Hamburg ahead

INTERNATIONAL BUILDING EXHIBITION HAMBURG

Smart Material House
WOODCUBE

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Building the City Anew

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Content

A Introduction

A. 1 Smart Material Houses

"Smart materials" are materials, material systems, and products that can be derived from them that behave not in a static but a dynamic way, in contrast to conventional building materials. In other words, because of their nature, these materials react to changing environmental conditions and adapt to them. These special characteristics result from physical or chemical influences, such as varying temperatures or sunlight falling on the building material.

The building shell is one of the most crucial elements in this respect: the use of smart materials in the façade can enable energy and material flows to be improved and kept as low as possible, since a large proportion of these materials draw energy directly or indirectly from the surrounding environment.

Smart materials can be found in nature. Microalgae, for example, can be bred in the glass sections of façades: they then use photosynthesis to turn solar thermal energy into heat energy, biomass, and heat. The façade itself becomes part of the building services.

A "Smart Material House" is a new form of residential building in which adaptable architectural designs can be combined with intelligent technologies and construction materials. As one of the main themes of the "Building Exhibition within the Building Exhibition", these constitute an architectural pilot project, using four exemplary building types to show how new technological approaches can be translated into a forward-looking architectural language, and traditional techniques reinterpreted.

As its starting point for the "Smart Material Houses" theme, the International Building Exhibition Hamburg (IBA) presented the following basic ideas. Smart materials are active, with a transformative character. They respond to changing environmental conditions. In an intelligent interaction with "smart technologies", this process can be extended to the level of networked building services, and can monitor and optimise energy and material maintenance.

For this purpose, the existing categories of materials must be considered afresh, because smart materials, being active, take on opposing properties and functions at different times. Material and technological innovations in architectural history were always associated with a fundamental change in what architecture could and should be. These days, it can be observed that sustainability forms the background to many design decisions.

- Smart materials and smart technologies, through their adaptive functions, make it possible to control energy and material flows sustainably.
- The adaptability of smart materials endows time processes with great significance.
- A performative understanding of materials and technologies enables and fosters a new approach to the architectural design process.

A paradigm shift towards decentralised infrastructure systems is becoming apparent. By decentralisation we mean the integration of urban functions with building technology. Water systems, power generation, the use of waste heat, miniature pumps, and combined heat and power are installed and deployed locally or in the immediate vicinity. Much of the energy consumed in buildings is to be recovered in the future from existing local anergy, to reduce the proportion of high exergy.

The infrastructures of the city need to be rethought and reorganised in this context:

- Through the integration of urban functions with building technology, the house becomes an active participant in a (communicative, i.e. feedback) network. Accordingly, it performs additional functions, such as being a "power plant", providing "energy storage", or comprising a "communications point" in the urban context.

- The building envelope is the central element of the energy exchange between inside and outside. It controls inflowing and outflowing energy streams and the circulation of material. Using smart materials and smart technologies, building envelopes can actively regulate energy and material flows.
- Since the beginning of the modern period, building services have been bundled away, centralised, and thus often rendered invisible. With the proliferation of smart materials, the material surface can itself become a medium carrying energy and information.
- The new technologies make it possible to multiply building services and distribute them to various surfaces. Materials become dynamic infrastructures that can produce variable, partly contradictory effects.
- With the extension of multifunctional surfaces, the time factor becomes an integral part of the design and simultaneously makes it possible to use space and buildings in hybrid ways. Along with the increasing importance of time processes, an "open layout" can be changed into a "reconfigurable layout". Reconfigurable layouts are generated from the mutability of the space, the transformability of the materials, and the adaptability of the technologies, no longer solely through their (static) openness to different uses.
- There is an emphasis on the "aesthetics of phenomena", which mainly focuses on the behaviour of materials. It is not important how the material presents itself, but when it makes its appearance.

The architectural and building services concepts behind the "WOODCUBE" are set out in detail in this White Paper. The planning process is also outlined clearly, as a large number of alterations were made between the design stage and the final execution of the project. The reasons behind these changes were technical, financial, or functional, meaning that some original targets had to be adjusted.

Model projects are particularly liable to undergo planning changes; indeed, besides presenting innovative end products, building exhibitions also seek to test out construction methods and processes. Only when the planning process is examined is it possible to ascertain whether a model building project can serve as a good example for the use of smart materials in the twenty-first century. In addition to setting out technical details for experts, this booklet is intended to provide an objective assessment of whether the "WOODCUBE" model project fulfils this aim, and whether and to what extent it has ultimately succeeded in achieving the goals set out before the planning stage.

After this short introduction the "WOODCUBE Smart Material House" will be presented in brief, and then explained in detail. The architectural and building services concept will then be described, followed by the planning process. Finally, the model project will be assessed. The focus throughout is on the "WOODCUBE's" energy concept, the flexible roof, and the wooden construction.

A. 2 WOODCUBE Project Outline

SPECIAL FEATURES

- The floor plan typology allows for different types of occupation, adapted to urban living requirements.
- The use of renewable building materials results in a structure that is carbon neutral in terms of its construction and operation.
- Multistorey solid timber construction.

Fig. 1: WOODCUBE from the southeast

Fig. 2: WOODCUBE from the southwest

The "WOODCUBE" is a five-storey apartment building with a flexible number of apartments. The design demonstrates the possibilities of forward-looking solid timber construction: the Efficiency House 40 largely avoids the use of non-renewable raw materials in both its construction and its operation. Energy and heat energy are carbon neutral and derived from renewable sources.

The "WOODCUBE" project is the first time that a apartment complex has been built that does not emit any greenhouse gases over its life cycle, and is almost completely biologically recyclable. All of the construction materials were therefore checked for their carbon potential and biological compatibility in building. A sophisticated building services concept with central building control and smart metering supports the consistently low energy consumption.

Compared with conventional buildings, approximately 8,500 tonnes of carbon were saved during the construction phase alone. Due to its carbon balance in construction and operation, the "WOODCUBE" demonstrates the potential, within the climate-neutral building sector, of solid wood construction and energy supply using renewable forms of energy.

Project partners	
Project development / initiation	DeepGreen Development, Hamburg
Developer	WOODCUBE Hamburg GmbH
Design	architekturagentur, Stuttgart
Structural planning	Isenmann Ingenieure, Haslach
Building biology	Baubiologische Beratung Wilfried Schmidt
Fire safety planning	Tichelmann & Barillas TIB Ingenieurgesellschaft, Darmstadt
Timber elements	Thoma Holz100 GmbH
Ecological assessment	Ina Planungsgesellschaft mbH
General building information	
Use	Residential building
Number of floors	5
Number of units	9
Size of units	70 - 190 m²
Plot size	1.130 m²
Gross floor area	1.480 m²
Net area	998 m²
Building volume	3.430 m³
Energy standard	KfW Efficiency House 40
Heat energy requirement	18 kWh/ m² per year
Final energy requirement	39,3 kWh/ m² per year
Primary energy requirement	21,3 kWh/ m² per year
Energy supply	Wilhelmsburg Central Integrated Energy Network and photovoltaic modules on the roof
Construction time	September 2012 to May 2013
Project costs	€ 3.8 million
Structure	
Foundations	Basement on pillar foundation
Outer walls	Solid timber construction (unglued, dowelled cross-laminated timber elements) with façade cladding made of untreated larch wood
Floor and ceiling elements	Solid timber construction (unglued, dowelled cross-laminated timber elements) with flush beams made of timber and steel composite construction elements
Interior walls	Non-load-bearing lightweight partitions
Vertical structure	Reinforced concrete

B WOODCUBE Project Details

B.1 Architectural Concept

The building has a basement floor with a pillar foundation, topped by five full storeys on a square layout, with an edge length of 15.10 metres. The cube is divided into three horizontal axes, whereby the dimensions of the centrally oriented staircase with its lift shaft define the dimensions of the respective central axes. The staircase core is also square. The outer wall of the entrance side is indented by half an axis, so that on this side the entrance to the central opening is located inside the cube itself.

The building is accessed from the north. From the ground to the third floor, there are two apartments on each level. The apartments on the west side of the second and third floors were joined together vertically to form a maisonette. The fourth floor, however, is designed as a closed unit. Each apartment has at least one balcony on a corner of the building and oriented east, south, or west. The roof, which is covered with a photovoltaic unit, is not accessible.

Large windows that run the width of the balcony and smaller square, or rectangular windows that seem to be arranged without reference to one another, break up the façade. The vertical openings for the building services installations are in ducts on the eastern and western outer walls. The bathrooms and kitchens are arranged around these ducts. Overall, the cubic form of the building makes it very compact.
Above the basement, which is a waterproof concrete tank, almost all of the load-bearing construction components are made of timber elements, with the exception of the staircase core. The basement contains space for storing bicycles and technical and supply rooms, along with a laundry room and storage spaces for the apartments.

Possibility of Conversion

Due to the large floor spans, almost every type of room layout can be achieved within the building. Every floor features different types of apartments. As there are no load-bearing walls, room structures can be changed at any time. Some of the apartments are also set up in such a way that, if required, they can be made completely accessible without major alteration work.

Design Concept

As part of the IBA Hamburg, the "WOODCUBE" was intended take on a clear structural form

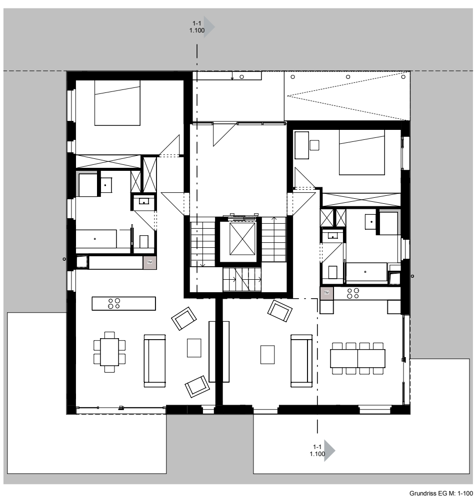


Fig. 3: Ground floor layout (oriented north)

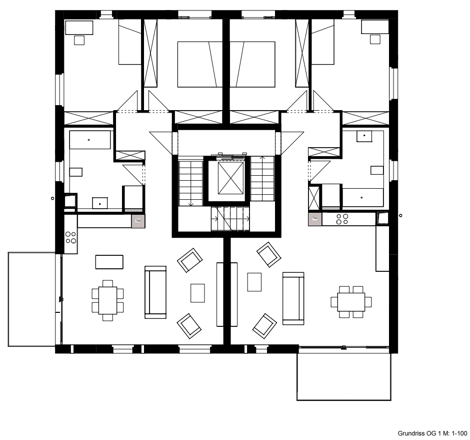


Fig. 4: First floor layout (oriented north)

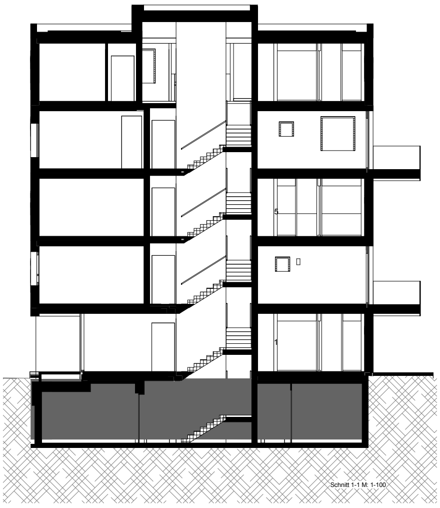


Fig. 5: Section

and act as a prototype. This gave rise to the distinct cube shape, which ensured a high recall value. The building's cubature is enhanced by irregularly spaced, freely overhanging balconies. These are designed in such a way as to give the impression that they swing out of the basic shape. This is emphasised by the way in which their undersides are clad in the same material as the façade. Inside the building, at the very centre, is the concrete lift and staircase core. This forms a clear contrast with the timber outer shell and the interior spaces within the apartments.

In order to ensure clear orientation, the entrance has been cut into the northern side of the building as a negative form. This allows the building's cube shape to appear closed. Deliberately mounted on a visible base, the main body of the building is on a level surface. The surfaces of the outdoor facilities are completely flat in order to display the cube from all sides to the same extent.

Many contrasting design elements were implemented in order to break up the strict look of the basic geometric shape. Clear geometry is important to the building's appearance from a distance, while from close up we see a detailed, horizontal alignment with the organic structure of the wood grain. This ambiguity is carried through to the division of the façades. In order to ease the defined structure of the balconies, square windows were positioned in the façade, seemingly at random. Their dimensions and heights do, however, follow the functional requirements. This results in deep windows that allow the people inside to see out even when seated.

There is further contrast inside the building: the structural system enables different layouts to be configured on each floor. Despite the building's outwardly uniform appearance, there is diversity inside.

The façade was made of larch wood, edged with timber moulding, in order to emphasise the use of a single material for the outer wall structure. Dark grey metal soffits complement the deep-set windows, enhancing the punctuated appearance of the façade. The surface of the cut-away area is covered in plaster in order to make it distinct from the timber.

The monolithic reinforced concrete core was simply given a wooden floor in the foyer and deliberately sparse lighting. On walking into the building one therefore encounters an open space that is flooded with light and has sweeping wooden surfaces.

Fig. 6: North façade

Fig. 7: Ground floor interior view

The emphasis of the design is on clarity of form and clear contrasts, even in terms of the materials used. A purist approach was deliberately chosen in order to ward off cosy associations with traditional timber construction. This very approach resulted in exciting contrasts between organic building materials and the systematic use of forms.

Deconstruction

All of the load-bearing outer walls and ceiling elements are simply screwed together and can be disassembled without waste. All of the elements can be separated from each other at a factory using a CNC joinery machine. In theory, the individual board layers and squared timbers can then be used again in new elements. In the same way, due to the dry, mortarless construction method used, whole levels can be divided up into their components and re-used without any further processing required.

Upgradability

In general, the materials were selected for their potential durability. The manufacturer provides a 50-year warranty on condensation and mould growth. Due to the permeable structure with highly insulating building components, these problems are virtually eliminated. The façade construction was examined in a durability simulation so as to ensure that living costs remain as low as possible. Optimal construction, fire safety, humidity control, and a weather-proof structure go hand-in-hand. High quality materials such as solid timber boards can also be re-integrated during conversion work. Empty ducts and flexible connection options (Homeway) also ensure maximum flexibility for building services in case of renovation or conversion.

B.2 Structure

Outer Walls

The outer walls are made of solid timber with cross-laminated timber elements. The board layers of these elements were fixed and mechanically joined to beech wood dowels using a specific system (DeepGreen/Holz100). The dowels are placed at right angles to the board layers, at frequent intervals (the spacing scheme is 30 cm lengthways and 24 cm at right angles, whereby the rows of dowels are offset in a lengthways direction, 15 cm from one another). The mechanical join within the board stack elements works using friction between the beech wood dowels and the perforations in the cross-laminated timber elements. The beech wood dowels are kiln-dried and incorporated during the manufacture of the elements, and swell up to the building humidity (approx. 15% ± 3%), so that they adjust to the pressure on the soffits of the holes. No separate component to ensure airtightness is necessary. From the inside to the outside, the exterior wall elements have a total thickness of 32.4 cm (heat transfer coefficient = 0.19 W/m²*K), as follows:

- 25.1 cm dowelled cross-laminated fir wood elements
- 4.4 cm soft wood fibreboard
- 2.9 cm fir wood board layer

The results in a 32 cm thick solid timber element dowelled in crosswise and diagonal layers. The solid wood element consists of an 80 mm thick static core layer and room-side board layers ranging in thickness from 29 mm to 26 mm, applied crosswise and diagonally as fire protective sacrificial layers. The timber used is 95 per cent fir wood and 5 per cent spruce, while the load-bearing solid timber core is grading class S 10 (strength class C 24), in accordance with DIN 4074-1. The average bulk density of the Holz100 element, as a solid timber composite cross-section, is 435 kg/m³. The composite dowels consist of predried beech wood.

On the outer side, the solid timber façade component has board panels with a thickness

Fig. 8: Façade section and floor and ceiling element structure

of 29 mm, inlaid and dowelled with the two soft wood fibreboards (Gutex Multiplex-top), each 22 mm thick. The fire performance of the soft wood fibreboards according to DIN EN 13501-1 corresponds to class E. The nominal bulk density of Gutex Multiplex-top is approximately 200 kg/m³.

Façade

The exterior wood panelling is 26 mm thick, slotted, ventilated board cladding made of untreated larch wood. The formation of the lathing is innovative, with closed 60 cm × 60 cm coffers that act as "small fire compartments". The interior walls, including the dividing walls within the apartments, are dry, mortarless constructions that are not load-bearing or stiffening.

All of the joins within the DeepGreen/Holz100 elements are glueless and purely mechanical. The connections are all non-toxic and meet the requirements for increased noise protection and smoke control.

The elements developed by DeepGreen consist of board layers ranging from 20 mm to 60 mm thick, laid crosswise (horizontally, vertically, and diagonally) on the inside and outside, with a vertical core, and top and bottom cords of 40 and 80 mm connected using beech wood dowels (approx. 20 mm thick) placed in the middle of the grid.

In the factory the exterior walls are fitted with a layer of wind paper, positioned between two board layers. The mechanically compressed and bone-dry hardwood dowels are hydraulically injected, and thus dampened, and take in additional moisture from their surroundings, swelling up inseparably within the wood around them. There is no other gluing, bonding or nails, resulting in a solid timber wall (up to 3 × 8 m in size, with a thickness of up to 40 cm), containing only wood.

The DeepGreen/Holz100 walls used during the construction process were developed specifically for the "WOODCUBE". Like the standard Thoma Holz100 timber walls, these consist of board layers 20-80 mm thick. They differ from standard elements by containing an inlaid soft wood fibreboard (providing insulation), and milled grooves in the individual board layers (integrated structural insulation). They provide macroscopic air cushions without circulation within the wall and reduce the wall's thermal conductivity, thus considerably improving the thermal insulation effect.

In addition, the system was optimised on the basis of comprehensive studies in order to ensure that the building would comply with ongoing regulations for classifying buildings according to the KfW-40 standard. In order to meet the higher requirements envisaged for the "WOODCUBE", an additional 4 cm thick soft wood insulation fibreboard was incorporated into the construction. Overall, the Wohnungsbaukreditanstalt (building society) deemed the project to pass the „hot box test process" and established the dynamic U-value. This is an important step towards ensuring that comparable timber structures will be available for everyone. Such efforts are also being made with regard to the KfW, in order to ensure that stronger support frameworks will be provided on a holistic basis over the whole life cycle of the building, in particular with regard to embodied (grey) energy and the carbon balance. In order to fulfil the requirements for the structural engineering of five-storey residential buildings, solid wood supports were integrated into the load-bearing outer walls, in contrast to the existing regulations.

Floor and Ceiling Elements and Access

The roof structure and the floor and ceiling elements also consist of unglued cross-laminated board elements, to the top and underside of which boards are applied at right angles. These 2.5 cm thick board layers are fastened to the board stack elements with beech wood dowels. The floor and ceiling structure consists of the following elements:

- 6 cm insulating board, including battens and solid wood floor
- 2 cm dry screed elements (glued to the front end)
- Kraft paper as a dividing layer
- 2 cm dry screed elements (placed in the gaps)
- 3 cm footfall sound insulation – Isover Akustic EP1
- 6 cm Fermacell honeycomb paper infill
- Kraft paper as trickle protection
- 23.5 cm Holz100 ceiling

The ceiling elements stretch from the exterior walls to the staircase core built in concrete, to which they are connected by a floating T-square. Ceiling-like joists for the stacked board element supports are positioned in such a way as to take account of the staircase walls and balconies in the case of an extension. This means that the floor surfaces allow for flexible layouts and uses. The joists act as composite cross-sections of the combination of solid timber beams with a vertical

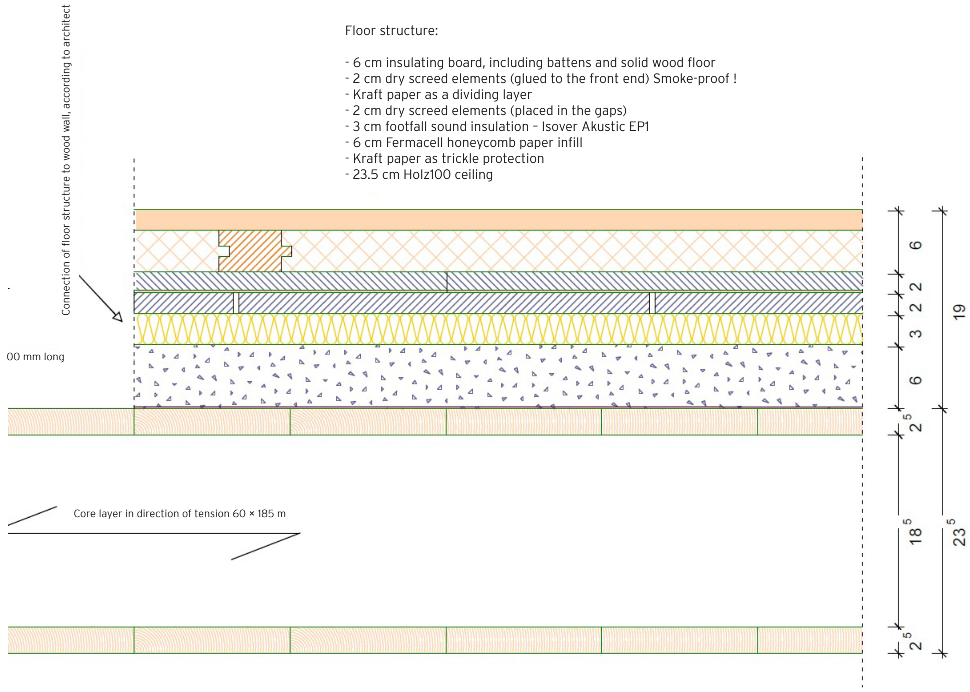


Fig. 9: Floor construction

UPE steel profile. The ceiling elements are attached to the solid wood beams by fully threaded screws, wedged into the steel profile with wooden fillers. The balcony slabs take the form of continuous ceiling elements, designed as cantilevered single-span girders.

In areas of higher loads due to the building components on top of them (in particular, underneath the cantilevered balcony slabs), solid timber supports are integrated into the outer wall structure. In addition, these supports are also found at the joins with the ceiling-like joists for the outer wall structure and as supports for the solid timber window lintels around the medium-sized and large window openings. Below the lintels above the large window openings are more steel beams that act as core support.

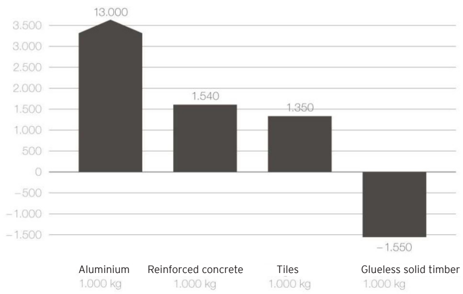
In addition, the upper sides of the floor and ceiling elements have dual-layered dry screed on 60 mm mineral fill and 30 mm mineral fibre insulation in order to ensure noise protection.

On top of this is the floor structure itself, made of solid timber boards on battens. Another soft wood fibreboard lies between the battens.

The central access core was built in class 3 reinforced concrete throughout, as were the walls and stair landings. The flights of stairs were assembled as precast concrete components.

B. 3 Timber as a Smart Material

CO_2 emissions from production (from IBO Ecological Building Materials Catalogue)



Sources: Ecological Building Materials Catalogue of the Institute for Building Ecology (IBO), Vienna. Erwin Thoma: For the Long Term Living and Building with Wood. Verlag Chr. Brandstätter

Fig. 10: Carbon dioxide emissions from solid wood

Sustainability was the key idea behind the "WOODCUBE" project. This informed the decision to use chemically untreated, carbon-neutral wood as a construction material. The "WOODCUBE" is made entirely of wood, with the exception of the foundations and access core. The structure, walls, insulating, materials and surfaces are all timber: wood is a smart material, and the "WOODCUBE" has harnessed its positive properties. The project is aimed not only at ensuring that the building can be run in an energy-efficient way, but also at considering the use of energy in producing the materials, the impact on the health of those who use the building, and the legacy of deconstruction.

Resource Efficiency and Sustainability

This urban timber building, which is free of toxins within the living area, can contribute to environmentally friendly and healthy living. In addition, there is scientific evidence that solid wood has a beneficial effect on the inhabitants.

The "WOODCUBE" is the first five-storey residential building that does not use glue or fire- protective encapsulation. In addition, the building is carbon neutral: no insulating materials that require lots of energy to manufacture were used unless absolutely necessary. All of the building materials can also be disposed of singly or reused. The "WOODCUBE's" concept is optimised with a view to saving non-renewable resources and ensuring that the building can be recycled at the end of its life span.

All of the building components were made of solid wood if this was technically possible. This saved abiotic resources (sand, gravel, cement, etc.) that would have been used for mineral construction, while also saving on non-renewable energy resources. The majority of the energy required for processing timber comes from renewable primary energy (the sun).

During the implementation of the project, great emphasis was placed on maximum recycling potential. Avoiding bonding and sandwich building elements meant that all levels could be divided up again. At the end of the building's life cycle, the resources could therefore be broken down into their different types and used again as building components or materials. This form of recycling represents another strand to the resource efficiency concept, as re-using the materials reduces resource consumption in the future. This is an important factor, as solid construction is not particularly sparing in its use of wood as a renewable resource. At present, this does not present any problems in Germany, as more wood is produced than is consumed. However, in future, and particularly in view of carbon storage and the availability of timber as a resource, the re-use of building elements for ends other than as fuel, as is prevalent today, will become more important. The "WOODCUBE" is an example of a closed material cycle in construction.

The aim is a traceable, material-specific system without hazardous waste. The unglued, solid wood boarded flooring is sealed with linseed oil, while the façade cladding is made of untreated larch wood, the insulating material of soft wood fibreboard, and all of the sealing sheets and tapes have a cellulose base. In order to create a healthy indoor climate without building materials that contain problematic substances, the paints are mineral, the construction panels are designed to purify the air, and the interior doors are tested for harmful substances. Integral windows with a

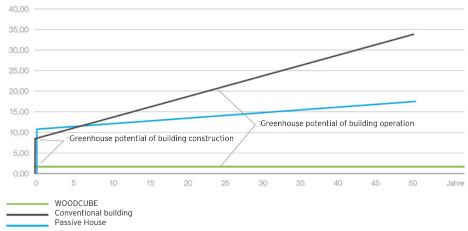


Fig. 11: Global warming potential in kg carbon equivalent /square metre net floor area per year

20 per cent lower aluminium content were installed in order to increase energy efficiency.

The timber used in "WOODCUBE" comes from local forests. By eliminating fire-protective encapsulation, the building components could remain visible on the inside. This meant that there was no need for additional coatings or protective structures, while the indoor climate benefits from a structure that is open to diffusion, with a higher heat storage capacity. The building's structural properties also allow construction without thick insulating material. Nevertheless, this project has similar energy properties to those of highly insulated Passive Houses. The model energy properties demonstrated here, along with the actual energy consumption, come below the calculation values stipulated by lending institutions.

Fire Safety

Given that the floor height of the top (fourth) floor is approximately 12.20 m above the surface at the middle of the site, and the units in use are less than 400 m2 in size, the building meets § 2 (3) of the regulations for buildings in Class 4 (GK 4).

The fire safety requirements for multistorey residential buildings are easily met at the "WOODCUBE", although the relevant building regulations and technical rules do not yet stipulate this level of quality. The building was approved through individual allowances in all areas. Exemptions were granted on the design of the building components in the areas of burn rates, fire protection, and flue gas risk analysis.

Due to the system-dependent features (dowelled cross-laminated timber elements and the outer wall structure with largely non-ventilated façades), specific checks had to be carried out as part of the planning process. These related to the fire safety of the solid wood components, the air-tightness and safety of condensate formation within the outer wall structure, and the façade cladding.

A fire safety concept was set out for the "WOODCUBE" in conjunction with the Technical University of Darmstadt. The conclusion was that wood is three to five times more resistant to fire than concrete or bricks. A thick wooden block does not burn, but only becomes charred on the surface. Wood's fantastic static properties are also retained much longer at extremely high temperatures in comparison with reinforced concrete structures, for example.

The outer wall components are resistant to fire from the inside for more than 90 minutes, due to the inbuilt 84 mm thick sacrificial layers, which burn at 0.9 mm per minute under optimal ventilation conditions. The sacrificial layers delay the fire reaching the load-bearing core layer by approximately 93 minutes. The 80 mm thick load-bearing core layer can be expected to burn through by another 15 mm. The building thus has a fire resistance capacity of about 120 minutes.

For the floor and ceiling elements, the lower cladding of the solid wood elements is applied as a burn-up layer. This reduces the requirements for the stacked board core to 28 minutes. In order to ensure that there is smoke control between the residential units, the upper sides of the floors are completely covered in the product Pro Clima Intello, and professionally joined together and made flush with the walls.

Long-term Cost Considerations

Solid wood supports in the required dimensions and of the desired quality are extremely expensive. In addition, steel bands had to be incorporated into the ceiling layers to create plates and stiffen the structure. Planning the installations, including electricity and sanitary facilities, plays a major role in solid wood buildings. The wooden elements were made in such a way that their quality is visible to the eye, but this required milling in the factory and precise and costly preliminary planning. The façades also presented the planners with major challenges. Ultimately, on the basis of comprehensive supplementary fire safety surveys, structural solutions were found that deviated from the non-flammable materials recommended in the building regulations, instead making it possible to construct a completely timber façade.

However, the prerequisite for this was a non-rear-ventilated façade structure, which required hygroscopic evidence of no structural damage. As a result, the extensive investigation led to a single-material timber structure solution that is the first of its kind in multistorey buildings.

The floor and ceiling elements were specially developed for the "WOODCUBE" project in order to allow spans of up to 500 cm and cantilever arms of approximately 250 cm, while also taking the noise protection and fire safety requirements into account.

"WOODCUBE" is a residential building with freehold apartments. Ongoing conversion work is not envisaged. Nevertheless, the goal is to keep running costs low. For the most part, the known life spans of all of the building components and recommendations on maintenance were taken into consideration, and the most durable types were selected for use. The higher initial investment will be largely amortised through the maintenance costs over the life cycle of the building. When making planning decisions the emphasis was therefore on longevity.

Compensation was made for this higher investment in various areas. For example, there was no need for coatings for most of the surfaces. Visible surfaces can be maintained much more cost-effectively than coatings over time by cleaning or sanding. This also applied to the untreated wood façade cladding, which was shown to be durable in a hygrothermal simulation.

Fig. 12: Test pieces of the solid timber element of the outer wall for WOODCUBE after 60 minutes subjected to a direct flame, at a temperature of approximately 900ºC

B. 4 Building Services Concept

Fig. 13: Wilhelmsburg Central Integrated Energy Network and the area around the WOODCUBE

Heat and Electrical Energy

Energy-saving technology was built into the energy concept in order to support the energy properties and existing resource efficiency of the solid timber system. This incorporated all of the optimisations in terms of requirements, energy efficiency during operation, and user comfort. In addition, all of the building services components are managed from a central unit within the apartments, rather than from a decentralised point. This saves building components and additional routeing.

Room heating and hot water are provided through the "Wilhelmsburg Central Integrated Energy Network". The heat energy thus comes from renewable sources. All of the heating conduits are made of stainless steel, so no composite pipes were installed, allowing materials to be separated in the event of deconstruction. The radiators are designed as optimised heating surfaces and can cope with peak loads. Radiant heating was shown to be preferable for the "WOODCUBE" in comparison with surface heating systems, which were unsuitable due to periods of inactivity and space requirements. The heating requirement is 18 kWh/m2 per year. The actual consumption is being evaluated by the Technical University of Braunschweig as part of an external monitoring project.

All of the apartments within the "WOODCUBE" building have controlled ventilation using façade ventilators with heat recovery, and central control of the living and sleeping areas. Automatic, moisture-dependent control has also been set up in the bathrooms. As part of an ongoing quality agreement with the IBA Hamburg, the building does not include a central ventilation unit. The design, which is open to diffusion, and the manufacturer's 50-year guarantee against condensation problems for the solid wood walls meant that ventilation would have been desirable for reasons of comfort alone. As a result, central ventilation would have been unprofitable. Another reason for doing without it was the aim of leaving as much of the wood visible as possible: if there were centralised ventilation, it would have been necessary to install a suspended ceiling. In addition, there were hygiene concerns with regard to the possibility of cleaning the pipes. Doing without this element also meant savings on maintenance costs.

Solar thermal analysis and optimisation of the exterior shading was carried out in order to keep the inside temperature steady without active measures. This meant that solar protection was applied only to the areas of glass where it was required.

A photovoltaic unit performing at 10kWp was installed on the green roof in order to provide electrical energy. This unit generates 23,000 kWh per year, corresponding to slightly more than the "WOODCUBE's" annual electricity consumption. Excess electricity is fed into the local grid and credited to the building's life cycle assessment. The remaining electricity requirement is currently being purchased from a green electricity provider.

Due to the coverage of the electricity requirement by a photovoltaic unit that feeds the excess power into the local grid, the already low carbon dioxide emissions caused by the heat supply are balanced. The "WOODCUBE" thus operates at a carbon balance.

General lighting is provided by LED technology. The lighting for the staircase and balconies consumes about 1 W. Light sensors are installed in individual rooms and react to the presence of people, thus automatically regulating the brightness of the rooms. The lift is equipped with a braking energy recovery (Kone) system, reducing its energy requirement by a further 60 per cent. The building is also laid with PVC- and halogen-free cables, reducing VOC emissions.

Smart Building Services Controls

All of the building services components can be controlled from central energy control units within the apartments, thus optimising living conditions and the level of consumption. All of the fans, blinds, actuators, radiators and window contacts are linked to one another, enabling smart metering via the ad hoc capture of electricity consumption through visualisations made by the Fraunhofer in-house system.

In every apartment several wirelessly networked Alpha Eos system sensors are installed in order to control the indoor air quality and heating curve. The energy for the signals is generated from sunlight and transmitted without any electromagnetic emissions. The building thus incorporates completely mains-free power, avoiding electrosmog.

B.5 Planning Process

Fig. 14: Visualisation from the first competition stage

Fig. 15: Visualisation following the project revision

Competition

In the first part of the two-stage "Smart Price Houses" competition, launched in late 2009, a planning team of architects and home technology experts developed a concept envisaging the "WOODCUBE" as a cost-effective, four-storey residential building designed especially for joint building ventures, based on glueless cross-laminated timber construction. The free layouts around a central access core formed part of the initial design. By implementing the building in timber and mixed construction, with an energy standard 30 per cent below the level stipulated in the energy conservation regulations (EnEV), the "WOODCUBE" was to serve as a model design in the "Smart Price Houses" category.

The striking architectural concept and emphasis on the use of largely prefabricated timber as a building material qualified the "WOODCUBE" as a "Smart Price House" in the eyes of the jury. The low-tech charm of the project convinced the Büro Institut für urbanen Holzbau (IfuH) that it merited this distinction, along with the major achievements of making the building Passive House standard, while ensuring flexibility in the layout design and low costs.

Constructed for a joint building venture, the project was not associated with a group of developers. As with many other smart material projects, the IBA Hamburg GmbH took on the task of approaching investors about the "WOODCUBE". However, both building contractors and developers voiced concerns about the timber construction in relation to noise protection, fire safety, and the intrinsic value of the material.
In the course of these discussions, the planning was revised in various respects. For instance, consideration was given to having a mezzanine floor instead of the large communal roof terrace put forward by the joint building venture.

In October 2010 DeepGreen Development GmbH entered into partnership with the P&P AG construction company, under the auspices of the project company WOODCUBE Hamburg GmbH, as investors in the project. Together with the IfuH, the project and the work that had gone into planning it moved from the competition stage to implementation.

Change from "Smart Price" to "Smart Material" Classification

In the first stage it was, however, ascertained that various concepts from the competition submission would not be feasible in construction terms or within the economic constraints of the project. The 2.5 metre freely overhanging balconies, for example, could not pass a statics test. Sound risks could not be eliminated. Fire safety requirements made the project more expensive and would have destabilising effects on the structure.

Fig. 16: Construction phase (November 2012)

Fig. 17: Construction phase (December 2012)

The construction partners could provide neither guarantees nor cost certainty. DeepGreen therefore took over all shares in the company and revised the project from scratch with the aim of fulfilling the development goals of the IBA, such as creating a sustainable model building that responded to climate change etc. as fully as possible.

DeepGreen put the emphasis on long-term stability, as far as possible, and maximum environmental friendliness. The aim was a largely chemical-free, single-material timber construction, with simple manufacturing and maintenance processes. The project was to serve as a model of solid timber construction. It was required to meet the highest noise protection and fire safety requirements, without using conventional encapsulation or compensatory fire protection measures.

For this reason, DeepGreen decided to use wood wherever possible. This meant that the original construction concept of additional insulated and glued cross-laminated timber walls had to be revised.

DeepGreen now took the decisive step of developing the project concept and sought to construct a building that made use of very few different materials, while remaining as free of toxic substances as possible and ensuring that the building components could be re-used. Encapsulation was completely avoided for the walls and ceilings (originally only the undersides of the ceilings were to have remained visible).
Cooperation between DeepGreen, IfuH, and the rest of the competition team broke down over these decisions. The Stuttgart-based firm architekturagentur was commissioned to implement DeepGreen's ideas in planning and technical terms. The company Holz100 was brought in on the manufacturing side, as it had already carried out a number of innovative solid timber projects, particularly in Austria.

DeepGreen developed their solid wood elements in conjunction with various universities and specialists, and came up with a building system that could be replicated elsewhere.

While the project complied with the concept agreed with the IBA and all seven of the "IBA Excellence" criteria, the choice of building materials was changed, with the agreement of the IBA, for reasons of sustainability and long-term affordability. Adaptations were made to details relating to the choice of timber construction system, building services, certification for the materials used, and aspects such as ventilation.

As a result of the changes made, the construction of the "WOODCUBE" used about 70 times less energy than the creation of a conventional building. The originally calculated costs had to be adjusted due to these changes. It was therefore agreed with the IBA that the concept would run

Fig. 18: Construction phase (January 2013)

under the banner of "Smart Materials" rather than "Smart Price".

The main changes in the planning phase were:

- Originally, only the structurally necessary parts of the walls were to be constructed with glued solid timber. This was revised so that the whole wall element would be built of glueless solid timber.
- Heat insulation was to be provided by conventional insulation in the load-bearing solid timber layer. This was revised so that the insulation would be provided by additional solid timber and wood fibreboard insulation.
- The wood was originally to have been made visible through a transparent fire protection layer. This was revised so that additional untreated wood layers would act as sacrificial layers, part of the walls' fire protection system.
- The wood façade was originally to have been rear-ventilated and built with horizontal fire-protective sheets. The project was ultimately implemented with a wood façade containing separate air pockets. The coffer arrangement of the substructure meant that each coffer formed a "fire cell", providing the necessary gaps. This mean that the horizontal metal sheets were no longer required.
- Carbon balance: due to the measures mentioned above, the proportion of timber used was much greater than originally planned, with the result that the amount of embodied (grey) energy, i.e. that used to construct the building, was greatly reduced. This had an impact on the carbon balance of the building. About 70 "WOODCUBEs" could be produced and constructed using the same amount of carbon emissions as those produced by the construction and use of a conventional building over 50 years.

As a result of these changes, construction of the walls and floor and ceiling elements began only in November 2012. The high level of prefabrication of the timber construction elements meant that only three weeks were required for building the shell structure, so that the "WOODCUBE" was finished as early as May 2013, including all the interior work, after a total of only seven months of construction.

B.6 Assessment

Fig. 19: Interior, ground floor

The "WOODCUBE" is the first carbon-neutral multistorey residential block in building class 4 to be constructed without toxic substances and to have the wood completely visible from the inside. As such, it constitutes a new timber construction system for urban settings that is resource-conserving, healthy, and long-lasting.

The experience gained as part of the implementation of the "WOODCUBE" prototype will be further developed and made marketable as a system building. This will involve new quality for timber construction, with a modular assembly system that brings various structural properties together at eexemplary prices. The different structural aspects are thus integrated with cost certainty and sound planning. Construction ecologists, architects, and structural engineers have worked together to devise a sustainable and healthy multistorey system building that is unparalleled on the market. DeepGreen Development has risen to the task of making the timber construction marketable by providing its own sales and information line. As a result, exclusive commercial partnerships have been agreed with various timber element manufacturers. DeepGreen is therefore managing the "WOODCUBE" as a reference building that will remain partly accessible to interested planners and contractors after the end of the IBA Hamburg 2013.

Timber Construction and Fire Safety

In the recent past, dowelled and mechanically joined solid wood elements such as those employed in the "WOODCUBE" were used only in environmentally friendly detached houses or various niche buildings. The "WOODCUBE" enters new territory by incorporating an exterior wall structure that contains dowelled cross-laminated timber elements as airtight building components, without the need for additional measures such as airtight pathways or engineered wood board.

The use of solid wood construction is also a novelty in Hamburg: this type of development is not provided for in the city's building regulations or those in force in other states (cf. the White Paper "Urbaner Holzbau" – Urban timber construction). Approval had to be sought for various individual cases before the project could be implemented. Ultimately, the project made recourse to building regulations that have been in force for several years in Switzerland.

Fig. 20: View from the northeast, from a neighbouring building (June 2013)

This was the first time that an unencapsulated, solid timber construction has been implemented for a class 4 building. Experts advised on the heating system design, burn-up approach and risk assessment of fire loads and smoke build-up. New construction principles were established for the façades, and these also comply with fire safety requirements without detriment to the single-material nature of the construction: the façades were developed with ventilated cavities in small-scale sections. This split up the partitioning required for fire spread into several sections.

The load-bearing wall components were optimised so as to comply with all of the requirements. This has resulted in a system component that brings sustainability, fire safety, and favourable energy properties together in synergy, while maintaining the strict single-material approach. This saves resources while ensuring a high level of efficiency.

The knowledge gained through the building process is currently being further developed. The aim is that in future projects the staircase core will also be made of wood. It is also hoped that the floor and ceiling elements can be developed in order to achieve larger spans and lower construction costs.

Energy Standard

TSB Ingenieurgemeinschaft drew up an energy saving plan for the "WOODCUBE", in compliance with the 2009 energy conservation regulations (EnEV). Passive House certification, which had originally been one of the "WOODCUBE's" goals, was no longer part of DeepGreen's agenda after switching to solid wood construction, as glued insulating materials and airtight levels that prevented diffusion would have been necessary. Such requirements for the building's shell directly contradict "WOODCUBE's" holistic approach, which is based on sustainable construction that is free of toxic substances. This once again demonstrates the need for the rigid rules of the energy conservation regulations (EnEV) to be revised.

The Thoma Holz100 system, which was thermally optimised in collaboration with various experts, now makes it possible for the "WOODCUBE" to achieve the KfW-40 standard. As several studies show, the considerable advantages offered by

Fig. 21: Interior, ground floor

the positive material properties of solid wood construction in terms of energy efficiency cannot be attained through conventional methods. The actual energy consumption is likely to be similar to that of a Passive House. If we look at the building's energy requirement purely in terms of the numbers, it comes to 18 kWh/m2 per year, which is roughly equivalent to the Passive House standard.

Process Evaluation+

The stated aim of the IBA Hamburg has always been to implement tha project using the team that won the competition. This did not happen in the case of the "WOODCUBE". However, the new team put together by DeepGreen thoroughly matched the quality of that in the competition.

Since repeated attempts were made throughout the project to implement genuine innovations, the planning process often reached a point where the whole project came into question. The restructuring within the project company also led to delays in the planning process. Ultimately, the project benefited from the difficult circumstances that it underwent on the way to its final concept, and the "WOODCUBE" makes an outstanding contribution to sustainable building typologies, while venturing far beyond prevailing construction standards and the current discourse surrounding sustainability in architecture. It is worth noting that the project did not receive the German Sustainable Building Council (DGNB) Gold Seal. This would have been possible if a preliminary investigation had been carried out, as its consistent environmental focus would have met the sustainability criteria, with energy savings of up to 95 per cent. After discussions with the DGNB, DeepGreen turned down the Gold

Fig. 22: Entrance area, ground floor

Fig. 23: View from the east, southeast end of building

certification on the basis that it did not want the "WOODCUBE" to be placed in the same category as other buildings that had received the Gold Seal. Nevertheless, the DGNB nominated the "WOODCUBE" for the 2013 German Sustainability Prize, which it shared with two other buildings.

Wood has been used as a construction material for thousands of years. Through a smart approach and the use of highly modern technology, it has been transformed into a smart material that can define inner city housing construction. The "WOODCUBE", developed as part of the IBA Hamburg 2013, is a prominent example of this approach.

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