Glued Laminated Timber

The owner of this hilly wooded residential site in Madison, Connecticut, wished to have year round walking access to the outer reaches of his property. A shallow, rock strewn ravine with a stream coursing through it during the wet seasons proved to be a formidable obstacle to anyone but a nimble goat. The owner also endeavored to partially rebuild a collapsed stone dam downstream that long ago reserved water for a farm but its restoration would further hinder his access. The owner decided upon a bridge to cross the ravine, but with two caveats. First, the bridge design must respond to the character of the terrain and, second, the terrain must not be scarred or changed by its construction.

A glued-laminated pedestrian bridge in the shape of an "S" was selected by the architect, Gray Organschi Architecture, New Haven, CT, to serpentine around trees and span across the ravine. The stream is approximately 15 feet below the bridge deck at the crossing. The bridge is approximately 70 feet in length, with slender stainless steel pipe columns providing intermediate support at two locations along the span of the "S".

The slender columns from a distance are indiscernible from the trees that they stand amongst. Concrete foundations were not specified under the columns to further conceal the columns. The steel columns, instead, are founded directly on outcrops of rock.

Construction Materials and Methods

The deck cross section is 5 feet 6 inches wide, and is comprised of 6 sections of preservative treated, glued laminated southern pine. Each of the six sections were fabricated offsite and then joined in the field atop temporary scaffolding. The glue planes are oriented vertical to the ground and the 6 sections vary in depth from 9-¼ inches at the middle to 6 inches at the edge. The sections were joined with tongue and grooved joints, a water-based epoxy, and then clamped with threaded rods concealed in holes bored through the full width. The threaded rods were tensioned to prestress the cross section against transverse flexural tensile stresses; their spacing is decreased where the transverse tensile stresses were predicted to be highest.

The 4-½ inch diameter stainless steel columns bear directly on rock — threaded female sleeves are embedded into holes core drilled into the rock. Epoxy was used to seal and stabilize existing cracks in the rock adjacent to the bearing locations.

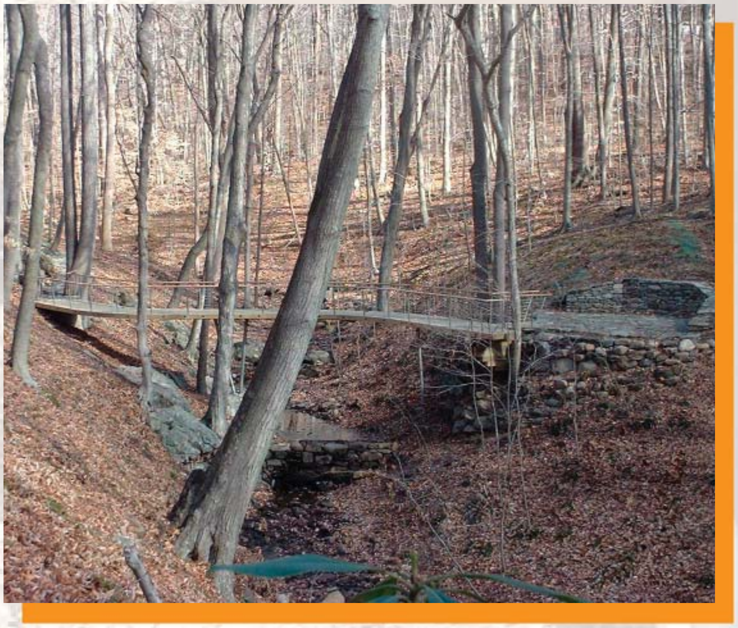
The steel columns were not installed until after the 6 wood sections of the deck were assembled atop temporary scaffolding and glued together into one. The columns had to be telescoping during erection because the column bases are embedded into the rock, and the tops of the columns are embedded into the underside of the wood bridge deck. A unique double-threaded joint at the base enabled each column to be lengthened by spinning them, up into a hole bored in the underside of the deck, until they were snug. A mechanical connection between the deck and column was made with a threaded rod inserted down through a drilled hole in the wood deck's topside, into a threaded hole in the column cap. The nut is concealed on the topside with a wooden plug.

The west end of the bridge bears on a shelf carved into exposed bedrock at the approach. The east end is supported on a timber crib that cantilevers out under the width of the bridge. The back span of the cantilevering crib is anchored to bedrock with steel rods to resist uplift. The end connections at the approaches include slots and oversized holes to allow for any seasonal expansion and contraction movement, in much the same way that butt glazed glass walls are detailed at their supporting spider connectors.

Design Loads

The bridge was designed for pedestrian loading only — the terrain precludes access by any mechanized vehicles. The static live load cases that were considered include the following.

- Uniform live load of 30 psf, which corresponds to the region's ground snow load.
- Uniform pedestrian live load of 40 psf.
- Concentrated live load of 1,000 lbs. at any location, with no uniform live load, to mimic a small group of people walking together.
- Unbalanced patterns of uniform live load of 40 psf to maximize twisting deformations of the deck.
- 1000 lb. lateral load to account for unpredictable lateral accelerations due to walking or running in-step.



Finite Element Analysis Model

Finite element software was used to create a 3-dimensional model of the bridge and its supports. The columns were modeled with pins at both the base and top. The deck was modeled as plate elements. Two nodes at each end, representing the anchorages at both the east and west ends were the only nodes with lateral load capacity. The locations of the steel columns were adjusted in the model to optimize stresses and the deflection performance of the bridge

Strength and Performance

Flexural bending stresses along the span of the wood deck were compared to published allowable stresses for the Southern Yellow Pine species. Flexural tensile stresses transverse to the span were reduced to acceptable levels by utilizing threaded rods through the full cross section to prestress the cross section, the same rods used to clamp the 6 sections of the wood deck together while the adhesive cured.

Vertical deflections due to the static load cases were limited to ½ inch. The natural frequency of the structure was analyzed to confirm that it did not fall within the range of excitation frequencies that vibration publications associate with pedestrians walking in-step over footbridges. The lateral stiffness of the bridge deck was evaluated as a horizontal diaphragm to resist lateral loads with no contribution from the steel columns. The owner was directed to regularly inspect the tightness of the nuts on the transverse rods, in the event that the wood deck shrinks permanently.

The bridge does indeed hide amongst the trees and its slim profile does not eclipse the features of the surrounding terrain it passes over.▪

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Pedestrian Bridge