

Timber floors in existing buildings - the possibility of strengthening for the revitalisation aims

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Abstract: *Timber floors in existing buildings - the possibility of strengthening for the revitalisation aims.* The paper presents the structural solution to the joisted floor when the solid timber joist and the concrete slab are interconnected via a special semi-rigid connection and form a timber-concrete composite floor, which can be applied for the revitalisation aims, especially for already existing timber floors. Theoretical researches on behavior of connection and sub-components of composite timber - concrete were carried out; the obtained results are presented and evaluated.

Keywords: timber-concrete, semi-rigid connectors, strengthening, slip modulus, revitalisation,

INTRODUCTION

The process of revitalisation involves the adaptation of spatial planning of urban areas to variable needs of urban societies and individuals, which create them [1]. The term - revitalisation - has become a keyword, commonly used to define corrective actions plans. Among currently renovated and refurbished dwellings and tenement blocks, erected from the half of XIX century to the 30's of XX century in Poland, which create a dense development of municipal streets, the majority of them have timber floors. In most cases these floors are replaced by steel and concrete floors, mainly in order to increase the values of strength in bending, fire-resistance and stiffness. However, the replacement involves not only the increases in the mass of a slab floor (up to 300 kg/m^2), but also higher structural repair costs. An alternative in the situation, when the technical condition of timber joists enables continued use, is their composite with a thin layer of concrete "in situ" on top of timber elements [2].

The result is a timber-concrete composite floor, where the concrete flange is mainly subjected to compression, and the timber web is subjected to tension and bending. The transfer of tensile stress between timber joists and concrete slab takes place by appropriate connection, inter alia by means of notches and nails or only nails [3]. The mechanical connectors between a concrete slab and timber joists are called semi-rigid connectors. Different kinds of semi-rigid connectors are shown in Fig. 1.

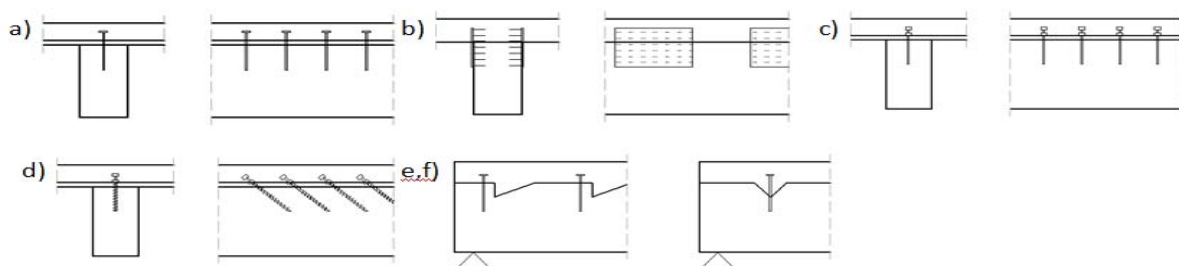


Fig. 1 Strengthening of the timber floors by concrete slab: a) connection by nails, b) by Gang-Nail plates; c) vertical screws; d) transverse screws; e, f) by means of notches and screws (Source: [4])

Timber concrete floor offers many benefits, such as:
- optimal use of specific features of applied structural materials (compressive strength, tensile strength, joint features),

-high stiffness and bending strength, which result in:

- lower susceptibility to vibrations,
- lower thickness of timber-concrete composite floor compared to full timber system,

- improved physical features:

- fire resistance,
- airborne and impact sound insulation,
- thermal mass,

- higher load capacity and better serviceability limit state conditions of already existing structures,

- lower weight relative to concrete floors (timber-concrete system can be used to increase heights, or storeys of existing structures due to its lightness).

DESIGN ASSUMPTIONS

In order to analyse the timber-concrete composite floor, some specific assumptions have been adopted for calculations in accordance to PN-EN 1995-1-1 2010 [5].

The thickness of concrete slab has been defined as 6 cm and the quality of the concrete C30/37. As connectors there have been used nails of diameter 4,5mm and of 125mm length. The spans of the timber joists have been assumed from 2,4 to 6,3m, spaced at 0,9m in two variants of cross-section: 12x24 and 15x30cm

There have been also defined the values of loads: permanent load 1,5 kN/m² and imposed load 3 kN/m² (according to EN 1991-1-1:2002(E) - that value applies for category "C" of loaded areas: e.g. areas in schools, cafés, restaurants, dining halls, reading rooms, receptions).

Timber-concrete composite floors should be designed as one span beam supported by two simple supports; of T-shaped cross section, where effective width of flange $b_f = b_w + 2b_p$, where $b_p = 0,15l \leq 0,5a$; and $b_p \leq 6h_f$ by slab cantilevers on both sides of the web or $b_p \leq 4h_f$ by slab cantilever on one end of a web of T shaped cross section; "a"- spacing of beams.

The results of calculations are presented in Fig.2, where crucial parameters were compared to one another, while using different input inter alia cross section of a beam, or diameter of connector.

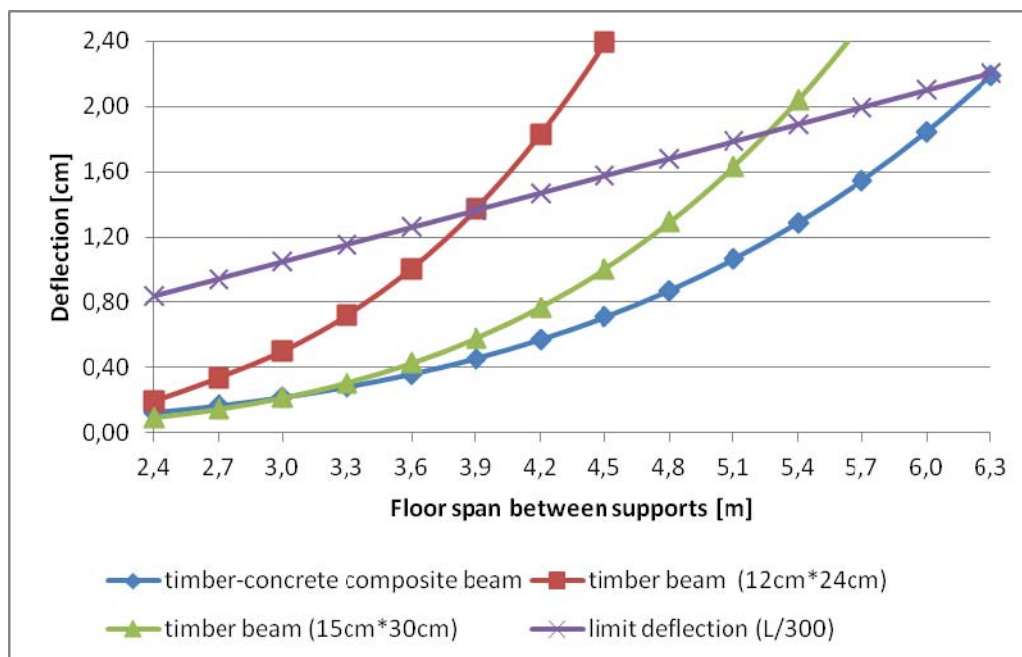


Fig. 2 Diagram presenting relationship between deflection and span

The limit value of timber beam deflection of cross section 12x24 cm is reached by the span of 3,9m, for the timber beam deflection of cross section 15x30 cm is reached by the span of 5,25m and the timber-concrete composite beam o T- cross section (timber web 12x24 and concrete flange 6x84cm reaches its limit value of deflection by the span of 6,3m.

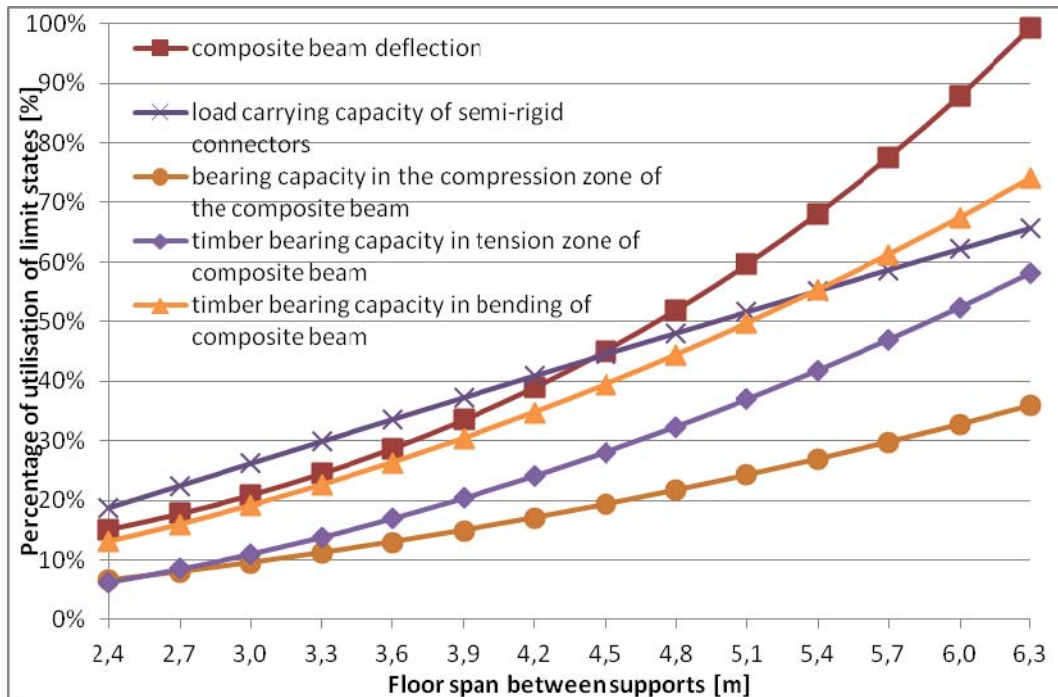


Fig. 3 Percentage of utilisation of limit states , depending on floor span.

The percentage of utilisation of composite beam cross section is shown in Fig.3 in reference to:

- Serviceability Limit State,
- Ultimate Limit State for connectors,
- Ultimate Limit State for stresses,

relative to the floor span between supports.

It was concluded, that by the floor span between 2,4 and 4,5m the bearing capacity of the composite beam is dependent on the load - carrying capacity of semi-rigid connectors. For the floor span between 4,5 and 6,3m, the deflection is responsible for the bearing capacity of composite beam.

DISCUSSION

On the basis of obtained results for timber joists before and after strengthening by concrete layer, a significant improvement has been stated concerning behaviour of the structure after the strengthening by concrete layer.

A significant element, which has a meaningful impact on the designed floor is a value of factor η - the efficiency of the interlayer connection. When the connection is very rigid, the factor η approaches unit; when there is no connection, the factor η approaches zero. The variables responsible for this factor are distance between shear connectors parallel to grain and slip modulus of the connection K_{ser} , dependent on the fact of whether the nails are applied with or without pre-drilling.

While designing the composite floor, the consideration should be given to:

- Ultimate Limit State for semi-rigid connectors (for short floor span),
- Serviceability Limit State (for long floor span).

The critical point while designing the composite timber - concrete floor of a long span is to satisfy the Serviceability Limit State. For fixed dimensions of cross section of existing timber beam, the deflection of composite floor may be minimalised by increase of concrete slab thickness. Increase of thickness of concrete slab influences the movement of neutral axis of composite beam cross section towards the connection timber joist - concrete slab. It concludes in increased load per connector and lower value of the factor σ . The Ultimate Limit State for semi-rigid connectors becomes the critical point while designing the composite floor, as the thickness of concrete slab grows.

The critical point while designing the composite timber - concrete floor of a short span is to satisfy the Ultimate Limit State for semi-rigid connectors. For fixed dimensions of cross section of existing timber beam, the load carrying capacity of semi-rigid connector may be increased by applying the maximal allowed number of pre-drilled connectors in a cross section.

The discussed method, which can be applied for the refurbishment of existing floors, is important in many respects. An existing timber floor can remain intact, which enables to preserve the current building style. Thanks to strengthening by adding a concrete slab, the wide range of possibilities appears concerning conversion inter alia of function of the object, that depends often on the increase of imposed loads. What is more, the amount of generated waste can be reduced, as well as the energy demand for making a timber concrete composite floor in comparison to concrete slab.

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Streszczenie: *Stropy drewniane w istniejących budynkach - możliwość wzmocnienia w celach rewitalizacji.* W artykule przedstawiono analizę wpływu zastosowania wzmocnienia stropu drewnianego poprzez zespolenie go z płytą betonową. Rozwiązanie to może być stosowane w celach rewitalizacji istniejących stropów drewnianych. Podstawą analizy były wyniki wartości obliczeniowych stanu granicznego nośności i stanu granicznego użyteczności stropu zespolonego przy różnych wariantach rozpiętości. Obliczenia wykonano na podstawie Eurokodu PN-EN 1995-1-1 2010 [5].

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