Ideas, projects and models for the first building in Carbon Concrete Composite

International Design Workshop at the HTWK Leipzig · 25th-29th September 2017

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The A2A workshop (Ascoli to Aachen) was founded in 2013 by Monica Rossi and Horst Fischer with the aim of creating a meeting and collaboration opportunity between Italian and German architecture students, from the University of Camerino (UNICAM) and the University of Applied Sciences of Aachen (FH Aachen). Since 2016, also students from the college of Civil Engineering (specialization in building construction) of the HTWK Leipzig University of Applied Sciences take part in the workshop; that changed the workshop’s name to AAL (Ascoli, Aachen, Leipzig).

The workshop has as main purpose the exchange of knowledge, skills, and experience. Students are involved in an extracurricular design activity in which mixed groups (with students coming from the different involved universities) elaborate in few, but very intensive days a project proposal about a specific design theme chosen by the host university.

Working in international and multidisciplinary teams is a unique experience for students who have the opportunity to collaborate with other students who for training and origin have a very different approach to the design of the built space.

It is not easy to achieve a design solution when the designers have different backgrounds. However, at every edition, the “magic” repeats itself: after the first moments of skepticism, teams are formed, and students work intensively for a few days to produce extremely interesting project proposals where it is possible to find the fusion of knowledge and skills in which everyone has learned something from the other.

“In contrast to us engineers, who start from the functional program to design a building, architects design looking at the building from the outside and creating a shape. In this workshop, I met professions different from mine, I learned to respect them, and I understood that there are many approaches to the same problem. This knowledge will surely be useful for my future work.”

Consideration from a student of the HTWK after the AAL workshop 2017

In the fourth edition of the AAL-workshop, held from 25th to 29th September 2017 at the HTWK Leipzig, an interdisciplinary design theme “CUBE: the first building in Carbon Concrete Composite” was chosen. To elaborate this theme properly, multiple skills are required, e.g. aesthetical and structural design, materials and components knowledge. This small book presents the results of 4 days working together at the AAL-workshop 2017.
Today, more than half of the world’s population lives in cities; by 2050 it is expected to be two-thirds. Thus, the densification of urban areas increases sharply, which in turn leads to high demand for resource and area-efficient facade constructions.

Also, building envelopes will have to be made even more energy-efficient in the future, as all buildings in the EU have to be constructed as nearly zero energy buildings from 2021 onwards. The material most commonly used in construction worldwide is concrete (after water). The concrete construction requires a high consumption of raw materials and causes enormous CO₂ emissions. The production of cement alone accounts for 6.5% of carbon dioxide emissions in the world. The aim must, therefore, be to reconsider classical reinforced concrete construction fundamentally. Against this background, the TU Dresden developed the vision of replacing the corrosion-susceptible steel in the concrete with non-corroding carbon reinforcement in a sustainable concrete matrix. The thick concrete layer, which protects the steel from corrosion, can be omitted when using carbon reinforced concrete. Consequently, it is possible to build lighter, free-form structures using less material than with traditional construction methods.

The carbon reinforced concrete is a composite of high-performance concrete and carbon fiber reinforcement (as strips or rods). The composite material exhibits advantageous characteristics. From an architectural point of view, the free formability, color choice and surface structure of single and multi-layered components are of interest. Also, there is a wide range of choices regarding format. Even large formats are feasible today. First prototypes, such as the vakutex façade (vacuum-insulated textile-concrete façade), shown in the picture, demonstrated good sound insulation properties. Furthermore, the elements are passive house compatible. Currently, investigations have been carried out to determine the fire resistance period. During preliminary experiments, the building material class A2 was achieved. To ensure the affordability of the new construction methods, a fully automated manufacturing process has been created. There are big cost savings resulting from the transport and installation of the carbon concrete components due to its lightweight nature. Ecological advantages result from the reduced use of cement; the substantially slimmer components also reduce the surface seal. Even today, it is clear from the requirements described at the beginning that using carbon reinforced concrete will enable a new, future-oriented construction that can make a valuable contribution to the sustainable concrete architecture of densely populated urban spaces.
The largest research project in the German construction industry “C³ – Carbon Concrete Composite” is currently underway researching carbon reinforced concrete construction. From 2014 to 2020, the necessary conditions will be created to introduce carbon reinforced concrete into the market. The Bundesministerium für Bildung und Forschung (BMBF, Federal Ministry of Education and Research) is funding the project with up to 45 million Euros. Also, about 15 million Euros come from the partners involved. The interdisciplinary consortium currently consists of more than 160 partners. Along the entire value chain, basic and application-oriented research projects into C³ are conducted, as well as multi-functional C³ components are created. The construction of the world’s first carbon reinforced concrete building “CUBE” exemplifies the results of this project, which will be completed in 2020. Such a construction will demonstrate to the public the practical suitability and the many advantages of the new construction method. CUBE will also serve as a venue for presentations as well as research into durability, viability, usability and building physics. The project partners are the TU Dresden (Institute for Concrete Structures), the HTWK Leipzig (Institute for Concrete Construction), the AIB GmbH Bautzen, ASSMANN Bauen + Planen Dresden, the precasting plant Oschatz and the Bendl-HTS GmbH Sebnitz.

C² – Carbon Concrete Composite ...

AND DESIGN TASK FOR THE AAL-WORKSHOP

Location of the CUBE property in Dresden | Source: schwarzplan.eu
Aerial view of the CUBE property | Source: google.de
Perspective from the south | Source: TU Dresden

ASSMANN Bauen + Planen Dresden, the precasting plant Oschatz and the Bendl-HTS GmbH Sebnitz.

CUBE was the design theme of the AAL-workshop (edition 2017 in Leipzig). For the CUBE, a new building plot in southern Dresden is available. It is located near the TU Dresden, on the main traffic artery (Zelleschen Weg) at an important junction (Fritz-Förster-Platz). The design of the building should reflect the connection between publicity and research at the TU Dresden and the important junction. To the north, there are multi-family houses; to the east, a side street (here the access road is arranged), and to the south, the tram stop.

On the north and east side of the property, there is a terrain gradient and vegetation; two trees must be preserved. In the neighborhood, there are different building types. In addition to high, public buildings (south, southwest, northwest) smaller residential development can be found here. Close to the driveway, from the east (Einsteinstraße), the parking areas have to be provided, whereby the front garden escape must remain undeveloped. To meet fire safety requirements, the design must comply with building class 1.
To present the novel carbon reinforced concrete construction to the public, the building should have a great symbolic effect and, also, present the many advantages and potentials of carbon concrete. The design intends to highlight its high performance, its lightness (conveyed by slim and free-formable components), its high durability through durable, high-quality surfaces, the possibility of multi-functionality and its great sustainability (through the significant resource savings). The building should exemplify to its visitors the ability of carbon reinforced concrete to “re-think building” and create contemporary and forward-looking buildings. In the building design, approximately one-third of freely shaped components should be used, and it should also be shown that carbon reinforced concrete is suitable for mass production (due to predominantly flat surfaces in a modular design). CUBE will have two main uses. A presentation area, with flexible furniture, which can be used for exhibitions, seminars, and other events, as well as for temporary office workplaces. Also, a laboratory section is planned in which new developments made of carbon concrete can be validated. Functionally integrated prototypes for energy generation, components for heating using carbon reinforcement, components with integrated lighting or PV-integrated C³ components are conceivable for the first use of the test areas.

The laboratories should be visible to the public but not accessible. Outside, in the first phase of use, C³ objects from the different stages of development of carbon reinforced concrete will be presented, and events will be held during the summer months. After the construction, on the one hand, scientific staff will work in CUBE and continue to research the new construction method. On the other hand, the building will be open to visitors.

Room program - building

<table>
<thead>
<tr>
<th>Area</th>
<th>Area in m²</th>
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</thead>
<tbody>
<tr>
<td>Secondary rooms</td>
<td>ca. 112 m²</td>
</tr>
<tr>
<td>House connection, building services room</td>
<td>ca. 25 m²</td>
</tr>
<tr>
<td>Laboratory area with three identical test rooms</td>
<td>ca. 36 m²</td>
</tr>
</tbody>
</table>

Room program - outdoor facilities

<table>
<thead>
<tr>
<th>Area</th>
<th>Area in m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parking spaces</td>
<td>ca. 60 m²</td>
</tr>
<tr>
<td>Event area</td>
<td></td>
</tr>
<tr>
<td>Carbon concrete outdoor furniture for 10-20 persons, e.g., seating or paths, permanently installed or temporarily usable; the seating area should be able to hold smaller information events.</td>
<td></td>
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</tbody>
</table>
The design proposal of group 1 intends to retrace the story of reinforced concrete as a building material, to show how the technological progress has allowed to develop different types of concrete construction components over time and to underline the role of the carbon concrete composite C3 as a major technological step in the history of concrete.

To achieve this goal, a modular design system was developed, based on a three-dimensional grid of 5m x 5m x 5m. This type of approach allows not only to design an extremely flexible building but also to develop a constructive and planning system that can be applied as well in other situations and places. The building can be modified and extended over time, and it is adaptable to an irregularly shaped lot (like the property in Dresden on which CUBE will be built). This modular-grid-concept allows obtaining square spaces of 25 m² that can be used in many different ways and can house different functions with the support of small separating elements.

Even if the functional module maintains a constant dimension, from the structural point of view, this module can be realized with different constructive elements, connected to different historical periods and techniques of concrete construction elements. In the future, it is also possible to expand the building with additional modules made with a more evolved concrete type. The modules cannot only form indoor spaces but also covered and opened outdoor spaces.

This theoretical concept becomes the design of a building, which is integrated into the triangular and densely vegetated lot at the corner Zellerscher Weg / Einsteinstrasse in Dresden. The building, with a surface of 10m x 30m, consists in 12 three-dimensional modules arranged in two rows and built with three different types of carbon concrete structures, which intend to represent the past, the present and
the future in the use of reinforced concrete as a building material.

The first four modules in the western part of the building represent the past. It is expressed by a system of simple wall panels and slap elements. In this area, the three testrooms (required in the space program) are placed, aligned with the street Zellerscher Weg to ensure a nearly optimal orientation towards South. The modular design makes it possible to provide space for an optional fourth test-room, if needed, or for the storage of experimental components or materials. In the rear part of this section, workstations are created as well as a small service unit and a kitchen area. This arrangement offers, on the one hand, the visibility of the innovative façade systems (that are tested in the test-rooms) from the sidewalk and the street, and on the other hand, ensures the privacy needed in the office spaces.

Three modules in the central part of the building show the present reinforced concrete use, and in particular, how an extending span can be realized with double T-beams in connection with pillars. In this area, the entrance and the covered outdoor areas for seating are located, as well as bicycle parking spaces and technical facilities and toilets. The use of glass façade elements invites people to enter the building, and it creates a visual connection between the building and outdoor context.

In the five modules in the eastern part of the building, future use of carbon concrete is presented, which provides the possibility to realize extremely slim bearing building components. Five structural elements, which take up the shape of trees (such as those that characterize the lot in which the building will be built), are made with very thin ribs in carbon concrete. In this area, the heart of the building, the showroom, is located. It is completely glazed and embedded in the park grounds. Therefore, structural construction and indoor exhibition spaces are visible from the outside and create a connection not only with the pedestrians on the street Zellerscher Weg but also with the building of the TU Dresden on the other side of the street. At the same time, the glass façade elements allow the people inside to develop a connection with the outdoor space of the lot on which sculptures and experimental components in C³ (like a small pedestrian bridge) are exhibited.
The main idea of the proposal of group 2 is to design an organic shape, able to integrate itself into the lot and to “lie down” between the two protected trees (defined as fixed points). Such a shape also attracts the attention of pedestrians due to its unconventional form and its proximity to the Zellescher Weg.

The contrast/mix between natural vs. artificial, green vs. concrete, private vs. public characterizes the project of the new building and the outdoor space close to it. Indeed the carbon concrete loop “embraces” one of the trees, “hiding” itself behind the other one and determines a separation of the area in the public area next to the street in the South and the private part behind the building in the North.

In the task, it was required to combine a conventional use (70%) with an innovative use (30%) of carbon concrete composite into a single organic form, creating continuity between tradition and future. This goal is achieved with a big roof that in the lateral parts (east and west) of the building is quite conventional and flat and in the central part becomes an innovative, dynamic, thin and curved shape. Also, the vertical structure differs: in the lateral parts of the building, there is a bearing-walls structure, and in the central part, high thin pillars with a wide span are used.

The lateral parts of the building are lower than the rest of the building. In the western part, it houses experimental rooms and, in the eastern part, office spaces, a kitchenette, and technical rooms. Experimental rooms, oriented towards South-West enable pedestrians and visitors to gain an insight into the work of a research institute and to observe the innovative façade systems in C³. The outdoor South-oriented walls are test-walls that can be changed over time and show to the different public applications of carbon concrete in the construction of façade systems and components. The entrance to the cars and the parking lot for the employees of the institute are on the eastern side of the area, at the Einsteinstraße. The parking is directly connected to the more privately part of the building (offices and laboratory). Heavy objects can be unloaded and brought into the building without difficulties.
The main entrance and the big showroom, designed as open space, are located in the central and higher part of the building. The roof starts from the ground, “grows up” in the central part of the building that has a very representative function. With its high thin pillars, wide spans and curved roof, it intends to demonstrate the possibilities and potentials of building with carbon concrete. It also has the aim to provide a glimpse into possible future developments. In addition to this impressive architectural design, technical innovations are applied: fiberglass is used in the roof of the showroom to allow additional light to enter through the light deck construction, with the result that visitors get the impression of standing under an almost transparent ceiling.

Also, the glass façade intends to highlight transparency of the showroom and creates a connection between exhibition space and the tree behind the building, and in general to the outdoor spaces close to the building and the urban context. The free space in front of the building is used to exhibit sculptures, as well as research objects like self-constructed benches, bridges or façades.
HIGH³

To design the first building in the world in carbon concrete composite, that shall present the many advantages and the potential of this new material, without neglecting possible mass-market compatibility, Group 3 proposes a design project called HIGH³.

The main idea is to develop an iconic building in which the use of carbon concrete is presented and experimented through three different constructive systems, which are integrated into one single architectural concept that involves the design of interior as well as external spaces. Other important topics of the project proposal are:

1) strong connection with the urban context: high apartment buildings on the North, a big main street with an intersection and soon a tram station on the South and, in particular, with the Technical University of Dresden located on the other side of the Zellscher Weg, where C³ was developed;

2) solid integration of the new building into the site, which is characterized by the two big trees and a ground sloping down from North to South;

3) differentiation of private and public spaces, as well as an outdoor space, semi-outdoor space and indoor space;

4) multiple levels that intersect each other: outdoor ground floor, ground and second floor in the buildings, accessible roof level.

The three developed structural systems made of carbon concrete are a large multifunctional roof, tree-shaped pillars and six boxes of different sizes. The roof has an organic form, covers a semi-outdoor space for temporary exhibitions and acts as a terrace with a bar as well as a staircase with wide stairs that invite visitors, students and employees of the research center to sit and stay. Further, it serves as a pedestrian bridge that connects the new building with the TU Dresden. Tree-shaped pillars intend to...
create a relationship with the existing trees, support the roof over the outdoor exhibition space. Boxes provide essential building elements that host functions such as experimental rooms, meeting and office rooms, kitchenette, toilets and technical room. The showroom, located in the southern part of the property closed to the main street, is also hosted in a big box. This is twice as high as the other ones and is the only building of this complex that is higher than the roof that “enters” the showroom like a balcony. Guests, students, and pedestrians, who are walking on the roof, are invited to come in and watch the innovative objects, systems, and components in carbon concrete exposed inside the big showroom.

In addition to the entrance via a pedestrian bridge and stairs, the lot has two main entrances, a pedestrian one in the South and vehicular access on the East. The presence of many access points, multiple paths on different levels that connect nature and artificiality, intends to highlight the multiplicity, flexibility and innovation nature of the first building complex in carbon concrete.
Textile wave, proposed by group 4, is a building in which three different core-ideas -“strength,” “technological” and “flexible”- are fused together to show in a single shape different possible uses of carbon concrete composite as a building material.

The project intends to take into account the pre-existent conditions in the lot, in the context of existing vegetation (in particular two big trees) and the TU Dresden, to design a building well integrated into the urban context. The accesses to the site are two: a pedestrian one in the south of the site, in close contact with the metro stop and a more private one, located in the rear part of the site and accessible by car or bicycle. The building, placed with the main axis parallel to Zeilscher Weg, will host two main functions: laboratories, located in a tower (technological), and an exhibition space comprised of a huge massive volume (strength). These two forms are connected to each other with a very attractive and innovative textile wave bridge (flexible), from which the name of the project derives.

The tower is shaped by stacked boxes realized by precast walls and ceilings and is orientated towards the west to optimize the performance of the laboratories. They will be used by researchers to develop and test new applications of carbon concrete as building materials. The second volume simulates a huge mass that is lifted from the ground and supported by thin columns. In there, four offices and a showroom, which can be transformed into a conference room, are located.

In contrast to the main volumes, realized with carbon concrete used traditionally, the textile wave, which connects the two volumes, has an organic shape, realized as a membrane. This innovative use of the carbon concrete intends to demonstrate the multiple constructive and form possibilities that this new material offers.
Although different technologies have been used, the result is one organic building with an iconic character that shows carbon concrete easily shaping to allow unlimited forms, changing during time. Therefore, not only the building but also the entire site becomes a manifest of the C³ new technology. Indeed, the exposition of innovative products is not restricted to the indoor space but continues outdoor, creating interesting ways and paths that can change during time, if the site will host a new exposition.

Furthermore, carbon concrete is used in very different ways in the project. Not only in the various constructive elements, but also as a technological device. For example, the use of innovative C³-elements enables to store energy, to be used as a station for the recharge of electronic devices. Another way to use the new material consists in the integration of the material with LED and optical fiber that allow creating rays of light. The idea is that the building could be improved over time with the use of systems and components in carbon concrete, that will be developed in the building in the future.
Conforming to the task-program, the proposal of group 5 intends to combine a conventional use of the carbon concrete composite (in 70% of the project) with innovative use of this material (30% of the project). To achieve this goal a system composed of five simple buildings and a roof characterized by a free organic form is developed.

The design of outdoor and indoor spaces take into account the urban context and the presence of natural elements of the site (including the two main trees) and creates a building complex able to attract visitors as well as passers-by to watch what happens inside the research and exhibition center. Walking through the site enables the possibility to move from a restricted area to an easily accessible one, from a closed building to an open one, from continuous structure to one point. This sequence could represent the passage from the traditional heavy concrete to the light, innovative C3.

The five buildings that constitute the conventional part of the project host three types of functions: labs, employers’ spaces, and public spaces. In the first one, there are three little mobile cubes used to test carbon concrete façade components. For this reason, it is possible to easily change its test-facades. Pedestrians who walk near the labs could see and touch the different types of materials and components. In the second one, there are offices and services (like a small kitchen and bathrooms) accessible only for employees. Finally, in the public space, there is a building, surrounded by a court, where visitors find a conference room, a bar with meeting points, and a showroom, where installations and products developed during the C3 research program are exposed.

The roof in addition to demonstrating with a practical example the innumerable aesthetic and structural possibilities that this new material offers, plays important functions both in relation to the internal spaces and to the external ones. Indeed, it connects buildings, protects people...
from the rain as they move from one building to the other one, and covers spaces that can be used as meeting points or exhibition.

The roof is not built with a single construction system, but is realized with the use of three different three-dimensional pre-fabricated “carbon concrete vaults.” Combining them allows obtaining an organic form that branches off between the buildings and is perfectly integrated into the site. To maximize this relationship between natural and built environment, the roof can also be used as a terrace from where people (visitors, students of the Technical University and employers) can watch the landscape around, stay together and observe the shows and the exhibition, which take place in the court below. The terrace itself also creates a link between the project area and the surrounding university grounds, inviting students to spend some time there.

The roof is conceived as an open system that can be expanded, adding further vaults. This can be improved with the use of integrated optic fiber to maximize the daylighting or with the integration of textile photovoltaic elements useful for charging electrical cars parked in the parking lot.
ACKNOWLEDGMENTS

I would like to express my gratitude to the many people who contributed to the success of the fifth edition of the AAL-workshop.

I would like to thank Anke Fissabre from FH Aachen, Massimo Perriccoli from UNICAM and Wilfried Lewitzki from HTWK Leipzig, for their support in the AAL-workshop 2017. Thanks also to the colleagues from HTWK Leipzig, Susan Neubert and Silvia Striese who helped me in the organization of the workshop in Leipzig and Martin Grünert for materials and tools to build models. Also thanks to the international office of HTWK Leipzig who, through the Erasmus+ program, co-financed the edition 2017 of AAL-workshop.

A big thank to Susanne Kirmse from the Institute of Structural Concrete of the HTWK Leipzig who proposed me CUBE as a very interesting design theme for the workshop. Also to the colleagues of the TU Dresden Michael Frezel, Sebastian Wilhelm, and Stefan Mirar who not only supported us in the development of the design theme and documentation of the results but also introduced the students to the new developments within C³. They provided insight into the carbon concrete composite design methodology along with meaningful discussions and supporting documents on the topic. Special thanks to Sven Hofmann for documenting and producing this book, to Patricia Gianbaldi for her editorial work, and to the BMBF for funding this publication.

I would like to thank Horst Fischer from FH Aachen and the Lions Club Ascoli Piceno Host who along with me funded this workshop in 2013. A special thanks to the students who participated at the AAL-workshop 2017 with engagement and a big enthusiasm in working together: Nicola Alessandroni, Maria Chiara Asteri, Andrea Bassetti, Simone Castellani, Sara D’Ambrogo, Felix Dauer, Katharina Dreisbach, Sarah Folomier, Cecilia Giardini, Francesca Hamburger, Uta Lambrette, Marla Lehmann, Anke Mannshausen, Luisa Nicolay, Arianna Pavia, Alessandra Principi, Giada Prosperi, Alida Rüger, Managazza Salvi, Cristina Vagnozzi, Simone Winkhardt, Laura Zielinski, Nadine Zschau.

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