

Building rethought

PERI 3D construction printing in architecture



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<p>Issue 10/2020</p> <p>Publisher</p> <p>PERI GmbH Formwork Scaffolding Engineering Rudolf-Diesel-Strasse 19 89264 Weissenhorn Germany info@peri.com www.peri.com</p>			<p>Important notes</p> <p>All current regulations and guidelines applicable in countries where our products are used must be observed.</p> <p>The photos shown in this brochure feature construction sites in progress. For this reason, safety and anchor details in particular cannot always be considered conclusive or final. These are subject to the risk assessment carried out by the contractor.</p> <p>In addition, the computer graphics used are to be regarded as system representations. To facilitate understanding, these and the detailed illustrations shown have been partially reduced to certain</p>	<p>aspects. The safety installations that are not shown in these detailed descriptions must nevertheless be available. The systems or items shown might not be available in every country.</p> <p>Safety instructions and load specifications are to be strictly observed at all times. Separate structural calculations are required for any deviations from the standard design data.</p> <p>The information contained herein is subject to technical changes in the interests of progress. Errors and typographical mistakes reserved.</p>

PERI 3D construction printing

An innovative technology is revolutionising the construction industry

The BOD2 is a modular printing system. This means that the printer can be configured in any direction and be used for a wide range of applications such as walls, columns, sewer manholes, stairs etc. The individual modules which form the portal for the printer can be flexibly combined. This offers you new architectural possibilities in the shapes, colours and surfaces in high-quality building design.

3D construction printing is particularly ideal for use in residential construction. 3D construction printing is also perfectly suited for the production of special precast concrete parts. The residential buildings and prefabricated parts can be printed in any individual form in a time and cost effective manner.

The BOD2 is already in the second generation. The results of the extensive test series of the first generation

carried out, have led to the realisation that the BOD2 is now a fully developed and particularly safe 3D construction printer. It is fully CE-certified and has a wide range of safety features such as pinch protection, emergency shutdown mechanisms and weight sensors. In addition, it has an IP67-certified cable system. Furthermore, the print head and print results are continuously monitored by a camera.

3D construction printing technology is currently still at an early stage. PERI has already developed 3D construction printing for the construction site together with the Danish start-up COBOD. The technology still has untold potential that we would like to discover and drive forward with you on the basis of specific construction projects. We are there to support you with your 3D printing projects right from the start.

World premiere in 3D construction printing

In autumn 2020, the go-ahead was given for Germany's first 3D-printed residential building by PERI. Before the start, the new construction technology went through all the official approval processes without any problems. Click here for the trailer:



3D construction printing has the potential to revolutionise the construction industry.

By means of a 3D printer, concrete structures can be quickly and inexpensively realised without any formwork and a high degree of design freedom. This makes the process perfectly suited for use in residential construction and in the creation of individual prefabricated parts.

Why does PERI offer 3D construction printing?

3D construction printing is a new technology that shapes concrete without the use of formwork. This is a technology that competes with PERI's traditional products from the formwork sector. It is precisely for this reason that PERI is actively involved with 3D construction printing. Because at PERI, it is better for the business model to be questioned from within the company than by someone else.

PERI is convinced that the technology will be used in various segments in the future and will significantly increase productivity in the construction industry. With the global megatrends of labour shortages and the need for more buildings, the

construction industry is facing a huge challenge that could be solved with the help of 3D construction printing technology. PERI's focus is primarily on residential construction and the production of individual prefabricated components.

Thus, PERI takes on the role of 3D construction printing expert and technology supplier and offers you a comprehensive service portfolio (see also "PERI construction printing services" on page 18). Thus, PERI not only offers support with the planning and execution of 3D construction printing projects, but also ensures high availability and productivity of the machine.

Advantages of the BOD2

Developing new architectural potential

As of autumn 2019, the BOD2 3D construction printer is the only 2nd generation 3D construction printer. It is ready for use on the construction site, where it impresses with its efficiency and safety. You benefit from a high degree of design freedom – at a constant cost.

Thanks to 3D construction printing, architects can be creative and easily develop and realise individual structures with unprecedented surfaces, shapes and colours. The result is resilient and architecturally innovative buildings – at no extra cost compared to conventional methods.

Thanks to 3D construction printing, you also benefit from a high degree of planning reliability right from the start. The final planning stage takes place before the project starts and provides all parties with planning reliability from the outset.

The printing process itself is also particularly efficient: producing 1 m² of cavity wall with the BOD2 takes about five minutes. An entire single-family house, which is otherwise built using brick or wood construction methods, can be easily realised in around 25 hours with the new construction method.

Another advantage of the method: other trades, e.g. installation of insulation materials or cable ducts, can be easily and quickly integrated which reduces the degree of coordination required and increases the efficiency on the construction site.

Help us to discover and advance the still untold potential of 3D construction printing using specific construction projects. In the process, you will gain valuable insights into the innovative technology and develop even more unique expertise early on. This will ensure you have the necessary edge in the field of 3D construction printing.



High degree of design freedom through new architectural possibilities at a constant cost



Reduction in construction time due to high printing speed and low coordination effort



Innovative pioneer in 3D construction printing by developing even more unique expertise at an early stage

High degree of design freedom

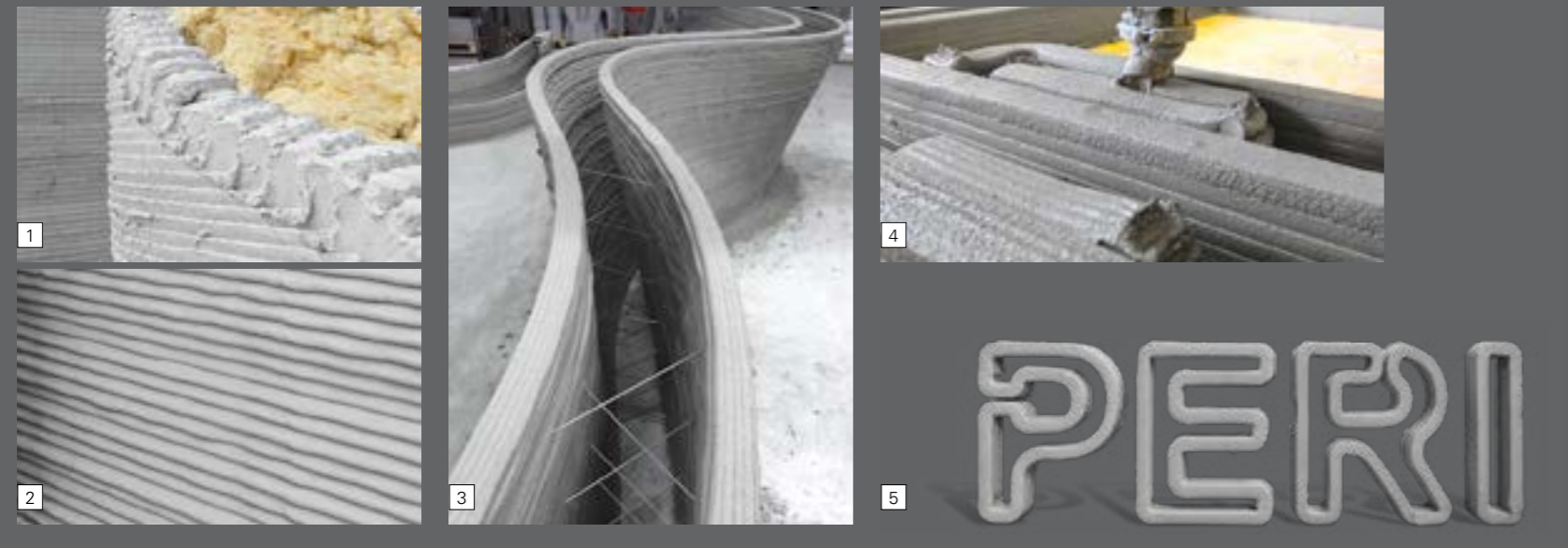
New architectural possibilities at the same cost

Compared to conventional construction methods, you benefit from a wider variety of designs when using innovative 3D construction printing. You can be creative and plan eye-catching buildings; the first and only ones of their kind.

The use of the BOD2 makes it possible to realise your required structures without any problems and to develop innovative forms in residential construction. It makes no

difference to the printer what it prints. This fits in perfectly with your design options and allows you to realise a high number of individual shapes, surfaces and colours. In addition, the use of the BOD2 also enables the problem-free production of overhangs and the use of different widths and heights for the print layers. You can print different materials – concrete and mortar with grain sizes up to 8 mm.

Your buildings stand out not only because of their special shape, but also because of the different colours and surface designs.



1 The BOD2 opens up completely new design possibilities. You can print the surfaces with a terrace structure, for example.

2 A characteristic feature of BOD2 buildings is the 3D print optics of the surfaces.

3 The BOD2 also enables the implementation of curved shapes that would not be feasible using formwork – and at no extra cost. This also applies to the printing of overhangs of up to 30 percent.

4 Apart from pulsating surfaces, smooth surfaces are also easily possible.

5 You can also print a large number of applications, ranging from logos to the additional printing of kitchen substructures, showers or fireplaces.

Reduction in construction time

High printing speed and low coordination effort

Changes, finishing work and project delays quickly drive up construction costs. Compared to traditional construction methods, 3D construction printing technology scores points for the reduced construction time and coordination effort.

3D construction printing offers a high degree of planning reliability for all parties involved right from the start. Even before the project starts, the final planning for the 3D construction printing is in place. This allows you to implement your digital construction models at the construction site itself. In the process, your 3D or BIM model is converted in our slicer software into specific instructions for the BOD2 and implemented by the machine, as planned, at the construction site.

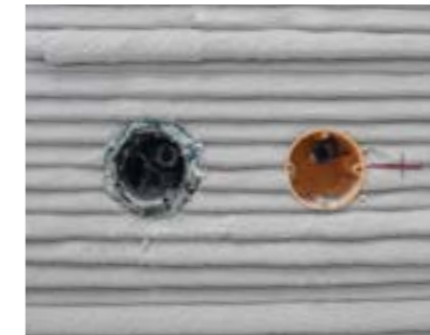
This allows you to print your project on schedule. Costly planning adjustments during the construction process are thus a thing of the past. This optimises the construction site processes on the one hand and also saves costs on the other.

After all, the faster you complete your construction project, the more cost-effective it usually is. With the BOD2 you only need about five minutes to produce 1 m² of cavity wall. An entire single-family house, which is otherwise built using brick or wood construction methods, can therefore be realised in around 25 hours with the new construction method. This makes the BOD2 the fastest machine on the market.

Only two people are needed to assemble and operate the BOD2. The high level of automation further accelerates construction processes and minimises the likelihood of human error.



With the BOD2 it is possible to print the inner and outer walls of a building simultaneously.



Integration and reduction of trades

When you choose surfaces in the 3D construction printed look, fewer trades are involved in the building process compared to traditional construction methods.

Facade work, for example, can be completely eliminated. In addition, it is possible to efficiently integrate the electrics or insulation into the printing process. Also, a fireplace or a kitchen substructure, for example, can be printed immediately. Time-consuming formwork work for the bottom slab is eliminated.

Particularly relevant for architects: When free building geometries are realised, surveying effort on the construction site can also be minimised. This is reflected in the simplified coordination of the construction project, which takes less time due to the sophisticated planning in advance.



The BOD2 is the fastest machine of its kind on the market. It takes only about five minutes to produce 1 m² of cavity wall.

Innovative pioneer in 3D construction printing

Early development of expertise that is still unique



3D construction printing technology is currently still at an early stage. However, PERI has also developed the technology for the construction site together with COBOD. Help us to discover and advance the still untold potential using specific construction projects.

In the process, you will gain valuable insights into the innovative technology and develop even more unique expertise early on. This will ensure you have the necessary edge in the field of 3D construction printing. While other

architects are still gaining their initial experience, you will be scoring points with your completed project and acting as a reference.

PERI offers you comprehensive support in all phases of the construction in the implementation of your projects. PERI 3D construction printing experts are available to advise you with their first-class know-how right from the start.

The customised PERI 3D printing solution package includes a large number

of services that support architects and contractors alike with their 3D construction printing project.

The service portfolio is specially tailored to the architects' requirements. Comprehensive implementation planning as well as training courses on the subject of 3D construction printing ensure the success of your project (more on this under "PERI Construction Printing Services" from page 18).



You may well ask yourself whether it is worth investing in the new technology? We at PERI are convinced that 3D construction printing will revolutionise the construction industry. Be among the first architects to print your individual building together with the support of PERI experts.

Source: Mense-Werner-Beyer Ingenieure + Architekten

The BOD2 at a glance



- The BOD2**
- with integrated pump and reservoir to enable starts and stops
 - Turnable rectangular **print nozzle** for printing even walls
 - **Z-axis** (available in 2.50 m modules)
 - **Y-axis** (available in 2.50 m modules)
 - **X-axis** (available in 2.50 m modules)
- optionally available:
- **Concrete block** for fixing the Z-axis
 - **Silo** for material storage
 - **Concrete pump**
 - **Mixing pump** for automatically mixing the concrete
 - **Hose**

Y-axis Z-axis X-axis Print head Turnable print nozzle Emergency shut-down mechanism



Configuration example with one X-axis module, two Y-axis modules and one Z-axis module respectively (consisting of four Z-axes).



Configuration example with three X-axis modules, five Y-axis modules and three Z-axis modules respectively per Z-axis.



Configuration example with four X-axis modules, eight Y-axis modules and three Z-axis modules respectively per Z-axis.

The BOD2

The only 2nd generation construction printer

As the only 2nd generation construction printer, the BOD2 offers you numerous advantages. Find out more about the technology of the robot-assisted printer below.

The BOD2

Each BOD2 consists of a portal system comprising several modules. The number of modules is selected to suit the respective construction project. Each module is 2.50 m long and can be extended at any of the three axes. The production of a modular machine makes assembly, cleaning and maintenance as well as moving and extending, particularly easy. Thanks to the integrated pump, the printing process can also be interrupted at any time.

The portal system

The portal system is optimal for both in-situ concrete projects and off-site element production. What's more, the portal system eliminates the need for frequent relocation and recurrent calibration of the printer. This saves a huge amount of time compared to using a 3D printer with a robotic arm, because each calibration process takes several hours.

The printing speed

The maximum speed of the BOD2 is 1 m/s. We print at a speed of 25 cm/s for safety reasons and to ensure that we can continue to incorporate manual operations into the printing process. For 1 m² of cavity wall, the BOD2 thus needs approx. five minutes.

The print head

The print head has a replaceable nozzle system and tangential control. This makes it possible – if required – to print very smooth surfaces. It is also possible to create rough surfaces as a stylistic element or to simplify the plastering procedure. The standard layer height is 2 cm with a width of 5 cm.

In addition, the integrated tangential control (hardware and software) always rotates the print head in the respective print direction. This allows you to print with the rectangular print head nozzle – also including sliding spatula.

Surface monitoring

When printing on an uneven or poorly levelled surface, the printer measures the distance to the foundation and collects the data in an "elevation map". When printing the first layers, the printer can automatically compensate for this unevenness layer by layer until the resulting print is completely level. This ensures a level upper wall, even in the case of very uneven ceilings.

Print material and reinforcement

You can use any locally sourced, 3D printable mortar or concrete (up to 8 mm grain). This means that you are not dependent on any manufacturer.

The assembly

The installation of the BOD2 is completely flexible. It can therefore be mounted on the foundation or on movable concrete blocks. A printer measuring 17 m in length, 12 m in width and 8 m in height requires one working day respectively for assembly and disassembly.

The printing of individual forms

Thanks to robotic 3D construction printing, you can fully express your architectural creativity – it makes no difference to the printer if walls are straight or curved.



Modular system

Due to the flexibility of the modules (available in 2.50 m lengths) and working in three dimensions, the printer can be used for a wide range of applications.



Smooth surfaces

Thanks to optimised nozzles, you can also print on smooth surfaces. Surface monitoring also ensures that unevenness is automatically compensated for.



The fastest 3D printer

With a speed of 1 m/s, the BOD2 is currently the fastest 3D printer on the market.



CE-certified and proven

As currently the only 3D printer of the second generation, the BOD2 has proven itself. It has full CE certification as well as numerous other safety features.

Further technical specifications

Printer and building sizes	Maximum dimensions of BOD2: 15 m wide, 10 m high, length can be adjusted according to your individual project requirements Example sizes for printable buildings: <ul style="list-style-type: none"> ■ 3D construction printer in our rental park: buildings with a maximum floor space of 204 m² and three storeys ■ Largest printer built to date: building with a floor space of 300 m² and three storeys
Printing speed	Maximum speed: 1 m/s Standard speed: 25 cm/s, which corresponds to a printing time of around five minutes for 1 m ² of cavity wall
Layer height and width	Realisation of layer heights between 1 cm and 3 cm as well as layer widths between 3 cm and 10 cm
Printing materials	Any locally sourced 3D-printable mortar or concrete with a maximum grain size of 8 mm
Assembly and disassembly time	Depending on the configuration of the 3D construction printer, for a printing area of 12 m width, 17 m length and 8 m height, for example, eight hours is required respectively for one machine
Safety technology	CE-certified and safe IP67-certified cabling and galvanised steel tracks Camera monitoring of the printing process and printing results
Slicer software file formats	All conventional CAD software formats (.STEP, .IGS, .BREP and .OCC)

PERI service portfolio

Professional support for all project participants



Training offer

You can also benefit from PERI's usual professional support for your 3D construction printing project. PERI takes on the role of 3D construction printing expert and technology supplier.

PERI can answer all questions relating to construction printing with the comprehensive expertise gained from countless printing processes. We are always available to advise all project participants on the planning and implementation of their 3D construction printing project. Apart from saving valuable time, this also saves costs.

The comprehensive service portfolio is equally tailored to the individual requirements of architects and construction companies.

Architects benefit from optimal support in their project and building planning.

Other project services include project implementation by contractors and ensure efficient site operations on site.

The PERI service portfolio starts before the project even begins. We offer regular training courses on the topic of 3D construction printing. They will provide you with valuable insights into construction printing technology.

3D construction printing course

The one-day course at PERI's corporate headquarters in Weissenhorn for architects and construction companies includes theoretical content on 3D construction printing as well as the practical application of the printer according to the latest technology. You will experience the potential of the technology during a close-up and authentic live print by the BOD2.

Scope:

- Introduction to 3D printed designs
- Global overview: Projects and operators
- The different technologies
- Materials
- Design and limitations
- Introduction to the functionality and control of construction 3D printers
- Slicing and printing
- Mixing and material supply
- Live printing with concrete (demonstration)
- Individual handout with the most important training contents
- Personal participation certificate

3D construction printing training

PERI also offers a one-week 3D construction printing training course for construction companies. In addition to theoretical content, the practice-oriented training also includes independent use of the 3D construction printer.

Project planning

Developing new architectural potential

Implementation planning

PERI can provide you with the implementation planning of the printing on request. First, the concrete surface requirements as well as the 3D model itself are checked. If a 3D model is not yet available, the architect's CAD planning is converted into a 3D printable model that can be adapted as required. The 3D building plan is then imported into the slicer software to generate the print program.

The advantage: Other trades are thus taken into account at an early stage of planning. For example, electrical lines can be printed directly, making the time-consuming and costly cutting of slots afterwards unnecessary.

During building planning, PERI will provide extensive advice and information regarding the feasibility of 3D construction printing as well as the 3D construction printing design guidelines for your project. Should there be any deviations from the design book that are relevant to individual approval, on request PERI will be able to obtain a construction permit on your behalf by means of a test print and corresponding tests.

Scope:

- Advice and information on building planning
- Checking the feasibility of the 3D construction printing project
- Implementation planning of the 3D construction print
- Advice on overall planning for the integration of other trades, such as electricians
- Organisation of an "approval in individual cases" (construction permit)

3D construction printing material

As an additional service, PERI offers project-specific planning of the printing material. This includes the material mix planning (recipe) of concrete or mortar with grain sizes up to 8 mm. The focus of the planning is on locally sourced materials, the planned print speed and the individual print layout. In addition, the respective weather conditions and forecasts are taken into account. Optionally, PERI also organises the purchase and delivery of the printing material as well as the mixing of the required material for you. You benefit from evenly formed layers and excellent concrete bonding strength.

With the BOD2, concrete and mortar with grain sizes up to 8 mm can be printed. COBOD has already tested over 20 materials for usage on the printer. As the correct mixing ratio always depends on locally available materials, PERI will provide guidance to customers in developing the right material for the respective region. Printable mortar from well-known material manufacturers is also available as bagged or silo goods.

The larger the ground plan, the less special the material mix needs to be. Consequently, you need fewer additives to accelerate the hardening of the concrete.

Scope:

- Material mix planning of concrete and mortar

Optionally available:

- Purchase and delivery of the printing material
- Material mixing



PERI helps you plan the optimum material mix that is specially adapted to your architectural requirements.

With the BIM methodology, we support you in your 3D printing project right from the start and provide you with various tools and services.





Printing options

With our technology, we print the walls of the building, but not the foundations, floor slabs or ceilings. These parts are still traditionally concreted.

However, we can facilitate the concreting of the slabs by printing the outer wall correspondingly higher, thus making stopend formwork unnecessary.

Surface design

The BOD2 creates new possibilities for intentionally using the surfaces as a style element. The BOD2 has tangential control. This technique makes it possible to print very smooth surfaces as well as to rough surfaces. The possibilities are endless – even if the printed surfaces do not correspond with the architectural concrete surfaces.

Construction permit (approval in individual cases)

However, due to the novelty of the technology, there are still no standard procedures for the approval of construction projects. Printable 3D concrete recipes are not yet included in the building codes. Therefore, we are currently printing column formwork in several places and then it is classically reinforced and filled with concrete. These cavities are then filled with insulation material. This facilitates the approval process.

Upon request, PERI will help you obtain a construction permit for your project. You then benefit from our extensive experience gained from numerous printing processes and individual cases.



The BOD2 is suitable for producing the walls of your project. Foundations and ceilings are constructed in a traditional manner.



It is already possible to obtain BOD construction permits for buildings by integrating reinforcement and filling the hollow spaces.



PERI offers the right solution for every project. In addition to purchasing, it is also possible to rent a BOD2 or to use the PERI 3D printing service.



The BOD2 is a modular printing system. Thanks to the 2.50 m long modules, it can be flexibly mounted in any direction.



The insulation can be integrated into the printed, double-shell cavity walls.



If you wish, an experienced 3D construction printing supervisor, will be on hand to offer advice and support during your project.

Project implementation

Optimum construction site workflow

PERI construction printing solutions

PERI offers a customised solution package for every requirement in the field of 3D construction printing. It is possible to purchase or rent the innovative technology. It is also possible to have your first projects carried out by the PERI 3D printing service.

Purchasing

The purchase of an individually configured 3D construction printer offers numerous advantages. By acquiring their own printer, the construction company can develop 3D construction printing expertise, are able to carry out projects independently, and are not dependent on the availability of rental printers.

Rental

In addition, PERI offers you the possibility of renting a project-specific configured BOD2 in Germany.

3D printing service

In order to be able to get a first impression of the technology, it is possible in the initial phase to get to know the 3D construction printing technology via the PERI printing service and to have your projects printed by PERI. For this purpose, PERI will provide a 3D construction printer including software and pump, plan the printing and the material, take care of the transport, the assembly and dismantling in addition to operating the printer. With the 3D printing service, you will also benefit from the on-the-job training of your employees so they can carry out projects themselves in the future.

Delivery and assembly

The bottom slab and basement of the project are initially realised in a conventional manner. In addition to the bottom slab, small foundations are laid. The BOD2 is then transported to the construction site by truck.

Next, the Z-axes are either bolted to the ground or fixed to concrete blocks that are positioned on the foundation or the ground. The Z-axes, like the other axes of the portal, can each consist of several modules – depending on the project requirements. The print head is attached to the X-axis of the steel structure. Finally, a commercially available silo as well as a conventional concrete pump are connected to the BOD2. The assembly is now complete.

The printing process

The BOD2 operates in three dimensions: the print head moves to the right and left along the X-axis, the X-axis moves forward and backwards along the Y-axis, and the entire XY group moves along the Z columns above and below. Thanks to this portal principle, the printer can move to any position within the construction whilst raising both the internal and external walls layer by layer. At the same time, it has been certified in such a way that workers can carry out work in the printing space during the printing process. In this way, manual work, e.g. the installation of conduits and connections, can easily be integrated in the printing process. The BOD2 is operated with the help of a control unit – either via a web interface or touch screen.

Integrating the reinforcement

The 3D construction printing is ideal for use in residential construction. No reinforcement is required in this segment, as the printed cavity wall meets the static requirements. The material itself carries up to 50 megapascals.

However, in order to facilitate the approval process for the 3D printed construction project, column formwork is currently being printed in several places and then it is classically reinforced and filled with concrete.

Insulating the walls

Basically, the walls can be insulated in any way. We recommend integrating the insulation into the printed, double-skin cavity walls and using blow-in insulation for this purpose.

Supervisor

During the entire 3D construction printing project, it is possible to receive professional support from a PERI supervisor on site at the construction site. This ensures efficient use of the BOD2 and optimum productivity during printer assembly and disassembly and subsequent printing.

Together with the responsible person from PERI, the site management team will learn how to safely handle the construction printer.



Experience the 3D construction printer in action



The BOD2 in action



BOD (Building on Demand), Copenhagen, Denmark

innovative 3D construction printing method implemented in Europe for the first time

The first 3D printed building in Europe is situated in Copenhagen and was built by the Danish start-up COBOD using the COBOD 3D construction printer. The building is aptly named BOD which is short for "Building on Demand" and impressively demonstrates the potential of new 3D construction printing technology – on an area of 50 m².

Thus, it not only shows how the automated workflow can reduce personnel costs, but also what the new technology has to offer in terms of design. As there are no straight walls in the house. Instead, curved and even wave-shaped walls were formed so that the house would be reflective of its location at the harbour. The windows and doors are the only straight elements found in the BOD structure. When using traditional construction methods, curved elements are not only a great challenge they are also very cost-intensive.

However, creative designs can be easily realised with the 3D printer – without incurring any additional costs. For this reason, even parts of the foundations were produced with the 3D printer. In addition, partially recycled materials could be added to the concrete recipe, which also benefited the environment.

During the construction of the building, eleven columns were initially printed which were subsequently filled with reinforcement and standard concrete. Using this solid basis, the roof was installed afterwards. The procedure not only led to a particularly stable and durable building, but also to the granting of a construction permit which the supporting structures from the 3D printer had not been granted up to this point.

- 1 The internal and external walls of the building were all printed at the same time.
- 2 After adding reinforcement and concrete into the cavities of the eleven sections of printed column formwork that make up the building, the roof could be installed.
- 3 Although only 50 m² in size, the innovative house exemplifies the new construction method in a very impressive way.
- 4 Due to the individual shaping of the walls, the superbly finished internal area is a very special design highlight.

Technology is evolving rapidly

The BOD building was printed for the first time in 2017. In 2019, further printing of the same project followed. The printing time required is particularly impressive: while the first print with the first generation BOD took two months, the printing time with the BOD2 was reduced to three days just two years later.



Formwork Scaffolding Engineering www.peri-usa.com

