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Engineering Innovation in Seismic Retrofitting: Towne Storage Gateway

When a 2020 earthquake compromised the historic Towne Storage Gateway building in Salt Lake City, engineers faced the challenge of reinforcing its unreinforced masonry facade while maintaining its original architectural character. Through an advanced combination of retrofit techniques using FRCM and FRP, the team delivered a seismic upgrade that enhances structural integrity while preserving the building's historic character.

By Sarah Outzen, PE, Clyde Ellis, and Jesse Davis

Located in the heart of Salt Lake City, Utah, at 510 W 100 South, the Towne Storage Gateway building serves as a striking example of how structural engineering can preserve history while meeting modern safety standards. Originally constructed in 1920, this four-story structure, repurposed as a storage facility, faced daunting challenges when its south-facing exterior wall suffered significant damage during a March 2020 earthquake. Built using unreinforced masonry (URM), the wall—measuring 55 feet in height and 100 feet in length—was no match for the lateral seismic forces exerted against it. The damage included significant cracking in the three-wythe brick wall, detachment issues, and compromised structural integrity, necessitating extensive repairs. The wall was analyzed per ASCE 41 and determined to be part of the building's lateral system, requiring strengthening for in-plane shear and overturning moment forces based on seismic demands. To address these issues, Simpson Heli-Ties were installed at 30-inch intervals to tie the wythes together, ensuring monolithic behavior and preparing the wall for advanced retrofitting techniques.

Beyond addressing public safety concerns, retrofitting the damaged wall became an urgent necessity due to refinancing conditions imposed by the property's lender. Approaching this problem required innovative design solutions, modern materials, and meticulous execution. Combining the expertise of WCA Structural Engineering, Menlove Construction, Simpson Strong-Tie, and Structural Preservation Systems, the project involved a cutting-edge approach employing Fabric-Reinforced Cementitious Matrix (FRCM) and Fiber-Reinforced Polymer (FRP) technologies to improve the capacity of the URM wall against lateral loads. Here, we provide an in-depth technical account of the project, from analysis to final application.

Systematic diagonal (shear) cracks appear between window groups.

Engineering Challenges

The unreinforced masonry (URM) south facing facade, like many historical structures, was designed without embedded steel to resist tensile forces. URM walls rely entirely on the compressive strength of bricks and mortar as well as the bond strength between units and mortar, making them highly vulnerable to lateral forces caused by earthquakes. This was compounded by the presence of multiple window openings, which effectively creates small piers and spandrels where the stiffness and strength are reduced. Seismic activity led to diagonal shear cracking and weakening of the piers, leaving the wall unable to resist overturning loads or out-of-plane movement.

The engineering team, led by WCA Structural Engineering, evaluated the extent of the damage using visual inspections and structural analysis in accordance with ASCE 41-17 standards for seismic evaluation and retrofit. It was determined that the wall needed global in-plane shear strengthening, enhanced tensile capacity at the piers, and improved overturning resistance.

A traditional method of repair might involve adding a 3-4-inch-thick layer of shotcrete (sprayed mixture of concrete) over the existing brick wall, filling and covering treated cracks caused by the earthquake.

However, shotcrete is a higher-profile solution that would have added more mass and load to the structure. Another commonly used solution involves adding near surface mounted tension reinforcement where slots are cut into the brick wall and vertical rebar is installed, but this method is a more costly fix. Clyde Ellis, Senior VP at Structural Technologies noted, "The chosen solution was thoroughly analyzed to ensure it fully met the design intent of the SEOR."

Retrofit Design

The team determined the solution required a hybrid approach combining traditional reinforcement techniques with modern composite materials. Key components included Fabric-Reinforced Cementitious Matrix (FRCM), Fiber-Reinforced Polymer (FRP), and helical anchors, applied in a sequence to stabilize and strengthen the structure holistically. WCA's engineering analysis dictated where critical strengthening elements like FRP were needed versus generalized FRCM coverage.

Fabric-Reinforced Cementitious Matrix (FRCM)

FRCM is a composite material consisting of a high-performance fiber grid embedded within a cementitious matrix. The combination offers significant flexibility in its application to URM walls. Unlike traditional FRP systems, where polymers carry the load, the cementitious matrix in FRCM is compatible with masonry substrates and provides enhanced fire resistance.

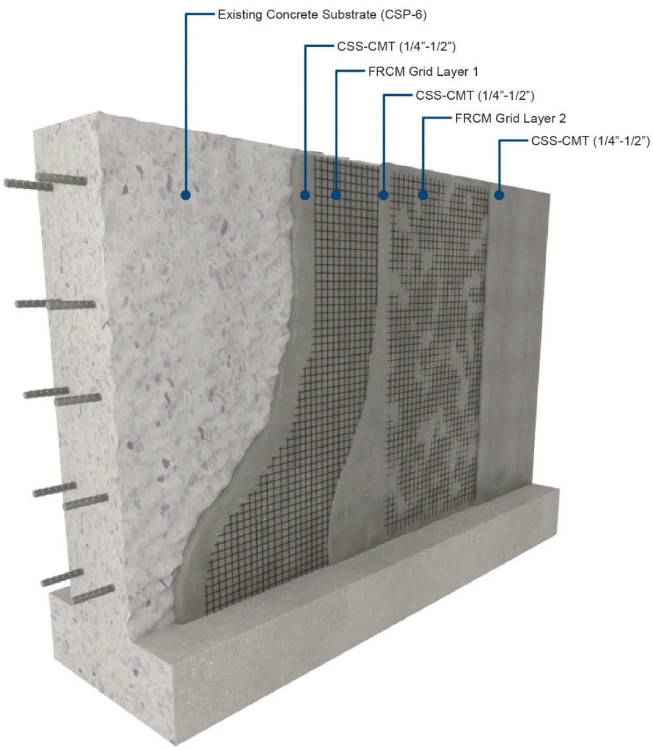
Material Properties:

The FRCM system utilized for this project included both unidirectional and bidirectional, high-strength carbon fiber grid embedded in a portland-cement-based mortar. The cured composite tensile strength of the fiber grid is 128,300 psi for the unidirectional product, and 143,000 psi for the bidirectional product. The FRCM grid was applied in multiple layers to achieve a final thickness of approximately 1.5 inches.

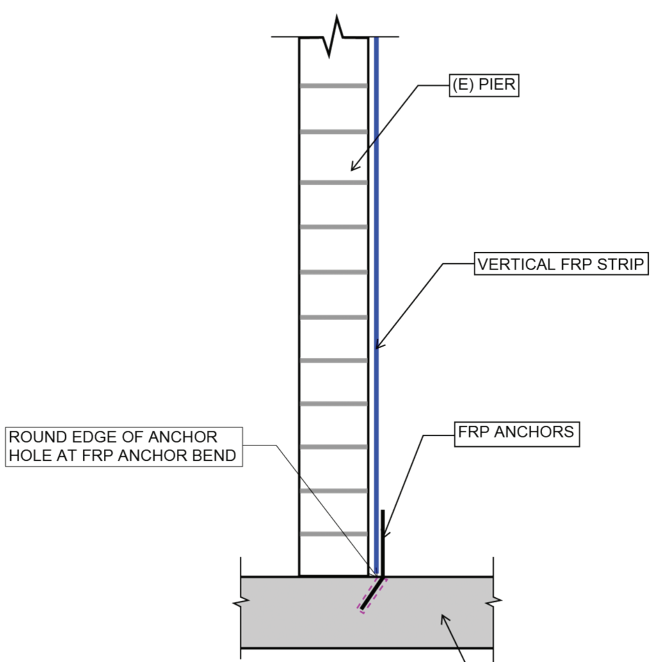
The project's FRCM system used a unidirectional carbon fiber grid (shown) along with a bidirectional grid, embedded in a portland cement-based mortar.

Mode of Action:

FRCM enhances the wall's in-plane shear strength by bridging diagonal cracks and distributing forces uniformly. It also fills large surface cracks and spalls during installation, bolstering the structural integrity of the facade without necessitating pre-repair crack filling.



A typical FRCM application is illustrated.



Embedded FRP anchors in the existing building's foundation is detailed.

Advantages:

The cementitious base is inherently compatible with masonry surfaces, allowing for optimal adhesion and reduced risk of debonding. Additionally, FRCM systems are vapor permeable, mitigating moisture entrapment and future degradation.

Fiber-Reinforced Polymer (FRP)

FRP, widely used in seismic reinforcement, is a high-strength composite material characterized by unidirectional carbon fibers encased in an epoxy matrix. For this project, FRP strips were applied vertically along the piers between windows to counter both tensile and flexural demands.

Material Properties:

The FRP strips applied had a tensile modulus of elasticity of 14,200 ksi and a tensile strength of 128 ksi. The strips were 6 inches wide and adhered using epoxy, meeting the requirements of ACI 440.2R-17 specifications.

Mode of Action:

FRP reinforces the piers by resisting tensile forces generated by overturning behavior during seismic events. The carbon fiber strips were anchored into the building's foundation to create a continuous load path for overturning forces.

Advantages:

The lightweight and high-strength nature of FRP allowed for targeted reinforcement without adding significant weight. Its ease of application on masonry walls made it ideal for areas requiring reconsolidation and tensile strengthening of piers.

Helical Anchors

Helical anchors were installed to address deficiencies in the overturning of the masonry facade. These anchors tethered the unstable brick veneer to the stable interior wythes, providing composite action and reducing risks of detachment during seismic loading.

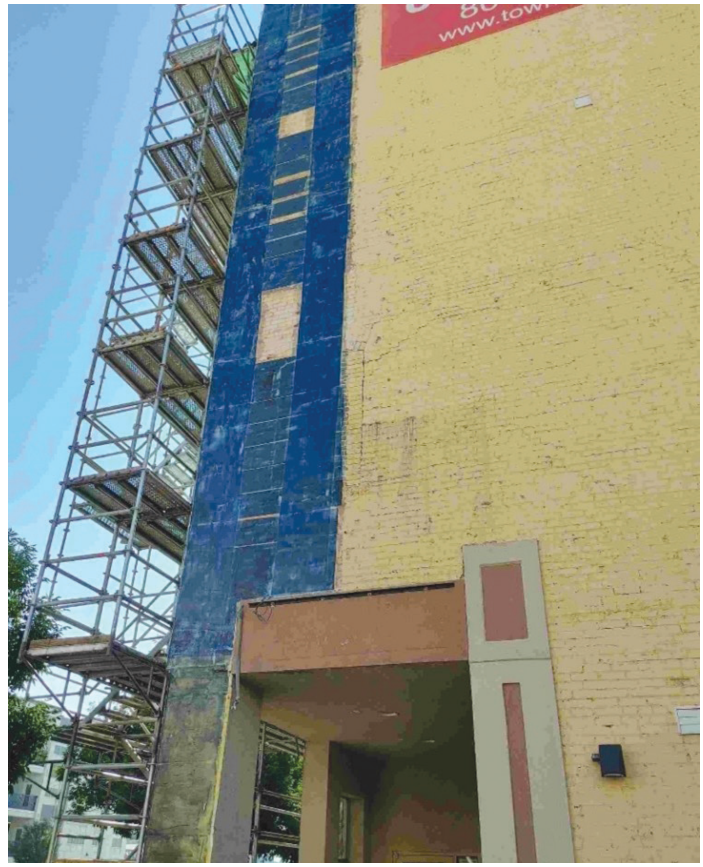
Spacing & Installation:

Anchors were installed in a 2-foot x 2-foot grid pattern across the wall, penetrating the facade at a shallow angle and embedding into the substrate at least 3 inches. Specialized drilling tools were used to avoid damaging the existing brick.

Execution and Processes

The engineering solution was meticulously implemented under the supervision of Jesse Davis, Construction Manager at Structural Preservation Systems, alongside field installation teams. The six-phase execution included surface preparation, helical anchor installation, FRCM application, crack repair, FRP installation, and final finishing.

The finished FRCM application is shown after several layers of FCRM were applied and allowed to cure.



Final FRP application (dark blue) is installed in strips on the URM wall.

Step-by-Step Process

1. Surface Preparation:

Existing stucco and paint layers were removed to expose the brick substrate. High-pressure water jets and abrasive cleaning were employed to achieve a roughened, moisture-compatible surface necessary for adhesion. Existing cracks were repaired with appropriate crack repair materials meeting industry standards.

2. Helical Anchor Installation:

Over 500 helical anchors were embedded into the brick substrate to secure the outer facing brick and interior wythes. This step addressed facade detachment and provided a critical anchor matrix for subsequent treatments.

3. Initial FRCM Layer Application:

A base layer of cementitious mortar was sprayed onto the wall using specialized sprayers. The high-tensile carbon grid was then embedded into the wet matrix, followed by a second coating. Special tools ensured uniform pressure during installation to optimize mortar penetration into porous masonry surfaces.

4. Final FRCM Layer:

Additional layers were applied as needed in high-shear zones. Each layer was allowed to cure for 24 hours under controlled humidity and temperature conditions. Thermal blankets were utilized to mitigate direct sun exposure and ensure uniform hydration.

5. FRP Application:

Vertical FRP strips were installed along piers. Strips were bonded using epoxy adhesives mixed on-site, with overlapping anchors embedded into the wall's foundation. Surface finishing minimized trap zones for air bubbles, ensuring full mechanical engagement of the laminate.

6. Finishing Treatment:

Aesthetic continuity was restored by applying a textured coat overlay across the entire wall surface to ensure uniformity between treated and untreated areas.

Coordination Between Disciplines

Coordination among WCA Structural Engineering, Simpson Strong-Tie, Menlove Construction, and Structural Preservation Systems was central to the project's success, particularly in managing the complexities of the site. Due to the building's proximity to public spaces, careful planning was required to synchronize scaffolding, material staging, and team rotations to maintain uninterrupted workflows. Measures were implemented to protect the surrounding area, including the establishment of a designated laydown area for materials and equipment. Additionally, an overhead protection system was constructed above the sidewalk and around the exterior to safeguard both traffic and pedestrians throughout the duration of the work.

Final surface finishing provides aesthetic continuity.

Closing Outcomes

The Towne Storage Gateway retrofit stands as a case study in engineering ingenuity, achieving an effective seismic upgrade while preserving the building's historic character. By leveraging innovative materials like Fabric-Reinforced Cementitious Matrix (FRCM) and Fiber-Reinforced Polymer (FRP), the project not only repaired the structure but also enhanced its resistance to future seismic events. These advanced systems addressed the vulnerabilities inherent in unreinforced masonry (URM) by strengthening, repairing, and protecting the brickwork in a single, cohesive solution. This hybrid approach fully mitigated the structural weaknesses of the URM walls, ensuring the building is better equipped to withstand potential earthquakes.

From a structural perspective, the project lays a foundation for the broader adoption of these systems in retrofits of similar scale and complexity, particularly in seismic regions. The Towne Storage Gateway project reflects the possibilities of material science and structural retrofitting, as well as the foresight required to preserve architectural heritage in hazardous environments. This comprehensive approach exemplifies technical excellence and sets a benchmark for future URM rehabilitations. ▪

Sarah Outzen, PE, is a Senior Strengthening Solutions Engineer supporting composite products at Simpson Strong-Tie since 2020. Before joining Simpson Strong-Tie, she worked for about a decade in structural engineering consulting, both in new construction and retrofit of existing structures.

Clyde Ellis is a Senior Vice President of Sales for strengthening solutions with STRUCTURAL TECHNOLOGIES. He has over 25 years of experience developing innovative design-build solutions for commercial and public structures that adds value and reduces cost for repair/rehabilitation, structural enhancement and protection from future deterioration.

Jesse Davis is a Manager of Construction with STRUCTURAL. He has experience in structural repairs including concrete strengthening, steel repair, hydro demolition and concrete overlays. In 2022, Davis took over the operations of the STRUCTURAL Utah division, overseeing all projects and personnel.