PREFABRICATED TIMBER-CONCRETE COMPOSITE FLOORS

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Summary

As the sustainability has become a very important part of our lives, a worldwide interest of timber based materials for structures has increased. Big theme for civil engineers is to design and build multi-story buildings commonly higher than 4 stories, but also up to 20 or 30 stories or long span structures with high stiffness and rigidity. There are solutions for each type of these structures, but from certain point each has some limitations and disadvantages. For these reasons, timber-concrete composite (TCC) structures are coming to be very important, especially for floor structures in multi-story buildings. They have many advantages compared to traditional timber floors and are widely used as an effective method for refurbishment of existing timber floors. Most researches all around the world are focusing on improving shear connection between timber and concrete and are associated with optimization of manufacturing and assembly process. Current research at CTU is focused on industrial production of prefabricated timber-concrete panels and their easy and quick assembly, in order to reduce the total cost of production, transport and assembly. A new shear connector – a modified punched metal plate fastener with double-sided teeth – was developed for those purposes.

Keywords: timber-concrete, prefabricated, multi-story buildings, floor structures

1 Introduction

1.1 Challenges for timber engineers

All around the world, it is possible to see an increased interest in wood based materials and structure systems in recent years. Constantly debated topic of sustainable development is very helpful, but also the gradual removing of prejudices and the desire to return to these once-traditional materials is important too. Also in the Czech Republic, increased interest of wood based technologies can be observed. Increased productivity is evident particularly in implementation of family houses. A worse situation is in implementation of multi-story residential buildings and amenities.

There is a big interest to design and build multi-story buildings. Some of these has been already built e.g. in the UK, Austria, Switzerland, Germany or Canada. The highest completed one with 9 stories is situated in London. But there are studies to develop timber towers with more than 20 stories that could replace current typical structures made of steel, or concrete. Traditional wood based structure systems could be insufficient with increasing

high of building. Problems involve spatial stability of all building, lower load bearing capacity, stiffness and rigidity of floors structures and their long-term deformations and vibrations. Fire resistance and fire safety regulations could be also constraining for multi--storey buildings. One of the possibilities to solve abovementioned constraints is the usage of timber-concrete composites primarily for floor structures.

Fig. 1 *Study of Timber tower with 20 stories by MGB architects, Canada.*

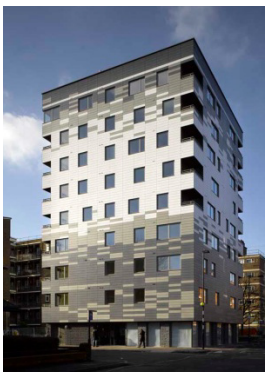

Fig. 2 *Highest completed timber building in the world – Murray Groove, London (9 stories).*

TCC is a structure where a thin concrete layer and wood or wood engineered product (e.g. solid wood, glulam, LVL, CLT, I-joist) are jointed together with some shear connection method. Plenty of material variations, shear connections and combinations exists and has been developed in last 20 years. Current researches are focused on all low-cost products, innovative shear connections, advance manufacture and assembly methods and involving recycled and ecological materials.

Thanks to a thin concrete layer, TCC structures are more stiff and rigid, so the load bearing capacity is increased and deformation and vibration are decreased. Overall stability of building is also significantly improved. Performance as regards fire resistance and acoustic parameters is much better. Mass of concrete could help to solve thermal stability of interior environment and could be also used for integrated heating and cooling systems.

2 Prefabricated TCC floors

2.1 Technical solution

Increasing competitiveness of timber structure producers in our region is major reason for developing of a new timber-concrete element. Even for multi-story buildings (higher than 3 stories) dry assembly is very important for successful application on the market. Thus, prefabricated variation with elimination of wet processes has been developed. For higher buildings, new and more strict requirements appears such a fire resistance of structures, higher stiffness and rigidity of floor structures and acoustic performance of separating structures. All abovementioned factors should take into account economical and thus fast production, transport and assembly.

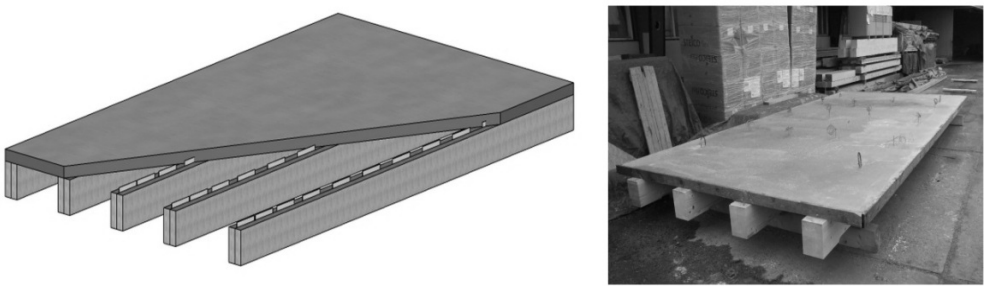

Fig. 3 *Prototypes of prefabricated timber-concrete panel with nailplate shear connection.*

For these reasons, the emphasis is focused on usage of commonly available materials and products in our region or products which can be easily and inexpensively manufactured. Concrete improves fire resistance, stiffness and rigidity of load-bearing structures and its application in timber-concrete composite sections can help in negotiating with the authorities granting building permits. Timber and concrete are commonly used materials in our region and thus development has been focused on shear connection between timber and concrete and technology used for shear connector assembly. To ensure low cost on production, neither gluing processes nor adjustments of timber beams like notches, dimples or holes have been willed.

Development of a new type of prefabricated composite timber-concrete elements (primarily for floor slabs) has been focused on improving of common punched metal plates placed between a pair of timber beams in whole length at once.

Two technology procedures can be used for achievement of composite structure. Pouring fresh concrete mixture in a factory over semi-prefabricated timber beams with installed shear connectors or concreting shear connectors into a slab and after hardening of concrete assembling of timber beams. In first case, caution with water cement ratio and removable formwork are needed. In second case, a special assembling machine has to be used.

2.2 Shear connection

For connecting timber and concrete to a composite structure, a modification of common punched metal plate fastener was chosen. Ideal position of steel shear connector is inside timber cross section, so steel is protected against fire. Due to this reason, teeth were punched to both sides so the plate can be punched between a pair of timber beams.

A double-sided punched metal plate fastener made of hot-dip galvanized 1,5 mm thin steel sheet with zinc coat S280GD + Z275 was developed. Dimensions and illustration of used innovative shear connector is given in Fig. 4.

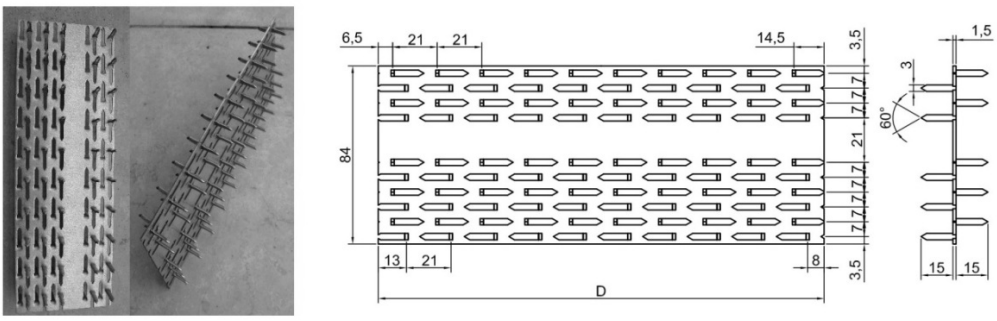

Fig. 4 *Modified double – sided nailplate for TCC shear connection.*

3 Conclusions

TCC structures solve many of problems which are related with both long-span structures and multi-storey buildings. It is a popular and highly researched technology that could be extensively used even in The Czech Republic.

The on-going research at Czech Technical University (CTU) deals in a complex way with the problems of timber-concrete composite floor structures. The aim of this research is to determine design models for timber-concrete composite beams that are applicable for computer simulations as well as for hand calculations. The biggest interest in research is focused on the development of prefabricated composite floor element thanks to advantages of prefabrication. An important part of the research was to design a new mechanical shear connector on the basis of punched metal plate fasteners which can be easily manufactured and placed to structure. Application for variation with renewable and recycled materials will be a scope of future research.

We believe that successful development of low-cost and simple technology can increase a share of wood based buildings for various purposes.

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References

[1] CECCOTTI, A.: *Timber-concrete composite structures*. Timber engineering STEP2, Centrum Hout (NL) 1995, ISBN 80-86 769-13-5.

[2] KUKLÍK, P.: *Timber structures*. Czech Chamber of Authorized Engineers and Technicians, Prague 2005, ISBN 80-86769-72-0.