Development of Timber Bridges in Brasil: Current Emphasis Areas

Prof. Carlito Calil Junior
THE BEGINNING:
ERWIN HAUFF TIMBER BRIDGE STRUCTURES

- Erwin Hauff, HAUFF COMPANY,
- born in Vienna, Austria
- graduated in civil engineering from the Technical University of Munich in 1920
- end of World War I moved to Brazil
- studies of Brazilian forest species
- in 1928, he founded the civil engineering company HAUFF
- built several types of roofing structures, bridges, scaffolding and other works in the city of São Paulo in the 1920s
HAUFF CONSTRUCTIVE SYSTEM

- characterized by its use of joint covers, common dovetail joints and wooden dowels used for the connection of skewed beams, forming the nodes of the structural elements

- use of the truss system composed of simple girder sections or of multiple elements (of simple sections) nailed together to form a girder of the desired length to resist active loads
DOVETAIL JOINTS AND MULTIPLE ELEMENTS
HAUFF system of common dovetail and dowel connectors
HAUFFT’S SUCCESS IN BRAZIL

- 1920s, 30s and 40s
- skilled labor which was abundant in those days as a result of foreign immigration
- several European technicians to train their workers, who were required to be qualified at a technical or specialized level in one area of carpentry
- foreign professionals were responsible for training many excellent Brazilian carpenters
- soffit scaffolding, framework scaffolding, antenna towers, roofing frameworks in general, and silos
SÃO PAULO - Tietê river – 38 meters of span
SAO PAULO - Garulhos – 52 meters of span
SAO PAULO - concrete formwork – 45 meters of span
SAO PAULO - concrete formwork – 78 meters of span
SAO PAULO - concrete formwork – 32 meters of span
ABOUT BRAZIL AND SÃO PAULO

- São Paulo state road system has 220,000 km of vicinal roads and about 1,500 km of bridges.
- 30% must be reconstructed or rehabilitate.
- São Paulo State doesn’t have native wood species.
- Reforestation pinus and eucalyptus species is a natural solution.
CURRENT TIMBER BRIDGES IN BRAZIL

- Most timber bridges in Brazil are not designed and constructed by technicals and constructors specialized in timber structures.
- This laid 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.
CURRENT TIMBER BRIDGES IN BRAZIL
CURRENT TIMBER BRIDGES IN BRAZIL
CURRENT TIMBER BRIDGES IN BRAZIL
CURRENT TIMBER BRIDGES IN BRAZIL
CURRENT TIMBER BRIDGES IN BRAZIL
CURRENT TIMBER BRIDGES IN BRAZIL
Timber Bridges: Current Emphasis Areas

- Development of new technologies to timber bridge constructions
- Analysis and improvement of the actual structural and constructive systems
- Adaptation of existent international technologies to national conditions
- Technology to construct safe timber bridges, with simple and modern constructive technics, with good durability and with a competitive cost
- Courses for the design and construction of timber bridges
- Softwares for the design of timber bridges
- Brazilian Handbook for the Design and Construction of Timber Bridges
Structural system constructed

- log bridges,
- stress laminated decks,
- composed plywood beams,
- glued laminated and
- composed log/concrete decks
Log beams

- reforestation specie Eucalyptus Citriodora treated with vacuum-pressure preservative treatment of CCA
Composed log-concrete decks

- *Eucalyptus Citriodora* specie
- epoxied steel rods as shear connectors
- vertical and 45 degrees steel rods
Stress-Laminated Timber Bridges

- Species used are eucalyptus treated with vacuum-pressure preservative treatment of CCA.
- Steel bars used in Brazil is dywidag bars with diameter of 15 mm.
Composite section of plywood and eucalyptus lumber

- Lumber of commercial cross sections
  plywood and sawn lumber to obtain lights girders with I, T or box cross-section
- Structural system composed of only girders or cellular prestressed plate
GLULAM BRIDGE

- Brazil doesn’t have important glulam industries
- capacity to make glulam beams longer than 6 meters
- wood species used are pinus and eucalyptus
- cost of the cubic meter of glulam is too expensive
OTB SOFTWARE

Equivalent girder

Equivalent orthotropic plate (OTB)

Finit Elements
OTB SOFTWARE
TIMBER GRADING
TIMBER GRADING
TIMBER GRADING
WEARING SURFACE
WEARING SURFACE
WEARING SURFACE
LOAD TESTS
THEORETICAL AND EXPERIMENTAL RESULTS
6 YEARS BRIDGES PROGRAM

- Construction of 20 composite timber-concrete bridges
- Two stress laminated bridges
- Two logs bridges
- One Plywood cellular prestressed bridge
- One GLULAM cellular prestressed bridge
- Four courses for design and construction of timber bridges
- TIMBER BRIDGE MANUAL publication
- Development of two softwares for design of timber bridges (logs and plates)
<table>
<thead>
<tr>
<th>Structure/Design Type</th>
<th>Log Bridge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Piracicaba - SP</td>
</tr>
<tr>
<td>Owner</td>
<td>Piracicaba Municipality</td>
</tr>
<tr>
<td>Length</td>
<td>6 m</td>
</tr>
<tr>
<td>Width</td>
<td>5 m</td>
</tr>
<tr>
<td>Number of Spans/Skew</td>
<td>1/0.0</td>
</tr>
<tr>
<td>Design Live Load</td>
<td>30</td>
</tr>
<tr>
<td>Primary Wood Species</td>
<td>Citriodora Eucalyptus Logs</td>
</tr>
<tr>
<td>Superstructure Preservative</td>
<td>CCA</td>
</tr>
<tr>
<td>Concrete</td>
<td>$f_{ck}: 18$ MPa</td>
</tr>
<tr>
<td>Foundation</td>
<td>Timber Piles</td>
</tr>
<tr>
<td>Deck</td>
<td>transversal planks with screw connections</td>
</tr>
<tr>
<td>Structure/Design Type</td>
<td>Vehicular bridge/ Composed Timber/Concrete</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------------------------------------</td>
</tr>
<tr>
<td>Location</td>
<td>Piracicaba - SP</td>
</tr>
<tr>
<td>Owner</td>
<td>Piracicaba Municipality</td>
</tr>
<tr>
<td>Length</td>
<td>7 m</td>
</tr>
<tr>
<td>Width</td>
<td>4 m</td>
</tr>
<tr>
<td>Number os Spans/Skew</td>
<td>1/0.0</td>
</tr>
<tr>
<td>Design Live Load</td>
<td>30</td>
</tr>
<tr>
<td>Primary Wood Species</td>
<td>Citriodora</td>
</tr>
<tr>
<td>Eucalyptus Logs</td>
<td></td>
</tr>
<tr>
<td>Superstructure Preservative</td>
<td>CCA</td>
</tr>
<tr>
<td>Concrete</td>
<td>fck: 18 MPa</td>
</tr>
<tr>
<td>Foundation</td>
<td>Timber Piles</td>
</tr>
<tr>
<td>Connection</td>
<td>X steel bars of 19 mm</td>
</tr>
<tr>
<td></td>
<td>diameter</td>
</tr>
<tr>
<td>Structure/Design Type</td>
<td>Vehicular bridge/Composed Timber/Concrete</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>Location</td>
<td>Piracicaba - SP</td>
</tr>
<tr>
<td>Owner</td>
<td>Piracicaba Municipality</td>
</tr>
<tr>
<td>Length</td>
<td>10 m</td>
</tr>
<tr>
<td>Width</td>
<td>5 m</td>
</tr>
<tr>
<td>Number os Spans/Skew</td>
<td>1/0.0</td>
</tr>
<tr>
<td>Design Live Load</td>
<td>45</td>
</tr>
<tr>
<td>Primary Wood Species</td>
<td>Citriodora</td>
</tr>
<tr>
<td>Eucalyptus Logs</td>
<td></td>
</tr>
<tr>
<td>Superstructure Preservative</td>
<td>CCA</td>
</tr>
<tr>
<td>Concrete</td>
<td>fck: 18 MPa</td>
</tr>
<tr>
<td>Foundation</td>
<td>Timber Piles</td>
</tr>
<tr>
<td>Connection</td>
<td>X steel bars of 12.5 mm diameter</td>
</tr>
</tbody>
</table>
**Structure/Design Type:** Composed Timber/Concrete  
**Location:** Piracicaba - SP 
**Owner:** Piracicaba Municipality  
**Length:** 7 m 
**Width:** 5 m  
**Number of Spans/Skew:** 1/0.0  
**Design Live Load:** 45  
**Primary Wood Species:** Citriodora Eucalyptus 
**Logs** 
**Superstructure Preservative:** CCA  
**Concrete:** $f_{ck}$: 18 MPa  
**Foundation:** Timber Piles  
**Connection:** vertical steel bars of 19 mm diameter
Structure/Design Type: Composed Timber/Concrete
Location: SP148 – KM 5- Santos - SP
Owner: DERSA - SP
Length: 23 m (6m+12m+5m) m
Width: 8 m
Number of Spans/Skew: 3/15.0
Design Live Load: 45
Primary Wood Species: Citriodora Eucalyptus Logs
Superstructure Preservative: CCA
Concrete: fck: 25 MPa
Fundation: Timber Piles
Connection: X glued steel bars
Structure/Design Type: Vehicular bridge/Composed Timber/Concrete
Location: Paracatu - MG
Owner: Uberaba University
Length: 20.45 (15.0+5.45) m
Width: 4 m
Number of Spans/Skew: 2/0.0
Design Live Load: 45
Primary Wood Species: Citriodora Eucalyptus
Superstructure Preservative: CCA
Concrete: fck: 18 MPa
Foundation: Concrete
Connection: X glued steel bars
Ibitiruna Bridge

Structure/Design Type: Vehicular bridge/Composed Timber/Concrete
Location: Piracicaba - SP
Owner: Piracicaba Municipality
Length: 6 m
Width: 4 m
Number of Spans/Skew: 1/0.0
Design Live Load: 30
Primary Wood Species: Citriodora Eucalyptus Logs
Superstructure Preservative: CCA
Concrete: $f_{ck}: 18$ MPa
Fundation: Timber Piles
Connection: 45 degrees inclined tension steel bars of 12.5 mm diameter
Monjolinho Bridge

- **Structure/Design Type**: Stress-laminated sawn lumber
- **Location**: São Carlos – SP
- **Owner**: São Carlos Municipality
- **Length**: 8 m  **Width**: 4 m
- **Number of Spans/Skew**: 1/5.0
- **Design Live Load**: 45
- **Primary Wood Species**: Citriodora Eucalyptus
- **Superstructure Preservative**: CCA
- **Connection**: dywidag bars
<table>
<thead>
<tr>
<th>Structure/Design Type</th>
<th>Vehicular bridge/Composed Timber/Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>São Carlos - SP</td>
</tr>
<tr>
<td>Owner</td>
<td>USP - EESC</td>
</tr>
<tr>
<td>Length</td>
<td>12 m</td>
</tr>
<tr>
<td>Width</td>
<td>10 m</td>
</tr>
<tr>
<td>Number of Spans/Skew</td>
<td>1/25</td>
</tr>
<tr>
<td>Design Live Load</td>
<td>45</td>
</tr>
<tr>
<td>Primary Wood Species</td>
<td>Citriodora</td>
</tr>
<tr>
<td>Eucalyptus Logs</td>
<td></td>
</tr>
<tr>
<td>Superstructure Preservative</td>
<td>CCA</td>
</tr>
<tr>
<td>Concrete</td>
<td>fck: 25 MPa</td>
</tr>
<tr>
<td>Foundation</td>
<td>Concrete Blocks</td>
</tr>
<tr>
<td>Connection</td>
<td>X steel bars of 12.5 mm diameter</td>
</tr>
<tr>
<td><strong>Structure/Design Type</strong></td>
<td>Vehicular bridge/Composed Timber/Concrete</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td>São Carlos - SP</td>
</tr>
<tr>
<td><strong>Owner</strong></td>
<td>USP - EESC</td>
</tr>
<tr>
<td><strong>Length</strong></td>
<td>12 m</td>
</tr>
<tr>
<td><strong>Width</strong></td>
<td>10 m</td>
</tr>
<tr>
<td><strong>Number of Spans/Skew</strong></td>
<td>1/25</td>
</tr>
<tr>
<td><strong>Design Live Load</strong></td>
<td>45</td>
</tr>
<tr>
<td><strong>Primary Wood Species</strong></td>
<td>Citriodora</td>
</tr>
<tr>
<td>Eucalyptus Logs</td>
<td></td>
</tr>
<tr>
<td><strong>Superstructure Preservative</strong></td>
<td>CCA</td>
</tr>
<tr>
<td><strong>Concrete</strong></td>
<td>fck: 25 MPa</td>
</tr>
<tr>
<td><strong>Foundation</strong></td>
<td>Concrete Blocks</td>
</tr>
<tr>
<td><strong>Connection</strong></td>
<td>X steel bars of 12.5 mm diameter</td>
</tr>
</tbody>
</table>
Structure/Design Type: Vehicular bridge/
Stress-laminated Cellular Plywood Box
Location: São Carlos - SP
Owner: USP - EESC
Length: 12 m
Width: 10 m
Number of Spans/Skew: 1/25
Design Live Load: 45
Primary Wood Species: Plywood and
Cupiuba Sawn Lumber
Superstructure Preservative: CCA
Foundation: Timber Piles
Stress System: dywidag bars 15 mm
diameter
Campus II USP Bridge 4 – São Carlos - SP

- **Structure/Design Type:** Stress-laminated Cellular Glulam Box
- **Location:** São Carlos - SP
- **Owner:** USP - EESC
- **Length:** 12 m
- **Width:** 10 m
- **Number of Spans/Skew:** 1/25
- **Design Live Load:** 45
- **Primary Wood Species:** Pinus glulam and Cupiuba Sawn Lumber
- **Superstructure Preservative:** CCA
- **Foundation:** Timber Piles
- **Stress System:** dywidag bars 15 mm diameter
Training courses for design and construction of timber bridges: 12 hours

Summary

1. Introduction.
2. Mechanical properties of timber.
4. Loads in bridges and load combinations
5. Design of timber bridges: log bridges, stress laminated decks, composed plywood beams, glued laminated and composed log/concrete decks
7. Inspection and maintenance of timber bridges.
8. Foundation of timber bridges

Bibliography: Timber Bridge Manual
ACKNOWLEDGMENTS

The author thanks the financial support of the Fundation of Support of Research of São Paulo State – FAPESP