Seismic Retrofit of a Concrete Tilt-up Building

The rehabilitation work performed at the Price Club's Richmond store is a good example of earthquake upgrading of concrete tilt-up buildings. Although constructed as recently as 1963, this building was found to need strengthening by the structural engineer responsible for the renovation. The upgrading of this industrial warehouse represents typical seismic strengthening techniques and costs.

BACKGROUND

The Price Club is a membership retail store that provides a large variety of commerical goods to members at discounted prices. It represents a unique approach to retailing in that the customer generally purchases large quantities of goods in a warehouse atmosphere where the overhead and cost for the display of goods are greatly reduced. Warehouse storage and display require a structure with a high ceiling and wide, unobstructed aisles to permit the movement of forklifts carrying loaded freight pallets.

The Price Club's Bay Area store in Richmond, California, is located in an industrial and warehouse district. The original warehouse building was constructed in 1963. Modification of the existing warehouse to a retail facility required some renovation. Both cosmetic as well as functional rehabilitation were in order, including a small addition, closing of a few existing doors, and installing new lighting, electrical, and mechanical systems. The Price Club hired Cabak, Randall, Jasper, Griffis and Associates Inc., an architectural/engineering firm based in Menlo Park, to design the remodeling. The renovation work was done by Hollander & Smith construction company of San Jose. Although it was not required by the building code, the structural engineer proposed to upgrade the structure to increase its earthquake resistance. The Uniform Building Code requires seismic strengthening...
when a building's use is changed to a higher occupancy classification (increasing the number of people in the structure). The requirement did not apply in this case. But the owner recognized the vulnerability of the structure and felt that seismic upgrading was appropriate to protect customers and to minimize economic loss in an earthquake. While the prevention of death and injury is of utmost importance, the economic loss from an earthquake can also be devastating to a business. The owner and the engineer decided that the structural renovations should be in "substantial compliance" with the 1985 Uniform Building Code seismic requirements for new buildings.

DESCRIPTION OF BUILDING

The Richmond Price Club is housed in a large one-story rectangular structure at the intersection of Griffin Avenue and 32nd Street. The building, measuring 400 feet by 870 feet, was originally divided into three equal sections. While the Price Club owns the entire building, the retail store uses only one third of the area; the other spaces are leased as industrial storage. Seismic upgrading was performed on the entire building in 1987. Like other industrial warehouses, the building has a high ceiling to allow for storage and movement of loading equipment. The perimeter areas are designed as loading docks and have large roll-up doors. The perimeter and interior load bearing walls were constructed using a precast concrete tilt-up system. The concrete wall panels were cast on the ground and lifted into place, and then joined together by cast-in-place concrete columns. The roof is supported by wood trusses which rest on the concrete walls and on interior steel columns. The wood trusses, in turn, support wood joists and purlins, and are covered by plywood roof sheathing. This "roof diaphragm" system, composed of these wooden elements transfers lateral forces into the walls. The construction system, materials, and dimensions of this building are typical of large tilt-up warehouse buildings.

The perimeter concrete wall panels are 20 feet wide, 23 feet high, and 6 inches thick. The typical panel has a door opening in the center measuring 10 feet by 10 feet, which opens onto the loading dock. The interior columns were fabricated from steel "wide-flange" sections and are spaced 40 feet apart in the east-west direction and 60 feet apart in the north-south direction. Each column supports main trusses in both directions. The
main trusses, in turn, support a secondary truss at their midspan and the roof above.

**METHOD OF STRENGTHENING**

From their analysis of the structure, the engineers found that the building could fail during an earthquake in two different ways, both typical of tilt-up construction. The first mode of failure would result from a large horizontal load in the north-south direction. The existing roof sheathing and framing were too weak to resist earthquake forces as required by current building codes. A large earthquake will place loads on the roof system that it was not designed to resist. The second weak link of the existing building was the connection between the wall panels and the roof members. In an earthquake, the heavy concrete wall panels could pull away from the roof and cause the roof to collapse.

To reduce wall deflection and diaphragm stress, the engineer decided to add two new interior lines of steel "chevron braces" in the north-south direction to transfer earthquake forces to the foundation. Adding braces at the interior of the building reduces the amount of force that must be carried by the diaphragm and resisting walls. Adding interior braces also increases the diaphragm's stiffness. An alternative to adding new interior braces was to strengthen the roof diaphragm itself. However, this would have required the removal and replacement of the existing roof membrane, which in this case was not economically feasible.

Addition of new braces involved several structural details to integrate the new elements with the existing structure. To keep the chevron braces from turning over in an earthquake, the footing under the adjacent columns were strengthened. To bring earthquake forces from the roof plane to the new steel braces, a "collector" was added to connect the roof trusses and diaphragm members to the rest of the building. A collector is a horizontal column-like member in the roof plane, designed to carry the lateral loads to the new braces. The engineer decided to use the bottom members of the existing trusses in line with the new braces to function also as the collectors. This requires that individual trusses be tied together with steel channel sections bolted at the ends across their column supports to transfer the tensile forces. Since the collectors can also be subjected to compression, they must also be braced for buckling. Diagonal braces, designed to hold the bottom truss chord in place were added for stability.

To remedy the second weakness of the existing structure, new anchors were added to connect the wall panels to the roof trusses and diaphragm. While panels commonly fall out because of poor anchorage to the roof, occasionally well attached wall panels pitch outward, pulling the roof structure with them. The upgraded structure should, therefore, be designed so that the forces created by the heavy wall panels are spread evenly into the roof diaphragm and then into the walls or braces without overstressing any individual part of these systems.

In review of the existing structure, the engineer determined that the panel-to-panel connections were sufficient for the east-west direction,
and that strengthening of the existing connections between roof trusses and wall piers would keep the walls from falling out. Tension ties were added to strengthen the piers-truss connections. To tie the north-south wall panels directly to the new roof, new anchor straps were added at every roof purlin. These purlins then transfer the lateral load into the roof diaphragm sheathing. To avoid local over stress of the roof sheathing and to increase the integrity of the structure, the existing bottom chords of north-south trusses resting on columns were modified to function also as "cross-ties." The cross-tie is a long strap through the building, connecting opposite outside walls together so that neither wall can fall away from the building. The modification consisted of metal anchor rods installed across the tops of the interior columns to connect the roof trusses together and to form a continuous cross-tie.

CONSTRUCTION AND COST

The seismic strengthening work was done as a separate element of the remodeling necessary to convert the warehouse for use as a retail outlet. Because the building was not occupied during strengthening, there was no disruption to building occupants. Most of the work was completed within ten weeks. The most difficult portion of the construction was the removal of several footings under existing columns and their replacement with footings to carry added loads. This required that the roof above the columns be supported while the work was completed. At the time of this report, the anchorage work in some portions of the building was not yet completed. The total projected seismic retrofit cost, not including the design fees, was $350,000, or approximately one dollar per square foot. Approximately 20% of the construction cost was related to anchorage and continuity measures, 40% was associated with new bracing and 40% was for new foundations.

The adaptive reuse of warehouse structures for retail outlets is becoming more common. This Case Study describes an approach that would be effective in strengthening many tilt-up buildings constructed under pre-1973 building codes. The original construction and strengthening methods used for this building are common to tilt-up industrial buildings. Although cost can greatly vary from project to project, the costs described here are representative of seismic upgrading expenses. As noted, the upgrading was completed when the building was not occupied. When it is necessary to strengthen an occupied building, the approach will be defined by the need to maintain occupancy, the cost will be higher and the construction time will be longer.

BAREPP

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