

A Site on a *Sliver* of Hillside

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How the design for an impressive research building on a challenging site came to be.

THE UNIVERSITY OF CALIFORNIA SAN FRANCISCO will soon have an impressive addition to its already tightly-packed Parnassus campus.

At first glance, most would never guess that a building could be built on the steep hills behind the dense medical and research campus of UCSF. The desire to efficiently use one of the last remaining slivers of land on the campus combined with a daring structural design employing state-of-the-art base isolation technology has resulted in the soon-to-be-completed Regeneration Medicine Building (RMB). The RMB, which is scheduled for completion in 2010, will house new laboratories for the university's stem cell research program.

Nabih Youssef Associates (NYA) and Rafael Viñoly Architects (RVA) collaborated to develop a design that responded to the site constraints and fulfilled programmatic needs, ultimately creating a 600-ft-long serpentine-shaped building with a dramatic panorama of the San Francisco Bay. The team's integration of architecture and engineering created an elegant structure on what could easily have been viewed as an otherwise un-buildable piece of land.

Complex Issues

NYA and RVA were tasked with a significant challenge: develop a showcase building on a demanding and steeply-sloping site constrained by myriad obstacles. Additionally, the building needed to be fully integrated into the exist-

ing campus to allow researchers to flow freely despite the significant gap between the new and old buildings. All of this needed to be accomplished within the context of the Bay Area's well-known high seismicity.

A number of site constraints dictated the building's form; most obviously the steeply-sloping hillside that the building rests upon and a winding roadway to the south. The hillside slope varies from 30° on the east end to an incredible 45° on the west end. The site is bounded to the south and east by the curving access road, to the north by the existing medical building complex, and to the west by the increasing steepness of the hillside. As a final challenge, an existing fire pump building located in the center of the site was required to remain operational during and after construction to serve to the adjacent hospital complex.

NYA and RVA delivered their design to the client in the form of Bridging Documents—a design package developed to a level that demonstrated the project concept in sufficient detail to be used as the basis for a design-build competition and the eventual completion of the project. (An additional article in this issue describes the design-build team's work.)

The Regeneration Medicine Building makes use of a narrow strip of undeveloped land between existing buildings on the University of California San Francisco's Parnassus campus. This conceptual view shows the cantilevered walkways and connecting bridge on the north side of the building.



Anthony Giammona (left) is a project engineer and Michael Gemmill (center) is a vice president at Nabib Youssef Associates, San Francisco.

Nabib Youssef is president of Nabib Youssef Associates, Los Angeles.





Nabih Youssef Associates

The RMB under construction by DPR Construction and Schuff Steel. Steel framing for the cantilevered walkways is clearly visible here, as is the existing fire pump building over which the new structure is being constructed.

An Elegant Solution

NYA and RVA viewed the site constraints and architectural demands as an opportunity to create a structure that has its form largely derived from the site. NYA balanced the architect's vision for the building to appear to cantilever from the hillside as dramatically as possible with the owner's desire for seismic performance beyond basic code compliance. The final result is a relatively simple and economical solution using a base-isolated steel space truss substructure topped with a conventionally framed steel superstructure.

Steel was chosen for the structure because of its ability to conform to the varied site profile, the opportunity to prefabricate complex trusses, and its relative ease of erection on the difficult site. The space truss substructure is versatile enough to accommodate the varying slope of the hillside and varying curves of the site while still maintaining a level platform upon which conventional steel framing could be economically built.

This versatility was fully utilized in the center of the building where the RMB spans directly over the existing fire pump building without making contact. Another key benefit of the space truss system is its ability to limit the number of touch-down points on the hillside, thus reducing the number of base isolators required as well as reducing the related foundation work on the steep site. An independent and seismically separated bridge structure spans for 140 ft between 80-ft-tall steel and concrete piers allowing for uninterrupted circulation by researchers between the RMB and the existing medical campus.

Space Truss System

Due to the complexity of the sloping site, few members of the space truss are aligned with each other, resulting in an intricate array of steel members sloping in many directions at the base of the building. Triangular trusses composed of horizontal wide flange beams and diagonal truss elements occur at regular intervals to form the transverse elements of the space truss. Truss element lengths and angles vary continuously to accommodate the slope of the site while providing a constant elevation at the top of the truss.

The triangular trusses are linked together longitudinally by two planes of sloping steel trusses. One plane is oriented near vertical and connects the centers of the triangular trusses. The other plane slopes outward to the north and connects the cantilever ends of the triangular trusses to the ground.

The large cantilevers at each end of the building are supported by extensions of the space truss. Standard infill framing completes the platform above the space truss. The entire space truss forms an elaborate system of concentrically braced frames (CBF) to resist both gravity and seismic forces.

The superstructure forms the shell of the usable space in the building and is composed of HSS columns and wide flange beams that follow the curves and steps of the space truss below. Metal deck is used without concrete fill on the high roof areas to reduce the seismic overturning forces. The lateral force resisting system of the superstructure is composed of a system of CBFs in both the transverse and longitudinal directions that bear directly on the space truss members below.

The entire building steps up a half floor at regular 150-ft bay intervals to follow the upward slope of the adjacent road. These areas required some of the most intense coordination on the project. The goal was to provide visual interconnectivity between

adjacent laboratory floors, while still maintaining structural continuity between the split-level diaphragms. The Bridging Documents team's final solution was to provide transverse braced frames to transfer shear between the split-level diaphragms and sloping chord elements at the perimeter of the building to transfer chord forces. This solution resulted in spacious high ceiling areas while minimizing the visual impact of the complex structural elements surrounding the space.

Base Isolation

The RMB was an ideal candidate for base isolation from the inception of the project. A base isolated building rests on a system of special bearings that are very stiff vertically yet very flexible laterally, allowing the building to "float" sideways in any direction when an earthquake occurs. This behavior uncouples the building from ground shaking and focuses the earthquake's energy into the isolation system to be dissipated through damping in the isolators. The results translate into a significant and simultaneous reduction in earthquake forces and drifts in the building. The reduced seismic force levels achieved through base isolation allowed the use of a light and unconventional space truss system that would not have been possible in a fixed-base building.

Additionally, two costly elements typically required for a base isolated building—an additional floor level to create a crawlspace for the isolators, and a perimeter isolation moat to allow the isolators to freely displace relative to the ground—were not required in the RMB because of its floating nature. As a result of these attributes, initial studies showed the cost of the isolated building

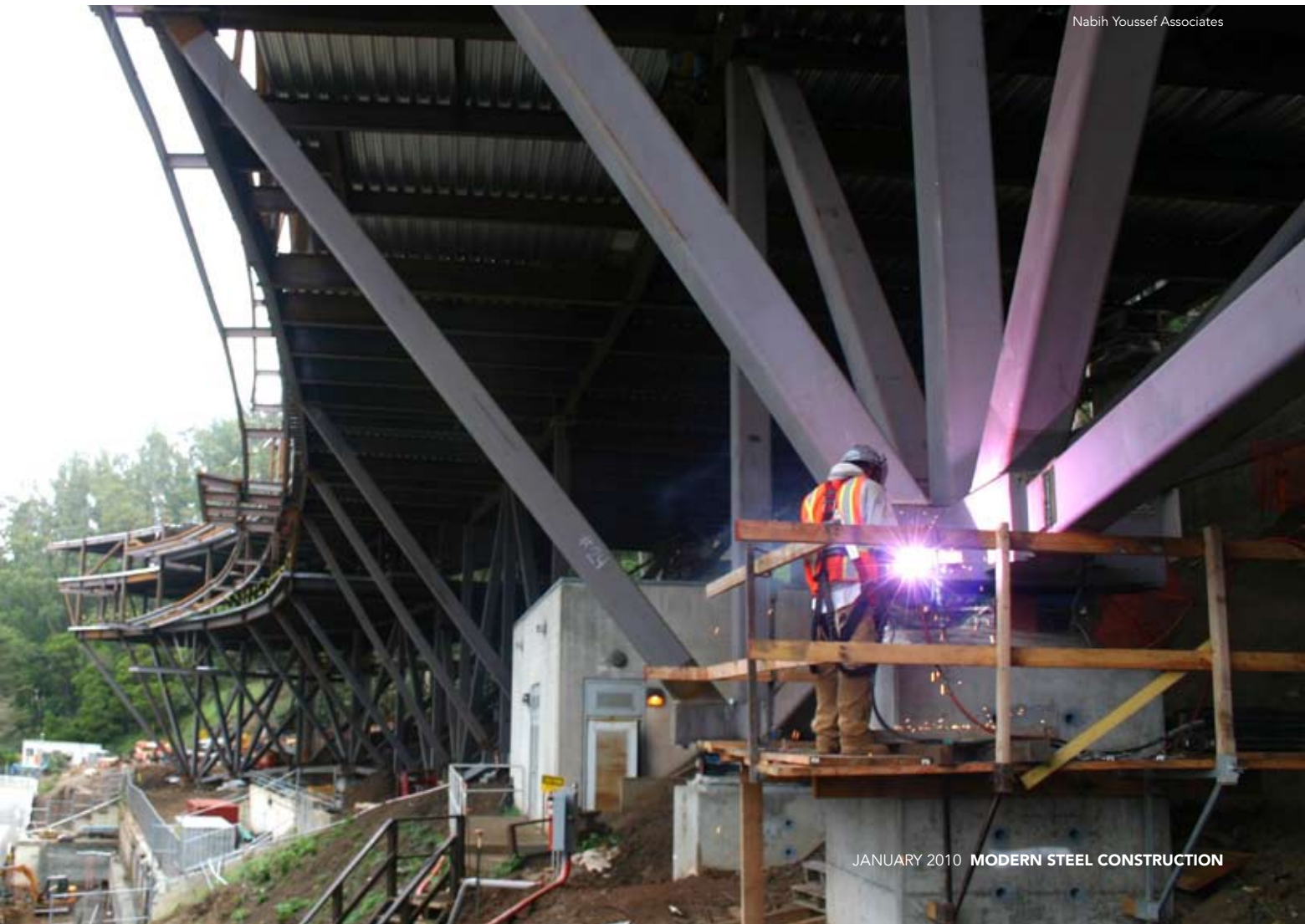
to be comparable to traditional fixed based alternatives but with substantially enhanced seismic performance. UCSF's desire for increased seismic performance combined with its ability to look forward at reduced life cycle costs associated with a base isolated building further justified the decision to isolate the RMB.

Triple Pendulum base isolators manufactured by Earthquake Protection Systems, Inc., Vallejo, Calif., were selected for the RMB because of their unique behavior that adapts to different levels of earthquake intensities. Isolators are located below each node of the space frame on the downhill side and below columns on the uphill side.

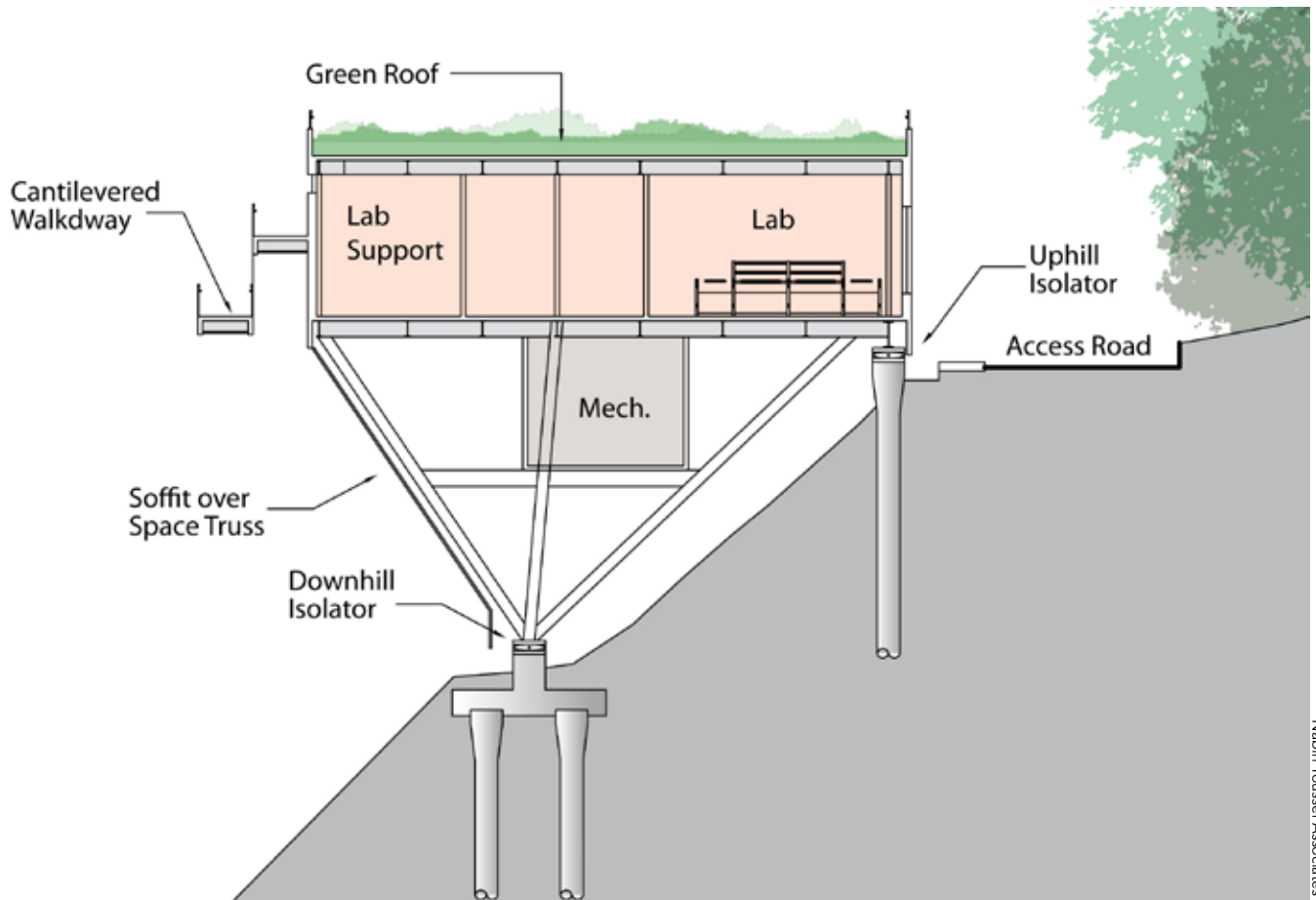
Continuity between isolators on the downhill side is provided through longitudinal steel tie beams joining isolators. Downhill isolators are joined to the uphill isolators through the chords of the triangular trusses adjacent to the hillside. The P-delta moments generated from the isolator displacements are resisted through bending in the space truss members connected to them. NYA performed nonlinear response history analyses (NLRHA) using SAP 2000 to verify the feasibility of the isolation and structural systems.

Isolator uplift was a concern from the beginning of the isolation system design due to the unique configuration of the building and the specific properties of the Friction Pendulum isolators—

Sloping space truss elements converge on isolation bearings that protect against seismic activity. The space truss provides the level base upon which the rest of the building is constructed. Each downhill bearing rests on a pier cap supported by drilled piers. The uphill bearings rest on single large-diameter drilled piers.



Nabih Youssef Associates



Nabih Youssef Associates

A typical section of the RMB shows the split-level base isolation system and the steepness of the hillside below.

once the building uplifts on the uphill side, all of the isolator load and hence all of the friction shifts to the downhill isolators, thus immediately increasing the global overturning moment. Although NLRHA showed only very limited uplift of several uphill isolators during the Maximum Credible Earthquake, NYA thought it prudent to specify tension restraints below the columns on the uphill side. These precautions are in addition to proportioning the building to have a weight distribution resulting in a factor of safety against overturning for gravity and seismic loads.

Deep Foundations

The downhill foundations for the building consist of drilled piers socketed into bedrock and topped by pier caps that support the isolators. The uphill isolators rest on large diameter drilled single piers that cantilever out of the ground. Because the building could not completely match the upward slope of the road, the drilled pier foundations were extended up by as much as 20 ft at some locations to meet the top of the space truss. Initial studies by NYA showed that the relative flexibility of the cantilevered drilled piers compared to that of the isolators would not adversely affect isolation system performance. As a precaution, however; an in-depth study was specified in the Bridging Documents to verify that the design-build team came to the same conclusions.

Looking Forward

The NYA/RVA team completed its initial role in the project when it presented the design and bridging documents to UCSF. A design-build competition was held and a team composed of DPR Construction, SmithGroup, and Forell/Elsesser Engineers was selected as the winner. The winning team has worked together to carry the project forward through construction while adding its own significant innovations and improvements to the original design. The NYA/RVA team has continued to serve as peer reviewers during the design-build team selection and current construction. **MSC**

Bridging Documents Team:

Architect

Rafael Viñoly Architects, New York

Structural Engineer

Nabih Youssef Associates, San Francisco

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