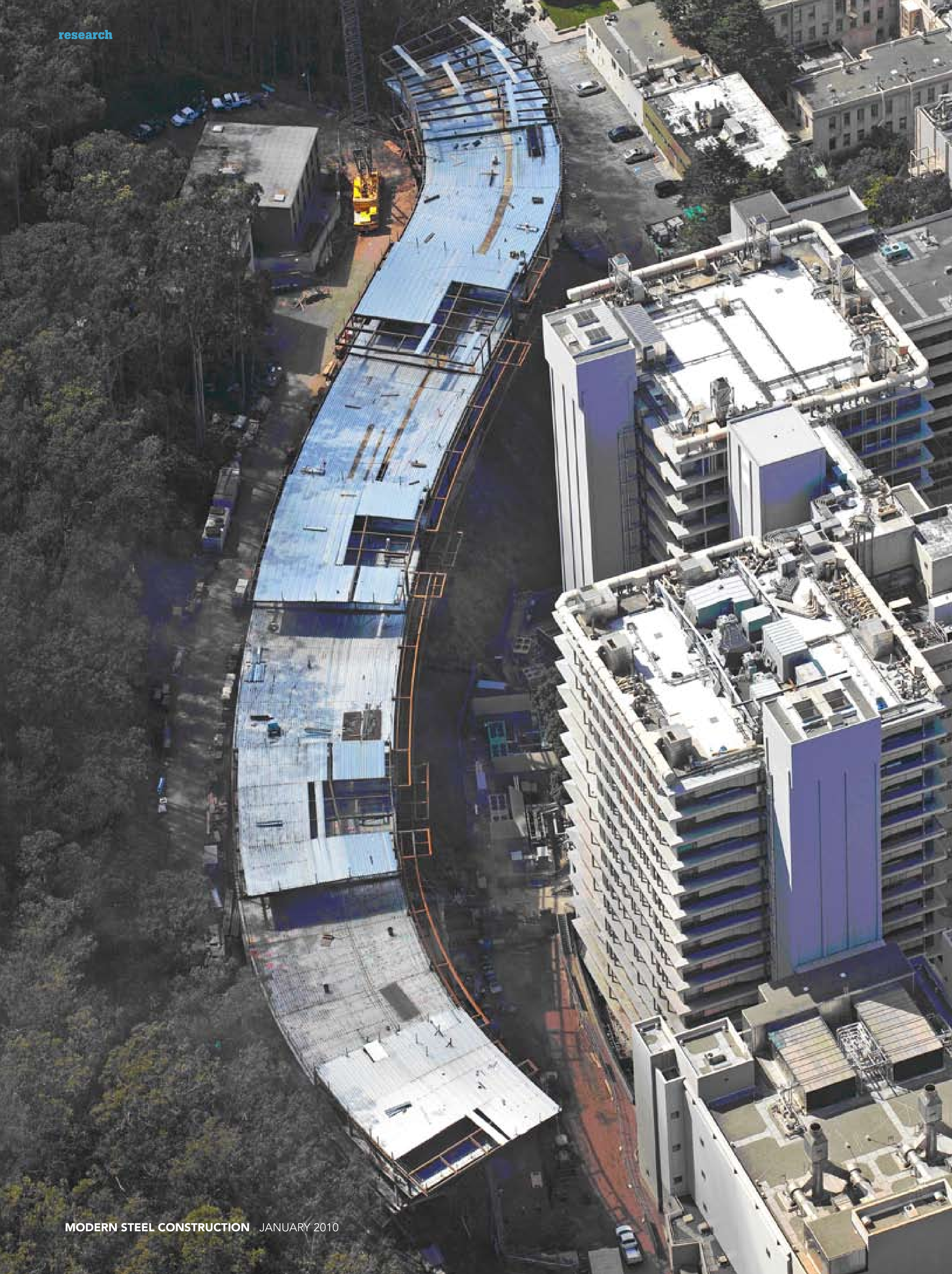


Preparing for Seismic Uplift

BY STEVE CARROLL, STEVE MARUSICH, S.E., AND MASON WALTERS, S.E.

Engineers get creative to ensure structural stability of cantilevered, serpentine building.

TO SPUR CONSTRUCTION INNOVATION—a prerequisite to building its unconventional Regeneration Medicine Building—the University California San Francisco held a nationwide design-build competition based on a relatively thorough preliminary design. General contractor DPR Construction collaborated with the SmithGroup (architecture and interiors planning) and Forell/Elsesser (structural and earthquake engineering), all based in San Francisco, to win the $85 million construction contract for the high-profile project. The team selected Schuff Steel—Pacific Division as the steel fabricator and erector.

The preliminary design was prepared by New York-based Rafael Viñoly Architects and structural engineer Nabih Youssef Associates, San Francisco. (An additional article in this issue describes the preliminary design.) The subsequent design-build process encouraged a constant exchange of ideas that streamlined fabrication and erection. Team members discussed and agreed upon major cost and constructability issues—when to bolt or weld, connection sizes, shoring options, and changes.

One of the innumerable construction challenges on the project has been the aggressive schedule. Schuff joined the project team at the end of April 2008. By July 2008, the company had placed its mill order and developed an erection schedule. The topping out was just 14 months later in September 2009.

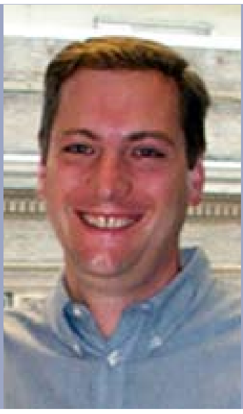
Schuff's early involvement and close collaboration with Forell/Elsesser saved field time, reduced costs and ensured proper alignment of the steel on site. The design of the substructure hollow structural steel (HSS) brace connections is a prime example. Due to the complexity of the gridline radial points and sheer number of brace clusters involved, it was determined that using CJP groove welded connections at both ends of the HSS braces would be difficult to keep aligned. Even more difficult would be providing access for final complete penetration welding at each end, which would be required immediately for continuous erection. This resulted in the decision to bolt the HSS braces to the underside of the first floor beams and land directly onto the column base boxes with full-depth partial penetration welds. For that to work, the caps at each end of the braces were CJP welded in the shop, where access for inspection was much better. The field crew then hoisted the

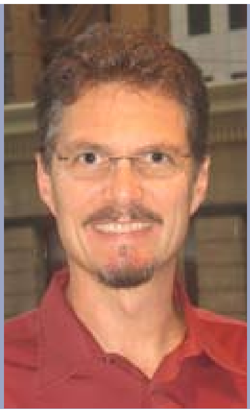
Oppostie page: The new Regeneration Medicine Building on the Parnassus campus of the University of California San Francisco is a 600-ft-long serpentine structure isolated from seismic activity by 42 Friction Pendulum bearings.

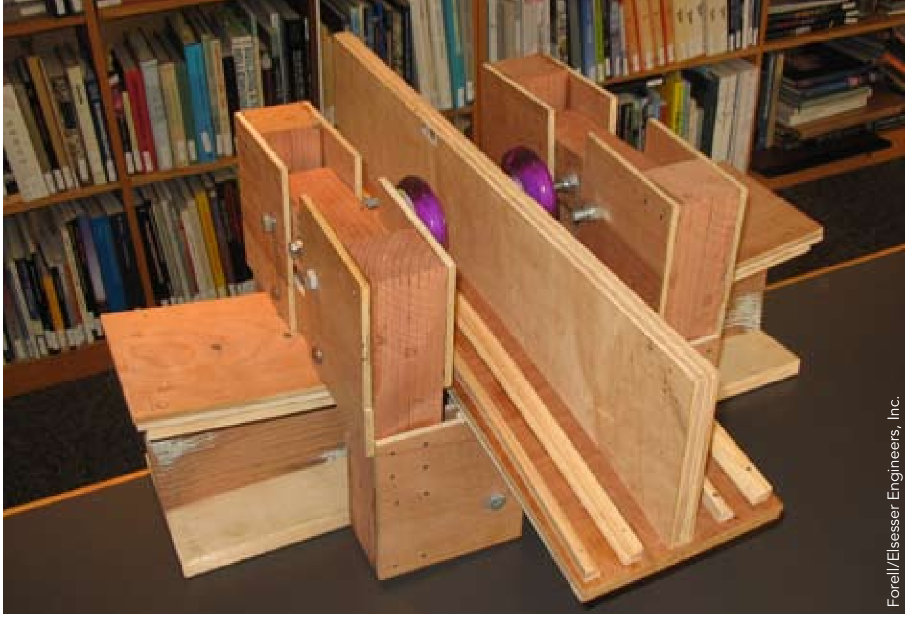
Photos by Schuff Steel unless noted.

Steve Carroll (left) is senior project manager with Schuff Steel–Pacific Division, San Diego.

Steve Marusich, S.E., is an associate and Mason Walters, S.E., (right) is a principal with Forell/Elsesser Engineers, Inc., San Francisco.







Above: The team bought into the concept of the uplift restraint devices after Forell/Elsesser's Mason Walters, S.E., built a ⅓-scale model using wood and roller blade wheels. The vertical restraint is only activated by an uplift force and still allows unimpeded horizontal movement.

Above: It's easy to see the numerous challenges in building on this narrow, steep slope wedged between a winding road and adjacent buildings.

Below: The HSS braces were bolted to the underside of the first floor beams and landed directly onto the column base boxes at the bottom with full-depth partial penetration welds.

braces to the underside of erected floor steel, matched bolt holes and landed the bottom of the brace on the column base. This method worked extremely well for both ease of installation and accuracy of final positioning.

Seismic Reinforcement

One of the more critical elements of the project was ensuring maximum earthquake protection for the facility. The horizontal motion during an earthquake is what causes the most damage to a building. Seismic isolators can prevent a building from being violently shaken—visualize the effect of a house floating on a frozen lake when the ice suddenly moves horizontally. Forell/Elsesser's design called for 42 Friction Pendulum seismic isolators, located between the foundation and the structure at each of the building's anchor points. These isolation bearings will allow the building to slide 26 in. in any horizontal direction and 2 in. vertically to "filter" the earthquake's movement, giving the building a relatively gentle ride.

The building is highly susceptible to uplift during an earthquake because a portion of the building juts out to the north and lacks ground support. Because Friction Pendulum bearings do not resist tension, Forell/Elsesser examined a number of different options to restrain uplift of the south side of the building. The project schedule was the driving force in the team's selection. They chose a one-of-a-kind uplift restraint device that could be fabricated as part of the steel fabrication process rather than having to wait for delivery of custom-manufactured elements.

Although the engineers completed many technical drawings and calculations demonstrating the capabilities of the uplift restraint, a homemade model is what convinced decision makers to move forward. Mason Walters, S.E., principal at Forell/Elsesser Engineers, used scrap wood and roller blade wheels to build a ⅓-scale model of the device in his garage. Once the design and construction team saw a three-dimensional model, the merit of the concept was realized.

The uplift restraints are located on the south side of the building, where they oppose the 20-ft cantilevers to the north. Physically separated from the Friction Pendulum bearings, the uplift restraints are designed to freely track the horizontal and vertical movement of the building. Only when an earthquake starts to lift the building do the uplift restraints engage and hold the structure down with as much as 100 tons of force, while continuing to allow free horizontal movement. A total of eight uplift restraints, each 6 ft square and 3 ft tall, are anchored to the concrete foundation and bolted underneath the floor line horizontal beams.

Fabricating the devices to the prescribed tolerances and the mixed use of structural and stainless steel with other non-metallic materials was quite challenging. Schuff fabricated the uplift restraints to within $\frac{1}{1,000}$th of an inch tolerance at its Gilbert, Ariz., facility. The uplift restraint bearings were manufactured by Hilman Rollers, Marlboro, N.J., and shipped to Schuff for assembly.

To validate the unique design, a prototype of the uplift restraint was tested at the University of California San Diego's Caltrans Seismic Response Modification Devices (SRMD) test facility. The device went through several days of setup and testing on UCSD's multi-axis table, which was able to mimic the travel path of the pendulum bearing dish radius and introduce the 100 tons of uplift force anticipated during a seismic event. All tests were successfully completed.

The testing also provided Forell/Elsesser and Schuff a hands-on opportunity to finalize installation methods. It was determined by this testing that the uplift restraints needed to ship as completed assemblies. The devices were shipped directly to the job site and then simply set over anchor bolts in the foundation with high strength bolts in the flange of the floor girder above. Each assembly was delivered in sequence, with final adjustments made after the structure was fully welded out.

Site Work

In spite of all the strategic planning that went into the project, its location was a constant reminder of the project's complexity. The 80,000-sq.-ft facility is being constructed on a narrow steep slope wedged between a winding road and adjacent buildings.

To prepare the site, DPR cleared the hillside, built a shotcrete retaining wall and installed 20 concrete pier foundations against the side of the hill. On the opposite side, the general contractor installed 22 large diameter concrete piers. The total width between the piers is 40 ft—two-thirds of the building's total width.

During site foundation work, there were several challenges that needed solving to construct the 1,270-ton building on the side of a hill. The south roadway was narrow, winding and at a significant grade.

Above: The unique uplift restraint devices installed in eight locations along the uphill line of supports were fabricated as part of the structural steel fabrication.

Below: The first of two sections of the access bridge floor framing being hoisted into place, from the mechanical yard 90 ft below, shows the tight clearances to the existing Health Science Building, where it connects the ninth floor with the main entrance of the new Regeneration Medicine Building.

Crane outrigger loads were critical due to the proximity of shotcrete walls along the edge of the road. Trucks bringing steel to the site were required to back up the hill while dodging equipment on either side. There also were access requirements for waste treatment vans scheduled to use the road during steel erection.

Steel Erection

The Regeneration Medicine Building is a series of four elevated connected building pods that resemble inverted pyramids with terraced grass roofs. Each of the four building pods steps up 9 ft higher than the next as the facility climbs up the slope at a slight angle. The multi-level 65-ft-wide, 600-ft-long structure required a complex sequence of steel erection, in order to maintain the structure's stability.

The entire north side of the building cantilevers out 25 ft beyond the only support columns on the structure. Temporary supports were welded to the foundations during steel erection until the uplift restraints were engaged. Procedures were carefully reviewed to ensure the steel was erected in a manner that would not tip the building over the balance point before the framing was fully bolted and welded.

Both the east and west ends of the building also cantilever out beyond any support columns. Schuff engineered, fabricated and installed 24-in.-diameter pipe columns to support the huge framing sections extending beyond the column grids. Once the diagonal HSS braces below were fully welded and bolted, the shores were lowered and removed.

The main entrance to the building is 90 ft above ground level. Access is provided by a freestanding elevator outside of the facility and by a 140-ft-long architecturally exposed structural steel bridge. The bridge consists of plate girders, wide-flange floor framing and an HSS roof structure that spans from the first floor walkway landing of the Regeneration Medicine Building to the ninth floor elevator lobby of the existing Health Science Building. The bridge floor framing was hoisted in two sections with tight clearances to the existing Health Science Building and mechanical yard located 90 ft below. The elevator tower and walkway tie-in to the bridge steel are scheduled to be erected in early 2010.

Advanced Technology

Building Information Modeling was not just a requirement of the project, but vital to its success. The facility's complex engineering combined with the aggressive timeframe and precipitous site location would have been too time-consuming to plan and build without the use of advanced technology.

The University of California San Francisco Regeneration Medicine Building is scheduled for completion in mid-2010. MSC

Design-Build Team:

General Contractor
DPR Construction, Inc., San Francisco

Fabricator and Erector
Schuff Steel - Pacific Division, Oakland/San Diego, Calif. (AISC Member)

Architect
SmithGroup, San Francisco

Structural Engineer
Forell/Elsesser Engineers, Inc., San Francisco

Preliminary Design Team:

Architect
Rafael Viñoly Architects, New York

Structural Engineer
Nabih Youssef Associates, San Francisco