CUSTOMER STORY

DESIGN AND EXPERTISE UNDER ONE ROOF

SOM'S MUMBAI AIRPORT DESIGN MASTERPIECE SOARS WITH ALTAIR SOLUTIONS

> "S-FRAME's ability to easily model irregular structures enables us to analyze complex building structures and achieve optimal results within tight timelines. The confidence with which we can design with structural steel makes S-STEEL a no-brainer.
>
> Preetam Biswas, principal, Skidmore, Owings & Merrill (SOM)

About the Customer

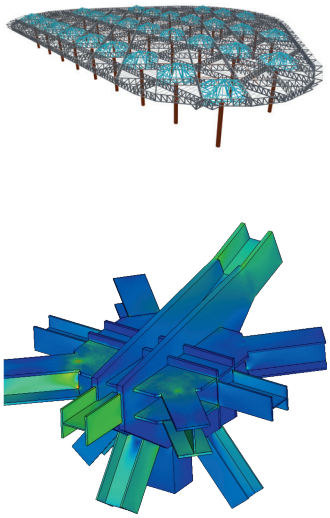
Skidmore, Owings & Merrill (SOM) is an international alliance of architects, designers, engineers, and planners and one of the largest architectural firms in the world. Founded in 1936, SOM has grown into an architectural, urban planning, and engineering firm and an international provider of structural engineering services, employing architects and engineers with highly specialized technical knowledge. Working from offices across the globe, the internationally renowned firm has been responsible for some of the world's most significant architectural and engineering achievements and public spaces. Aiming to create buildings for the future, the team uses best-in-class software and emerging technologies to achieve their design goals. Considering sustainable regulations and building constraints, the structural design specialists at SOM use Altair solutions to evaluate their designs.

Their Challenge

In an expansion project for Mumbai's Chhatrapati Shivaji International Airport, SOM was tasked with designing an integrated terminal building that combined domestic and international operations and was to be built at the site of the existing in-operation airport. The project needed to address multiple key structural challenges: The headhouse roof was required to span an area of 17 acres (70,000m^2) over various functional buildings and facilities. It needed to meet the architectural space and form requirements of a low-profile roof with an undulating ceiling and an open interior space below. In addition, to account for regional climatic conditions, the roof needed to prevent water leakages from extreme monsoon-caused winds and rainfall while also being tolerant of thermal expansion and contraction. The long-span roof supported by fluted columns required a modular truss system that could be efficiently fabricated on or near the ground and hoisted into place.

As such, the challenge was to design a headhouse roof without expansion joints to prevent leakage that spanned the roof's entire 17 acres. SOM engineered a roof structure that would move independently of the base concrete structures in response to loads, expansion, and contraction caused by temperature variation. The resulting long-span truss system with a depth of just four meters was supported by widely spaced composite mega-columns. This roof system addressed these challenges and provided an efficient way to build the structure on the ground and hoist it into place.

And since the roof was supported by columns but not attached to the individual structures below, the SOM engineers opted to design a unidirectional cable wall system with special features that created several challenges in the structure's design and detailing. To design one of the largest single roofs in the world without expansion joints and create the new cable wall system, the SOM team needed specialized design software to evaluate the structure's structural efficiency.



TOP: Headhouse roof 3D framing model **BOTTOM:** 3D solid finite element analysis model of steel roof connection

Our Solution

While concrete was selected as the primary building material for the base building, steel was the material of choice to create a lightweight design for the roof structure. To allow the roof to move independently of the base concrete structures below, 30 supporting mega-columns, each with an unbraced height of 30 meters and a 2.7-meter diameter, were designed to pass through the sub-structure openings. The SOM team needed a tool that would manage this complex geometry and building system complexity. To do this, they chose Altair® S-FRAME® and Altair® S-STEEL® for the structural modeling and steel design, which they had used in previous projects to analyze and design structures regardless of their geometric complexity. Using S-FRAME and S-STEEL, the team could model the entire headhouse and analyze and evaluate the steel structure's ability to withstand external loads while meeting design code requirements.

The 40-meter tall composite mega-columns were studied using non-linear buckling analyses. Since the design methods in the standards don't correspond exactly to the behavior of these columns, the SOM team performed a stability analysis for both each segment of the column and the complete mega-column system. The engineers also used S-FRAME to model and analyze the terminal building's curtain wall, including two cable wall systems of more than 1 kilometer in length and 11,000 m^2 in area, making it the world's longest, largest cable wall. The SOM engineering team was particularly impressed by the workflow that ensured seamless transitions between S-FRAME and S-STEEL. S-FRAME offered fast BIM import and easy modifications to the complex roof model. And with integrated steel design, SOM could rapidly generate transparent, comprehensive results so the team could iterate faster.

In addition, for non-standard steel connections between the mega-columns and roof structure, SOM deployed Altair® HyperMesh® and Altair® OptiStruct® to design the major connections to ensure optimal material use. The connections' meshed three-dimensional geometry was loaded at the connection work point with forces directly obtained from the S-FRAME headhouse roof analysis results. The HyperMesh study ensured no part of the connection exceeded the maximum steel yield stresses.

Results

Thanks to Altair's solutions, SOM was able to design the headhouse roof to meet architectural requirements, satisfy building design codes, and optimize the steel members. S-FRAME gave the SOM team unmatched adaptability and flexibility to handle complex structures and perform nonlinear analysis. The data import was easy, and the software's comprehensive, transparent design output from S-STEEL provided reliable results that let the team work confidently, which helped shorten the design cycles.

Additionally, the team benefitted from HyperMesh and OptiStruct to assess the performance of non-standard complex steel connections and ensure structural integrity. The team met all requirements, achieving the best possible result while also meeting tight timelines.

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