2006 Award of Excellence

Strengthening Category

Seismic Retrofit of McKinley Tower

Anchorage, Alaska

Submitted by QuakeWrap, Inc.

Fig. 1: Damage to walls caused by the earthquake

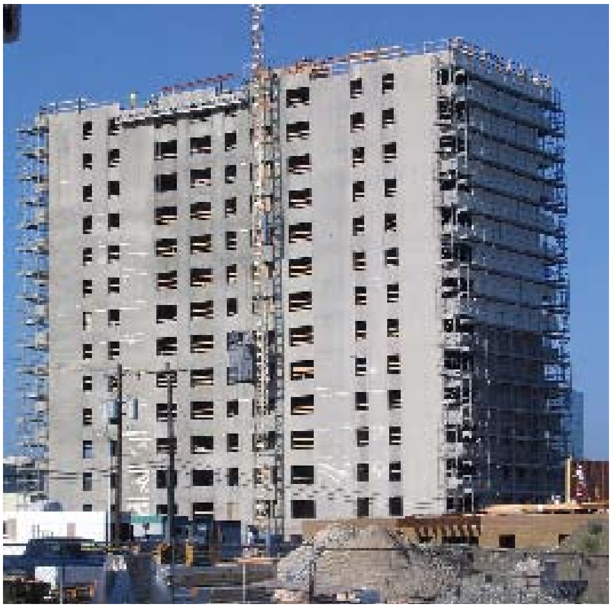

Fig. 2: Stripped building was an eyesore for over 20 years

The McKinley Tower Apartment Building is a 14-story reinforced concrete high-rise structure, constructed in 1951-52 in Anchorage, AK. The total height of the building is 122 ft (37 m), and it has a rectangular footprint of 130 by 52 ft (40 by 16 m), giving it a total of 108,160 ft^2 (10,048 m^2) of construction, including basement and roof.

The building survived the 1964 "Good Friday" Alaska Earthquake, which had a Richter scale magnitude of 9.2, making it the strongest earthquake in North America to date. Damage to the building consisted of shear failure of exterior spandrel beams and extensive diagonal cracking of exterior walls (Fig. 1). The east vertical pier on the north-end wall failed up to the third floor at a construction joint and similar failure was observed on the south-end wall. The walls around the building's core suffered light diagonal and horizontal cracks at construction joints, with damage being more severe from the third to sixth floors.

After the earthquake, the building was vacated and put up for auction. In 1965, some repair work was done, consisting of patching exterior cracks, replacing damaged reinforcement of ornamental spandrel beams, removing loose material, and fixing spalled areas in the stairwell and elevator core.

In 1965, the building was sold and renamed the McKay Building. Up to 1984, the ground floor of the building was used as office and commercial space. The lower floors were remodeled for office space and the top story for penthouse residences. In 1984, the building was vacated again due to fire-safety code violations. The building was resold in 1992 and renamed the McKinley Tower Apartment Building, but it remained vacant.

The current owner acquired the building in 1998. Since then, extensive structural repairs were undertaken to bring the building up to current seismic code requirements. Due to the excessively high costs involved, however, all repair work was stopped. As a consequence, the building remained vacant for more than 20 years, becoming an eyesore in downtown Anchorage (Fig. 2).

Partially Implemented Conventional Retrofit

To bring the building to current seismic design code requirements in 1998, typical retrofit measures were undertaken. These consisted of constructing new exterior and interior shearwalls, which required significant redesign of the foundation system, and increasing the size and reinforcement of existing columns that were tied to the new shearwalls.

Cutting the floor slabs was performed at new interior shearwall locations to provide continuity for wall construction. As mentioned previously, however, excessive high costs caused all retrofit construction to stop. At this point, all foundation retrofit was completed; shearwalls were completed up to the 4th floor, with reinforcement cages partially finished up to the 5th floor; and additional floor cutting was completed above the 5th floor. At this stage in the retrofit work, the fiber-reinforced polymer (FRP) retrofit project was begun.

Fiber-Reinforced Polymer Retrofit

This alternative method consists of applying FRP fabrics to 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 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 remains practically the same, which significantly reduces the lateral seismic forces and the foundation redesign requirements when compared to aforementioned traditional retrofit. Also, because the fabrics are applied like "wallpaper," installation procedures are simple and retrofit time is reduced significantly.

Based on the seismic demand evaluation of McKinley Tower at the retrofit stage prior to FRP installation, several structural elements were found to require additional retrofit. The majority of this retrofit concentrated on Floors 5 to 14. The following is the FRP design solution for each type of structural element:

Columns

Unidirectional glass FRP (GFRP) fabrics were applied to all columns to provide a confining effect to the concrete, which increased its compressive strength and ductility. This eliminated the need to increase the size and steel reinforcement of all existing columns. The fabric was supplied in 24 in. (61 cm) wide tapes that were wrapped around the column in two or more layers; along the height of the column, the bands of fabric were butt jointed (Fig. 3).

Fig. 3: Wrapping of columns with GFRP

Structural Walls

The north- and south-side bearing walls above the 4th floor were converted to shearwalls 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 shearwall constructed up to the 4th floor. To assure proper load transfer to the floor system at each level, a special structural detail was developed (Fig. 4).

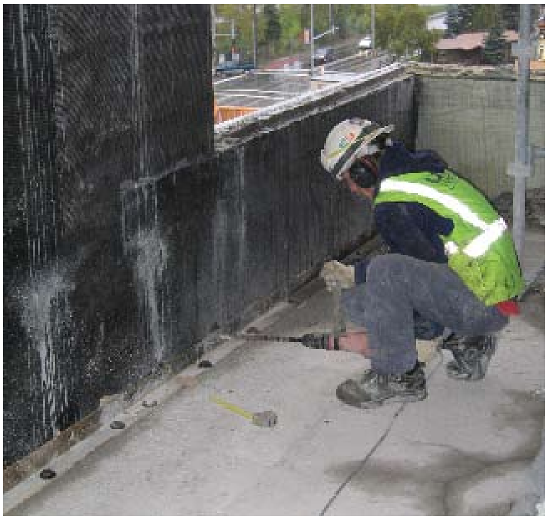

Fig. 4: Steel angles and bolts for transfer of loads from shearwalls to floors

For the east- and west-side shearwalls, boundary elements were created by wrapping horizontally oriented unidirectional glass fabrics on the three sides of window corner openings. Additional 5/8-in. A307 bolts were specified to provide proper confinement of the boundary elements.

No strengthening of the FRP retrofit design was found necessary for the interior shearwalls poured up to the 4th floor.

Beams

Coupling beams for east and west shearwalls were reinforced for shear by applying biaxial GFRP on the inside face (Fig. 5). 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 reinforcement was achieved by applying a biaxial carbon fabric on the inside face. Cantilever beams were also reinforced for negative flexural strength 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

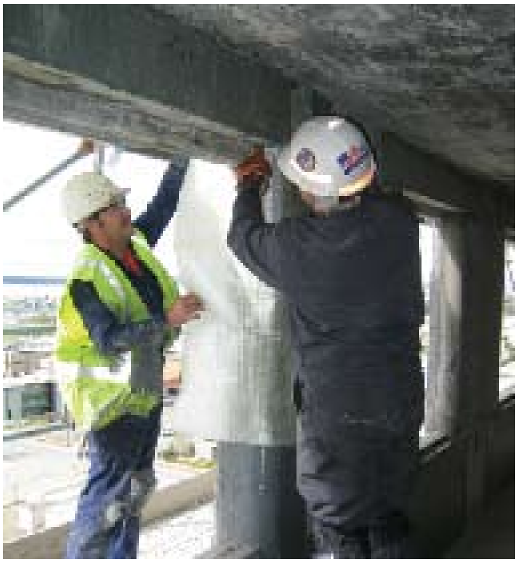

Fig. 5: Reinforcing boundary elements in shearwalls with GFRP

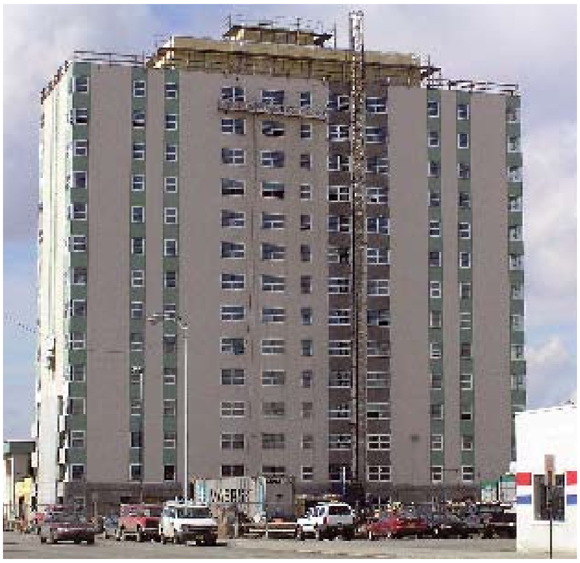

Fig. 6: The building nearly completed and painted

heavy equipment that were to be placed on the roof. These areas were retrofitted on the bottom (inside) face of the slab with 6 in. (15 cm) wide unidirectional carbon fabric strips placed 12 in. (30 cm) on center and spanning in the directions of the main slab steel reinforcement.

Special Unique Project Features

- *Ease of installation*: Installation procedures were very simple and quick, which allowed for small crews of 8 to 10 workers that were locally trained. The supervision of installation and training of workers were provided by the FRP materials supplier. Also, preliminary surface preparations were kept to a minimum because most of the surface was sandblasted during previous retrofit work;
- *Meeting tight construction deadline*: Given the historical landmark status of McKinley Tower in downtown Anchorage, significant public pressure was imposed to finish the building retrofit under a tight deadline. A total of 55,000 ft^2 (5110 m^2) of FRP fabric was installed in 11 weeks, allowing for a quick reopening of the retrofitted building;
- *Economical seismic retrofit*: In addition to the savings generated by a quick installation, the lightweight characteristics of FRP allowed for the mass and seismic lateral force demands of the existing building to remain unchanged. This is in sharp contrast to traditional shearwall retrofit, which adds significant mass to the building, which in turn increases and changes the behavior of the seismic demand. Because retrofit with FRP does not change the dead weight of the building, the original foundation system is usually adequate. In this case, however, the original foundation had already been retrofitted at a high cost to accommodate the new shearwalls that were part of the conventional retrofit that was later abandoned;
- *Maximizing interior floor space use*: New interior shearwalls always impose architectural restrictions to interior floor use, especially when remodeling projects are undertaken. By eliminating the need for these walls, these restrictions were abolished above the 4th floor, where the new interior shear construction was stopped;
- *Inspection by local structural firm*: The City of Anchorage did not have the expertise to perform inspection of the installation of the FRP system. A local structural engineering firm provided special inspection of all FRP installation on behalf of the city; and
- *Approval process by third-party review*: Due to a combination of time constraints and lack of familiarity with FRP systems, the City of Anchorage agreed to rely on the services of an independent consulting firm to perform plan checks and to review the project. A firm specializing in seismic design and construction, with offices in Los Angeles and San Francisco, evaluated the seismic demands of the building and found that the FRP retrofitted building met all current local seismic code requirements.

McKinley Tower

Owner
Marlow Development
Anchorage, Alaska

Project Engineer/Designer
Schneider & Associates
Anchorage, Alaska

Repair Contractor
QuakeWrap, Inc.
Tucson, Arizona

Material Supplier/Manufacturer
QuakeWrap, Inc.
Tucson, Arizona