The FRP Retrofit Experts

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Strengthening of Coolidge High School Gymnasium

The high school gymnasium for the Coolidge School District is a two-story, round structure with a dome roof, constructed in the 1960s. The gym floor is located at grade in the center of the building and is flanked by an elevated mezzanine at one courtside, and a two-story space with locker rooms at the other. Due to the popularity of high school sporting events, the school district wished to open up the courtside spaces to create elevated mezzanines with bleachers. This would allow the district to move all public seating off of the gym floor and provide spectators with a great viewing area overlooking the games.

The existing second floor framing consisted of 3x6 nominal wood decking over glulam beams spaced at approximately 10’-0” on center. Once the design process began, it was determined that the existing second floor was not capable of supporting the design live load for the new assembly space with bleachers and spectators. Calculations showed that the moment capacity of many of the floor beams would need to be increased by 30 to 40 percent in order to support the new loads. Shear capacities were closer to the new demand levels, but still inadequate in some instances. The addition of columns in the space below would have severely reduced the functionality of the first floor area.

The collaboration between the project engineer (Mark Larsen) and the FRP materials supplier technical staff (Mo Ehsani) led to the development an innovative technique that utilized both high-strength carbon plates and fabrics. A laboratory investigation at the University of Arizona proved the viability of this new concept.

The carbon plate has a tensile strength of about 310 ksi and is 0.05-in. thick x 3-in. wide. The flexural capacity strengthening of the glulam beams required the bonding of one carbon plate to the bottom of the beam. To balance this force with an equal compressive force, a plate of the same area had to be added to the top of the beam. In order to prevent buckling of the plate in compression under large strains, two 1 5/8 in. deep x 1/8 in wide groves were cut horizontally near the top of the beam along the span. The 3-in. wide carbon plate was divided into two 1.5-in. wide strips; these narrower plates were saturated with resin and inserted (i.e. hidden) inside the aforementioned grooves. This creative installation allowed the carbon plates on the compressive side of the beam to contribute significantly to the increased moment capacity of the retrofitted beams.

Laboratory tests indicated that if only the carbon plates were added, the capacity of the beam would be limited by a horizontal shear failure near the bottom of the beam (between two laminates). To prevent this mode of failure, the beams were wrapped in a carbon fabric. The carbon fabric had fibers in both directions. Therefore, the fibers along the axis of the glulam beam contributed to flexural strength while the fibers in the vertical direction increased the shear capacity of the beam (similar to stirrups in a R/C beam). Laboratory tests demonstrated that the flexural strength of such a beam could be increased by 67% and that the carbon fabric eliminated the undesirable shear failure that was observed in previous test when only the carbon plates were used.

QuakeWrap provided sealed design calculations, the materials and installation for the retrofit system. Twenty one beams were strengthened using this approach. The construction took less than two weeks, with little interruption to the ongoing use of the locker rooms. The cost of the retrofit was approximately $1300 per beam, or $8.50 per square foot of floor area. This cost was much less than other retrofit strategies that were reviewed. For the Coolidge School District, this relatively new technology provided a good solution to an old problem.

A 3-page article highlighting some of the unique features of this project was published in the February 2004 issue of ***Structure Magazine***.

Overview of the Roundhouse Gymnasium at Coolidge High School

Once the horizontal grooves were cut along the top of the beam, the bean surface was sanded and cleaned with air pressure

The carbon plates (QuakeWrap™ DU50C) are coated with a thixotropic epoxy (QuakeBond™ J200TC) prior to bonding to the glulam beams

The carbon plates are bonded to the tension face of the glulam beams; the narrower plates can be seen inserted into the beam near the top (compression) face

The carbon plates (DU50C) are firmly attached to the beams with the help of a roller

The carbon fabric (QuakeWrap™ TB20C) is cut to size and saturated with a low viscosity resin (QuakeBond™ J300SR)

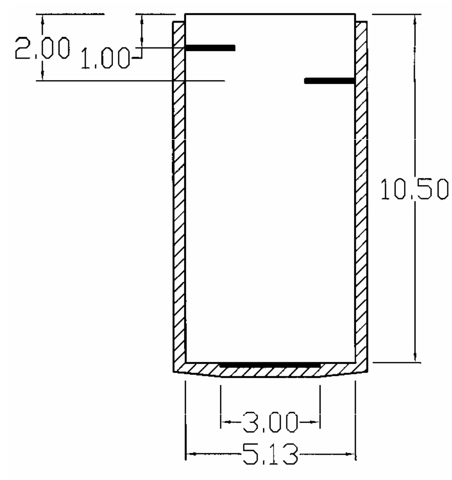
The saturated carbon fabric is bonded to the two sides and bottom face of the beam

The retrofitted beams shown here can be painted if desired

The mezzanine floor above the locker rooms (far side) awaits installation of bleachers

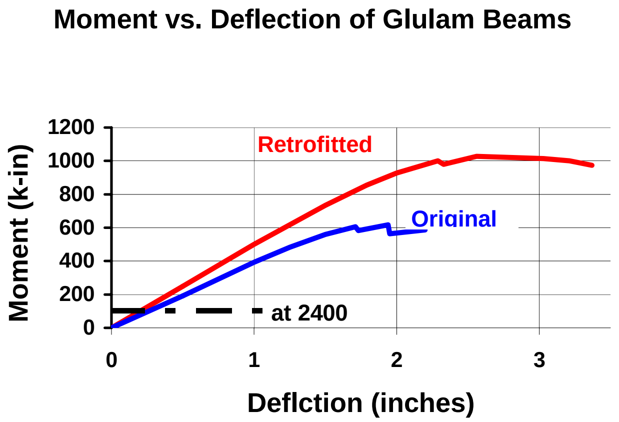
Photos and Sketches of the Laboratory Investigation

The cross section of the glulam beams that were tested and the location of the carbon plates



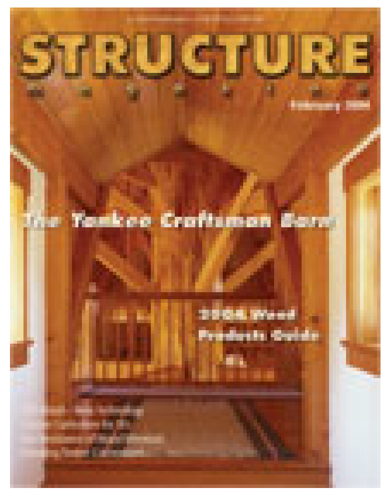
The retrofitted beam approaching failure load; note the large deflection and the ductility of the beam

Moment vs. mid-span deflection response of original and retrofitted beams, exhibiting 67% increase in strength and considerable improvement in ductility (deflection)



At the conclusion of the test, the carbon fabric was removed to reveal the extent of damage even tough the beam was supporting such high loads

A 3-page article in the February 2004 issue of Structure Magazine describes this project in more detail



CREDITS:

Project Name & Location:	Retrofit of Roundhouse Gymnasium Coolidge High School Coolidge, AZ
Construction Date:	August 2003
Structural Engineers:	Paragon Structural Design, Inc., Phoenix, AZ QuakeWrap, Inc. (*for design of the retrofit*)
Architect:	HAD Architects, LLC, Phoenix, AZ
Contractors:	Adolfson & Peterson, Inc., Tempe, AZ QuakeWrap, Inc. (*sub for the retrofit installation*)
Owner:	Coolidge Unified School District No. 21; Coolidge, AZ