WOOD-CONCRETE COMPOSITE SLABS
CONSTRUCTION VARIANTS AND
DIMENSIONING
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General construction requirements

Building large-span, lightweight structures is no problem given the materials and dimensions available in wood construction. Apart from the load-bearing capacity of such structures, properties having an impact on the living or user experience are of very high importance. The requirements on these properties have to be determined at a very early planning stage and have a decisive impact on what structure will be chosen.

For wood structures in particular, there is an especially critical focus on the properties mentioned above. This is why there should be a range of effective and cost-efficient floor constructions that comply with fire and noise protection requirements and feature a good vibration behavior.

Noise protection requirements

Noise protection is an important parameter for all floor structures. In floors, noise protection is strongly influenced by the floor’s structure, i.e. the sequence of layers. Usually, the layers consists of flooring, floating screed and footfall sound insulation. The individual layers and overall structure form a spring-mass system. Here, the footfall sound insulation acts like a spring between screed and structure.

Additional, massive layers further and significantly improve noise protection properties of wood floors. Even so, sufficiently ballasted floors made of wooden beams or massive wood are still considerably lighter than floors made of reinforced concrete. Together with footfall sound insulation, featuring a low dynamic stiffness, added ballast leads to better floor properties with frequencies above the resonant frequency. These measures do not have any impacts with low frequencies.

Bonding ballast and wooden floor does lead to greater stiffness and but that also entails poorer sound insulation properties than screwed systems.

Impact of WCC slabs on these properties

Unlike ballasting or weighting, concrete slabs are more than only an additional layer to increase the mass. Using screws to connect the concrete slab to the substructure provides sufficient stiffness to clearly increase the overall stiffness of the structure. At the same time, such a connection is ductile enough to dampen some of the vibration.

Fire protection requirements

Amendments to local construction regulations allow for the construction of buildings of up to eight floors made entirely of wood. This entails tougher requirements with regard to fire resistance of the individual components.

Unless the floors are protected by corresponding fire protection cladding, proof that the components comply with the required fire resistance time can be provided in accordance with EN 1992-1-2 and EN 195-1-2. Fire resistance ratings of R90 and more can be proven by means of calculation.
Composite action of wood and concrete using screws

There are several systems available on the market for shear connections of concrete slabs and wooden substructures. Some of them have a European Technical Approval. The following difference can be made for the different systems:

⇒ Connection using fasteners: shearing forces are transmitted by means of axially or laterally stressed fasteners (e.g. screws, perforated sheet metals,...).
⇒ Connection though recesses (millings in the wood, that are filled once the concrete is cast): shearing forces are transmitted by means of contact.

Several factors have an impact on the selection of the shear connector to connect concrete slab and wooden substructure.

A wood-concrete composite using wood screws is characterized by the simple and straightforward processing of the latter. There are no particular requirements with regard to staff or material when it comes to processing or using them. Screws approved for the use in wood-concrete composite structures are either special screws that are exclusively approved for the particular application, or standard screws that can be used universally, such as the full-thread ASSY® plus VG.

Effectiveness of wood-concrete composites using screws

Any screws used as shear connectors in composite structures can be stressed laterally or axially. The angle to the shear joint at which the screw is placed is decisive for how much the screw can be stressed.

Screw pattern at an angle of 90° to the shear joint

Screws placed vertically to the shear joint are stressed with shear loads. The load-bearing capacity and stiffness of such connections are comparatively low. From a cost-efficiency point of view, such screw patterns should only be used as exceptions (e.g., for low or only structural composite), or in combination in areas where there is not enough room for an angled screw assembly.

Screw pattern at angles of 30° or 45° to the shear joint in direction of shear force

Due to the high load-bearing capacity and stiffness of axially stressed screws, these should be placed at an angle that is as flat as possible to the shear force. Such a pattern splits the force into two resulting stress components. One part of the force acts in the direction of the screw axis and exerts a tensile force on the screw. The remaining force acts vertically to the shear joint. This force is transmitted through the contact between concrete and wood, pressing the concrete slab to the substructure.

![Fig. 1: Pattern of ASSY® plus VG screws](image)

The information provided in this document is a planning aid. All values need to be determined separately for each project by authorized experts.
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With a pattern of crosswise arranged screw pairs, the shear force is divided into two load components that are borne by the two crosswise screws. Here, one of the screws is under tensile, the other under compressive load. No positively acting contact pressure can occur with such screw patterns.

These screws are inserted into the wooden structure for the screw head to protrude into the concrete at sufficient length (≥ 50mm). In completed composite structures, the screw is encased by concrete. The load from the screw is transmitted to the concrete below the screw head and/or through the thread flanks or profiles.

Depending on the selected screws, their lengths and the chosen connection design, the dimensioning of the deck screw is done based on the screw’s pull-out strength or point of failure (steel failure). The greater the embedment length of the screw in the wood surface, the greater is its pull-out strength and the connection’s stiffness. Use of material and assembly times can be optimized by selecting the screws’ length and pattern accordingly.

The screw’s drilling tip reduces the splitting effect compared to other fasteners. This is why it is permissible to choose very small distances perpendicular to the grain for Würth ASSY® plus VG screws (edge spacing of 3d, axial 2.5d). If these screws are mounted in oak, pre-drilling in accordance with ETA-11/0190, table 1 is required.

Installation of wood-concrete composite slabs using screws

There are two options for assembly or construction of composite floors using screws:

1. The screws are screwed into the existing or pre-assembled wooden structure (beams or solid wood elements). For screw connections to beams, formwork or similar is required to hold the concrete. Make sure the screw connections comply with the angle range specified in the approval. The use of a screw template is recommended. During planning, make sure you bear in mind existing rising components to ensure screwing is possible. Between the wood and/or formwork and the concrete layer, a film is required to protect the wood against any humidity from wet concrete. Afterwards, the concrete is added. The structure has to be propped until the concrete has completely dried (usually 28 days) to avoid any permanent deformation caused by additional load (wet concrete). Avoid the storage of high loads on the composite floor during the drying phase of the concrete.
2. Floor elements of new buildings can be prefabricated. To that end, the screws are first screwed into the wooden beams or slabs. Subsequently, the beams are turned upside down and dipped into the formwork for the screws to completely disappear in the concrete. The beams have to remain in this position until the concrete has fully hardened. Subsequently, the elements can be transported in one piece to the construction site and installed. This option requires exact working during pre-assembly of the wooden structure and manufacturing of the floor elements. Even minor dimensional deviations may lead to troubles during assembly on the construction site.

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FT connectors: an extended screw system

The FT connector launched in 2012 is a shear connector available for wood-concrete composite structures that allows for a combination of high load-bearing capacities and a high degree of prefabrication. The existing infrastructure of the precast reinforced concrete industry can be used for prefabrication. It is possible to manufacture concrete slabs with a strength ranging from 7 to 12cm.

**Effectiveness of the FT connector**

Thanks to a steel plate/washer positioned at the head side, a flat screw-in angle and the high load-bearing capacity of the full-thread Würth screws (ASSY® plus VG) used, this shear connector allows for a very high shear force transmission while offering the corresponding, high stiffness.

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Fig. 4 – 5: FT connector

Fig. 6: Pattern of ASSY® plus VG screws and FT connectors

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30.01.2020
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The concrete transfers its load to the steel plate through compression. The plate, in turn, transfers the load to the screw head of Würth ASSY®plus VG full-thread screw, which is anchored in the wood underneath. The force resulting from this load transfer acts perpendicular to the joints between the structural members and creates a contact pressure that increases the frictional resistance between wood and concrete.

![Fig. 7: Load-bearing capacities of different WCC shear connectors (fastening systems)](image)

**Fig. 7: Load-bearing capacities of different WCC shear connectors (fastening systems)**

(1) **FT connector in prefabricated concrete slabs**

While “traditional” systems require the wet concrete to be added to the wood structure, this system offers the option to prefabricate the concrete slab separately from the wood structure. Like with solid structures, the **prefabricated concrete slabs** are delivered to the construction site, laid and screwed to the wood structure. With the positioning of the screws, the concrete and wood substructure bond immediately. Note that the concrete elements may also be screwed to the substructure at a later point in time. Depending on the requirements, elaborate propping of the floor structure until the concrete is dry can be completely done without.

![Fig. 8: FT connectors used for the manufacturing of prefabricated concrete parts](image)
Make sure you mount perpendicular ASSY® 3.0 SK partial-thread screws with a diameter of $\varnothing = 10\text{mm}$ (e.g. at the quarter points) to ensure contact closure between concrete slab and wood.

Installation of the remaining structure can continue immediately. There are no curing or drying periods. As the parts are prefabricated, there is no ingress of moisture nor contamination of the wood components by moisture separations of the concrete.

No separating layer is necessary to protect the wood. The high degree of prefabrication leads to a massive reduction of delivery and assembly costs as well as construction time. The bottom side of the concrete slabs may remain visible if their quality allows for it. Large-span floors featuring visually appealing exposed wood beams can be built in a short installation time using wood-concrete composite floors with prefabricated concrete slabs.
Fig. 12 – 13: Laying prefabricated concrete parts (exposed ceiling) with integrated FT connectors on cross beams

We recommend using a 110mm AW 50 bit to screw the prefabricated concrete parts.

Fig. 14: Tightening the ASSY® plus VG screws

(2) FT connector combined with in-situ concrete

Alternatively, FT connectors can also be used for “standard” casting of wet concrete right on the construction site. By combining the right component cross-sections, material qualities and high load-bearing capacity of FT connectors, both approaches can lead to composites featuring high load-bearing capacities, despite a reduced number of shear connectors being required.

The following flow chart representing the assembly process of the two options shows the advantages during assembly (speed).

Fig. 15: Laying FT connectors to be cast with wet concrete on laminated timber
A guide hole has proven worthy in the field. Individual screw templates are a tried-and-tested solution for large floor surfaces.
Different creeping and shrinking properties of the materials

Here, the stress and deformation ratio at the beginning of use \((t = 0)\) and at point in time that comprises the entire service life of the structure \((t = \infty)\) is assessed. The different creeping behaviors are factored by a corresponding reduction of the stiffness parameters specifically for each material.

Concrete shrinkage is simulated by adding an additional external load. This is not necessary when FT connectors are used in prefabricated concrete parts, as most of the concrete shrinkage will be over at the time of installation.
Reduction of the concrete cross-section: concrete in state II

Depending on geometry, loads, cross-sectional dimensions and static system, the concrete slab is affected by both bending moments and normal forces (only compressive forces in the case of an individual beam). If the tensile stresses from the bending moment caused by the normal forces are not compensated for and the critical moment is exceeded as a consequence (exceedance of the tensile strength of the concrete), cracks may occur in the concrete, which means the concrete cross-section goes from state I to state II. This leads to a reduction of the concrete cross-sectional area and, possibly, to a reduction of stiffness. This change of the effective cross sections may induce a change of the stiffness ratios between wood and concrete, which can result in a shift of the section forces.

Bracing

If the bracing of the composite floor is to be achieved by means of the concrete, the respective shear connectors have to be positioned at the edge of the concrete slab. This serves to deviate the forces resulting from the slab effect to the actual supporting structure. In addition, these edge components have to be large enough to adsorb or transfer the belt loads. Butts may need to be appropriately rigid in compression and tension and the load distribution into the vertical, stiffening components has to be ensured.

Usability

For usability, attention has to be paid to compliance with the deformation threshold values and to testing the floors’ vibration susceptibility. It is not possible to build cost-efficient floor structures with span widths of 5 to 6 meters that meet the required threshold value for a resonance frequency of 8Hz using wood only.


Fire protection

Evidence for unprotected components and their composites can be delivered in accordance with EN1992-1-2 and EN1995-1-2. For wood, the burning rate has to be borne in mind. This rate helps to determine the cross section remaining for the structural fire design analysis. In addition, a temperature increase in concrete and wood leads to a reduction of stiffness and impairs the load-bearing capacities of reinforcement and fasteners.

As long as the components are of dimensions meeting the corresponding requirements, proving fire resistance periods of up to 90 minutes and more is possible using these procedures.

Comparison of WCC slabs and reinforced concrete floors

The criterion of usability is decisive when it comes to the dimensioning of the floor thickness of both lightweight floor structures made of wood and reinforced concrete floors. In accordance with EN1992-1, the following applies for reinforced concrete floors with untensioned reinforcement to limit deformations in case of increased loads (to avoid damage of adjacent components, e.g., lightweight separation walls): (l/d)max > K² × 150/l with K = 1.0 for single-span slabs.

EN1995-1-1 also provides for limits to deformations to allow for user convenience (e.g. vibrations) but also to ensure no adjacent components are damaged.
WOOD-CONCRETE COMPOSITE SLABS

Comparative calculations taking into account the criteria stated above lead to the floor thicknesses shown in figure 19. Apart from the resulting dead loads, a dead weight of the floor structure of 1.5 kN/m² and a ceiling with a weight load of 1.50 kN/m² was assumed as the permanent load. The variable loads were assumed to be 2.30 kN/m² (floor in residential building plus lightweight separation walls).

![Fig. 19: Required floor thicknesses with respect to span width and design version](image)

On principle, several versions are possible for composite floors, as the overall stiffness of the floor, and thus the distribution of internal forces, can be influenced by the number of shear connectors used.

For the calculations of the WCC slabs, wall-to-wall laminated timber floors were assumed. On average, this results in a utilization of only 62% of the timber cross-sections.

The position and number of shear connectors was optimized for them to always be stressed by almost 100%. For the versions with ASSY® plus VG Ø 8mm screws directly encased in concrete and depending on span width and component stiffness ratio, this results in a demand of approximately 10.5 to 16.6 screws per square meter (13.6 screws/m² on average). The number of screws required for floors with prefabricated slabs and subsequent connection with FT connector and ASSY® plus VG Ø10mm screws is 2.4 to 9.3 screws per square meter. On average, this results in approximately 5.1 screws/m². Note that here, too, the edge parameters mentioned above have a decisive impact on the number of shear connectors required.

If the horizontal bracing is to be achieved by the concrete slab, further shear connectors are necessary around the slabs. This serves to distribute the forces resulting from the slab effect.
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WCC slabs connected with FT connectors usually require components that are marginally thicker than WCC slabs connected with ASSY® plus VG Ø 8mm (see figure 19). The reasons for this are that only 35-40% of shear connectors are used and the combination of FT connectors and ASSY® plus VG Ø10mm leads to less stiffness than ASSY® plus VG Ø8mm. This reduced stiffness can be explained, among other things, by the untapped screw length within the FT connector.

Tables 1 and 2 show an overview of results from calculations for different floor span widths. Note that alternative solutions (component thickness and number of shear connectors) are possible.

**Table 1:** Floor thickness for WCC slabs with ASSY® plus VG Ø 8mm shear connectors; dimensioning results for different floor span widths; concrete slab on laminated timber

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<th>L (m)</th>
<th>g (kN/m²)</th>
<th>Stk. (m²)</th>
<th>Stk./m²</th>
<th>t (cm)</th>
<th>t_con (cm)</th>
<th>t_sce (cm)</th>
<th>I_con (cm⁴)</th>
<th>I_con (cm⁴)</th>
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<th>η_t_con (°)</th>
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**Table 2:** Floor thickness for WCC slabs with FT connectors and ASSY® plus VG Ø 10mm; dimensioning results for different floor span widths; concrete slab on laminated timber

Ideal use of FT connectors is made when floor beams are used instead of wall-to-wall laminated timber elements. Here, the only element transferring loads in transverse direction is the concrete slab while the composite only acts in the main spanning direction.

The cross-section height of the floor beams allows for a concentrated introduction of stiffness into the system. As a consequence, the floor’s share of wood can be as little as less than 40%. Moreover, the number of shear connectors required can be considerably reduced while the results remain the same.
Table 3: Floor thickness for WCC slabs with FT connectors and ASSY® plus VG Ø 10mm; dimensioning results for different floor span widths; concrete slab on floor beams with a distance e

Summary

Cost-efficient wood-concrete composite slabs with large span widths can easily be built using ASSY® full-thread screws positioned at an angle. Even tough requirements on fire protection and floor vibration behavior can be met.

FT connectors in combination with ASSY® plus full-thread screws excel with a high load-bearing capacity compared to other screwed composite systems. In combination with prefabricated concrete parts, the construction period is reduced considerably, there are no long drying times incurred by in-situ casting on the construction site, any moisture penetration in the wood structure is avoided and installation times are clearly reduced.

FT connectors can be installed in prefabricated slabs with a thickness of 70 to 120mm. They can be used in even thicker slabs when cast in situ (e.g., in combination with filigree concrete slabs). The required concrete slab thickness depends on the requirements and/or load-bearing capacity, usability and noise protection.

With the corresponding positioning and dimensioning, screws with and/or without FT connectors can be used to transfer bracing slab forces. This is possible for all WCC structure versions presented here, be that with prefabricated concrete slabs and subsequent connection or with in-situ concrete.
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Additional information

Product and approval

European Technical Approval ETA-13/0029 governs the use of ASSY® plus VG screws and FT connectors to build wood-concrete-composite slabs. For more product information, go to the Würth online shop (www.wuerth.de) and look up article number 0165 300 10, or go to the ASSY® service website under www.wuerth.de/ASSY®. The ASSY® service website also contains CAD drawings for the products in the bulk file for ASSY® wood construction screws made of steel.

Dimensioning aids / software

The service website for ASSY® screws (www.wuerth.de/ASSY) also includes an online dimensioning tool useful for wood-concrete-composites.
Technical details and notes

What to bear in mind during planning

Several issues have to be born in mind to ensure a smooth procedure of the project.

- Define the quality of the substrate: Laminated wood, for instance, has different product characteristics depending on the manufacturer. A subsequent change of material may require a revision of the existing structural analysis.

- Take rising components into account: If rising components are used, make sure the shear connectors are positioned in a manner that still allows for the insertion of the screws, i.e., position the first shear connectors at the corresponding, greater distance from the edge.

- Mark the beam positions: We recommend marking or setting out the position of the individual beams prior to the mounting of any formwork to ensure proper positioning of the FT connectors and/or ASSY® plus VG screws.

- Full-surface wood structures require a sufficient overlap of laminated timber joint and prefabricated concrete part joint.

- Recesses and routing ducts in the prefabricated concrete part

- Get Würth sales rep involved early on to ensure the required products are available at the right time.

Attachment of the FT connector to the formwork panel or inserted wood slats during manufacturing of prefabricated concrete elements of >7cm

Attach the FT connectors to the formwork panel to ensure they are positioned as outlined in the laying plan. We recommend attaching the FT connectors using hot-melt adhesive if formwork panels made of steel or multiple-use formwork panels made of wood are used. Attach FT connectors to a slat to reduce the preparation time or if the thickness of the prefabricated concrete element exceeds 7cm. Use ASSY® plus MDF back panel screws, for instance, to attach the FT connectors to the slat, which, ideally, is planed and straight. Attach the wooden slat to the formwork panel using hot-melt adhesive.
Sample pattern of ASSY® 3.0 SK screws for pre-assembly and positioning of the dry prefabricated element using a laminated timber element

Make sure you mount perpendicular ASSY® 3.0 SK partial-thread screws with a diameter of ≈ 10mm (e.g. at the quarter points) to ensure contact closure between concrete slab and wood.
The insertion point in the software output represents the point where the screw is inserted in the surface of the **load-bearing** timber element. When formwork is used, the insertion point in the concrete element is shifted by the corresponding dimensional factors.

**Fig. 24**: Point of insertion of ASSY® plus VG screws as specified in the software drawing

The recesses/screw routing ducts for ASSY® 3.0 SK screw connections have to be considered during the manufacture of the prefabricated concrete parts. We recommend using conventional empty plastic sleeves for this purpose. Attach these to the formwork panel using hot-melt adhesive. Cover/close the upper end of the plastic sleeves to make sure the concrete does not enter the sleeves when it is cast. Practical tip: Use countersunk head screws to close the plastic sleeves when the concrete is cast (see figure).

**Fig. 25 – 26**: 90° screw routing ducts for ASSY® 3.0 SK screws

The information provided in this document is a planning aid. All values need to be determined separately for each project by authorized experts.
Consolidation of the individual planning components for wood-concrete composite slabs containing prefabricated concrete parts

The existing planning details have to be consolidated to manufacture the prefabricated concrete parts for a wood-concrete-composite slab.

1. Detailed planning of the load-bearing wood structures
2. Detailed planning of the prefabricated concrete parts to be produced
3. Detailed planning of the structural positioning of the FT connectors (see fig. 23, online software laying plan)

Example: Separation of the 7 cm thick precast concrete elements

Example: Separation of the 14 cm thick CLT slab elements

Fig. 27 – 28: Sample detailed planning of wood structure and prefabricated concrete parts
Transportation of prefabricated parts

We recommend using a four-point attachment including a load-spreader bar to transport prefabricated concrete slabs. The lifting loops anchored in the reinforcement can be removed as soon as the slabs have been laid. If there are any recesses in the slab for attachment to the reinforcement, close them once the slabs have been laid.
Note that the shipping radius should be as small as possible to meet assembly schedules, keep transport costs low and to ensure smooth cooperation between prefabrication plant, freight forwarder/delivery and assembly. If the components are delivered on trucks by the prefabrication plant, we recommend a shipping radius of no more than 200km. Larger distances reduce the efficiency of the system. When delivering to or passing through urban areas with heavy traffic, allow for possible traffic jam times to optimize the hiring fees of the crane system. Make sure the wood structure is protected from any rain and the resulting moisture intake of the wood in case it was delivered on the previous day.

**Sample connection of dry prefabricated concrete elements in transverse direction**

Available:
- Wood cross section w/h = 20/36, GL32c, L = 6.00m
- Butt joint with gap of 10mm between the slab elements

Selected:
11 x connection points at a distance e ≤ 68cm with:
(1) Würth flat connector, type 95mm x 35mm, plus.
(2) 2 x ASSY® countersunk washer ∅ 33mm
(3) + Würth ASSY®plus VG 10x360mm
**Minimum edge distance of the FT connector to the lateral edge of the prefabricated concrete element and spacing**

Allow for a lateral spacing of at least 20mm for the FT connectors. No further requirements with regard to the screws or FT connectors in concrete have to be observed. For the requirements to the reinforced concrete slab with regard to reinforcement, concrete, durability, etc., refer to the specifications of the applying reinforced concrete standards.
Usability design

The dimensioning program allows to select from three different types of verification.

1. **Deformation limits**
   
   This is a deformation analysis only. You can enter a limit value for the deformation in relation to span width for permanent and quasi-permanent loads.

2. **Standardized verification methods in accordance with DIN 1052 or EN 1995-1-1/NA**

   Verification in accordance with DIN 1052:2004-12 includes a deformation analysis, a simplified vibration analysis and a detailed vibration analysis as specified in the explanations on DIN 1052. The simplified vibration analysis limits the midspan deflection under quasi-permanent loads to 6mm. More thorough analyses are required if the deflection limit is not met.

   Verification in accordance with EN 1995-1-1/NA includes a deformation analysis and a vibration analysis based on the limit values recommended in the national application document. The floor’s resonance frequency has to be above the threshold value of 8Hz. In addition, threshold values for stiffness and vibration acceleration have to be met.

3. **Recommendations in accordance with Hamm/Richter**

   The German Brettsperrholz-Handbuch – Holz-Massivbauweise in Brettsperrholz [Laminated timber handbook—solid construction using laminated timber; 1] presents a calculation method for a vibration analysis of floors. Threshold values for resonance frequency and deflection with regard to different requirements for the vibration properties of the floor are suggested. A difference is made between floors within the same usage unit and floors between different usage units. The minimum resonance frequency and vibration acceleration requirements for floors within the same usage unit are lower than for floors between separate usage units.
COMPLETED STRUCTURES

Project: H7
Contractor: Brüninghoff GmbH & Co. KG
Planning: Arup Deutschland GmbH
Products: ASSY® plus VG + FT connectors
Method: Factory-fitted prefabricated parts

The information provided in this document is a planning aid.
All values need to be determined separately for each project by authorized experts.

30.01.2020
Project: Office building in Stade, Germany
Planning: Gebr. Schütt Ingenieur-Büro GmbH
Contractor: Gebr. Schütt KG
Products: ASSY® plus VG 10x480mm + FT connectors
Method: Factory-fitted prefabricated parts, laid on cross beams, maximum span width of 6.5m

The information provided in this document is a planning aid. All values need to be determined separately for each project by authorized experts.
Project: German Biomass Research Center, Leipzig
Planning: Mathes Beratende Ingenieure GmbH
Contractor: Kunert Dächer und Bau GmbH
Products: ASSY®plus VG + FT connectors
Method: On-site casting, 10,000m², 4 floors

Image courtesy of Mathes Beratende Ingenieure
COMPLETED STRUCTURES

Project: Haus der Bauern, Freiburg, Germany
Planning: Göppert Bauingenieure, Lahr
Contractor: Werkgruppe Lahr
Products: ASSY® plus VG + FT connectors
Method: On-site casting, 4 floors

Image courtesy of Werkgruppe Lahr
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ASSY® PLUS VG

THE SCREW FOR WOOD-CONCRETE COMPOSITE ELEMENTS

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