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SEISMIC SUCCESS

By Robert L. Reid

An innovative seismic retrofit has prepared the nearly 90-year-old Robert A. Young Federal Building in St. Louis for the future. Despite extensive work within the 1 million sq ft structure, the building remained fully occupied throughout the roughly two-and-a-half-year construction phase.

The concrete-framed Robert A. Young Federal Building in St. Louis was considered vulnerable to seismic activity because it is located within 150 mi of two seismic zones. (Photograph Courtesy of McCarthy Building Companies Inc.)

The Robert A. Young (RAY) Federal Building is a massive structure, measuring roughly 1 million sq ft in size, spread over a 3-acre site in downtown St. Louis. Completed in 1933, the concrete-framed facility features one basement level and 10 stories aboveground for most of its footprint, with a tower on the building's northeast corner rising an additional 11 stories. Over the decades, the RAY building served first as a railroad warehouse before being acquired by the federal government for the Army in the 1940s. In 1961 it was turned over to the U.S. General Services Administration (GSA), at which time it was converted to office space.

Despite its size and apparent sturdiness, the RAY building was considered vulnerable to seismic activity because of its location within 150 mi of two seismic zones-the Wabash Valley and New Madrid faults. An "upsurge in frequency and intensity of seismic activity in the area" led the GSA, which manages the property, to analyze the building's seismic performance over a decade and eventually propose a seismic renovation, according to an alteration prospectus prepared by the GSA in 2013. The goal was to provide the building's roughly 3,000 daily occupants with "both shelter in place opportunities during and safe exit from the building following a seismic event," the GSA noted.

The resulting $75-million design-build project, completed last year, was led by St. Louis-based McCarthy Building Companies Inc. The project team included, among others, the Dallas office of San Francisco-based Gensler as the lead designer and architect of record; the international engineering firm Thornton Tomasetti as the structural engineer; and Etegra Inc., of Olivette, Missouri, as the associate architect.

Although early iterations of the seismic renovation called for a traditional strategy heavily weighted toward the installation of new concrete shear walls on multiple levels of the structure, the team eventually provided a more innovative solution that combined viscous dampers, steel braces, and shear walls concentrated in just the basement, notes Ryan Molen, LEED BD+C, a McCarthy vice president. This approach not only eliminated a large percentage of the shear walls that may have been required for a traditional solution, it was also the least disruptive method for the building's occupants. Some employees were moved about within the facility as construction proceeded, but no one had to relocate to an entirely different building, Molen says.

Steel bracing was installed to support the building’s tower, above curved concrete sections that once held water tanks. (Photograph Courtesy of McCarthy Building Companies Inc.)

"Our final design solution minimized the footprint for construction operations, thereby requiring less space to be taken out of service at any given time," Molen notes. By contrast, the concrete for shear walls on any given floor would have been placed from the floor above, requiring the construction team to work on two levels at the same time, while also "doubling or tripling the area you'd need to demolish and have access to so you could install the proper formwork," Molen explains.

A shear-wall-focused solution would also have required rerouting much more of the existing utilities, ductwork, sprinkler pipes, and other mechanical systems than the damper systems did, Molen adds.

In addition to the construction of new concrete shear walls only in the basement, the design called for multiple steel frames on each of the first 10 floors, says Joel Barron, P.E., M.ASCE, an associate principal in Thornton Tomasetti's Dallas office. Arranged in an upright chevron configuration, resembling an inverted V, the new framing incorporated fluid viscous seismic dampers with hydraulic pistons that move in and out during a seismic event. "When a floor starts to move, the piston inside that damper starts to move and compresses the fluid and takes the energy out, so it counterbalances-like a car shock absorber," Barron explains.

Steel frames without dampers were used to reinforce the building's tower, he adds, and the facility's interior concrete masonry unit walls and mechanical ductwork were braced to prevent anything from collapsing during a seismic event.

Because the damper systems are made from steel framing, there is open space within the structural elements through which mechanical systems could be located-another advantage over solid concrete shear walls. In most locations, the dampers were ultimately concealed from view within architectural partition walls-except for one pair of dampers that were left exposed in the building's cafeteria to help the tenants better understand the work that had been done.

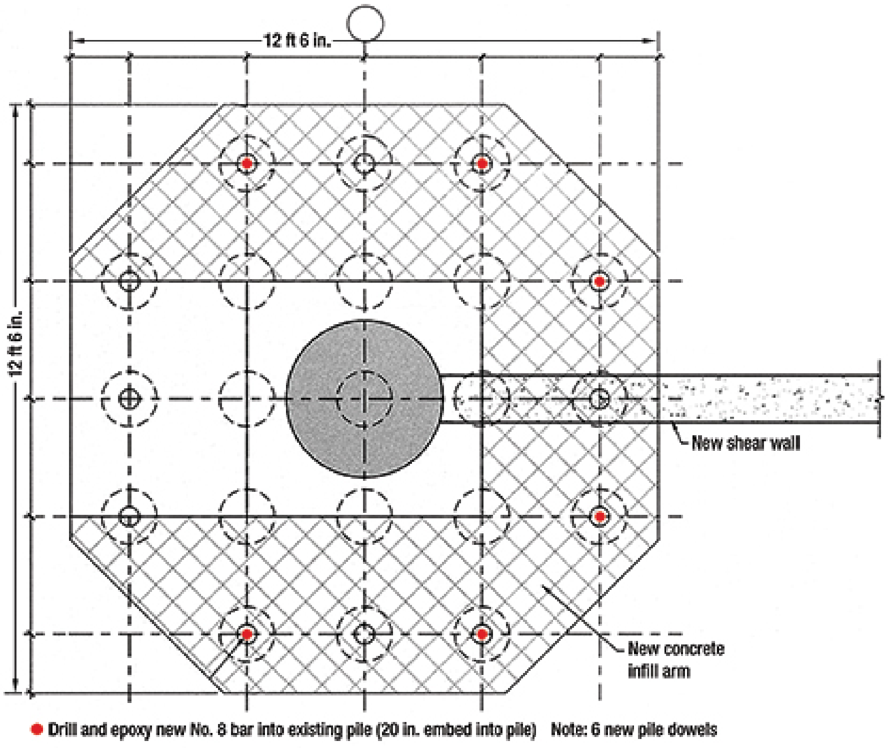
Most of the seismic dampers were concealed within partition walls, except for one pair left exposed in the cafeteria to help tenants see and learn about the work that had been done. (Photograph Courtesy of McCarthy Building Companies Inc.)

Thornton Tomasetti's Dallas office led the structural engineering side of the project. The firm's Los Angeles office assisted by creating nonlinear analyses, ground motion time histories, and computer modelling, notes Kerem Gulec, Ph.D., P.E., an associate principal in the Los Angeles office. In particular, the Los Angeles office modelled the existing RAY building's structure to determine the best locations for the hundreds of dampers installed throughout the facility and also designed the basement shear walls. "We applied these realistic ground-shaking time histories to our nonlinear models," Gulec explains, "and then verified that the new components we added were sufficient and the existing building [would] be acceptable following a large earthquake."

To determine the correct number of dampers needed to seismically protect the RAY building, the Los Angeles office "used engineering judgment and some fundamental principles to come up with a rough number … and roughly distribute them to different floors," Gulec says. But the final verification came from the nonlinear analyses generated through Perform-3D software, manufactured by Computers and Structures Inc., of Walnut Creek, California.

Although the seismicity in St. Louis is not as high as in Los Angeles or other parts of California, "the procedures and methods we used were similar to what we'd have done here," Gulec adds. "The main difference is the ground motions obviously would not be as strong in St. Louis as if the site was in certain parts of California-but otherwise we used the same software and very similar procedures."

Because the Los Angeles office needed to know how much reinforcing steel was used in the existing concrete and where it was located, samples were taken from the concrete columns and floor slabs and tested for strength, Barron says. In general, the strength of the steel and concrete turned out be sufficient-"about what we'd expect for a building from that era," he notes. In some places, however, the concrete was so tightly reinforced it posed problems during the construction phase.



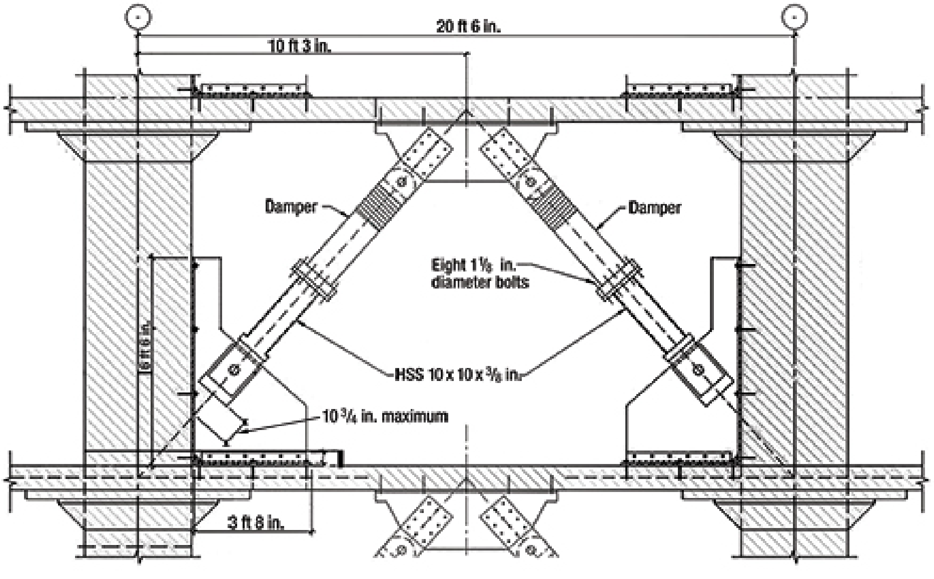
Pile Cap Retrofit Plan (Drawing Courtesty of Thornton Tomasetti)

"Some of the columns on the lower floors had so much reinforcing, it was a challenge to get an anchor in between all the rebar," Barron recalls, adding that the anchors were spaced at somewhat larger distances than typical "so we'd have to drill into existing concrete less."

Shaped in plan like a flipped, reversed L, the RAY building also incorporated two sections of an old masonry wall in the south-eastern portion of the structure. Four stories tall and structurally tied into the RAY building, these load-bearing walls had once been part of an adjoining building, long since demolished, says Barron. Presumably brittle, the old walls might crumble during a seismic event or prevent the lower floors of the RAY building from deflecting-and thus prevent the seismic dampers there from engaging, Barron explains.

To resolve this potential problem, the RAY building's slabs at levels 2 to 4 were saw-cut to separate them from the masonry walls. The slabs were then supported from beneath by steel angles. The masonry walls still support the slabs for gravity loads, Barron notes, "but if the slabs want to move parallel to the walls, they're free to move in that direction-so we'll get the deflection that's needed to activate the dampers."

New shear walls, varying in size but generally about 12 in. thick, were installed in the basement because the existing foundation walls there were stiff enough to prevent dampers at that level from activating, Barron notes. In the locations at which a new shear wall met an existing column, the work crews had to carefully dowel rebar into the column to secure the new wall without damaging the existing rebar and thus weakening the original column, Molen says. Because the available drawings lacked certain details, the work crews had to either x-ray the columns to identify where the rebar was located or physically chip away some concrete to see exactly where that rebar was, Molen says.



Typical Damper Detail at Flat Slab (Drawing Courtesty of Thornton Tomasetti)

McCarthy worked with Thornton Tomasetti to determine the exact number of samples needed and then to perform whatever remediation was needed afterward, Molen adds.

Wherever possible, the chevron damper systems were stacked directly above the new shear walls and directly above each other from floor to floor. This enables the shear walls to absorb some of the forces coming down through the dampers. But "we didn't quite have free rein to put these [systems] wherever we wanted to," Barron adds.

The locations of the basement shear walls and the damper systems on the floors above the basement had to be carefully coordinated with other members of the project team, from the architects to the mechanical systems engineers, and especially with the building's tenants. The RAY building houses offices for several dozen federal agencies, including the Internal Revenue Service (IRS), State Department, Department of Homeland Security, U.S. Army Corps of Engineers, and U.S. Coast Guard. Some of these agencies had special facilities, computer server rooms with enhanced security, or even holding cells in their areas of the building. Plus, there was large mechanical equipment in the basement that could not be moved. All these locations had to be avoided in laying out where to install the new shear walls and damping systems, Barron explains.

Thus, in some locations the damping systems had to be constructed in adjacent bays, for example, and transfer beams installed to take the loads coming down from the floors above and transfer them over to the systems in the adjoining bays and then back to the stacked bays below.

As part of the project, the existing foundations of the RAY building had to be examined and fortified where necessary, says Molen. Castle Contracting-a wholly owned sister firm to McCarthy-excavated tests pits in the basement to evaluate the pile caps, footings, and other foundation elements. Because the RAY building was occupied throughout the project, Castle was unable to use conventional, carbon-dioxide-emitting excavation equipment on the site. Instead, the firm utilized a combination of hand digging and a hydro-excavation application that sprays high-pressure water into the ground and then sucks up the resulting muck via a vacuum hose system that at times required 500 ft lengths of hose. Moreover, because this work was conducted at night, when there were no facilities open for emptying the vacuum truck, Castle had to maintain three such vehicles on-site at the same time.

Once the existing foundations had been exposed and investigated for shear and vertical loads as well as the building's potential overturning forces, it was determined that the expected new loads at certain locations would exceed what the piles and pile caps could likely accommodate-especially at the point at which the piles connected to the caps, Barron says.

To improve the seismic capacity of those systems, holes were drilled through certain pile caps and new rebar was installed into the existing concrete piles and epoxied in place-a process that some dubbed a "root canal," Barron jokes. This work was completed in three locations, involving between two and six of the existing piles per cap. Each pile cap sits atop some 40 individual piles, each roughly 12 in. in diameter, that extend to depths of 30 to 40 ft. The new rebar was installed through the pile caps and roughly 20 in. into the strengthened piles, Barron says.

Additional concrete was placed to fortify the footings, Molen adds. New concrete grade beams were also installed in certain locations at which the loads imposed by the damper system frames were likely to overload the existing piles during a seismic event. Thornton Tomasetti's Los Angeles office provided the Dallas office with data on the expected reactions. "We'd know what the existing caps could take, and if they couldn't take it, we'd design a grade beam to engage the next pile cap over," Barron explains. "So now you'd have three pile caps taking the loads."

To minimize the disruption to tenants during the project, McCarthy carefully coordinated the work with the GSA in a process that Molen describes as "ten parts planning, one-part execution!" The firm even installed a "move manager" on-site to work directly with the federal agencies. All potential constraints were identified-for example, the IRS offices could not be worked on during tax season-and all potential issues related to moving personnel around were integrated into the construction schedule, Molen says.

McCarthy identified the limited but available vacant space within the RAY building-dubbed "swing space"-and converted one of these areas into "an open floor space that could be universally utilized by anyone," Molen says.

Once the swing space was ready, McCarthy did one of three things with individual tenants:

- Some were moved out of their existing spaces and temporarily relocated to the swing space until the work in their own offices was completed.

- Others underwent a "compress in place" process, in which entire offices were moved-compressed-into just a portion of their existing spaces, which meant workers never actually left their own offices.

- Where possible, McCarthy also followed a "work over" process, in which "we'd work at night in an occupied space with temporary protection measures in place," Molen says. McCarthy's team would work through the night, "then clean the space and return it to the users the way we found it…then we'd do the same thing the next night," he explains.

Whenever a tenant moved out of its offices, McCarthy used cameras to document the "as-is" condition of the space. That way, once the work was completed, the space could be restored to its original state, and "when the tenants came back in, it was like we had never been there," Molen says.

During the design process, McCarthy was not able to remove ceiling tiles and determine the exact locations of all mechanical systems. Thus, some relocations of these elements had to be done during the construction phase. In one particular incident, a 6 in. diameter waterline had to be rerouted to accommodate a new shear wall without shutting down the water pipe, Molen recalls. The solution involved the use of a device that froze a plug of water at each end of the affected segment, which could then be removed and relocated. Once the segment was in its new location, the plugs at each end were thawed and full service was restored "without ever turning the water off," Molen notes.

The RAY building's sprinkler system was also braced seismically with new fittings that allow movement as the existing pipes pass through walls, Molen adds. And an estimated 13,000 light fixtures throughout the building were replaced with high-efficiency light-emitting diode (LED) fixtures.

The construction phase of the RAY building seismic retrofit began in 2016 and was completed in May 2019. Because the RAY building is located "in an urban site with zero clearance all the way around," there was no space for cranes. As a result, much of the steel and other material for interior work had to be carried into the building and up to the correct floor by hand or on custom-designed carts, Molen says. Despite those and other logistical and technical challenges, the project was completed "nearly 30 days ahead of schedule," explained a GSA press release, which especially praised the "exceptional coordination and collaboration" that made the effort such a success.

Another success to be expected-should the retrofit be tested in a major seismic event-is that "dampers [will not be] damaged after an earthquake, so they don't need to be replaced," notes Gulec. Moreover, whereas shear walls are designed to resist seismic motion, the dampers actually work to reduce those motions, which in turn, can reduce the amount of damage, including nonstructural damage, a building experiences in a quake, Gulec says.

That's significant, because many buildings that remain structurally sound after an earthquake are, nonetheless, taken out of service for considerable lengths of time because of nonstructural damage to things like partition walls or sprinkler systems. With the sort of damping system installed in the RAY building, however, "you are reducing the motions, which means the nonstructural components will be protected," Gulec concludes.

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PROJECT CREDITS Client U.S. General Services Administration **Designbuild team leader** McCarthy Building Companies Inc., St. Louis **Lead designer and architect of record** Gensler, Dallas office **Structural engineer** Thornton Tomasetti, Dallas and Los Angeles offices **Associate architect** Etegra Inc., Olivette, **Missouri Mechanical, electrical, and plumbing engineer and fire protection engineer** Mazzetti/William Tao, St. Louis **Geotechnical consultant** Geotechnology Inc., St. Louis **Seismic damper supplier** Taylor Devices Inc., North Tonawanda, New York