Fiber Reinforced Polymers

Seismic Retrofit of the McKinley Tower

By Mo Ehsani, Ph.D., P.E., S.E.

The McKinley tower has an interesting history, both in the traditional and structural sense. Constructed concurrently with her sister building, the Inlet Tower, between 1951 and 1952, the McKinley building, at 122 feet tall, marked the first high-rise building built in Anchorage, Alaska. Constructed of reinforced concrete, the McKinley Tower building has a 130- by 52-foot rectangular footprint. The interior of the building contains a central core that houses the chimney, elevator, and stairwells, while the exterior walls of the structure are the main bearing walls, designed as columns. The tower, located at the intersection of two main streets, 4th Avenue and Denali Street, is a landmark in downtown Anchorage.

The McKinley towers served as both office and residential space until March 27, 1964, when the 'Good Friday' earthquake (magnitude 9.2) struck the Prince William Sound area of Alaska. Anchorage, located a mere 100 miles from the epicenter of the earthquake, was severely affected. Among the 150 commercial buildings that were damaged or made unstable by the quake, the McKinley building sustained significant damage. The spandrels were broken beyond recognition, while the bearing and interior walls developed large diagonal cracks. The vertical pier on the north end wall failed up to the third story, as did piers on the south end wall.

Figure 1: Damaged McKinley Tower sat vacant for more than two decades.

Conventional Retrofit

After the earthquake, the building was vacated and put up for auction. In 1965 some repair work was done consisting of exterior crack patching, replacement of damaged reinforcement of ornamental spandrel beams, removal of loose material, and fixing spalled areas in stairwell and elevator core (*Figure 1*).

The building exchanged owners several more times after these initial repairs, until it was purchased by its current owner in 1998. The building had been vacant for the past twenty years and had gained a reputation as an eyesore in downtown Anchorage. It had also fallen behind the seismic codes and needed a retrofit before it could be used.

To bring the building to current seismic design code requirements, traditional retrofit measures were undertaken consisting of construction of new exterior and interior concrete shear walls and the placement of structural steel shapes along the entire height of the building.

Figure 2: Original retrofit scheme required new shear walls and enlargement of existing columns.

There were several disadvantages to this retrofit design, the most problematic of which was excessively high cost. The foundation system was found to be adequate for the original design, but required significant improvements to resist the loads imposed by the current code, design standards, and the additional seismic mass created by the retrofit. To resist overturning, 88 soil anchors were needed to resist uplift due to seismic forces. Another disadvantage was that the long steel shapes proved to be a construction challenge, in addition to changing the overall profile and appearance of the historic tower.

The retrofit was begun, and the shear walls were completed up to the 4th floor (*Figure 2*). The majority of the foundation retrofit was also completed, but the funds dwindled and the project was stopped. It was at this point that alternate retrofit options were reviewed.

Retrofit with FRP

In 2004, the owner and project contractor hired local structural engineering firm Schnieder and Associates to conduct an investigation of seismic retrofit options. The use of external Fiber Reinforced Polymer (FRP) was selected as a cost effective solution to retrofit and strengthen the structure.

FRP fabrics were applied to various structural elements using an epoxy resin as adhesive. The fabric provides a confining effect and additional reinforcement, which significantly increases the strength and ductility of the elements. FRPs are applied to the wall surface like wallpaper and reach strengths twice that of steel in 24 hours. Due to the fabric's very light weight, the existing mass in the building remained practically the same, which, when compared to the traditional retrofit described above, resulted in significantly reduced lateral seismic forces and lower foundation redesign requirements.

Figure 3: Confinement of a typical interior column with FRP.

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Figure 4: Retrofit of walls with carbon fabric and connection of wall to floor.

A dynamic analysis of the structure was conducted using a 3D model for the existing building structure, based on available as-built drawings. This model identified the possible areas of excessive stress during a seismic event. Both interior and exterior shear walls were identified as over-stressed, with localized high stress in the spandrel and cantilevered wall panels. The majority of this retrofit concentrated on floors 5 to 14. A discussion of the FRP design solution for each type of structural element follows:

Columns

Unidirectional glass FRP fabrics were applied to all columns to provide a confining effect to the concrete, which increased its effective compressive strength and ductility. This eliminated the need to increase column size or to add steel reinforcement to existing columns. The fabric was supplied in 24-inch wide tapes that were wrapped around the column in at least two layers. Along the height of the column, the bands of fabric were continued by butt joints (*Figure 3, see page 35*).

Structural Walls

The north and south side bearing walls above the 4th floor were converted to shear walls by applying biaxial carbon FRP on the inside face of the wall up to the 9th floor. Vertically oriented unidirectional glass fabric was placed between the 9th and 10th floor. Additional horizontally oriented unidirectional glass fabric was applied on the end of the new exterior shear wall constructed up to the 4th floor. Specialized structural details were developed to ensure proper load transfer to the floor system at each level (*Figure 4*).

For the east and west side shear walls, wall boundary elements were created by wrapping horizontally oriented unidirectional glass fabrics on the three sides of window corner openings. Additional ⅝-inch A307 bolts were installed through the wall to provide confinement of the boundary elements.

Beams

Coupling beams for east and west shear walls were reinforced for shear by applying biaxial glass FRP on the inside face. The same design was applied on the inside face for shear reinforcement of cantilever beams on the west and east building elevations. For the cantilever beams on the north and south elevations, shear strength was increased by applying a biaxial carbon fabric on the inside face. Cantilever beams negative moment strength was increased by applying unidirectional carbon FRP to the top face.

Floor System

Certain areas of the roof slab required additional flexural strength to support a water storage tank and heavy equipment that were to be placed on the roof. These areas were retrofitted on the bottom of the slab with 6-inch wide unidirectional carbon fabric strips placed 12 inches on center in the both directions.

Figure 5: View of nearly-completed and painted building.

Advantages of FRP

Using FRP to retrofit the McKinley towers was a success, as it allowed the project requirements to be met in an economical fashion. A significant amount of savings was generated by fast installation; procedures were simple and quick, which were performed by small crews of 8-10 locally trained workers. In addition, FRP's lightweight characteristics allowed for the mass and thus seismic lateral force demands of the existing building to remain unchanged. This is in sharp contrast to traditional shear wall retrofit which adds significant mass to the building, which in turn increases the seismic demand and thus significantly changes its behavior. Since retrofit with FRP does not increase the dead weight of the building, the original foundation system is usually adequate. In this case, however, the original foundation had already been partially retrofitted to accommodate the new shear walls that were part of the conventional retrofit that was later abandoned. Despite this, a considerable saving was achieved by reducing the number of soil anchors by more than half, from 88 to 40.

In addition to the economic advantages of the FRP retrofit, this design provided other advantages by meeting project requirements. Part of the funding for this project was from a grant provided because this building was a historical structure. For this grant to be awarded, the seismic retrofit could not significantly modify the original exterior elevations. Unlike the original retrofit design, which required structural steel columns for the full height of the structure, the FRP was installed on the interior side of the walls (*Figure 5*). Also, due its historical landmark status, there was significant public pressure imposed to finish the building retrofit under a tight deadline.

*The Anchorage Daily News wrote an article about the retrofit of the project that was published on August 18, 2005. Similarly, the local CBS affiliate visited the site during construction, and showed extensive videos of the retrofit and installation of the FRP system on their evening news. These videos can be viewed at **www.QuakeWrap.com**. In addition to recognition from the media, this project received the 2006 Award of Excellence from the International Concrete Repair Institute.*

Summary and Conclusions

The upgrading and reopening of the McKinley Tower was a major success for the city of Anchorage and its citizens. A total of 55,000 square feet of FRP fabric was installed in eleven weeks, making this the largest building project to be retrofitted with FRP.▪

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