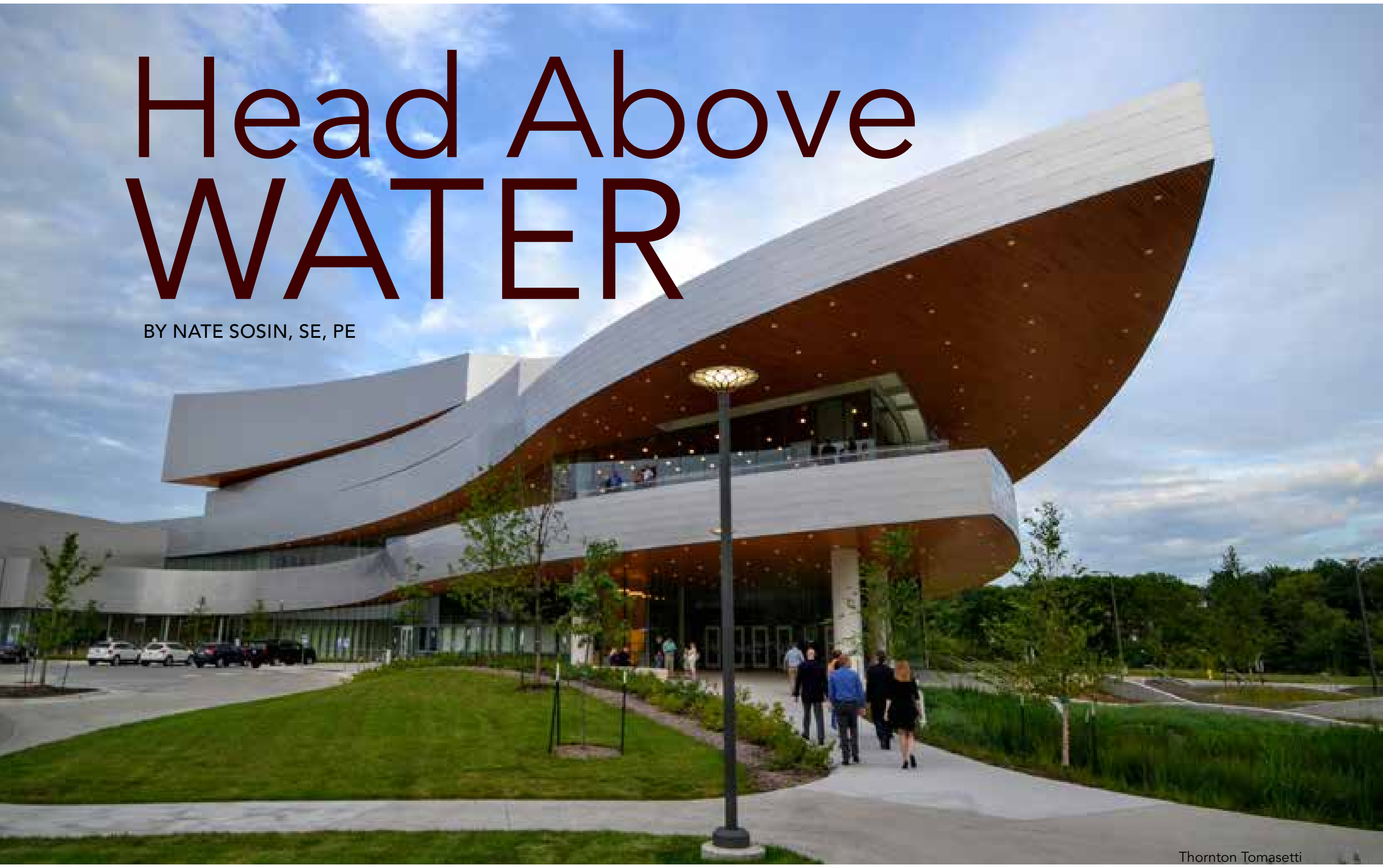
An epic flood ended the long and celebrated run of a prominent university concert hall. But thanks to an elegant, innovative steel framing system and flood-resistant design measures, its replacement is poised to be a smash hit.

Head Above WATER

BY NATE SOSIN, SE, PE



Thornton Tomasetti

FOR MORE THAN 30 YEARS, the University of Iowa's Hancher Auditorium was widely recognized for commissioning new works of dance and music. As a major cultural landmark of eastern Iowa, the renowned venue attracted audiences from far beyond the university's Iowa City campus.

Hancher's location along the Iowa River was one of the most scenic on campus—but also one of the most flood-prone. When a 500-year flood hit the area in 2008, the auditorium was one of many structures severely damaged by the record-high river waters and was forced to close. Hancher—the organization—persevered without its namesake building, sponsoring performances in local venues and open spaces after the flood. And after an eight-year hiatus, the venue's new incarnation, near the original site but on higher ground, opened this past fall with a completely reimagined design. (The adjacent music building and recital hall, also closed due to the flood, were rebuilt on a different part of campus.)

The 185,000-sq.-ft performing arts center, which incorporates 4,400 tons of structural steel, seats 1,800 and hosts music, dance, opera and theatrical performances. The building also contains spaces for rehearsals and teaching, offices, a scene shop and a costume shop. On the exterior, the three-level main lobby is surrounded by a façade of 14,000 brushed stainless steel shingles and glass. Gently curving forms cantilever at the south end of the building, creating striking overhangs for the lobby and a second-level terrace and mimicking a nearby bend in the Iowa River. And this time around, Hancher's new home includes a robust series of flood-resistance design elements.

The project's expedited schedule and sculptural form heightened the design's complexity, and early steel bid packages necessitated that the team coordinate design criteria, equipment choices and loading requirements, which increased the quality of the construction documents and reduced the potential for coordination issues. Beyond this, the structural design team helped deliver multiple innovative elements.

Iconic Cantilevers

Two sweeping forms cantilever over Hancher's main, south entrance, creating a striking focal point that draws guests into the space while providing views and solar shading for the multi-level main lobby. The second-level canopy acts as an occupied terrace, and 70-ft, two-way cantilevers project out above this terrace at the

The new Hancher Auditorum replaces the original building, which was damaged by severe flooding of the Iowa River in 2008.

A structural model of the building, which uses 4,400 tons of steel

Truss installation.

The new facility opened this past fall.

Before and after cladding shots of the underside of both cantilevers.

third level, with floor-to-ceiling glass walls between the cantilevers offering sweeping views of the campus and river. Architect Pelli Clarke Pelli initially proposed a 98-ft cantilever (as measured from the innermost column at grade). Structural engineer Thornton Tomasetti reviewed this canopy, considering wind loads, vibrations, deflection limits and loads imposed by exterior walls, and proposed a more cost-effective alternative that reduced the span to 70 ft without compromising the architect's design intent.

Arriving at the "sweet spot" of 70 ft involved multiple iterations. In order to limit the vertical frequency of the cantilever structure to avoid fluttering, the original concept—a multi-story Vierendeel truss—would have required more than 70 psf of structural steel at Level 2 and more than 100 psf of steel at Level 3. These quantities were helpful in grabbing the attention of both Pelli Clarke Pelli and construction manager Mortenson Construction. Both responded positively and constructively, providing solid, actionable design direction after a few investigative iterations. Columns were relocated accordingly, resulting in a more than 40% reduction in tonnage for these cantilevers and a substantially simpler erection process. The final design featured large girders (51-in. plate girders at Level 2 and 69-in. plate girders at Level 3) and 28-in. built-up steel columns that contributed to vertical and lateral stiffness.

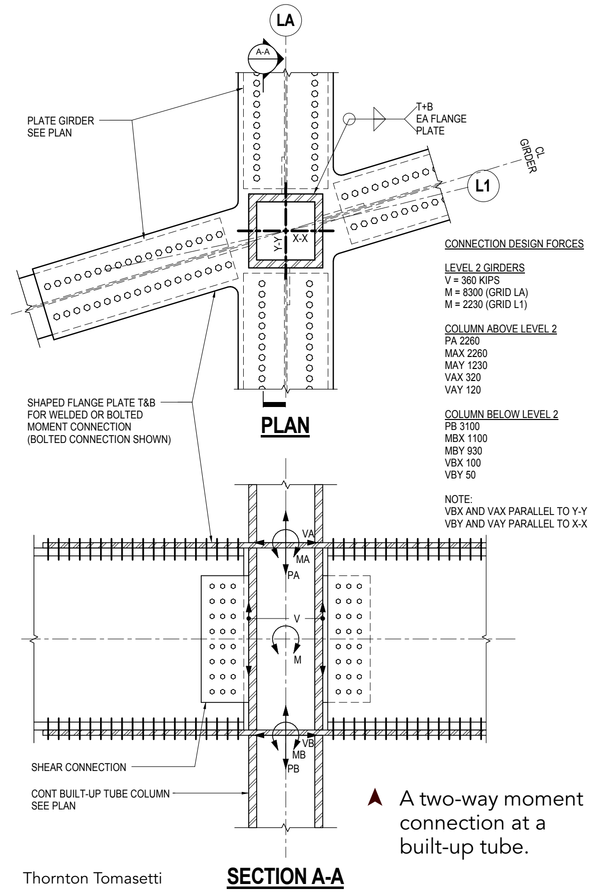
Acoustic Considerations

The structure is divided into "in-box" areas inside the performance space surrounded by structurally and acoustically isolated "out-of-box" areas. Perimeter isolation is provided by 24-in.-thick concrete walls and a 2-in. isolation joint around the performance hall, while three steel trusses span between 100 ft and 120 ft to support a precast concrete lid slab that seals off the top of audience chamber. Structural steel framing above and south of these trusses helps create the sloping, curving architectural form

Nate Sosin (nsosin@thorntontomasetti.com) is an associate with Thornton Tomasetti's Chicago office.

▲ Steel-reinforced bearings for acoustic and structural isolation.

▼ Plate girders on-site.



▲ A two-way moment connection at a built-up tube.

that visually links the fly loft over the stage (the tallest portion of the structure) with the southern cantilevers.

In some cases, it was necessary to support cantilevering in-box structure on top of out-of-box structure, and unfortunately these transfers occurred near out-of-box mechanical rooms. To prevent the transmission of equipment vibration through the structure and into the auditorium, steel-reinforced rubber bearings were used to provide both acoustic and structural isolation.

These bearings provide structural isolation with an unguided stainless steel-on-PTFE (polytetrafluoroethylene, AKA Teflon) sliding surface, while acoustic isolation is achieved by "tuning" the axial stress in the rubber under service loads to minimize the transmission of vibration in the range of typical mechanical equipment (about 7 Hz). Being too conservative with the service level loads would have reduced the bearings' effectiveness as an acoustic isolator, so it was crucial for the design team to accurately predict and report these loads to the manufacturer in advance of the bearings' design.

Thermal Considerations

Large portions of the building's 500-ft-long cantilever roof slab are exposed to unoccupied exterior space on both the top and bottom faces. Given Iowa City's large temperature differentials, a slab of this length would typically require a visually unappealing and maintenance-intensive expansion joint. Instead of settling for the obvious, lower-quality solution, Thornton Tomasetti worked with the entire team to find a combination of temporary expansion joints, structural detailing, mechanical and skin system design and operational guidelines to control thermal self-straining stresses without sacrificing aesthetic priorities or sustainability goals. The criteria were carefully coordinated with the construction team throughout steel erection, slab placement and mechanical system commissioning to prevent the accumulation of large thermal stresses in the structure later on.

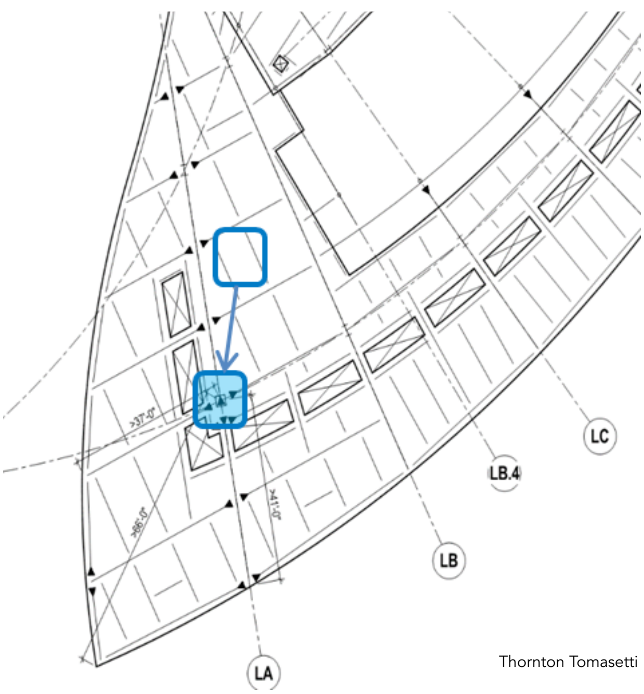
Design for thermal loads begins by recognizing that thermal self-straining forces result from a change in structural temperature, $\Delta T = T_2 - T_1$, where T_1 is the temperature at which you "lock down" the structure, and T_2 is either the maximum or minimum temperature the structure sees during its service life. An iterative design process evolved within this framework: Thornton Tomasetti proposed values for ΔT that resulted in reasonable structural designs; the construction team provided input on T_1 lock-down temperatures with respect to the anticipated construction schedule; the architect and mechanical engineer designed skin and conditioning systems that achieved the required T_2 temperatures; the sustainability consultants evaluated the resulting building energy use and presented it to the university's "Energy Hawks" for comment; and the process was repeated until building systems and structural design criteria were aligned. Finally, the fully coordinated basis-of-design T_1 and T_2 temperatures were documented on the structural contract drawings.

A temporary expansion joint was installed between the north and south lateral systems to allow construction to proceed year-round, including periods when the structural temperature fell outside the allowable T_2 range. The erector and concrete contractor locked down this joint when 1) the structure was within the allowable T_1 lockdown range and 2) conditioning required to maintain the basis-of-design T_2 temperatures could be met for the remainder of the structure's service life. All told, this comprehensive approach substantially reduced the self-straining forces in the final condition.

The structure was designed to share the remaining diaphragm forces—thermal as well as wind and seismic—between the reinforced composite steel slabs and the structural steel

Flood Resistance

While the stage and main levels of the new Hancher Auditorium are located 2 ft above the 500-year flood elevation, the programming still required MEP equipment to be located in the basement and below the flood line. The schematic design cost estimate assumed a typical 6-in. basement slab on grade, which would not have been capable of resisting the uplift caused by the basis-of-design 10 ft of hydrostatic head. The solution to protecting the basement from the flood loads was a 40-in.-thick hydrostatic slab that spans between 800 driven steel H-piles designed to resist both tension and compression, which created a permanent, reliable "bathtub."



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▲ Roof trusses for the auditorium.

◀ Analysis determined more efficient column placement.

▼ The newly built venue can seat 1,800.

framing. In most cases, steel beams were able to resist the axial diaphragm forces without upsizing and with fairly modest impact to their extended shear plate connections.

Exterior Coordination

In addition to performing structural work, Thornton Tomasetti also acted as the façade engineer and developed a stainless steel rain screen cladding system as well as a high-performance envelope system, incorporating a loads-imposed basis of design for early structural bid packages. A jointing study performed by Thornton Tomasetti's structural and façade teams, documenting the exterior wall sections, provided robust information for the rest of the design process.

The goal for the typical exterior wall back-up detail was simplicity and repetition vs. absolute material efficiency. Ironically, the structural and enclosure depths were roughly equal at the tip of the cantilever and diverged from there, with the structure becoming shallower and the enclosure becoming deeper toward the north. To laterally brace the fascia and vertically support the soffit, a vertical W21 was cantilevered down off the tip of the cantilevered floor framing, and a sloping HSS20×8 spanned nearly horizontally between W21 hangers. This detail eliminated the need for kickers and kept the soffit open for mechanical equipment and maintenance access, and was used extensively around the cantilevered perimeter.

Serving as a cultural hub for the University of Iowa and beyond, Hancher's international reputation for excellence has been rebooted. The best of steel construction combined with innovative structural design has created a new landmark whose best practices will advance the building profession—and allow the new venue to flourish, without the worry of succumbing to future floods—for years to come.

Owner
University of Iowa, Iowa City, Iowa

Construction Manager
Mortenson Construction

Architects
Pelli Clarke Pelli Architects, New Haven, Conn.
OPN Architects, Cedar Rapids, Iowa

Structural Engineer
Thornton Tomasetti, Chicago

Steel Erector
Midwest Steel, Detroit AISC CERTIFIED ERECTOR