San Francisco's High-Profile Living Roof

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The green roof at the California Academy of Sciences has become internationally famous. The roof and surrounding gardens in the context of Golden Gate Park resonate strongly with the public.

The seven hills of San Francisco – Twin Peaks, Russian Hill, Mount Sutro, Nob Hill, Telegraph Hill, Mount Davidson, and Rincon Hill – served as the inspiration for Renzo Piano's iconic roof design for the new California Academy of Sciences. Completed in 2008, this museum project, recipient of numerous design and sustainability awards, has been extraordinarily well received by the public and architectural critics alike. Billed as the world's greenest museum and a masterpiece in sustainable architecture, the Academy is located in the heart of Golden Gate Park. The building is nestled in groves of mature evergreen trees that frame the museum grounds on three sides.

The new Academy forms the cultural centerpiece of San Francisco's largest park, in concert with the Music Concourse, a large, sunken plaza originally created for the 1894 California Midwinter International Exposition, and the recently re-built, Herzog & de Meuron-designed De Young fine arts museum with its landmark twisted tower. The Academy's evocative, undulating roofscape –

The now-famous mounded shapes of the green roof make a harmonious contrast with the surrounding landscape of Golden Gate Park.

currently the most famous green roof in California – resonates strongly with the public. Many park and museum visitors who view the rooftop plantings from a distance or close-up from the Academy's roof observation deck experience a living roof for the first time. While some might feel reminded of the Teletubbies' home, most visitors are in awe of the living roof's sculptural qualities, beauty and ecological benefits. The Academy of Sciences project has spurred a number of subsequent Mediterranean-climate green roof constructions on the West Coast. It continues to educate and inspire the public, scientist, and the design community.

Founded in San Francisco in 1853 as the first scientific institution of the western United States, the original Academy building was destroyed during the 1906 Great Quake and subsequently re-opened in the North American Hall in Golden Gate Park in 1916. Over the decades several components, such as the Steinhart Aquarium, the Simson African Hall and the Morrison Planetarium, were added to the large museum and research complex.

Major structural damage sustained during the 1989 Loma Prieta earthquake resulted in the relocation of the Academy to a temporary location in downtown San Francisco. When the nearly ten-year long design and construction period for the new building began in 1999, the Academy of Sciences developed a bold vision to "create an institution for the 21st century – a premier destination of grand design, and one that would bring the latest in scientific research to the public in the most engaging, educational and inspiring way imaginable."

After the Academy's board had commissioned six architecture firms to develop visions for the project, Renzo Piano's design was selected for realization. The project team from Renzo Piano Building Workshop in Genoa was supported by the San Francisco-based firm Stantec Architecture (formerly Chong Partners Architecture & Gordon H. Chong + Partners) and engineering teams from ARUP and Rutherford & Chekene. Led by John Loomis, the SWA Group's Sausalito office provided full landscape architectural services for the new California Academy of Sciences grounds and roofscape. Paul Kephart's firm Rana Creek Living Architecture served as the horticultural consultant. Construction of the 500 million dollar complex at the old location in Golden Gate Park began in November 2005, and the new California Academy of Sciences opened on September 27, 2008.

Among the diverse exhibits housed by the new 38,000 square meter Academy complex are a natural history museum, a planetarium, an aquarium, the deepest coral reef exhibit in the world, and a four-story tropical rainforest. These building components are grouped around the Central Piazza, a partially glazed, multi-functional open courtyard featuring natural ventilation. Renzo Piano describes his main idea behind the roof design as "lifting up a piece of the park and putting a building under it."

When viewed from above, for example from the top of the De Young museum's tower or the Academy's roof observation deck, it becomes obvious that the architects achieved this important design goal. The new Academy building fits harmoniously into its Golden Gate Park context yet serves as a new landmark. The roof landscape with its iconic domes that mimic the hills of the surrounding city reflects the complexity of the museum components that lie underneath. The two largest mounds, one densely

Roof access allows visitors to observe some of the over 1.7 million plants on the roof's paneled structure. The panels were planted and managed to achieve the perfect mix.

penetrated by round skylights that direct sunlight into the building and serve as ventilation openings, the other more enclosed, house the tall tropical rainforest exhibit and the planetarium. The hills of the roofscape are arranged around the Central Piazza in a way that guides cool air into the courtyard. The use of glass and the general openness of the architecture seem to invite Golden Gate Park into the Academy building and make the museum part of the surrounding landscape.

In consonance with the facility's mission, sustainability played a major role in the design concept for the new California Academy of Sciences. The building design embraces concepts of energy efficiency, natural lighting and ventilation, water retention and reclamation systems, and re-use of demolition material from the old building and other recycled materials such as recycled blue jeans as insulation. A large solar canopy that contains a band of 60,000 photovoltaic cells surrounds the living roof and provides partial shade and cover for the building façade and entrance areas. The U.S. Green Building Council awarded the building a Platinum-level LEED (Leadership in Energy and Environmental Design) certification, and the Academy on its website proudly claims to be "the largest public Platinum-rated building in the world, and also the world's greenest museum."

The at-grade landscape surrounding the new California Academy of Sciences consists of the on-structure main Entrance Plaza on the building's north side as well as the East and West Gardens. These side gardens were designed by SWA to be planted with native species. The gardens provide visual connections from interior spaces of the museum to the larger Golden Gate Park environment and accommodate fire lanes as well as areas for gatherings, receptions, and outdoor dining. The West Garden is also home to the Aviary, which houses rescued birds of prey, and two Maya Lin sculptures. The open, multi-functional Entrance Plaza – an intensive green roof on top of a two-story parking structure – connects the Academy to the Music Concourse and De Young museum. The reduced, functional design comprised of steps, gently sloping ramps, a wide piazza, concrete retaining and seat walls, terraced lawns, and palm trees is characterized by simple and clean lines. It provides access to the museum and spaces for visitor gatherings and drop-offs.

The most significant and highly praised component of the Academy's landscape design, however, is the large, sculptural green roof. Renzo Piano's formal intentions for the building, the design team's sustainability goals, functional building requirements as well as the museum's educational and research objectives, resulted in the construction of a unique and site-specific hybrid type of semi-intensive living roof.

To this date, the Academy features the most prominent, most visited, and – at one hectare in size – the largest green roof in the San Francisco Bay Area. A major contributor to the building's sustainability strategy, the undulating, greened rooftop connects the building to the surrounding park landscape, defines the new Academy's iconic landmark appearance, and, at the same time, serves as an important museum exhibit. The unusual demands and hybrid functions of this high-profile vegetated roof have resulted in significant design and maintenance challenges.

The various layers of the Academy's living roof provide insulation, significant gains in heating and cooling efficiency and thus energy savings, rain water filtration and retention as well as microclimatic benefits and habitat value. These performative functions are comparable to those of contemporary, low-maintenance living roof constructions. However, unlike conventional extensive green roofs, which are mostly flat, not showy, self-sustaining, and not designed for human use, the California Academy of Sciences' sculptural roofscape, through its observation deck, is accessible year-round to hundreds of thousands of museum visitors with high expectations regarding the appearance and lushness of the rooftop's vegetation. Despite a planting substrate depth of only 15 centimeters, the demands described above, coupled with the decision to use California native species as rooftop plants, resulted in a highly engineered, irrigated, fertilized, and relatively high-maintenance, semi-intensive living roof.

Roof slopes of up to 60 degrees in the steepest areas of the central domes presented an engineering challenge. For about two years SWA and Rana Creek worked with full-scale mock-ups to test the roof layering's anchoring, drainage, soil, and native plant systems. The Academy roof's waterproofing, root barrier, insulation, drainage, and filter layers are held in place by an

orthogonal 7.3 by 7.3 meter grid of linear basalt-filled gabions that structure the roof surface, improve drainage functions and facilitate maintenance access. In the steepest areas a denser, secondary grid of gabions was introduced and polyester straps anchor the gabions and planting modules. The areas between the gabion channels were filled with a 7.5 centimeter thick layer of rooftop soil. The plant material was brought out in the form of BioTrays, a modular planting system custom-developed and patented by Rana Creek. The 43 by 43 centimeter trays consist of flat, porous, biodegradable containers made from coconut fiber. The flats that hold a depth of 7.5 centimeters of planting substrate were pre-cultivated in Rana Creek's nursery in Carmel Valley prior to their delivery to the construction site. Once on site, workers laid out the approximately 40,000 planted trays (containing 1.7 million plants) like tile on top of the layer of rooftop soil that was already in place. Over time, as the plants grew, their roots penetrated the degrading coconut fiber and interlocked the tray patchwork into one stable vegetated soil mat.

The native plant material selected for the Academy roof had to be able to thrive in an exposed rooftop condition in Golden Gate Park's harsh, ocean-influenced, summer-dry Mediterranean climate, fulfill Renzo Piano's requirement of visual uniformity as well as visitors' expectations of greenness and lushness, and provide habitat for native insects, butterflies and birds. The vegetation needed to be able to self-propagate on the roof and, unlike many California native plants in nature, look lush and bloom year-round. In order to achieve these goals, Rana Creek's Paul Kephart and Frank Almeda, Curator of Botany at the Academy, experimented with more than 30 species before narrowing down the plant palette to nine California native plants: four perennials and five annual wildflowers. Since the Academy's opening in 2008 the rooftop plant composition has evolved and changed. Soon after the installation *Prunella vulgaris* dominated the aspect of the green roof. Several of the annual species and a few perennials that are adapted to poorer soil conditions, such as the California Poppy (*Eschscholzia californica*) or Sea Pink (*Armeria maritima*), were no longer competitive in the network of plants. A number of more aggressive volunteer species, dispersed by wind and wildlife, have taken root on the Academy roof, where currently approximately 75 plant species can be found. In the areas with the steepest slopes erosion problems slowed the establishment of vegetation.

Originally conceived as a self-sustaining green roof low in maintenance and, once established, adapted to summer drought and reliant on natural precipitation alone, the built reality of the California Academy of Sciences' vegetated rooftop presents itself very differently. It clearly cannot be considered an extensive green roof. The high-profile character of the whole project and the expectation for the plant material to look beautiful year-round require regular irrigation, fertilization, and, consequently, weeding and other frequent maintenance.

However, while the Academy's living roof design can certainly not serve as a direct model for extensive, low-maintenance and inexpensive Mediterranean-climate green roofs, there is no doubt that this project with its spectacular visual presence and rock star status very successfully raises public awareness and educates millions of museum visitors about issues of ecology and sustainability.

SWA Group designed the surrounding landscapes at street level to accommodate park and museum visitors, and to connect the interior of the museum to the outside.