A BREATH OF FRESH AIR

By Steve Carter, Edwin Shlemon, S.E., M.ASCE, Steve Ratchye, S.E., and Erin McConahey, P.E.

Cody Andresen, Arup

The new, 18-story San Francisco Federal Building was designed in accordance with the goals of the U.S. General Services Administration’s Design Excellence Program, which seeks to improve the quality and value of public buildings so that the structures can ultimately become respected landmarks. It is considered the first building in the Design Excellence Program that is similar to a traditional office building.

Close collaboration on the part of the engineers and architects of the new San Francisco Federal Building has created a facility that advances the goal of sustainable development by incorporating features that maximize the use...
of natural ventilation and natural lighting. The iconic structure is considered a model for future federal buildings. By Steve Carter, Edwin Shlemon, S.E., M.ASCE, Steve Ratchye, S.E., and Erin McConahey, P.E.

Completed in March 2007 and formally dedicated last summer, the San Francisco Federal Building is more than just a structure that was built to consolidate the offices of various federal agencies and departments previously housed at different sites around the Bay City. According to Lurita A. Doan, the administrator of the U.S. General Services Administration (GSA), which commissioned and owns the project, the building is also “a statement. It says we can coexist with our environment, and in spectacular fashion; it says we are committed to the world outside our buildings as well as the workers within.”

In praising the $144-million federal project on July 9, 2007, during the dedication ceremony, Doan noted that “the lessons learned here, including how to take bold, revolutionary ideas from conception to construction, will be applied to all GSA projects.”

The new federal building is the product of close collaboration on the part of Morphosis—a Santa Monica, California, design firm led by the Pritzker Architecture Prize–winning architect Thom Mayne—and Arup, an international engineering firm. SmithGroup, Inc., of San Francisco, was the local executive architect.

Designed in accordance with the goals of the GSA’s Design Excellence Program, which seeks to improve the quality and value of public buildings in the hope that the structures will ultimately become respected landmarks, the San Francisco edifice is the first structure in the Design Excellence Program to be similar to a traditional office building, notes Brandon Welling, Morphosis’s project architect. Most other buildings in the program have been specialized structures—courthouses or scientific facilities, for example—Welling explains (see “Sky Watcher,” Civil Engineering, May 2007, and “Taking the Lead,” Civil Engineering, December 2007).
The centerpiece of the project is a slender, 18-story concrete structure in the city’s Mid-Market neighborhood that rises from the northwestern edge of a site at the corner of Mission and Seventh streets. The site also accommodates three new steel-framed buildings—a four-story annex along the southwestern edge of the property, a single-story freestanding café, and a single-story day care center—as well as a public plaza that encompasses approximately 1 acre (0.4 ha).

The plaza was designed, in part, to frame another federal structure that is located across the street, namely, the building housing the U.S. Court of Appeals for the Ninth Circuit, which was constructed in 1905 and underwent a $91-million renovation in the mid-1990s.

Rising 240 ft (73 m) above grade, the 605,000 sq ft (56,000 m²) tower is twice as tall as the surrounding buildings on nearby Market Street, which historically have been restricted to 120 ft (36.6 m) by San Francisco’s urban planners. That difference in building heights was critical to the design team’s plans to cool the tower through natural ventilation. There is at least one structure of equal height located on the southwestern edge of the site, but it does not interfere with the winds.

The typical floor plate of the tower is rectangular, its width being 60 ft (18 m) and its length 342 ft (104 m). After examining records describing the area’s wind climate to determine the predominant wind directions, the design team oriented the length of the tower along the northwestern edge of the site in order to capture the prevailing breezes on warm days.
From the southeast, the tower’s appearance is dominated by an undulating scrim of perforated metal panels constructed of stainless steel on galvanized steel supports that provide shading in the morning hours; later in the day, desk-high panels rotate upward to provide unobstructed views. Randomly placed rotating panels impart activity to the facade throughout the day.

The sunscreen system also rises up and folds over the roof of the tower to conceal the mechanical systems on the roof of the structure, which is located in the city’s Mid-Market neighborhood on a site at the corner of Mission and Seventh streets. Levels 11 through 13 of the tower feature a publicly accessible sky garden—glazed on the northwestern side and open to the air on the southeastern side—that includes an art installation.

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The sunscreen system also rises up and folds over the roof of the tower to conceal the mechanical systems there, and it spreads out to the southeast at the base of the tower as an undulating perforated canopy that covers the plan the day care center, and the café. Galvanized steel anchor bolts attach the
scrim support structure to the concrete frame of the tower’s southeastern facade, and a gap 3 to 6.5 ft (1 to 2 m) wide between the facade and the panels accommodates catwalks for window cleaning and maintenance. The roof and plaza portions of the sunscreen canopy, which do not include rotating panels, are supported on galvanized steel trusses.

On the northwestern facade, a series of frosted glass fins are attached vertically at 90 degree angles to the face of the building to provide additional shading.

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In a March 14, 2007, review, “More Openness in Government (Offices, The Is),” Nicolai Ouroussoff, the architecture critic for the New York Times, hail the San Francisco Federal Building as Mayne’s “most powerful government work to date” and predicted that the building “may one day be remembered the crowning achievement of the General Service Administration’s Design Excellence Program.” Ouroussoff was particularly laudatory in describing the building’s “slender form and perforated metal skin,” which he saw as offering “a clever play on notions of transparency in an era when the fear of terrorist attacks is prompting government agencies and corporations to turn their offices into armored compounds.”

But the facility has more going for it than aesthetics; it has also been designed with a strong sense of environmental stewardship. The structure incorporates numerous features to reduce energy demand by taking advantage of natural lighting and natural ventilation. The natural ventilation system made sense at this site because San Francisco’s temperatures range from 44°F to 78°F (7°C to 25.5°C) throughout the year. Thus, the tower could feature operable windows; only the first five levels are cooled mechanically. Security concerns prohibited operable windows below level 6.

The windows in every other bay on level 6 and in all the levels above open and close automatically, and the sunscreen panels are
controlled by a computerized building automation system that monitors temperatures within the structure and tracks such external environmental conditions as the wind’s speed and direction. Described by the design team as the tower’s “living skin,” the system has been designed so that cool breezes will enter through windward openings on the northwestern facade and be channeled out through the leeward southeastern facade under the predominant wind conditions.

The design team worked with the Lawrence Berkeley National Laboratory, in Berkeley, California, to model the structure’s thermal performance. During the day, the thermal mass of the exposed concrete soffit is expected to absorb heat from computers, people, and lighting. At night, the computer-controlled windows open to allow the evening air to flow through the building and cool the concrete. The window wall system features low-emissivity insulated glazing, a finned tube convector system for heating, and small motorized ventilation grilles (“trickle vents”) that help to maintain at least a minimal flow of fresh air even when the windows are closed. The tenants can also open windows manually.

The windows and movable sunscreen panels are integrated with the building fire protection system. In the event of a fire, the mechanically operated windows will all close to help prevent smoke from escaping from one floor to the building only to be sucked back into the next floor, and the sunscreen panels will all open to help dissipate the smoke from the facade.

The design team and the contractor—a joint venture of the Dick Corporation of Pittsburgh, and the Morganti Group, of Danbury, Connecticut—relied on the building information modeling software MicroStation Triforix, developed by Bentley Systems, Inc., of Exton, Pennsylvania, to determine the geometry of the sunscreen prior to the fabrication of the sunscreen’s metal elements. Because the sunscreen supports were constructed from hot-dipped galvanized steel, the pieces were then bolted together on-site to avoid on-site welding, which would have required that the welded areas be retreated through a cold galvanizing process that is not as durable as the original treatment.
galvanized steel, the goal was to avoid any on-site welding. Such welding requires that the welded area then be retreated with a cold galvanizing proc that is not as durable as the original treatment, Welling notes.

As a result of the computer modeling process and close cooperation between the design team and the contractor, all of the metal parts for the sunscreen system—the panels, the bolts, the shear plates, the supports, and even the holes in the attachments—had already been welded before being hot dipped. “Then they were brought out to the site and bolted together like a big Erector set,” Welling explains.

Because of the technical adjustments and “learning curve” that the tower’s unique ventilation and shading systems would require and the need to move in tenants from other federal offices around the city in phases, the GSA did not attempt to track environmental cost savings during the building’s first year of occupancy, notes Welling.

Although such tracking has commenced only recently, the building has been designed to exceed the GSA’s goal that federal buildings should use no more than 55,000 Btu of energy per square foot (644,722 kJ/m²) per year. The energy savings are achieved through the use of natural ventilation and by having approximately 85 percent of the work spaces illuminated with natural light. Lighting typically accounts for as much as 40 percent of a facility’s total energy demand.

Natural daylight penetrates deep into the work spaces thanks to the tower’s narrow profile, high ceilings (averaging 13 ft [4 m]), and floor-to-ceiling window wall system. Furthermore, the electrical lighting used to supplement the natural

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*Because the building is so long and thin and its elevator core is located in the middle, the design team was concerned that a small entrance might result in a compressed, tunnel-like passage from the side streets to the elevators. The team therefore chose to splay the six sloping columns to form a grand entrance space for the structure. Five of the columns are partially exposed within the building to frame the dramatic, 65 ft (20 m) tall entrance lobby and create an appearance reminiscent of Gothic architecture.*
lighting is controlled by sensors so that the lights switch off at unoccupied workstations.

In a naturally ventilated spa with hard, exposed concrete ceilings there is no background hiss from an air conditioning system to mask unwanted sounds. To compensate, the design team added small devices that are attached to and powered by the hanging lighting fixture to generate a broad spectrum of low-level background static.

The reduction of the building’s carbon footprint began during the construction phase when a recycled waste product from the steel industry—blast furnace slag—was substituted for 50 percent (by volume) of the portland cement that would otherwise have been used in the concrete mix for the structure’s foundation and frame. Because the manufacturing process for portland cement releases approximately 66 lb (30 kg) of carbon dioxide for each 110 lb (50 kg) of cement, using the slag in the mix was the equivalent of removing the greenhouse gas emissions of 600 cars for an entire year, even allowing for the environmental consequences of transporting the slag from South Korea to San Francisco. A water-reducing admixture was incorporated into the concrete mixture to maintain workability.

The reflection of interior lighting by the whitish shade of the exposed slag concrete also is expected to reduce the structure’s electricity demand.

In an age when the term “sick building” has entered the nation’s lexicon to describe structures that can be unhealthy for the people who work or live inside them, the San Francisco Federal Building has been expressly designed with the health of its occupants in mind, in part by encouraging walking and stair climbing through the conveniently connected spaces. For instance, the tower features an elevator system in which most of the cars stop only at every third floor; people are thus encouraged to walk up or down a flight of stairs to reach their destinations. Certain cars, however, do stop at each floor to accommodate those who are unable or unwilling to use the stairs.

To further encourage walking, the café has been placed outside the tower and the annex at the southeastern corner of the facility, a...
San Francisco needed the new federal building to consolidate the offices of larger agencies within the GSA region encompassing San Francisco. Among the major tenants in the building are the Department of Labor, the Department of Health and Human Services, the Social Security Administration, the Department of Agriculture, and the Office of Personnel Management.

The new federal building complex was constructed in a section of the city that the San Francisco Business Times has described as “a gritty neighborhood” that previously housed “an old Greyhound bus parking lot,” according to a March 28, 2008, article entitled “San Francisco Federal Building For investing in such a neighborhood and for combining environmental stewardship with beauty, the paper named the project its 2007 deal of the year.

The tower structure features slab and beam construction supported on columns at the perimeter of the floor slabs. The perimeter columns are spaced 28.5 ft (8.7 m) apart. Four beams extend along the full length of the slabs, two along the perimeter and two in the interior. The perimeter beams are supported on the perimeter columns while the interior beams are supported on shear walls that house the elevators, stairs, and service location that is also expected to foster interaction between the federal workers and the general public.

Tim Griffith, both

The perforated metal skin of the sunscreen panels suggests transparency “in an era when the fear of terrorist attacks is prompting government agencies and corporations to turn their offices into armored compounds,” according to a March 14, 2007, review by the architecture critic of the New York Times, Nicolai Ouroussoff. In the event of a fire, the mechanically operated windows will all close to help prevent smoke from reentering the building, and the sunscreen panels will all open to help dissipate the smoke from the facade.

A series of frosted glass fins are attached vertically at 90 degree angles to the northwestern facade of the building to provide additional shading. The ventilation system is designed so that cooling breezes will enter through the windward openings on the northwestern facade and be channeled out through the leeward southeastern facade under the predominant wind conditions.
shafts. The beams are typically 39 in. (990 mm) wide and 28 to 35 in. (710 to 890 mm) in depth.

The beams are upturned—which means they are located atop the slabs—and the slabs that span between the beams have a waveform profile. Ordinarily, the beams support the slabs from underneath. But in this case such placement would have blocked the airflow required to make the concrete perform as a thermal mass. The upturned beams were chosen to create an unobstructed soffit across which air could flow unimpeded, promoting the desired heat transfer.

Unfortunately, the upturned beams—spaced 22 ft (6.7 m) apart—also create tension in the ribbed concrete slabs, which increases the possibility that the concrete will crack. To strengthen the slabs, the design team chose a waveform slab design wherein the thickness of each slab would vary from 43/4 to 125/8 in. (120 to 320 mm). The thicker portions feature lateral rebar members that act like ribs or miniature beams to reinforce the slabs between the upturned beams.

The wave profile also helps to reduce the concrete mass, and the larger surface area increases air contact. Other benefits are that it improves lighting by eliminating shadows and enhances the spaces aesthetically. A raised acc floor covers the upturned beams to create the finished surface of the floor above.

Seismic considerations led to the placement of reinforced-concrete shear walls at each end of the tower, forming a large C-shaped core that defines the center of the floor plate along with two smaller box cores that occur at intermediate locations to ensure lateral stability. The walls vary in thickness from a maximum of 35 in. (890 mm) at the base of the tower to 15 in. (380 mm) at the uppermost stories. Because the design loads for the shear walls were dictated by seismic considerations, a concrete strength of 8,000 psi (55 MPa) after 56 days of drying was specified for the basement level through level 6. From level 6 to the roof, the walls were specified to have a concrete strength of 6,000 psi (41 MPa) after 56 days of drying.

In addition to the perimeter columns that support most of the floors, six sloping columns 4 in. (1,200 mm) square rise from grade on the southeast side of the structure.
with the wave slab on level 6 stiffen the lower portion of the tower. One of these reinforced concrete supports is located outside the structure on the northeastern edge of the site. The other five are partially exposed within the building, where they help to frame the dramatic, 65 ft (20 m) tall entrance and create an appearance reminiscent of Gothic architecture, explains Welling.

Because the building is so long and thin and the elevator core is located in the middle, the design team was concerned that a smaller entrance might result in a compressed, almost tunnel-like passage from the side streets to the elevators. The columns were therefore splayed to form a grand space that “helps to draw you to the vertical circulation area without making it seem like such a long haul to get there,” notes Welling.

Although a dual system of shear walls and moment-resisting frames is typically used for concrete towers of this size in California and in fact was...

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In addition to the tower, the $144-million complex accommodates three buildings that feature steel moment-resisting frames—a four-story annex along the southwestern edge of the property, a single-story freestanding café, and a single-story day care center—as well as a public plaza that encompasses approximately 1 acre (0.4 ha). Considered a model for future federal building projects, the complex is designed to promote walking and stair climbing. For example, the elevators stop only at every third floor, and the café is outside of the main building.

As the fr...
considered during the early stages of the design, that approach was ultimate rejected. First, the design team’s desire to create large column-free bays would have limited the number of moment-resisting frames. Second, the sloping columns would have introduced horizontal loads that, in combination with the requirements set forth in the 1997 edition of the Uniform Building Code (UBC)—published by the International Conference of Building Officials (now part of the International Code Council)—for a dual system’s moment-resisting frames, would have resulted in prohibitively large beams and columns. Finally, the structural design team felt that the favorable ductility factor allowed for dual systems in the UBC would have resulted in less robust system. In the end, a shear wall system was selected, and even though it had to be sufficiently robust to withstand higher seismic forces, cost estimates showed that the elimination of the moment-resisting frames would bring considerable savings.

The complex’s steel structures—the annex, the café, and the day care center—were constructed with steel moment-resisting frames.

Geomatrix, of Oakland, California, the project’s geotechnical consultant, examined the loose, sandy soil conditions at the site to develop a response spectrum on the basis of an anticipated earthquake. This analysis resulted in acceleration values that were significantly higher than the UBC design spectrum for the period of the tower. The design team’s structural engineers however, were concerned over the fact that the code allows designers to ignore the localized increase in acceleration that can occur and to scale the shear down to prescriptive levels. Moreover, although the 240 ft (73 m) height of the tower equaled the UBC limit for a concrete shear wall and the team members were also concerned over the fact that more recent publications, including the International Code Council’s International Building Code, actually limit the height of shear wall buildings with the torsional characteristics of the tower to only 160 ft (48 m). Finally, the designers felt that the outrigger effect caused by the sloping columns warranted further investigation.

Given the limitations of code-based prescriptive design procedures, the GSJ accepted the design team’s proposal to conduct a nonlinear analytical check accordance with the requirements set by the Federal Emergency Management Agency (FEMA) in its document 356 (“Prestandard and Commentary for the Seismic Rehabilitation of Buildings”) to confirm that the tower would provide the desired safety level during a seismic event. FEMA 356 is the standard for conducting a performance-based nonlinear analysis that considers the complex postyield behavior of the building materials and also captures the effects of increased local accelerations. This analysis was performed using the nonlinear version of SAP2000, developed by Computers & Structures, Inc., Berkeley, California.

Although this analysis indicated that only minor increases were required in the shear strengths for the link beams and in the reinforcing bars in the boundary elements of the shear walls, the analysis served a vital purpose in that it made it clear to both the GSA and the design team that the proposed solution offered the best value over the long term.

The tower’s foundation consists of approximately 1,100 auger-drilled, cast-
place piles tied together by large pile caps. The concrete was 70 percent sligh
t and the piles varied in length from 70 to 120 ft (21 to 36 m), depending on t
particular loadings and subsoil conditions. Given the possibility of localized
liquefaction, a suspended slab system for the lowest-level slab was chosen.

By combining stunning aesthetics with the use of innovative energy-saving
systems, the San Francisco Federal Building seems well on its way to
achieving recognition and influencing future construction. In June the
structure won the 2008 White House Closing the Circle Award, which
recognizes outstanding federal achievements in environmental stewardship.
Maria Ciprazo, a GSA project executive in San Francisco, has noted that the
building “is anticipated to initiate a new generation of highly energy-efficie
federal projects.”

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Project Credits
Owner: U.S. General Services Administration, Washington, D.C.
General contractor: Joint venture of Dick Corporation, Pittsburgh, and the
Morganti Group, Danbury, Connecticut
Design architect: Morphosis, Santa Monica, California
Executive architect: SmithGroup, Inc., San Francisco
Structural, mechanical, electrical, and plumbing engineer: Arup, Los
Angeles
Concrete contractor: Webcor Concrete, San Mateo, California
Construction manager: Hunt Construction Group, Scottsdale, Arizona
Geotechnical engineer: Geomatrix, Oakland, California
Concrete supplier: Bode Gravel, San Francisco
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