# SCOPE OF WOOD AND CONCRETE COMPOSITE MEMBERS

**You Wei[1]， Анатолий Яковлевич Найчук[2]**

[1] аспирантура, Brest State Technical University, Brest, Belarus,18206599529@163.com，+375257611324

[2] PhD in engineering，Professor of the Building Structures Department，Brest State Technical University

**Abstract**. Wood-concrete composite material is an interesting engineering wood product, which is usually used for structural members that mainly bear bending loads, from simple floor system to long-span bridges. In this way, we can make full use of the tensile strength of wood and the compressive strength of concrete. Firstly, this paper introduces various types of wood-concrete composite structural members, including member types, connection types and types of wood and concrete. Then, the basic mechanical principles of wood-concrete composite structural members are introduced, and some design methods are briefly described, and the specific characteristics and advantages of wood-concrete composite structural members are deeply discussed from the perspectives of engineering, architecture, construction and ecology. At present, Belarus has also been committed to introducing wood as a sustainable ecological material in the construction industry.

**Keywords:** wood lightweight concrete, building construction, structural engineering, sustainable building, wood-concrete structure.

## INTRODUCTION

In order to optimize the structural performance, usability, energy saving and ecological characteristics of wood composite system, the Department of Structural Design and Wood Engineering (ITI) explored the combination of wood products with other traditional building materials and components in several research projects [1,2]. These technologies provide high-efficiency components for low-energy buildings, support the rapid assembly of modular buildings with prefabricated dry components, and improve efficiency, thus creating opportunities for reducing carbon emissions. As a representative example of these developments, the composite component of wood-concrete structure, as a new application of structure, illustrates the degree of correlation involved in developing complex system solutions to improve resource efficiency.

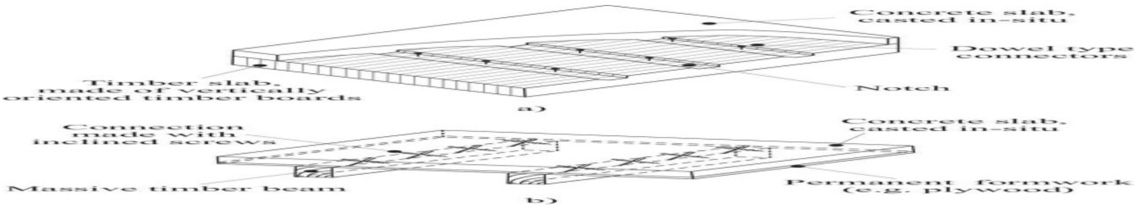
The main categories of wood-concrete structures include: logs and concrete; Sawn wood and concrete; Glue wood and concrete; Laminated veneer laminated wood (LVL) and concrete; Cross-laminated wood (CLT) and concrete. Wood-concrete composite structural members (TCC) are usually horizontal members, which bear unidirectional loads (so-called unidirectional span members) and are subjected to uniaxial bending. The wood and concrete parts of TCC members are connected by one of several types of connectors to achieve composite action [3]. Because the tensile strength of concrete is almost negligible, wood is usually located on the lower side of the member (tensile stress is expected), while concrete is located on the upper side (compressive stress is expected). Although there are some reverse TCC structural members with concrete at the bottom [4] and even some TCC wall systems [5], this paper focuses on the most typical application and test mechanism of the above TCC structural members.

## MATERIALS AND METHODS

### 1. Various designs

There are many kinds of TCC structural members. Although there are only two main geometric shapes of TCC floor (beam and plate), the connection between wood and concrete is varied and the performance is quite different. In addition, there are various types of concrete, and the types of wood are even more diverse.

**1.1 beam and plate TCC floor system**




TCC structural members are usually plate members (floors in buildings and decks of bridges), which can be uniform in thickness or ribbed, depending on many factors such as aesthetics, height restrictions and material availability. At the same time, TCC structural members are almost always unidirectional span members, which can be modeled as beams and bear uniaxial bending loads. Therefore, there may be some confusion between terms. So we define it. The beam-type section of TCC beam is composed of wood web and concrete flange, that is, the wood part is much narrower than the concrete part. Therefore, the neutral axis of the entire TCC section is located on the web. Plate TCC means that the width of plate concrete and wood parts is equal, and the neutral axis is usually located in the concrete part. As shown in Figure 1, apart from the appearance difference between the two types, the position of the neutral axis is also different, which will affect the part of concrete where tensile cracking may occur, thus affecting the appropriate design method.

Figure.1 Examples of slab type and beam type of TCC floor system

(a) An example of the plate type of a)TCC floor. (b) An example of beam type of b)TCC floor

**1.2 Wood-concrete connection**

Wood-concrete connection has great influence on the performance of TCC structural members. A perfect connection should have enough strength to transfer the shear force between two materials, enough rigidity to allow limited slip, and enough ductility to avoid brittle failure of the connection. In addition, the non-mechanical characteristics of connection, such as cost and convenience, will also affect the choice of connection type [6]. However, a perfect connection is almost impossible to achieve in practice. At present, a variety of connection systems have been developed, each with its own advantages:

Pin fasteners include pins, screws, oblique screws, nails and other metal connectors. Except oblique screws, pin fasteners are the connection systems with the lowest stiffness and the greatest ductility [7].

Notched connection Notched connection is one of the most brittle connection types, and its notch shapes are various (rectangle, circle, vertical edge or inclined edge, etc.). Adding steel fasteners (pins or screws) at the notch can significantly improve the ductility of the notch connection [7].

When the strength of bonded joints exceeds the specified value, they will be brittle failure. Its advantage is high rigidity, and almost complete composite action can be realized. In addition, they can ensure uniform shear distribution and can be used to connect wood and precast concrete slabs [6].

There are many designs of nail-plate connecting plates; One possibility is that the lower part of the plate is designed as a nail plate, which is located between two wooden beams, and the upper part is designed as a perforated plate [8].

Friction-based connection is based on the vertical wooden board system with variable height, which is mainly used in Switzerland [6]. Therefore, the design of TCC structural members is varied; In particular, there are many types of connectors, and each connector has its own characteristics. If the properties of connectors (such as shear strength, slip modulus, spacing, etc.) are known, one of the existing simplified TCC structural design methods can be used to determine the bending strength of TCC members..

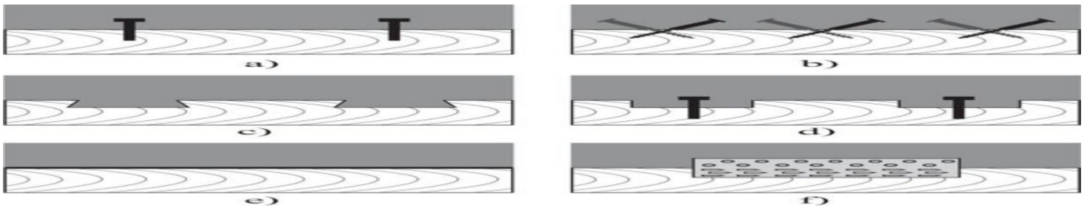



Figure.2 Main connection types

(a) connect with a pin. (b) Connect with two rows of 45 inclined screws. (c) Notched connection with inclined sides. (d) Connect with the vertical side and the notch connected with the pin. (e) glued connection. (f) connect with a nail plate.

In the one-way span simply supported floor slab (TCC floor slab is the most common), the maximum shear force at the joint occurs near the support, but can be ignored in the middle of the span. The failure of one connector near the support will cause the other connectors to bear additional loads, which may lead to more serious brittle failure of TCC members [7]. In order to avoid this situation, the spacing between connectors near the support is sometimes reduced, while the spacing between connectors in the middle span can be increased [9].

**RESULTS**

**2. Introduction of experimental mechanism of beam TCC**

For experimental group 1 (with six connectors), all staggered wooden decks of V1 and V2 are Mandioqueira (Quaea (Acuminata) V3, the outer layer is Angelimpedra (Hymenolobium Petraceum), and the middle layer is Mandioqueira. Where the wood surface is dry, the nominal size of 50×75 mm and 5 0×38 mm is in the wood with average moisture content (MC) of 15%. The average specific gravity of wood at 15% MC is 0.74. The cross section of the laminated wood used is 3.05 meters long, and five vertical components with two alternate depths are nailed together horizontally with 80-millimeter-long galvanized spiral handle nails. The vertical direction is shown in Figure 4, and the nails are numbered from 1 to 4. Repeat this pattern every 300 mm along and in the middle. In order to accommodate horizontal shear connectors (building steel bars with a diameter of 10 mm), two holes with a diameter of 12 mm and a center-to-center spacing of 100 mm were pre-drilled in the middle of a length of 250 mm wide and at both ends of 300 mm.. The hole penetrates the entire thickness of the central layer wood member and half the thickness of the outer layer wood member. Before nailing the last outer wood member, the steel bar connector is in place, as shown in Figure 3. Concrete formwork was built around the concrete slab with 12mm thick plywood to accommodate 30mm deep top concrete slab (Figure 5).

For experimental group 2 (with 8 connectors), the outer and middle layers of all staggered boards of MAN 1, MAN2 and MAN4 are Mandioqueira(Q. acumminata). The surface of wood is dry, and the nominal size of wood of 50× 100mm and 50× 50mm is used, and the average MC state is 12%. The laminated wood used has a cross section of 3.05 meters and consists of five staggered vertical parts (Figure 3). The wooden members are nailed together horizontally in the same way as the first group (Figure 4).

Figure. 3 Wood–concrete beam and horizontal shear connection detail [10]

In order to accommodate horizontal shear connectors (building steel bars with a diameter of 10 mm), two holes with a diameter of 12 mm and a center-to-center spacing of 100 mm were pre-drilled at 300 mm and 700 mm at both ends of 250 mm width. Before nailing the last outer wood member, each connector has been installed in place (Figure 5). Use 12mm thick plywood to build concrete formwork around, as shown in Figure 5.

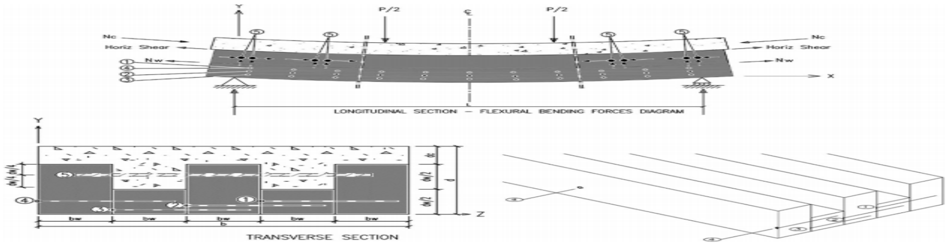



Figure. 4 Pattern of connectors for sets 1 and 2 [10]

The mechanical properties of the building steel bars used are as follows: elastic modulus E = 200,100 MPa, yield strength fy = 250 MPa. All wooden members are subjected to nondestructive testing with Metriguard strain gauge to determine the longitudinal elastic modulus ED. The average values of Ed in group 1 and group 2 were 11,887 MPa and 15,491 MPa respectively.

The concrete layers of experimental group 1 and experimental group 2 were delivered in batches according to the specified strength of 18MPa and 10MPa (the average value of the three cylinders tested on the 28th day), which were strengthened by vibration and wet-cured. After the concrete is cured, the wood concrete is transported to the laboratory for testing.

Figure. 5 Wood deck, steel connector, formwork, and finished beams [10]

## CONCLUSION

The increasing popularity of TCC structural members is related to the many advantages of its system compared with more mature all-concrete and all-wood systems. The main advantages of TCC members over all-wood members are higher bearing capacity and stiffness, better air-borne sound insulation effect, and reduced vibration interference to users. The connection between wood and concrete is a very important part of TCC system. Its strength and sliding stiffness ensure the composite action of wood and concrete, and if the connection is properly designed, it can also improve the ductility of TCC structural members. Compared with all-concrete members, TCC members have better aesthetics and ecology, lighter self-weight, better sound insulation effect, and effectively reduce impact noise.

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