10.2478/tvsb-2013-0001

**Transactions of the VŠB – Technical University of Ostrava**

No. 1, 2013, Vol. XIII, Civil Engineering Series

paper #1

**Radim ČAJKA[1], Kamil BURKOVIČ[2]**

# TECHNOLOGY OF COUPLED TIMBER–CONCRETE CEILING USING BONDED SHEAR CONNECTORS

# TECHNOLOGIE SPŘAŽENÍ DŘEVO BETONOVÝCH STROPNÍCH KONSTRUKCÍ POMOCÍ LEPENÝCH SMYKOVÝCH LIŠT

**Abstract**

The article describes the specific technological process that has been examined in the reconstruction of the ceiling structure of a house on Sokolska Street in Ostrava. Following experimental testing in laboratories at the Faculty of Civil Engineering VSB - TU Ostrava the technology of bonded shear bars under static reinforcement of timber ceilings was first applied and successfully tested in construction practice. This paper deals with the possibilities of using coupled timber-concrete structures by means a glued coupling bar. The described process of static reinforcement is particularly suitable for reconstruction of historic timber ceilings and places where it is necessary to prevent damage to non-supporting structures (e.g. ceiling, plaster, stucco decorations, etc.). The method is also employed in those cases where it is necessary to allow traffic-flow in the rooms below the reconstructed ceiling.

**Keywords**

Coupled structures, timber-concrete ceiling, bonded shear connectors, reconstruction

**Abstrakt**

V článku je popsán konkrétní technologický postup, který byl ověřen při rekonstrukci stropní konstrukce domu na Sokolské ulici v Ostravě. Po předchozích experimentálních zkouškách v laboratořích na Fakultě stavební VSB – TU Ostrava tak byla poprvé aplikována a ve stavební praxi úspěšně ověřena technologie lepených smykových lišt při statickém zesilování dřevěných stropů. Tento příspěvek se zabývám možnostmi využití spřažených dřevo-betonových konstrukcí s využitím vlepené spřahovací lišty. Uvedený postup statického zesílení je vhodný především u rekonstrukcí historických dřevěných stropů a všude tam, kde je nutno zamezit poškození nenosných konstrukcí (např. podhled, omítku, štukovou výzdobu apod.). Metoda se uplatní rovněž v takových případech, kdy je nutno zachovat provoz v místnostech pod rekonstruovaným stropem.

**Klíčová slova**

Spřažené konstrukce, dřevobetonové stropy, lepené spřahovací lišty, rekonstrukce

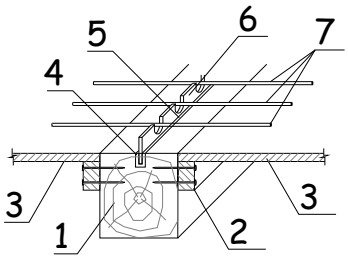
[1] Prof. Ing. Radim Čajka, CSc., Department of Structures, VŠB - TU Ostrava, Faculty of Civil Engineering, Ludvíka Podéště 1875/17, 708 33 Ostrava - Poruba, tel.: (+420) 597 321 344, e-mail: radim.cajka@vsb.cz.

[2] Ing. Kamil Burkovič, ARMING spol. s r.o., Ocelářská 6/338, 703 00 Ostrava-Vítkovice, tel.: (+420) 602 744 313, e-mail: kamil.burovic@arming.cz.

## 1 INTRODUCTION

In the total reconstruction of older buildings, or for attic spaces allowing for new use, there is a problem regarding the bearing capacity of the original timber ceiling structures with an increased load. In an effort to maintain the existing supporting structure, ceiling, or traffic in the rooms below the reconstructed ceiling there are several options for its reinforcement.

After taking down the floor layers the ceiling structure reinforcement using newly inserted timber or steel beams, enlargement of the existing cross-section by shims, preload of original features using suspension or support of the existing ceiling by the new supporting structure, etc. can be carried out [6], [7].




1 – Beam
2 – Distant casing board
3 – Casing board
4 – Groove
5 – Glue
6 – Steel coupling connector
7 – Reinforcing rods (mesh)

Fig. 1: Scheme of application of bonded shear connector

Another option is the reinforcement of existing timber beams with the newly made concrete slab. This method increases the load capacity, both vertical and horizontal rigidity, sound insulation as well as fire resistance of the original timber structure. The typical disadvantages and the defects of the old timber ceilings, such as excessive deflections, vibrations, cracks and low fire resistance [5] in ceilings are also significantly eliminated.

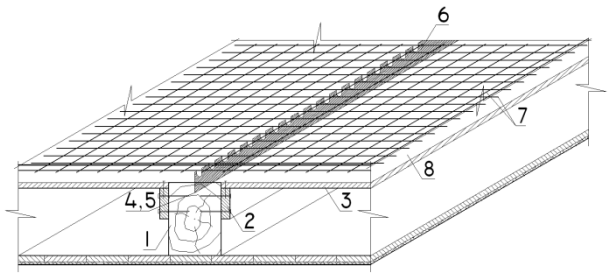
The principle of reinforcement of the existing wood beamed ceiling by applying concrete to a coupling slab is to create a load-bearing T-profile with stretched fibres in a timber beam and a pressed surface in the concrete slab [9]. The carrying capacity of the formed composite cross section depends on the dimensions and on the margins of individual load-bearing elements [11][12], i.e. the timber beam and the concrete slab. The coupling devices used also play an important role. These ensure interaction between the two parts of the cross section, transfer longitudinal shear forces and affect stiffness and bearing capacity of the coupled structure depending on the distance of the supports [10].

The most common coupling devices are straight/conical-shaped steel elements (nails, screws, staples, reinforcing rods, steel pins, etc.) or slabs consisting of steel plates of various shapes, with depressions, openings, etc. Their disadvantage is usually time/technologically-consuming assembly under the restricted conditions of reconstructed buildings.

## 2 BONDED COUPLING CONNECTORS

Significant acceleration and simplification of the construction allows the coupling between the timber beams and the concrete slab using the so-called bonded shear connectors. These consist of steel perforated plate, which is glued into the longitudinal grooves formed on the upper surface of the beam.

The advantage of this coupling method lies in the elimination of adverse effects during the assembly of coupling elements. When performing the more common method of coupling using steel nails a high noise and vibration level during the hammering into the timber beams occurs. These shocks may endanger the traffic in rooms under the renovated ceiling or damage the ceiling plaster with the historic stucco décor or paint.




1 – Beam
2 – Distant connector of casing
3 – Casing boards
4 – Carved longitudinal groove
5 – Glue
6 – Bonded coupling connector
7 – Concrete reinforcement rods or reinforcing mesh
8 – Reinforced concrete slab

Fig. 2: Principle of coupling of original timber beams with thin reinforced concrete slab using a bonded shear connector

The basis for validation of this technology in construction practice were the necessary structural calculations and laboratory tests of shear resistance of the bonded joint of wooden elements and steel shear connectors. Test protocols carried out in the Laboratory of Building Materials, Faculty of Civil Engineering at VSB-TU Ostrava are a part of the thesis (Frankova, V., 2007) [3]. The numerical verification of strain and stress thus coupled timber-concrete "T" cross-sections using the FEM method proved a relatively close agreement with the assumptions of linear solution according to the principles of construction mechanics and elasticity (Mikolášek, D., 2010) [8]. Technology of shear bonded connectors is protected by a registered utility model No. U1 22590 "Static reinforcement of existing timber ceiling" [1].

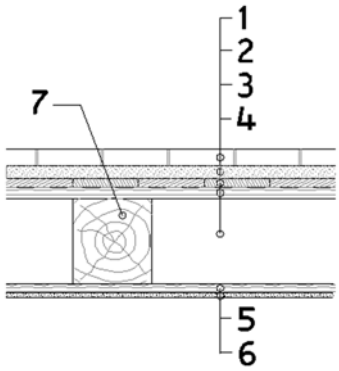
## 3 BONDED COUPLING CONNECTORS

The reason for the reconstruction of the building on Sokolska Street No. 936/21 in Moravska Ostrava was the adjustment of 3.NP loft space for office suits, securing of the gable wall and overall bracing of the building in the horizontal plane.

Fig. 3: Overall view of the facade of the reconstructed building with coupled with timber-concrete ceilings

### 3.1 Original condition of the ceiling structure.

The historic house at Sokolska Street was built in the beginning of the last century and currently rented to law firms. Vertical load-bearing structures consist of outer and inner brick walls on stone foundations. Horizontal load-bearing structures consist of wooden beamed ceilings on the floors above the ground floor, basement ceilings are then vaulted. Some rooms are decorated with ornamental limestone-plaster ceilings. Before starting the construction works the building diagnostics, including drill holes into the ceiling in the attic along the front wall, were performed. The floor layers were removed from here, which consisted of bricks, slag embankment and wooden decking. After removing the upper layers, the profiles of the main supporting beams, their axial distance, and the original floor composition were measured.




1 - Brick 50 mm
2 - Cinders 25-50 mm
3 - Shutter 25+35 mm
4 - Gap 260 mm
5 - Shutter 25 mm
6 - Plaster 15 mm
7 - Beam 240/260 mm

Fig. 4: The original structure of the ceiling in the attic space

Fig. 5: Drilling hole in the ceiling structure in the attic

### 3.2 Implementation of coupling process technology.

The individual floor layers were stripped down to the supporting beams as part of the attic reconstruction. Existing underside covering including the stucco ceiling was preserved. Exposed load bearing wooden structures were covered with a protective impregnation coating against wood-eating pests and decay.

Most of the well-preserved boards of the original upper deck were used to provide the permanent casing for the concreting of the new reinforced concrete slab. The casing was properly sealed by a polyurethane foam to prevent leakage of the batch and treatment water during the pouring the concrete.

Fig. 6: Bonded shear connector fitting test

The 50 mm deep grooves were milled into existing timber beams and subsequently bonded to the 3 mm wide coupling connectors. PURBOND HB 110 glue will be used for bonding. The cut-outs in coupled connectors were designed to function as spacers to create a cover layer for the plate reinforcement. The reinforcement meshes KARI-W 6/100-6/100 mm were placed on the casing in compliance with reinforcement concrete cover of at least 20 mm. Anchors in the facade were also installed, which provided outer brick walls coupled with the newly concreted coupled slab. This coupling enabled a significant reinforcement of outer walls in the horizontal direction and increased the building resistance to shocks caused by public transportation.

After the fitting of all the concrete reinforcement and detaching elements the concreting of the 60 mm thick slab made of the concrete grade C25/30-XC1-Cl0, 20-Dmax22-C1 (B30) according to EN 206-1 was carried out. When completing the concreting process it was necessary to take a cautious approach towards a sealed casing with respect to the risk of mixed water leaks and fragility of ornamental plaster on the bottom side of the ceiling. The finish of the concrete was made smooth and treated according to the design principles.

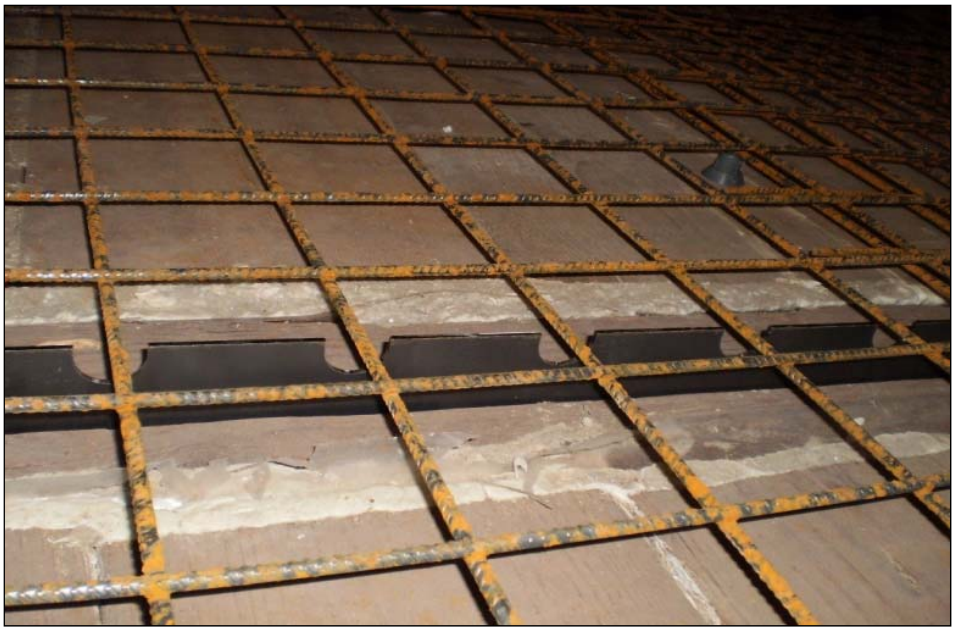


Fig. 7: Detailed fitting of shear connector and reinforcement mesh

### 3.3 Verification of the technology and experience from the implementation.

Since there has been no practical experience with the implementation of coupling using bonded shear connectors in reconstructed buildings, several improvements were made when verifying the proposed technology.

Fig. 8: Concreting of reinforced concrete slab coupled with timber beams

Coupling connectors were designed in the shape of grooves so the rods of welded meshes could be inserted into the grooves. Since the coupling connectors, the so-called grooved structure, were manufactured to be one meter long, the gaps between the individual pieces and the movement of

the groove grid for the mesh rods occurred in some locations. A similar problem occurred in places of splicing of wire mesh by the overlap. These deficiencies have been addressed by cutting the mesh and insertion of rod shims of the same profile. Another disadvantage was the lack of glue in some places. During bonding the glue is supposed to visibly leave the groove during its hardening. In places where this phenomenon did not occur additional glue was applied to the corner between the steel connector and the beam. These deficiencies were addressed in the report during inspection days at the construction site in the building logbook with the participation of the designer, investor, contractor and representatives of the Building Authority.

## 6 CONCLUSION

During renovations of historic buildings it is often necessary to increase the capacity and reliability of the original timber ceiling structures. An efficient, quick, materially/financially economical method of increasing the bearing capacity is the coupling of the original timber beams with a thin reinforced concrete slab using bonded shear connectors.

The advantage of this solution and technology of coupling is not just a high bearing capacity, rigidity and small deflections of the resulting composite ceiling structure, but also the total spatial building bracing in a horizontal direction. Another advantage of this proposed coupling technology is acceleration and simplification of the use of coupling elements, elimination of dynamic effects during construction and also the possibility of additional anchoring of the ceilings into vertical structures. The method is thus also suitable for increasing an additional stiffness of spatial structures damaged by floods or by mining activities [2]. The minor disadvantages include higher costs due to the use of adhesives, and the production of shear steel connectors, the so-called grooved structure. With regard to the greater dispersion of mechanical-physical properties of elements with higher age, it is recommended to perform statistical analysis [4].

Several years of operation after the reconstruction confirmed the high efficiency and effectiveness of the above described coupled timber-concrete structure. The proposed coupling technology "Static reinforcement of existing timber-beamed ceiling structure" protected by the registered utility model U1 22590 [1] can be regarded as proven in practice.


### ACKNOWLEDGMENT

The paper has been supported by the project of “Conceptual development of science and research activities 2013” on the Faculty of Civil Engineering, VSB-TU Ostrava.


### REFERENCES


[1] AGEL, P. & LOKAJ, A. Load Bearing Capacity Tests of Mechanical Joining on Timber-Concrete Beam (2013). *Transactions of the VSB - Technical University of Ostrava. Construction Series.* Volume XII, Issue 2, Pages 1–32, ISSN (Online)1804-4824, ISSN (Print) 1213-1962, January 2013, doi: 10.2478/V10160-012-0011-9

[2] ČAJKA, R. Static reinforcement of existing timber ceiling (2011). *Registered Utility model No. U1 22590,* Industrial Property Office, Czech Republic, Prague, August 2011

[3] ČAJKA, R. Soil – structure interaction in case of exceptional mining and flood actions (2005). *COST 12 – Final Conference Proceedings*, 20th – 22nd January 2005, University of Innsbruck, Austria, ISBN 04 1536 609 7.

[4] FRANKOVÁ, V. & MENCL, V. Estimation of properties of materials for compound wood – timber ceilings (2007). *Diploma thesis,* Faculty of Civil Engineering, VŠB – TU Ostrava, 2007.

[5] JANAS, P. & KREJSA M. & KREJSA V. Structural Reliability Assessment using a Direct Determined Probabilistic Calculation: paper 72. In: *Proceedings of the Twelfth International*

*Conference on Civil, Structural and Environmental Engineering Computing*: *CC 2009, Funchal, Madeira, Portugal*. Edited by B.H.V. Topping, L.F. Costa Neves and R.C. Barros. Kippen, Stirlingshire, Scotland: Civil-Comp Press, 2009, abstract (1 page), full paper (20 pages). ISBN 978-1-905088-31-7. Elsevier B.V., 2012. ISBN 978-190508830-0. DOI: 10.4203/ccp.91.72.

[6] KUČERA, P. & LOKAJ, A. & KAČÍKOVÁ, D. Assessment of reliability of timber structures elements exposed large-scale fire test (2012). *Acta Facultatis Xylologiae*, 54 (1), pp. 95-104, ISSN 13363824

[7] KUKLÍK, P. & NECHANICKÝ, P. & KUKLÍKOVÁ, A. Development of prefabricated timber-concrete composite floors (2012). *World Conference on Timber Engineering 2012*, *WCTE 2012*, pp. 519-526. ISBN: 978-162276305-4

[8] LOKAJ, A. & VAVRUŠOVÁ, K. & RYKALOVÁ, E. Application of laboratory tests results of dowel joints in cement-splinter boards VELOX into the fully probabilistic methods (SBRA method), (2012). *Applied Mechanics and Materials,* 137, pp. 95-99. ISSN 16609336, ISBN 978-303785452-5, doi:10.4028/www.scientific.net/AMM.137.95

[9] MIKOLÁŠEK, D. & SUCHARDA O. Numerical modelling of a composite timber-concrete floor structure (2012). *Civil Engineering Journal*, 9/2012, pp. 272 – 276, ISSN 1805-2576 (Online), ISSN 1210-4027 (Print)

[10] ORAVEC, P. & HAMALA, M. Acoustic Qualities of a Ceiling from Prefabricated Timber – Concrete Composite Panels (2013). *Transactions of the VSB - Technical University of Ostrava. Construction Series.* Volume XII, Issue 2, Pages 117–122, ISSN (Online) 1804-4824, ISSN (Print) 1213-1962, doi: 10.2478/v10160-012-0025-3, January 2013.

[11] POŠTULKA, J. & SANDANUS, J. Berechnungsverfahren für eine Holz-Beton-Verbunddecke mit Nägeln als Verbindungsmittel (1999). *Bautechnik,* 76 (11), pp. 1026-1030 (5 p), ISSN 09328351.

[12] SANDANUS, J. Parametric study of the factors affecting the resistance of a composite timber-concrete cross-section (2007). *Wood Research*, vol. 52, no. 3, pp. 109-114. ISSN 13364561.

[13] VAVRUŠOVÁ, K. & LOKAJ, A. Timber Structures Fire Resistance (2011). *Transactions of the VSB - Technical University of Ostrava. Construction Series.* Volume X, Issue 2, Pages 1–6, ISSN (Online)1804-4824, ISSN (Print) 1213-1962, doi: 10.2478/V10160-010-0025-0, April 2011.

[14] VAVRUŠOVÁ, K. & LOKAJ, A. & ŽÍDEK, L. Reliance of embedment strength on dowel diameter in joints of cement-splinter boards (2012). *Applied Mechanics and Materials*, 188, pp. 242-246 (5 p), ISSN 16609336, ISBN 978-303785452-5, doi: 10.4028/www.scientific.net/AMM.188.242.

[15] VAVRUŠOVÁ, K. & LOKAJ, A. & ŽÍDEK, L. The bearing capacity of one-shear nail joints in cement-splinter boards (2013). *Applied Mechanics and Materials*, vols. 256-259 (part 1), pp. 901-904 (4 p), ISSN 1660-9336, ISBN 978-303785565-2, doi: 10.4028/www.scientific.net/AMM.256-259.901.

[16] BATHON, L. A. AND BLETZ, O. (2005), Holz-Beton-Verbundsystem mit eingeklebten HBV-Schubverbindern. *Bautechnik,* 82: 322–327. doi: 10.1002/bate.200590109.

**Reviewers:**

Doc. Ing. Petr Kuklík, PhD., Department of Steel and Timber Structures, Faculty of Civil Engineering, Czech Technical University in Prague.

Doc. Ing. Jaroslav Sandanus, PhD., Department of Steel and Timber Structures, Faculty of Civil Engineering, Slovak University of Technology in Bratislava.