CASE STUDY

GenerativeComponents Scores Stadium Design Goal

Use of Parametric Design Helps Football Venue Achieve Exceptional Design Quality and FIFA Requirements

PROJECT SUMMARY

Organization
Technical University Munich, LT, Prof. Dr. Barthel, Dipl. Ing. Eike Schling, Dipl. Ing. David Kosdruy

Solution:
Building

Location
Krakow, Poland

Project Objective
Design an exceptional new stadium in Krakow

Products Used:
GenerativeComponents®

FAST FACTS

- Seating for 45,000 with sightlines no more than 95 meters to the center point of the field
- Structural system relies on equilibrium forces created by the inner tension of closed elliptical rings
- Transparent foil façade
- The stadium design takes into account the latest FIFA regulations
- GenerativeComponent fabrication planning delivered highly complex models in just days rather than months
- As a proposed venue for the 2012 European Football Championship, it was designed as a final university project in only 3 months

When David Kosdruy and Eike Schling conceptualized their final architectural project to complete a graduate thesis at the Institute for Design and Construction Technology, Technical University of Munich, they settled on the structural behavior behind the design of a 45,000–seat stadium in Krakow, Poland. The project is one of the proposed venues for the 2012 European Football Championship, which Poland and the Ukraine will co–host.

To realize a geometric solution for the stadium roof structure, a crucial element of the planning stage, would require innovative technology. Therefore, Kosdruy and Schling deployed GenerativeComponents® to optimize and adjust the roof design to its spatial and functional needs.

GenerativeComponents is Bentley's unique generative design software that enables architects and engineers to pursue designs and achieve results that were virtually unthinkable before. Empowered by computational methods, designers can direct their creativity to deliver inspired, sustainable buildings that are freer in form and use innovative materials.

The Krakow stadium is the type of design challenge for which GenerativeComponents is well suited. Utilizing this solution, any variable could be adjusted – from the basic dimensions of the facility to the detailed solution of the transparent foil façade. To comply with FIFA requirements Kosdruy and Schling designed the stadium with functional layers that work from the inside out. One requirement is that spectator sightlines could be no more than 95 meters to the center point of the field.

FIFA requirements also call for field dimensions of 68 meters by 105 meters. Additionally, seating bowls must have a maximum slope of 56 centimeters to 80 centimeters, and spectators must be able to view the action from any boundary. FIFA also requires an emergency safeguard that allows spectators to exit in seven minutes.

To meet these requirements, Kosdruy and Schling designed a triangular glass structure that folds itself through each stadium level while adjusting to the volume and shape of each floor. Within this structure Kosdruy and Schling designed restaurants, business lounges, and technical areas by approximating the volume of the different functions. Two horizontal levels connect entrances and public areas on an elliptical perimeter creating a spiraling system of staircases connecting the levels. The result: a shell around the outermost layer that adjusts to the height, width, and spiral geometry of the inner functions, creating a unique and efficient structure.

Using GenerativeComponents Kosdruy and Schling programmed a mathematical function to create a given number of spirals around any torus shape. The process allowed spaces and cantilever length to produce an optimal geometry by adjusting them to predefined ranks. Kosdruy and Schling then used the 3D model to script a structural grid on top of the spirals.

The final 3D model consisted of a basic spiral grid with several factors – length, width, height, stretches, and contractions – programmed as variables. This defined an exact foundation ring as well as an inner roof and structural connection ring. In the end, the complete façade structure with 288 polygonal steel beams fit into this predefined geometry.

Kosdruy and Schling also used GenerativeComponents to script different geometric possibilities, which determined the number and slope of the spirals, the density of definition points, and other mathematical variables. A façade sub–system was developed by rotating radial axles along the designated spiraling curves.

Digital raw models were produced and analyzed using RSTAB static software to calculate the resulting shift from deformations and internal

> *"Fabrication planning delivered highly complex models in just days rather than months."*

forces. Next, an iterative process was used to test and compare the efficiency of 2D sections and full stadium models of different structural solutions. This enabled Kosdruy and Schling to develop the final stage comprising two separate systems.

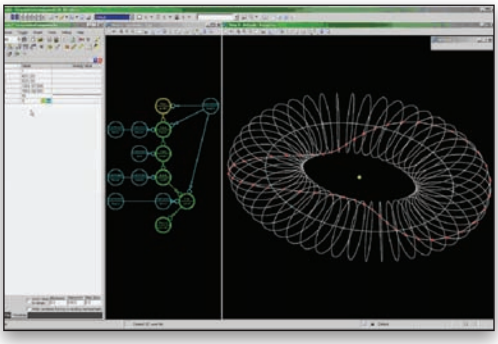
The façade structure, which consists of 32 radial beams and eight closed rings to withstand tension and pressure, sits on an elliptical perimeter around the stadium and forms an open basket where a second structurally independent roof system is placed. The façade is braced by 16 spirals that carry the staircases. The inner roof, which is held by a lower tension ring pulled back by radial tension cords around the stadium, follows the façade grid.

As for the structural system, it relies on equilibrium forces created by the inner tension of the closed elliptical rings. This allows the two systems to work together when joined. The tension cord that pulls at the inner ring is extended in the façade structure, creating an efficient distribution of forces.

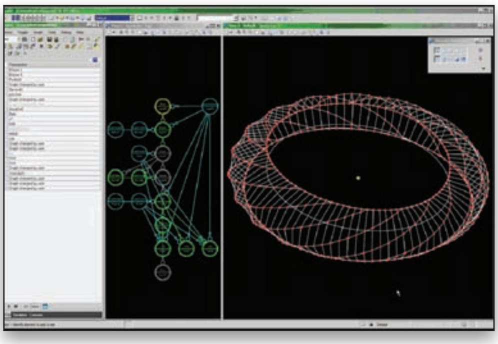
With the structural system defined, Kosdruy and Schling established a detailed plan of the joints and profiles. To complete the 3D model the duo created small digital models of the different joints and inserted them into the initial raw model file.

The completed GenerativeComponents model was used to layout all structural beams and create ready–to–use machining files. Additionally, 2D milling, 3D milling, 3D prototyping and laser cutting created detailed models of different scales. Indeed, without deploying parametric technology in each design aspect, this particular concept would have been unimaginable.

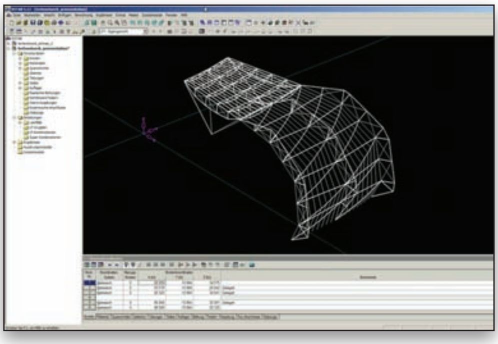
This ability to design complex geometry without reworking documentation allowed the designers to analyze and understand different spiral geometries throughout the process. Additionally, the GenerativeComponents model enabled Kosdruy and Schling to optimize all functions and spaces maximizing accuracy.



Creating the spiral façade of the stadium shell by using a GenerativeComponents transaction and functions that turns around an ellipse.

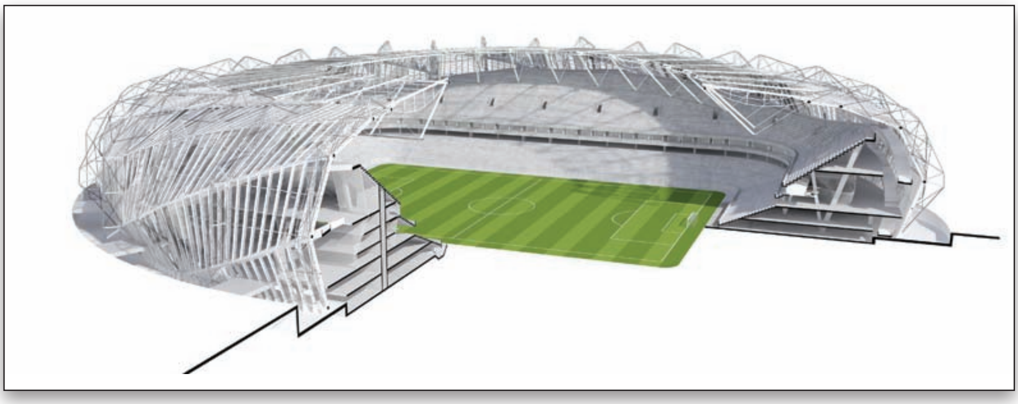


Applying different densities of spirals to achieve different design iterations quickly.



Investigating the structural design developed in GenerativeComponents with RSTAB.

GenerativeComponents also generated a large number of structural alternatives and adjusted the overall geometry to its structural behavior. Moreover, GenerativeComponents fabrication planning delivered highly complex models in just days rather than months.



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