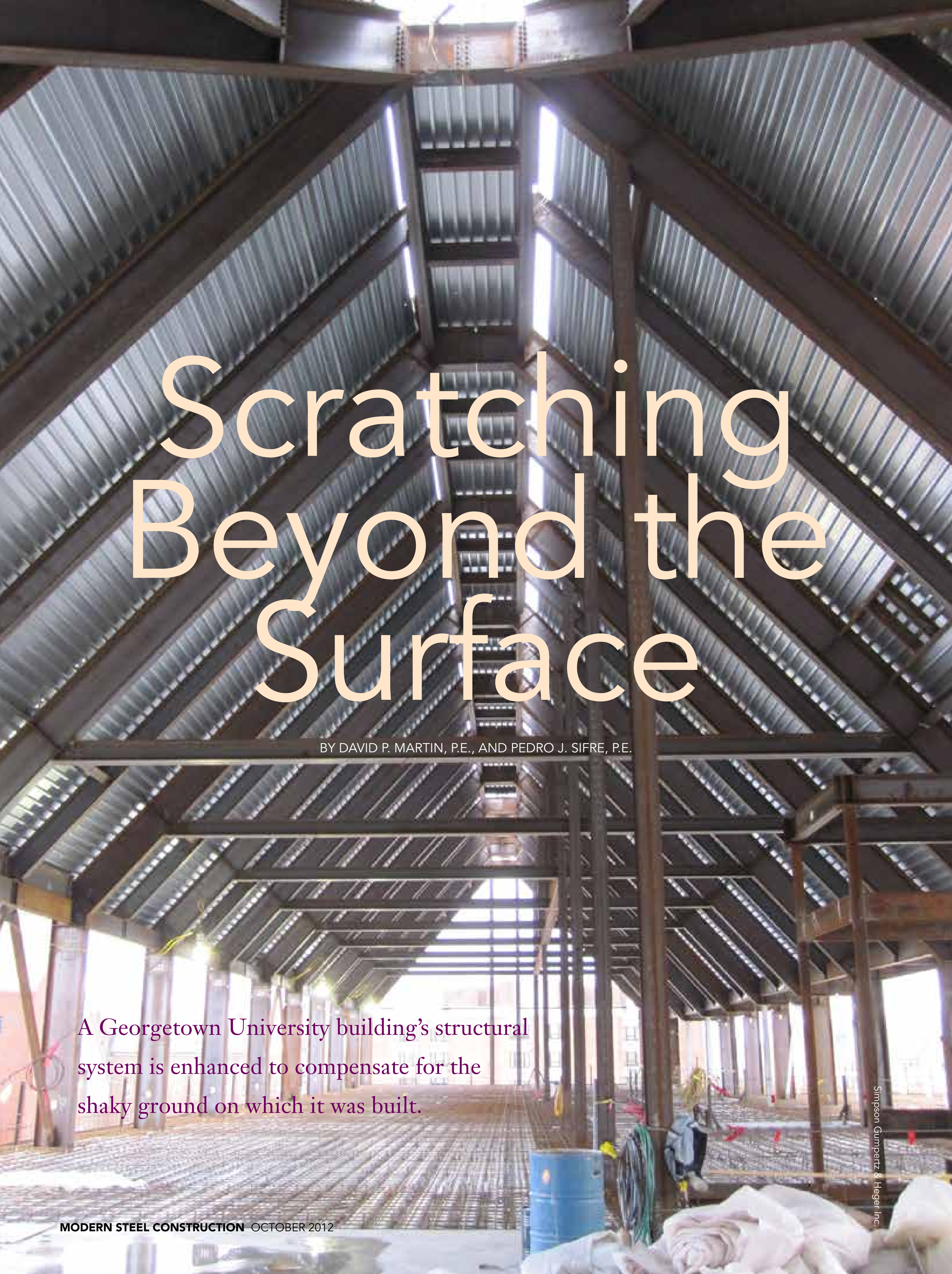

Scratching Beyond the Surface

BY DAVID P. MARTIN, P.E., AND PEDRO J. SIFRE, P.E.

A Georgetown University building's structural system is enhanced to compensate for the shaky ground on which it was built.

Simpson Gumpertz & Heger Inc.

GEORGETOWN UNIVERSITY'S new science center is designed to maximize collaboration and interdisciplinary research among the biology, chemistry and physics departments and to support endeavors for scientific discovery and advancement.

Interestingly, the building site and the building project itself (which opened in August) offered an intriguing lesson in scientific discovery and collaboration.

The facility, Regents Hall, is five stories, 154,000 sq. ft and located within the Piedmont Physiographic Province of Washington, D.C. The Piedmont is an erosional surface consisting primarily of fill over Paleozoic igneous and metamorphic rocks. With this type of site, there is the potential for building costs to spike from unknown subsurface conditions. Early on, these conditions threatened the project with cost overruns that, in turn, required that the design team mitigate the cost impact of this uncertainty with creative solutions.

From the structural standpoint, it was determined that the best structural approach would be to limit the demand on the foundations by increasing the ductility of the steel lateral-load-resisting system (LLRS). While this resulted in a higher level of seismic detailing than is typically used in the Washington, D.C., area, it also reduced the design seismic loads on the structure and foundations, decreasing the demand on the poor-quality soil. In turn, this limited the potential cost overruns and delays during the installation of the foundations while keeping the steel framing on budget.

The Site

The near-surface soils at the building site consist of 50 ft to 70 ft of urban fill and disturbed natural soils (the area used to be a ravine that was filled many years ago during initial site development). Beneath the layer of fill and disturbed materials is the upper residual natural sandy silt soil of the Piedmont. Considering these factors and the variable thickness of the decomposed, weathered rock in the area, the project's engineer, Simpson Gumpertz and Heger (SGH), considered it likely that caisson drilling would encounter obstructions and variable bearing conditions that could lead to budget overruns and schedule delays.

The numerous existing buried site utilities added another facet to the below-grade challenges. Some utilities were to be removed, but many were to remain. In

◄ View of penthouse roof rigid bent frames.

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▲ View of foundation construction in progress with loading dock in foreground.

▼ Ordinary concentrically braced frame facing Georgetown University's Harbin Field/Multisport Facility.

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View of Regents Hall from the south.

View of Regents Hall's west curtain wall façade from Plaza Level green roof.

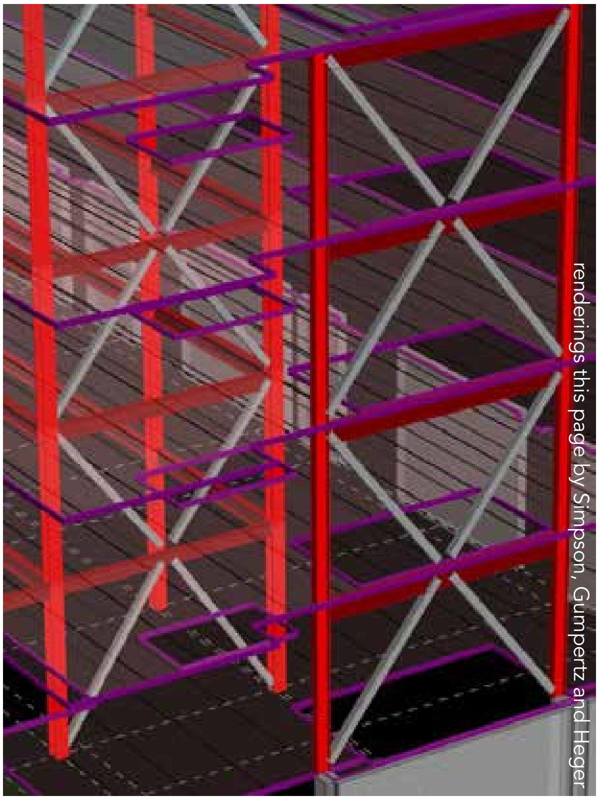
addition to the manholes that needed to remain at the proposed loading dock area, a 21-in.-diameter pipe and a 96-in.-diameter sewer line running through the site posed yet another obstruction to the caisson installation. For the ground-level structure, SGH elected to use a structural two-way reinforced concrete slab-on-grade bearing on the caissons. The weight of these foundations increased with a large number of grade beams that were required to bridge over existing utilities and to support heavy CMU walls, dock leveler pits and other features. With these baseline loads, SGH felt that avoiding additional demands on the foundations would be essential to reducing the diameter and number of caissons.

The Budget

At the completion of the design development phase, the project's construction cost estimate was approximately $4 million over the $72 million budget. The structural steel framing and decking were estimated at $3.75 million, and the site work was estimated at $4.5 million, including a $175,000 allowance for caisson obstructions/additional depth requirements. In the 90% conceptual cost estimate, the caisson portion of the site work was originally estimated at $1.1 million, including a $100,000 allowance for obstructions/additional depth. Recognizing the potential for foundation installation difficulties with additional subsurface exploration, the construction manager increased their obstructions/additional depth allowance from $100,000 to $175,000.

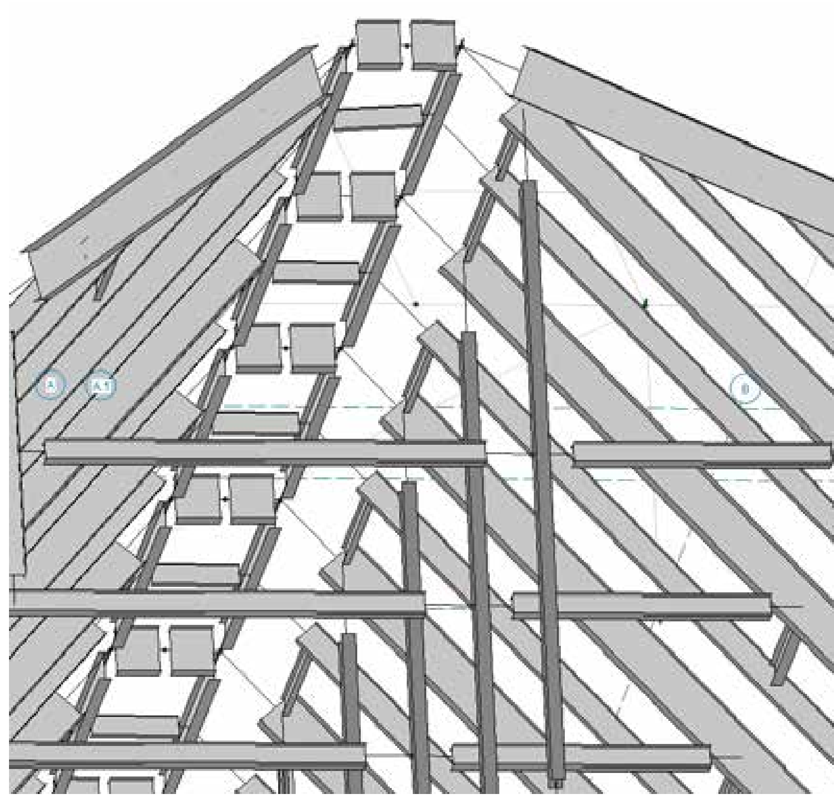
While the overall project was over budget at the completion of the design development phase, the structural steel framing and deck cost estimate was slightly under budget. At that time, the LLRS had been designed as a steel concentrically braced frame system not specifically detailed for seismic resistance (R = 3), and the caissons were designed for an allowable end bearing pressure of 80 ksf.

Facing the likelihood of foundation construction cost overruns and project delays, SGH worked with the geotechnical engineer (ECS Mid-Atlantic, LLC, of Chantilly, Va.) to lower



renderings this page by Simpson, Gumpertz and Heger

RAM Frame rendering of the lateral load resisting system model.



RISA-3D rendering of the penthouse roof framing.

the demand on the foundations and recommended additional geotechnical studies in an effort to increase the allowable bearing pressure. In addition, rough cost analyses were performed to determine the potential benefits of using a LLRS with greater ductility.

Seismic Detailing

Regents Hall was permitted under the District of Columbia Building Code (DCBC), 2003 Edition, which amends the ICC International Building Code (IBC), 2000 Edition. With the adoption of the 2003 Edition of the DCBC came AISC's 1997 *Seismic Design Provisions*, referenced by the IBC. (The predecessor to this DCBC version, the 1999 DCBC, was based on the 1996 Edition of the BOCA National Building Code and had minimal seismic detailing requirements.) One of the more notable (and visible) nuances in the 1997 *Seismic Design Provisions* was the significantly larger gusset plates. AISC provisions require that brace connections be designed to permit end rotation for brace buckling and to resist the maximum expected loads of the brace. This combination of requirements and the $2t$ linear clearance from the intersection line of the gusset plate used to achieve this often lead to large, thick gusset plates. However, large gusset plates are often an architectural coordination challenge, not to mention also a tough sell to contractors, fabricators and owners.

Based on historical seismicity, the Washington area has long been considered a low-seismic region. As such, there was some initial skepticism from the project team when increasing the building's steel ductility and R-value were originally proposed. Generally, D.C.-area buildings assigned to Seismic Design Category A, B or C are designed with $R = 3$ because it is considered a simpler, less-expensive structure for steel fabricators, erectors and inspectors. The downsides of an $R = 3$ design are the larger seismic loads, greater LLRS steel tonnage and greater demand on the foundation.

As the design team determined that a reduction in demand on the foundations might be critical to the project, the feasibility of using increased ductility in the steel LLRS was discussed. Some concerns were expressed, including the cost associated with removing backing bars at moment connections as well as whether local steel fabricators would bid on a R > 3 project. The construction manager eventually found multiple fabricators willing to bid on an $R > 3$ project, eventually awarding the contract to SteelFab, Inc., of Charlotte, N.C. The final design used ordinary steel moment-resisting frames ($R = 4$) in the building's north-south direction and ordinary steel concentrically braced frames ($R = 5$) in the east-west direction, and moment-resisting rigid bent frames were designed for the penthouse to maximize the open floor space and to provide lateral load resistance in the east-west direction.

Digging Deeper

While adding a higher level of steel detailing doesn't sound like a cost savings or schedule accelerator, in this case it was important to look beyond the surface and discover the impact of the poor soil and everything else that lay beneath. The site obstructions caused a 10-week delay in the overall project schedule and added a cost of $815,000 to the project. Primarily because of the site obstructions encountered during foundation construction, the actual cost of caissons ended up totaling $2.05 million—nearly twice the original budget. Higher seismic loads associated with an $R = 3$ building would have required larger drilled caissons, exposing the project to correspondingly greater difficulties and costs related to caisson installation.

But by increasing the ductility in the LLRS, foundation-related cost overruns and schedule delays were limited and the overall project was kept within budget. Including the greater degree of seismic detailing and field work, the structural steel framing and decking still came in below budget at $3.32 million. By increasing the allowable soil bearing pressure by 20% and using seismic detailing for the concentrically braced frames and ordinary steel moment frames, most caisson diameters were reduced by 6 in. or more.

In the end, the larger, thicker gusset plates and more-stringent connections reduced loads on the structure as a whole and had a positive influence on project schedule, structural steel budget, foundations budget and structural performance.

In an unexpected turn of events, the building's LLRS was put to an early test shortly after the structure was completed. Toward the end of August 2011, the building (still under construction) was subjected to the second largest earthquake ever felt in Washington, D.C., and to the high winds of Hurricane Irene. The 5.8 earthquake was centered near Mineral, Va., less than 100 miles from the project site. The hurricane brought sustained winds of 35 to 45 mph with gusts of approximately 70 mph. Although these phenomena did not constitute design-level events, the project team took comfort on the fact that Regents Hall showed no signs of distress following the historic combination of events that Mother Nature chose to deliver as a christening of sorts. MSC

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