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A model shared!

David Chadwick looks at the way architects collaborated with engineers using GenerativeComponents on the Lansdowne Road stadium project

Picture the scene. To the North and South you are bounded by low-rise residential buildings, with quite reasonable rights-to-light. Overhead, air traffic control regulations limit your expansion upwards to 50m. To the West you have the railway, and a local rugby club lies on your Eastern boundary. And in the middle of all this you want to drop a National Stadium, capable of seating 50,000 people, and you want the pitch to have sufficient daylight to grow a decent patch of grass!

This was the situation at Lansdowne Road, just outside of Dublin. You may remember that we wrote about the innovative methods that were used by the architects to lay out the seating in CAD User last year, where GenerativeComponents (GC) from Bentley were very much to the fore. There is rather more to the story though, as Roly Hudson of Bath University explained, as the design tool was used in other areas of the project, fostering a necessary collaboration between architects and structural engineers.

With so many potential areas of contention involved in building a complex free-form building in a highly constrained location, the architects expected a considerable amount of pressure in meeting the constraints and variations on the design suggested by the structural engineers, Buro Happold. To prevent this delaying the development of the project it was decided to use a parametric design solution, GenerativeComponents which, being numerically controlled, allowed changes suggested by them to be integrated into the shared model and to automatically update it.

The architects retained control of the external geometry of the stadium, whilst the structural engineers designed the structural system to support it. A hypothetical boundary surface separated the remit of engineering responsibility from that of the architect.

MODEL STRUCTURE

In any parametric model built for GenerativeComponents there are three main components; the static geometry files that comprise the CAD model, the numeric parameters for the model elements (held, in this case, in an Excel spreadsheet) and the GenerativeComponents script file, which referenced the parameters to generate the model.

Three main design areas of the stadium used GenerativeComponents to manipulate the spreadsheet parameters and to modify the geometry - and also to extract the 2D architectural plans, sections and elevations required to construct the stadium. A radial grid comprising the main structure of the stadium was developed using CAD prior to being passed to the structural engineers for analysis, and subsequently recombined into the model.

A team of cladding specialists were responsible for the detailed design and construction of the stadium envelope. A further team was responsible for the specialist seating bowl, which used GenerativeComponents to optimise the seating positions for 50,000 spectators, so that everyone had a view and was able to see a spot 18 metres above the centre of the playing field, and that the roof curtain on the drip line didn't impinge on the view of the pitch for those sat in the highest row of the grandstand!

The stadium was constructed as an array of vertical planes that established the locations of the tertiary members of the roof structure. On each plane a sectional curve was defined. This was the curve that separated the responsibility of the architects (outside the curve) from that of the engineer (inside). The footprint was devised around eight parametrically controlled tangential arcs, with a second set defining the inner roof edge or drip line (a wonderfully evocative term). The intersection of the footprint and the radial structure determined the origin of the sectional planes.

Other planar control curves mapped the position of the upper tier of seating and the edge of section above ground level and horizontal components were defined by intersection points of the radial grid with the drip line, seating bowl curve and stadium footprint. Another parameter ensured that a normal sized spectator in the top row had adequate headroom! With all of these parameters, the centre, start and end position of the two arcs, and the line that described the sections could be calculated.

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The parameters were referenced into the GC model and stored in the parameter spreadsheet, and used to construct the control curves for the geometry, mapping vertical variations clockwise from the North around the stadium. This meant that the control mechanism in place allowed vertical components of the stadium to be sampled at any point around the perimeter. It also meant that the sections could be divided further to produce a secondary structural system to support cladding panels.

STRUCTURAL LAYOUT

Having created the line of the roof, the structural members needed to support it had to be analysed and defined. A long span structural system was chosen, eliminating a need for columns on the pitch or amongst the spectators, and to transfer the load back to the columns outside the seating bowl.

A complex arrangement of primary, secondary and tertiary trusses was developed, spanning radially from the columns and cantilevered inside the primary horseshoe to extend the covered area of the roof. Key considerations were the sightlines of the spectators, inserted as a constraint into the parametric model, and the depth of the primary truss to provide maximum structural depth whilst giving spectator's a clear view of the pitch. With a design based on a circular arc for aesthetic reasons, a final consideration was a maximum truss depth of 4.4m to allow for off-site construction and transportation to the site.

To include engineering analysis into the parametric workflow required some innovation. An MS Visual C# programme was embedded within the GC environment that took the parametric model and created a data file for the structural engineers' chosen analysis programme, Robot Millennium. GenerativeComponents only deals with geometry, and doesn't understand structural member dimension, so the C# programme had to be pre-programmed to understand which section size was to be assumed for each element type, initially estimated based on engineering loading conditions and spans, and refined as the design process progressed. Model boundary conditions used to represent structural supports and member releases to simulate connections and movement joins were also embedded into the export model.

Loading was applied to represent the weight of the cladding, snow and wind loads. The complex nature of the double curved geometry resulted in 207 different triangular loads calculated for each of 2 base load cases (perpendicular and gravity loads). To calculate these by hand would be prohibitively time consuming, if they were to be recalculated every time the model changed shape. However, as the parametric model understood the relationship between each tertiary truss and its neighbour, the loading calculations could be performed inside C# and exported with the geometry to the analysis software.

The result was a fully automated parametric system capable of modelling the entire stadium roof geometry from architect-driven conceptual principles, through structural geometry layout and to engineering design software ready for analysis, without any need for manual intervention.

CLADDING STUDIES

Similar benefits accrued to the cladding studies that explored various setting-out points for arrays of planar and twisted panels in both construction terms and to assess visual impact. User defined tools looked at drainage across panels and at a way of flagging panels out of plane dimension - as defined by the manufacturer's specifications for the chosen material.

The stadium skin was divided into two distinct zones separated by a gutter running around the roof edge truss. Below this, the panel was a rain screen system, and above a sealed system to cover the roof. The cladding system consisted of a folded polycarbonate profile panel of equal width but varying length fixed to a standardised bracket system with two axes of rotational freedom.

LESSONS LEARNED

The collaboration between architects and engineers worked well, in general. A division of responsibilities was agreed early on. Sensibly, they both decided to freeze any software upgrades until the project was complete, so they could be sure of maintaining full compatibility.

As the architect's model was used as the start point for the engineer, some engineering consequences of changes to the architectural model were not fully understood at first, but once the causes - generally confusion over the orientation of sections of the model - were established, the parametric nature of the model enabled problems to be quickly rectified.

A caveat, however. As GenerativeComponents is a new technology it fell to the parametric modeller to build and operate the parametric model, understandably causing bottlenecks in the design process, with engineers having to wait for the model to be updated before progressing further. Until the technology is understood by more members of a project, it is suggested that companies tread warily before they embark on similar projects.

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