An Altair Publication

SPRING / SUMMER 2009

Concept To Reality

Ideas and Strategies In Product Development

Structural Innovation Takes Shape

Structural Innovation Takes Shape

Structural optimization plays a **key role** enabling Skidmore, Owings & Merrill, LLP to create **buildings with unique shapes and aesthetic values.**

by **Beverly A. Beckert**

From skyscrapers such as the Sears Tower and the John Hancock Center in Chicago to government buildings to airport terminals, Skidmore, Owings & Merrill, LLP (SOM) has made its mark as one of the leading architecture, urban design, engineering, sustainable design and interior architecture firms in the world. Founded in 1936, the company has completed more than 10,000 projects in more than 50 countries.

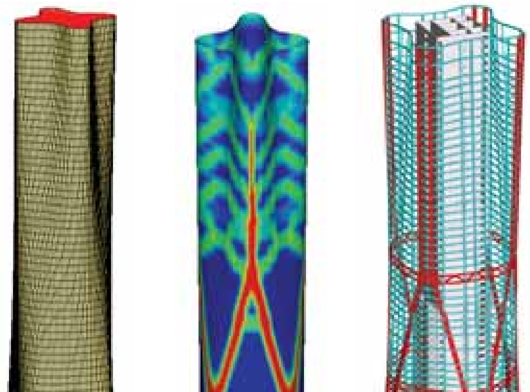
Known for its innovative buildings, the firm faces engineering challenges day in and day out. That's because each project is unique.

What remains constant, however, is SOM's reliance on sound structural principles – and the commitment to use technology to improve engineering processes and end products.

A Building Perspective

Today, architectural design is very sophisticated. According to William Baker, SOM partner in charge of structural and civil engineering, "We are doing more work with fewer people, and the projects are more complicated. In addition, building materials have evolved. For example, modern concrete is stronger, denser and can be placed more easily than traditional concrete. Also, there are new steels on board that are affordable and readily available."

SOM's buildings are never the same. While the firm deals with standard components, such as steel, the concrete and building shape are always customized. Baker says, "There are no off-the-shelf products, as in other industries. We start with a blank sheet of paper and try to create a structure that takes into



Skidmore, Owings & Merrill, LLP utilizes computer simulation to optimize buildings. Altair OptiStruct optimization results supporting SOM's design of the White Magnolia Plaza are shown.

consideration the desires, program requirements and sites of the clients."

Taking 12 to 18 months to design a building, and two years or more to build it, is not unusual. SOM relies on judgment and past experience to make informed decisions before every "i" is dotted and "t" crossed.

Baker explains that the SOM process starts with the concept phase and then moves into schematic design. Design development, in which details are fleshed out, follows. At this juncture in the process – about halfway through – SOM staff knows the building weight and geometry and can start work on the foundation. The actual design phase entails collaborating with contractors and handling construction documents. In the construction administration phase, SOM works with the client and the contractor to address construction issues.

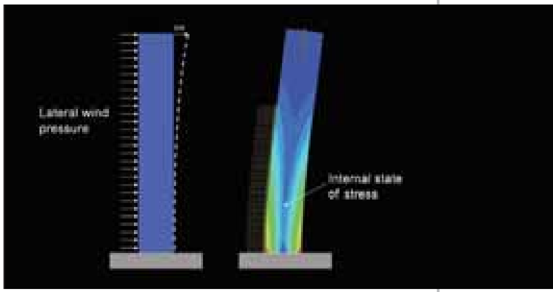
Buildings are complex in nature, with mechanical systems, ventilation systems, lighting systems, egress in emergencies and other elements that need to be addressed. SOM strives to fit various functions into one location, and it takes a lot of coordination to make these ideas work.

In addition, Baker notes that dealing with the forces of nature, including weight, gravity, seismic activity and the wind, is part of the development process. Buildings must be constructed to resist the forces of nature.

The Role of Technology

SOM has been using computer technology in building design for more than 40 years. While an initial design might be done on the "back of an envelope," followed up with hand calculations, computers are helpful in visualizing nuances of behavior.

Alessandro Beghini, SOM structural engineer, explains that computer simulation enables the evaluation of the building's behavior and the understanding of how forces are transmitted through the structure, their elements and element connections. In simulations, line elements are typically used for beams and columns, and shells or plates are used for walls. Solid elements, like bricks or tetrahedrons, are more demanding computationally. Therefore, they are employed only in special applications where the understanding of the three-dimensional stress state is crucial, like in the analysis of the performance of a complex steel connection.



Simulation is used by SOM to minimize displacement at the top of the building under lateral wind pressure using the least amount of material.

Many of the design problems studied are similar to those in the manufacturing industry, such as vibration, stability/buckling and load-carrying capabilities. In addition, for high-rise buildings, SOM evaluates the aerodynamic performance of the structure using wind tunnel testing.

"Starting about two years ago," says Beghini, "we added several optimization programs to our structural toolbox. OptiStruct, part of the Altair HyperWorks CAE suite, is one of these tools. OptiStruct allows us to rapidly develop efficient designs by creating initial concepts based on the package space information. OptiStruct's shape and size optimization capabilities can be later applied to further improve the design."

Optimization Matters

A balance of function, strength and aesthetics is integral to structural engineering. SOM believes

A Leader in Innovation and Excellence

SOM

Since its inception in 1936, Skidmore, Owings & Merrill, LLP (SOM) has been a leader in the research and development of specialized technologies, new processes and innovative ideas, many of which have had a lasting impact on the design profession and the physical environment.

The firm's long-standing leadership in design and building technology has been honored with more than 1,100 awards for quality, innovation and management. The American Institute of Architects has recognized SOM twice, in 1962 and 1996, with its highest honor, the Architectural Firm Award. In March 2009, SOM was the only architecture firm to be included on *Fast Company* magazine's list of "The World's 50 Most Innovative Companies."

SOM's sophistication in building technology applications and commitment to design quality has resulted in a portfolio that features some of the most important architectural accomplishments of the 20th century. Examples include the Sears Tower and John Hancock Center in Chicago; Jin Mao Tower in Shanghai; Canary Warf in London; the Washington Mall and Constitution Gardens in Washington, D.C.; and the Lever House in New York City.

Standing Tall

The Chicago office of Skidmore, Owings & Merrill LLP (SOM) is currently working on what will be the tallest building in the world, upon completion this year. The final height of the Burj Dubai, United Arab Emirates, is still a secret. However, to envision the height of the structure, George Efstathiou, SOM managing partner for the project, invites people to imagine the John Hancock Building stacked on top of the Sears Tower.

Designers purposely shaped the concrete structure of the Burj Dubai – "Y" shape in plan – to reduce the wind forces on the tower and keep the structure simple for ease of construction. The structural system is a "buttressed" core. Each

Burj Dubai, designed by and copyright to Skidmore, Owings and Merrill LLP; model photo by Steinkamp-Ballogg Photography.

wing buttresses the others via a six-sided central core, or hexagonal hub. The result is a tower that is extremely stiff torsionally.

The setbacks are organized so that the tower's width changes at each setback. The advantage to the stepping and shaping is to confuse the wind. Wind vortexes never get organized because at each new tier the wind encounters a different building shape.

Upon completion, the Burj Dubai will be the tallest building in the world in all four categories recognized by the Council on Tall Buildings and Urban Habitat. Buildings are ranked on the basis of spire height, the highest occupied floor, roof height and pinnacle height.

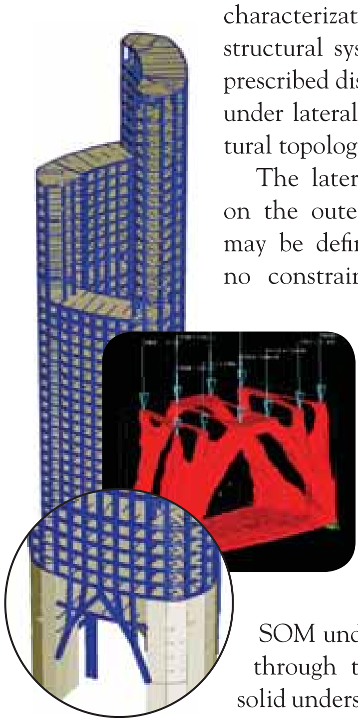
that a refined science of engineering leads to the most efficient solutions, resulting in least material and least cost.

For example, in the recent conceptual design of a high-rise building, SOM applied OptiStruct for the characterization of the lateral (wind-resisting) structural system. The goal was to determine a prescribed displacement at the top of the building under lateral wind pressure and define the structural topology with the least amount of material.

The lateral structural system was developed on the outer envelope of the building, which may be defined by architectural constraints or no constraints at all. When the constraints are known, the lateral system is defined by means of a topology optimization of the exterior surface. When constraints are not known, the overall form of the building is allowed to vary, and shape optimization techniques are applied.

In this instance, the architectural building envelope was known. SOM understood how the forces were flowing through the building and, therefore, had a solid understanding of the structure. After carrying out several OptiStruct topology optimization studies, SOM arrived at a solution and strategically placed the material where the forces were.

"Sometimes," says Beghini, "our architects approach us with projects for which there are no specific constraints on the building envelope, as in a proposed building in Korea. That structure's volume, equivalent to the overall floor area of the building dictated by the client's program, was used as a constraint, and we performed a series of shape optimization studies."



SOM employed OptiStruct to aid in the design of building base transfer structures.

The resulting structure featured a unique tapering profile recalling the shape of a water's drop. SOM later validated the results of the optimization study with another program from its toolbox based on a different algorithm.

OptiStruct has also been successfully employed on a smaller scale for studying local areas of a building's structure, such as at column transfer zones where high stress concentration occurs. Other SOM applications of the Altair HyperWorks suite include characterizing the gravity system of structures, meshing and analyzing complex geometries and topology studies for bridges.

SOM is extremely proud of its reputation for designing unique, high-functional buildings that transform natural forms into extraordinarily beautiful architectural compositions. OptiStruct and the HyperWorks simulation suite are among the technological tools helping to streamline the advanced finite element analysis process that is critical to the successful structural engineering of such buildings. C2R

Beverly A. Beckert is Editorial Director of *Concept To Reality* magazine. **William Baker,** Partner in Charge of Structural and Civil Engineering, and **Alessandro Beghini**, Structural Engineering Associate, Skidmore, Owings & Merrill LLP, Chicago, contributed to this article.

All images courtesy of Skidmore, Owings & Merrill, LLP

For more information about Skidmore, Owings & Merrill, LLP and OptiStruct, visit *www.altair.com/c2r* or check 05 or 06 on the reply card.