All world eyes mega space weaved in steel

By **Margrit Colenbrander**

The world has become familiar with this massive new venue in Beijing as the 'Bird's Nest', due largely to the lattice of interwoven steel enveloping what is one of the world's largest enclosed spaces.

Signature project of the 2008 Olympic Games, the Beijing Olympic Stadium is the visually stunning venue for the main track and field events and the opening and closing ceremonies.

The stadium can seat up to 91,000 spectators, reducing to 80,000 after the Games. It is 330 metres long, 220 metres wide and 69.2 metres tall. The floor area measures 250,000 square metres.

The unique design was created by Swiss architects Herzog and de Meuron in collaboration with Chinese artist, **Ai Weiwei**, Arup and China Architecture Design & Research group. **Michael Kwok** from the Beijing office of Arup headed up the structural design team for this prestigious project.

The unique steel frame combines façade and structure rendering form and function one and the same. The huge steel beams mutually support each other and converge into a grid formation resembling a bird's nest, the structural elements twisting and swirling over and around the great red concrete arena. This lattice of interwoven steel sections is formed from 42,000 tonnes of unwrapped steel, measuring 36km in total.

The bird comparisons aren't just confined to the nest-like shape of the structure as design tools borrowed from the aeronautic industry were taken advantage of.

The team relied on a combination of 3D design software CATIA CAD and purpose-designed software to achieve optimum design. CATIA is extensively used to generate the advanced 3D sheet metal designs required in the aerospace industry and includes applications for design and drafting, shape design, image rendering and interfaces.

The great advantage of using a core 3D model is that it acts as a central repository of ideas for the project so that the design can easily be changed over the lifetime of the project to meet the often conflicting needs of the stakeholders. The model can also be developed and made available in a format that suits various needs and interactivity tools. It helped calculate the precise fit of the web of steel for the 'Bird's Nest', minimising the quantity of steel used and improving its overall stability.

Model data could easily be passed to subcontractors for steel component fabrication, assembly and erection.

Construction began in December 2003 and was completed in May this year. In 2004, work was stopped due to concerns about spiralling building costs and it was decided to eliminate plans to build a retractable roof on the stadium. As Beijing is situated within a major seismic zone, many believe this improved the already strong earthquake-proof design. The design included splitting the stadium bowl into eight zones, each with its own stability system and effectively its own building.

Twenty-four steel beams are arced to define the shell and outline the central opening at a tangent. These are supported by 24 main columns that curve in at the top and are tied together by a 'nest' of random diagonals. Each column weighs 1000 tonnes, far more than the weight of those used in a conventional stadium. Although apparently random, the structure is actually a hierarchical series of primary, secondary and tertiary members. Due to its geometry, the structure only has two-fold rotational symmetry so there are only two of any joint type or element in the building.

Steel plate used to fabricate the beams was 10mm thicker than the Chinese national standard and the scope of its use was unprecedented. The steel proved strong, stable and highly manageable. A polyurethane coating shields the steel against the elements.

The three-tier stands of the stadium are supported by a seven-storey shear wall system with concrete framework. The upper part of the stand and the stadium steel structure are actually separated from each other but both of these are based on a joint foundation.

Precast concrete was used to minimise formwork construction on the bowl. A terrace of L-shaped precast units spanning areas between the supporting reinforced concrete in-situ beams makes up the section of the middle and upper tiers.

The spaces in the structure of the stadium are filled with inflated ETFE (ethylene tetrafluoroethylene) cushions which are mounted on the inside of the structure where necessary to provide wind protection. The roof over the stands is a simple ETFE membrane designed to keep out the sun and storms without impeding natural light and acts as a foil to the highly detailed steel skeleton. This is the same type of membrane that was used in the neighbouring National Aquatic Centre or 'Water Cube' as it is commonly known.

L-shaped angles welded to the steel beams were used to attach the membrane and also create a channel to carry runoff water. A translucent PTFE (polytetrafluoroethylene) acoustic lining is attached to the side walls of the inner ring to keep noise down. Geothermal heating and rainwater tanks complete the green design.

Project Team

Client: National Stadium Company, China International Trust and Investment Corporation Consortium

Architects: Herzog and de Meuron, ArupSport China Architecture Design & Research Group

Structural engineers: Arup

Fabricators and building contractors: CITIC International Contracting; Beijing Urban Construction Group; Chanjiang Jinggong Steel Structure; China First Metallurgical Construction

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