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# Study on Fatigue Properties of Timber-concrete Composite Beams

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## Abstract

**The timber-concrete composite beam is a new type of composite structure with compound effect, which is a combination of timber beam and concrete slab, and the TCC beam has better fire resistance and sound insulation performance than the pure timber beam, and also has better strength and stiffness. At present, there are more studies on the static performance of TCC beams at home and abroad, but less studies on the performance of TCC beams under fatigue loading. This paper summarises the current status of research on the fatigue performance of TCC beams and provides a reference for future research on the fatigue performance of TCC beams.**

## Keywords

**Timber-concrete Composite Beam; Fatigue Life; Fatigue Stiffness.**

## 1. Introduction

The TCC beam, which is composed of timber, concrete and connectors, is an efficient composite structure. The concrete slab and the timber beam are connected by shear connectors to form a whole and bear the force together. Under the action of external loads, the compressive properties of concrete and the tensile properties of timberen beams are fully exerted. Timber has gradually attracted public attention due to its high strength-to-weight ratio, good flexibility, impact resistance, low energy consumption, easy processing and decomposition. With the continuous advancement of my country's economy and society, the demand for traditional building materials steel and concrete with high energy consumption and high pollution has increased. It is inconsistent with the theme of green development advocated by my country. Therefore, the development of new environmentally friendly building materials to replace traditional building materials has become a new challenge. For bridges, it is bound to bear the vibration load of the vehicle. Since the actual use of TCC is relatively late, the fatigue load loading of the TCC beam in normal operation is still in the early and middle stages, and its maximum harm has not really been revealed. Therefore, the timber-concrete composite beam It is particularly important to carry out a reasonable design for the fatigue.

## 2. Current Status of Domestic Research on Fatigue Properties of Timber-concrete Composite Beams

At present, Chinese experts and scholars mainly conduct static load tests on TCC beams, but the research on fatigue performance of TCC beams is almost blank in China. At present, there is no systematic theoretical system and related industry norms.

In 2019, Lian Zeng from Central South University of Forestry and Technology conducted static and fatigue tests on three 1:4 timber-concrete stud-connected composite beams, and obtained the fatigue performance of timber-concrete composite beams connected by studs. The experimental results It shows that under the action of low load amplitude, the composite beam still has good fatigue

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performance after 2 million times of fatigue loading. When the amplitude of the fatigue load increases, the stiffness of the timber-concrete composite beam connected by the studs degrades significantly, and the life gradually decreases with the increase of the loading times. Lifespan declines faster. The finite element model is established by ANSYS, and the results obtained from the model are in good agreement with the experimental values.

In 2020, Ziyuan Ding from Central South University of Forestry and Technology studied the fatigue performance of two stud shear connectors and two timber-concrete composite beams. The experimental results show that the displacement of the push-out parts increases with the number of cycles, and the stiffness decreases continuously. After 2 million load cycles, the bearing capacity was reduced by 17.8% and 22.9%, respectively, compared with the static test. After the TCC beam was subjected to 2 million fatigue loads, the residual deformation gradually increased, the stiffness gradually decreased, and the composite beam has not yet been damaged. And the larger the fatigue amplitude, the larger the residual deformation and the more obvious the stiffness degradation. A nonlinear FEM model is established, and the experimental and finite element results are compared, and the data of the two are in good agreement.

## 3. Current Status of Foreign Research on Fatigue Properties of Timber-concrete Composite Beams.

In 2004, Weaver et al. conducted a 2 million-piece fatigue load test on seven FRP-reinforced steel bar connection push-outs and two FRP-reinforced timber-concrete composite beams. The test results show that the effect of fatigue loading on the shear strength of the timber-concrete push-out is negligible. Under the action of fatigue load, the stiffness and bearing capacity of the two beams are continuously reduced, and a load-slip model is established according to the experimental results.

In 2007, Hanswille, G et al. conducted a series of tests using EC4 push-out parts to study the mechanical performance of the screw-connected push-out parts under the action of fatigue load under ring load. The fatigue test results are analyzed, and on the basis of summarizing the results of 71 ejection tests done by predecessors, the test results of the push-out parts are sorted and re-analyzed according to the strength of the push-out parts, the peak value and amplitude of the fatigue load , and an analytical expression for predicting the fatigue life and reduced strength of timber-concrete composite beams under high-cycle fatigue loads is presented. In addition, the linear damage accumulation assumption proposed by Palmgren and Miner was revised and improved to account for fatigue load loading sequence effects and nonlinear behavior.

In 2008, Balogh J et al. studied the fatigue performance of timber-concrete composite beams using slot-screw connection, and 12 composite beams with a timber moisture content of 12% were loaded and unloaded for 21,600 times. Variation of failure mechanism, stiffness and bearing capacity of connected timber-concrete composite beams under fatigue loads. The experimental results show that there are two failure modes of the composite beam, one is the shear failure of the timber at the notch position and the end of the composite beam, and the other is the bending failure of the timber at the mid-span position. Fatigue loading increases deflection and decreases stiffness in the initial elastic stage.

In 2010, Bathon L et al. conducted 60 fatigue tests of HVB connectors at the HS-RM University of Applied Sciences Wiesbaden, Germany. The test results show that the fatigue of the composite cross-section mainly depends on the ductility of the HVB connector, and the predicted fatigue load is closely related to the failure mechanism. , and established a fatigue design method for HVB connectors.

In 2011, Aldi P et al. carried out fatigue load tests on TCC beams connected by notch and "X" oblique steel bars. According to the fatigue test results of the connectors, the corresponding "S-N" curves were fitted, and the two connections were combined. The fatigue test results of the composite beams are used to verify the fitted "S-N", and the two match well. A comparison with the model of the Eurocode found that the Eurocode was conservative with respect to the test results.

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In 2013, Yeoh D et al. tested the fatigue performance of two different connection methods of timber-concrete composite beams in the Structural Laboratory of the University of Canterbury, namely rectangular slotted screw connection and toothed metal plate connection. After 2 million fatigue loads, pusher and composite beam specimens were loaded to failure to quantify their maximum strength. The test results show that the strength of the rectangular notch connection after fatigue loading is 0.95 times that before loading, while the strength of the toothed metal plate connection is 0.60 times. Rectangular notch connections exhibit greater slip resistance than toothed sheet metal connections. After 2 million cycles, the rectangular notch-connected composite beam showed no obvious stiffness loss, while the toothed metal plate-connected composite beam had poor fatigue performance, failing after 350,000 cycles, which was comparable to the composite beam before fatigue load loading. In contrast, the loss of strength, stiffness and composite action is significant, and it is recommended to use a rectangular slotted screw connection system instead of a toothed metal plate connection in the bridge design.

In 2013, Rautenstrauch K et al. conducted fatigue performance studies on push-out parts and timber-concrete composite beams of slot + double screw connection (Serie E-K-A) and PC + slot screw connection (Serie E-K-PC) in the Weimar laboratory of Bauhaus University. The experimental results show that Serie E-K-PC has higher strength and stiffness, and the S-N curve is fitted according to the experimental results. Briefly describe the procedure for verifying the fatigue of timber-concrete composite bridges according to current standards.

## 4. Outlook

At present, researchers at home and abroad have carried out preliminary research on the fatigue performance of TCC beams. The relevant research cannot support the development of timber-concrete composite beams in practical engineering, and the research depth and breadth are still far from steel-concrete composite structures. Far. A systematic theoretical system has not yet been formed, and there is no relevant specification for TCC beams in the industry, which severely restricts the development of timber-concrete composite structures. Therefore, it is necessary to increase the research on the fatigue performance of TCC beams. The following suggestions are made in this paper:

(1) Study the fatigue performance of TCC beams under different degrees of shear connection; understand the failure mode of each component under fatigue state, and predict the maximum damage position of timber-concrete composite beams under fatigue.

(2) The fatigue properties of TCC beams with different connection methods were studied, and the failure modes and remaining life after fatigue loading were analyzed.

(3) The residual bearing capacity and residual stiffness of timber-concrete composite beams after fatigue loading are studied in order to evaluate the working state of timber-concrete composite beams.

(4) A complete theoretical system and calculation method are deduced and established to provide a reliable theoretical basis for the fatigue design of TCC beams.

(5) Promote the development of timber-concrete composite structures at the national level, compile relevant industry regulations, and promulgate and implement them. Provide theoretical and normative basis for designers.

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