Photos: John Sumnicht/SGH

On the Grid

BY JOHN SUMNICHT

Seismic isolators, sandwiched between two steel grids, separate an existing San Francisco building from its vertical addition.

THIS PAST DECEMBER, CONSTRUCTION REACHED SUBSTANTIAL COMPLETION on a technically innovative seismic isolation project. The building: 185 Berry Street in San Francisco's China Basin district. Simpson Gumpertz & Heger, Inc. (SGH) helped meet the owner's goal of expanding the existing three-story, 216,000-sq.-ft building by 150,000 sq. ft in two new stories, with minimal disruption to tenants.

The existing building is 825 ft long and 110 ft wide. In order to accommodate the length of the building, two expansion joints are located approximately at the one-third points along the building's length, dividing it into three separate structures. The second and third floors and roof are post-tensioned, concrete flat slabs. The grade level slab is a conventionally reinforced, structurally supported concrete flat slab. Foundation support is provided by prestressed, precast concrete pile groups beneath columns.

The building was designed in 1988 to the requirements of the 1984 San Francisco Building Code, which was based on the 1979 Uniform Building Code (UBC). The design of the building included provisions for a light, one-story addition of 50,000 sq. ft above the roof. It thus had nominally more lateral strength than required to support the three stories, and the foundations had additional vertical load-carrying capacity.

A Heavy Addition

The addition of the two new floors triggered an upgrade of the entire building to meet the requirements for new construction under the 2001 California Building Code (CBC). Initial analysis considering a conventional fixed-base addition demonstrated that the building did not satisfy some of the prescriptive requirements necessary under the currently enforceable 1997 UBC (on which the 2001 CBC is based). Conventional upgrade approaches, involving the addition of reinforced concrete shear walls, steel braced frames, or dampers throughout the structure, would have been highly disruptive and intolerable to the bio-science laboratories operated by University of California at San Francisco within the building.

SGH suggested that the two new stories be constructed on seismic isolation bearings over the roof of the existing structure, essentially converting the addition into a mass damper. This concept had never previously been implemented in any building in the U.S. In initial feasibility studies, SGH demonstrated that this technique enabled the new construction to perform like a mass damper, which would reduce the seismic response of the existing structure below. This permitted the new space to be constructed without requiring a major structural upgrade of the existing building, thereby eliminating the need for an intrusive and disruptive construction in the currently occupied space.

The project's challenges were significant. The existing columns and foundations had only a limited amount of additional vertical load-carrying capacity. The addition is a continuous, approximately 800-ft-long structure bridging the three, independent structures below. Underlying soils are liquefiable. There were large amounts of active HVAC equipment on the existing roof that needed to remain functional during and after construction. The stair and elevator towers needed to be extended through, but isolated from, the new floors. And, all of the construction work had to be completed while the building remained fully occupied.

In order to minimize the weight of the addition and maintain Type I construction, steel framing was the logical choice. The addition consists of a new fourth and fifth floor and roof constructed over an interstitial space formed between the existing building roof and the new fourth floor. The fourth and fifth floors consist of lightweight concrete topping over metal deck on top of steel framing. The roof consists of lightweight topping over metal deck in the center bay for most of the length of the building, and untopped metal deck in the outer bays. The new superstructure uses approximately 3,000 tons of structural steel.

Performance-Based Design

The seismic isolation provisions contained in the 2001 CBC require that the structure below the plane of isolation remain essentially elastic under design earthquake shaking; the existing structure had insufficient strength to ensure elastic behavior. Upgrade of the structure to provide such strength was impractical due to cost and tenant disruption. Therefore, SGH used a performance-based approach to demonstrate that although the substructure would not remain elastic, it would perform to acceptable standards. The City of San Francisco required a strict peer review to oversee the design process on behalf of the city. The agreed-upon performance objective was that the existing building and addition would provide a similar level of reliability against collapse or life safety endangerment to that of a new building designed to the current code. The FEMA 356 provisions for seismic evaluation and rehabilitation of existing buildings were followed as a basic guideline; however, these were modified with project-specific criteria applicable to this groundbreaking technical achievement.

The engineers constructed a full three-dimensional, non-linear model of the three wings in RAM Perform (now CSI's PERFORM-3D); this software allows users to model full material and geometric non-linearities in the existing beams, columns, and shear walls. The frame non-linearities were modeled using discrete plastic hinges with properties based on relevant tabulated values in FEMA 356, modified using moment curvature analyses. Using the composite action provided by the floor slab along with the existing prestress gave the model its frame beam flexural capacities. Since SGH expected pounding between the existing three structures, we added contact-only elements to the model to capture the effects of pounding. To help reduce the amount of pounding, we added dampers across the existing expansion joints at the existing roof.

The non-linear time-history analysis justified that the base-isolated addition was not detrimental to the existing structure. However, the peer review team wanted us to demonstrate that the building, along with the addition, possessed the necessary toughness of a code-compliant structure. To demonstrate that, we performed a reliability analysis using the results from incremental dynamic analyses, in order to estimate a confidence level associated with the existing building's ability to resist global collapse at maximum considered earthquake (MCE) level shaking.

The height of the interstitial space, measured from the top of the existing roof to the top of the fourth floor, was set at approximately 11 ft. This height was adequate to accommodate a grid of new steel beams above the existing roof but below the isolators, the isolators themselves, and another grid of steel beams as part of the fourth-floor framing above the isolators. It also allowed many pieces of the existing, active HVAC equipment to remain on the existing roof, saving money and potential downtime.

The grid of large structural steel members above and below the isolators was required to resist the moments from the displaced isolators. We took advantage of the inherent stiffness of the heavy steel grid at the fourth floor to provide enhanced vibration characteristics—4,000 micro-inches per second—since the owner was pursuing biotech and laboratory tenants for the new space.

In order to protect the relatively thin prestressed concrete roof slab, we utilized an interlocking shear transfer system consisting of concrete pads connected to the roof, and steel shear lugs connected to the lower steel grid. The connection of the concrete pads to the existing roof employed 6-in.-diameter pipes cored into the slab, as well as threaded rods epoxy grouted into the slab.

Coring and drilling into the existing post-tensioned slab was not the only challenge faced by the contractor. There were large amounts of existing HVAC equip-

The seismic isolator can be seen in between the two structural steel grids.

Mechanical systems at the existing roof level.

ment and piping on the roof. The contractor had to raise approximately three miles of existing piping to install some of the lower steel grid, and special care and detailing was required to thread the steel members—some weighing as much as 7.5 tons—around the units, ducts, and piping.

The project employs 87 seismic isolation bearings, including 33 lead-rubber bearings and 54 combined elastomeric/slider bearings. The design of the isolation system presented a significant challenge: isolating a relatively light superstructure while keeping the isolators stable at a displacement of +/- 45.5 in., which was 1.5 times the code-required maximum displacement of +/- 30 in. This required an isolation system consisting of 45-in.-diameter lead-rubber bearings and a new combined system of sliders in series with elastomeric bearings, where the PTFE sliders provided +/- 30 in. of displacement and the additional +/- 15 in. of displacement was accommodated in the 24-in.-diameter elastomeric bearing. Prototype testing demonstrated the stability of both bearings.

The use of seismic isolation as a means of providing new floors to an existing building and improving its seismic performance is truly an innovative application that set a high bar for technical accomplishment, advanced structural design and review, and collaboration among the team members. Most importantly, by applying seismic isolation in this way, we helped the owners achieve their scheduling and cost objectives on a highly constrained project. MSC

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