

TIMBER CONSTRUCTION USING BAUBUCHE

**The world's largest roof truss made of BauBuche:
design and assembly of SWG's new production hall**





A NEW DIMENSION OF TIMBER CONSTRUCTION

A BauBuche structure spanning up to 82 meters is a world record! Timber has long been used as a building material in residential and public buildings. What's new about this project: designing, calculating and finally building a production hall covering more than 10,000 m² of floor space that is entirely made of BauBuche. That very endeavor was undertaken on the premises of SWG Schraubenwerk Gaisbach GmbH, a

screw manufacturer belonging to the Würth Group. In spring 2019, the company broke ground for the largest production hall made of wood worldwide. This brochure provides an insight into the construction and assembly techniques used. The key aspect in this construction project: the innovative building material BauBuche, a laminated veneer lumber made from European-sourced beech, which is gaining in importance in times of climate change.

Overall area: 12,800 m²

Dimensions: 96.50 m x 113.30 m x 12.00 m

Materials: 420 m³ of BauBuche, 900 m³ of cross-laminated timber, 330 m³ of glued laminated timber

Maximum span: 82 m resting on just one column

Screws: 250,000 ASSY® screws

Utilization: approx. 20 % storage space, 70 % production and logistics space, approx. 10 % exhibition area and sanitary facilities

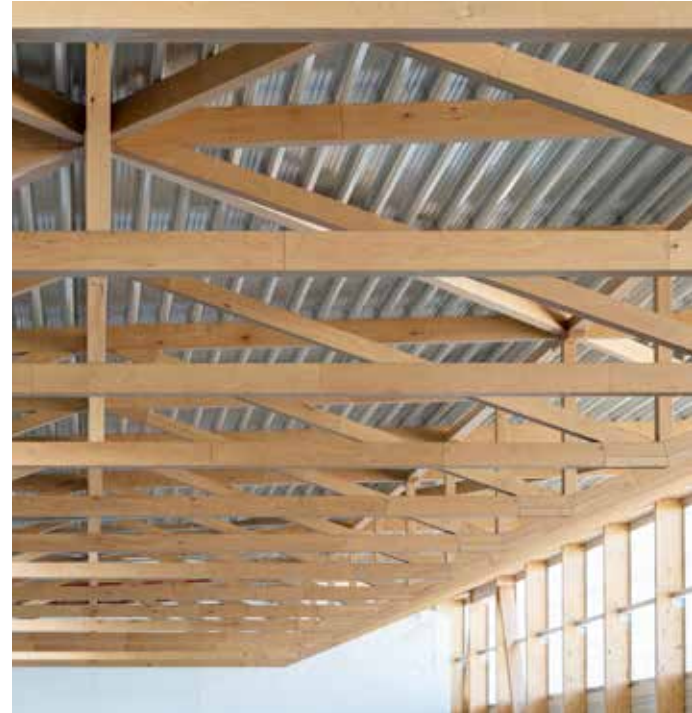
Architects: Hermann Kaufmann + Partner ZT GmbH, Schwarzach (Austria)

Structural design: SWG Engineering, Rülzheim

Building owner: SWG Schraubenwerk Gaisbach GmbH, Production Unit, Waldenburg

Execution: Schlosser Holzbau, Jagstzell

Truss made entirely of BauBuche



BauBuche truss nodes

“WE VENTURED PAST THE LIMITS OF WHAT IS POSSIBLE.”



Henning Ernst from SWG Engineering is the mind behind the design and construction of SWG’s new production hall. The below interview outlines his reasons for choosing BauBuche as beam material and sheds light on the constructional and technical challenges that had to be overcome.





Interview with Henning Ernst

How did you come up with the idea of using BauBuche for the entire truss of the new production hall?

Our aim was to point the way for timber construction and showcase the opportunities it offers. Combining two high-performance products, BauBuche and ASSY®plus FT full-thread screws by Würth, helped us achieve this goal. BauBuche excels by its comparatively high strength. In combination with ASSY® timber screws, it is possible to optimize the size and cross-section of the building components.

What motivated you to use BauBuche in your design?

The material's high strength and consequently the possibility to build strong, yet very slender structures. At present, the market does not offer any other standardized material that even begins to compare to the properties of BauBuche. So having set ourselves the goal of creating a roof structure that was as resource-efficient as possible, there was no way around BauBuche.

Did the implementation go according to plan?

There were a few unexpected incidents we had to cope with when producing and assembling the truss. Yet we found suitable solutions that pleased everyone thanks to a close and very trusting collaboration between the architects, truss designers, and the executing contractors. My colleagues and I were in close contact with our building contractor Schlosser Holzbau when planning the truss design/the timber structure to make sure the ideas we came up with would be feasible to implement. Schlosser Holzbau tested the feasibility of ideas and joining of truss members early on in internal tests and trial runs. This way, we managed to eliminate any unpleasant surprises at an early stage. The result of our collaboration speaks for itself: Feel free to visit the hall in Waldenburg.

So what exactly is new about the roof structure of SWG's hall? Which constructional details make it different from and

better than what has been known so far?

Above all, it is the combination of different dimensions: creating a large span while using very slender beams. We also invested a lot of time in developing our joints. The new thing is that we can use almost 100 % of a beam's cross-section without the joints determining the cross-section of the beams. By redistributing loads, we managed to enlarge the contact areas, thus completely eliminating the necessity to use fasteners for the application of compressive forces. Tensile forces, on the other hand, are



taken up by the ASSY® timber screws and transmitted to the connected building components.

What did you learn from this project? What are your tips for BauBuche structures that you would like to share with other planners?

We ventured past the limits of what is possible. BauBuche allows us to design high-performance structures that are very slender and look really nice and elegant. Using ASSY®plus FT full-thread screws allows us to join components almost irrespective of their internal forces. Furthermore, the handling of forces acting on the steel parts connecting the building components must not be underestimated. The forces acting on these parts



require the use of high-strength screws and steels. By combining BauBuche and ASSY® plus FT full-thread screws, we open up new fields of application, which we have already tested in other projects. These projects include joints and other points designed to transfer high loads, which could be solved easily by using these products, thus replacing elaborate, welded steel parts.

Please describe the role played by fasteners in such a project. Which fasteners would you recommend?

The fasteners used and the resulting joints play a vital role. Without proper joints, forces cannot be transferred from one component to the other. It is crucial that fasteners are tested and approved for use in BauBuche. The correct installation of these fasteners must also be ensured.

When joining roof truss members in industrial settings, it does not matter whether the holes for screws used in BauBuche must be pre-drilled or not. In theory, fastening wood screws without pre-drilling a hole may be possible. However, the joints in our project require dozens or even hundreds of short and long screws to be driven into the wood.

Due to the large number of screws to be used, the required precision, screw lengths, and the limited space available for joints of this kind, pre-drilling is essential. When using BauBuche in other projects, I recommend choosing the right fasteners based on their maximum load-bearing capacity, pull-out strength, screw spacing,



SWG Engineering

Engineering support provided by experts from SWG Engineering (Würth Group)

The use of self-tapping timber screws in structural timber constructions requires a sound knowledge of the required approvals and standards. In an engineer's day-to-day work, it is nearly impossible to keep track of all the normative and product-specific regulations.

The SWG Engineering team supports engineers in all screw connection matters, helping with the design of joints, the calculation of screw connections or pointing out alternatives. Furthermore, the services provided by the engineers at SWG Engineering include the structural design, execution planning and construction of timber engineering projects, the development of timber-construction-specific calculation software, participation in associations and contributions to standardization efforts as well as the development of suitable fasteners and fastening systems, both improving tried and tested methods and designing new connections. Contact us!

application instructions and other requirements, which are included in each fastener's European Technical Approval (ETA), in this case ETA-11/0190. These factors are decisive for planning, designing and building such construction projects.

To which customers do you offer your planning services?

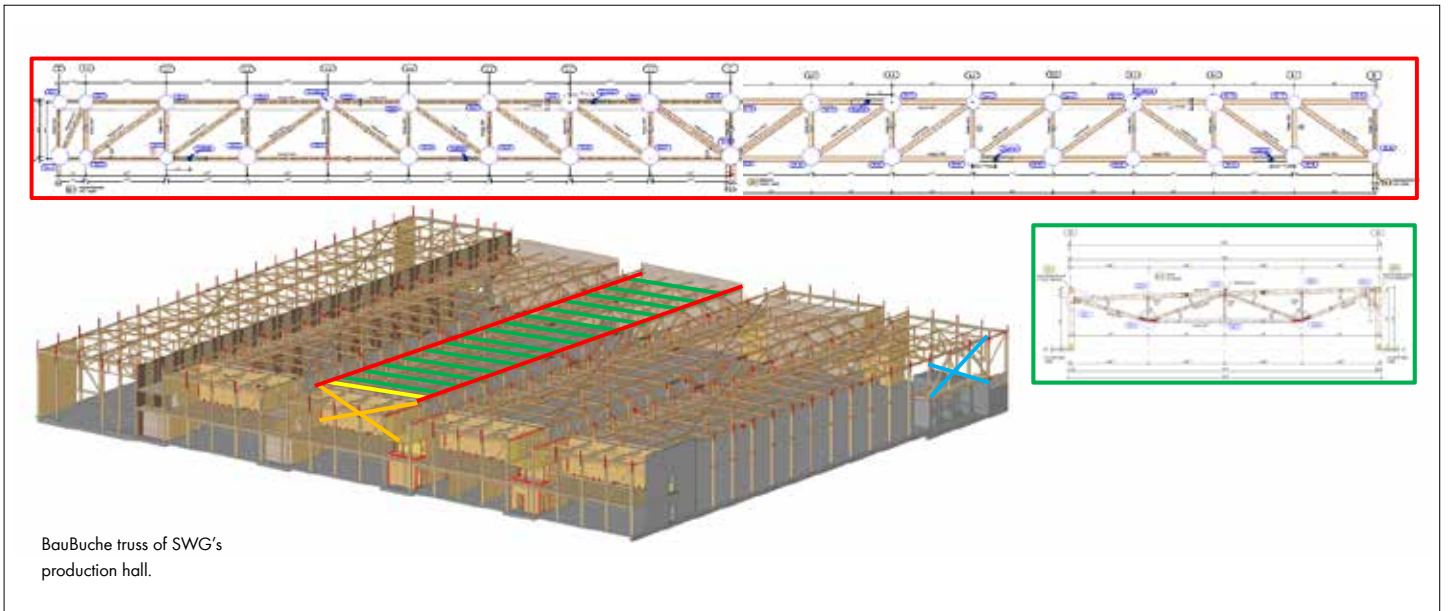
We would be happy to share the experience we gathered and our findings with any planner or building owner interested, helping them develop their projects—be they with BauBuche or other materials.



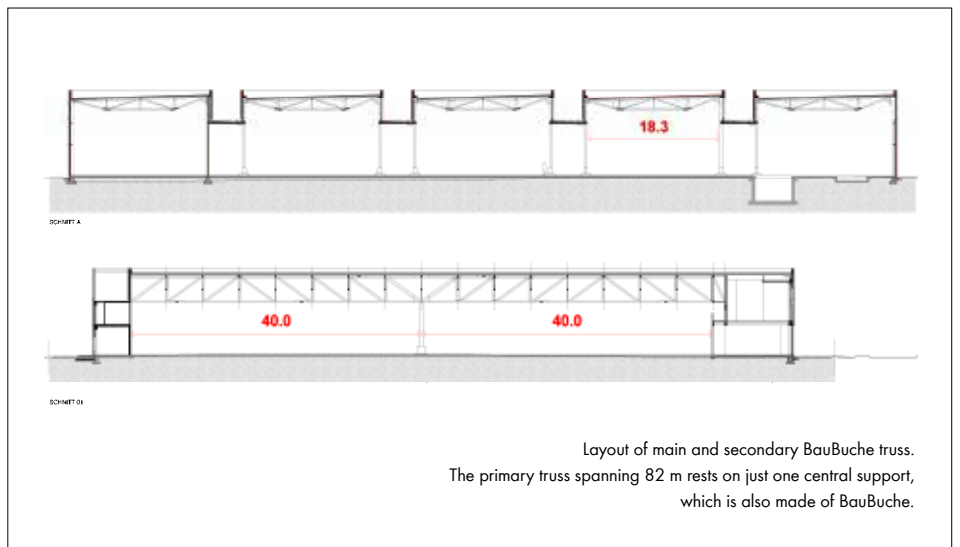
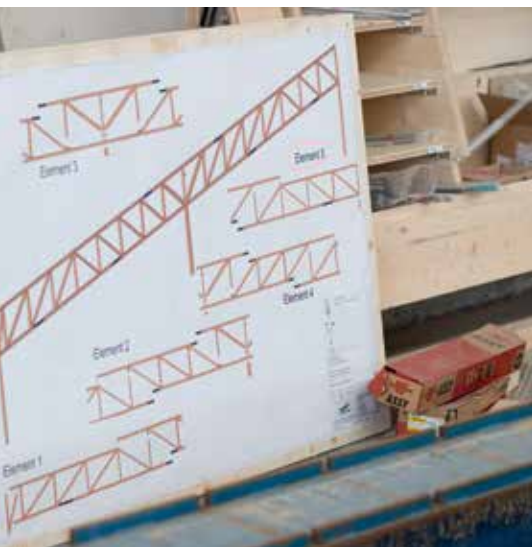
BAUBUCHE BEAMS

Climate change and bark beetles are giving coniferous forests a hard time, which is why future cultured forests will certainly have to evolve into mixed forests with a higher share of hardwood trees. Beech wood is an interesting material for timber structures. Creating a truss of BauBuche, a building material made from laminated beech veneer, facilitates building more slender structures than would be possible with steel, concrete, or glued laminated timber made from spruce. As a result, less load is applied to the ground, which greatly reduces the effort required to prepare the building ground. Smaller foundations may be needed, which is a prerequisite for unique architectural structures.

SWG's production hall is around 114 m long and 96.5 m wide. Along its entire length, the production hall has been divided into five bays each measuring 18.7 m in length. Between the bays, the rooftop drops by about 5 m before rising again to normal height over the next bay. A 9 m annex on the eastern side of the production hall (which is the front part in the isometric projection) will house common areas, seminar and training facilities. The western part of the hall accommodates a mechanical room of approx. 5 m.



© SWG Engineering



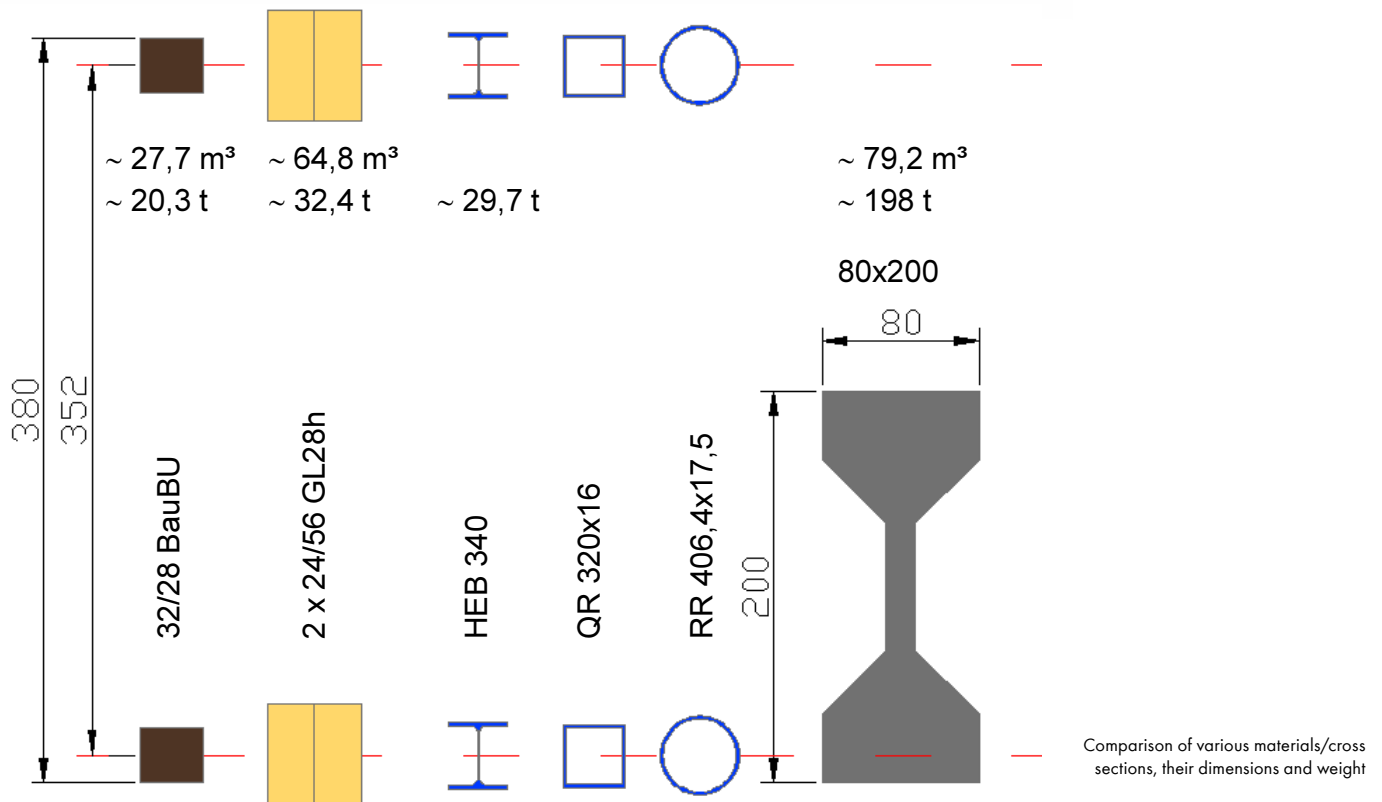
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Detailed planning is the prerequisite for efficient timber construction.

SLENDER, LIGHT-WEIGHT, SEXY!

Compared to spruce, steel, and concrete, BauBuche excels as a building material for supports thanks to its properties. **Calculated internal forces: $N_{t,Ed} \leq 2806 \text{ kN}$, $M_{y,Ed} \leq 33.24 \text{ kNm}$**



INNOVATIVE JOINTS

The most interesting aspect for planners: the joints designed for the SWG project using BauBuche and steel components.

Joint detail: main truss, node at center post beam

Five truss members meet at the center post beam supporting the main truss' bottom chord. Every member is subjected to compressive forces. As the bottom chord has been designed as a continuous member, the transfer of loads in the bottom chords must be guaranteed. The compressive force from the diagonal members is transmitted in two points each. As a consequence, these forces acting along the diagonal members are applied in two directions at the joint:

- Load component 1 acts perpendicular to the angle bisector between the diagonal member and the center post beam.

- Load component 2 acts perpendicular to the angle bisector between the diagonal member and the bottom chord/shear cleat (see bottom ill.)

To achieve this distribution of forces, the inner parts of the diagonal members were removed and the bottom chords reduced on the outside to create a tongue and fork joint with the diagonal members. The diagonal members' open mortises thus fit around the bottom chord, while the reduced ends of the bottom chords form a butt joint in the center. For transferring the forces from the diagonal members ($N_{c,Ed} \leq 1984 \text{ kN}$), the ends of both the center post beam and the open mortises of the diagonal members are cut along their angle bisector and butt-joined. The inner part of the diagonal members' open mortises rests



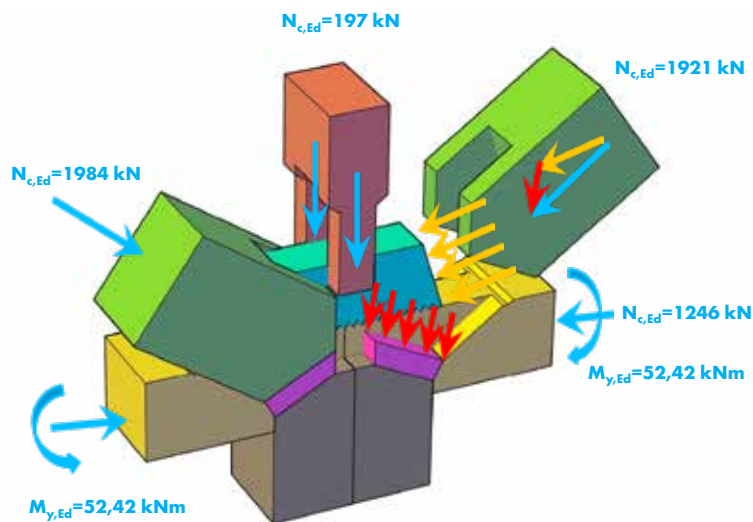
Example of an extended multiple step joint

against a shear cleat, which, among other things, connects both diagonal members horizontally. This shear cleat and the inner part of the open mortises have been cut along their angle bisector and butt-joined as well.

This way, load component 1 of the diagonal members is transferred directly into the center post beam through the ends of the open mortises. Load component 2 of both diagonal members is transferred into the cleat through the remaining cross sections on the insides of the open mortises, where both forces partly balance each other. The remaining share of this load component, which results from the difference of the opposing forces, is transferred into the bottom chords through the notches on the underside of the cleat. Any unbalanced forces resulting from the load transfer through the notches is taken up and released into the bottom chords by additional screws inserted vertically into the cleat. The relatively low compressive force acting along the vertical member is transferred into the center post beam through a similar tongue and fork joint.

The transmission of compressive force between the two bottom chords is achieved through a butt joint. The force moment acting on this point in the bottom chord can be split into two horizontally acting forces. The tensile force component acting on the top of the bottom chords is transferred through the notched joint between the bottom chords and the above cleat. As described above, the unbalanced forces resulting from the notched chord-cleat joint are taken up by additional screws.

NODE AT THE CENTER POST BEAM



Load acting on the center post beam node

JOINT DETAIL—MAIN TRUSS, PRIMARY DIAGONAL MEMBER

The planners designed the structural system of the main truss so that all diagonal members are in compression and all vertical members are in tension.

Connecting diagonal members

Depending on the forces to be transferred, diagonal members are joined using a multiple step joint or an extended multiple step joint. A multiple step joint is a succession of several notched joints.

As a rule, the shear force acting on the notches in the chord is decisive when verifying the structural strength of the joint. The following design considerations improved the load-bearing capacity of the joints:

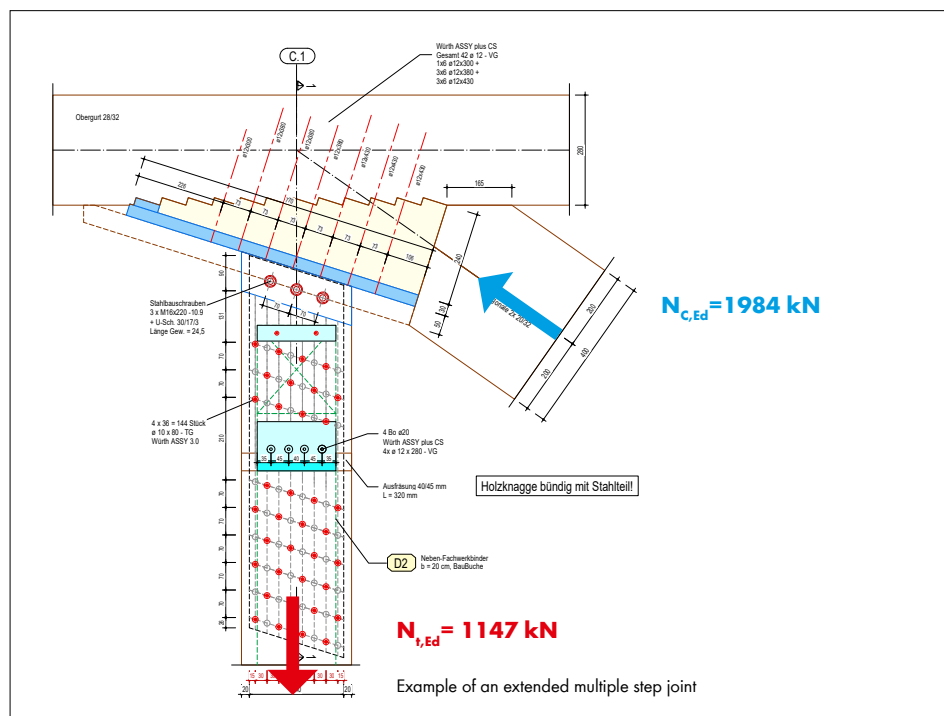
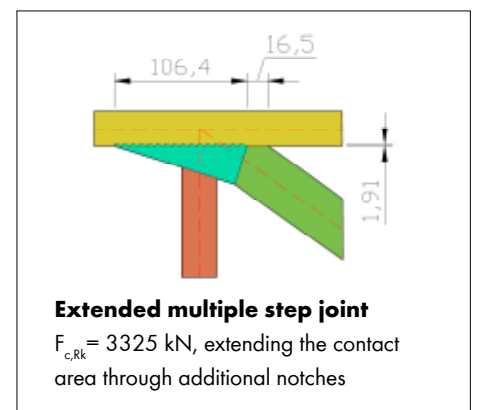
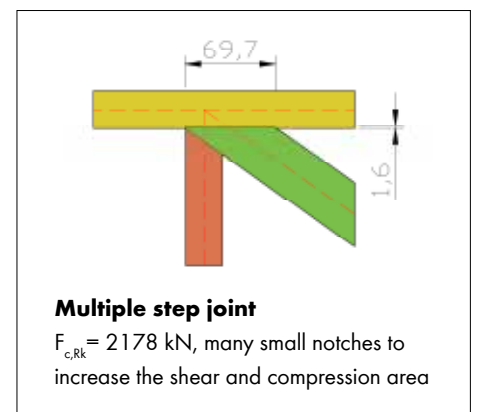
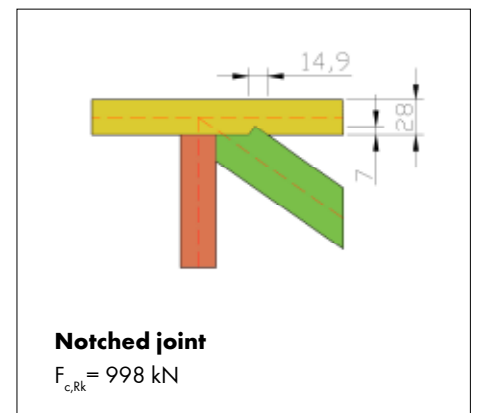
- According to ETA-12/0354, the shear strength of BauBuche is assumed to be 4.5 N/mm² (when taking into account the specific cross-

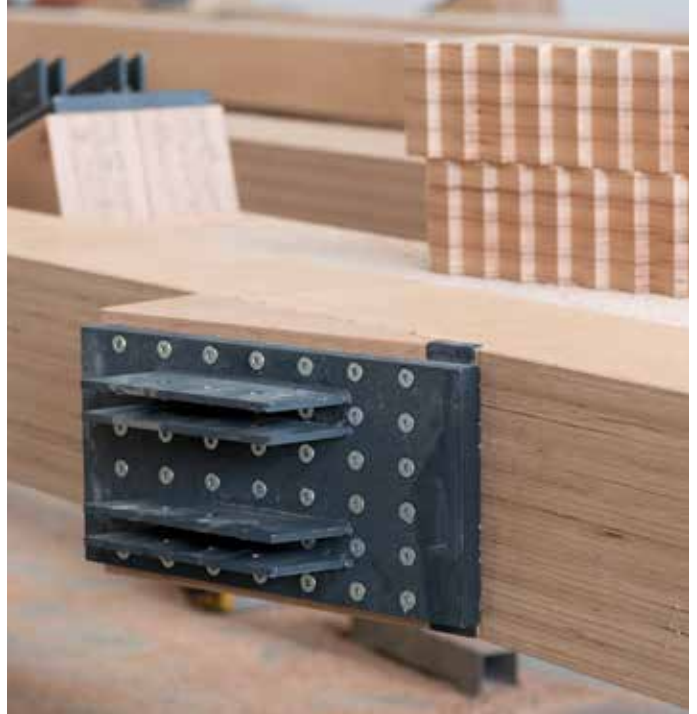
sections used in this project: approx. 4.9 N/mm²). The assumed edgewise shear strength of laminated veneer lumber is 8 N/mm² for this type of joint.

- If the shear strength is not sufficient, the contact area must be enlarged (e.g. by making the contact area longer). This goal can be achieved by mounting a cleat. The diagonal force is thus redirected into a shallower angle. The corresponding load component acting perpendicular to the chord member is transferred into the chord through lateral compression.

A comparison of the load-bearing capacities of a conventional notched joint and a multiple step joint or an extended multiple step joint establish the following capacities for the present use case: (see illustrations on the right).

Increased load-bearing capacity thanks to a variation of the step joint: notched joint, multiple step joint, extended multiple step joint



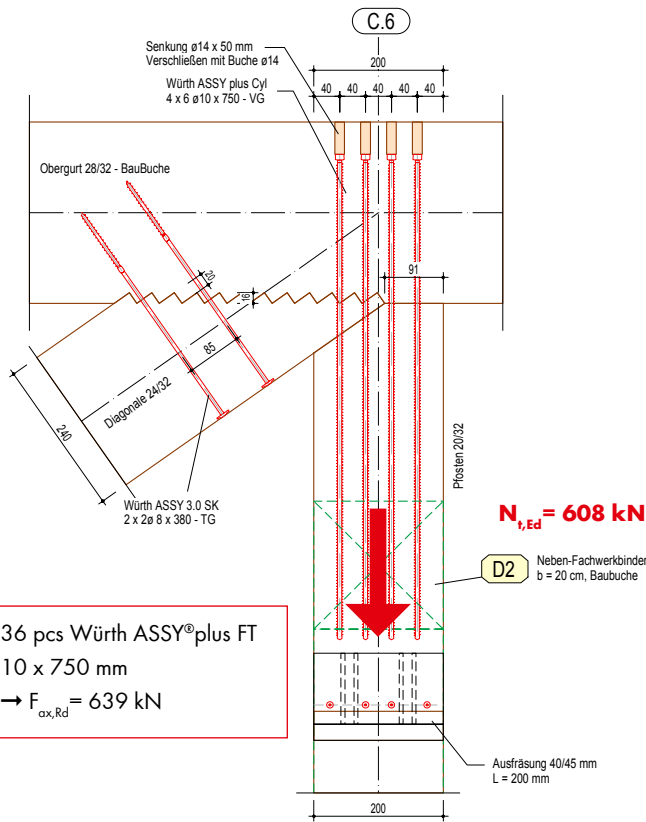


Extended multiple step joint

Connecting the vertical members

Depending on the acting forces, the vertical members can be joined using one of the following two options:

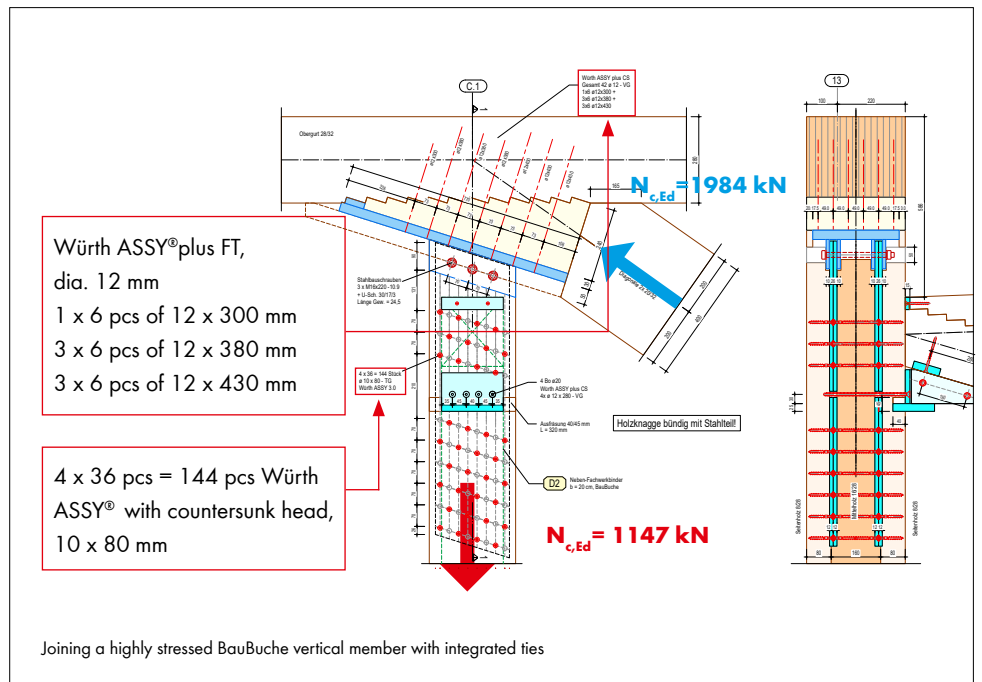
If only a small force is applied, long full-thread screws are used exclusively in the joint, with the screws aligned perpendicular to the top chord and in parallel to the grain of the vertical member. The Würth ASSY®plus FT full-thread screws used here have a diameter of 10 mm and need only be anchored 314 mm deep if aligned in parallel to the grain in order to achieve their maximum load-bearing capacity in the vertical member (load-bearing capacity of steel $f_{tens,k}$).



Vertical members are connected to the top chord using ASSY®plus FT full-thread screws installed parallel to the grain of the vertical member.

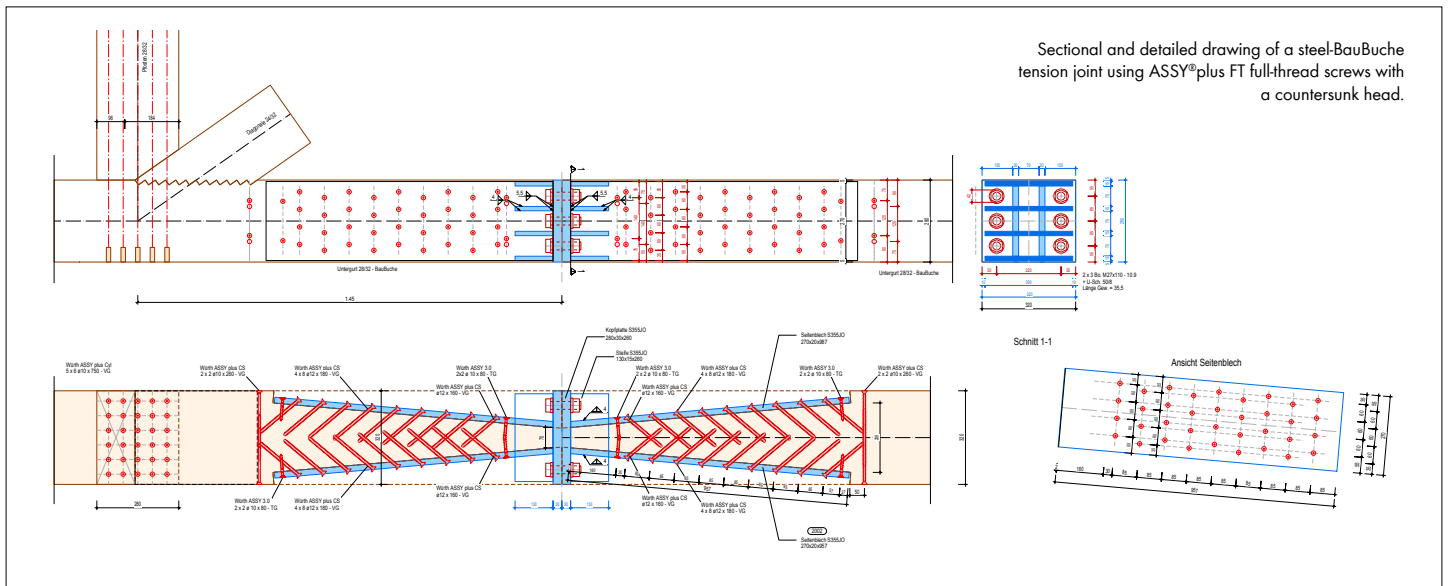
© SWG Engineering

Highly stressed vertical members are joined using steel parts. The vertical members consist of three pieces (80 mm/160 mm/80 mm) that have been cut out to house two steel ties. The combination with the 10 x 80 mm Würth ASSY® 3.0 wood screws aligned perpendicular to the shearing surface plane creates a quadruple-shear joint with the concealed steel ties. These ties are connected to a cap plate using three M16 (10.9) steel construction screws. The cap plate is anchored in the top chord using Würth ASSY®plus FT full-thread screws with a diameter of 12 mm. As these screws are not arranged in parallel to the tensile force acting along the vertical member, this creates an unbalanced force acting in parallel to the cleat in addition to the force acting along the screw axis. Through the cap plate, this unbalanced force is in turn balanced by the force acting along the diagonal member.



Joining a highly stressed BauBuche vertical member with integrated ties

© SWG Engineering



© SWG Engineering



Example of a metal-wood joint using ASSY®plus FT full-thread screws and 45° angled washers.

Tension or compression joints using ASSY®plus FT full-thread screws

Due to a restriction of timber lengths for transport, manufacturing a hall beam that spans the entire length of the hall is hardly ever possible. In order to be able to join the individual parts on site, the compression and tension joints need to be economically feasible.

A combination of ASSY®plus FT screws and 45° angled washers is recommended for transferring high loads.



In addition, lubricating grease is applied to reduce friction when screwing into BauBuche.

PLANNING AND PREPARATION

Safely and efficiently working with BauBuche requires meticulous planning and preparation. The most important findings from our pioneering project have been summarized below.



Trimming BauBuche beams and cutting a multiple step joint to take up compressive loads.



Cutting to size

Cooperation with CNC machine manufacturers would be recommended for the preparation and cutting of the timber. When preparing multiple step joints in compression, the following aspects of CNC trimming need to be taken into consideration:

- Shorter calibration intervals to ensure the perfect fit of the joint
- Shorter service life of the carbide cutting edges
- Minimization of component sizes due to the higher weight of the components
- Reduced production output of the woodworking machines

PROJECT PLAN- NING, PROCESS PLANNING, AND STORAGE.

Make sure to provide sufficient storage space early on. Ensuring the secure interim storage of the pre-assembled truss structures is essential.



Safe and efficient assembly requires detailed project planning, adjusted processes and prior capacity and storage space planning.

Protection against moisture

Moisture may become a problem when working with BauBuche. Therefore, take precautions to avoid a penetration of moisture.

- Break cutting edges to apply a sufficient amount of hydrophobic agent
- Allow for sufficient storage space or—if outsourcing the impregnation against moisture – just-in-time production and delivery



SCREWS AND ASSEMBLY DETAILS

Around 250,000 ASSY® screws were used in the SWG production hall. Next to providing more detailed assembly information, we will also explain the advantages of the new ASSY® 4,

Pre-drilling for ASSY® screws with longer threads

* Note: Using the Merk/Zübling drilling system, a simple dust protection and a conventional drill jig is recommended for large pre-drilling depths.

- Assembly of truss butt joints using roof truss jigs
- Execution of secure steel-BauBuche joints (hard joint application) by using driving tools in conjunction with torque angle gauges and documenting the tightening torque for quality assurance purposes
- Simple assembly of strong joints using screws in tension in combination with 45° angled washers and a suitable fire-resistant cover
- High-strength connections thanks to steel ties Detailed planning, exact pre-drilling and careful assembly help prevent fasteners from colliding in such joints.



On-site pre-drilling and countersinking for screw connections in the multiple step joint. The Würth BS13SEC drill driver is a robust and powerful allrounder.

STEEL-BAUBUCHE JOINT

Do not forget to allow for personal protective equipment such as hearing or dust protection in your project plans. A protective cover made from cardboard is a very pragmatic aid.



Creating tension joints and nodes capable of bearing high loads thanks to steel ties

The key question in every construction project is: How to take up and transfer the forces acting on the individual joints? There are two possibilities: On the one hand, loads can be transferred from BauBuche component to BauBuche component and on the other, loads can be transferred into the cross-sectional areas of BauBuche components through steel parts. Timber engineering has been and still is relying very much on glued laminated timber. While high loads acting on a structure often made the glulam timber cross-sections and not the fasteners fail, it proves to be the other way around with BauBuche structures as a newly "invented" construction method capable of bearing high loads. Thanks to the high strength of BauBuche, the fasteners often fail before the cross-sections.

In order to make optimum use of the fasteners and to keep timber cross-sections as slender as possible while allowing for the required edge distances, it is advisable to arrange the ASSY® wood screws in a specific pattern. By aligning the ASSY®plus FT full thread screws to bear only tensile loads, it is possible to improve effectiveness and profitability significantly.

Combining load-transferring metal ties with 45° angled washers will help reduce the thickness of the steel ties to be installed. These washers are inserted in pre-drilled elongated or round holes and greatly reduce the steel thickness required compared to angled countersunk holes.

When a level steel tie surface is required, ASSY®plus FT full-thread screws with a 90° countersunk head may be used if the beam cross-section is sufficient. In order to increase the load-bearing capacity of a screw connection consisting of several full-thread screws, you can use ASSY®plus FT full-thread screws to increase the transverse tensile strength. To do so, install an ASSY®plus FT full-thread screw perpendicular to the multiple screw connection that needs to be reinforced. The screw connections need to be calculated in compliance with ETA 11/0190 Appendix 6. Steel-BauBuche joints are considered hard joint applications. To ensure a smooth transfer of force, screws must be fastened using steady torque. Driving tools with integrated data-logging system and torque angle gauge would be recommended for series production.

The utilization of hole or drill jigs prevents screws in connections with multiple screws from touching each other to create highly accurate steel-BauBuche joints.



ASSEMBLY AIDS DURING PRODUCTION

The material properties of BauBuche allow transferring large loads in spite of the building components' relatively small cross-sections. As a result, builders can choose from a whole new range of design possibilities in hall construction, as wide-span structures can now be much sleeker than structures using conventional glued laminated timber. However, large or particularly long BauBuche components present a special challenge in production, as they cannot be moved manually and must be lifted using appropriate gear. Limits to component length due to transport restrictions must also be taken into account in the planning stage. Beams made up

of several pieces are a suitable solution to this problem: They can be joined on site using special tension and compression joints.

As compared to spruce, BauBuche has a much higher specific weight. That aspect does not only affect in-plant but also on-site handling and transport, with lifting gear also required on the construction site. To ensure successful project implementation, detailed planning, adjustment of processes, provision of assembly and transport aids as well as capacity and storage space planning must therefore be thoroughly monitored up until the start of the construction works

and adjusted if need be. In order to facilitate assembling individual components, workplaces should have an ergonomic height. Customized jigs help avoid assembly inaccuracies and boost profitability when preparing several identical joints. BauBuche's higher specific density may result in a higher tool wear and lower production output. According to ETA 11/0190, ASSY® screws with a thread-length-to-diameter ratio of up to 10:1 can be screwed in directly and do not require any pre-drilling. ASSY®Plus FT full-thread screws, on the other hand, always require pre-drilled holes – a process step that needs to be taken into account when calculating production times.

Impregnation with hydrophobing agents, just-in-time delivery and swift assembly

One of the critical properties of BauBuche is its moisture sensitivity. In order to prevent irreversible swelling, it is therefore crucial not to expose BauBuche to any moisture. Any BauBuche material must therefore be kept from coming into contact with splash water during transport and be protected from the effects of moisture during assembly. This can be achieved by impregnating the building components with a hydrophobing agent. Before using such agents extensively, we recommend testing them on samples. At the same time, prepare an exact delivery schedule, allowing for interim storage that is as brief as possible, swift assembly of the components and the final assembly and the quick attachment of roof cladding.

In order to keep assembly times as brief as possible, provide required subcarriers or mobile assembling dollies with adequate tools and fasteners. In this endeavor, the support provided by Würth's construction site logistics and the accessibility of the closest Würth shops in the area is an immense help.



When assembling individual components, you may want to use transport systems or handling hooks. The individual components are assembled at optimum ergonomic height.



ON-SITE ASSEMBLY



In order to ensure the quick and smooth on-site assembly of building components delivered just in time, your machinery and tools need to be well organized. Given the higher density of BauBuche, suitable screwdrivers, fasteners and accessories must be available on site.

Plan ahead for the transport and interim storage of large prefabricated components. Besides marking off the required storage space and ensuring its accessibility, also specify ways and means to secure your stored goods. Furthermore, take into account that you need to plan and provide lifting equipment to handle the heavier components.



Würth offers service boxes to handle hand and power tools on site.



As a rule, components for long spans need to be assembled at greater working heights. For making your employees' on-site work as safe as possible, you need to provide suitable fall protection equipment.



THE NEW ASSY4: MADE FOR YOUR PERFORMANCE.

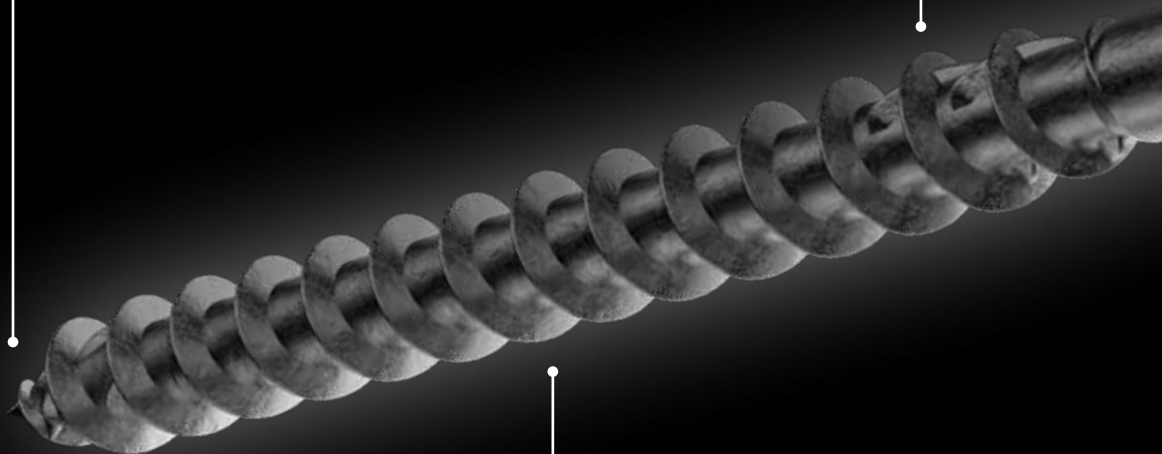
INNOVATI

NEW TIP

The gently expanding tip with a linear rise in the counter thread reduces splitting

NEW MILLING SHANK

Moving the milling shank forward into the thread allows for easier driving-in of the screw.



NEW THREAD

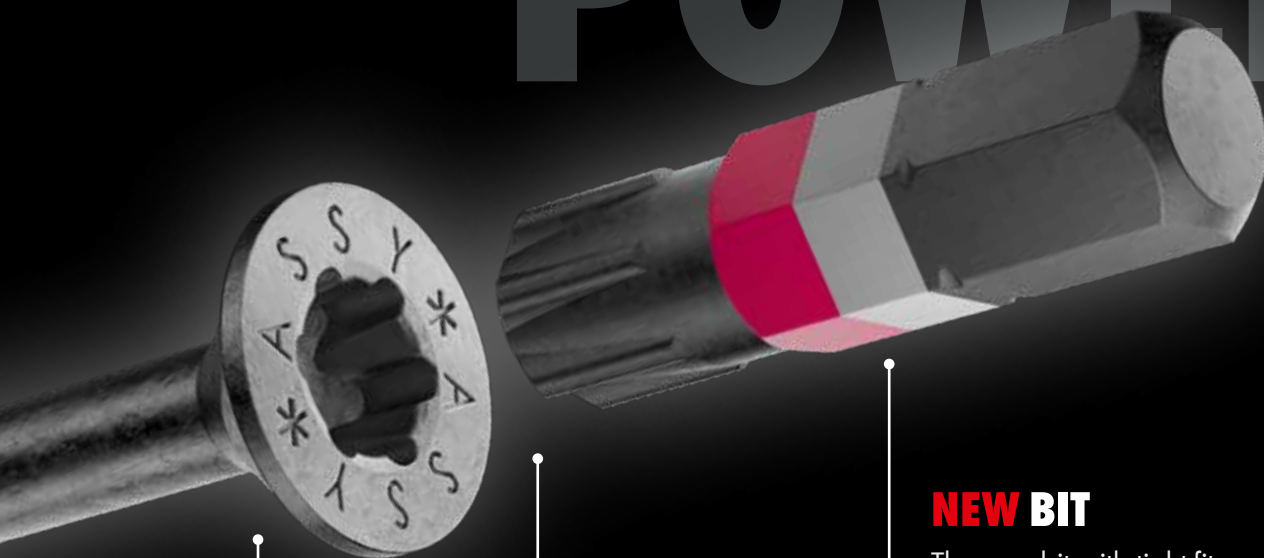
The new thread pulls boards together much better, e.g. when building cabinets.



ASSY[®]4
MADE FOR YOUR
PERFORMANCE



VE POWER



NEW MILLING POCKETS

The greater number of milling pockets makes it easier to install the screw in hard surfaces.

NEW BIT

The new bit with tight-fit recess for improved grip allows for more efficiency: 80 % of all applications can be done with only two bits.

NEW DRIVE

The larger contact surfaces on the new RW drive allow for even better torque transmission.



STRUCTURAL TIMBER CONSTRUCTION IN COOPERATION WITH WÜRTH

Würth and SWG Production offer much more than just good products.

Würth's Construction Site Project Management team helps you to optimize time-consuming communication processes within the framework of major construction projects by establishing well-coordinated planning and production processes. The sophisticated interplay of building owner, architect, planner, timber construction business, and the Würth Group's construction experts facilitates smooth project handling and minimizes construction costs.



Your benefit: 100 % support from planning to execution

Expert advice—100 % support

Würth supports your construction project from the planning stage all the way to its execution:

- Technical calculations by our inside staff
- Approvals, calculation aids, load tables, expert reports and CAD drawings available for download from wuerth.de/assj
- On-site sales service
- Product advice provided on the phone by our inside staff
- Technical on-site key account support



Your benefit: Receiving 100 % quality – in any place, at any time.



100 % high-quality products

Würth's product portfolio is huge. From A in ASSY® to Z in ZEBRA®: Würth offers ASSY® screws, ZEBRA® tools, WÜRTH MASTER power tools and anything else you need to treat material or protect yourself and your workers –supplying our top-quality products worldwide. Many of our Würth-branded products have been designed and produced by Würth. **Your benefit: Receiving 100 % quality – in any place, at any time.**



Your benefit: 100 % expertise in timber construction – caring for every detail

Detailed information on timber joints – 100 % expertise in timber construction

For more detailed information on suitable timber joints, please refer to the ASSY® service site at www.wuerth.de/assy



Your benefit: 100 % goods availability around the clock

Construction site logistics and delivery service – 100 % product availability

Thanks to the Würth Express Service, Würth delivers any required goods within a few hours. Our experts in Construction Site Project Management would be happy to discuss with you the optimum material supply to your construction site. We offer our Bauloc® modules in various sizes, thus guaranteeing permanent material supply and maximum theft protection.

TIMBER CONSTRUCTION USING BAUBUCHE

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