Wood-concrete composite (HBV)

Comparison of current connectors - Effective 08-2015

Rainer Bahmer and Sascha Hock

Nature is delivering the raw materials and thus the base for sustainable construction that goes easy on resources. The skillful and intelligent combination of steadily regrowing timber and sustainable concrete enables us to plan, construct and sustain energy-saving, cost-efficient, steady and durable buildings.
It seems that timber technology is still afraid of the cold, wet and heavy element concrete. However for future constructions it is important, that during the planning and realisation the woodworker works together with the concrete worker just like the future building is using the wood and concrete to remain solid.
The biggest and most effective chance for the interaction of timber and concrete are the floor slabs of a building. The span widths are getting larger and larger, as well as the requirements on construction physics by the side of the client and construction standards.

HBV-floor slabs and timber technology

Meeting high requirements through intelligent solutions

Ceiling constructions have to meet high requirements due to modern clients and the normative requirements of construction physics. The sheer and "light" wooden beam ceiling provides satisfying outcomes only by great effort. The sheer and „heavy" reinforced concrete floor is often limited in use for woodworkers due to statics and connections.

The clever composite of wood and concrete with their different material properties allows us to design an ideal building that offers the following advantages:

- Efficient soundproofing
- Predictable vibrations
- Fire protection
- Ideal proportion of span width and weight
- Sustainability
- Resource-efficient

Comparison of the different ceilings:

With the usage of wood-concrete composites we achieve different advantages compared to conventional reinforced concrete floors and wooden beam ceilings.

Compared to a sheer wooden beam ceiling we achieve following advantages:

- Load capacity and stiffness are increasing about 60 % by the same height of the component. Due to this fact we can easily realise high span widths as well as we can carry big loads into the structure.

- Lower deformation compared to a sheer wooden beam ceiling or system without a compound.

- The fire resistance rating gets essentially increased. Flammable gases cannot penetrate through the concrete slab that is applied on the wood. It acts like an insulation for the overlying floors so that the flames cannot reach the next floor of the building. (see [Haller und Pannke 1999]).

- Significant improvement of the soundproofing due to weight of the top concrete layer.

- We can achieve a high degree of prefabrication with half-done and prefabricated components. Best suitable for this are plate elements made out of glue-laminated timber (BSH) and cross laminated timber (CLT). The top concrete layer can be poured in the factory or on site.

- A horizontal disc is build for bracing. Due to the concrete slab we easily achieve a plate effect for the horizontal brace of the ceiling. The production of such a plate is difficult with timber technology because traditional wooden ceilings are made of rodlike elements (beams and planks).

Compared to a sheer reinforced concrete floor we achieve following advantages:

- Significant reduction of the dead load along with nearly the same load capacity.

- Suitable use of the material for the intended application: According to Eurocode 2 (see [Eurocode 2 1992]) the concrete rips open by two-thirds at the ultimate limit state. That means that only one-third of the concrete slab contribute to the load transfer, while two-thirds of the concrete slab only contribute to the load transfer of the shear forces. The two-thirds of the concrete that rip open are replaced by the wood in the composite structure. As a result a force couple manages the load transfer and additionally the moment load capacity of the wooden beam is activated.

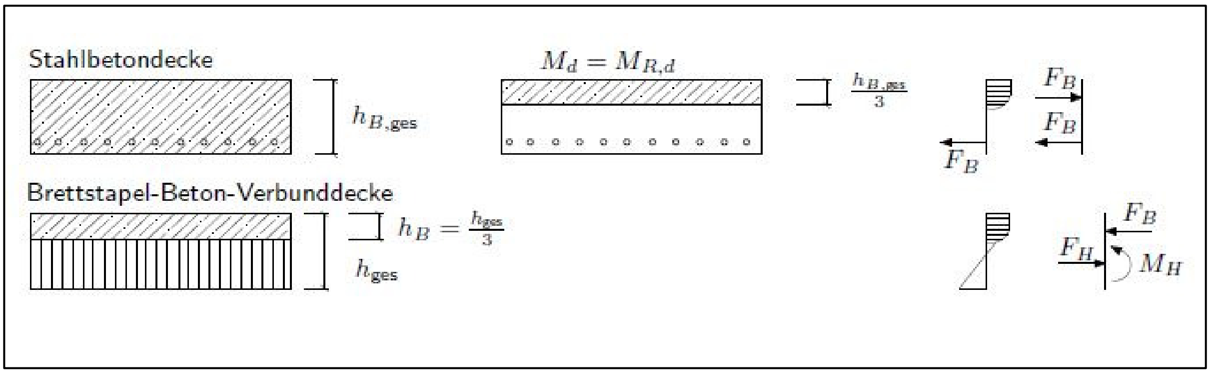


Image 1: Comparison of the load-bearing behaviour of a reinforced concrete floor and a glue-laminated timber concrete composite ceiling (see [Schänzlin 2003])

- Significant improvement of the ecological balance: Two-thirds of the ceiling comprise of regenerative materials and the use of steel (that needs high energy for production) gets minimized.

- Simplification of the dismantling: The materials are seperated by a joint so that the recycling of the materials is much easier.

- Speed-up of the construction process: With the use of visible board stack elements or beams a further development of the ceiling e.g. through a ceiling covering, can be dropped.

- Natural aesthetic and variety of designs of the renewable resource wood

With all these advantages there is also a presumed disadvantage:

- Two till now separated shareholders have to work together: With the direct cooperation of concrete workers and woodworkers there can be „interface problems". We could see that these problems clearly minimized over time through repeated application.

Connectors for HBV-floors with General Building Authority Accreditation

The successful application of single HBV-systems depend in particular on the effectiveness of the respective connectors between wood and concrete. From the planning engineers point of view it is desirable that the composite effect between wood and concrete of the HBV-system is as large as possible. Thus it is ensured that we have a preferably high load capacity and usability of the composite section. At the same time a composite system should have a preferably ductile behaviour and certainly not be brittle or have an occuring sudden failure.

In recent years the focus of research was especially on optimizing the connectors, which should have the following characteristics:

- High load capacity
- High slip modulus
- High ductility
- Low production and installation costs

The economic efficiency of a HBV-structure is therefore depending on the stiffness and load capacity of the used connectors. The most common and authorized connectors (screws, nails, flat steel locks etc.) create a mechanical punctiform connection between wood and concrete. Only the authorized HBV-shear connector of TiComTec GmbH manages it to create a wide area connection. Corresponding to this the slip modulus, which describes the efficiency of a connector, is higher compared to punctual connectors (see [Bathon 2004]).

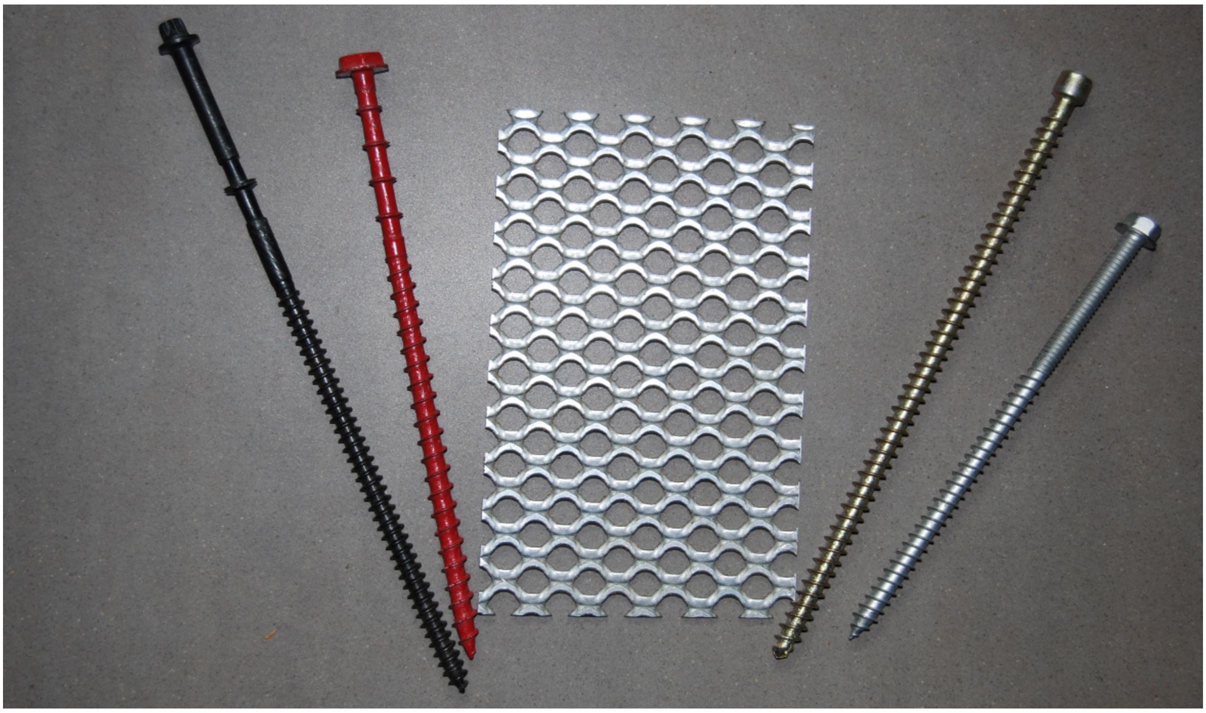


Image 2: Flat area and pin-shaped connectors for HBV-structures

Currently there are the following connectors for HBV-structures that have a General Building Authority Accreditation:

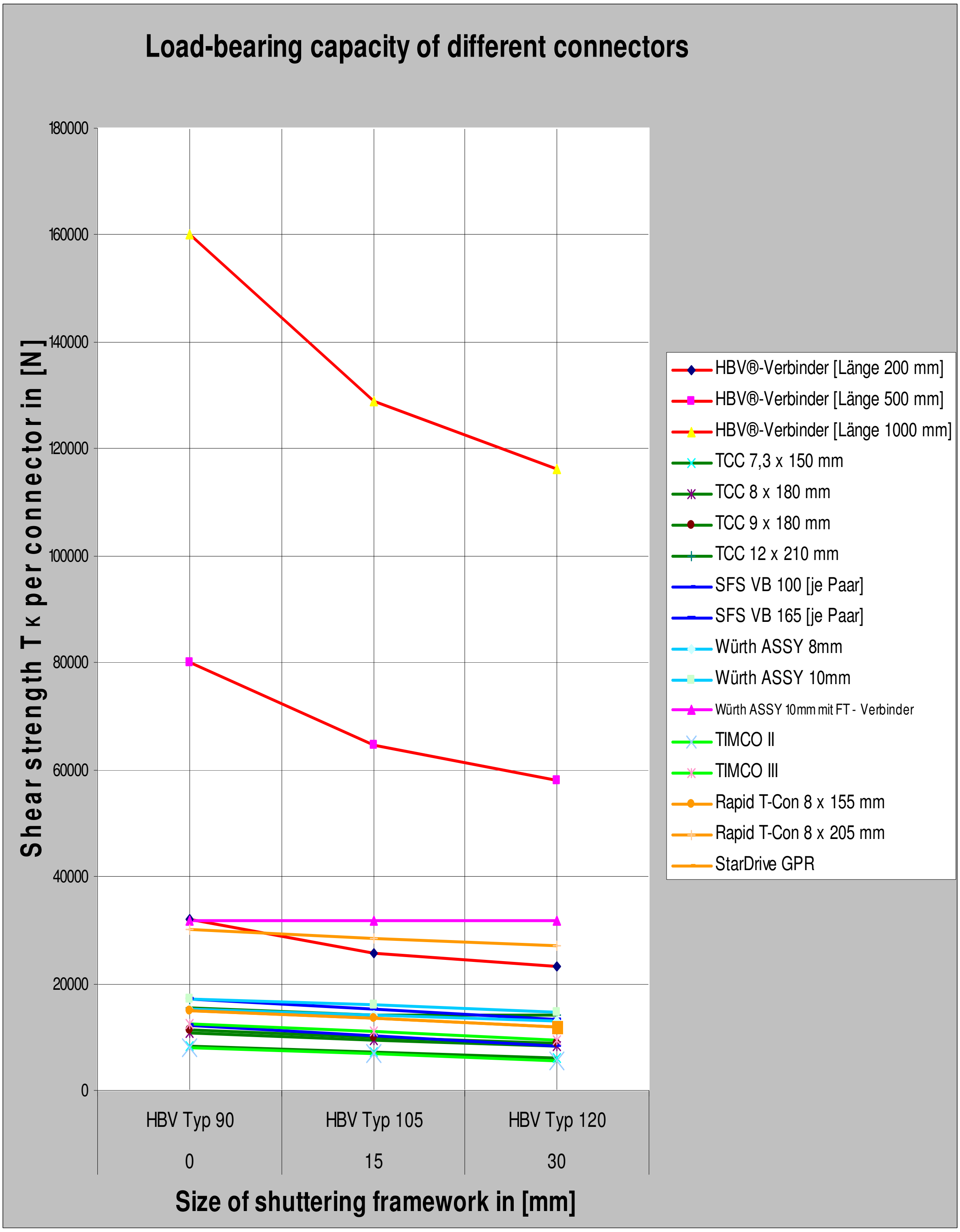
Approval number	Authorisation holder	Connector	Valid until
Z-9.1-342	*SFS intec AG*	SFS VB Schrauben als Verbindungsmittel in Holz-Beton-Verbundkonstruktionen	2020
Z-9.1-445	*Sieglinde Amrath Timco Vertrieb Deutschland*	Timco II und III Schrauben als Verbindungsmittel für das Timco Holz-Beton-Verbundsystem	2017
Z-9.1-473	*Hubert Schmid Bauunternehmen GmbH*	Brettstapel-Beton-Verbunddecken mit Flachstahlschlössern	expired
Z-9.1-557	*TiComTec GmbH*	HBV-System mit eingeklebtem HBV-Schubverbinder	2020
Z-9.1-603	*Com-Ing AG*	TCC Schrauben als Verbindungsmittel für das TCC Holz-Beton-Verbundsystem	2020
Z-9.1-648	*Adolf Würth GmbH & Co. KG*	Würth ASSYplus VG Schrauben als Verbindungsmittel für Holz-Beton-Verbundkonstruktionen	2017
Z-9.1-845	*Schmid Schrauben Hainfeld GmbH*	Star-Drive und RAPID Schrauben als Verbindungsmittel für das Schmid Schrauben Holz-Beton-Verbundsystem	2019

High load capacity

Decisive for a preferably as stiff as possible load-bearing behaviour of a composite structure are the characteristic resistance and the high slip modulus of the used connectors. Therefore the different connectors can be calculated on the basis of their General Building Authority Accreditation and so we can oppose their performance capabilities in subject to the intermediate layers.

	Shear strength (F_{rk} oder T_k in [N])	**Instantaneous slip modulus** (K_{ser} in [N/mm])
HBV-Verbinder HBV Typ 90/200	32000	165000
HBV-Verbinder HBV Typ 105/200	25803	79061
HBV-Verbinder HBV Typ 120/200	23236	66282
Würth ASSY 10mm mit FT Verbinder	31713	9000
TCC 7,3 x 150 mm je Schraube	8320	42423
TCC 8 x 180 mm je Schraube	10647	47241
TCC 9 x 180 mm je Schraube	11293	48368
TCC 12 x 210 mm je Schraube	15365	55108
SFS VB 100 [je Paar]	12090	22800
SFS VB 165 [je Paar]	17180	32400
Würth ASSY 8mm je Schraube	15167	20000
Würth ASSY 10mm je Schraube	17235	9000
TIMCO II je Schraube	8134	12740
TIMCO III je Schraube	12350	16900
Rapid T-Con 8 x 155 mm je Schraube	10000	9000
Rapid T-Con 8 x 205 mm je Schraube	10000	9000
StarDrive GPR je Schraube	10000	9000

Graphical comparison of the shear strengths:

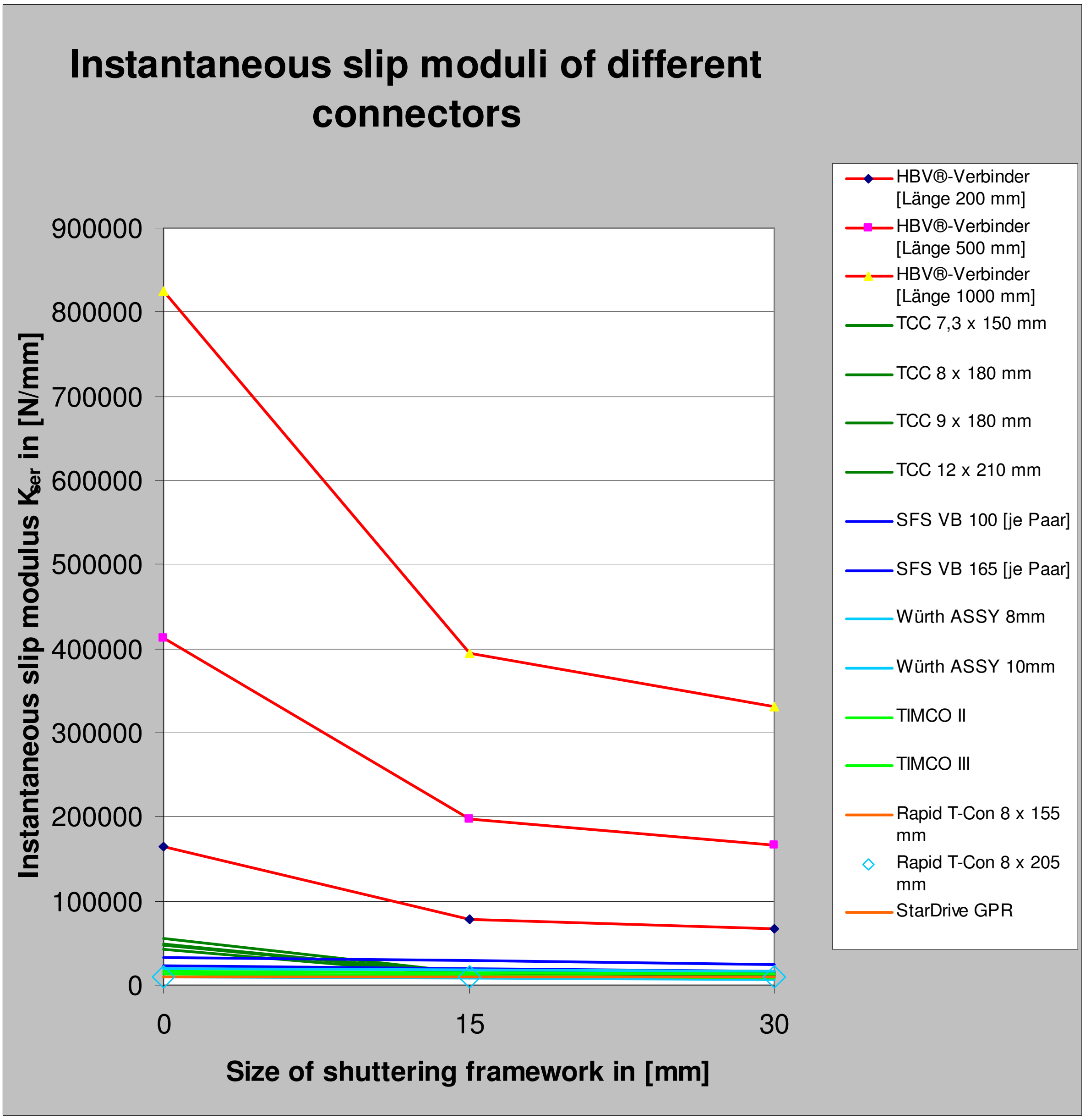


The graph shows us that between the smallest HBV-shear connector and the FT-Verbinder of Würth are nearly no differences in the load-bearing capacity (T_K = 32kN). The remaining screw systems have a relatively small distribution of their load-bearing capacity. The value T_K fluctuates between 6kN for the SFS VB100 screw and about 15kN for the Würth ASSY and TIMCO III screw.

High slip modulus

The slip modulus enables the engineer to calculate the deformation of a connection for different load situations. The instantaneous slip modulus K_{ser} is used for the verification of the serviceability. For the verification of the ultimate limit state load-bearing capacity K_u is used. K_u is calculated from $K_u = 2/3 \times K_{ser}$.

Graphical comparison of the instantaneous slip moduli:



The graph makes the difference between the various instantaneous slip moduli K_{ser} of flat area glued connectors and mechanical punctiform connectors obvious. The difference between the various screws are vanishingly small. The instantaneous slip modulus of the smallest HBV-shear connector amounts 165 kN/mm. The instantaneous slip modulus of the different screws fluctuate only between 9 kN/mm (Würth ASSY 10mm, Rapid T-Con, Stardrive GPR) and 55 kN/mm (TCC 12 x 210 mm).

High ductility

In materials science, **ductility** (derived from the latin word *ducere* which means pull, lead) is a solid material's ability to deform under tensile stress before it fails. For example untreated glass is breaking without any recognizable deformation while steel plastically deforms up to more than 25 % depending on the steel grade. Gold has such high ductility that you can cast it out up to a thickness of just a few atom layers. Materials with this characteristic are vitally in the building and construction industry. The support structures visibly show their upcoming malfunction if exposed to too high tensions.

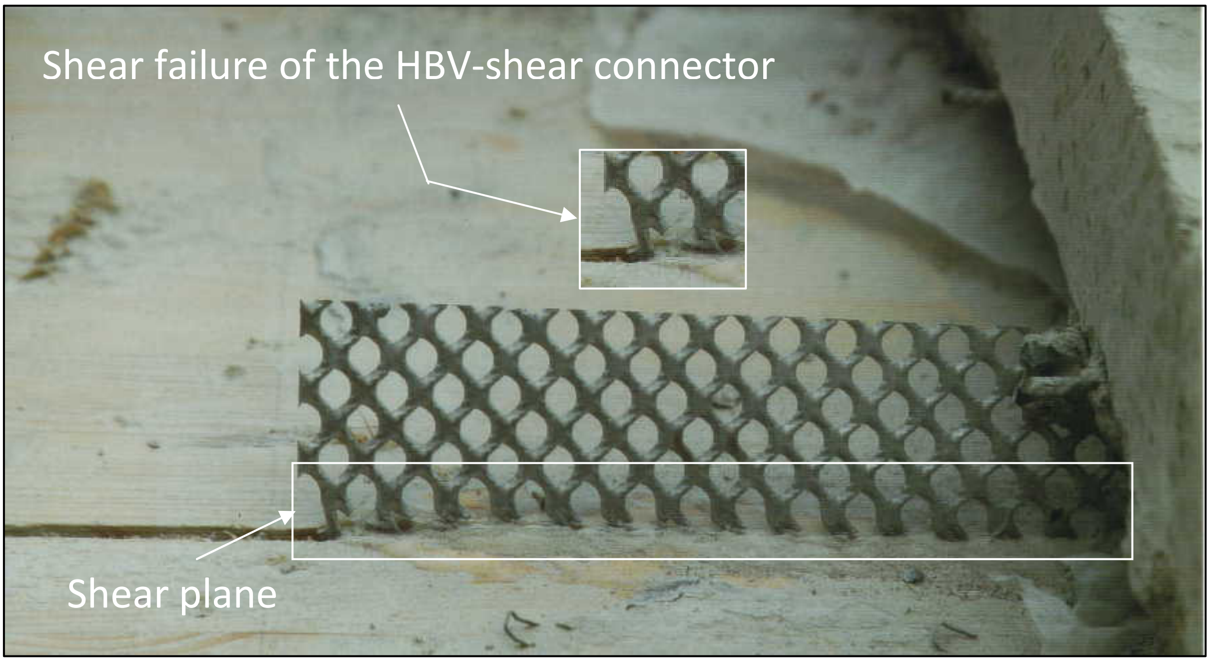


Image 3: Shear failure of flat area connectors using the HBV-shear connector as an example (Source: RheinMain University)

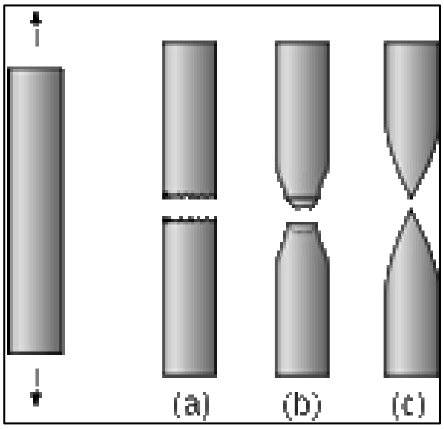


Image 4: Tension failure of pin-shaped connectors (Source: Wikipedia)

Relevent literature distinguishes between the following failures for pin-shaped connectors:

(a) brittle fracture
(b) ductile fracture
(c) complete ductile fracture

Material and manufacturing costs

Besides the shear material costs also the manufacturing costs determine the economic efficiency of a connection system. Web search resulted in material costs for the screw systems which fluctuate between 0,98 € (TIMCO II; see www.rosa-moser.at) and 4,21 € (Würth ASSY 10x480mm; see www.eshop.wuerth.de) per screw. The costs for screws without a General Building Authority Accreditation or Fear Eastern plagiarism are much lower, of course. If we reduce the material costs of the authorized system down to the better comparable unit €/kN, we have material costs for one connector between 0,10 and 0,25 €/kN.
Regarding manufacturing costs there are also different statements. To achieve comparable values we have to forego certain things like on site conditions, set-up times, preparation times, hourly wages etc. We now compare only the time for marking and mounting of the connectors.
Screws for wood-concrete composites are mainly used for the redevelopment of wood-beamed ceilings. Screwing in the screws is relatively easy and can be done by anyone. A special verification of the manufacturing is not necessary. Using the FT-connection system of Würth you can produce concrete slabs which will be „dry“ screwed onto the wooden components. This kind of dry construction offers advantages for prefabricated system timber construction.
The glued in HBV-shear connector can be applied very individual and is the only connection system that is authorized for dynamic loads at the moment. Application areas of the HBV-shear connectors are not only the redevelopment of wood-beamed ceilings and prefabricated composite floors but also highly stressed supporting structures in earthquake regions as well as heavy load bridges. In order to carry out the adhesion of the HBV-shear connectors you need an official glueing authorisation and furthermore the adhesion should be carried out by trained personal.

Manufacturers of screws and similar pin-shaped connectors specify an average processing time of about 180-200 screws per hour. This also includes the marking, positioning and mounting of the composite screws. For processing the FT-connector of Würth you can certainly calculate with only 80-100 connectors per hour. About 2 minutes are needed for the marking, cutting and glueing of a 100 cm long HBV-shear connector.

Tabularly the performance comparison is as follows:

Connector	Load-bearing capacity T_K [kN per Unit]	Units per hour	kN per hour
Screws	9 - (Ø 12) - 17	200 Stück	2400
FT-connector	32	100 Stück	3200
HBV-shear connector	160	30 m	4800

Further costs arise with the use of screw systems for spacers that are needed for the steel reinforcement of the concrete. By using the HBV-shear connector normally no spacers are needed. The steel reinforcement is simply placed onto the HBV-shear connector.

Outlook

Wood-concrete composite floors managed it to gain a little market share in the building and construction industry over the last 15 years. The amount of connectors with a General Building Authority Accreditation nearly quadrupled over this time period. The higher construction physics requirements as well as the growing market for buildings and building parts let us hope that also the share of wood-concrete composite floors will grow with. Because of the great number of connectors it gets more and more difficult for the planner and the engineer to decide on the right connector for their special project. Specialists are now needed and should be requested in the early planning phase.

Literature

[Haller und Pannke 1999] Haller, P. ; Pannke, K.: Beiträge zur Statik und Bauphysik von Brettstapel-Decken und -Wänden. In: Haller, P. (Hrsg.): Brettstapelbauweise und ökologische Dämmstoffe, TU Dresden, Institut für Baukonstruktion und Holzbau, 1999

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[Eurocode 5 DIN EN 1995-1-1:2010-12 Bemessung und Konstruktion von Hochbauten und Ingenieurbauwerken bzw. Bauteilen aus Holz oder Holzwerkstoffen, die geklebt oder mit mechanischen Verbindungsmitteln zusammengefügt sind]

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Several General Building Authority Accreditations for different wood-concrete connectors

Information gathered from the different connector manufacturer’s web presences