Stuttgart 21 is one of the largest infrastructure projects in Europe. *© Aldinger+Wolf*

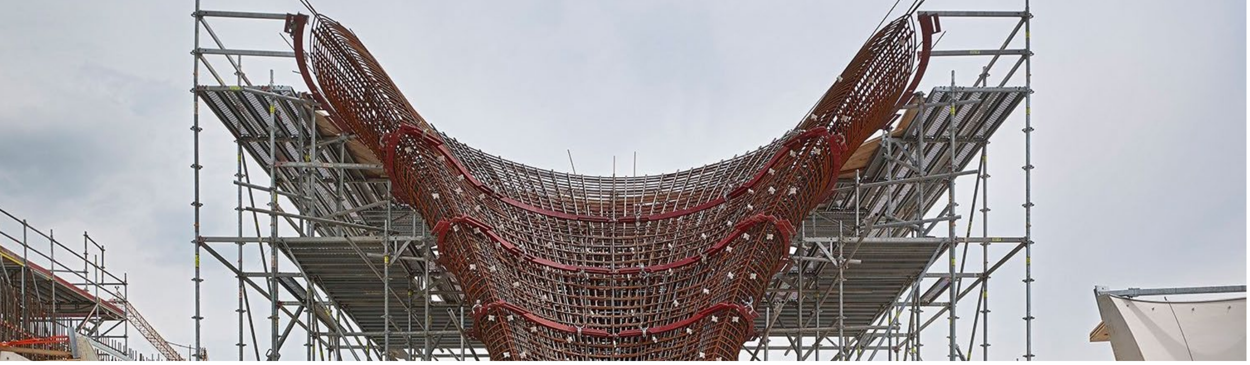
Allplan in practice

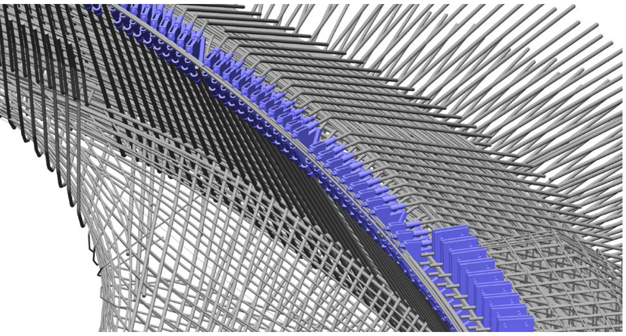
STUTTGART 21: DIGITAL WORKFLOW ON A MEGA PROJECT

The advantages of the BIM working method are fully exploited during implementation.

Stuttgart 21 as a part of the Stuttgart-Ulm rail project is one of the largest European infrastructure projects. Within the whole project, five new stations, about 120 kilometers of new railways and two new quarters are being built. But it's not just the size that makes this project so impressive. In addition, engineering history is being written here, both in terms of design and technology. Special attention will be paid to the station concourse of the new underground through-station in Stuttgart, designed by ingenhoven architects. An architecturally highly sophisticated shell roof, supported by 28 geometrically highly complex chalice-shaped columns, qualifies this as a masterpiece of modern architecture that the world has never seen before. Without the use of powerful BIM software and production processes specially developed for the project, the implementation of the building would be impossible. The engineering firm Werner Sobek AG, which was responsible for the structural, shell and reinforcement design of the underground through-station concourse, therefore relied largely on 3D for the design. On the basis of this 3D planning, the company Ed. Züblin AG is now fully exploiting the advantages of BIM during implementation thanks to Allplan Bimplus. A prime example of a digital workflow in construction.

ALLPLAN BIMPLUS BY ALLPLAN





Picture above: and right: Reinforcement of a chalice-shaped column of the new Stuttgart underground station *© Ed. Züblin AG / Achim Birnbaum*

Picture left: Detailed view of reinforcement of a chalice-shaped column in 3D reinforcement model. *© Werner Sobek AG*

DEMANDING FORM

The station hall for the new underground through-station in Stuttgart is to be approximately 420 metres long and 80 metres wide. The associated shell roof – a highly complex structure of anticlastic curved surfaces – can be mathematically described as free-form, since there are no mathematical regularities that describe it. Despite all apparent freedom, however, this shape is by no means arbitrary, but rather follows the course of forces in a highly efficient manner and implements the requirements of a wide-span and light-flooded station concourse in a material-optimized way. It is supported by 28 chalice-shaped columns, which can be divided into 23 standard columns with edge-reinforcing cover (scoop) on the upper side, four flat columns without edge-reinforcement and a larger special column, which opens as an access area to the city centre.

Due to its enormous geometric complexity, the shell roof had to be planned completely in 3D. In collaboration with Werner Sobek AG, ingenhoven architects generated a 3D model in Rhinoceros. In addition to the pure surface geometry, the model also contains further information such as formlining joints and the coordinates of installation parts. It served as a basis for the object planning of ingenhoven architects, the shell and reinforcement planning of Werner Sobek AG as well as for the development of the formwork construction by ZÜBLIN. The reinforcement design proved to be very complex due to three boundary conditions: Firstly, the geometry with constantly varying component thicknesses, synclastic and anticlastic curved areas as well as a combination of circular and orthogonal reinforcement systems led to complex transition and overlapping areas with multiple crankings and bends. Secondly, high demands on the visible surface required small deviations in the concrete cover and extremely precise bending forms. Thirdly, the accuracy in the manufacture of the complex bending shapes of the reinforcing bars was limited.

12,000 REINFORCEMENT DRAWINGS FOR ONE ROOF

Based on these boundary conditions, Werner Sobek's engineers created so-called tracks (reinforcement axes) with Rhinoceros in combination with Grasshopper and C# for the reinforcement of the free-form geometry using the 3D model next to the surface. Since these tracks consisted of splines and could therefore not have been produced economically, the geometry had to be simplified in a first step. This could be solved by means of specially developed scripts, which were used for parameterized simplification and grouping of bar shapes. In this way, bending forms coordinated with Ed. Züblin AG were achieved as curved trains with up to three arcs and polygons. The engineers used Allplan Engineering to produce those bars that did not have a free-form geometry. The previously mentioned final traces were then also transferred to Allplan and, together with the reinforcement already generated there, processed into an overall reinforce-

Concreted cup support for the platform hall of the new Stuttgart underground station.
© Ed. Züblin AG / Achim Birnbaum

ment model including all bar properties, reinforcement-relevant inserts as well as concreting and vibrating coils. On the basis of this 3D reinforcement model, a collision check was first carried out and then the reinforcement drawings were generated. A few figures reveal the enormous complexity: 350 DIN-A0 drawings include the reinforcement design of a typical inner column with a reinforcement mass of about 300 tons. Approximately 1,500 different positions occur per column. A typical column, with around 350 tons of reinforcement steel, has 400 drawings. The total shell roof is shown on 12,000 reinforcement drawings.

OPTIMIZED EXECUTION THANKS TO ALLPLAN BIMPLUS

The reinforcing bars are bent in a bending shop specially set up for the project, mainly by means of an interface between the bending machine and the reinforcement model, and checked by means of true-to-scale laser projection. 11,000 different, partly three-dimensionally curved bar shapes, including many unique specimens, have to be placed per column on the construction site. In order to ensure exact positioning, each component of the shell roof is provided with a coordinate list with Gauss-Krüger coordinates in addition to the reinforcement drawings. With the help of a surveyor, the guide bars can be precisely measured and further bars can be placed between them. For the correct assignment of the bars, the beginning and end of the bars are defined in the reinforcement drawings, which in turn are taken over by the bending company by means of a colored marking in addition to the position number on the bar. However, the 3D reinforcement design also improves the execution by providing further assistance: With the help of Allplan Bimplus, the 3D model is used directly on site to provide support and the installation of the reinforcement bars is coordinated. ZÜBLIN uses both a large screen in the container and a mobile solution for direct access at the installation site. This makes the highly demanding production of reinforcement much clearer and much easier, which illustrates the enormous benefits of a digital workflow in this masterpiece of civil engineering - from design to execution.

PROJECT INFORMATION AT A GLANCE

- **Focus:** Engineering
- **Software reinforcement design:** Allplan Engineering, Allplan Bimplus
- **Client:** DB Projektbau GmbH, Stuttgart/Germany
- **Design:** ingenhoven architects
- **Structural, shell and reinforcement design; façade design:** Werner Sobek AG
- **Execution:** Ed. Züblin AG
- **Planning period:** 2010 – 2020; remaining work until spring 2021
- **Execution time:** 2011 – 2025

„Allplan Bimplus is an essential component of the newly developed digital work processes, without which it would not be possible to produce the architecturally very sophisticated roof construction.“

Bernd Mehlig, overall project manager Ingenieurbau Stuttgart 21 at the Ed. Züblin AG

WERNER SOBEK AG

The architect, consulting engineer and test engineer for structural engineering of all disciplines, Prof. Dr. Dr. E.h. D. h.c., founded the Werner Sobek Group in 1992. This group stands worldwide for engineering, Design and sustainability. It has more than 350 employees and operates worldwide. Werner Sobek works on all types of buildings and materials. Special emphasis is placed on building construction and façade planning. The work is characterized by high-class design based on outstanding engineering and integral concepts for minimizing energy and material consumption.

ZÜBLIN AG

Founded in 1898 by the Swiss engineer Eduard Züblin, Ed. Züblin AG is today the number one in the German building and civil engineering industry thanks to its innovative strength, which is reflected in intelligent designs, new building materials and advanced manufacturing methods. Last but not least, the member of the globally active STRABAG SE owes its success to the wealth of ideas and commitment of its 14,000 employees who, as a large team, are able to realize even complex construction projects on time and at the best price thanks to perfect processes.

ABOUT ALLPLAN

ALLPLAN is a global provider of BIM design software for the AEC industry. True to our "Design to Build" claim, we cover the entire process from the first concept to final detailed design for the construction site and for prefabrication. Allplan users create deliverables of the highest quality and level of detail thanks to lean workflows. ALLPLAN offers powerful integrated cloud technology to support interdisciplinary collaboration on building and civil engineering projects. Around the world over 500 dedicated employees continue to write the ALLPLAN success story. Headquartered in Munich, Germany, ALLPLAN is part of the Nemetschek Group which is a pioneer for digital transformation in the construction sector.

ALLPLAN Inc.
10 N. High Street, Suite 110
West Chester, PA 19380
Phone 1-844-425-5752
sales.us@allplan.com
allplan.com

ALLPLAN
A NEMETSCHEK COMPANY