SÃO PAULO UNIVERSITY
SCHOOL OF ENGINEERING OF SÃO CARLOS
DEPARTAMENT OF STRUCTURAL ENGINEER
LABORATORY OF WOOD AND TIMBER STRUCTURES

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Development of Timber Bridges in Brasil: Current Emphasis Areas

Prof. Carlito Calil Junior
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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

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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

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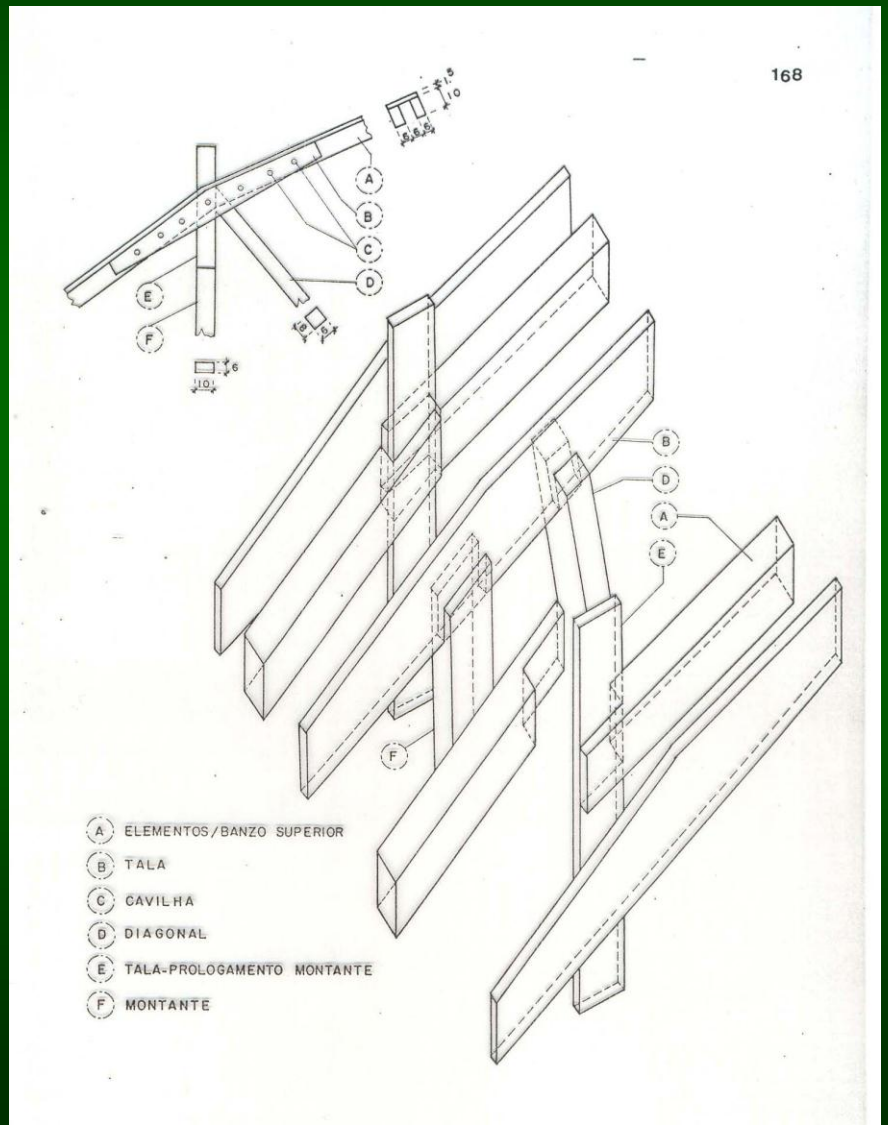

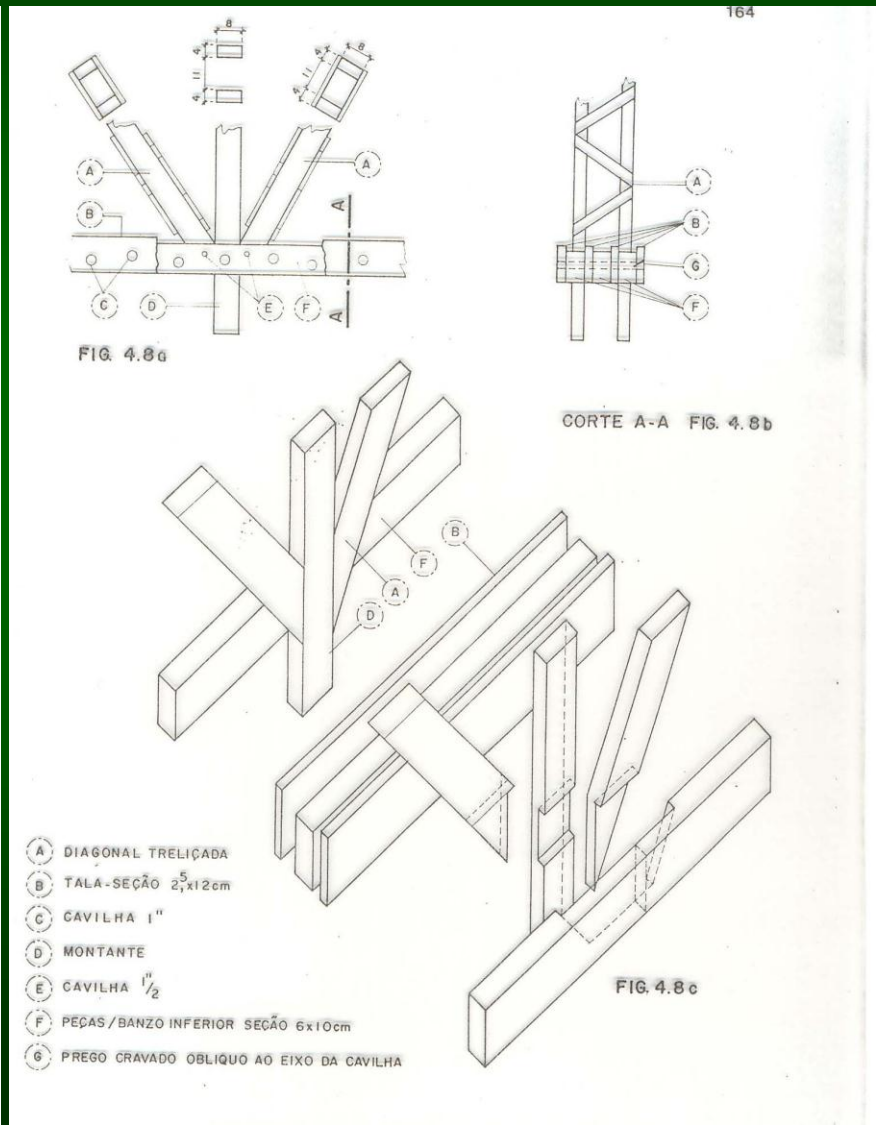

HAUFF system of common dovetail and dowel connectors

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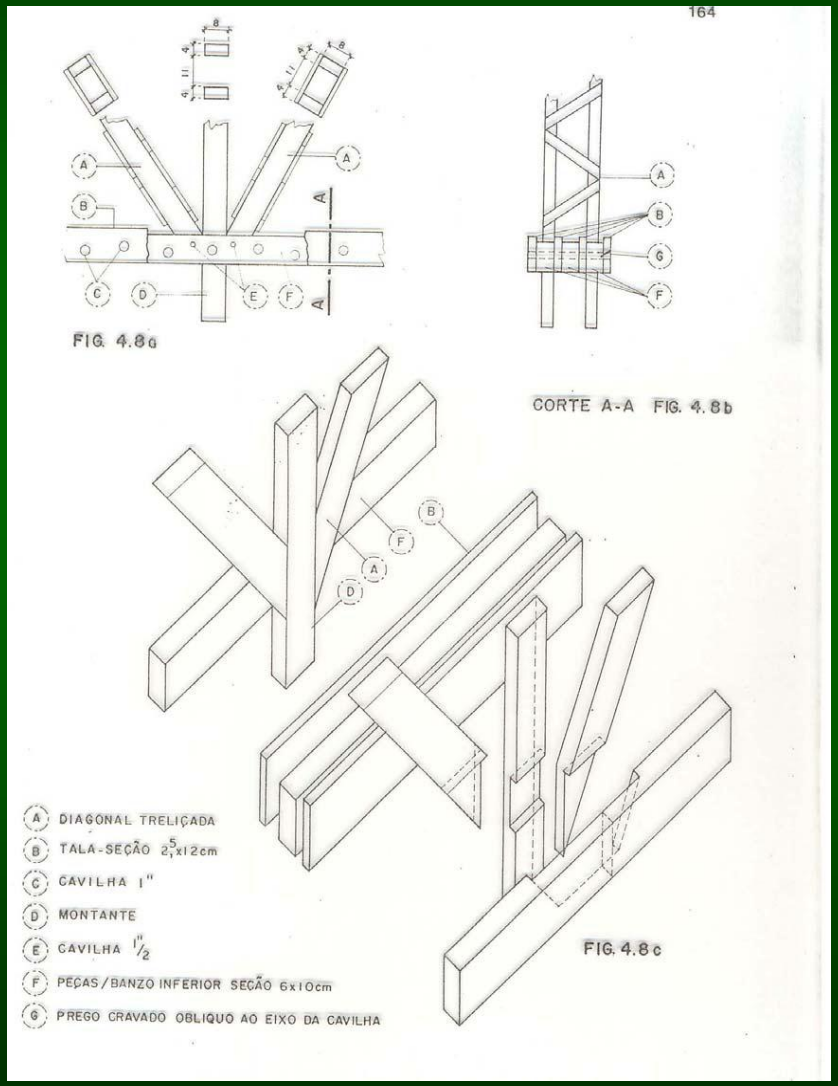

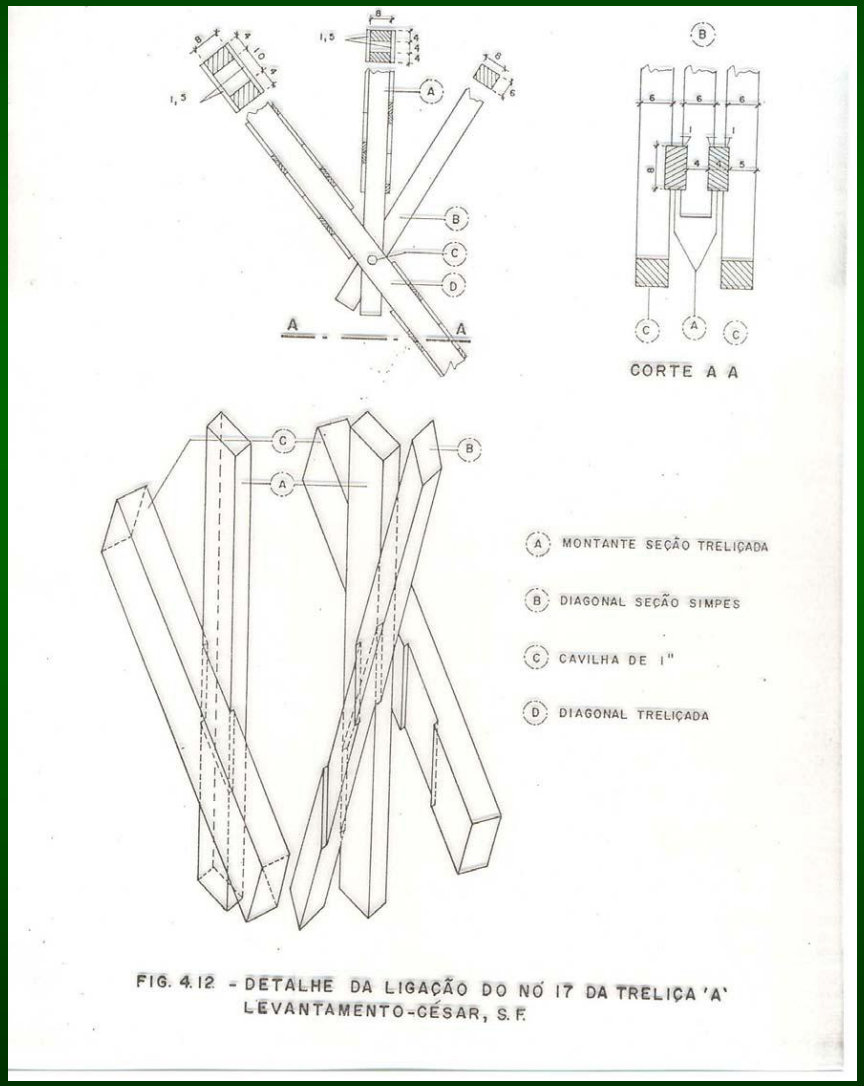

HAUFF´S SUCCESS IN BRAZIL

- 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

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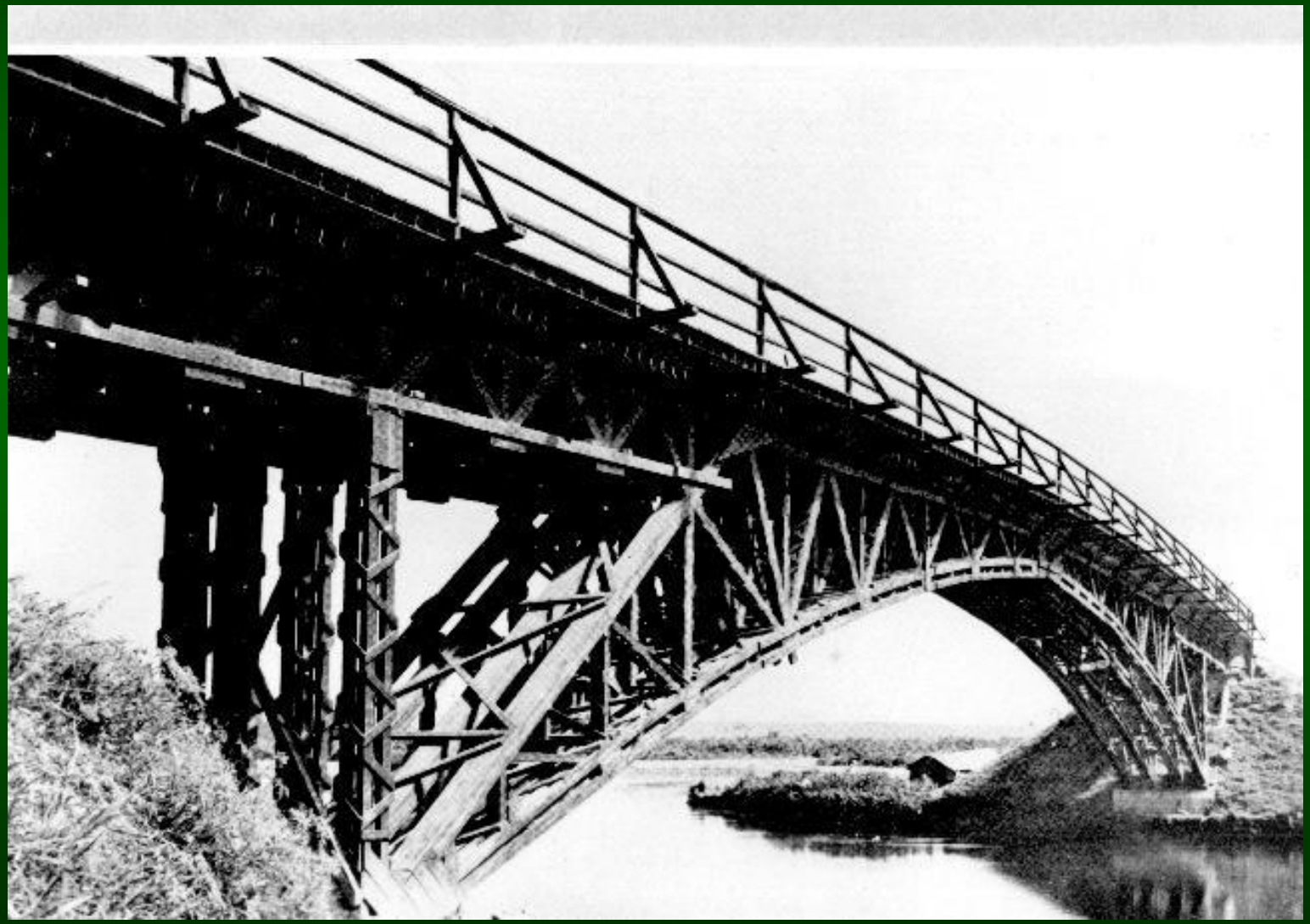
SÃO PAULO - Tietê river– 38 meters of span



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SAO PAULO - Garulhos – 52 meters of span

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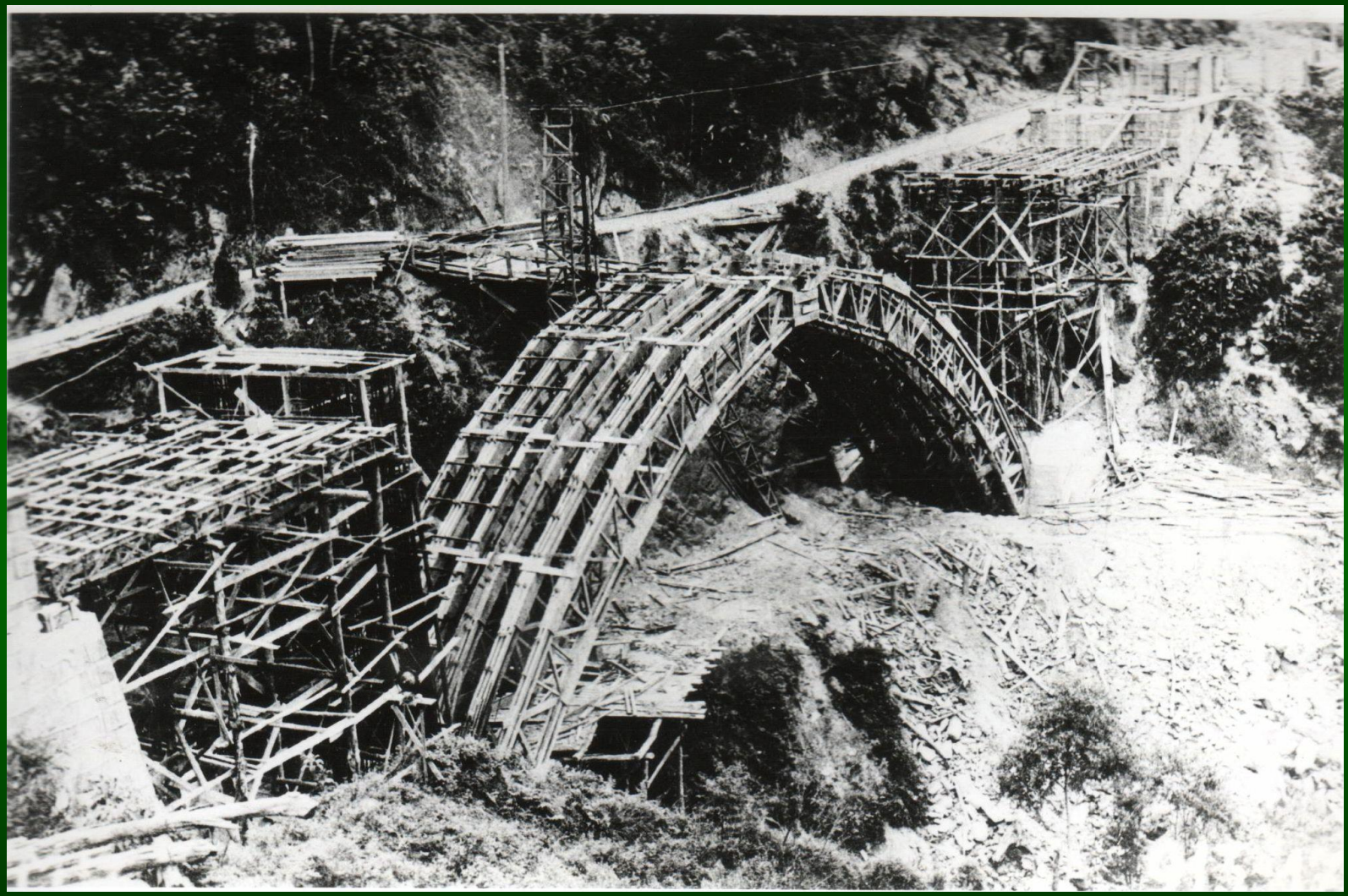
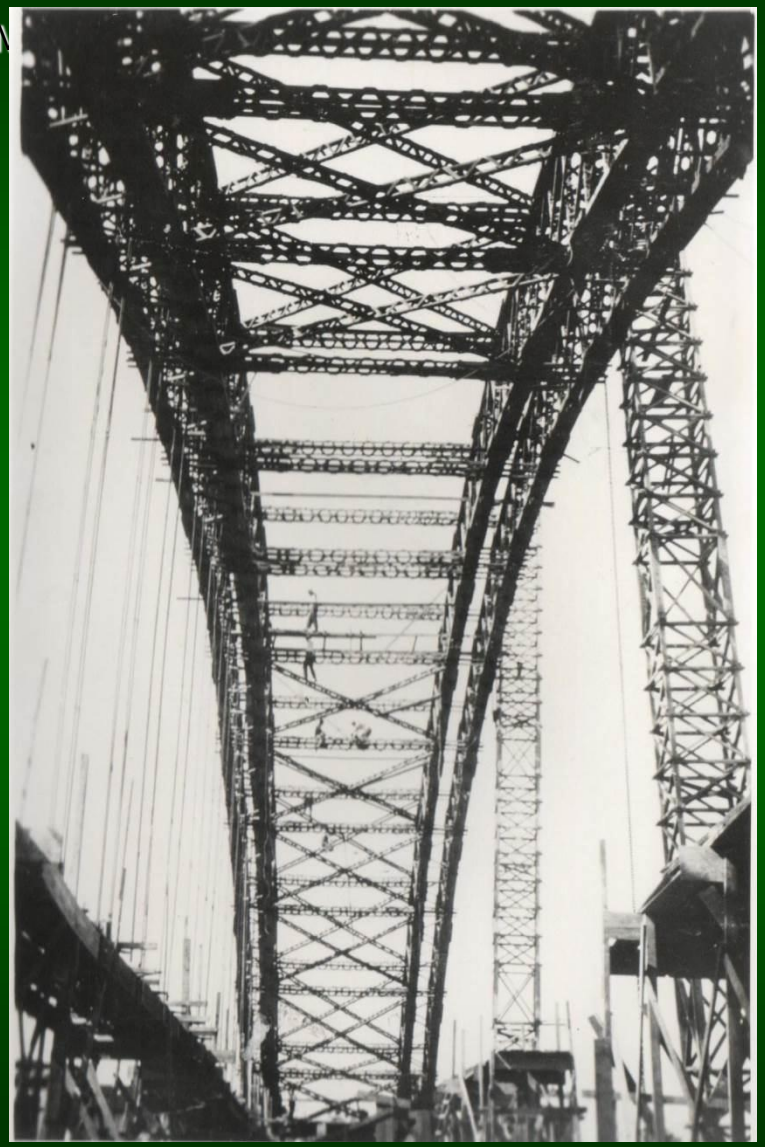
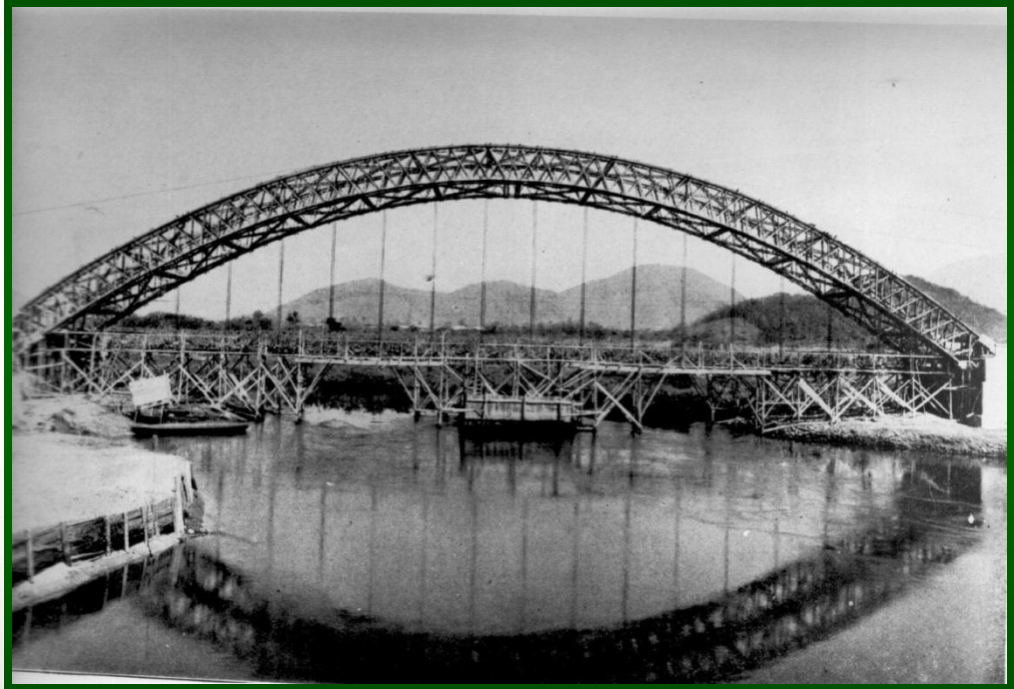
SAO PAULO -concrete formwork – 45 meters of span



SAO PAULO -concrete formwork – 78 meters of span





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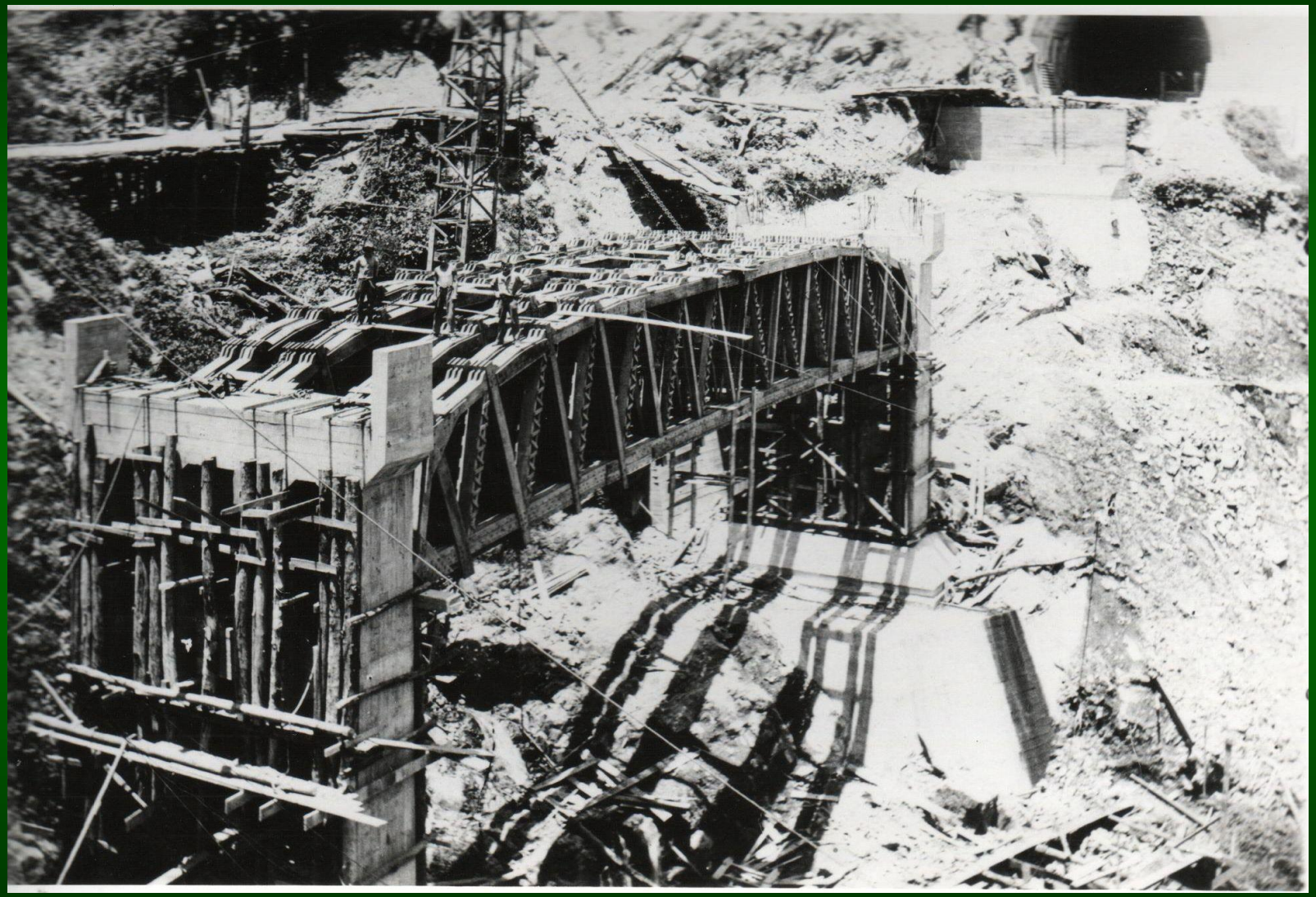
SAO PAULO - concrete formwork – 32 meters of span



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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

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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

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CURRENT TIMBER BRIDGES IN BRAZIL

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CURRENT TIMBER BRIDGES IN BRAZIL

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CURRENT TIMBER BRIDGES IN BRAZIL

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CURRENT TIMBER BRIDGES IN BRAZIL

Motorista do caminhão, Vanderlei Ferrari saiu ileso do acidente ocorrido numa estrada vicinal do município de Terenos, na noite de quarta-feira

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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

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Structural system constructed

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

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Log beams

- reforestation specie Eucalyptus Citriodora treated with vacuum-pressure preservative treatment of CCA

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Composed log-concrete decks

- *Eucalyptus Citriodora* specie
- epoxied steel rods as shear connectors
- vertical and 45 degrees steel rods

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Stress-Laminated TimberBridges

- 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

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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 celular prestressed plate

GLULAM BRIDGE

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- 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

Finit Elements

Equivalent orthotropic plate (OTB)

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OTB SOFTWARE

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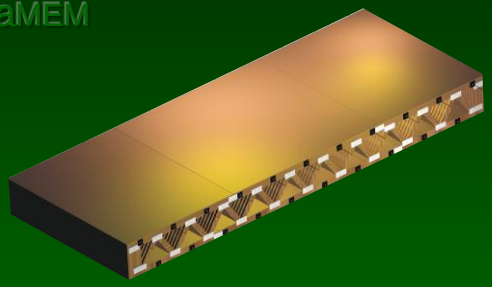

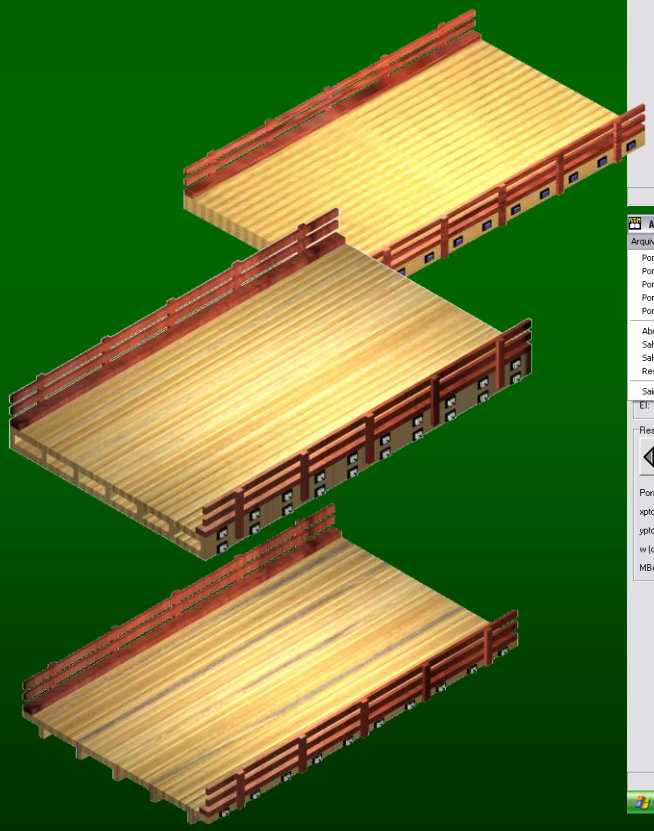

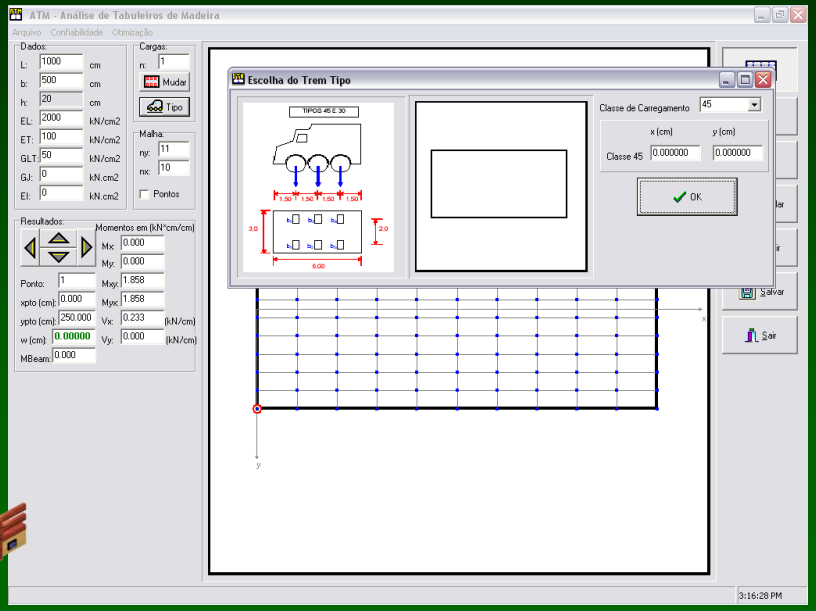

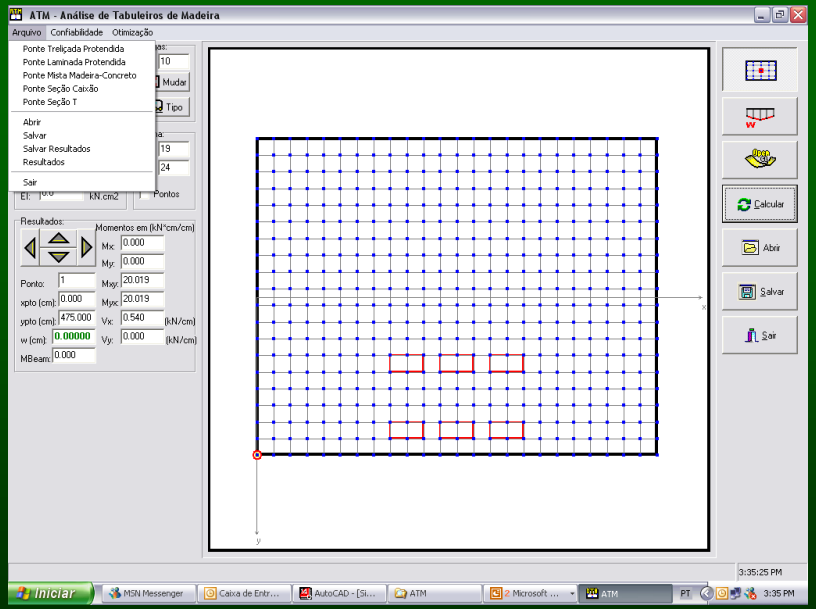

OTB SOFTWARE

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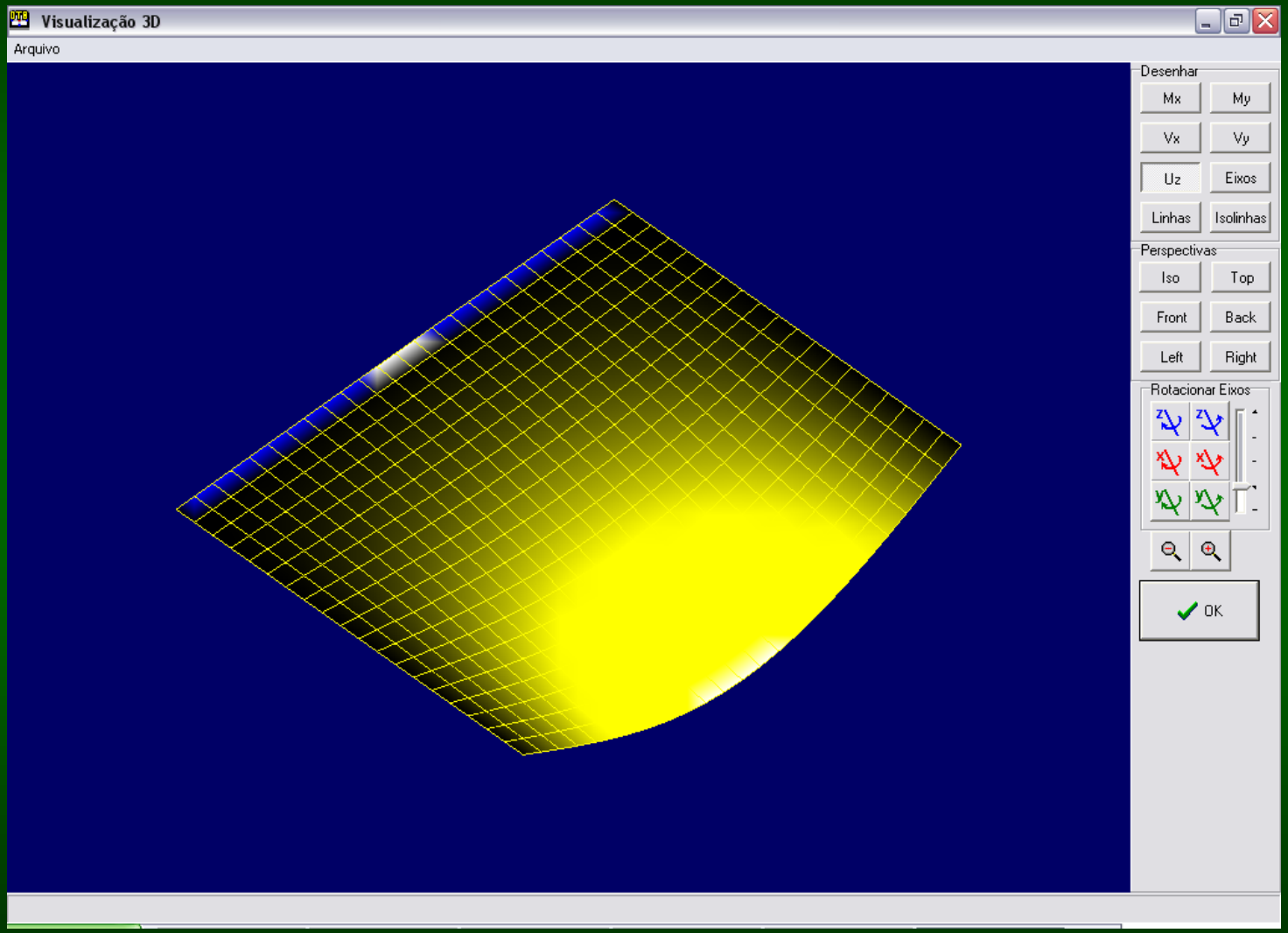

TIMBER GRADING

TIMBER GRADING

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TIMBER GRADING

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WEARING SURFACE

WEARING SURFACE

WEARING SURFACE

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LOAD TESTS

THEORETICAL AND EXPERIMENTAL RESULTS

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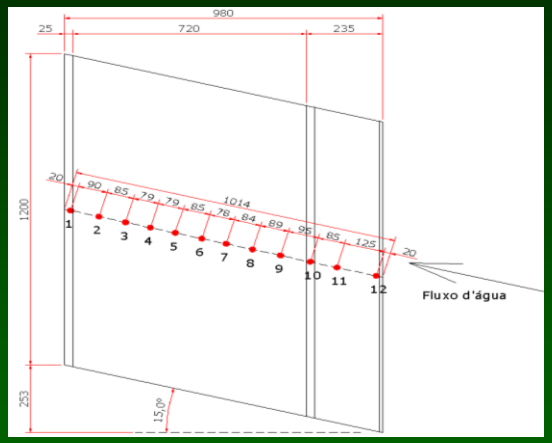

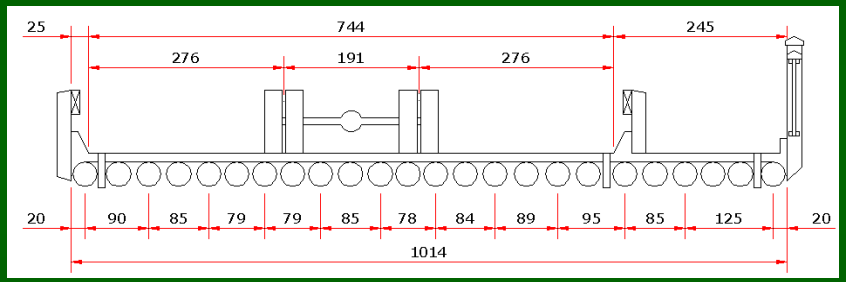

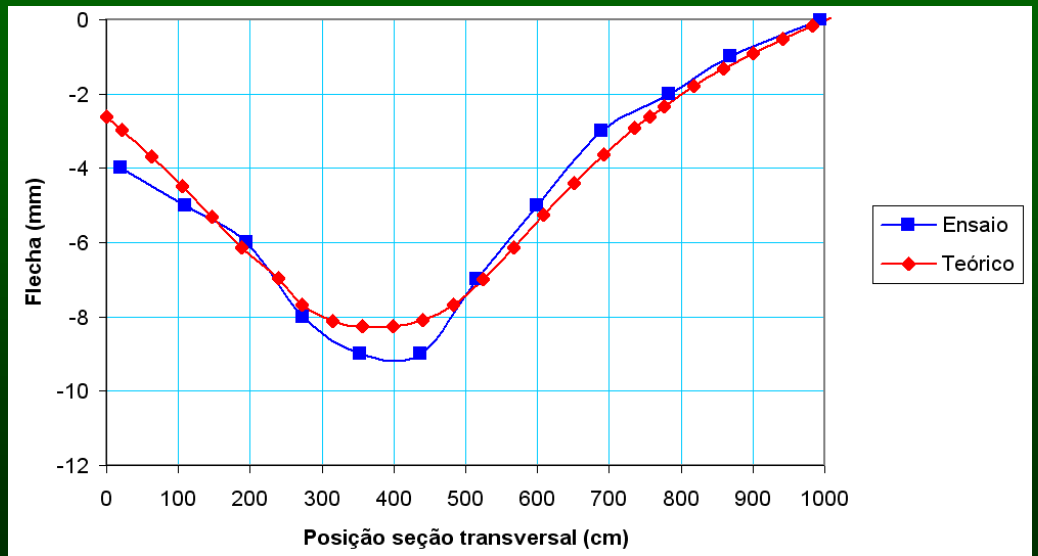

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6 YEARS BRIDGES PROGRAM

- Construction of 20 composite timber-concrete bridges
- Two stress laminated bridges
- Two logs bridges
- One Plywood celular prestressed bridge
- One GLULAM celular 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)

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Floresta Bridge – Piracicaba - SP

Structure/Design Type: Log Bridge
Location: Piracicaba - SP
Owner: Piracicaba Municipality
Length: 6 m
Width: 5 m
Number os Spans/Skew: 1/0.0
Design Live Load: 30
Primary Wood Species: Citriodora Eucalyptus Logs
Superstructure Preservative: CCA
Concrete: fck: 18 MPa
Fundation: Timber Piles
Deck: tranversal planks with screw connections

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Florestinha Bridge

Structure/Design Type: Vehicular bridge/ Composed Timber/Concrete
Location: Piracicaba - SP
Owner: Piracicaba Municipality
Length: 7 m
Width: 4 m
Number os Spans/Skew: 1/0.0
Design Live Load: 30
Primary Wood Species: Citriodora Eucalyptus Logs
Superstructure Preservative: CCA
Concrete: fck: 18 MPa
Fundation: Timber Piles
Connection: X steel bars of 19 mm diameter

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Paredão Vermelho Bridge – Piracicaba - SP

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Structure/Design Type: Vehicular bridge/ Composed Timber/Concrete
Location: Piracicaba - SP
Owner: Piracicaba Municipality
Length: 10 m
Width: 5 m
Number os Spans/Skew: 1/0.0
Design Live Load: 45
Primary Wood Species: Citriodora Eucalyptus Logs
Superstructure Preservative: CCA
Concrete: fck: 18 MPa
Fundation: Timber Piles
Connection: X steel bars of 12.5 mm diameter

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Capela Bridge – Piracicaba - SP

Structure/Design Type:
Composed Timber/Concrete
Location: Piracicaba - SP
Owner: Piracicaba Municipality
Length: 7 m
Width: 5 m
Number os Spans/Skew: 1/0.0
Design Live Load: 45
Primary Wood Species: Citriodora Eucalyptus Logs
Superstructure Preservative**: CCA**
Concrete**: fck: 18 MPa**
Fundation: **Timber Piles**
Connection: **vertical steel bars of 19 mm diameter**

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Caminho do Mar Bridge - Santos-SP

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

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Paracatu Bridge – Minas Gerais

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 os Spans/Skew: 2/0.0
Design Live Load: 45
Primary Wood Species: Citriodora Eucalyptus
Superstructure Preservative: CCA
Concrete: fck: 18 MPa
Fundation: Concrete
Connection: X glued steel bars

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Ibitiruna Bridge

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

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Monjolinho Bridge

- **Structure/Design Type**: Stress-laminated sawn lumber
- **Location**: São Carlos – SP
- **Owner**: São Carlos Municipality
- **Length**: 8 m **Width**: 4 m
- **Number os Spans/Skew**: 1/5.0
- **Design Live Load**: 45
- **Primary Wood Species**: Citriodora Eucalyptus
- **Superstructure Preservative**: CCA
- **Connection:** dywidag bars

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Campus II USP Bridge 1 – São Carlos - SP

Structure/Design Type: Vehicular bridge/ Composed Timber/Concrete
Location: São Carlos - SP
Owner: USP - EESC
Length: 12 m
Width: 10 m
Number os Spans/Skew: 1/25
Design Live Load: 45
Primary Wood Species: Citriodora Eucalyptus Logs
Superstructure Preservative: CCA
Concrete: fck: 25 MPa
Foundation: Concrete Blocks
Connection: X steel bars of 12.5 mm diameter

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Campus II USP Bridge 2 –São Carlos - SP

Structure/Design Type: Vehicular bridge/ Composed Timber/Concrete
Location: São Carlos - SP
Owner: USP - EESC
Length: 12 m
Width: 10 m
Number os Spans/Skew: 1/25
Design Live Load: 45
Primary Wood Species: Citriodora Eucalyptus Logs
Superstructure Preservative: CCA
Concrete: fck: 25 MPa
Foundation: Concrete Blocks
Connection: X steel bars of 12.5 mm diameter

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Campus II USP Bridge 3 –São Carlos - SP

Structure/Design Type: Vehicular bridge/ Stress-laminated Cellular Plywood Box
Location: São Carlos - SP
Owner: USP - EESC
Length: 12 m
Width: 10 m
Number os 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

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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 os 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

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Training courses for design and construction of timber bridges : 12 hours

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Summary

1. Introduction.

2. Mechanical properties of timber.

3. Structural and construcive systems for timber bridges.

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

6. Preservation and protection for timber bridges.

7. Inspection and mainatance of timber bridges.

8. Fundation of timber bridges

Bibliography: Timber Bridge Manual

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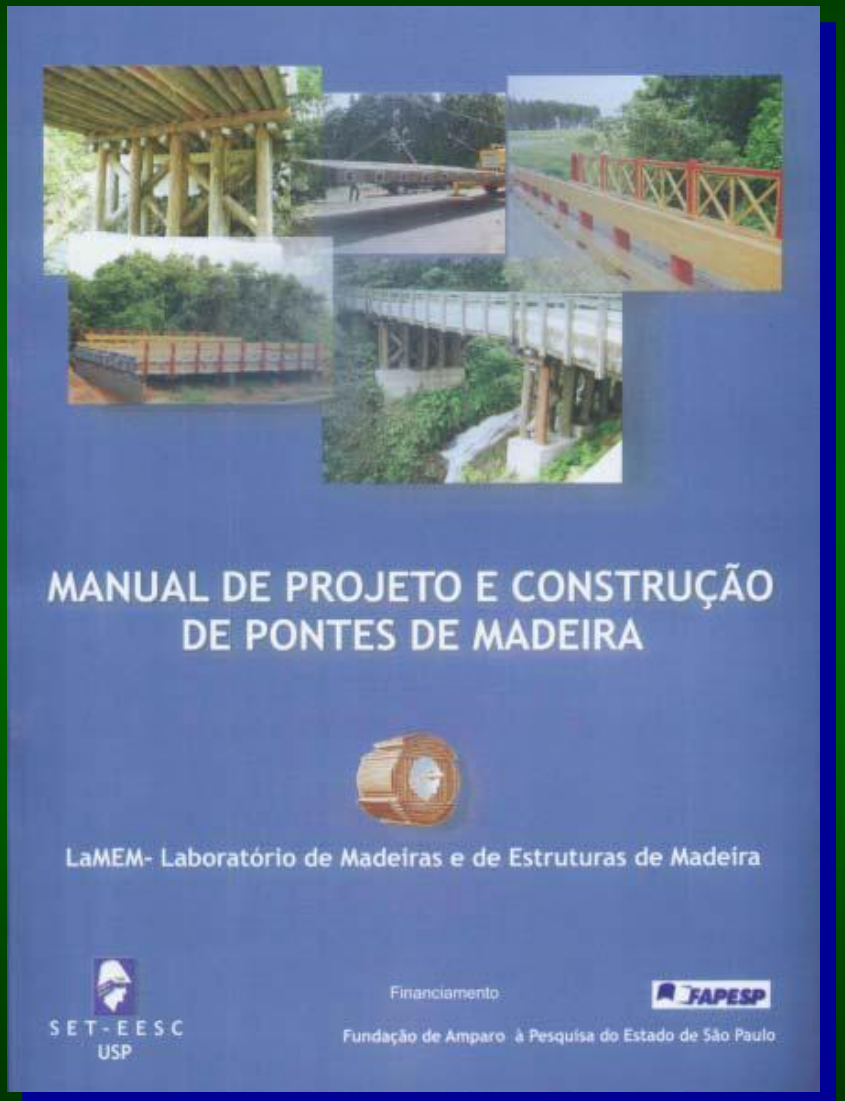
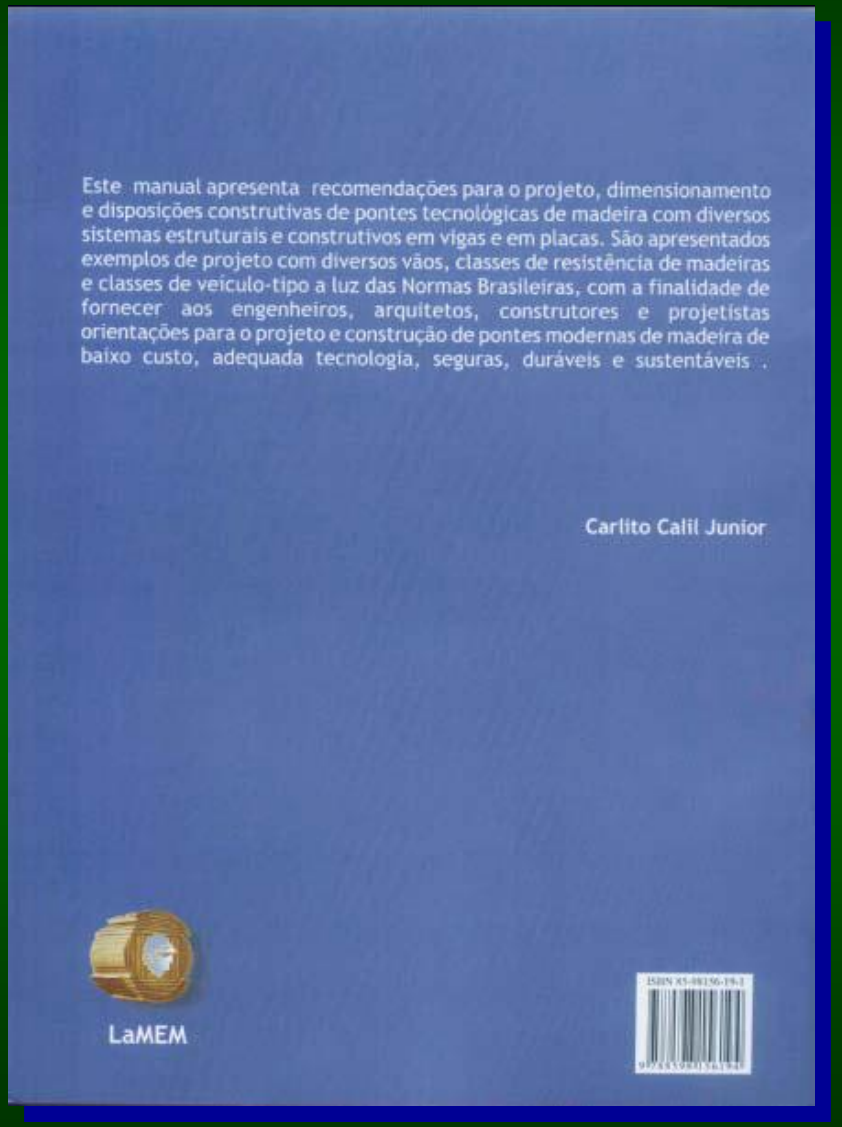
TIMBER BRIDGE MANUAL





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