Hybrid Construction

Timber External Walls

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DETAIL Practice

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Contents

Hybrid Construction – Timber External Walls

To tackle climate change, the energy- and carbon-efficient use of raw materials and products in construction can play a crucial role in satisfying the urgent need to minimise the emission of climate-damaging greenhouse gases. Wood is a construction material with unique properties, not least due to its status as a renewable resource. It has a favourable energy and carbon footprint and can be used for a wide range of purposes in buildings. Timber construction also has advantages for material recycling and energy recovery.

Buildings are increasingly assessed using environmental indicators such as primary energy, raw material productivity or greenhouse gas emissions. This assessment is increasingly becoming a part of the building designer's responsibility, leading to a focus on wood as a building material and its ecological qualities. Reinforced concrete is ideal for creating low-cost load-bearing structures that comply with structural and fire regulations for all building classes and work with conventional building services, fire protection and sound insulation concepts.

Particularly efficient solutions can result from combining wood and concrete while making the most of their individual advantages and strengths. The realisation of a large number of such projects has shown that hybrid buildings with prefabricated, highly insulated timber facade elements and a load-bearing structure with a reinforced concrete skeleton or crosswall construction have much lower energy and carbon footprints than concrete and masonry buildings. This affects not only energy efficiency in the use phase by reducing the operating energy demand, but also makes efficient use of the "grey energy" embodied in the building fabric.

Using this type of hybrid construction results in a considerable improvement in the whole life cycle assessment of a building from construction, operation and demolition to reuse, recycling or disposal.

In addition to the beneficial material properties of wood, the relatively standard construction methods largely based on detachable connections have further advantages when it comes to the eventual demolition of facade components and their recyclability. Highly insulated timber facade elements with comparable thermal insulation properties are much thinner than the corresponding external walls built in concrete or masonry incorporating additional thermal insulation. This increases the usable floor area of these buildings.
In addition, the high degree of prefabrication means they are quicker to build – usually without scaffolding – which can mean a shorter construction time and substantial cost savings compared to traditional concrete and masonry buildings.

This combination of timber facade elements with a concrete load-bearing structure offers timber fabricators and mainstream construction companies who have previously worked exclusively on concrete construction an opportunity to widen their fields of activity in the building market. By working closely together and increasing standardisation, both branches of industry can offer clients shorter construction times and better quality.
The fact that prefabricated timber facade elements are still used comparatively rarely in Germany in today's reinforced concrete, steel or mixed construction buildings, despite the advantages mentioned above, may be due to a lack of experience in dealing with "unfamiliar"

trades and materials or to knowledge gaps on the part of architects and engineers in the areas of sound insulation, fire protection and deformation compatibility. In addition, progress on the development and presentation of typical details for the required detachable connections has been inconsistent.

On the basis of German and European building codes and standards, this publication therefore provides clear and practical basic knowledge for use in the design, approval and implementation of economically efficient connections between reinforced concrete floors or walls and timber external wall elements. Essential structural and constructional topics, aspects of the necessary sound and thermal insulation as well as fire and moisture protection measures are addressed. While the described technical information, especially fire protection and sound insulation as well as the case studies, relate to the situation in Germany in 2019, the information given can be transferred to other contexts and countries as long as individual adjustments are made regarding regionally varying rules and building regulations.
Building on this basic theoretical knowledge, the reference details of various connection points between timber and reinforced concrete construction contained in this publication are a valuable aid in the design and implementation of hybrid construction in practice.

The detailed presentation of successful built examples towards the end of the book contains information on design and construction to assist designers and contractors in implementing their own hybrid construction solutions based on sound technical principles, with the aim of achieving the highest possible quality and defect-free construction.

The information demonstrates how this sustainable construction method can help bring about a significant improvement in the energy demand and CO_2 emissions of such buildings or construction methods over their life cycle.

This book is based on the research project “Facade elements for hybrid construction. Prefabricated integral facade elements in timber construction for use in new hybrid reinforced concrete buildings” (published in German), which was funded by the Bavarian construction industry. Without the financial support and the outstanding collaboration of all the participating companies, research bodies and testing institutions, particularly with regard to their knowledge and expertise, these practical guidelines would never have been produced. The editors and authors of this publication would like to sincerely thank everyone involved.

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Principles

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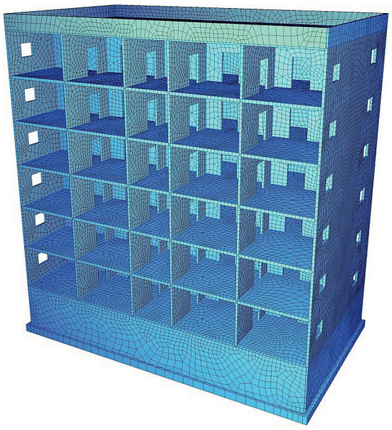
Application and Construction Variants

At first glance, “hybrid construction” appears a very abstract term. In a general sense, it could apply to almost any type of construction that involves a combination of different building materials. A single component, such as a floor slab, can be a form of hybrid construction itself when you consider the waterproofing, insulation and structural layers. However, for the purposes of this publication, hybrid construction is defined as the combination of a reinforced concrete load-bearing structure with a non-structural timber panel construction element facade.
The non-structural external wall consisting of timber panel construction elements contributes nothing to the structural stability of the building, i.e. it performs no load-bearing or stiffening function for the building as a whole. Wind loads are normally transferred floor by floor into the building’s load-bearing structure. Dead loads can likewise be transferred floor by floor or from wall element to wall element and into the foundations.
In building classes 4 and 5, the facade element must be designed to be fire-retardant (EI 30). In the event of a fire the load-bearing capability of individual elements spanning the storey on fire must be ensured (Fig. 22, p. 30).
The studies and application examples presented here focus on the German market. Thus, the named regulations refer to the German standards and rules. Wherever possible, reference is made to the requirements on a European level.

Construction of the Load-bearing Structure

The load-bearing structure is normally a reinforced concrete skeleton frame or crosswall construction (Fig. 1).

Skeleton Frame
One of the main advantages of skeleton frame construction is the flexibility it allows for the final floor layout of the building. Only the column grid and the stiffening cores affect the floor plan. By using non-structural walls, the usable floor space can be relatively simply reconfigured during the life of the building. The floor slabs are designed for the average distance between columns and their thickness dimensioned so that disruptive downstand beams are unnecessary. Another advantage of flat slabs is their simpler construction, which in turn results in shorter completion times. Ventilation ducts and electrical cabling for building services equipment can be fitted directly to the underside of the floor and there are fewer penetrations through structural components to be designed. Transfer of load through individual columns, considered to be point supports, requires a higher proportion of reinforcement at the support points, such as increased bending reinforcement in the top of the slab. As a rule, punching shear reinforcement is arranged around the columns. Calculation of overall building stiffness is more challenging than with crosswall construction because there are only a few stiffening shear walls available, mostly at the stairwell cores and the separation walls between residential units. Buildings in earthquake zones, for example, require additional measures to ensure structural stability. The stiffening action of the columns can certainly be brought into the calculation but, compared to the performance of shear walls, is relatively inefficient.
The overall stiffness of the frame formed by the columns and the flat slabs is considerably less than that of a shear wall. Eliminating the need for punching shear enforcement is one argument for using downstand beams.



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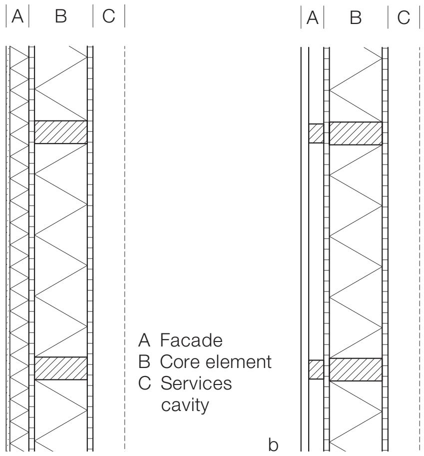
1 Three-dimensional computer model
a Reinforced concrete frame construction
b Reinforced concrete crosswall construction



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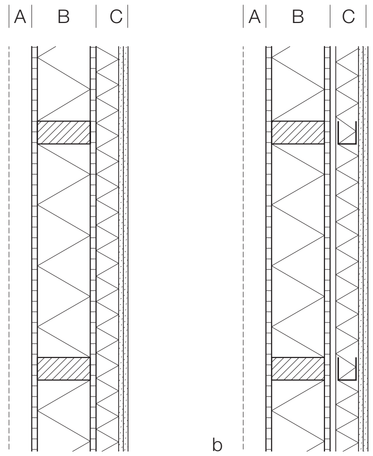


3a b

Crosswall Construction

Crosswall construction is extremely suitable and widely used for residential buildings. Structural crosswalls supporting primarily one-way spanning floors acting as continuous beams are characteristically seen in crosswall construction. The structural system is simple and clear. Reinforced concrete crosswalls forming part of the structural frame separate living areas and provide effective insulation against structure-born sound thanks to their solid construction. Crosswall construction reveals its advantages where the layout of the rooms is likely to change only slightly during the life of the building. Subsequent reconfiguration of the floor layout is very expensive to implement. Proof of structural adequacy requires considerably less effort than for a reinforced concrete skeleton frame because the required building stiffness is simply based on having an adequate number of structural shear walls.

Construction of the Timber Panel Construction Elements

Timber panel construction elements have three basic system areas: facade, core element and services cavity (Fig. 2 and 3). These areas of the building system form the non-structural external wall, which is attached to the building's reinforced concrete load-bearing structure (see "Connecting to the Load-bearing Structure", p. 9). The timber panel construction elements form the exterior of the building and combine excellent insulating properties with low wall thickness and lightweight construction.

The facade (area A) with the core element (area B) provides thermal insulation and protection against moisture. The facade is primarily there to protect against weather and has a considerable influence on the appearance of the building. Facades can be considered as rear-ventilated/ventilated or non-rear ventilated. A compact facade constructed using an external thermal insulation composite system (ETICS) provides some of the thermal insulation (Fig. 2a). A ventilated/rear-ventilated facade is designed as a type of curtain wall (Fig. 2b).

To use an ETICS in timber construction currently still requires a national technical approval (abZ) in Germany. In accordance with the current Model Administrative Provisions – Technical Building Rules (MVV TB), there must also be a European Technical Assessment (ETA). The relevant technical rule B 2.2.1.5 in the MVV TB refers to an ETA in accordance with guideline ETAG 004 for the use of European construction products. However, this European guideline, which is also intended to ensure compliance with national building requirements in Germany, refers only to masonry and concrete construction. Nevertheless, ETAG 004 permits timber construction as a departure from an applicable technical rule, providing the protection goal or level required by building law is achieved just as adequately. Even if the use of an ETICS in timber construction is not yet completely clarified under building law, it has already been used successfully and in accordance with good practice for years. You can therefore rely on the experience of the companies and engineering professionals carrying out the work. The requirements for the use of ETICS in timber construction may differ in other European countries.

The core element (area B) is of timber panel construction. It is based on the same principle as timber frame construction but with a higher degree of prefabrication. In addition to providing thermal insulation and protection against moisture, the core element also transfers loads and acts as sound insulation and fire protection. Slender, linear structural members consisting of vertical studs, a bottom and a top rail transfer dead loads and horizontal wind loads to the support points (Fig. 4). The space between the studs and rails is filled with void-free insulation. The structural frame is stiffened on both sides by nailed or stapled wood-based material, gypsum fibreboard or plasterboard boards. This cladding in combination with a waterproofing membrane and adhesive tape ensures the structure is wind and airtight.

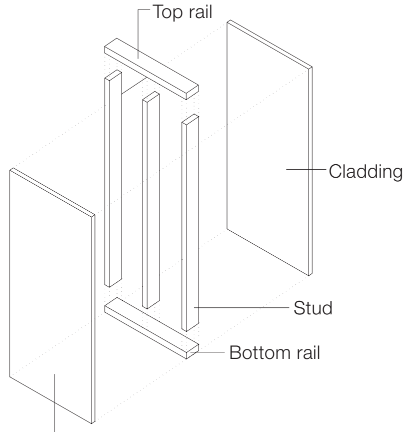
The services cavity (area C) provides for simple and concealed routing of pipes and cables. If the insulation thickness of the facade and the core element is insufficient to satisfy insulation standards, the services cavity can also be used as an insulation layer for thermal insulation (Fig. 3). Creating the services cavity on site offers several advantages: no penetrations for services are required in the airtightness layer of the core element. All services cavities can be easily installed, concealing the fastenings for the external wall elements in a simple way. Sound protection is also improved. For increased sound protection requirements, a completely decoupled and free-standing curtain wall is highly recommended, which can further improve sound protection with self-supporting external walls. However, a decoupled curtain wall involves considerably more installation work. Therefore, it should be checked early in the design phase whether increased sound insulation is required and a free-standing curtain wall detailed if the calculated values are inadequate (see "Sound Insulation", p. 41ff.).

Timber panel construction elements, including the facade, lend themselves to being made, with a high degree of prefabrication and accuracy, in the factory and then transported to site. This represents a considerable advantage of the method of construction and timber construction in general. Prefabrication goes hand in hand with a short construction time on site, which increases the cost-effectiveness as well as the quality of this construction method. Fabrication in a controlled factory environment is not affected by changes in weather conditions. The use of floor-height prefabricated timber facade elements has become very widespread.

Connecting to the Load-bearing Structure

Three common forms of connections are available for attaching the timber panel construction elements to the reinforced concrete load-bearing structure: self-supporting, suspended and inserted (Fig. 5). They differ from one another in their position and the way they transmit loads. The connection types put different demands on the fastening elements and involve different installation sequences. Attachment is generally done using steel angles with bolts and anchors. Further information can be found in “Load-bearing Structure and External Wall” (p. 19ff.) and “External Wall Joints” (p. 49ff.). The connection types have different effects on the building physics characteristics in the area around the connection.

In the case of the self-supporting type, the external wall is set forward from the load-bearing structure. The dead load (vertical force) of the external wall is transferred at the base of the individual element into the contiguous floor slab below or via the individual wall elements down to the foundation. This variant represents an optimum solution with respect to thermal insulation because the insulation layer is not interrupted. At the same time, it places greater demands on sound insulation and fire protection. For example, the transmission of flanking sound must be prevented by suitable measures (see “Fire Protection”, p. 37ff. and “Sound Insulation”, p. 41ff.).



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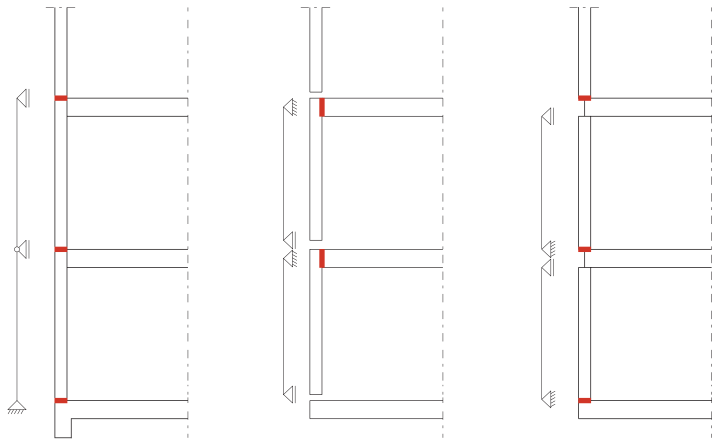
Connection variants	Self-supporting external wall element	Suspended external wall element	Inserted external wall element
			
System	• Stand-alone system in its own plane outside the building structure	• Stand-alone system in its own plane outside the building structure	• Single-span system, floor by floor within the extent of the building structure
Advantages	• Larger tolerance capacity, can compensate for dimensional deviations • Continuous insulation skin with almost no thermal bridges • Easy to install the airtight vapour barrier	• Vertical studs do not need to be checked for buckling • Continuous insulation skin with almost no thermal bridges • Easy to install the airtight vapour barrier	• Structural frame members can be integrated within the facade • Reduced secondary sound transfer paths • Fire propagation paths interrupted by solid structural members
Disadvantages	• Increased construction effort to comply with sound insulation and fire protection requirements	• More complex proof of compliance with sound insulation and fire protection requirements • Connections are more complex in comparison to alternative facade types	• System sensitive to settlement • Larger gaps at the structural frame for installation reasons • Increased risk of thermal bridges • More difficult to install the airtight vapour barrier

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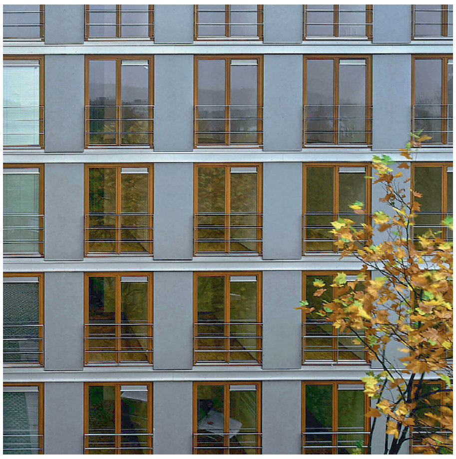
2 Wall constructions
a Compact facade and core element
b Ventilated or rear-ventilated facade and core element
3 Wall constructions
a Core element with a directly connected services cavity
b Core element at a distance from self-supporting services cavity
4 Construction of a timber panel construction element
5 Summary of the advantages and disadvantages of the connection variants of non-structural facade elements and an idealised structural system for permanent and variable loads (red = position of gap/joint, attachment)

6a



b

c

The suspended timber panel construction element facade can also be positioned in front of the load-bearing structure and is suspended floor by floor at the wall head from the reinforced concrete slab above. Unlike the self-supporting variant, the suspended facade is not at risk of the vertical studs buckling. However, the design of the connection points is more complex as a consequence.
In the case of the inserted type, the central vertical axis of the external wall element is almost in line with the front edge of the floor slab and the elements are installed floor by floor directly on the reinforced concrete slab below. This has advantages in connection with the reinforced concrete structural frame because the load-bearing columns can be integrated into the external wall construction if necessary. In addition, the required level of sound insulation and fire protection is easier to achieve because the degree of integration inherently prevents direct propagation paths, such as through party walls. The degree of integration of the columns can be varied to improve sound insulation and fire protection within the bounds of what is structurally achievable. At the same time, this form of construction can be disadvantageous in terms of thermal insulation because of possible thermal bridges. With the inserted type, the installation joints are larger than with the two other external wall types, which has implications for its installation on site.
With all three facade variants, the positive (pressure) and negative (suction) forces arising from wind loads are conducted floor by floor into the reinforced concrete structure.

Areas of Application

In the context of construction engineering and energy, the form of hybrid construction discussed in this book shows itself to be an advantageous combination of a robust structure and a resource-conserving, individually designable building envelope. Hybrid construction can be used for a wide range of buildings, including residential and administration buildings. The design freedom allowed for the facades is equally wide. In accordance with German building regulations, non-structural timber elements can be erected up to a high-rise building height restriction (top storey floor level $\leq$ 22 m above the average level of the surrounding ground). This may differ in other countries.
In general, this form of construction is advisable, particularly where multistorey buildings must be completed quickly. This applies above all for designs with large external wall surfaces and repetitive facade features in which the use of standardised facade elements can reduce fabrication costs per m^2 of external wall. With a well-planned construction programme, the structural frame and the facade can be completed more or less in parallel, to the benefit of the total construction period. Standardised construction does not mean that facades must be monotonous, on the contrary: design requirements can be met through a wide choice of coloured facade panels, metals, timber cladding and plaster systems (Fig. 6).
Thus, the construction method is becoming increasingly popular for apartment buildings and represents a good alternative to masonry and concrete for urban social housing. This form of construction is also recommended for office buildings. The high standard of insulation and low external wall thicknesses result in a greater usable floor area and pleasant indoor climate. The advantages of hybrid construction show themselves not only in new buildings but also in refurbishments. For example, in refurbishments where