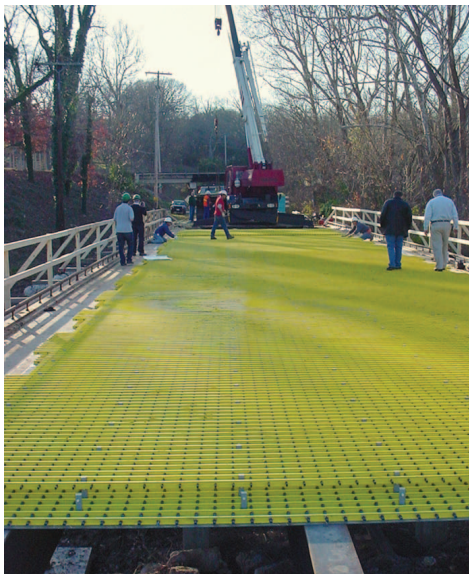
GEF Incorporated

Winfield, WV
Phone (304)755-1600
Fax (304)755-3150
www.gefinc.com

BRIDGE COMPONENTS

FIBER REINFORCED POLYMER COMPOSITES



Introduction

Strongwell is the world's leading pultruder of fiber reinforced polymer (FRP) structural shapes and operates three ISO-9001:2000 certified pultrusion plants. The company's FRP composite products have been used since 1956 to solve problems for customers in a wide variety of markets, some of which are shown below. Strongwell's in-house staff of registered professional engineers represents nearly every engineering discipline, including structural engineering. The company also has complete fabrication facilities and the largest production capacity in the industry to ensure that customer needs are satisfied quickly and completely. The company manufactures FRP structural shapes, grating, handrail, ladders, planks and other building products.

GRIDFORM™ Stay-in-Place FRP Bridge Deck System

Since 1995, Strongwell has focused its design engineering and manufacturing resources on the development of FRP products for vehicular bridges. Our newest product, GRIDFORM™ is a stay-in-place concrete bridge deck system that is designed to replace steel rebar in reinforced concrete bridge decks. GRIDFORM™ consists of two layers of pultruded FRP I-bar grating separated by FRP connectors with nylon bolts. The grating features standard I-bars on 4" centers and cross rods on 4" spacings. A 1/8" pultruded FRP plate is bonded to the bottom grating layer to create a stay-in-place concrete form.

History of GRIDFORM™

2001

Strongwell began development of the GRIDFORM™ system with the University of Wisconsin.

2003

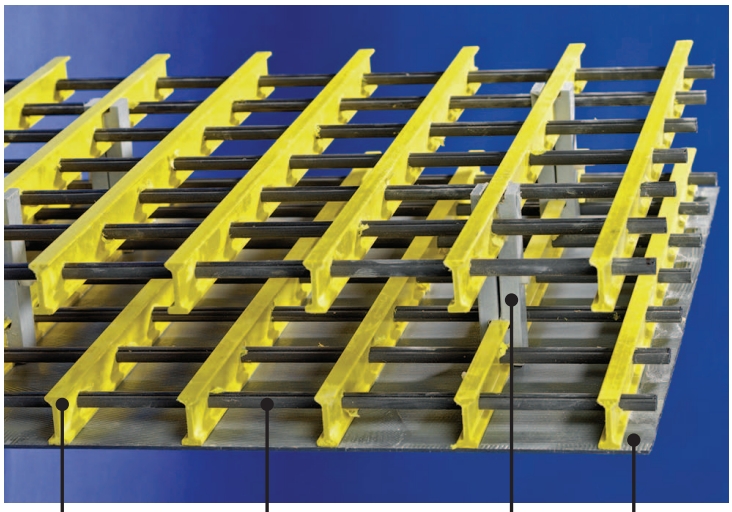
The first generation of the GRIDFORM™ system was installed on a Waupun, Wisconsin bridge.

2004

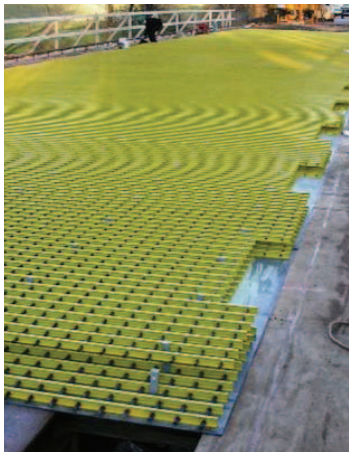
The second generation of the GRIDFORM™ system was installed on a bridge near Fond du Lac, Wisconsin, by the Wisconsin D.O.T. This research project allowed for a comparison of two bridges: one constructed using the GRIDFORM™ system and another constructed with conventional steel rebar reinforcement.

2005

The third generation of the GRIDFORM™ system was installed on a vehicular bridge in Greene County, Missouri. The 1/8" thick FRP plate was integrated into the system and bonded to the bottom layer of grating to create the stay-in-place concrete form.



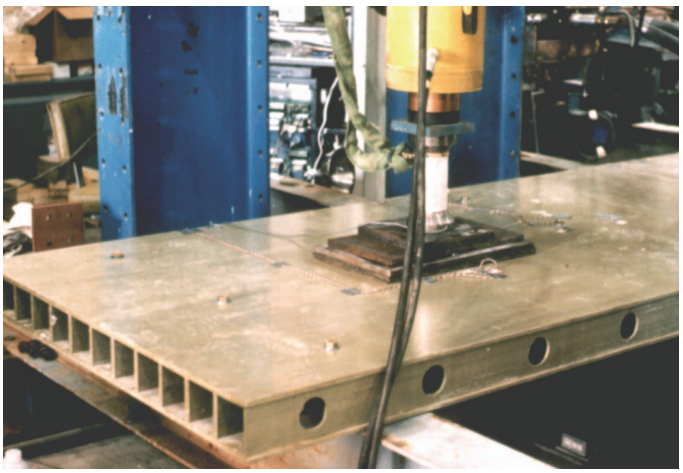
Greene County, Missouri Installation



This field application in Greene County, Missouri, shows the GRIDFORM™ installation from start to completion. As you can see, FRP panel setting, anchoring and concrete forming is easily done with a small work crew. The 144-foot bridge deck and concrete railing system was completed in only five days.

FRP Bridge Decks

Strongwell manufactures a fabricated FRP tube and plate bridge deck panel. The vehicular bridge deck is produced by combining pultruded square tubes and pultruded plate. The deck system can be designed for optimum performance depending upon design loads and stringer spacing. Tube sizes are typically 4" x 1/4" or 6" x 3/8" and plate thickness is typically 3/8" thick. The deck system comes complete with fastening hardware to allow positive attachment to steel, concrete or FRP bridge stringers.

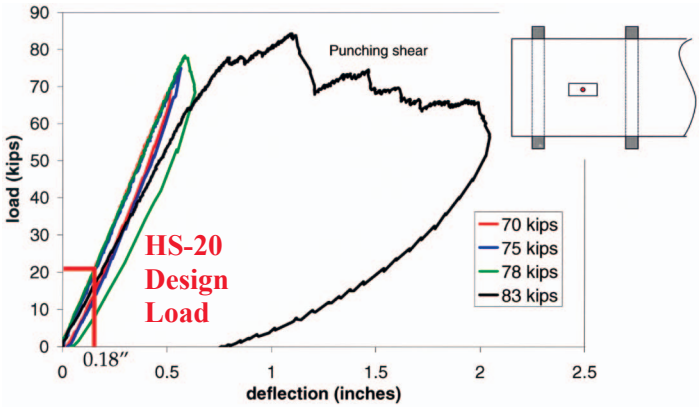


Strongwell's deck panel has undergone extensive laboratory testing as well as field demonstration testing. Load testing of the FRP bridge deck indicates superior strength in AASHTO HS-20 or HS-25 bridge deck design requirements. The AASHTO testing of the Strongwell bridge deck yielded a safety factor approaching four (4).

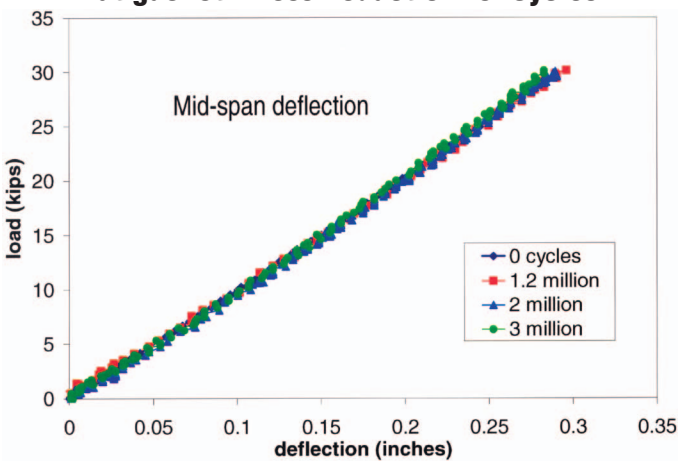
Strongwell's bridge deck has been fatigue tested at 30 kips for three million cycles with no loss of strength.

Field testing of the Strongwell deck in a truck weigh station near Troutville, Virginia, showed no signs of deterioration after 1,200,000 trucks. The second FRP deck at the Troutville test bed was subjected to 5,000,000 trucks before its removal in December 2002. Each truck represents three loading cycles.

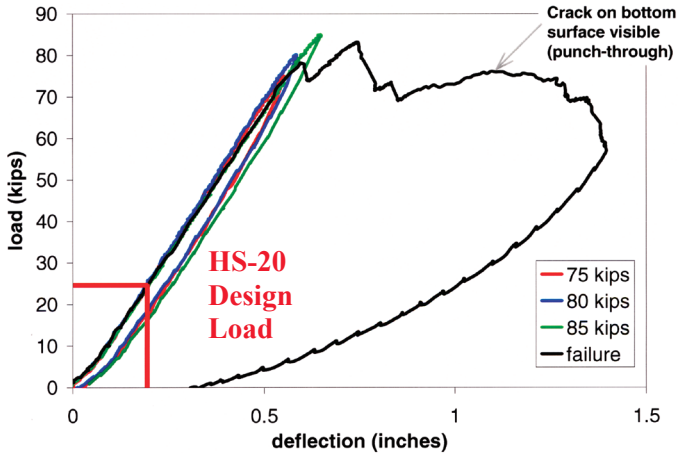
As-Fabricated Strength



Fatigue: Stiffness Reduction vs. Cycles



Remaining Strength After Fatigue (3 million cycles)



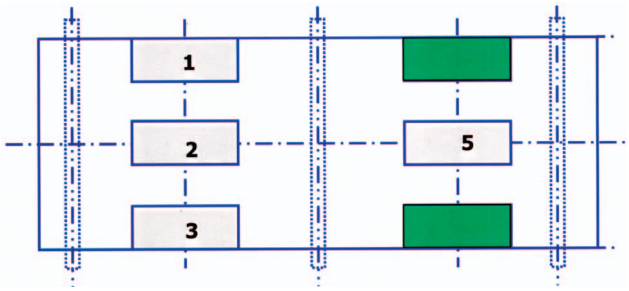
Laboratory testing shows virtually no loss of stiffness or strength after 3,000,000 cycles of loading.

Deck Post Service Test After 1,200,000 Trucks

FEA Comparison with Experimental Results - Deflections

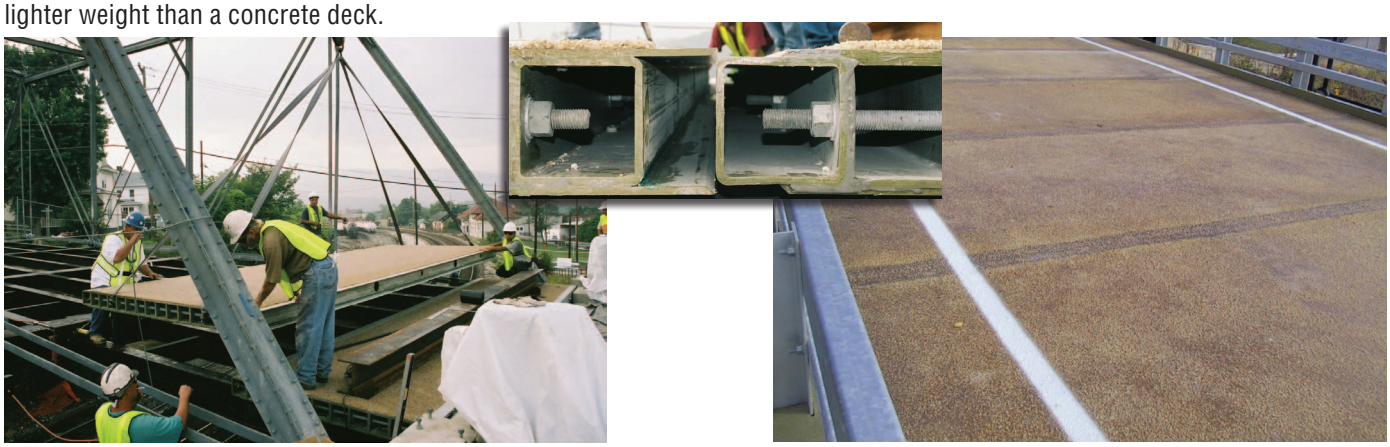
Loads	Experimental Results	FEM Results	Differences (%)
HS20, 5	L/517	L/513	0.7
HS25, 5	L/431	L/413	4.4
HS20, 4 & 6	L/328	L/311	5.5
HS25, 4 & 6	L/268	L/248	8.2
HS20, 2 & 5	L/605	L/605	0.0
HS25, 2 & 5	L/473	L/484	-2.4

Loading configuration and load amplitude



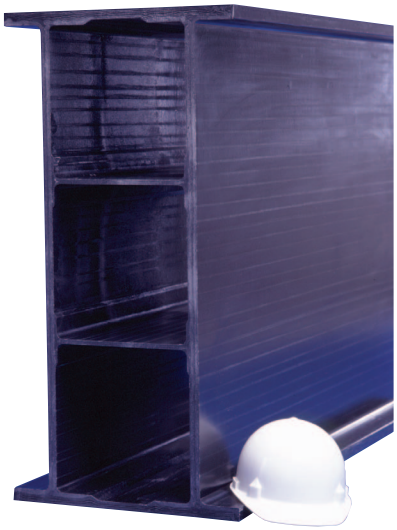
Decking Applications

Strongwell partnered with Virginia Tech and the Virginia Department of Transportation to install a composite bridge decking system on the severely deteriorating, historic Hawthorne Street Bridge in Covington, Virginia. EXTREN® square tubes and plate, adhesives and galvanized steel connection hardware were used to create a new tube and plate decking system that replaced the existing concrete deck. The composite deck not only exceeds the life expectancy of the previous concrete deck but is also 70% lighter weight than a concrete deck.



A project on Virginia's Tangier Island required each component of the bridge deck system, including galvanized steel connection hardware, to be packaged, loaded on a barge and then shipped to the island. There, the decking components were unloaded and installed on one of the main routes in this remote island community. The installation of the Strongwell deck was quick, without problems and extremely successful for the bridge contractor.

FRP Bridge Girders



A 36" x 18" double web beam has been designed for use in vehicular bridges. The primary features of the 36" x 18" EXTREN DWB® that are beneficial to bridge construction are:

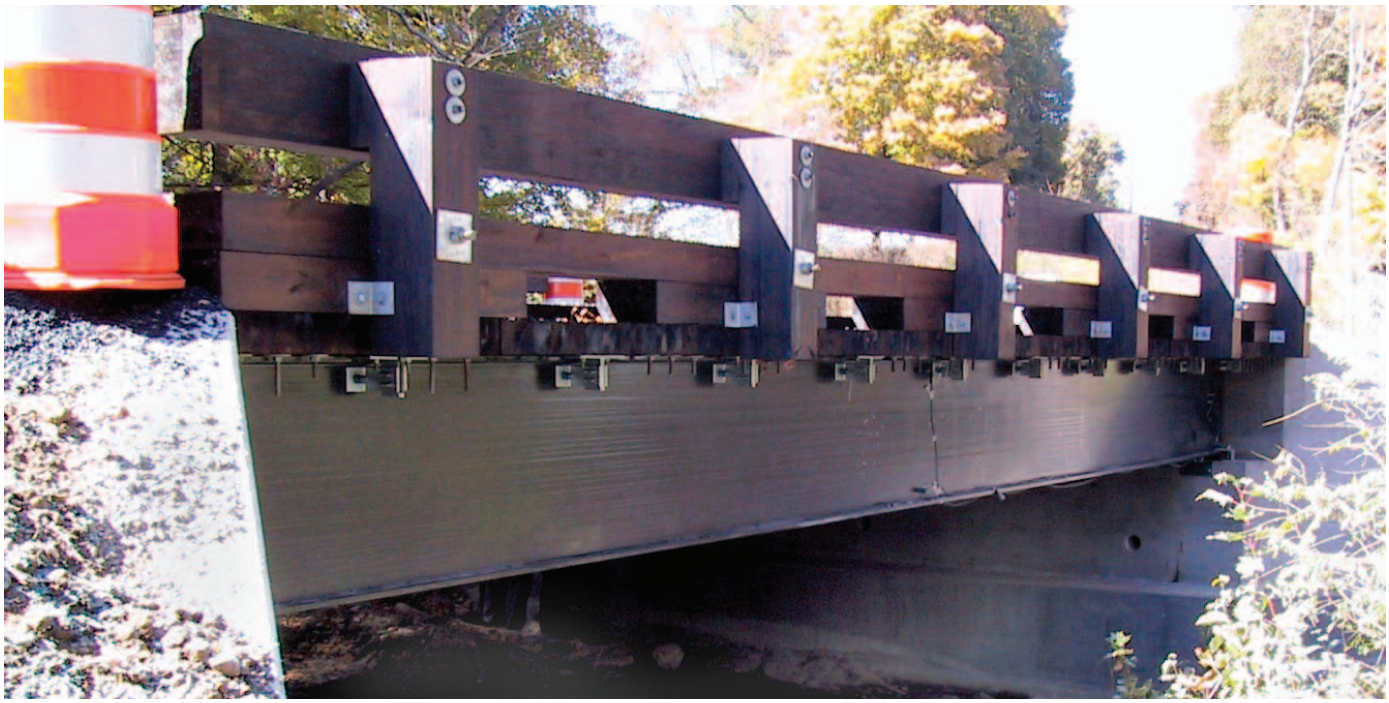
- High strength-to-weight ratio
- Corrosion resistance
- Extremely stable — reduces the number of lateral bracing diaphragms
- Dimensional stability
- Low conductivity — thermally and electrically

The 36" x 18" EXTREN DWB® is a uniquely designed FRP structural shape incorporating traditional fiberglass rovings, continuous strand mat, 0^{o}, 90^{o} and $\pm 45^{o}$ stitched fabrics and carbon fiber tows. The carbon fiber tows are located in the top and bottom flanges for increased stiffness. The stitched fabrics are located in the webs and internal stiffeners for improved torsional resistance and shear.

The 36" x 18" EXTREN DWB® has a modulus of elasticity of 6.0 msi versus a modulus of elasticity of 2.6 msi for traditional FRP structural shapes. The double web shape provides excellent stability with torsional rotation less than 1/2% in three point laboratory loading.

The Sugar Grove, VA Project

The 36" x 18" EXTREN DWB® was installed in a Federal Highway Administration (FHWA) sponsored demonstration bridge project as part of the Innovative Bridge Research and Construction Program (IBRC) in September 2001. University professors from Virginia Tech performed a series of tests on the 36" x 18" EXTREN DWB® including stiffness testing of each beam. Eight beams were selected for the 38' span AASHTO HS-20 bridge located on Route 601 in Sugar Grove, Virginia.

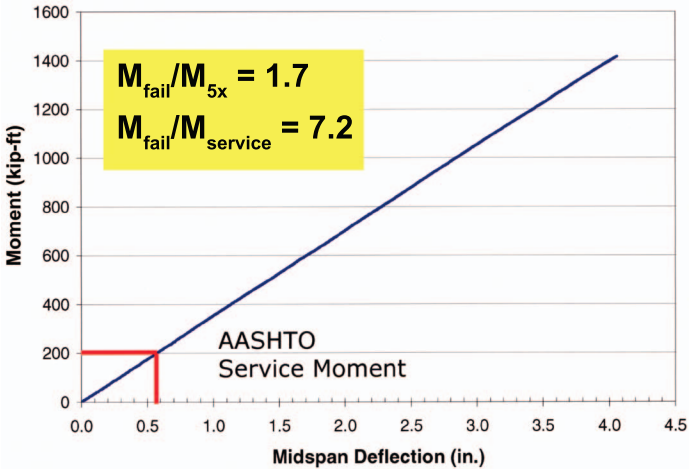


Individual Testing Of Each Beam For Sugar Grove Bridge Project

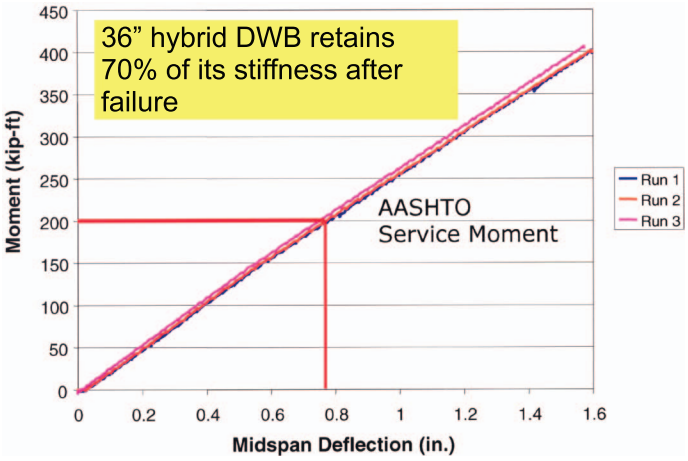
Girder #	E (Msi-in^2)	KGA (Msi)	E_{eff} service loading	Strain at service loading*	Ratio of strain to ultimate strain
1	6.45	24.3	5.49	431	14%
2	6.35	23.1	5.38	433	14%
3	6.05	24.8	5.21	459	14%
4	6.06	25.0	5.23	456	14%
5	5.88	30.7	5.22	475	15%
6	6.18	26.2	5.35	446	14%
7	6.20	34.1	5.54	445	14%
8	6.59	25.2	5.62	422	13%
Weibull Mean:	6.21 ± 0.27	----	5.27 ± 0.19		

- Ultimate strain = 3170 me (top flange)
- Max moment = 1415 kip-ft comes from 1 test on beam #13

Moment - Deflection to Failure



Moment - Deflection (Post Failure)

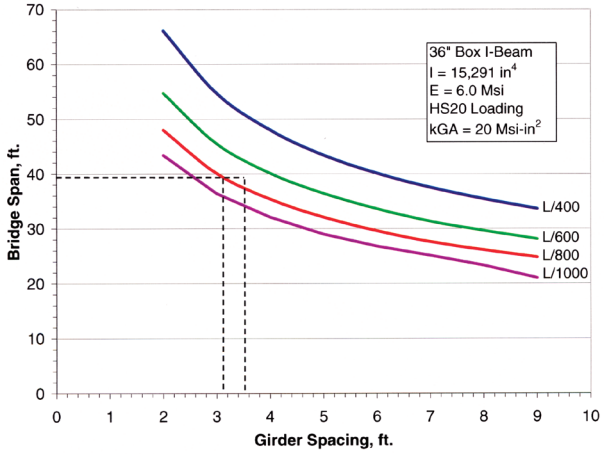


NOTE: 36" x 18" DWB® safety factors are significantly greater than normally required for traditional materials.

Conservative Properties Assumed In Design

E=6Msi & kGA = 20 Msi•in^2

The Sugar Grove bridge was designed based upon stiffness of 36" x 18" DWB®. Beam strength much greater than normal design requirements.



Winfield, WV

Phone (304)755-1600

Fax (304)755-3150

www.gefinc.com

ST0111