Book of Full Papers

sb13 munich

Implementing Sustainability – Barriers and Chances

Sustainable Building Conference
Munich April 24-26, 2013

Fraunhofer IRB Verlag

sb13 munich

Implementing Sustainability – Barriers and Chances

April 24-26, 2013

Organised by

Conference Organisers

Prof. Dr.-Ing. Gerd Hauser (Technische Universität München, Fraunhofer Institute for Building Physics)
Prof. Dr.-Ing. habil. Thomas Lützkendorf (Karlsruhe Institute of Technology, iiSBE)
Prof. Dr.-Ing. Natalie Eßig (University of Applied Sciences Munich, Fraunhofer Institute for Building Physics)

In Cooperation with

Federal Ministry of Transport, Building and Urban Development, Hans-Dieter Hegner
Deutsche Bundesstiftung Umwelt, Sabine Djahanschah

Organising Committee

Lukas Ackermann
Franz-Josef Balmert
Robert Burkhard
Sabine Djahanschah
Janis Eitner
Annette von Hagel
Hans-Dieter Hegner
Oliver Heiss
Prof. Dr. Roland Krippner
Dr. Johanna Leissner
Nicole Schneider
Nadja Schuh
Prof. Dr. Klaus Sedlbauer
Dr. Heinrich Schroeter
Wolfgang Stoermer
Jan Struck

Editorial Team

Prof. Dr. Natalie Eßig
Matthias Heinrich M.Sc.
Ahmed Khoja B.Sc
Simone Magdolen B.Sc

Edited by: Hauser, G.; Lützkendorf, T.; Eßig, N.

ISBN (E-Book): 978-3-8167-8982-6

Programme Committee

Sabine Djahanschah (Germany)
Prof. Dr. Thomas Hamacher (Germany)
Prof. Dr. Gerhard Hausladen (Germany)
Prof. Dr. Hermann Kaufmann (Germany)
Prof. Dr. Werner Lang (Germany)
Prof. Dr. David Lorenz (Germany)
Prof. Dr. Thomas Lützkendorf (Germany) (Chair)
Prof. Dr.-Ing Harald Müller (Germany)
Prof. Markus Neppl (Germany)
Prof. Dr. Frank Schultmann (Germany)
Prof. Andreas Wagner (Germany)
Prof. Dr. Stefan Winter (Germany)
Prof. Dr. Josef Zimmermann (Germany)

Conference Office

Prof. Dr. Natalie Eßig (Chair)
Matthias Heinrich
Ahmed Khoja
Simone Magdolen
Paul Mittermeier

Scientific Committee

Franz Josef Balmert (Germany)
Prof. Dr. Luis Braganca (Portugal)
Dr. Sven Dammann (Belgium)
Dr. Jan de Boer (Germany)
Sabine Djahanschah (Germany)
Prof. Dr. Manuel Duarte Pinheiro (Portugal)
Sebastian Eberl (Germany)
Melanie Eibl (Germany)
Dr. Finn Englund (Sweden)
Hans Erhorn (Germany)
Prof. Dr. Natalie Eßig (Germany)
Prof. Dr. Wolfgang Feist (Austria)
Prof. Dr. Norbert Fisch (Germany)
Matthias Fischer (Germany)
Tajo Friedemann (Germany)
Andrea Georgi-Tomas (Germany)
Prof. Dr. Vanessa Gomes (Brazil)
Dr. Roland Göttig (Germany)
Dr. Gunnar Grün (Germany)
Dr. Annette Hafner (Germany)
Dr. Linda Hagerhed Engman (Sweden)
Prof. Dr. Petr Hájek (Czech Republic)
Dr. Tarja Hakkinen (Finland)
Prof. Dr. Thomas Hamacher (Germany)
Joost Hartwig (Germany)
Prof. Dr. Gerd Hauser (Germany)
Prof. Dr. Gerhard Hausladen (Germany)
Matthias Heinrich (Germany)
Oliver Heiss (Germany)
Prof. Dr. Runa Hellwig (Germany)
Dr. Eckhart Hertzsch (Germany)
Dr. Kati Herzog (Germany)
Dr. Markus Hiebel (Germany)
Daniel Hiniesto Muñoz de la Torre (Spain)
Prof. Dr. Andreas Holm (Germany)
Sebastian Hölzlein (Germany)

Hermann Horster (Germany)
Frank Hovorka (France)
Pekka Huovila (Finland)
Prof. Dr. Kazuo Iwamura (Japan)
Andreas Kaufmann (Germany)
Nicolas Kerz (Germany)
Ralf Kilian (Germany)
Lars Klemm (Germany)
Prof. Dr. Jens Knissel (Germany)
Holger König (Germany)
Prof. Dr. Oliver Kornadt (Germany)
Dr. Michael Krause (Germany)
Prof. Dr. Roland Krippner (Germany)
Dr. Martin Krus (Germany)
Dr. Hartwig Künzel (Germany)
Prof. Dr. Werner Lang (Germany)
Nils Larsson (Canada)
Dr. Johanna Leissner (Belgium)
Prof. Dr. Philip Leistner (Germany)
Richard Lorch (UK)
Antonin Lupisek (Czech Republic)
Prof. Dr. Thomas Lützkendorf (Germany)
Prof. Dr. Anton Maas (Germany)
Dr. Florian Mayer (Germany)
Prof. Dr. Miguel Mitre (Spain)
Dr. Andrea Moro (Italy/UK)
Dr. Isabell Nehmet (Germany)
Prof. Dr. Markus Neppl (Germany)
Dr. Sylviane Nibel (France)
Prof. Dr. Bjarne Olesen (Denmark)
Sumee Park (Germany)
Alexander Passer (Austria)
Dr. Bruno Peuportier (France)
Dr. Michael Piasecki (Poland)
Dr. Michael Prytula (Germany)
Cornelia Reimoser (Germany)
Dr. András Reith (Hungary)
Thomas Rehn (Germany)
Dr. Britta von Rettberg (Germany)
Dr. Wolfgang Rid (Germany)
Prof. Dr. Carsten Rode (Denmark)
Doris Rösler (Germany)
Dr. Stefanie Rössler (Germany)
Andreas Rößler (Germany)
Prof. Dr. Ronald Rovers (Netherlands)
Thomas Rühle (Germany)
Christina Sager (Germany)
Dr. Nikos Sakkas (Greece)
Christian Schittich (Germany)
Dr. Dietrich Schmidt (Germany)
Dr. Eva Schmincke (Germany)
Dr. Carmen Schneider (Germany)
Dr. Heinrich Schroeter (Germany)
Dr. Dirk Schwede (China)
Prof. Dr. Klaus Sedlbauer (Germany) (CHAIR)
Martin Shouler (Great Britain)
Dr. Marjana Šijanec Zavrl (Slovenia)
Eva Sikander (Sweden)
Simone Steiger (Germany)
Gencay Tatlidamak (Germany / Turkey)
Dr. Dieter Thiel (Germany)
Vinh-Nghi Tiet (France)
Joel Ann Todd (U.S.A)
Martin Townsend (UK)
Prof. Dr. Martin Treberspurg (Austria)
Dr. Wolfram Trinius (Germany)
Prof. Dr. Holger Wallbaum (Switzerland / Sweden)
Christian Wetzel (Germany)
Prof. Dr. Stefan Winter (Germany)
Bastian Wittstock (Germany)
Holger Wolpensinger (Germany)
Wim Zeiler (Netherlands)
Bruno Ziegler (France)
Prof. Dr. Josef Zimmermann (Germany)
Prof. Dr. Peter Zlonicky (Germany)

Cooperation Partners

DBU

Federal Ministry of Transport, Building and Urban Development

Organising Committee

BAUINDUSTRIE BAYERN

Bayerische Architektenkammer

Bund Deutscher Architekten BDA

BUNDESARCHITEKTENKAMMER

Bayerische Ingenieurekammer-Bau
Körperschaft des öffentlichen Rechts

Fraunhofer

Bundesanstalt für Immobilienaufgaben

bauKULTUR BUNDESSTIFTUNG

Partner

DGNB®
Deutsche Gesellschaft für Nachhaltiges Bauen e.V.
German Sustainable Building Council

International Co-Sponsors

iiSBE

UNEP Sustainable Buildings and Climate Initiative
Promoting Policies and Practices for Sustainability

cib

FIDIC

Table of Content

CompactHabit: Sustainable mass modular building construction

Paco Conde
Partner
CompactHabit
Spain
paco.conde@compacthabit.com

Summary

CompactHabit has introduced the eMii system (the Spanish acronym for “integral industrialized modular building”) to enable the large-scale production of finished modules. The system entails the manufacture of three-dimensional monolithic modules of reinforced concrete. They are routed through an assembly process of the various components, building services and materials until they leave the production facility fully equipped and with the interior finished to customer specifications.

The production solution adopted for the CompactHabit module involves the manufacture of a single piece of concrete in two braced stages. To achieve this, a mould was developed, as well as proprietary formwork that enables horizontal concreting phases, thereby solving the problem of mix placement from above. The mechanical formwork can be adapted to different lengths and widths.

The module’s structural element is a ribbed concrete prism that varies in size depending on the project. This structural element serves as the frame for the rest of the features: façades, installations, flooring, interior cladding, kitchen, baths, appliances and so on. The module is transported by semi trailer to the new location of the building. The semi trailer takes the dwelling unit to the building site, where a heavy load crane sets it in place.

Once the modules are in place, they are connected to each other and the vertical utilities services are installed on the outside with no need to access the interior. Using this procedure, we can compose buildings of up to eight stories without any additional structures. In addition to the speed involved in assembly, this structural system also represents a considerable improvement in the building’s response to seismic movement. As independent structural elements, a certain amount of movement can occur without creating structural cracks or breakage. The modules fit together with elastic joints and are subsequently screwed together at the joints to facilitate dismantling the modules if necessary. At CompactHabit, we can dismantle a building and move it somewhere else in exactly the same manner as we built it. We can take it back to the factory to replace worn elements, change finishes, repair flaws and put the building back into use. It would even be possible to temporarily place buildings on sites destined for another use in the long term. The concept of a “nomadic”, demountable building opens up new opportunities in land management.

Keywords: Sustainable; modular; building; industrialization

1. Product and Process innovations

The eMii modular building system allows rationalize and standardize process, materials and constructive solutions, and it is based on:

1.1 eMii structural system

It is based on a reinforced concrete self-supporting chassis, involving the development of joints between modules which makes the building structure as floating. This chassis behaves as containing the constructive components implanted within an assembly chain. This structural system is exclusively owned by CompactHabit, and no competitor offers similar solutions in terms of structural system and module size (max 15 x 5 x 3,5 m). Similar solutions offered only reach basic three-dimensional systems, with limited size (6 x 3 x 2,8 m) and without floating joints available. The structural system is protected by international PCT.

1.2 eMii industrialized system

The manufacture process is composed by two main procedures, (1) the chassis construction and subsequently (2) the chassis displacement to the work stations distributed along the assembly chain. This path is aimed at standardizing the module to as much components of the building as possible within the same area, allowing thus a reduction of the interventions at the building site. Along the path the system provides such flexibility that allows the introduction of any further technology planned. Although the modular industry include further manufacturers specialized in industrialized edification, nevertheless the assembly chain is not used, while a building assembly method similar to the traditional construction is used, but located within an industrial factory. In some cases of lightweight construction this allows the increase the industrialization degree, connecting the production needs with large series. On the contrary the eMii system uses an assembly chain process similar to the cars production but limited by the reduction of the series of production, reaching in this way the maximum optimization of processes.

1.3 eMii assembly system:

The assembly system, based on large industrialized components, is not integrated in any other company within the industrialized edification sector, being used smaller components. The eMii solution allows assembling with high speed and precision any building within its production. The increase of the modules size directly influence the joints reduction, reaching a higher degree of the interior and external finish still in the factory, meaning greater speed and minimum intervention at the building site.

Fig. 1: Large-scale production of CH modular units

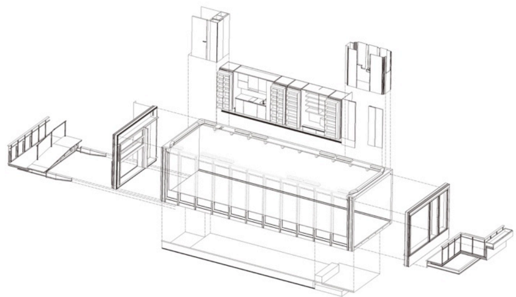


Fig. 2: The dwelling elements

Fig. 3: CH modular unit

Fig. 4: Student dormitory built with CH modular units in Girona, Spain

2. Description of eMii advantages

The eMii advantages can be broken down into several categories:

2.1 Reinforced structure

The use of the reinforced concrete structure produces a monolithic building, meaning important added values for it such as sound insulation, thermal inertia, fire resistance, earthquake resistance, and durability. Among the industrial systems commonly used, the lightweight construction is outstanding but not able to provide the same performance as the eMii system, characterized by high robustness of the structure together with the industrialization of large modules built as finished parts constituting the building. While other manufacturers often work with 2.5 m widths, the developed system can reach 5 m width, thus reducing the assembly time and finish work.

2.2 Structural system self-supporting floating modules, with anti-seismic capacity.

The developed structural system is unique in the world. It proposes a modules stacking system using union system and floating supports. This feature allows each building unit to be independent of its adjacent (elastic unions) involving a great improvement in acoustics, seismic resistance and adaptability of the structure to the movements of the building. This flexibility allows a better absorption of the deformations produced by an earthquake and prevents breakage of the structure. The system joints and elastic elements cause a break in the continuity of structure preventing the structure breaking: that structure is ‘previously fractured in a controlled way’, meaning a strong difference with other industrialized systems, which are mainly based on rigid joints.

2.3 Elastic seismic structural system resistant to fire.

The use of elastic elements of steel within developed system ensures the system durability and resilience to fire situations. Commonly used resilient systems are based on neoprene, meaning a great risk in case of fire, because these systems can merge and lose effectiveness to seism after a fire. Furthermore, neoprene manufacturers provide no guarantees in years of durability but only data on resistance to ozone, not allowing a conversion to years of durability. On the contrary, eMii includes joints and system structure able to double the structural life of the building, according to the current regulation, contributing thus to the building life cycle improvement.

2.4 Industrialized modules dry assembly

The building joints and assembly elements are mechanical, neither mortars nor concrete are thus needed. The system presents a relevant speed, due to the large size and easy assembling. Unions are simply gravity connection between modules with hardware and elastic joints. The building as it grows it becomes structurally finished. Structural additions are not required. The structure is self-supporting up to 8 floors. The crane assembly capacity in site will be of 500 m^2 to 1.000 m^2 per day (1 shift), depending on the project.

2.5 Flexibility: building relocatability and reuse.

The resolution of dry joints allows the dismantling of the building at any time since the modules can be recovered without any alteration or damage in the action. The recovered module can be used in another building without modifying or rehabilitating it if needed: a concrete-framed building, removable and transportable generates a new concept of building.

2.6 Industrial quality.

The industrialized building process allows continuous monitoring of quality, very different to those used in traditional construction. Industrialization will ensure the product traceability, impossible to implement in other building systems. The building process and the subsequent quality control allow higher legal requirements for quality, meaning a general improvement in standards without increasing costs.

2.7 Standardization

The industrialized production enables the standardization of materials, components and construction solutions, simplifying the supply chain by encouraging stable relationships with suppliers and approaching economies of scale scheme.

2.8 Procurement.

Increases the ability for collaboration and single point of responsibility.

2.9 Design process.

Wide-ranging benefits of increased collaboration and flexibility.

2.10 Financial - cost control.

Lowers hard costs, soft costs, financing costs, out-of-service costs, and provides a faster return on investment.

2.11 Construction schedule.

This construction system also reduces considerably the time of the construction process, achieving execution times ranging between 25% and 30% of one built with traditional systems.

2.12 Security at work.

The application of industrial processes in the construction of a building means a significant reduction in accident rates and improved conditions at work.

2.13 Comfort - Insulation and acoustics.

The floating structural system and the double walls and floors allow an outstanding insulation, well above the legal requirements: increasing the insulation requirements means a technological innovation directly associated with economic viability. In fact, an improvement in the acoustic performance within the whole economy of the building means an innovation in the construction process. The interior acoustic treatment is realized under the same criteria. Both concepts, insulation and acoustics, are critical for comfort and wellbeing.

2.14 Environmental impact reduction.

The eMii building process is designed under criteria of deconstruction, control and waste reduction: for every 100 kg of waste generated in traditional construction, with the eMii system will be less than 28 kg for the completed building; the thermal and acoustic insulation of each module maximizes further the energy efficiency in use, significant savings in consumption, allowing the “A” energy certification for buildings; in the whole life-cycle of the building it is expected in terms of energy savings and CO_2 reduction up 35% up to 60%.

ENVIRONMENTAL ADVANTAGES AND SUSTAINABLE BUILDING

Compact Habit substantially improves the levels of technical, functional and environmental quality of buildings. With this system the ecological footprint (energy consumption and CO2 emissions) of a building is reduced by 35% compared with the same building constructed using traditional systems. The installation of photovoltaic panels means Compact Habit only consumes 35% of the energy it generates.

The thermal and acoustic insulation of each module maximises its' users comfort, and the energy efficiency achieved, in addition to significant savings in consumption, has led it to obtain the maximum building energy certification.

ENERGY SAVINGS

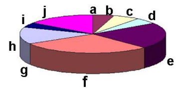
The Compact Habit factory has its own solar plant producing electrical energy with the capacity to generate 468,465 KWh of net energy per year with CO2 savings equivalent to 219,073.44 kg (Spanish mix). We are conscious of the environmental problems of the earth. Compact Habit joins to companies that provide specific solutions to the environmental problems of the present and the future.

The very nature of industrial production favours the ongoing optimisation of processes and is without doubt an essential factor for savings in energy and resources.

WATER SAVINGS

The optimisation of resources inherent to an industrial production system also affects water. The water savings achieved in the industrial construction process of Compact Habit compared to conventional systems is approximately 20%.

Extraction and manufacture of materials



Materials*

Percentage of emissions of kgCO2/m2

a. Pegging out and earth-moving	0.00%
b. Foundations and retaining walls	4.84%
c. Common spaces	5.69%
d. Conventional roof	5.15%
e. Structure(1)	21.95%
f. Façades	28.74%
g. Interior partition walls	0.00%
h. Interior finishes	14.19%
i. Terraces	4.26%
j. Building services	15.19%

1) Includes the correction of concrete dosage and the net energy of the photovoltaic panels at the CH factory.

*Data based in Manresa Building.

MATERIALS AND CONSTRUCTION SYSTEMS

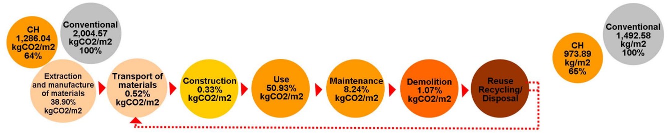
Using the automotive sector as a reference, the process for the production of CH modules consists, firstly, of the manufacture of a structural chassis of reinforced concrete, which is placed on a production line and equipped with all its components (coverings, building services, joinery, façades, etc.), resulting in a completely finished building module.

This process allows rigorous management and coordination of all tradespersons involved in the process, optimising processes, minimising unforeseen circumstances and providing value to the construction sector with the concept of "ongoing improvement".

Similarly, due to the speed of the construction system and the fact it is an industrialised process, the construction materials used must be placed using dry construction (quick and easy placement, no drying time, easy maintenance, good waste management, etc.).

WASTE

In an industrial process like that of Compact Habit, waste management is fundamental and it is much easier to establish a system for it than in regular construction processes. In our case the construction of homes is linked to strict requirements in the industrial world regarding waste. The separation, classification and possible reuse of waste is perfectly studied at the facilities of Compact Habit where all these processes are studied from the point of view of the complete process and where one of the most important objectives is to close the life cycle of the majority of the materials involved in the construction.



Location . . .

The ground floor of the north building is 3 metres higher than the south building (common spaces for services). This lets more light into the north building.

Energy . . .

Winter: gain of solar radiation and reinforcement of thermal insulation.
Through the south glass façade, solar radiation is gained. The other faces are especially insulated to avoid energy losses (façades with 90 mm of mineral wool and roof with triple layer of insulation).

Passive systems . . .

Summer: solar protección

The solar protection on the south façade is a fixed cantilever and with adjustable slats. The rest of façades are ventilated, as is the roof (to dissipate the solar radiation). The homes face both north and south, so they have cross ventilation.

Water consumption . . .

Reduction of consumption by means of a flow reduction system (taps, dual flush toilets) and reuse (both grey water from sinks for toilets, and rainwater for irrigation).

Waste . . .

The CH system has different advantages that reduce the production of waste in the demolition of the building: the home itself has less kg/m2 of material than the same building built using a conventional system; the structure is calculated to last 100 years, double of the average life of a building; and the use of dry materials facilitates their separation in a controlled environment such as a factory, for reuse and recycling.

Data from the study "Life Cycle Assessment, comparing Compact Habit and conventional buildings" by the company "Societat Orgànica". Final report: 25 September 2008.

sb13 munich

Implementing Sustainability – Barriers and Chances

24 - 26 April 2013

Fraunhofer IBP · KIT Karlsruhe Institute of Technology · TUM

Best Poster Award

to

Paco Conde

For a very significant contribution in the field of Building sustainability entitiled:

„Compact Habit: Sustainable mass modular building construction"

and published in the proceedings of sb13 munich conference

Munich 26 of April 2013

Prof. Dr. Gerd Hauser
Technische Universität München,
Fraunhofer IBP

Prof. Dr. habil. Thomas Lützkendorf
Karlsruhe Institute of Technology KIT

Prof. Dr. Natalie Essig
Munich University of Applied Sciences,
Fraunhofer IBP

In Cooperation wilth:

DBU Deutsche Bundesstiftung Umwelt

Federal Ministry of Transport, Building and Urban Development