

**February 2022 ABC-UTC Monthly Webinar: World's Longest Pultruded Pedestrian Bridge -
Bermuda's Flatts Inlet FRP Bridge**

#	Questions	Responses
	Design	
1	Can you discuss climate change and resiliency in respect to this project?	Bridges are built at a height greater than 20 ft above Highest High Tide, so sea level rise is unlikely to have an effect. By facilitating sustainable transport, this bridge connection may have slightly reduced Bermuda's transport emissions.
2	Did you use fiberglass bolts, stainless steel bolts, or a mix and why?	A316 Stainless Steel Bolts were used for their reliability and strength. Bolt strength does not control connection design.
3	Can you discuss the FRP truss connections?	Connections consisted of generally two bolt connections, except for splices as illustrated in the presentation. Unlike steel connection design, FRP connections are tested for the capacity of the member and member bearing. Bolt capacities were computed as normal based on AISC bolt capacity.
4	Can you discuss the analysis, code checks, calculation of stress ratios, design drawings, contract notes, and special provisions for this project?	The bridge was modeled with RISA-3D and verified by STAAD. The applied loads were compared to the member capacities according to tension and compression. Euler buckling of compression members was checked along with the connections. Servicability checks were completed for deflection and frequency. Design drawings were sealed by a third-party engineer in Pennsylvania and Bermuda. No special provisions were part of this project. The contract required testing of the bridge before shipping.
5	What design code was used for the design, and was it designed for high winds and earthquakes?	Bermuda follows the IBC (International Building Code), and the bridge was designed for wind loads up to 158 mph. Earthquake forces did not control.
6	What material specifications and properties were used for the FRP shapes?	FRP material properties are at this time based on the Manufacturer's testing. See www.creativecompositesgroup.com website for specifications or email dwiney@pultrude.com for typical specifications that include our material properties.

7	How can we apply this technology in our soon-to-be real-world jobs?	Given its light weight and low maintenance properties, FRP use is likely to continue increasing. Anywhere corrosive action occurs is a good location for application of FRP structures.
8	Can pultruded bridges be used to rehabilitate or replace moveable bridges?	Yes, the lightweight nature of the material and the high strength make it viable for using decking or structural shapes for moveable bridges.
9	What are the limits (e.g., length, width, weight) for these pultruded FRP bridges? Can they be used for vehicular bridges also?	These bridges are limited by the resin type and reinforcing material types (material type, material patterns, etc.). They are not normally used for vehicular bridges such as an HS-20 Truck; however, maintenance trucks such as H5, H10, and H15 can be accommodated.
Construction		
10	Did the use of FRP pultruded composites save time in assembly and installation and make the client happy?	The use of FRP saved time in installation. Assembly was done by over 50 local volunteers (at various different points), who subsequently became very invested in the success of the project.
11	What is the total weight of the bridge, and what UV (ultraviolet) protection does the structure have?	The bridge weighed approximately 60,000 lbs. In the resin there is an additive, which is a UV inhibitor, plus the top members exposed to the sun are painted with a polyurethane paint. This paint is relatively less expensive than repainting a steel bridge.
12	Can you discuss claims and changes of plans during construction?	The bottom chord at both ends was strengthened and replaced when it had local failure under the full-scale load test. This was before construction in Bermuda. No other changes to the FRP truss were completed in Bermuda.
Maintenance		

13	Can you discuss in situ repairability if hit by a ship (e.g., sailboat mast) or errant maintenance vehicle?	We've had the experience of a fishing boat hitting one of the Bailey's Bay Bridges (~65') during a hurricane. The bridge survived with some damage to the bottom chords, outriggers, and crosspieces (though the boat did not). The bridge was repaired in situ with parts shipped from Creative Pultrusions. Total repair cost was ~\$10,000. Where FRP members are damaged, the structure can be temporarily supported, and the damaged member can be replaced.
14	Can you discuss UV (ultraviolet) degradation, creep of the bridge, tie-downs to hold it on the foundations during flood and high winds, and loss of ductility over time?	This is a good question. As FRP structures become older, we will be able to examine any effects from UV degradation and creep. UV degradation can be limited by painting. We currently have bridges in very warm climates such as California, and they have held up well for over 20 years from UV degradation. As far as creep goes, a bridge we had installed experienced a snow load of 3 times the design load and only minor damage occurred at one connection.
Cost		
15	How does the cost to build this bridge compare to, say, a steel bridge of the same size?	This varies, but our bridges up to 120 ft are very competitive if only pedestrian loads are required. We are working on being more competitive for up to 150-ft spans.
16	What is the construction cost of the bridge?	Please contact Creative Pultrusions, Inc.
Questions during Webinar		
17	Does Bermuda have local wind speed data for design purposes?	Bermuda does collect local wind speed data, though design criteria is set at 158 mph (a high Category 4 hurricane).
18	Does the connection design include a safety factor when test results are used?	Yes. Testing produces a characteristic design ultimate strength. Further reductions can be made based on temperature, service life, and loading type.
19	Can you speak about the need to have an FRP bridge instead of a prestressed concrete bridge?	The light weight, low shipping cost, previous experience, and easy assembly (without bringing in expert labor) were all important factors that led to the preference of FRP.

20	You mentioned that natural frequencies (modes and values in Hz (hertz)) were calculated. How were accelerations calculated, since the Setra document table classifies the degrees of comfort according to accelerations caused by the pedestrians' usage?	The basic equation is force equals mass times acceleration. Since we know the mass and we calculated the force due to synchronized pedestrian wave equations, the acceleration can be computed. The Setra document explains the process and gives the equations.
21	What is the thermal coefficient of expansion for FRP compared to steel and concrete?	See Pultex Pultrusion Design Manual from our website - www.creativecomposites.com . For example, a channel has a coefficient of thermal expansion in the length-wise direction of 4.4×10^{-6} in/in/°F.
22	Was uplift a concern in the design of the connections for the bridge?	Yes, uplift was considered for the anchorage of the bridge to the foundation.
23	What vessel collision protection have you provided for the bridge?	The bridge has a ~20-ft clearance and sits over an inlet that is primarily trafficed by small center console boats. There is no sailboat access to the Inlet as the Sound on the other side is blocked by a bridge with much lower clearance. The foundation pylons are oversized from the previous steel structure.
24	Have you considered earthquake loads for the design?	Earthquakes are not an important factor in Bermuda, though FRP has been designed (with success) elsewhere to meet earthquake loads.
25	What is the design life for pultruded FRP members?	Our bridges have been in service for around 20 years. We reduce our capacities based on a factor to provide a service life of 75 years. If additional service life is required (i.e., Eurocodes require greater service life), then we can extrapolate our strength and reduce our member capacities even more; thus, accounting for a higher required service life.
26	Did you use A325 bolts for the bridge? If so, were they galvanized? What was the method of tightening the bolts?	No, we used A316 Stainless Steel Bolts.
27	FRPs are sensitive to impact. Have you had any issues in transporting the members?	We had a fracture of single x-brace that occurred during shipping. It was replaced by Creative Pultrusions under insurance coverage.

28	How did you reproduce the camber when reassembling the bridge?	We laid out the bridge on a relatively flat surface and carefully followed Creative Pultrusions assembly drawings and used shims that were shipped with the bridge. Where necessary, we used a sight level to check the height of the camber.
29	Is the decking made of FRP or real wood? It looks beautiful.	Yes, the decking is pressure-treated southern pine.
30	It looks like wooden planks are used for the deck. Why were FRP planks/panels not used to provide the same durability as the truss?	We preferred wood for its non-slip surface and aesthetics. It is pressure treated, so we expect it to have a significant lifespan. While FRP decking would provide greater durability, the FOB (Friends of Bermuda) used wood based on economy.
31	How was the decking connected to the truss; for example, were the holes predrilled or drilled in the field through the FRP members?	Decking was connected by carriage bolts that were attached to the bottom chord FRP members through predrilled holes.
32	What is the design life of the FRP with respect to UV (ultraviolet) light degrading the FRP?	See Question 25.
33	How about UV (ultraviolet) exposure? What is the past experience with long-term performance of FRP bridges?	See Question 25.
34	What is the life expectancy of the bridge, and of the UV (ultraviolet) protection?	See Question 25.
35	How do you repair any damaged members? How do you check the hollow members for internal damage? Why do you say FRP is ductile?	Where FRP members are sufficiently damaged, the structure can be temporarily supported and the damaged member can be replaced with a new member. You cannot check the members for internal damage; the damage should show itself with cracking of the tube webs and/or extraordinary deflections. I misstated that FRP is ductile; the members are brittle; however, FRP systems are very ductile because of the FRP's low modulus of elasticity and that the lower torque (i.e., than steel) bolted connections are utilized.
36	What was the total cost of the project?	Please contact Creative Pultrusions.

37	What is the bridge cost per square foot, including material, shipping, and installation?	Please contact Creative Pultrusions.
38	FRP strength-to-weight ratios are very efficient; however, the light weight can cause issues during hurricanes, tsunamis (Is Bermuda seismically active?), fire, and vibration. Do you have any comments on this?	Bermuda is not seismically active, and seismic forces did not control. Potential uplift or overturning due to wind from hurricanes was accounted for in the connection to the foundations and the weight of the foundations. FRP connections can be efficient, but only if serviceability requirements (i.e., deflections or frequency analysis) do not control. See the slides for frequency analysis comments.
39	Does this bridge undergo normal bridge inspections much like in the United States and, if so, how often are the FRP bridges inspected and what are the main issues that you would expect to see in the future during inspections?	At this time, inspections are not required. The issues we might expect or be alert to are any degradation of the material from UV exposure and any degradation of the stainless steel bolts.
40	Can you talk about fire resistance of the FRP bridge?	The bridge does not contain a fire retardant additive in the resin mixture, but is available.