Steel Plate Shear Walls

Library Seismic Upgrade

The renovation of the historic Oregon State Library, which included seismic strengthening, upgrading the existing mechanical systems, improving space utilization and providing accessibility improvements, was accomplished without closing the building to normal use.

By Keith Robinson, P.E., and Debbie Ames

Today, renovation of existing historic buildings often requires construction methods to be less intrusive and construction materials to be smaller, thinner, and more manageable in order to minimize any damage to the structure's appearance. However, the renovation of the Oregon State Library in Salem, OR, had an additional complexity: It was important that the building remained open and in business during the renovation.

Designed in 1937 by Whitehouse and Church Architects of Portland, OR, the library offers many significant architectural features. In addition, it is the sole provider of "Books on Tape" for the local vision-impaired community. The original structure was a cast-in-place, concrete frame with pan joist floors framing to rectangular concrete girders and columns. The building is clad with marble panels with granite skirts supported by 3-wythe unreinforced clay brick. The primary goals of the renovation were to provide seismic strengthening of the existing structure, upgrade the existing mechanical systems, improve space utilization, and provide entrance and accessibility improvements.

KPFF Consulting Engineers, Portland, provided structural engineering services for the seismic analysis, seismic strengthening, renovation, and restoration of the existing building. In addition to keeping the building open during construction, it was critical that the design preserve the existing historic finishes. To accomplish this, KPFF designed an innovative steel plate shear wall system and strengthened many existing architectural elements.

Because the project was constructed through the construction management/general contractor process (CM/GC), KPFF received input from the general contractor prior to the completion of construction documents, allowing many details to be customized according to the contractor's work and phasing plans. With the assistance of the general contractor to determine cost and feasibility, KPFF was able to "test" many innovative ideas for mitigating seismic hazards and provide the greatest risk mitigation possible within the project budget. Once construction began, KPFF provided rapid response to the contractors' requests for information and provided site visits on an on-call basis to deal with unforeseen conditions. Construction manager on the project was Milstead & Associates, Inc., Clackamas, OR, and cost estimates were provided by Architectural Cost Consultants, Portland.

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The unconventional and successful application of the steel plate shear walls provided new opportunities for engineers to accommodate more demanding architectural requests. The structural analysis involved finite element models and site-specific response data to determine accurate building response and design forces. KPFF created a computer model that analyzed all modes of the building's response when subjected to ground motions specified by the geotechnical engineer, Geotechnical Resources, Inc., Beaverton, OR.

Using steel plates rather than concrete shear walls allowed the design team to overcome many design constraints and was less disruptive to the building's occupants. The owner had no budget to temporarily relocate the library and its many historic volumes; and, the moisture generated by pouring vast amounts of concrete in the building could harm the historic documents. The use of steel plates solved this problem. It facilitated access and installation in confined spaces, and provided flexibility for architectural space planning. At the request of the contractor, KPFF was able to design the steel plates so they could be installed by hand rather than with machinery. The plates were sized so that two men could carry a plate and install it manually, which eliminated the need for large equipment, lifts, and cranes. The plates were spliced together with structural Tees, which also serve as stiffeners for the plates. To the extent possible, connections were made using bolts rather than welding to minimize the risk of fire from welding in the library. The plate walls are relatively thin in comparison to concrete shear walls.

Because the existing building did not have a well-defined lateral force-resisting system, it was assumed that the existing structure provided no resistance to lateral loads. The walls were designed to resist seismic force levels for Zone 3 of the 1994 Uniform Building Code (UBC). Because many of the existing structural elements were sensitive to excessive deflections, building stiffness was often a controlling factor in the shear wall design. Through manipulation of the finite element computer model, KPFF was able to configure and proportion the steel plate shear walls so that anticipated deflections were within the capacity of the existing structural elements. After establishing the required wall configuration and proportions, axial, shear, and bending forces were obtained from the site specific response spectrum analysis. One of the major challenges encountered in the design of the building's seismic strengthening involved transferring loads from the existing structural elements to the new shear walls. Extensive use of steel members as drag struts in combination with drilled-in-expansion type or adhesive type anchors facilitated this load transfer.

Overturning forces from the new shear walls exceeded the capacity of existing footings at the ends of the walls. To provide additional footing capacity and to hold the ends of the walls down from "uplift," pin piles were installed at strategic locations within the eight-foot clear height basement. These 40'-long piles were drilled into the ground in 4' lengths and spliced as they were installed.

It was also necessary to reinforce

some of the existing two-story columns in the library's reference room, which were inaccessible without damaging historic finishes. The columns were deficient for out-of-plane seismic loads due to a short, mid-span splice in the existing reinforcing material. To mitigate this deficiency, KPFF developed a plan to core through the center of the existing columns lengthwise about 40' and install high-strength, threaded reinforcing bars, which were post-tensioned to precompress the columns. This prevented any net tension from developing in the column under seismic loads.

Shown above is the installation of one of the new steel plate shear walls, which were sized so two workers could lift one.

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