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REVIEW

Review on antibacterial characteristics of bridge engineering biomaterials

Zhao Qing-qing [a], **Chen Meng-yao** [a], **He Rui-lin** [a], **Zhang Zhong-feng** [a,*], **Muhammad Aqeel Ashraf** [b]

[a] *Furniture and Art College, Central South University of Forestry and Technology, Changsha 410004, China*
[b] *Water Research Unit, Faculty of Science and Natural Resources, University Malaysia Sabah, 88400 Sabah, Malaysia*

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Abstract This review summarizes the research on timber construction materials used in bridge construction. It focuses on the application of antiseptic treatments and the use of timber engineering materials in decks and bridges. This review also provides an overview on the future research and prospects of engineered timber materials.

Contents

1. Introduction

Timber bridges are in widespread use in China. Using timber in bridge construction can save resources, reduce costs, and benefit the environment. Timber materials that are used in civil engineering include traditional logs, sawn timber, and modern timber composites. After being integrated into high-tech manufacturing processes, bridges built with modern timber

* Corresponding author.
E-mail address: csfuzzf@163.com (Z.-f. Zhang).
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construction materials are not only natural, esthetically pleasing, and environmentally friendly, but they also compare favorably with modern concrete and steel structure bridges in terms of handling large loads and being able to span long distances. Friedlander (2006) showed that timber has received renewed interest from bridge contractors and engineers because of the progress in science and technology; timber bridges are now also an esthetic choice for architects, engineers, and contractors. The use of timber preservatives ensures that such bridges will have long service lives. In addition to antiseptic treatments, the improvement of the laminated composite process has also increased the applicability and performance of timber used in modern vehicular bridges (Friedlander, 2006).

In the United States, modern timber bridges have become an important style of medium- and small-span highway bridges, especially for highway bridges with low transport volumes (Ashraf et al., 2012a,b). In Germany, timber is used as a load-bearing structure in viaducts serving pedestrians and cyclists. In addition, the innovation of timber bridges has become the byword of modernization (Frenette and Flach, 2008), and research into the use of antiseptic treatments and related timber construction materials in bridge decks and bridges has developed rapidly. It has been shown that wood extracts can improve the mechanical properties of construction materials (Zulkifley et al., 2013a,b). Many woody extracts, as well as the chemical composition of biomass, have been determined via improved molecular identification methods. Such studies have been very effective and are of great value.

2. Bridge decks

Bohannan (1972) reviewed research advances into timber bridge decks at the US Forest Products Laboratory (Bohannan, 1972). Tuomi (1976) pointed out that timber bridges are widely used in rural areas and on forest service roads. Timber bridges are durable, cost-effective, and require fewer technical tools and equipment to erect. Glued-laminated (glulam) bridge decks, which have been developed recently, can provide excellent structural performance, and there is a hope that these can prolong the service lives of bridges by protecting their upper structures (Tuomi, 1976). Wipf et al. (1996) studied the behavior of longitudinal glulam bridge decks of highway bridges by establishing a finite element model. Such bridges are more competitive with steel and reinforced concrete bridges within the range from small to medium spans (Wipf et al., 1996). Buttlar and Mozingo (1993) showed that the rigidity, toughness, and creep resistance performance of timber bridge decks reinforced with a steel sandwich plate are superior to those of ordinary timber bridge decks. Additionally, by analyzing dynamic and static models, they found that timber bridge decks reinforced with a double steel sandwich plate are better than single steel sandwich plate-reinforced timber bridge decks (Buttlar and Mozingo, 1993). Dagher et al. (1997) built a timber bridge deck reinforced with glass fiber, and confirmed that the glass fiber reinforced timber bridge deck had a sufficient prestressing force after 4.25 years of monitoring (Dagher et al., 1997). Larson et al. (1997) found that the asphalt pavement was worn on 1378 timber bridges in the US state of Minnesota. This study evaluated the degree of premature deterioration of the asphalt of timber bridges, and it determined the main mechanism that caused the deterioration of the surface. Additionally, the authors put forth suggestions for improving the performance of asphalt pavements of bridges (Larson et al., 1997). Stenko and Chawalwala (2001) showed that a polysulfide epoxy resin coating layer is an economical and reasonable material for protecting trestle bridge and concrete bridge decks. In recent years, an epoxy cover layer was also successfully applied to fiber-reinforced plastic and timber bridge decks (Stenko and Chawalwala, 2001). A report by Rogers (2004) analyzed the performance of a thick layered, timber–concrete composite beam under a series of experimental load tests, and it showed that a thick-layered beam is a possible precursor for studying a thick-layered, timber–concrete bridge deck system in the future (Rogers, 2004).

3. Bridges

Gutkowski and Williamson (1983) summarized research activities directed toward timber bridges, and they tracked the evolution of the form of modern bridges (Gutkowski and Williamson, 1983). Williamson (1990) summarized the use of structural glulam timber, which was first introduced in the US in 1934, as a construction material. The development of fully waterproof adhesives in the 1840s led to the use of structural glulam timber in exposed, natural environments, which subsequently led to the use of laminated timber in bridges. Interestingly, some of the glulam timber highway bridges that were built in the 1940s are still in use today. The 50-year lifespans of these bridges illustrate the potential for structures of this kind. The multifunctional size, shape, and bearing capacity of glulam timber, combined with technological progress and improvements in pressure and anti-corrosion treatments, enabled glulam timber to be used as a substitute material in bridges (Williamson, 1990). Vandergriend (2004) showed that new forms of timber construction materials allow engineers to design larger span timber bridges that have better durability. Progress in material processing and construction methods (such as stress lamination) can lead to a longer service life than ever before. A form of timber composites now in use is that of parallel laminated strand lumber (PSL). The design stress of PSL is 35% higher than that of standard sawn timber or plywood (Vandergriend, 2004). Mettem (2003) described major breakthroughs in timber materials, including the development of third-generation structural timber composite materials, as well as the bonding of structural timber with completely invisible connections; laminated veneer lumber is a typical example of a third-generation structural timber composite material (Mettem, 2003). Manbeck et al. (2007) used red oak timber as a raw material to build a bridge, and they described the details of the bridge design, as well as an anti-corrosion timber treatment (Manbeck et al., 2007). Freedman (2009) put forth the optimal design and construction of various forms of stress-laminated timber bridges. Timber can also be combined with other materials to make up for its structural defects. Gilham (1995) introduced the design of a glulam beam using high-strength fibers, and they summarized the design method of the fiber-reinforced, glulam beam. They believe that the addition of high-strength fibers into the timber makes beams cheaper, and their beam not only used low-grade timber, but also showed better performance than a traditional glulam