Photo by David Wakely

A seismic renovation turned an old parking garage into an eye-catching landmark

Renovation Creates New Landmark

By Adam Greco, S.E.

OWNED AND OPERATED BY THE CITY OF BERKELEY, CA, THE SATHER GATE GARAGE WAS IDENTIFIED AS A SEISMIC HAZARD that could potentially create life safety risks to garage users, City employees and pedestrians. As a result of the City's seismic risk reduction program, the garage was selected for a seismic upgrade in order to minimize the risk of injury and death associated with the structure's potentially poor performance in an earthquake.

The structural design firm of Degenkolb Engineers, working closely with Baker Vilar Architects, determined that an exterior steel bracing scheme was the best solution for strengthening, and in the process, created a new city landmark.

The main life safety concerns identified with the structure were its concrete columns and brick masonry veneer. Built in 1966, Sather Gate is a five-story, 191,000 sq. ft., non-ductile concrete frame garage originally constructed as two separate buildings with a joint isolating the north and south ends. A total of six concrete frames support its post-tensioned, slab floor construction, as well as the building's east and west lateral force resisting system. Reinforced brick masonry infill walls located along the structure's east and west exterior elevations provide seismic resistance in the north/south direction. The building's north and south exterior elevations are brick veneered.

The City of Berkeley required that the Garage, which contains ground floor space for retail shops, remain in service throughout the construction period. The strengthening scheme also had to keep the Garage's north and south elevations, and floor areas, relatively open to allow for natural ventilation. Using reinforced concrete moment frames would not provide the adequate stiffness needed to protect the building's nonductile concrete columns, and the requirement for open floor areas eliminated the use of concrete shear walls. Steel bracing was the optimal choice.

"Only exterior steel bracing could provide the lateral strength and stiffness needed to protect the existing concrete columns from brittle failures," pointed out Adam Greco, Degenkolb's Design Engineer on the project. "The exterior solution satisfied the City's requirements for minimal disruption to the garage's daily operations during construction, while maintaining the building's existing ventilation characteristics."

The design team determined that the reinforced brick masonry shear walls provide enough

Photo by David Wakely

strength and stiffness to protect the building's columns against excessive north/south interstory drifts. As a result, the complete seismic upgrade included: entirely removing the brick veneer along both the north and south elevations, and adding steel braced frames; strengthening the existing foundations which support the new bracing; and adding new collector and shear elements across the floor construction joints to tie the structures together. The upgrade required a total of 700,000 pounds of steel.

Adding the steel braced frames to the exterior faces of the building not only met the structural requirement as the building's main east/west seismic resisting system, but provided a new architectural image for the building as well. Because the frames are visually exposed to pedestrians and mall users, they were detailed with this architectural function in mind. The typical beam connections, for example, are web shear plates with added diamond-shaped, stainless steel filler plates. The filler plates were used to provide a flush surface with the beam webs for a more uniform appearance. Additionally, stainless steel cables were used as guardrails to help lighten the structure.

The pin connections used on this project met structural and architectural needs as well. Headroom was required under the new bracing members to allow pedestrian access into the building and around the building's plaza. To create space for headroom, it was necessary to locate the bottom ends of the bracing members approximately three feet above the sidewalk's finished elevation. The existing building's elevation included concrete arches located between columns at the plaza level. To achieve continuity between the existing architectural elements and the new bracing, the bottom ends of the braces were set where the base of the arches connect to the building columns. The pin connections at the braces not only prevent pedestrians from bumping into the bracing members, but serve as convenient benches at the garage entrances, adding a human element to the structure.

Exterior Steel Braced Frames: Design Considerations

A three-bay steel braced frame was erected on the building's north exterior elevation, and a five-bay steel frame on the south. The columns are W12x190, with W12x87 sections shop spliced at the third floor. The 2nd floor beams are W12x65 sections, and beams above the second floor are W12x53 sections. Brace sizes consist of W12x106 sections at the ground story, W12x65 sections at the second story, W12x58 sections in the third story and W12x53 sections in the top two stories. The frames were designed to meet the specifications outlined in ATC-14, Evaluating the Seismic Resistance of Existing Buildings. All of the braced frame members were fabricated from ASTM A572 Grade 50 structural steel. The five-bay frame members are all lighter W12 sections, relative to the three-bay frame, due to the added strength and stiffness which the additional two bays of bracing provide.

Typical brace connections consist of welded stiffener plates oriented to provide a direct axial load path between bracing members above and below the connections. The connections were designed to meet the requirements of the 1988 Uniform Building Code, and the Risa 2D analysis program was used to evaluate the frames' member forces and lateral drifts.

A built-up steel plate girder encased in a large concrete grade beam and pier foundation system supports each braced frame. Steel tapered pedestals extend up from the plate girders at the braced frame column locations, and the braced frames are connected to the pedestals through "pins." The tapered pedestals were fabricated from A36 steel plate and welded to the bottom stainless steel bearing plates. The frame columns and braces were welded directly to the top stainless steel bearing plates.

Each pin connection consists of a 5-inch diameter stainless steel dowel connecting a total of nine gusset plates. Four 1-7/8"-thick stainless steel gusset plates were welded to a 2½"-thick stainless steel bearing plate located one foot above the center line of the 5-inch diameter pin dowel. Five gusset plates of 1and 5/8-inch thick stainless steel plate were welded to a 2½"-thick stainless steel bearing plate located one foot below the pin's center line. Complete joint penetration groove welds join the gusset plates to the bearing plates.

The pin connections serve to transfer the seismic forces resisted by the braced frames to the steel pedestals. The pin diameter and number of gusset plates were selected based on the seismic force demand on the pin connections. High strength steel was used to keep the pin diameter to a minimum and to provide net gusset plate sections that meet the force demand with reasonable plate dimensions.

Painting and Maintenance Issues

Once the pin connections were completely fabricated, access to the surfaces of the pin connections' gusset plates, bearing plates and dowels was not possible. The proper maintenance needed to provide weather protection would not be possible after the braced frames were erected. As a result, stainless steel was selected as the material for the pin connection gusset plates, bearing plates and dowels.

The braced frame's structural steel is exposed to the weather and required several layers of paint for protection. The steel surfaces were cleaned in accordance with SSPC-SP6 Commercial Blast Cleaning prior to painting. The steel coating system consisted of three shop-applied coats of paint manufactured by the Tnemec Company. The first coat was an organic, zinc-rich urethane primer, the second coat was an intermediate layer of polyamidoamine epoxy and the finish coat was a Hi-Building Acrylic Polyurethane Enamel, International Orange, graffiti-proof and very durable.

Fabrication

The braced frame columns were shop fabricated in full height lengths with all the required connection stiffener plates welded in place. The brace to beam connections were fabricated in units and shop welded to the beams, while the built-up plate girder foundation beams were fabricated in three segments.

In order to avoid distortion in

the fabrication of the pin connections and the tapered a pedestal, welding was kept to a minimum and was sequenced to balance distortion and minimize residual stresses. The pin connections were fabricated from Armco Nitronic 50 Stainless Steel, UNS Designation 20910, type XM-19 in the ASTM 240 Specification. Nitronic 50 Stainless Steel is of the austenitic stainless steel type and has properties that increase the tendency for distortion which include a high coefficient of thermal expansion, low thermal conductivity and high yield strength. Starting at the pin connections' line of symmetry, the fabrication process worked outward through the width of the pin connection on both sides. External bracing was provided to secure the plates during welding. Due to the need to maintain symmetry, the external bracing was used to help oppose shrinkage forces on both sides of the pin connections. To relieve residual stresses during welding, the weld passes were peened and the amount of heat input was limited.

Photo by David Wakely

Construction Sequence

The design of the steel braced frames, pin connections and built-up plate girders influenced the overall construction sequence for erecting the steel framing and fabricating the pin connections. General Contractor for the project was West Bay Builder.

The initial design intent and preferred erection sequence included:

1. Fabricating the built-up steel foundation plate girders in the shop, in lengths to allow for transportation.
2. Fabricating the stainless steel pin connections in the shop, in units consisting of the stainless steel gusset plates, bearing plates and dowels.
3. Fabricating the built-up tapered pedestals in the shop, shop welding the pin connections to the pedestals and the pedestals to the built-up foundation plate girders.
4. Fabricating and shop welding the column and brace stub sections to the pin connection top bearing plates to allow for field splices between braced frame members and the stub sections during the frame erection.
5. Transporting and placing built up foundation plate girders with pin connection assemblies and field splicing plate girder sections together.
6. Casting the concrete foundation grade beam and encasing the steel plate girder in concrete.
7. Erecting the remainder of the frame above the pin connections.

This erection sequence allowed for all of the critical and most difficult welding to be performed in the shop where the greatest controls could be employed. The welds between the stainless steel plates, and between the stainless steel plates and the carbon steel plates, were identified as the most critical welds associated with the pin connections and tapered pedestals. It was also preferable to shop weld all of the joints between the stiffener plates and the pin connection bearing plates, and the tapered pedestals and the braced frame members. To a lesser degree, it was preferable to shop weld the large full joint penetration grove welds between the base of the pedestals and the steel foundation plate girder top flanges. This was desired due to the amount of weld material required.

The availability of the Armco Nitronic 50 Stainless Steel played a critical role in the construction sequence of the steel frame and the foundation system. At the time of construction, there was approximately a 12-week waiting period for it. Due to the potential for weather impact on the project schedule, the foundation had to be completed within that time period. As a consequence, the construction sequence was revised after the project was underway. The foundation system was completed prior to the fabrication of the stainless steel pin assemblies. The pin assemblies were fabricated in units, delivered to the site, and field spliced to the steel foundation plate girders. The remaining steel framing members above the pin connections were then erected.

The altered construction sequence required blocking out a top portion of the concrete foundation pour around the bases of the tapered pedestals to facilitate field welding. The initial construction sequence assumed the field splices would be located about two feet above the stainless steel pin connections. As a result of the revised construction sequence, field splices needed to be located below the pin connections between the top flange of the steel foundation plate girders and the bottom of the tapered pedestals.

Steel erection above the pin connections proceeded as planned. The columns were erected first in full height lengths. Next, the beams were placed between the columns and the bracing members were field spliced between the beams and columns. The new steel column and beam sections were structurally connected to the existing concrete frames with steel plate connections bolted to the concrete and welded to the steel.

COMPLETED SEISMIC RENOVATION

With the completion of the $2.8 million seismic upgrade of Sather Gate Garage in 1996, the City of Berkeley has gained an eye-catching landmark. Exterior steel braced frames drastically reduced the seismic hazard associated with the original garage, and also provided a new architectural image for the building. City employees, garage and mall users, and pedestrians can now utilize an improved facility that is both structurally sound and visually appealing.

Adam Greco is a Design Engineer with Degenkolb Engineers in Los Angeles, California. With its San Francisco and Portland offices, Degenkolb is a 90-person structural engineering firm providing over 50 years of experience in design and seismic retrofit.