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Central campus with shading feature roof

Zayed University in Abu Dhabi—Engineering for an Iconic Project

Ingenieurbüro Dr. Binnewies GmbH

The Emirate of Abu Dhabi is implementing its Master Plan 2030 in huge and successful steps. Education plays a central role in this plan. Part of this is the new campus of the Zayed University, which is located in the future Capital District directly on the important connecting road between the Abu Dhabi international airport and the old town peninsular.

The main design element of the Zayed University is the filigree and iconic free-form feature roof. Dr. Binnewies structural engineers were responsible for the structural design from inception until handover of the campus as well as for regular inspections during operations of the campus.

The new campus of the Zayed University, named after the late national founding father H. H. Sheikh Zayed bin Sultan Al Nahyan, is housing up to 6,000 students on 75 ha grounds. Accommodation, sports facilities and stores are available on a gender-segregated basis. The central campus area includes a conference center and library as well as administrative buildings, faculties and cafeterias.

Following the airport road from downtown Abu Dhabi towards the airport, the first impression of the Zayed University is the iconic feature roof, floating above the university buildings as a slim line. This gives a first impression of the jointless free-form roof of 25,000 m² surface area made of steel with aluminium cladding. Coming closer via the library, finally the viewpoints from the central campus show the spectacular design completely. German architects BRT's symbolic-rich design moulds the 100,000 m² GFA of buildings in the central campus area into a huge sculpture. The shape and the lightness of the roof echoes the traditional Arabic chador.

Finished central campus area

Design and build within an ambitious time frame

As of the beginning of the project for the German design team in April 2009, the site was already mobilized by the main contractor's joint venture Al Habtoor & Murray/Roberts. Only 27 month of design and construction time remained until the contractually required handover date of the complete campus in July 2011. This lead to the need to build a strong and effective team with optimized workflow. The majority of the architect and engineer teams worked from Germany with only a few colleagues on site, who served as communication and project leading parts with close contact to the main contractors site team.

BRT architects were assigned mainly up to design development and interior design. Subsequent to this, the local architects Pascall+Watson were commissioned for the detailed documentation of the buildings. For the free-form roof, however, the detailed design including all coordinating tasks and clarification of interfaces were done jointly by the structural engineers and the main contractors project managers in a shared and successful hands-on approach.

Because of the complexity, the structural engineers from Dr. Binnewies were fully assigned from the initial idea until completion of the roof and are due to the needed special knowledge supporting the facility management of the feature roof with regular inspections.

Parametric design and building information modelling as key for success

After assignment, the full structural design of buildings and feature roof had to be completed during the remaining eight months of 2009. During the process of form finding of the feature roof, 16 different primary shapes and a corresponding number of secondary variations of the geometry and the structural design were developed and tested in close cooperation with the architects. Only 12 weeks after assignment and developed from a total of 80 variations, the final and efficient form was signed off.

This was only made possible by the use of a holistic, fully parameterized 3D-architectural model of the buildings and the free-form roof in Rhinoceros® in conjunction with a new software developed in-house by the structural engineers that generates all structural elements within the shape of the architectural model. The development, programming and verification of this software were carried out during the project period in parallel with the individual design steps and has been used successfully for a number of other projects with iconic character ever since. This approach was part of the projects award winning overall building information model (BIM).

Central Feature Roof under construction

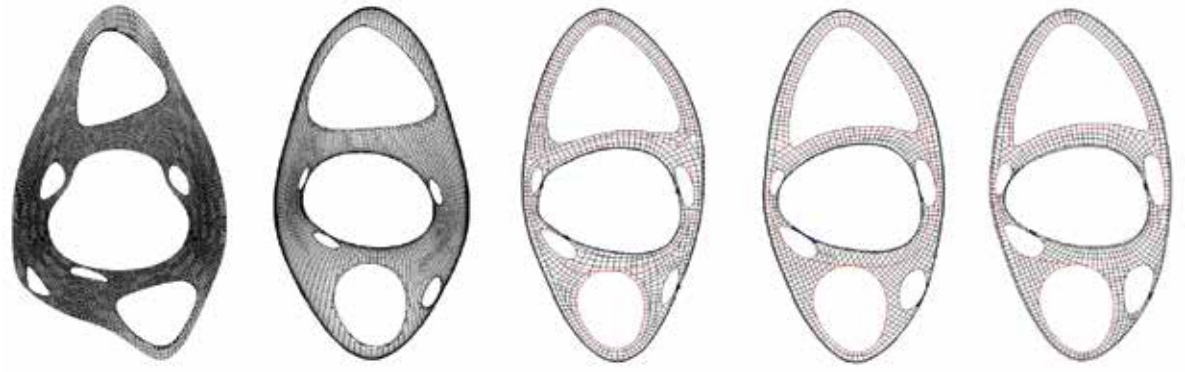
An ambitious external appearance with high sustainability needs

The sculptural roof was conceived to be a jointless, continuously curved shape of aluminium with a constant overall thickness of only 1.75 m and not connected to the buildings. The engineering challenges in this were multifaceted. Along with high architectural requirements of evenness, continuity of curvature, clean lines and non-visibility of joints, sustainability played a major role in the design.

Due to the extreme environmental conditions and the need of lowest facility management cost, the roof needed to be smooth and jointless and preferably bearing less. Also, emphasis fell on cost with minimized steel consumption, ease and time of construction and the use of local products and workmanship whereever possible. As a result, the particularities and capacities of the locals market were fully taken into account during the design, leading to the fabrication of the structural steel completely in the UAE.

The roughly 25,000 aluminium panels have typical dimensions of ca. 1,500 mm x 1,500 mm by 3 mm thickness and are mounted on their own substructure at the upper side ceiling and the soffit. This left a structural height of constantly only 1.50 m.

Evolution of roof shape during form finding



Interaction with the buildings

In order to preserve the slim appearance of the free-form roof, it was essential to support it from the buildings at particular points. For the convention center, the administration and the library, interaction with the roof was thus an additional design requirement that mandated a high level of full 3D-modelling and coordination with the parallel building design process, also done from Dr. Binnewies engineers. According to the architects' specifications, all structural supports of the roof needed to be nearly invisible. This was achieved by using very slender columns, large spans and a positioning away from the edges of the building.

Concept design and form finding

The structural concept was developed based on the structural engineers in-house experience with iconic structures, supported by the drafting of characteristic sections and by curvature analysis. Also, the loads from the harsh environmental conditions with extreme temperatures, water ponding, sand loads, wind and earthquake were taken carefully into account. In order to achieve a cost efficient solution within the only 1.50 m structural depth, the shell-like load-bearing behaviour of the structure in the central campus, characterized predominantly by normal forces, was optimized in close cooperation with the architectural design, leading to the smooth arches and openings and also to the positioning of the four integral fix points of the roof.

The flat areas of the roof above the library and the convention center are mainly working following torsion and bending principles. The aerodynamic behavior under wind loads for these areas were investigated based on engineering experience and calculations as per Eurocode 1.

To arrange the complex steel structure within the roof shape, the configuration of the structural grid was first worked out in plane projection, based on the previously identified principles of an optimum global load-bearing behavior with a primary ring structure and a secondary truss structure with an empirical grid of 5.00 x 5.00 m.

Then this two-dimensional configuration was projected as beams onto the middle surface of the free-form roof using the in-house developed software. The spatial coordinates of the free-form roof required to do this were acquired from the architects' geometrical data. The spatial orientation of local beam axes was also determined automatically by aligning the strong axes of the beams in the directions of the normal surface vectors of the architectural model.

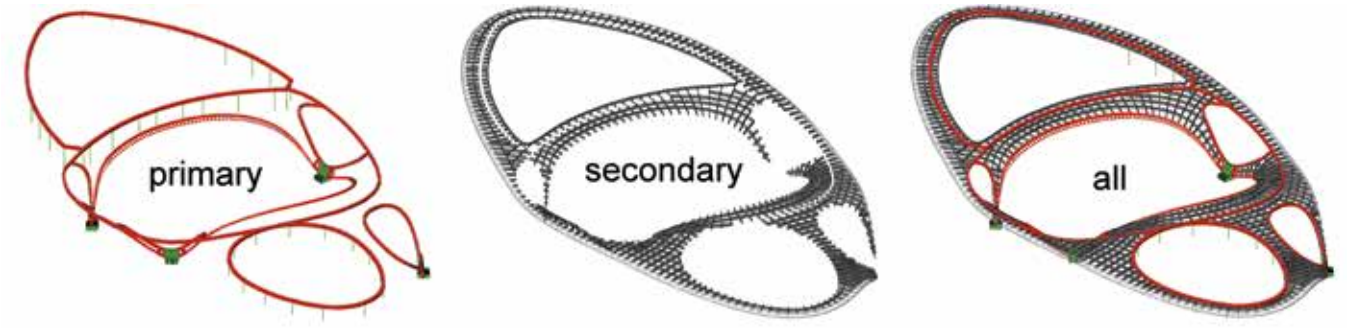
Early tender for the structural steelwork

Tendering for the steel structure of the free-form roof started even before finishing the concept design. This lead also to the need of the determination of the gross steel tonnage to be finished only 16 weeks after assignment including definitions of cross sections, starting with prefabrication in parallel. After reaching this important milestone, the structural design mainly had to be completed by the end of 2009 with all corresponding connection forces and the full three-dimensional geometry to be submitted digitally to the steelwork contractor.

Detailing and optimization

Due to the design to cost requirements, the shape of the free-form roof and the spatial configuration of the structure within were further optimized interdisciplinary. In the detailed design, the spatial structural configuration was finalized, transferring the former beams into light and efficient trusses. This full three-dimensional geometry including presetting was submitted to the steel work contractor and directly used as basis for the workshop design. Also, the four complex inte-

Hierarchical arrangement of structural elements

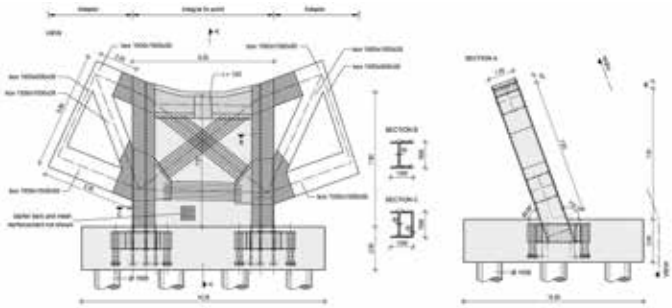


Erection of the secondary steel structure subsequent to primary ring structure

gral fix points as junction between steel structure and pile foundation with its high loads were detailed.

Finally, the structural engineers had to check the workshop design provided by the steelwork contractor in parallel with already ongoing fabrication and erection and also had to provide a full set of calculations regarding assembly planning and presetting. A supervision of the site works with the complex temporary building stages and depropping sequences was carried out, too.

Drawings and assembly of integral fix point



Facility management

The need of a cost efficient facility management was defined early during the project's inception. After the first two years of operation it can be stated, that the roof is a highly efficient structure with lowest maintenance needs. The simple yearly inspections from outside can be done from the local facility management. Only the inspections from inside of the roof need to be done from the structural engineers. Focus is laid on corrosion, signs for overloading and deterioration, taking the highly loaded points of the roof into account. These bespoke inspections are carried out relying on the German VDI-guideline 6200, which represents the latest development in the field

of building inspections, containing i. a. roof structures like the Central Feature Roof.

Goal achieved

The new Zayed University Campus in Abu Dhabi is a successful example of international cooperation between designers and builders from multiple continents, the potential of the main contractor philosophy and the benefits from BIM-equivalent design approaches. Besides extreme time constraints, the project required mastery of numerous engineering challenges, different design philosophies, difficult interfaces between design and construction works as same as a huge construction site with up to 8,000 workers running in parallel to the design works. Together with the employees and students of Zayed University, the main contractor and the architects, we are happy that our shared goal could be achieved in such a short time. We would like to thank Mubadala under the patronage of H. E. Sheikh Nahyan Bin Mubarak Al Nahyan, UAE Minister of Culture, Youth and Community Development and former President of the Zayed University, for trust and confidence they extended to the whole team.

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