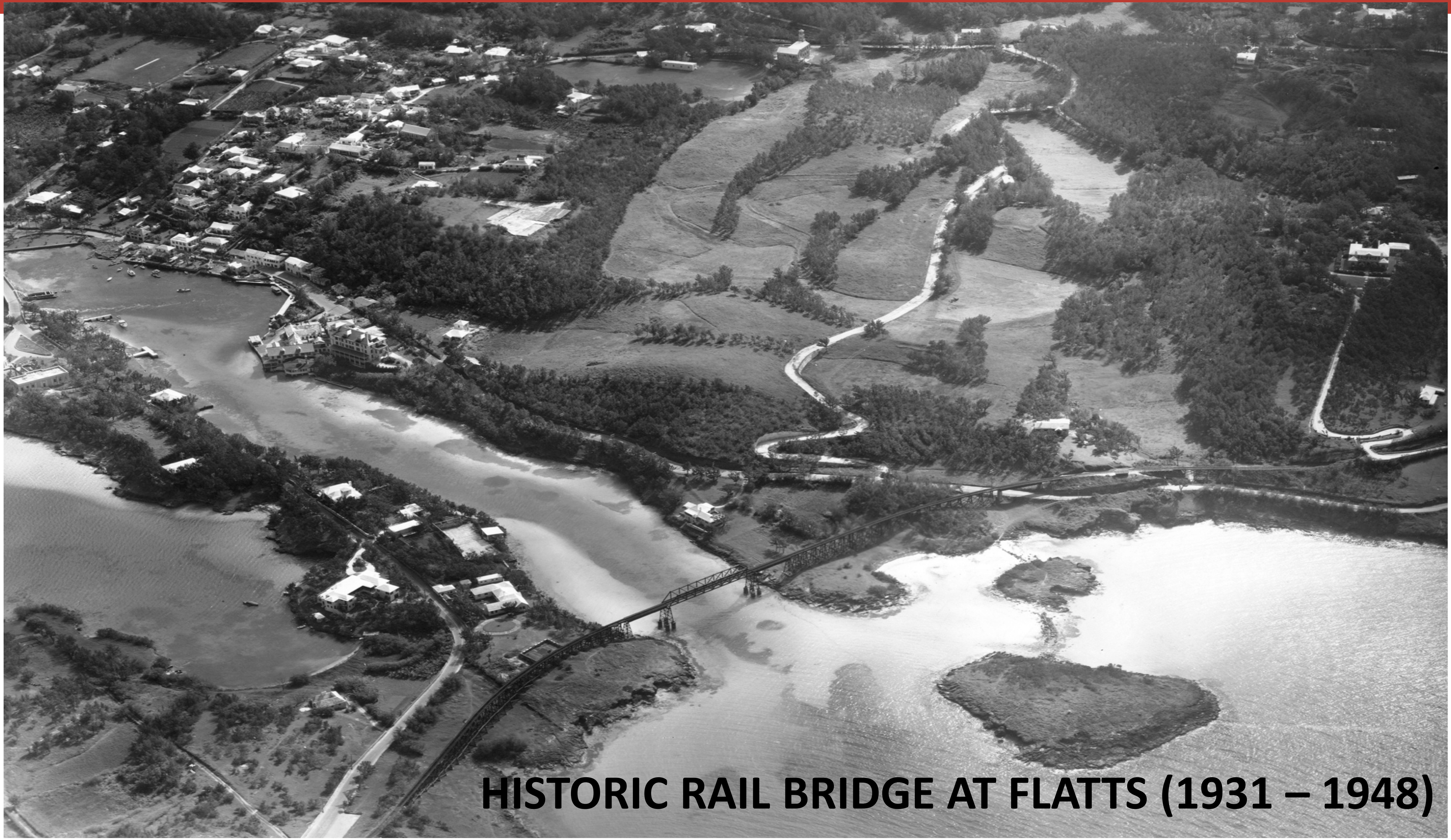
- In 2012 the Murphy family formed a local charity called Friends of Bermuda Railway Trail.
- Their goal was to reconnect the old Bermuda Railway route into a single, continuous trail for pedestrians and cyclists.
- The challenge of working in one of the most isolated and saltiest marine environments in the world, which is also hurricane prone, prompted them to look for a low maintenance, corrosion-resistant material that could meet local safety and performance codes and withstand harsh weather.




BAILEY’S BAY PEDESTRIAN BRIDGE
COMPLETED BY FRIENDS OF
BERMUDA TRAIL IN 2014

USE AT BAILEY'S BAY (AVG. TRIPS PER WEEK)





HISTORIC RAIL BRIDGE AT FLATTS (1931 – 1948)

In 2017, Friends of Bermuda Railway Trail tapped Creative Composites Group to provide a fiber reinforced polymer (FRP) pedestrian bridge from its E.T. Techtonics product line. Eric Johansen had oversite of design with Dan Winey of CCG. Both Rick and CCG have a long-standing relationship with Structural Fiberglass Inc. for the fabrication of E.T. Techtonics bridges. There was one major hurdle…

DESIGN OF MAIN SPAN BRIDGE

Design Requirements

- Bermuda Building Code (2015 International Building Code (IBC) / ASCE 7-10) using **allowable stress design method**
- Hurricane Wind load is based on 158 mph wind (3 second gust) which results in 112psf*0.6=67psf net design pressure as if enclosed structure; 2008 AASHTO Guide Specifications for Design of FRP Pedestrian Bridges is 35psf as if enclosed structure at 100 mph. For AASHTO LFD service load design at 158 mph wind, the net design pressure would be 87psf*1 (ASD LF for wind)/1.25 (Group III overstress factor (125%))=70psf as if enclosed structure.
- Live load is reduced to 65psf as permitted by IBC; current AASHTO pedestrian load is 90psf.
- Dead load of structure is approximately 65,000 lbs (relatively light compared to concrete and steel bridges)

DESIGN PROCESS / TESTING OF MAIN SPAN BRIDGE

Design Process

- Preliminary Design
- Validation/Testing of member capacity including truss tension, compression, Euler Buckling of compression members and connection bearing.
- Final Design of bridge components and connections.
- Bermuda Crane Pick Check

Pre-assembled At Factory For Testing

Testing

- Full structure testing to 110% of the uniform live load (1.1*65psf=72psf)
- Crane Pick validation

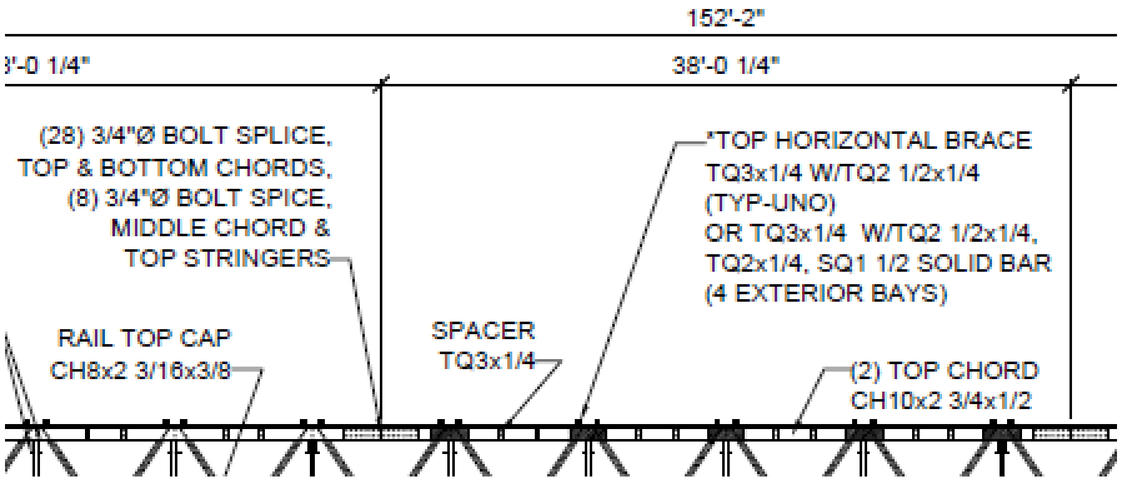
8’-3” wide (c/c truss) box structure cross section – 20 bays @ 7’-7 ¾”± spacing

Bottom chord length of bridge is 152’-2” ; 148’-8” c/c bearings bridge length

FACETS OF DESIGN

Shipping Length Limitations

- Maximum length of member used was 38’-0 ¾” due to shipping maximum container length of 40ft. Weight of longest member is approximately 226 lbs.
- Compression members were checked at splice locations with top chord splices controlling design. We located splices as far as possible away from center of span. The design force at splice was 94,000 lbs at 0.375*span length.



FACETS OF DESIGN

Design Frequency

- 2008 AASHTO Guide Specifications for Design of FRP Pedestrian Bridges requires vertical frequency of 5 Hz and transverse frequency of 3 Hz minimum for negligible risk.
- Actual frequencies (not including decking rigidity in analysis) were 2.888 Hz (low risk) in the vertical direction and 2.587 Hz (negligible risk) in the transverse direction of the bridge.

In both vertical and horizontal directions, there are four frequency ranges, corresponding to a decreasing risk of resonance:
Range 1: maximum risk of resonance.
Range 2: medium risk of resonance.
Range 3: low risk of resonance for standard loading situations.
Range 4: negligible risk of resonance.
Table 2.3 defines the frequency ranges for vertical vibrations and for longitudinal horizontal vibrations. Table 2.4 concerns transverse horizontal vibrations.

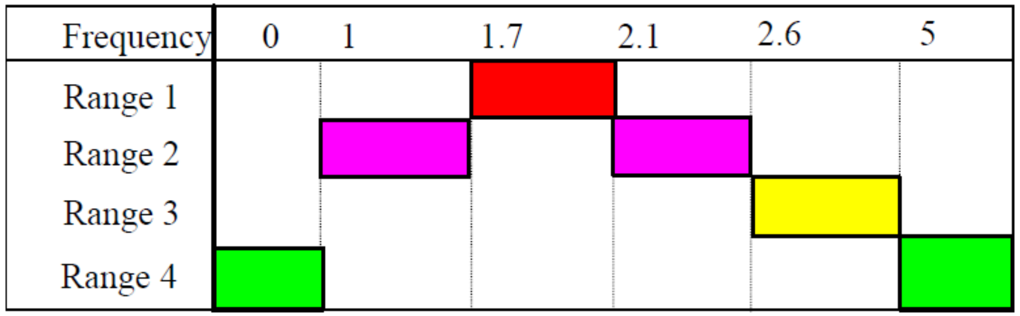


Table 2.3: Frequency ranges (Hz) of the vertical and longitudinal vibrations

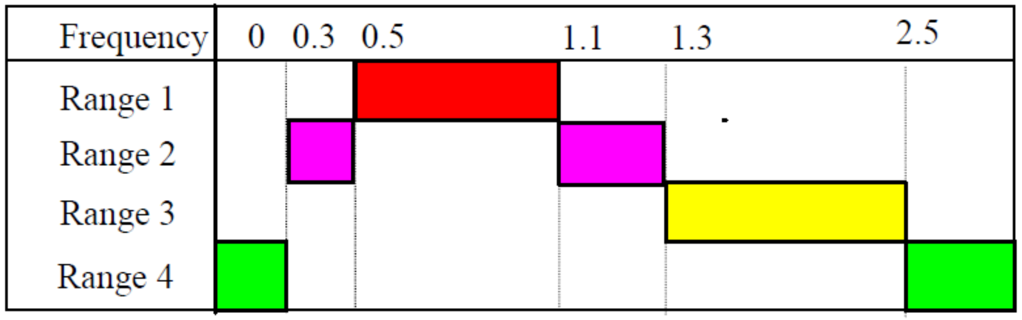


Table 2.4: Frequency ranges (Hz) of the transverse horizontal vibrations

Design Frequency (cont'd)

- A dynamic analysis according to 2006 Setra (referenced in AASHTO pedestrian design specifications) was completed following design of the bridge. The results of that analysis, which looks at acceleration of the bridge during synchronized pedestrian motion was that the bridge in each direction was at a low risk, maximum (green areas to right) comfort level for vibrational, resonating issues.

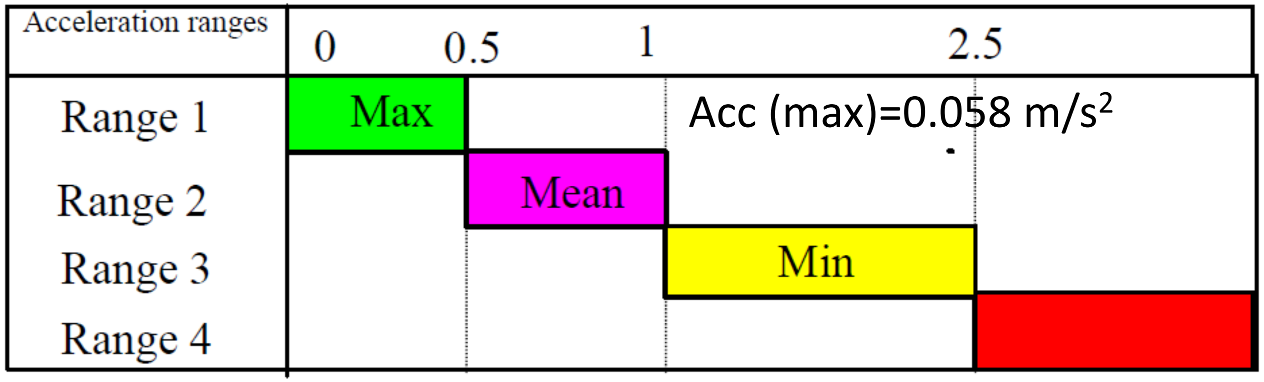


Table 2.1: Acceleration ranges (in m/s^2) for vertical vibrations

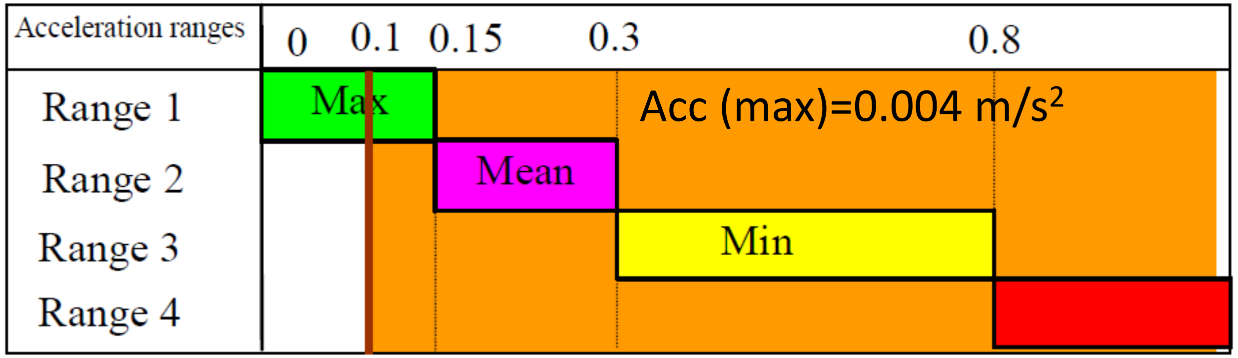


Table 2.2: Acceleration ranges (in m/s^2) for horizontal vibrations

The acceleration is limited in any case to 0.10 m/s^2 to avoid "lock-in" effect

Crane Lift for Installation of the bridge was a critical logistics driver. Bermuda was limited by the cranes that are available on the island. As part of test program, the lift was simulated the Bermuda pick in the CCG yard. Each lift utilized eight pick points. Equipment here shown was sent to Bermuda, except the crane. The lift required was 20ft in the air.

Testing: Utilized water filled pools to safely apply the uniform live load

Uniform Load Test - 72psf (dead+live=164,000 lbs ±) without anchorage in CCG yard

INSTALLATION / CONSTRUCTION

- Bridge was disassembled, kitted (packaged) and shipped to Bermuda in containers during COVID 19.
- Reassembled near the job site
- Barged to the piers
- Lifted into place in one morning (when winds are generally calmer).

Bridge assembled on pier in Bermuda, ready to be ferried to site.


Views from
Main Span

Hit the Trail…Questions?

Inquiries can be sent to

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For more info or news on the bridge or info on FRP pedestrian bridges and boardwalks: CreativeCompositesGroup.com

PRESENTATION REFERENCES

1. 2002 AASHTO Standard Specifications for Highway Bridges, 17th Edition
2. 2004 The New and Improved Pultex Pultrusion Design Manual of Standard and Custom Fiber Reinforced Polymer Structural Profiles
3. 2006 Setra (French Association of Civil Engineering) Technical Guide Footbridges: Assessment of Vibrational Behaviour of Footbridges under Pedestrian Loading
4. 2008 AASHTO Guide Specifications for Design of FRP Pedestrian Structures, First Edition
5. 2009 AASHTO LRFD Guide Specifications for the Design of Pedestrian Bridges with 2015 interims
6. 2010 ASCE Standard ASCE/SEI 7-10 Minimum Design Loads for Buildings and Other Structures
7. 2015 International Building Code (IBC)
8. 2015 National Statistic Bermuda