EMERGING TIMBER BRIDGE PROGRAM IN BRAZIL

A Five-Year Report

By Prof. Carlito Calil, Jr., LaMEM, SET, EESC, USP

The Emerging Timber Bridge Program in the state of São Paulo, Brazil (ETBPSP) was started in 2001 with the main objective of research and development of new technologies for timber bridge construction. After five years, eleven demonstration timber bridges were constructed in the State of São Paulo. Also, eight composite timber/concrete bridges, one log timber girder bridge with transverse sawn deck, one transverse lumber prestressed timber bridge, and one transverse cellular plywood box prestressed bridge were constructed.

A final objective is communication of the structural systems in extension courses to municipal engineers and in a complete publication of timber bridge project plans with the different structural systems.

Backround

Most timber bridges in Brazil are not designed and/or constructed by engineers and builders familiar with timber structures. This leads to expensive, unsafe, and low durability timber bridges. The actual state of degradation of these bridges shows a very negative picture of the use of wood as a structural material. Therefore, it is very important to develop wood technology for the construction and rehabilitation of timber bridges on county and state roads.

If one considers that the São Paulo state road system has 220,000 kilometers of roads and 0.5% of that distance includes bridges, this translates to 2,200 kilometers of bridges. Assuming a span of 10 meters per bridge would mean 111,000 bridges.

Recent research conducted by the Laboratory of Madeiras in a number of counties in the state showed that for each 1,000 bridges and pedestrian bridges, 30% must be reconstructed or rehabilitated. Since São Paulo State doesn't have native wood species, the use of reforested species is a natural solution. In reforested areas, pines and eucalyptus are best suited for use in construction and their availability is very good. Timber used for log or sawn beams in timber bridges normally includes the application of preservative treatment.

Objectives of ETBPSP include: the development of new technologies for timber bridge construction; analysis and improvement of the actual structural and construction systems; and adaptation of existent international technologies to national conditions. The goal is to develop technology to construct safe timber bridges with simple and modern construction techniques, with good durability like other structural materials, at a competitive cost.

Constructed bridges

After five years of this program, eleven demonstration timber bridges were constructed in the State of São Paulo. This included eight composite timber/concrete bridges, one log timber girder bridge with a transverse sawn deck, one transverse lumber prestressed timber bridge, and one transverse cellular plywood box prestressed bridge. Examples are shown in *Figures 1* through *4*.

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Figure 1: Monjolinho Bridge

Structure/Design Type: Vehicular bridge/ Stress-laminated sawn lumber
Location: São Carlos – SP
Owner: São Carlos Municipality
Length: 8 meters
Width: 4 meters
Number of Spans/Skew(angle road/river): 1/5.0
Design Live Load: 45 tons
Primary Wood Species: Citriodora Eucalyptus
Superstructure Preservative: CCA
Connection: Post-tensioning (ST85/105) bars

Figure 2: Floresta Bridge

Structure/Design Type: Vehicular bridge/ Log Bridge
Location: Piracicaba - SP
Owner: Piracicaba Municipality
Length: 6 meters
Width: 5 meters
Number of Spans/Skew: 1/0.0
Design Live Load: 30 tons
Primary Wood Species: Citriodora Eucalyptus Logs
Superstructure Preservative: CCA
Concrete: f_c': 18 MPa
Foundation: Timber Piles
Deck: tranverse planks with screw connections

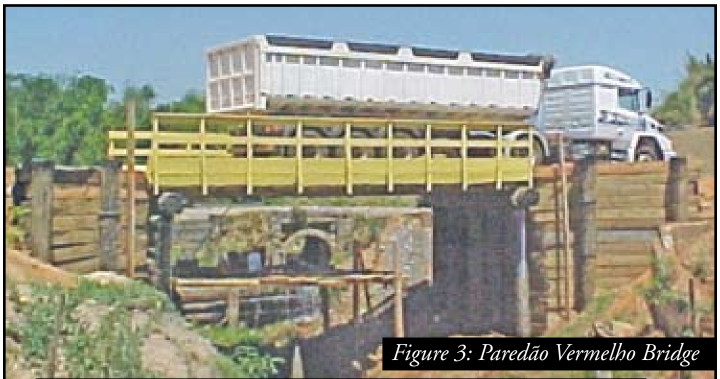

Figure 3: Paredão Vermelho Bridge

Structure/Design Type: Vehicular bridge/ Composite Timber/Concrete
Location: Piracicaba - SP
Owner: Piracicaba Municipality
Length: 10 meters
Width: 5 meters
Number of Spans/Skew: 1/0.0
Design Live Load: 45 tons
Primary Wood Species: Citriodora Eucalyptus Logs
Superstructure Preservative: CCA
Concrete: f_c': 18 MPa
Foundation: Timber Piles
Connection: X steel bars of 12.5 millimeters diameter

Figure 4: Campus II USP Bridge

Structure/Design Type: Vehicular bridge/ Stress-laminated Cellular Plywood Box
Location: São Carlos - SP
Owner: USP - EESC
Length: 12 meters
Width: 10 meters
Number of Spans/Skew: 1/25
Design Live Load: 45 tons
Primary Wood Species: Plywood and Cupiuba Sawn Lumber
Superstructure Preservative: CCA
Foundation: Timber Piles
Connection: Post-tensioning bars 15 mm diameter

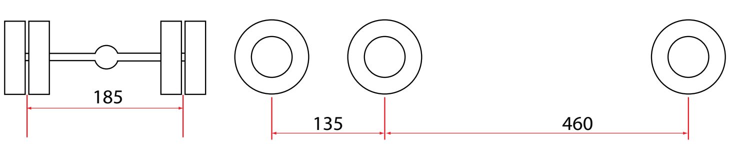

Figure 5: Load test truck configuration (units in cm).

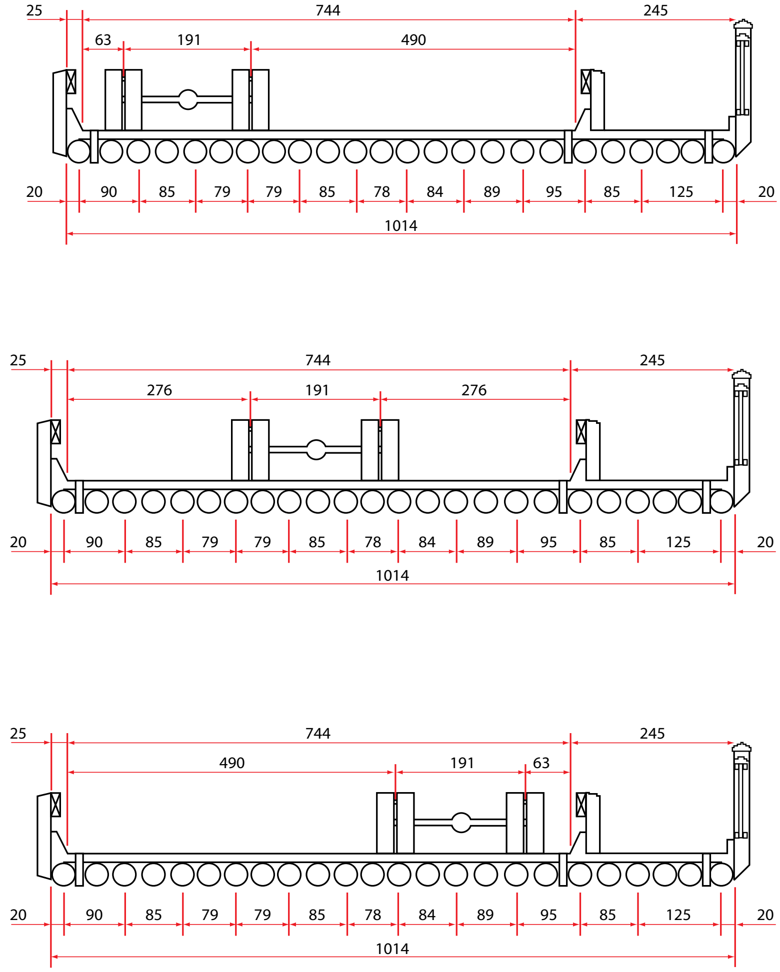

Figure 6: Load test transverse load positions (units in cm).

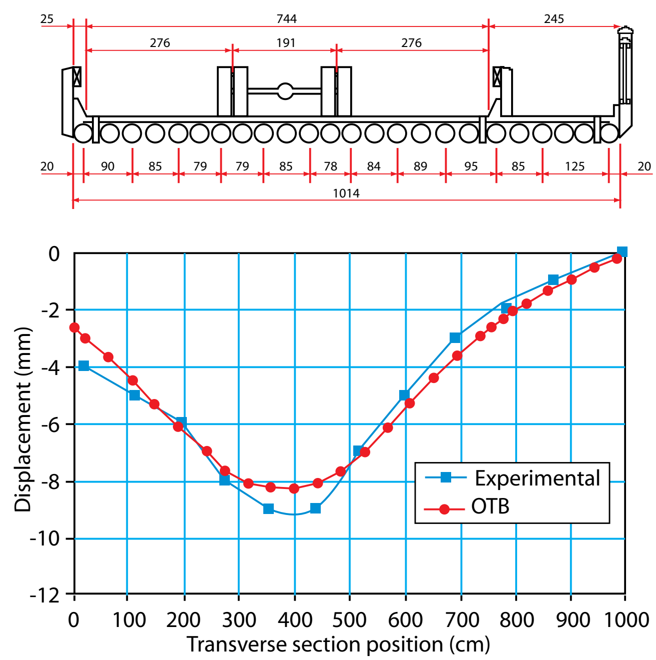

Figure 7: Comparison of the measured deflections – vehicle centered.

Analytical Evaluation

Predicted deflections based on analytical modeling were also determined for comparison with static load test results. An orthotropic plate computer program adapted for highway bridges was used to simulate the deck behavior of each bridge under actual test-truck axle loads. This software, named Orthotropic Timber Bridge (OTB), was used to analyze five types of plates: composite timber-concrete plate, stress laminated sawn lumber plate, stress laminated T-section plate, stress laminated cellular box plate, and stress laminated truss plate. *Figure 7* show a theoretical-OTB and experimental results comparison.

Load Test Behavior

Static-load tests were conducted during construction, and after some time period, to determine the response of the bridges to full truck loading. Each test consisted of positioning a fully loaded truck on the bridge deck and measuring resulting deflections at a series of transverse locations at midspan. Measurements of bridge deflections were taken prior to testing (unloaded), for each load position (loaded), and at the conclusion of testing (unloaded). In addition, analytical assessments were conducted to determine the theoretical bridge response. The test vehicle consisted of a fully loaded three axle dump truck with a gross vehicle weight of about 25 tons (*Figure 5*). The vehicle was positioned longitudinally on the bridge so that the two rear axles were centered at midspan. Transversely, the vehicle was placed for three load positions (*Figure 6*). Measurements of the bridge deflection from an unloaded to loaded condition were obtained by placing a calibrated rule on the deck underside and reading values with a surveyor's level.

Results

Results of the emerging program include: bridge construction, five courses of design and construction of timber bridges for engineers in the Department of Roads of São Paulo State and for construction engineers of São Paulo Provinces, four class note publications for the courses, and the software OTB (Orthotropic Timber Bridge) for the design of timber bridges. The final report will take the form of the *Manual for Timber Bridge Design and Construction*.▪

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