SL RASCH collaborates with ESI to achieve architectural excellence in Mecca and Medina

Challenge

Architecture firm SL RASCH took on the complex project of designing and constructing the highly innovative Medina Haram Piazza. The flexible shading umbrellas and the huge elastic wing-like clock hands on the top of the Mecca Royal Hotel Clock Tower presented very specific challenges. With the objective of creating wind- resistant designs, SL RASCH conducted initial studies using wind tunnel tests on reduced scale rigid models. However, these models could not predict the flexible behavior of the structures under wind load. In order to address their design challenges, the team turned to ESI and their simulation solutions.

Benefits

Using simulation, SL RASCH was able to confidently investigate the effect of wind load on the umbrellas and clock tower for the first time. The studies helped SL RASCH make solid decisions on how to construct these two massive structures.

> *"With the know-how of ESI experts and the capabilities built into ESI's advanced CAE software solutions, designing our innovative structural systems became possible".*
>
> **Dr. Mahmoud Bodo Rasch**,
> Founder and owner of SL RASCH GmbH
> Special and Lightweight Structures.

Story

SL RASCH & ESI: The Collaboration

Today the millions of pilgrims that travel every year to the Great Mosque of Medina in Saudi Arabia are sheltered by more than 250 foldable 26x26m hydraulically hinged arm umbrellas (Fig. 1). These translucent umbrellas fold away at night and open up during the day to create a microclimate beneath them that is up to 8°C cooler than the surrounding area. They also add materially to the beauty of the Piazza.

The Mecca Royal Hotel Clock Tower (Fig 2.) is another significant site for pilgrims travelling to Saudi Arabia. This complex is located just a few steps away from the Grand Mosque and in 2012 the tower became the second tallest building in the world. The complex serves the pilgrims and is a fine example of modern architecture in the city of Mecca.

SL RASCH, a German based company, specializes in buildings and lightweight structures, integrating architecture and engineering. SL RASCH began working on both of these projects for Mecca in 2005.

In order to test their projects, SL RASCH initially used reduced scale physical models. However, this process had room for improvement. As a result, Dr. Rasch, CEO of SL RASCH, and his longtime friend Dr. Eberhard Haug, co-Founder of ESI Group and author of the lightweight structure analysis code LISA, began collaborating to apply simulation methods in elaborating the design of these structures. Dr. Haug's knowledge in flexible structures along with ESI's numerical simulation solutions helped SL RASCH in designing, testing and installing all the umbrellas at the site of The Great Mosque of Medina. Simulation also provided insightful flow analysis for the uppermost part of the Mecca Royal Hotel Clock Tower.

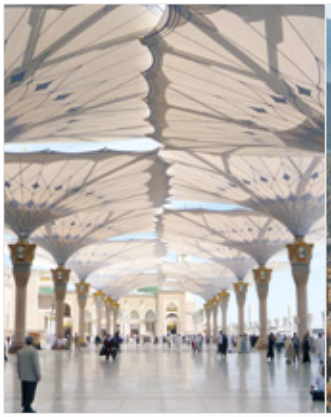

Fig. 1: Umbrellas at the Mosque of Medina

Fig. 2: The Mecca Royal Hotel, also known as 'Abraj Al-Bait Towers'

Simulation of Lightweight Structures

SL RASCH and ESI combined their knowledge and best simulation technologies to achieve the desired results. SL RASCH virtually built and tested different types of minimal energy lightweight structures for this architectural project by relying on Virtual Performance Solution (VPS), ESI's software to assess all domains of product performance. SL RASCH used tailor-made modules developed by both companies to model naturally turbulent wind loads and optimize the shape and structure of the umbrellas. To achieve that objective the fabric of the umbrellas was represented by optimal minimum energy flexible membranes, which are physically analogous to self-forming iso-tension soap films. For structural analysis of turbulent wind load on such lightweight structures, the team used Fluid-Structure Interaction (FSI) simulations, coupling Computational Fluid Dynamics (CFD) and Computational Structural Dynamics (CSD).

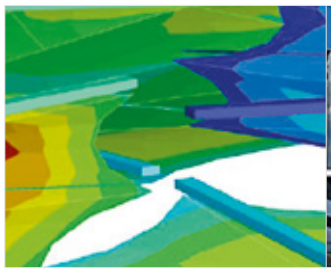

Fig. 3: Results showing that the overlapping umbrellas will not touch each other during deformation.

Fig. 4: Left to right: Folding and stowing of real umbrella, Stowing Simulation.

Medina Haram Piazza Shading Umbrellas

The umbrellas were designed and analyzed for form, deformation, wind loads, and coupled FSI behavior. CFD simulations were performed for the full layout of 182 umbrellas in the Medina Piazza to test under severe wind load and detect critical wind directions. FSI simulations helped evaluate aero-elastic dynamic vibration resonances, as well as check for collisions between overlapping membranes and arms of umbrellas deforming under wind load. Umbrellas were required to overlap to minimize unshaded areas.

Folding and Stowing Simulation of Umbrella Membranes

Simulating the folding and stowing of the giant umbrellas was complex, as it had to take into account gravity, overlaps, and wind load during folding or unfolding of the membranes.

ESI's expertise in the simulation of airbag folding for the automotive industry proved to be invaluable as they were able to use their Virtual Performance Solution software to simulate the folding and stowing of the umbrellas in their narrow containers.

Mecca Royal Hotel Clock Tower

This tower is made of a high strength steel structural skeleton, clad with lightweight ornamented carbon-epoxy sandwich panels. The lightweight composite claddings and the large hollow-section composite clock hands of the Clock Tower had to be aerodynamically stable under high wind velocities and pressures.

Fig. 5: CFD wind simulation results with velocity vector time snapshot in a vertical section.

The project team performed structural analyses of the topmost 200 meters of the tower using wind tunnel analysis and Computational Fluid Dynamics (CFD). The result exhibited in Fig. 5 is CFD wind simulation for the uppermost piece only.

CFD analysis also provided detailed evaluation of the wind pressures on smaller structures such as the corner towers, the telescope used to observe the moon during Ramadan, and the hilal (the crescent mounted on top).

Based on the results, the project team designed panels of the skeleton and the hollow composite clock hands.

Illustrated in Fig 6, the clock hands (23 meters long in the case of the minute hand), were designed to withstand strong lateral winds in the least favorable 12 o'clock position where the danger of periodic aero-elastic flutter is highest. FSI simulation allowed the team to design the wing- like large hollow section to resolve the flutter issue (consultant: Prof. Löhner).

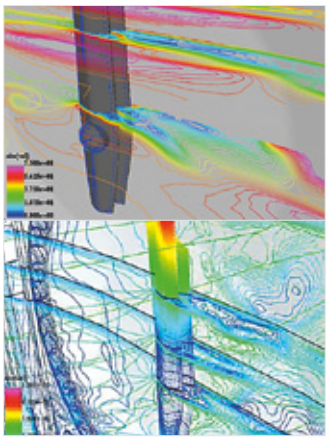

Fig. 6: CFD and FSI simulations of the clock hands at 12 o'clock position. (images: FEFLO Prof. Löhner)

Conclusion

SL Rasch designed the umbrellas and the tower clock by using simulation methods, instead of building and testing physical prototypes. The project team were able to test different versions of the design and achieve optimal results while addressing all applicable safety requirements. This study helped save time, energy, and considerable cost. Today, these highy complex, innovative structures can be admired and appreciated by every visitor to Mecca and Medina.

About SL RASCH

SL RASCH specializes in Special Buildings and Lightweight Structures; integrating architecture and engineering. An interdisciplinary team of professionals, composed of architects, structural, mechanical and aeronautical engineers, physicists and computer specialists together with in-house departments for project management, graphic design and model making, brings state of the art techniques and knowledge to design development and problem solving. For more information please visit www.sl-rasch.com.

About ESI GROUP

ESI is a pioneer and world-leading provider in Virtual Prototyping that takes into account the physics of materials.

ESI boasts a unique know-how in Virtual Product Engineering, based on an integrated suite of coherent, industry-oriented applications. Addressing manufacturing industries, Virtual Product Engineering aims to replace physical prototypes by realistically simulating a product's behavior during testing, to fine-tune fabrication and assembly processes in accordance with desired product performance, and to evaluate the impact of product use under normal or accidental conditions.

ESI's solutions fit into a single collaborative and open environment for End-to-End Virtual Prototyping. These solutions are delivered using the latest technologies, including immersive Virtual Reality, to bring products to life in 3D; helping customers make the right decisions throughout product development. The company employs about 1000 high-level specialists worldwide covering more than 40 countries. ESI Group is listed in compartment C of NYSE Euronext Paris.

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