

Sizing Up A Seismic Retrofit

Written By Brett Conway



Upgrades restore functionality to building once condemned as dangerous

Like so many of a building's systems, it is often only when one breaks down that you notice. But when a building's HVAC system malfunctions, it's merely inconvenient. When a building's earthquake resistance system fails, it's catastrophic. Put simply, failure is not an option when it comes to seismic retrofitting.

The potential for structural failure caused city officials in Vancouver, Wash., to abandon several downtown buildings and put them up for sale, seemingly spelling the end of their useful lives. But a major retrofit that included significant seismic upgrades brought new life to the old buildings, repeating a story that is taking place in many of this country's seismically active areas.

As the recent earthquakes in Haiti and Chile illustrate, utter and complete devastation lurks under the surface of the Earth and strikes without warning. The two quakes demonstrate the importance of constructing buildings to meet high seismic resistance standards. In Chile, an earthquake measuring 8.8 on the Richter Scale — the seventh strongest ever recorded — caused far less structural damage relative to the one in Haiti, which saw its capital city literally leveled by a 7.0 quake, some 500 times less powerful. A critical factor in the disparity of the damage caused is that earthquake resistance standards are much higher in the seismically active Chile. In the United States, seismic retrofitting is growing alongside the rest of the retrofit industry, and the example found in Vancouver shows that seismic upgrades can fit seamlessly into the overall retrofitting of older buildings.

Risk forces city to abandon buildings

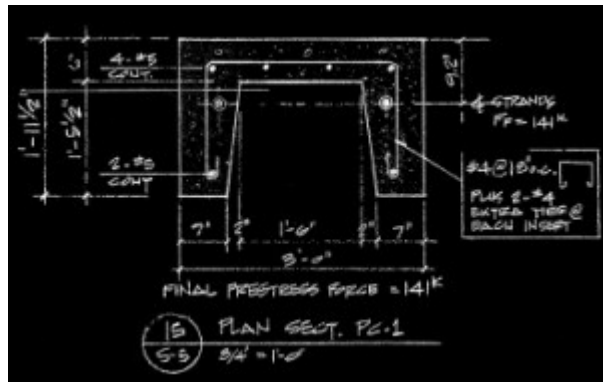
The Citizens Service Building and the adjacent Data Center were owned by the City of Vancouver and occupied by numerous city departments, most recently — and ironically — by the planning and building departments. The site consisted of a 1967 single-story heavy timber building originally designed as a

branch bank. It was attached to a 1970 four-story office building with a basement. The four-story building was constructed of both pre-cast and cast-in-place elements and relied upon concrete shear walls to resist seismic loads.

The city commissioned Tier 1 and 2 Earthquake Risk Evaluation studies. These were completed based on American Society of Civil Engineers ASCE 31-03, the current state-of-the-art structural standard for evaluating existing facilities for seismic vulnerabilities. The tiers of the ASCE 31 evaluation address the performance of the structural and non-structural elements of an existing structure.

“When retrofitting an existing building to code, the performance level is life safety,” said Dave Roggenkamp, the structural engineer contracted for the project. “Tier 1 is a basic check on the presence of seismic load paths and a review of conservative ‘demand on’ versus ‘capacity of’ the seismic elements.

“The deficiencies found in Tier 1 are then confirmed or refuted in the Tier 2 evaluation, where demand values are typically lowered through a more refined analysis and capacity values are typically raised through testing of existing in-place materials.”



The C-shaped columns depicted above bore the gravitational load of the building but were found to be structurally deficient because their shape rendered them non-ductile.

Alarming, according to the evaluation “the ability of ... the structure to resist the forces of a major earthquake is very doubtful.” The primary structural problem with the building was its unusual C-shaped columns. Due to the C-shape, the columns had the potential to shatter, possibly causing the building to lose vertical support resulting in partial collapse in a major seismic event or leading to floors “pancaking” upon one another. A critical factor in a building’s ability to resist lateral loads, or forces acting on its sides, is the use of ductile structural support materials that will bend but not break. The C-shaped columns were found to be non-ductile, or brittle.

The building was classified as a “dangerous building” because of two main seismic deficiencies: the non-ductile columns that if failed during a seismic event would cause a loss of gravity support for the floors and a lack of adequate diaphragm connection to the shear walls.

The “dangerous building” designation is deemed upon buildings that have conditions that “exist to the extent that life, health, property or safety of the public or its occupants are endangered.” Specifically, this building exhibited two instances of having a “supporting part, member or portion less than 66 percent of the strength, as required by law, in the case of a newly constructed building of like area, height and occupancy in the same location.”

The city vacated the building within six months of receiving these findings and put it up for sale.

Fitting seismic upgrades into a comprehensive retrofit

Although the building was tired and dated, the location was excellent and the site offered numerous amenities that would have been expensive to assemble otherwise. As a condition of the sale, the city required the purchaser to implement significant seismic upgrades to the building. The eventual purchaser,

iQ Credit Union, a non-profit financial services organization, was seeking a prominent downtown location. It put the site under contract and undertook a due diligence study. The study evaluated the scope of necessary seismic upgrades and overall building renovations to ensure the building would be suitable for use as a headquarters.

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-Jim Morrell, iQ Credit Union

Jim Morrell, senior vice president of support services and chief information officer at iQ, said assembling a team of experts was the first step. “There was a bit of an unknown factor,” Morrell said. “We knew nothing about seismic retrofits. To make us more comfortable, we conducted a lot of site visits and interviews” with firms who could do the work.

Ultimately, the Seattle-based architectural firm EHS Design Inc. was hired to lead the due diligence effort in conjunction with a local general contractor, Team Construction Inc. Collaboration between design and construction professionals was critical since re-envisioning the facility was required and renovation costs would be significant and difficult to quantify. Morrell said much thought went into finding the right partners, adding that working with EHS Design, Team Construction and the other project principals helped him understand more about seismic retrofits than he ever imagined he would.

“In this region, there is an impetus for reusing existing buildings,” Morrell said. “The cost of the overall project was probably about equivalent to what it would have cost if we built from the ground up. That is, if we had found bare land, which is difficult.” The location was strategic for its visibility and marketability, Morrell said, and iQ was able to take a building “that wasn’t necessarily a downtown landmark and turn it into a landmark.”

The project team developed conceptual strategies for the site and building. A wide range of options were explored, presented, refined and tested. A preferred option was selected by iQ’s executives and board of directors, and the team developed a comprehensive conceptual design strategy and cost model. A coordinated effort was critical given the multitude of proposed retrofits.

“Successful implementation of the seismic upgrades required very close collaboration of the project team” said Curtis Bales, project manager for EHS Design. “Literally every penetration which was made in the existing structure to accommodate the new building systems needed to be defined and negotiated per structural requirements. For example, the new curtain wall window system was fastened through the [reinforcing column wrap] back to the concrete column. The quantity and spacing of the fasteners was defined to ensure the seismic wrap was not compromised and that the window system was securely fastened.”

Opening a door

The seismic upgrade stipulation by the city actually allowed the team to look at a much more comprehensive renovation of the building as a whole. “The city requirement ... opened the door to making other needed improvements,” said Bales. “The need to access the entire structural concrete frame for seismic upgrades required the demolition and replacement of the existing single pane and leaking glazing system.”

Roggenkamp said when an existing building is being renovated and given “new life,” as opposed to being razed for a replacement building, seismic retrofits are vital to provide upgraded protection for the renovated building against earthquakes.

“Upgrading an existing structure to increase seismic resistance begins with understanding how best to utilize the existing seismic resistance of the structure, thus minimizing the physical amount of retrofit

work required,” Roggenkamp said, adding that retrofits should build on existing seismic capacity. “Obviously, these constraints are not encountered in the design of a new building.”

Options for mitigating the seismic deficiencies were developed and studied. Mitigation options for the non-ductile concrete columns consisted of either adding columns to the building to support floor loads if the existing columns were to fail during a seismic event, or confining the existing concrete in the columns by filling in the open C-shape of the column with reinforced concrete and then wrapping the columns with fiber reinforced polymer (FRP). Because of the useable floor space that would be lost by the addition of columns, the FRP wrap was chosen as the preferred option.



Workers prepare to reinforce non-ductile columns.

The deficiency of the connection of the floor diaphragms to the shear walls was mitigated by removing a portion of concrete slabs in the stairwell and re-casting a thicker, more heavily reinforced slab that was appropriately doweled into the shear walls. The diaphragm was reinforced with steel tubes inside the stairwells in order to transfer load to the offset shear walls. These mitigations did not encroach on the useable floor space and did not obstruct the building’s occupancy.

Design, Documentation and Construction

One of the early key decisions involved how to permit and build the project — a decision that determined how the documents would be developed. The team elected to develop four document packages: demolition, seismic upgrade, shell and core improvements and tenant improvement packages. Four packages allowed for rapid permit submittal and early commencement of construction activities. The mitigations of the two seismic deficiencies were designed and documented in different ways. The upgrade that strengthened the floor diaphragms was fully designed and detailed on the structural drawings, as this mitigation consisted of conventional renovation construction.

Because the design and the application of FRP is a specialty sub-contract, the requirements for the FRP column wrap was specified to be equivalent to a reinforcing steel column spiral of a certain size and pitch and designated as “bidder-designed.” The FRP shop drawings were accompanied by fully engineered calculations that verified the capacity of the FRP to perform equivalent to the specified spiral reinforcement.

The demolition and seismic packages were executed together, followed by the shell and core renovations and the tenant improvements. The construction phase was eight months in duration and required exposing the building during the worst weather months in the Columbia River Valley. Significant snow and rain events coupled with extended cold snaps slowed progress at times. Since construction is often a sequential process, some key aspects of the project were held up due to the exterior wall not being closed up.

The FRP seismic retrofit work was executed by a subcontractor with its propriety system. This entity received design performance parameters and details from the structural engineer, architectural constraints from the architect, as well as the constraints presented by the existing facility. Their scope included demolition to expose the area of work, scaffolding, column surface and corner preparation work and the installation of the FRP wrap. The column rebar reinforcing system and concrete in-fill placement were performed by the general contractor, as was the final column cladding once the FRP installation was complete.

Retrofitting delivers cost savings

The seismic factor in the project, while pivotal, yielded little risk and was completely invisible to the occupants.

Following the successful completion of construction, iQ moved into a nearly 40-year-old building that was given a new life. In comparing the costs between renovating the building and constructing a new facility, the designers found that costs were similar. However, four notable factors made retrofitting the smart business decision: the time to market was nine months shorter; traffic impact fees were virtually zero for renovation versus \$500,000 for new construction; design fees were lower as a percentage of the total project cost with renovation; and finding choice urban lots is nearly impossible.

Jim Morrell, the iQ chief information officer, said that while he's happy his company may have saved some money and a lot of time through the retrofit, perhaps even more important was the attendant peace of mind. "I sleep better at night knowing we've done everything we can to make this building as safe as it can be."

Team

Owner: iQ Credit Union, Vancouver, Wash., www.iqcu.com

Architect and Interior Designer: EHS Design Inc., Seattle, Wash., www.ehs-design.com

General Contractor: Team Construction Inc., Vancouver, Wash., www.teamconstruction.com

Civil/Landscape: HJD Design Group, Vancouver, Wash., www.hdjengineers.com

Structural engineer: Roggenkamp, Erickson and Associates, Vancouver, Wash., www.reastructuralengineers.com

HVAC: Entek Coproration, Vancouver, Wash., www.entekhvac.com

Plumbing: JRT Mechanical, Battleground, Wash., www.jrtmechanical.com

Electrical: Cochran Inc., Portland, Oreg., www.cochraninc.com

About Brett Conway

With more than 25 years of experience, Brett joined EHS Design 15 years ago. A Michigan native, he has worked with clients throughout the country, including Citicorp, IBM, Weyerhaeuser Employees' Credit Union, Yale School of Medicine and Bank of America Data Center. Brett's hobbies include designing and fabricating "whimsical, sensitive, animated and fun" light fixtures, finding there is "bliss in craft." He developed this passion while studying in Denmark where he was inspired by many great Danish designers. Brett lives with a vista of Puget Sound with his wife and two young children.