concrete

The finished Caltrans District 3 state office building in Marysville, Calif.
Courtesy of Art Gray

An office building that self-rights after a seismic event

Fully integrated design and building system exposes the benefits of precast hybrid moment frame.

By Brian Miller, P.E., LEED AP

Architect
AC Martin, Los Angeles, Calif.
Engineer of Record
Englekirk & Sabol Consulting, Los Angeles, Calif.
Precaster
Clark Pacific, West Sacramento, Calif.
Specialty Precast Engineer
Clark Pacific, West Sacramento, Calif.
Owner
Department of General Services, State of California

The Caltrans District 3 state office building in Marysville, Calif., uses a precast hybrid moment frame (PHMF) to provide seismic resiliency and create open interior spaces. The LEED Silver structure also utilizes an architectural finish on exposed structural members, and a thermally efficient skin to help reduce energy use.

At 230,000 square feet, the five story building provides offices for 758 employees, as well as meeting space and a 200-seat auditorium. A central, four-story atrium or "canyon," which begins on the second level of the structure, harvests natural light from south-facing clerestory skylights, and provides the surrounding offices with maximum daylighting. It also provides the structure with a studio or loft look, ideal for the resident transportation and landscaping architects and designers.

The project's design was the result of a design/build competition based on a budget stipulated by the Department of General Services (DGS). The goal was to have a healthy, user-friendly facility that encourages employee communication and productivity, and meets the new California mandate that all new state facilities be sustainable.

Detail of the Caltrans District 3 precast hybrid moment frame.
Photo by Clark Pacific

A total precast design using PHMF proved to be the most cost-effective solution, beating two competing steel structure proposals and meeting the target budget specified by the competition.

“The precast hybrid moment frame was a differentiator,” said Carey McLeod, AIA, DBIA, principal for AC Martin. “It’s the reason we were able to do the project. The competitors were not able to certify that they could complete the project for the state’s stipulated sum.”

Structurally resilient

Utilizing an innovative, structurally-resilient PHMF (see sidebar), the building combines an exposed, exterior precast concrete structural frame with a precast architectural finish. This cost-effective approach eliminated the need for fireproofing and a secondary façade system, which sped up the construction schedule. The precast panels were left exposed on the interior, further reducing costs.

“The building’s structural system creates a seismically ‘resilient’ building. It is the best performing lateral resistance system available, due to its unique ability to ‘self-right’ after a major seismic event,” said Don Clark, president of the precaster Clark Pacific. “The building’s structure and architecture were designed as a unit, rather than separate components. The result is a fully integrated design and building system.”

Design capitalizes on the PHMF, also known as the PRESSS (precast seismic structural systems) frame. The system was developed through extensive research in the 1990s, followed by testing of a five-story, 60 percent scale structure at the University of California in San Diego. The ductile system is designed to take advantage of a jointed precast system, rather than emulating cast-in-place. Through the use of unbonded post-tensioning, the moment frame has a self-righting mechanism (no residual drift) that creates a very resilient structure. The Caltrans District 3 state office building is the first state building in California to feature the PRESSS frame.

Bay size critical

In the design, the structural bay size was critical to allow for flexible, column-free work space. The space also had to maximize efficiency for the specified workstation furniture modules. The team developed a solution that facilitated a reduction in the client’s proposed structural bay size, thereby reducing the building footprint, while maintaining the required occupancy, program requirements, and furniture module sizes.

The typical floor plate dimension of the structure is 200 by 280 feet, which incorporates the 115 by 42 foot canyon. The structural floor consists of hollow-core plank, a precast/prestressed concrete voided floor system with a 4-inch-thick cast-in-place (CIP) topping. The floor is supported on precast/prestressed concrete L-shaped beams with alternating spans of 42 feet and 34.5 feet.

Full-height precast concrete columns were used to support the girders/beams. On the exterior, the hollow-core is supported by architecturally finished load-bearing precast spandrels or lateral-load-resisting PHMF beams, which span between architecturally finished precast columns. This allowed for an open, flexible floor plate free of shear walls and internal bracing. Foundations consisted of spread footings.

"The time and ease of assembly, as well as the ease of integrating building systems into the structure, were both key factors in the decision using the PHMF system," Clark said.

Highly sustainable design

Set back 20 feet, the building is augmented by a green tree-lined parkway and pedestrian path leading to the entry court. Local mature shade trees were planted along the main entrance. Site disturbance was minimized by the use of precast concrete components, which were produced offsite and as needed. Additionally, the precast concrete components were erected in just 14 weeks.

All precast concrete components were manufactured locally, thereby reducing transportation-related CO2 emissions. The project utilized architectural panels, brick-clad architectural wall panels, spandrels, column cover panels, hollow-core plank, I-beams, and integrally finished moment frame beams and columns.

The design takes full advantage of the thermal storage capacity of the precast concrete exposed in the interiors. This not only reduces peak heating and cooling loads, but also delays the time at which these occur. As a result, less energy is needed for cooling and heating, and the temperature is more uniform, thereby improving user comfort. DGS expects this approach will result in an overall reduction in the building's energy use of approximately 15 percent.

The HVAC system features a nightly air purge that exchanges warm interior air with fresh evening air, cooling the interior and concrete structure. Electric lighting is controlled by occupancy sensors and dimmers at perimeter zones adjacent to the building's exterior. The central canyon uses exhaust fans to perform night flushing of air to improve indoor air quality and reduce HVAC demands. The exterior also features clear, high-performance low-E glass, further reducing heat gain/loss.

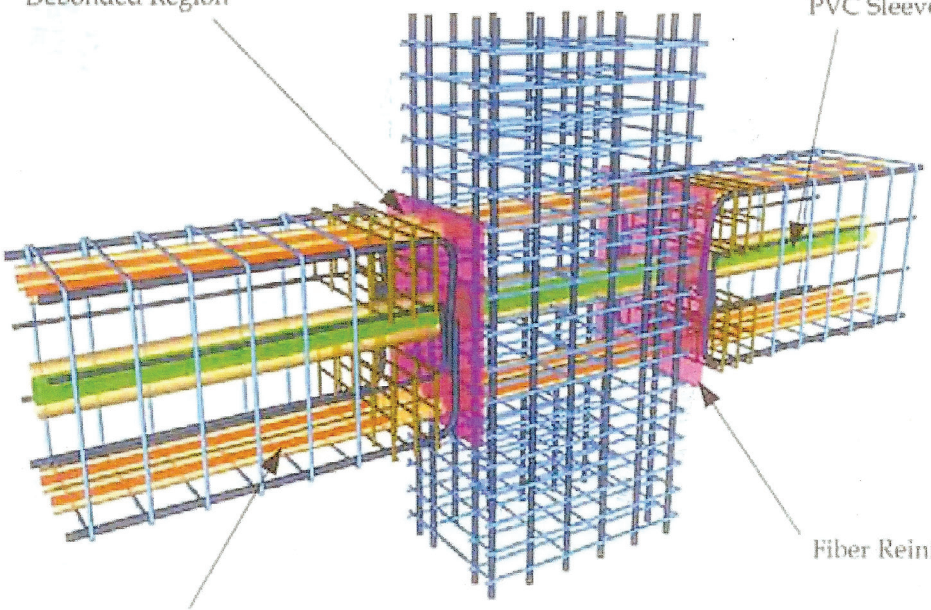
To maximize daylighting, the structure was aligned on an east-west axis. The four-story central canyon creates open, unobstructed views throughout the facility while allowing for light and air to filter throughout the workspace. At the top of the canyon, natural light is brought in through south-facing clerestory windows. Reflectors are used to project light off the ceiling and deep into the space below. The canyon also provides for visible access to areas of the building that would have otherwise been closed off by walls. Employee work spaces are never more than 37 feet from the building perimeter or the interior canyon.

It all adds up to a state-of-the-art, sustainable and seismic-resistant structure.

Brian Miller, is managing director, business development, for the Precast/Prestressed Concrete Institute, Chicago, Ill.

Another detail of the precast hybrid moment frame.
Photo Credit: Clark Pacific

How the precast hybrid moment frame works



Drawing courtesy Suzanne Dow Nakaki, S.E., The Nakaki Bashaw Group, Inc.

In the precast hybrid moment frame system, connections between precast columns and beams employ both standard reinforcing steel and high-strength, post-tensioning cables. This provides both inelastic action to absorb energy caused by movement of the joint, and elastic action for the shear and moment resistance needed to hold the joint together.

Post-tensioning strands, running unbonded through ducts in the beams, act like rubber bands during a seismic event. In effect, seismic energy is absorbed independent of the integrity of the structural members. With a low initial post-tensioning force, the high strength steel stays within its elastic range which, in an earthquake, makes the joint self-centering. When the building deflects, the strand pulls it back to its original position without residual drift or building lean. Since the rebar is not fully bonded to the concrete, movement does not cause spalling. Shear forces are handled in the moment frame.

In short, the building is self-righting, allowing the beam-to-column joints to open and close in a seismic event, minimizing damage and making possible immediate reoccupancy after the event.

Conducted at the University of California in San Diego throughout the 1990s, the PRESSS research was sponsored by the National Science Foundation (NSF), the Precast/Prestressed Concrete Institute (PCI) and the Precast/Prestressed Concrete Manufacturers Association of California (PCMAC). Codification of the system followed over the next several years. Several structures have since been completed using the system.

The PCI continues its research on seismic design with precast concrete systems. The latest project, Diaphragm Seismic Design Methodology (DSDM) program, looks at several precast concrete diaphragm systems and their connections. PCI is in the process of codifying this research as well.

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STRUCTURAL ENGINEER

Volume 16, Number 10