CREATIVE COMPOSITES GROUP

AASHTO H-5 Pultruded Fiberglass Reinforced Polymer (FRP) SuperDeck® Realization & Validation

Validation of CCG's SuperDeck Lite for the Design Manual and H-5 Truck Load

WHITE PAPER

01.09.2023

Contents

Abstract

The SuperDeck Lite pultruded fiberglass reinforced polymer (FRP) decking product has been developed for the pedestrian, bicycle and access structures markets. The decking product has been designed to support both uniform live loads and AASHTO H-5 wheel loads. The AASHTO H-5 wheel load imposes a highly concentrated load over a rather small area of the deck. Therefore, the deck was designed to withstand concentrated wheel loads resulting in significant shear stresses while maintaining the deflection limitations detailed in the applicable AASHTO Specifications. The intent of this white paper is to document the results of the static structural tests used to validate the assumptions and calculations made in developing the FRP SuperDeck Lite product. The information presented in this white paper is based on the FRP decking supported on longitudinal stringers or beams, not supported on floor beams.

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Introduction

The design of FRP Pedestrian Bridges is primarily governed by the *AASHTO Guide Specifications for FRP Pedestrian Bridges, 1st Edition* which references many of the provisions of the *AASHTO LRFD Bridge Design Specifications, 7th Edition*. When designing an H-5 rated pultruded pedestrian bridge deck, design elements such as bending, shear and serviceability limit states are weighed against the applicable specifications.

Based on our extensive experience with producing FRP decking products for bridges, the Creative Composites Group designed the FRP SuperDeck Lite product to comply with the following requirements:

- **Strength I Limit State:** The Strength I limit state is used to check the ultimate strength of the decking. The Strength I limit states requires a 1.75 load factor to be applied to live load and the dynamic impact factor (IM) is set to zero in accordance with section 2.12 of the FRP Pedestrian Bridge Guide.
- **Service I Limit State:** The Service I limit state is used to check deflections and the allowable stresses in the FRP decking.
- **Deflection:** Uniform live load deflections are limited to L/500. Since the FRP Pedestrian Bridge Guide does not provide any guidance on deflection requirements associated with vehicle loads we've chosen to limit the deflection under vehicle loads to 0.25 in. This practical limit is based on experience and considers differential deflection between planks.
- **Tire Contact Area:** Since the FRP Pedestrian Bridge Guide does not include any guidance on how to distribute the wheel loads (i.e., tire contact area) to the FRP decking, we've chosen to use the guidelines as presented in the commentary section C3.6.1.2.5 of the LRFD Bridge Design Specifications:

$$Tire\ Width = \frac{P}{0.8} = 5''$$

$$Tire\ Length = 6.4\gamma\left(1 + \frac{IM}{100}\right) = 11.2''$$

where:
$\gamma = \ load\ factor = 1.75$
$IM = dynamic\ load\ allowance\ percent = 0$
$P = design\ wheel\ load = 4\ kip$

Based on the above requirements and a calculated tire contact dimension for the AASHTO H-5 truck, we determined a tire width of 5 in. and tire length of 11.2 in. CCG's engineering team developed the SuperDeck Lite cross-section shown in Figure 1 and designed the fiber architecture and resin formulation that meets the H-5 requirements with the appropriate safety and/or reduction and Φ factors.

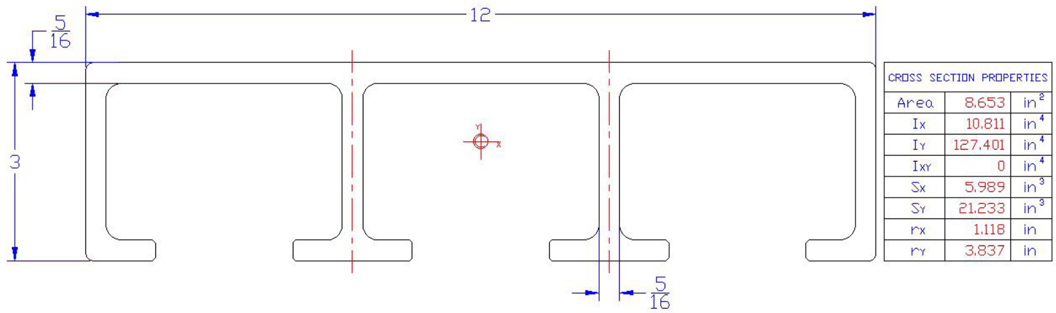


***Figure 1:** SuperDeck Lite profile*

After the initial production run of the SuperDeck Lite, experimental testing was conducted to develop the ASTM D7290 characteristic full section flexural strength, characteristic in-plane shear strength, and the average full section modulus of elasticity. The mechanical attributes described are the governing values necessary for both structural and serviceability computations when the loads are applied across the full width of the panel. The data collected was used to develop standard point and distributed load tables for inclusion in marketing and engineering literature.

Testing was conducted using footprint load based on the given wheel area dimensions to determine the ultimate capacity of the deck when subjected to vehicular loading. Following the footprint loading, 12 lengthwise v-notch shear coupon level specimens were cut from the top web for testing per ASTM D5379. This provided a correlation between full section testing and coupon level testing, which can be used for quality assurance during production of the deck.

Procedure

Twelve full width planks, at both 30 in. and 150 in. lengths, were taken from production to perform full section testing per ASTM D8069-17A to determine the characteristic and average values for shear, flexure, and the modulus of elasticity. The characteristic flexural strength and average modulus of elasticity values were determined from the three-point bending test of the 150 in. length parts at an eight-foot span (Figure 2), while the characteristic in-plane shear values were determined from the three-point bend test of the 30 in. length parts at a two-foot span (Figure 3).

***Figure 2:** Eight-foot span three-point bend test*

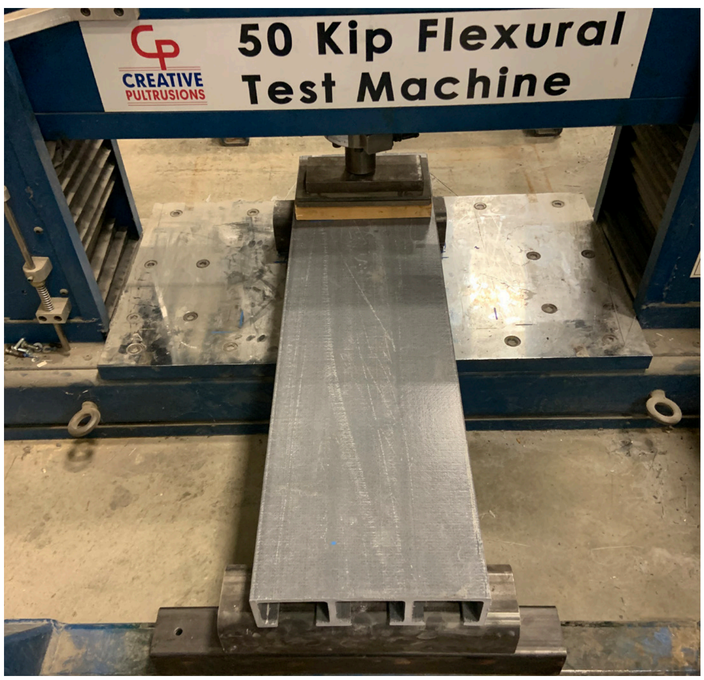
The three-point bend test was conducted by using a 2 in. wide steel bar to distribute the load across the full width of the panel. Supports topped with 4 in. diameter steel rods were used for the eight-foot span and two 4 in. x ½ in. steel square tubes were used

Figure 3: Two-foot span three-point bend test

for the two-foot span. The supports and specimens were marked to allow the load cell to be centered on the part for each test. Tie down straps were used at the ends of the eight-foot span to prevent the panel from sliding out from under the load cell. The straps were tightened to a snug fit to prevent any additional loadings that may have affected the test results.

All H-5 wheel load simulation testing was performed with the wheel footprint running across the width of the pultruded deck assuming the deck would be placed perpendicular to the main bridge support girders. The simulated wheel test permitted the CCG to determine the reaction and magnitude thereof and failure mode based on a typical H-5 tire footprint.

Figure 4: Schematic of SuperDeck Lite shear load testing



The pultruded deck section was cut to 44 in. to achieve a 36 in. clear span. The span was based on the theoretical design shear capacity determined from the results of full section testing at two-foot span lengths. To represent the tire footprint, a section of southern yellow pine (SYP) board was cut to the dimensions specified above, of 5 in. by 11.2 in. To prevent the load cell from crushing the wood block and to distribute the load evenly across the wood section, two pieces of steel were placed on top of the SYP board (Figure 4).

The pultruded SuperDeck Lite was positioned under the 50 kip full section test machine and tested to failure using a 50-kip load cell. To ensure consistency between tests, marks were made on the machine and steel support tubes to mitigate variance when positioning the deck and wheel footprint for testing.

The simulated wheel footprint was centered across the width of the panel and adjusted to be one inch away from the closest end support. Positioning the SYP wheel footprint to one side of the span creates the worst-case shear load scenario.

The certified technician applied the load through the calibrated load cell at a rate of approximately 2,000 lbf per minute. A calibrated data acquisition system was used to record the load and deflection at a rate of four readings per second. The load was applied until failure of the SuperDeck Lite pultruded deck section occurred. Failure was determined when the specimen experienced a catastrophic failure or when the load dropped twenty percent or more during testing.

Results

Table 1 presents the calculated results of the eight-foot span full section characteristic flexural strength and the average modulus of elasticity. Table 2 presents the calculated results of the two-foot span characteristic in-plane shear strength. The results are based on the data collected from twelve full section tests, conducted on two different spans. The ASTM D7290 protocol was used to calculate the characteristic design values. The average modulus of elasticity was determined in accordance ASTM D8069-17A. Reference figures 2 and 3 for the test setup photos. Figures 5 and 6 show the corresponding failure modes for the two different spans.

Table 1: *Eight-foot span three-point bend test results*

	Peak Load	Moment @ Peak Load	Effective Elastic Modulus	Flexural Strength
# of Specimens:	12	12	12	12
Mean Value:	19,204 lbf	38,407 ft-lb	4,872 ksi	76,956 psi
St. Dev.:	388 lbf	777 ft-lb	51 ksi	1,557 psi
COV:	2.3%	2.3%	1.6%	2.3%
Characteristic Value:	17,546 lbf	35,093 ft-lb	4,808 ksi	70,314 psi

Figure 5: *Eight-foot span tension failure*

Table 2: *Two-foot span three-point bend test data (center load)*

	Peak Load	Moment @ Peak Load	Shear Strength
# of Specimens:	12	12	12
Mean Value:	41368 lbf	20684 ft-lb	8274 psi
St. Dev.:	1194 lbf	597 ft-lb	239 psi
COV:	3.5%	3.5%	3.5%
Characteristic value:	36896 lbf	18448 ft-lb	7379 psi

Figure 6: Two-foot span shear failure

The results of the simulated H-5 wheel footprint testing is shown in Table 3 and Figure 7. Table 3 represents the characteristic shear strength, while Figure 7 represents the load vs. displacement to failure results. Figure 8 shows the failure mode resulting from the footprint load test.

Table 3: Footprint test results

Test Piece Description	Peak Load (lbf)	Shear Strength (psi)
Specimen 1	29,185	10,539
Specimen 2	31,595	11,409
Specimen 3	30,905	11,160
Specimen 4	30,979	11,187
Specimen 5	27,155	9,806
Specimen 6	29,189	10,540
Specimen 7	29,518	10,659
Specimen 8	30,997	11,193
Specimen 9	33,957	12,262
Specimen 10	30,819	11,129
Specimen 11	33,295	12,023
Specimen 12	33,351	12,043
# of Specimens:	12	12
Mean Value:	30,912 lbf	11,163 psi
St. Dev.:	1,986 lbf	717 psi
COV:	6.83%	6.83%
Characteristic Value:	25,367 lbf	9,160 psi

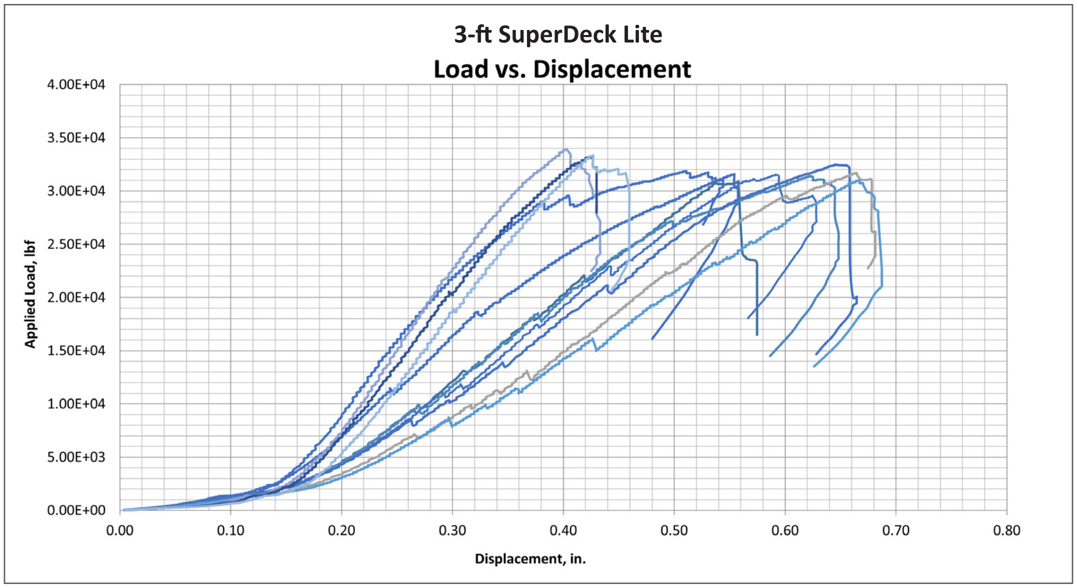


Figure 7: *Wheel footprint load vs. displacement*

Figure 8: *Shear failure from footprint load*

As stated in the introduction, further specimen testing was conducted to ensure future quality assurance testing could be performed for validation during production. In-plane shear specimens were extracted from both the webs and flange in the lengthwise direction, as the fiber architecture is similar in both locations.

The in-plane shear values obtained from ASTM D5379 testing can be used to certify the panel meets H-5 load conditions because the characteristic shear strength determined via ASTM D5379 is within 1% difference of the full section wheel footprint shear test results.

Table 4: *ASTM D5379 V-Notch shear*

	Thickness *(in)*	Notch Width *(in)*	Area *(in^2)*	Maximum Load *(lbf)*	Shear Strength *(psi)*
Specimen 1	0.3150	0.4660	0.147	1,542	10,506
Specimen 2	0.3120	0.4440	0.139	1,669	12,050
Specimen 3	0.3160	0.4640	0.147	1,549	10,567
Specimen 4	0.3160	0.4570	0.144	1,521	10,534
Specimen 5	0.3160	0.4650	0.147	1,551	10,557
Specimen 6	0.3130	0.4500	0.141	1,632	11,584
Specimen 7	0.3160	0.4540	0.143	1,557	10,852
Specimen 8	0.3160	0.4620	0.146	1,594	10,918
Specimen 9	0.3160	0.4500	0.142	1,599	11,246
Specimen 10	0.3160	0.4540	0.143	1,521	10,602
Specimen 11	0.3160	0.4600	0.145	1,566	10,770
Specimen 12	0.3160	0.4540	0.143	1,633	11,380
Mean Value:	0.3153 in	0.4567 in	0.144 in^2	1,578 lbf	10,964 psi
St. Dev.:	0.001 in	0.007 in	0.003 in^2	47.479 lbf	497.209 psi
COV:	0.43%	1.51%	1.79%	3.01%	4.54%
Characteristic value:	-	-	-	1,402 lbf	9,241 psi

Calculations

Applications utilizing the SuperDeck Lite panel can be designed using either allowable stress design (ASD) or load and resistance factor design (LRFD) methodologies.

Structures designed using the ASD methodologies can be designed with established industry safety factors. A minimum safety factor of 2.5 was considered for members in bending, while 3.0 is used for members in shear. In regards to the *AASHTO Guide Specifications for FRP Pedestrian Bridges, 1ST Edition* the minimum safety factor requirement of 4.0 is used.

The *Pre-Standard for Load and Resistance Factor Design (LRFD) of Pultruded Fiber Reinforced Polymer (FRP) Structures* can be used for designs requiring the LRFD design methodologies. As the panel does not adhere to the geometric criteria for many of the standard provisions, Section 2.3.2 can be implemented to calculate an appropriate resistance factor (Φ) based on the statistical aspects of the full section test results.

The statistical aspects of the full section flexural and shear tests are shown below in table five. The resistance factors were calculated using section 2.3.2 of the FRP LRFD Pre-Standard.

***Table 5:** Resistance factors*

SuperDeck Lite Panel Testing			
Variables	**2-ft Span**	**8-ft Span**	**Wheel Load** *(3-ft span)*
Failure Mode	Shear	Flexure	Shear
n =	12	12	12
p =	0.99	0.99	0.99
$t_{n-1,p}$ =	2.718	2.718	2.718
V_R =	0.0350	0.0230	0.068
Φ_p =	0.906	0.937	0.825

Conclusions

Based on the test results, the SuperDeck Lite will meet and exceed the load requirements established in the *AASHTO LRFD Bridge Design Specifications, 7th Edition* and *AASHTO Guide Specifications for FRP Pedestrian Bridges, 1ST Edition*.

The characteristic lengthwise in-plane shear strength of 7,380 psi, determined in the two-foot span, three-point bend test shall be utilized for computing the shear load capacity.

The ASTM D5379 v-notch shear test results correlate well with the H-5 wheel footprint testing. Therefore, the ASTM D5379 v-notch shear test can be used for quality assurance purposes.

The flexural strength and average modulus of elasticity, determined per ASTM D8069-17A, in the eight-foot span three-point bend test, shall be used for serviceability and strength computations.

The resulting H-5, H-10 and uniformly distributed loads (UDL) associated with the maximum deflections and spans can be viewed in Table 6. This deck was designed predominately for H-5 applications, however in some instances the deck can be used for H-10 applications. The 90 psf and 65 psf loads are standard requirements for live loads in different specifications.

Table 6: Max spans for various design loads

	Max Allowable Span *(in) (Single Span)*						
	L/D Ratios			Deflection *(in)*			
Design Load	**240**	**360**	**500**	**0.25in**	**0.375in**	**AASHTO Max. Service Load**	**IBC Max. Service Load**
H-5 Wheel Load	47	36.5	29	51.5	59.5	120	144
H-10 Wheel Load	30	21.5	15	39.5	46	17.5	25
UDL (90 psf)	130	113	101.5	107	118.5	144	144
UDL (65 psf)	144	126.5	113	116	128.5	144	144

*Characteristic Flexural Strength - 70,300 psi
*Characteristic Shear Strength - 7,380 psi
*Average Modulus - 4.87E+06 psi
*IBC In-plane Shear & Flexural Safety Factor - 3 & 2.5
*AASHTO LRFD Equivalent Shear & Flexural Safety Factor - 3.5
*Shear Area - 3.75 in^2
*Max Span was capped at 144 in
*H10 wheel load behavior is predicted and has not been tested

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ABOUT THE COMPANY

Creative Composites Group is a custom design, engineering and Fiber Reinforced Polymer (FRP) deck manufacturer. We offer comprehensive design, consultation and fabrication for unique structural decking projects. Our manufacturing capabilities include the broadest range of engineered FRP solutions to build your ideal projects. That's possible only with our proven engineering processes, end-to-end collaboration, service and support resources. Since FRP composites last longer than conventional materials they often have a lower lifetime cost when you consider longer service life and low to no maintenance costs.

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CCGWP01092023R2