FIBRE COMPOSITE PEDESTRIAN BRIDGES ON THE DOMINION TRAIL

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ABSTRACT: The City of Frisco has embarked on a project to utilize green space as an active transportation trail, constructing the "Dominion Trail" walkway. The 1.26 mile pathway, mainly concrete slab on ground, required 3 elevated walkway sections to maintain accessibility through the topography. 500 linear foot of bridge, and 267 lineal foot of prefabricated boardwalk was required. Fiber composite materials were selected with 9 bridges constructed with spans of up to 100 foot. The intent was to utilize lightweight composites to allow a light touch to the environment, reducing sizes of cranes required, and allowing a narrow corridor to be utilized for construction. Fiber Composite bridges also give superior durability performance, giving the city of Frisco a long life asset. This paper will discuss the structural aspects of design of FRP footbridges and boardwalk, through to the installation methods.

INTRODUCTION

The Panther Creek shared trail required a series of connections to complete the 1.25 mile trail network. The scope of the project was to provide a 12′ wide shared use pathway using AASHTO standards and limit the rise of Panther Creek during a 1 in 100 year event.

This paper focusses on the FRP materials selected for the crossing sections.

DESIGN WORK

OVERVIEW AND LOADING - The overall area of the FRP structures/walkways in Dominion Trail project is around 9000 sq.ft. This is over three sections of elevated trail in the floodplain, with eight truss bridges and three boardwalks as detailed below:

- Trail A – Four truss bridges (40ft-70ft-60ft and 40ft) and 100ft boardwalks
- Trail B – Three truss bridges (40ft-70ft-40ft)
- Trail C – Two truss bridges (100ft and 40ft) and two boardwalks 135ft and 35ft

The FRP bridges were designed in accordance with the applicable code mentioned below, considering the design loads summarized in Table 1. The load combinations of SLS and ULS are adopted following Table 3.4.1-1 in the AASHTO LRFD highway bridges while considering the exceptions in clause 3.7 AASHTO LRFD pedestrian bridges

- AASHTO LRFD Design Specification for highway bridges 9th Edition
- AASHTO LRFD Design Specification for pedestrian bridges, 2009
- AASHTO Guide Specifications for Design of FRP Pedestrian Bridges 1st Edition
- WCFT Design Guide and Testing Results

Table 1 Primary load case summary

Primary Load	Value	Comment
Dead loads Decking	Self-weight 6 PSF	FRP components, inserts and Stainless-steel connections hardware
Live loads	90 PSF H5 Loading	Pedestrian loading Vehicle loading
Wind Loads	35 PSF 20 PSF	Horizontal load Overturning force AASHTO FRP Specifications
Seismic Loads	0.1 kips/ft	Equivalent Lateral Force Procedure - ASCE
Flood Loads	As per the Hydraulic report	
Thermal Loads	Maximum 120 °F, minimum 0 °F, T_{dif} 120 °F	AASHTO LRFD Specifications
Deflection criteria	Span / 360 under Live load	AASHTO FRP Specifications

The detailed structural design and analysis of Dominion Trial was undertaken using multiple analysis methods and software packages. A summary of these can be found below

Table 2 – Analysis and design tools summary

Item	Software Package	Purpose
Load analysis	In-house MS Excel Spreadsheets and hand calculations	Simple methods for deriving member loads for the inputs of numerical models
3D Structural analysis Ultimate and serviceability limit state design.	Space GASS - 3D analysis and design software	Member forces, moments, shears, deflection, natural frequency. Subsequent connection forces
Simplified Connections	In-house MS Excel Spreadsheets	Standardised connection verification based on member forces from Space GASS analysis
Highly loaded and non-standard connections	Hand calculations and refined FEA models using Strand7 & ANSYS	Hand calculations to determine approximate results. Strand7 and ANSYS for 3D modelling of connections with multiple axis loading, contact surfaces, gusset plates and weld requirements.

TRUSS GEOMETRY – The longest FRP bridge in Dominion trial is 100ft long, width 12ft traffic width to allow for pedestrian and H5 vehicle loading. The precise geometric proportions and dimensions of the outer trusses are crucial to ensure the structural integrity (strength and stiffness wise) to withstand the applied loads on the bridge. Several design iterations were undertaken using in-house design spreadsheets following Parallel Axis Theorem to quickly analyze few truss options i.e. chords size, truss depth, etc. Once a suitable truss geometry is identified, time/efforts were spent to fully model/analyse the truss bridge in 3D using Space GASS. The analyses results of the Space GASS model were interpreted to verify the member sizes and design the bridge details and connections.

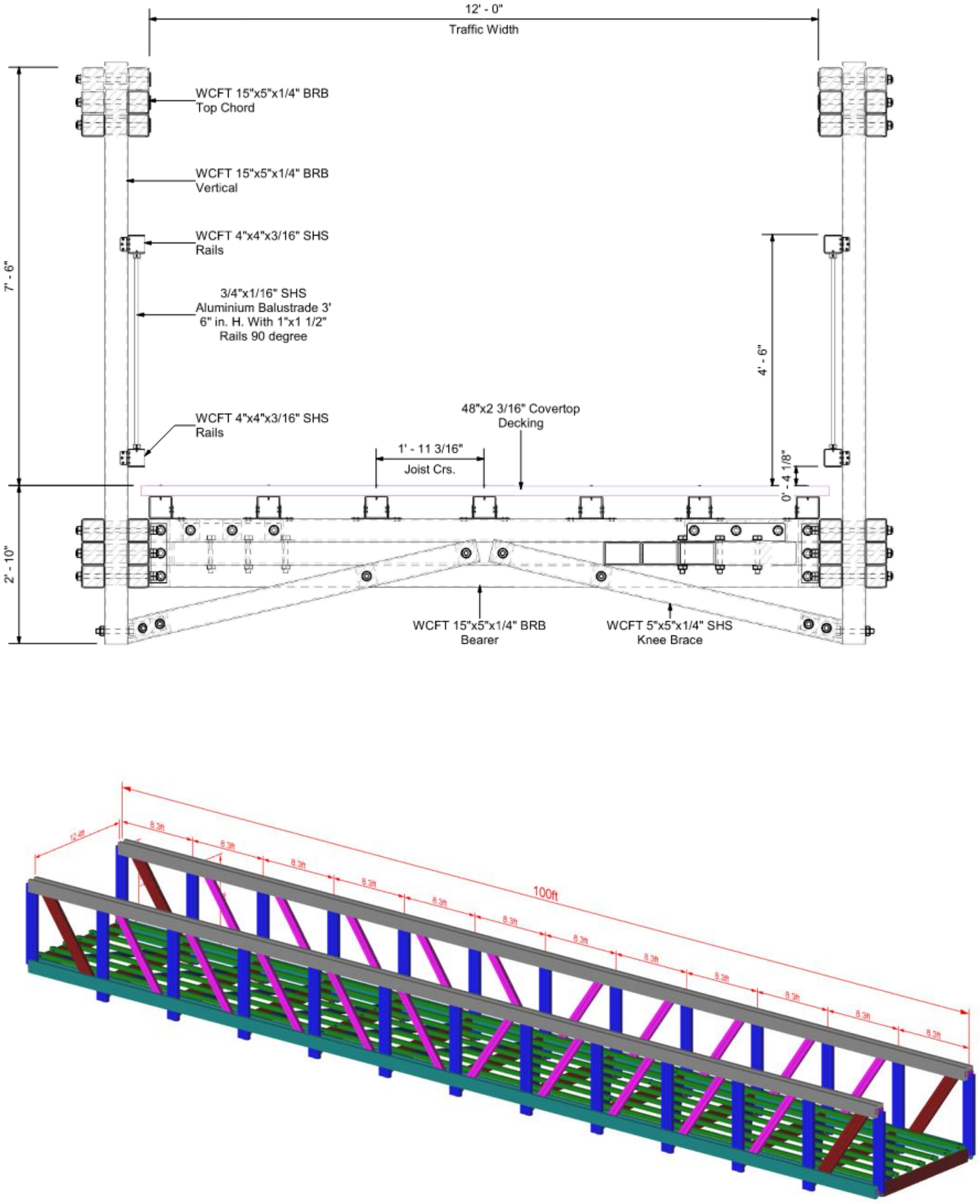


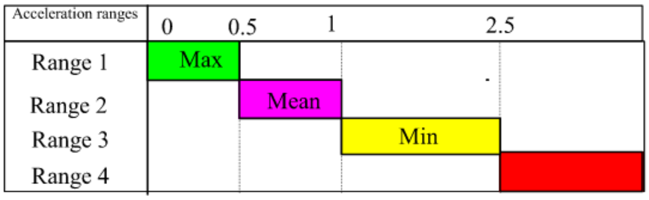
Figure 1. 100ft Bridge Geometry (Cross-section and Elevation view)

DYNAMIC PERFORMANCE

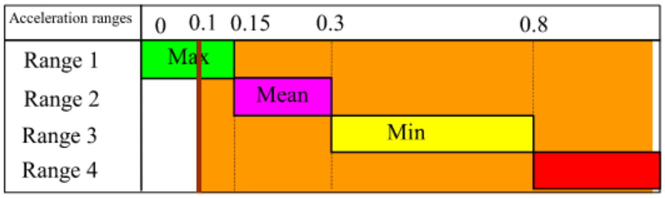
PEDESTRIAN COMFORT - Verification assessments were conducted to evaluate the pedestrian induced excitation performance of the 100ft FRP pedestrian bridge. The wavefront solver of Space GASS was used to determine the fundamental vertical and horizontal frequency of the FRP bridge.

Further dynamic checks were also undertaken to assess the pedestrian comfort criteria. Transient solver was used to determine the maximum nodal acceleration under various pedestrian loadings and compared with comfort level ranges as shown in Figure 2 (Setra 2006 End note). The assessment consisted of modelling a pulsating force load produced using Fourier Transformation equations to replicate the vertical and horizontal impact of a footfall load. This load was applied to the deck in a 3D model and factored to account for the effect of multiple pedestrians walking in-sync and out-of-sync across the structure. Generally, the bridge structure did not show deck accelerations in excess of the perceived limit except for a slow walking, synchronized footfall event, such as those from a marching band.

AEROELASTIC INSTABILITY – Aeroelastic instability occurs when the motion of the structure in wind produces aerodynamic forces magnifying the same motion. Dominion trial bridges are not subject to wind speeds capable of producing aerodynamic instabilities. Aerodynamic performance assessment were also undertaken in accordance with British Standards Bridge Design part 49/01 whereby checks were completed against vortex excitation, limited amplitude response / turbulence and classical flutter



(a) Vertical vibrations



(b) Horizontal vibrations

Figure 2. Acceleration vibration ranges (in m/s²)

Connections

CRITICAL CONNECTIONS – Due to the primary loads summarized in Table 1 been applied on the truss bridge, there were several critical truss connections that were highly loaded, and careful attention was considered in the detailed design of these connections, which are:

- End chord to verticals
- End diagonals to chords
- End chords/verticals to the abutment
- Horizontal subfloor bracing

All these connections are bolted connections and were designed considering the bolted connection capacity tables in WCFT Design Guide V2.0 (2024).

SPLICE CONNECTION - Due to transportation and logistics constraints, a splice connection design was required to connect the bridge chords together on site, effectively joining two bridge segments to create one long span.

The main issue with splice connections (Figure 3) for bridge chords is they are required to carry the full axial, shear and bending load requirements across the broken joint from one chord to the next. Within this vicinity, a number of items are required to be checked such as ultimate strength performance of the splice, serviceability performance of the splice and fatigue performance.

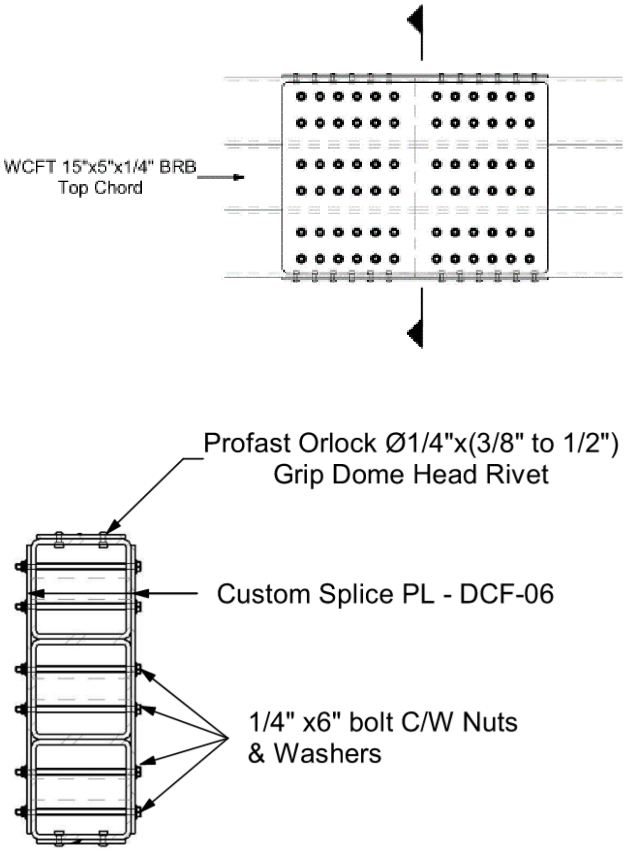


Figure 3. Details of the splice connection

The design of the splice connection riveted group was undertaken using an in-house spreadsheet for the assessment of a bolt patterns ability to resist torsional moments perpendicular to the plate by using the polar moment of inertia of the group. This is represented by the below figure.

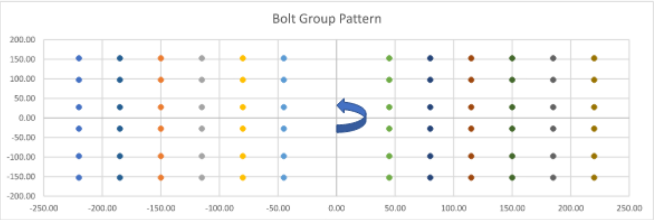


Figure 4. Splice connection design for the rivet (“bolt”) group – incorporating polar moment of inertia

Next, the forces and moments were broken down into maximum resultant and component shears to assess shear capacities and bearing strengths. The detailed design analysis, subsequent preparation of load testing and analysis of testing results of the compression chord splice plate were based upon manual hand calculations for plate buckling and further verified using a study that us published by Kelpša and Peltonen (2019). The theory presented in this paper were coded into a spreadsheet and used to verify different plate geometries under multiple loading criteria.

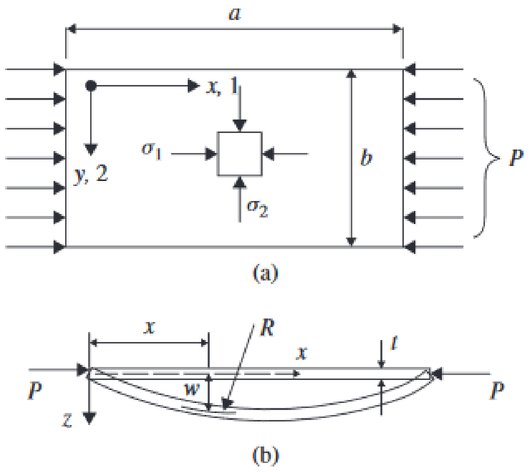


Figure 5. Buckling of a wide plate strut by Kelpša and Peltonen (2019)

Experimental Testing/Verification of The Spliced Connection

The physical, mechanical and chemical properties of the FRP components are already characterised and presented in the Design Guide of Wagners CFT Design Guide V2.0 (2024). As detailed in the previous section, the truss bridge was designed to be spliced at the top and bottom chords stainless steel plate and 1/4” structural rivets as shown in Figure 3. Considering the nature and the importance of this splice connection, A prototype of the spliced connection was fabricated to be tested for the ultimate design axial forces that were to be transferred through the truss chords as proof load verifying the theoretical design.

TEST METHODOLOGY – The test sample and test setup are shown in Figure 6. The test sample was fabricated as a replica of a single side of the chords, with internal glued anti-crush blocks at the top and bottom ends to avoid any local crushing. A 20mm gap was left between the two FRP sections for testing purposes only to simulate potential onsite tolerancing allowance. As a worst-case scenario, the design was done in a way to allow for the full load to be transferred through the splice itself with no bearing between chords. The axial displacement was captured using a linear potentiometer, and the test load was applied using a hydraulic ram and 50t load cell, both the load and deformation were recorded using a DT80 Datataker.

The test load was adopted based on the consolidated ultimate design force obtained from the bridge structural analysis using SPACE GASS software (60.3 kips). In addition, the ultimate design load was factored up considering a coefficient of variation of structural characteristics (Vsc) of 1.256 for 6% variation on the prototype testing as per AS/NZS1170.0. The Ultimate Limit State load (ULS) for testing purposes was therefore determined to be 75.6 kips. The test procedure was then carried out following the below loading steps:

- Preload to 50% of ULS load (37.8 kips), return to zero load and measure the gap distance
- Apply and hold ULS load (75.6 kips) for 15 minutes, and return to zero
- Load until failure

Figure 6. Experimental compressive test setup of the spliced connections

TEST RESULTS AND OBSERVATION – The splice prototype was tested/loaded to 50% of ultimate limit state, 100% ultimate limit state, and then to final failure. The sample successfully withstood the ultimate test load for 15 minutes as shown in Figure 7. After that, the sample was loaded until it failed ultimately at 117 kips where the steel plates buckled at the mid-height as expected (Figure 8). It is noteworthy to highlight that that there was no failure in the FRP components, and higher spliced connection capacity can be achieved by using thicker plates. The test results verified the theoretical design and provided confidence in the proposed connection to be used in Dominion Trail truss bridges.

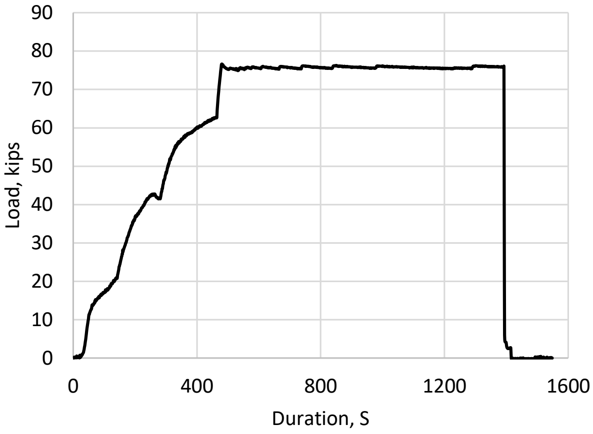


Figure 7. Ultimate test load vs duration curve

Figure 8. Failure mode of the tested sample

CONCLUSIONS

The Dominion Trail project demonstrates the successful application of fiber composite materials in pedestrian bridge construction, offering significant environmental and structural benefits. The use of FRP composites enabled the creation of lightweight, durable, and efficient bridges that minimized environmental impact during installation and ensured long-term asset performance for the City of Frisco. The detailed design and rigorous testing of the FRP truss bridges, particularly the critical connections and splice joints, validated the theoretical models and confirmed the robustness of the structures under various loading conditions. This project exemplifies how innovative materials and engineering solutions can be effectively employed to enhance infrastructure sustainability and functionality.

ACKNOWLEDGEMENT

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