Building on a Global Reputation

NInsight verifies the architectural design of landmark buildings using engineering simulation.

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In the world of architecture, practitioners like Frank Gehry are pushing the limits of building design with their use of novel shapes and innovative materials, while engineers face the practical task of bringing these elaborate visions to life. Architectural and structural engineers not only ensure the integrity of the architect's original concept, they also address such pragmatic issues as structural soundness, occupant and pedestrian safety, wind and rain loads, and the long-term effects of weather on building materials.

The Austrian firm NInsight has developed a worldwide reputation for helping architectural engineers conduct research, analyses and simulations that verify building designs before significant funds are invested in construction. Founded in 1992, the organization studies and modifies architectural designs and building materials, among other projects, in a virtual environment with the aid of software from ANSYS.

One of NInsight's most visible projects is the Guggenheim Museum in Bilbao, Spain, designed by Gehry and immediately lauded as an architectural landmark when it opened in 1997. The Guggenheim boasts one of the world's most recognizable designs, with its titanium surface and organic contours. But when Gehry conceived his architectural vision in the mid-1990s, there were many unknown factors, including how the unique shape would affect wind flows and velocities around the structure, whether the single-support canopy at the entrance would remain stable over time, and how the new titanium alloy would withstand the coastal environment.

Austrian engineering research firm NInsight used ANSYS software to verify some critical design elements for the world-renowned Guggenheim Museum in Bilbao, Spain.
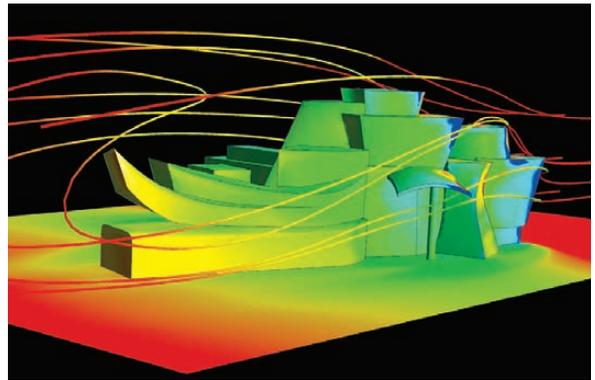
NInsight modeled the Guggenheim Museum's facade with spline surfaces, which helped to create a high-quality mesh for subsequent simulations. This hybrid tetrahedra/hexahedra mesh with prisms in the inflation layer consisted of approximately 3,600,000 discrete elements, leading to an extremely accurate and realistic simulation environment. This simulation shows the streamlines and pressure distribution for typical wind conditions in the city.

"ANSYS software was absolutely critical to the engineering verification performed for the Guggenheim Museum Bilbao because of its ability to handle complex shapes and free-form surfaces."

Using ANSYS ICEM CFD and ANSYS CFX software, NInsight simulated wind patterns, streamlines and pressures around the structure and suggested small design modifications—such as slight changes in the shape of the building near ground level and modifications to the entrance canopy. The original shape of the canopy led to undesirable effects, including wind velocities that were too high at the pedestrian level. Engineers addressed this issue by modifying the shape of the canopy so that pedestrians could move safely and comfortably around the building's perimeter.

ANSYS ICEM CFD software enabled NInsight researchers to create an incredibly detailed geometric mesh of the Guggenheim structure. The meshing process was conveniently driven by automatic curvature, proximity and quality criteria. This helped to avoid extensively distorted or skewed elements that would degrade the quality of the simulation, lead to slow convergence of results, or make it impossible to attain results at all. The powerful capabilities of ANSYS CFX empowered the NInsight engineering team to carry out wind flow simulations with a flow solver for discrete Navier–Stokes equations using the k-ε model for turbulence.

Architectural researchers also simulated the long-term effects of weather on the exterior's titanium alloy, which resulted in slight changes in the material's composition that would improve its resistance to erosion. To predict erosion effects, they used the mathematical model by Finnie, which relates wear to the rate of kinetic energy of particles impacting the surface. For particle–air momentum coupling, NInsight used the model by Schiller–Naumann found in ANSYS CFX software.

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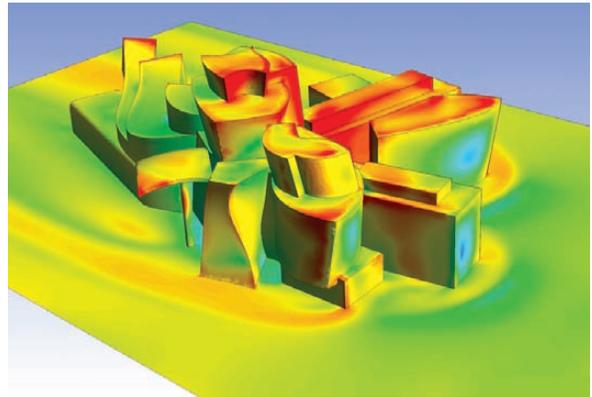
The visual appearance of the Guggenheim facade — particularly the reflective properties — was critical to the ultimate success of the building. Because Bilbao is in a coastal region, it was necessary for NInsight to analyze the long-term erosion effects of sand particles on the facade. In the simulation shown here, the red highlights indicate regions where the effects of erosion would be most pronounced. Based on this analysis, engineers studied several different material compositions to find the optimal resistance properties.

Without the software, NInsight's analysis would have entailed creating multiple physical models for testing under changing conditions in wind tunnels and other physical environments. The simulations would have been virtually impossible to re-create with physical prototypes and tests, due to both the costs and time involved. Instead, the architectural team quickly and intuitively created more than 150 virtual test cases that subjected the Guggenheim design to a variety of changing conditions and scenarios — which would have taken years to duplicate with real-world testing. The software saved the company time and money and created a much greater degree of confidence in the safety and performance facets of this landmark structure. The parametric studies originally were automated with custom-designed scripts,

ANSYS and NInsight: a Longtime Collaboration

NInsight has leveraged landmark projects to build its global reputation for supporting the research needs of engineering firms — and ANSYS software has always been the firm's tool of choice.

"The algorithms of ANSYS software are the most stable I have ever seen, which has allowed our research team to push the limits of engineering simulation — just as our architectural clients are challenging the boundaries of building design," said Stadler. He noted that ANSYS software makes it possible for NInsight researchers to model complex shapes and free-form surfaces, like the Guggenheim, as well as to perform multiphase simulations required by the Florence, Italy, railway station project. "In 18 years of working with this software, we have never encountered an engineering simulation challenge that ANSYS tools were not equipped to address," said Stadler.

While gaining a reputation for simulation of architectural projects, NInsight also simulates the performance of biomedical devices, engines, and a variety of industrial and consumer products.

"Whether we are modeling an entire building or a small coronary stent, ANSYS tools help our clients to see the actual effects of complex systems and mechanisms that would otherwise be difficult, time consuming and prohibitively expensive to measure," said Stadler. "Engineering simulation helps our customers to understand exactly what is going on, both quickly and cost effectively. This knowledge is indispensable for the successful design of a range of systems, from architectural landmarks to medical devices, consumer products and industrial components."

because the ANSYS Workbench platform was not yet available when the building was analyzed. However, with the introduction of ANSYS Workbench, these studies became even easier to manage. With bidirectional CAD connectivity, automated meshing, a project-level update mechanism, pervasive parameter management and integrated optimization tools, ANSYS CFD delivered unprecedented productivity in analyzing multiple design variations.

Extraordinary Designs ... Practical Considerations

More recently, NInsight's architectural research team worked to verify some design elements for yet another landmark structure: the breathtaking new Florence Railway Station, commissioned by the Italian government and conceived by world-renowned architect Sir Norman Foster. Scheduled to open in 2016, this innovative structure is already being hailed for unique features such as its dramatic arching roof, which allows an abundance of natural light into the interior spaces of the building.

The roof is the station's most striking feature, and it is the most problematic from an engineering perspective. The roof's shape necessitates the collection and safe distribution of massive amounts of rainwater. NInsight was commissioned to analyze the roof's open-channel drainage system and to perform a series of complex rain flow simulations. These analyses were aimed at studying the roof's performance under different rainfall and drainage situations, the erosion patterns of its many glass surfaces, and the effects of falling rainwater on pedestrian safety.

Analyzing the roof's drainage systems was particularly challenging because water is channeled through both pipes and open channels. There are points where rain water is ejected from a drainage pipe and travels through the air onto glass panels — so the NInsight team needed to work in
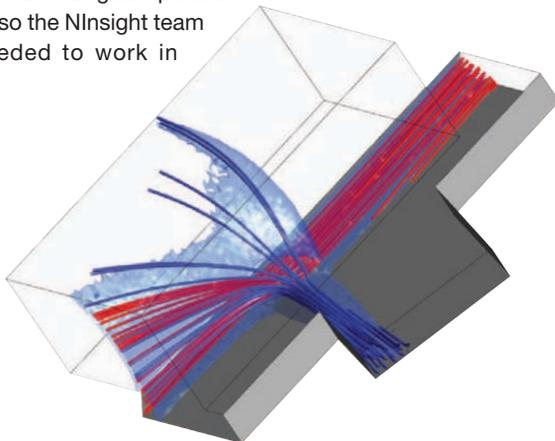
NInsight researchers used ANSYS software to create 3-D CFD simulations for a variety of rainfall conditions in assessing performance of the station roof's unique open- and closed-channel drainage system. This simulation shows two different drainage streams (red and blue) converging in a single channel near the perimeter of the building. As shown here, the original design resulted in a large jet of water being ejected from the channel at this intersection. To avoid this, the perimeter channel was modified to include a secondary drainage system for overflow conditions.

Architectural researchers at NInsight were integral in assessing and improving the drainage system of the Florence Railway Station's roof — the building's most striking and challenging feature.
Image courtesy Foster + Partners.

multiple phases to study the effects of both air and water. Fortunately, ANSYS CFD software has the capability to model both typical water flows and the more complex open-channel hydraulics associated with the roof's unique design.

The NInsight team conducted a number of complex computational fluid dynamics simulations of key intersections of the roof's open-channel drainage system to assess real-world consequences of overflow rainfall. By using ANSYS software to simulate various characteristics of these intersections, NInsight researchers used various flow models to assess the impact of various degrees of blockage of the lower channel.

The simulations demonstrated that there were some intersections where water volume would present a danger to pedestrians walking below — so the roof's drainage system was modified to address this issue. By adding a second drainage channel underneath the primary system to handle overflow conditions, rainfall was distributed in a way that would protect pedestrians and minimize erosion issues associated with jets of ejected drainage water hitting lower portions of the glass roof.

Slight modifications suggested by NInsight have been incorporated into the final design of the Florence Railway Station. Analysis with ANSYS software, which was conducted in 2007, allowed the construction project to proceed as scheduled, without the need to build actual models of the drainage system and conduct physical tests with water.