WHITEPAPER

Complex concrete Formwork - More efficiency with 3D printing

MORE EFFICIENT FORMWORK WITH 3D PRINTING

voxeljet AG has perfected 3D printing for complex formworks over years of research and development work. The construction industry is set to benefit greatly from this progress in the future.

The 3D printing process from voxeljet is particularly helpful for complex formwork constructions. Traditional systems are designed to create level walls which are positioned at a 90-degree angle to each other. Any protrusion, bend or offset makes a special formwork urgently necessary. Usually, these are prepared by the formwork contractor in time-consuming manual labor. Three-dimensional curved construction elements are even more challenging. For these elements, the formwork must first be milled from wood or plastic, manually assembled and then subsequently grinded and coated several times. Since such formworks are usually composed of individual segments, the formwork contractor glues them together. In order to achieve a uniform concrete surface, it is then necessary to grind and seal the joints. Much simpler, faster and more accurate are formworks that are produced using the 3D printing process. For this purpose, voxeljet uses powder binder jetting technology. The major advantage is that it enables the most complex formwork elements to be designed using CAD specifications.

THE PROCESS: POWDER-BINDER-JETTING

Powder-binder-jetting is an additive manufacturing process. Powder materials, such as sand or plastic, are applied to a build platform by recoaters in extremely thin layers. A printhead then applies binder only to areas where the desired component is to be produced. This results in the powder particles being bonded together by polymerisation. Then the building platform is lowered by one layer thickness (150-300 micrometers) and powder and binder are applied layer by layer again. This process is repeated until the component is finished. Depending on the material and binder, a distinction is made between a chemical and a physical process. The printing process can be implemented with all available voxeljet printing systems and materials. The only requirement is that 3D-data is available. After the printing and infiltration process, the 3D-printed formwork elements can be applied like conventional formwork.
The binder-jetting process only requires the components CAD-data to start printing.

THE KEY ADVANTAGES:

In order to accurately assess the advantages of 3D printed formwork for individual construction needs, it is vital to be familiar with a few details:

- Thanks to the digital and effortless process, a lot of time can be saved, especially with multiple-curved concrete elements, as these are manufactured far more precisely and thus no time-consuming corrections - which may delay the entire construction process - have to be made.
- Depending on the geometry, the formwork produced with powder binder jetting technology can be used up to 40 times. This reduces the costs per concrete surface for each further use.
- voxeljet formwork elements withstand concrete casting pressure of up to 100 kN/m².
- There are no limitations regarding used release agents and concrete.
- If a three-dimensional shape is repeated - but in a different size, the 3D data can be easily digitally rescaled and used to create another mold.
- voxeljet elements can provide valuable services as a master mold in the fabrication of polyurethane or silicone formwork matrices, e.g. for facades – regard less from the elements texture.
- With the voxeljet VX4000 printing system (the largest industrial 3D printing system for sand molds in the world), building volumes of 4.00 m x 2.00 m x 1.00 m can be realized.

With the help of the VX4000 by voxeljet, formworks with a building volume of 4.00 x 2.00 x 1.00 m can be manufactured.

BINDER JETTING COMPARED TO CONTOUR CRAFTING

voxeljet's Binder Jetting technology should not be mixed with contour crafting. In contrast to voxeljet powder binder jetting, contour crafting aims to erect the entire house or building element extruding fast-hardening concrete with a robot. However, the process sometimes reaches its limits, for example when it comes to integrating reinforcements, creating three-dimensionally multi-curved concrete walls, producing components with undercuts or fine textures. Currently, this is only possible up to a certain angle of inclination.

Delicate structures and details can currently not be visualized. The goal of contour crafting is to replace years of experimental concrete construction with a new process. This is in complete contrast to voxeljet’s technology. The latter aims to expand and optimize construction methods which have been proven and established over many years. Primarily, this should significantly simplify the manufacturing of three-dimensional building elements today. voxeljet starts where contour crafting currently reaches its limits.
A FIRST-CLASS REFERENCE: DOKA USES VOXELJET FOR THE CREATION OF COMPLEX FORMWORKS

During the construction of the headquarters of the Sächsische Aufbaubank in Leipzig (Germany), a semi-circular staircase with an intermediate platform was to be erected, which is mounted on a supporting wall. In order to give the staircase a smooth, uniform curve, an incredibly complex but precise concrete formwork was required. The project managers entrusted the world-renowned formwork supplier Doka with this task. After extensive evaluation and definition of the formwork design for the staircase, the different surfaces were categorized according to their complexity. Single-axis curved surfaces with cylindrical or conical shapes were formed conventionally. The specific feature of this staircase, however, was the triaxially curved surface, which represents the rounded overhang of the staircase to the inside of the supporting wall. The production of such shapes with conventional craftsmanship is extremely time-consuming. Wooden bars have to be cut, bent into shape, fixed and bonded together. Subsequently, the surface must be sanded and smoothed several times before it is varnished twice. The result is a part whose load-bearing components have been assembled under tension and were manufactured out of organic materials. Under the influence of temperature and humidity fluctuations at the construction site as well as general weather conditions, wooden cracks can easily occur which visibly affects the quality. This is where 3D printing from voxeljet offers considerable advantages. Components can be produced quicker and with less engineering effort directly from 3D data. The 3D-printed components are manufactured precisely and tension-free and are therefore dimensionally very stable. The homogeneous material offers additional quality assurance in regard to the weather influen-

Um den voxeljet-Elementen eine erhöhte Stabilität zu verleihen, wurden sie auf einer Trägerkonstruktion befestigt.
Like every building technology, the use of voxeljet formworks brings different advantages, disadvantages, risks and, of course, opportunities. We have outlined the key aspects below:

**STRENGTHS**

- The greatest advantage: with voxeljet formworks, three-dimensional, curved concrete elements can be manufactured much more simply, quickly and cost-effectively. This requires less planning and manufacturing effort, and the higher quality results in significant time savings. This will revolutionize concrete construction processes over a long-term period.

- The complete process is based on a closed data structure – from CAD planning to the finishing of the formwork element through 3D printing and CNC milling. Because components correspond to the digital model 1:1, their elements are custom-fit, which makes them easy to assemble.

- Higher accuracy eliminates the need for manual rework on site.

- voxeljet formwork elements can be reused up to 40 times, depending on the formwork geometry. This reduces the price for the formwork for each further use and the investments are amortized more quickly.

- Since the voxeljet formwork does not resonate (as is often the case with wood formworks) and does not otherwise change, the quality of the casting result is always consistent and satisfactorily.

- voxeljet formworks are extremely weather-resistant. Heat, moisture and cold have no influence of the reworked formwork elements. Unlike wood, they do not absorb water or yield (e.g. compared to plastic formwork).

- voxeljet enables the production of formwork elements with a total building volume of 4.00 x 2.00 x 1.00 m with a build progress of 139 l/h.

- Building components can be nested digitally into the jobbox. This guarantees optimum utilization of the machines.

- Scaling is possible without any problem.

- Proven construction processes are not changed. Construction techniques and material characteristics which have proven over decades can be retained.

- voxeljet formwork elements can be brilliantly combined with other formworks as hybrid approaches.
UNDREAMED-OF POSSIBILITIES FOR THE CONSTRUCTION INDUSTRY

In addition to the manufacturing of complex concrete formworks, the voxeljet 3D-printing technology can also simplify additional areas of architecture:

FOR MODELING

Architects are creating ever more realistic models to present their projects to interested parties in a comprehensible way. This is a difficult, time-consuming and cost-intensive task. Digital plans with CAD systems have long been a standard feature of architectural practice. All relevant data specifications are already available in 3D in a data cloud and can easily be imported for 3D printing. It is therefore much faster and cheaper to create the models directly in 3D printing. Above all, voxeljet printing systems are able to reproduce the buildings in more detail than it would be possible with manual model making.

voxeljet formworks are suitable and rugged enough for the use on construction sites and in pre-casting environments.

voxeljet elements withstand a concrete casting pressure of < 100 kN/m².

WEAKNESSES

Since the elements consist of a powder and a chemical binder, they must be disposed of separately.

Depending on the geometry, voxeljet formwork is usually more cost-intensive than conventional formwork in pure production.

RISKS

One of the greatest risks is, that the concrete industry, still dominated by conventional thinking, will consider this solution to be too radical and will unnecessarily hinder this technology.

The disposal of the elements as hazardous waste could counteract the current trend for ecological construction.

CHANCES

Formwork builders can offer the voxeljet technology in combination with their own formworks and gain a decisive advantage in the market.

Thanks to the development of CAD technologies, architects today plan three-dimensional curved buildings much more frequently. Until now, realizing such buildings has been very difficult. With the voxeljet technology, these can now be built much more easily.

With the introduction of the voxeljet technology in the construction industry, areas of application and buildings will develop that are currently unthinkable.

One big challenge which still remains is to develop 3D printing technology in such a way as to make it possible to dispose of the formworks in an environmentally friendly manner.
FOR THE PROTECTION AND RENOVATION OF HISTORICAL MONUMENTS

The task of monument preservation is to protect cultural memorials and culturally significant buildings. Often, individual building components and complete sculptures have to be rebuilt in order to replace the original. This rebuilding involves a lot of work and can be simplified in the most diverse ways using 3D printing. For this, the threedimensional data specifications of the component must be available digitally. If the original is halfway intact, its information can be compiled using a 3D scanner. This data can either be used to form a mold which is subsequently filled with concrete, bronze or another material which corresponds to the respective application. Or it serves as a 1:1 model for the mason or wood carver. This makes it possible to rebuild historical elements true to the original.

SUMMARY

With Powder-binder-jetting, voxeljet introduces a process to the construction industry with unique possibilities. Most notably, the concrete industry benefits enormously because architects can now design and build three-dimensional concrete parts which have been difficult to realize until now. Only a few specialists are able to produce such formworks conventionally and economically. With the voxeljet technology, such multi-curved formwork elements can be created with a fraction of the amount of work previously required. These formwork elements can also be designed so that they can be combined with existing formwork without any problem. Where necessary and complex, voxeljet formwork can now be used. Standard formwork is still used for simpler components. All in all, the industry now has a technology at hand, that complement conventional methods perfectly. In addition, there is a closed data chain. The transfer from software to hardware costs hardly any time and does not permit any (material) losses. Since CAD is used for design, fast adaptation is possible. An additional advantage of the voxeljet formwork elements is, that they are suitable both for use in prefabrication as well as on the construction site. This means that the wishes of the planner can be met perfectly. Since the formwork absorbs no moisture and does not change in terms of its characteristics, it is also perfectly suited for exposed concrete and withstands changing weather conditions.

Conclusion: The use of voxeljet formwork elements will revolutionize concrete construction in the long term and give companies the decisive market advantage.