Inspection to assessment of roundwood composite stringers bridge at Yolanda Farm in São Carlos city, Brazil

Ricardo de Mello Scaliante, Coordenadoria de Projetos e Obras (CPO), Universidade Federal do Mato Grosso do Sul (UFMS), Campo Grande, MS. e-mail: ricardo@scaliante.eng.br

Diego Henrique de Almeida, Campus Experimental de Itapeva (CEI), Universidade Estadual Paulista “Júlio de Mesquita Filho” (UNESP), Itapeva, SP. e-mail: diego.henrique@grad.itapeva.unesp

André Luis Christoforo, Departamento de Engenharia Mecânica (DEMEC), Universidade Federal de São João del-Rei (UFSJ), São João del-Rei, MG. e-mail: alchristoforo@yahoo.com.br

Carlito Calil Junior, Professor Titular, Laboratório de Madeiras e Estruturas de Madeira (LaMEM), Departamento de Engenharia de Estruturas (SET), Escola de Engenharia de São Carlos (EESC), Universidade de São Paulo (USP), São Carlos, SP. e-mail: calil@sc.usp.br

Abstract: The bridge structures should have stricter monitoring once the importance of bridges in region development as flow of people, products and medicines, providing to society a quality of life. This paper presents the criteria used to assessment of the timber structural elements of the roundwood composite stringers bridge with transverse roundwood deck and concrete as wearing surface, situated on the Yolanda Farm, in São Carlos, Brazil. The structural system of the bridge consists of two roundwood composite stringers of Eucaliptus citriodora (Corymbia citriodora) timber, where each stringer section is composed by two roundwood arranged at the ends interconnected by metal rings, with 10.20 meters of free span and a transversal roundwood 4.20 meters wide deck. The aim of this paper is to identify and assess the main pathologies presented in each structural element. For this evaluation, was used the non-destructive technique (NDT) technique for visual inspection. During the inspection, were evaluated the structural elements of the bridge, after 30 years of service and deterioration as biological attaches and fire. The main problems observed in the structures were: the stringers have already reach in serviceability limit state; the ultimate limit state have already reached in one of stringers and also a fire compromised it; the transverse roundwood deck elements were attached by xylophages organisms, mainly in its heartwood; the metal rings are rusty and deteriorated by fire; and finally, the foundations are cracked. It is concluded that the bridge is condemned and is in a precarious situation for rehabilitation. In general, there is a deficiency of preventive maintenance on rural and low-traffic bridges in Brazil. In this context, it is evident that it is essential to perform preventive maintenance on structures of timber bridges, with expert qualified professionals accompanying.

Keywords: bridges, assessment, timber structures, visual analysis
1. Introduction

Since the civilization beginning, wood is used as a construction material for houses, tools and big structures, as bridges, to transpose obstacles like rivers and lakes. The bridge construction must be performed respecting some guidelines such as: wood treated with adequate preservative; bridge design following the normative and standardization documents; the use of professional and specialized manpower; and others factors that interfere in bridge construction feasibility (Calil Junior et al., 2006(1)).

Wood is a great structural material to be used in bridges when compared with other materials as concrete and steel, once wood has many mechanical and physics properties that allow it to resist impact and quick loads, such as a low ratio between strength/density, providing a lighter structure (Pfeil and Pfeil, 2004(2)). The mechanical processing of the wood is also simple and allows a fast and rational construction of bridge members, considering a modular design.

Brazil has a huge watershed with many rivers in its territory, being very important economically for a lot of people subsistence. Thus, bridges are important structures that provide a social and economic development for a region, once it’s used to flow the rural production and also to allow medicines and food supplies, provides scholar and emergency transportations, influencing directly in people’s quality of life.

Short and medium spans bridges (from 6 to 12 meters) constructions are very common in Brazilian rural roads, and wood is the main material used in them. However, after construction, the preventive maintenance is required with the aim to guarantee the timber bridge durability and providing a secure structure for community use.

As any other timber structure, timber bridges are subjected to degradation passing the years of service, principally when no preventive maintenance is realized, providing a huge number of problems such as timber decay from moisture excess or xylophages organisms attach and the undue use of the bridge with inappropriate heavy traffic supported by superstructure (Ridout, 2009(3)).

Wooden components of the bridges when treated adequately prolong the life of the structure from a few years to many decades, resulting reduction of transportation infrastructure costs and increased public safety (Brooks, 2000(4)).

Visual inspection is the simplest method for locating deterioration in timber structures. The inspector observes the structure for signs of actual or potential deterioration, checking the areas for further investigation. Visual inspection requires strong light and is suitable for detecting intermediate or advanced surface decay, water damage, mechanical damage, or failed members (Ross, et al. 2005(5)).

The aim of this work is to use a Non-Destructive Technique (NDT) to analyze the medium span 30 years old Timber Bridge constructed at Yolanda Farm, in São Carlos city, at São Paulo state, Brazil.

2. Materials and Methods

The studied timber bridge was built 30 years ago at Yolanda Farm, in São Carlos, at São Paulo state, and transposes Laranja Azeda river (fig. 1), located at 22º 8’ 55,24” S and 47º 51’28,53”W Global Position System (GPS) coordinates. It’s a simple span bridge of 10.20 meters span and 4.20 meters width, supported by concrete walls which also retain the bridge embankments, and all the superstructure structural elements made by roundwood of Corymbia citriodora and initially constructed with concrete wearing surface to make the regularization of deck surface (fig. 2).
The method used to identify the bridge’s defects was based on Brazilian Standardization for Timber Structures, ABNT NBR 7190: 1997(6), with the aim to analyze visually the presence of decay problems through NDT of entire structure, registering by photography and real situation of the timber bridge elements: deck, 2 roundwood composed section stringers, foundation and supports.

The visual analysis was done with the aim to identify the pathologies that occurred in all bridge structure during all the service life. The main pathologies identified were: long exposure time of bridge to high moisture and sun, xylophages organisms attaches, fire exposure, and others.

3. Results and Discussions

The studied timber bridge was built 30 years ago at Yolanda Farm, in São Carlos, at São Paulo state, and transposes Laranja Azeda river (fig. 1), located at 22º 8’ 55,24” S and 47º 51’28,53”W Global Position System (GPS) coordinates. It’s a simple span bridge of 10.20 meters span and 4.20 meters width, supported by concrete walls which also retain the bridge embankments, and all the superstructure structural elements made by roundwood of Corymbia citriodora and initially constructed with concrete wearing surface to make the regularization of deck surface (fig. 2).

- **Foundations and Supports**

The simple span bridge is supported by two concrete walls. Those concrete walls present vertical and transversal cracks (fig. 3) from excessive heavy traffic. The stress propagation in
the bridge embankment provided an increase of stresses in the wall. Also can be analyzed the default of bearing support for the stringers. Thus, the stringers are also concreted together to the foundations, in addition to having the end in contact with the embankment material, causing an increase of moisture in the stringers and providing the proliferation of fungi and stringers decay (fig. 4).

Figure 3 – Cracks in concrete wall.

Figure 4 – Stringer’s support defects and xylophages organisms attach.

In the contact between embankment and concrete wall, it’s evidenced the loss of embankment material and the full deterioration of a piece of deck element (fig. 5). This default provides a serious damage of structure performance once the embankment moisture can cause deck deterioration and the absence of embankment material can cause a local timber deck collapse.
• **Bridge superstructure**

In bridge superstructure, were evidenced many problems caused by the absence of specialty maintenance during its three decades of service life. The deck of the bridge was constructed by a series of roundwood elements, with 15cm diameter, positioned transversally to the traffic direction, and in the initial design project had a layer of concrete as wearing surface. During the service life, the concrete surface had been deteriorated and locals had put over it a layer of soil. This wrong and non-recommended providences allowing the accumulation of water and the retention of high moisture over the deck, potentiating the actions of wood decay agents (fig. 6, fig. 7 and fig. 8).

Figure 5 – Contact between the embankment and the superstructure.

Figure 6 – Layer of soil over the deck of the bridge.
The stringers from the bridge, made by two 40cm diameter roundwood elements interconnected by metal rings (102 mm diameter and 19 mm thick), acting as a bi-circular composed section, are also condemned by xylophages organisms attach, high moisture content and the oxidation of metal connections between the log beams (screws and metal rings) (fig. 9). The steel cables used to interconnect deck elements with stringers are also oxidized, and, in some elements, loosens.
One of the stringers from the bridge has already reached the Ultimate Limit State, suffering a rupture parallel to grain by traction from bending, as showed in fig. 10. It’s also evidenced the presence of heavier traffic than the maximum allowed load in Brazilian rural roads and, associated to the stringers deterioration, had compromised the bridge safety. In the region nearby the bridge, around the river, had occurred a big fire which had propagated through the stringers and bottom of the deck, and it probably had potentiated the actual state of bridge components deterioration (fig. 11).

![Figure 10 – Stringer ruptured by traction parallel to grain from bending.](image1)

![Figure 11 – Deck and stringer attached by fire.](image2)

In the original design conception, stringers should work as a simple span, however, during the bridge service life with no maintenance, and the aggravating of heavy traffic and timber elements deterioration, locals have made another handmade solution, with no-technique supervising as the construction of a series shoring (or bents) with the aim to avoid the structure collapse (fig. 12).
Loosen of connections
In metal rings connections had also been evidenced many problems such as oxidation and principally the loosen of through screws that provide a better join between the log beams from composed section stringers. This loosen of connections (fig. 13) propitiates to composed section reduction of effective stiffness, letting it more propitious to deflexions and, consequently, increasing stresses in the section.

Analyzing visually timber bridges constructed in the region of Pato Branco city, at state Paraná, Brazil, it had been found similar situations like the timber bridge studied in this work, with many pathologies such as: insect and/or fungi attach; timber decay; defaults in timber elements from the deck; damages caused by excessive load (Milani and Kripka, 2012(7)).
In others short and medium span timber bridges in the region of Campinas city, at São Paulo state, Brazil, it had been found the same pathologies and problems presented at Yolanda Farm, like stringers decay, high moisture content in deck elements caused by water retention of soil layer applied incorrectly over the timber bridge deck (Sartorti, 2008(6)).

4. Conclusions
The number of short and medium span timber bridges constructed in Brazil is very expressive, but, nevertheless, the government neglect in relation to timber bridges maintenance bring on them a precocious loss of utility and degradation, influencing directly to society quality of life,
In Brazil, many timber bridges are in the same status of the bridge at Yolanda Farm, with the Ultimate Limit State already reached, but they keep being used after no-technique and non-recommended providences made by locals, presenting risk for them. Hence, a serious problem of Brazilian timber bridges is that most of them are constructed by no-technique and no-scientific knowledge, without engineer design and supervision, and with none adequate maintenance during their service life. For the studied bridge of Yolanda Farm, the solution is the demolition and the construction of a new one in the same local, once the actual structure presents a serious danger for traffic that use it.

6. References


