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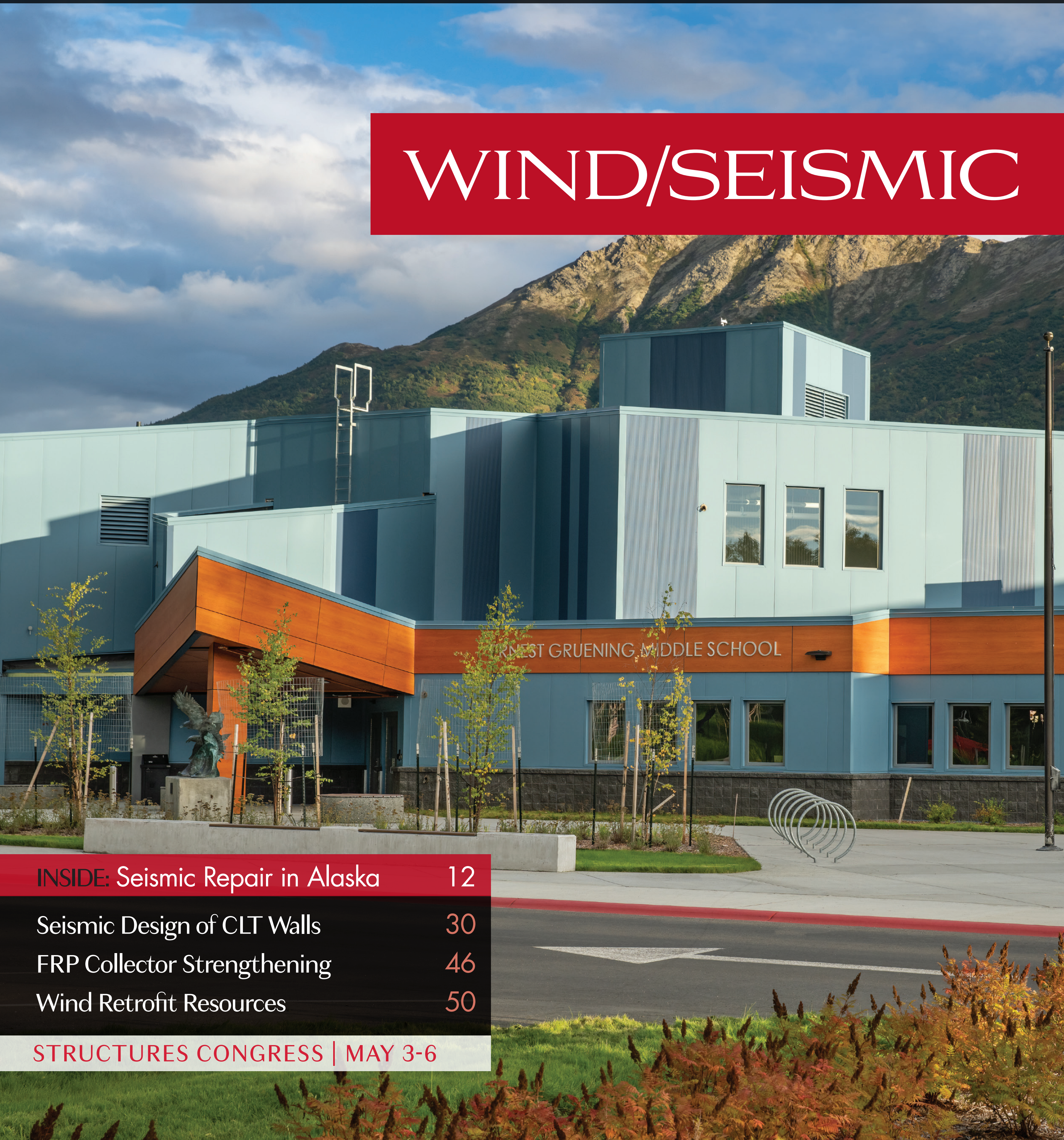

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Seismic Repair and Retrofit in Alaska

By Ellen Hamel P.E., S.E.

Gruening Middle School, located in Eagle River, Alaska, was significantly damaged during a magnitude 7.1 earthquake on November 30, 2018. The epicenter of the earthquake was only 11 miles from the school. Due to the damage, Gruening was shut down for almost three years for earthquake repair, seismic upgrades, and programming upgrades. The Gruening Middle School Earthquake Recovery Project was an important effort by the Anchorage School District (ASD) to repair and upgrade the almost 40-year-old school (*Figure 1*). The project was a success thanks to committed team members and the first use of Simpson Strong-Tie (Simpson) Fabric-Reinforced Cementitious Matrix (FRCM) in Alaska.

Background

Gruening was originally designed in 1981 as a two-story, approximately 124,000-square-foot building that is X-shaped in plan. The gym and multipurpose room (MPR) are both 2-story spaces that infill the arms of the X. The building is wood framed with both wood shear walls (interior and exterior) and stack bond Concrete Masonry Unit (CMU) shear walls (interior only). The exterior wood shear walls were covered in 5-inch masonry veneer that is identical in appearance to the interior CMU walls (Figure 1). Foundations are concrete spread footings.

A lateral redesign was completed in 1984; these *Corrective Actions* addressed significant flaws in the original seismic design. The 200 added details in the Corrective Actions included new shear walls and upgraded many of the lateral connections. Reid Middleton reviewed the 1981 drawings and the 1984 *Corrective Actions* drawings as part of the repair and upgrades project. In addition, selective demolition was done to confirm material types (wood versus masonry) in select locations.

Seismic Screening

As part of ASD's commitment to evaluate and upgrade all the 91 facilities in its inventory to current seismic standards, engineers performed an ASCE 41-13 Seismic Evaluation and Retrofit of Existing Buildings (ASCE 41) Tier 1 screening on Gruening Middle School in 2013. The Tier 1 screening indicated the following non-compliant items:

Checklist for Building Type W2 – Wood Frames

1. SHEAR STRESS CHECK
2. DIAPHRAGM REINFORCEMENT AT OPENINGS

Figure 1. Gruening Entry Before and After

3. DIAGONALLY SHEATHED AND UNBLOCKED DIAPHRAGMS

Checklist for Building Type RM1 – Reinforced Masonry Walls

1. OPENINGS AT SHEAR WALLS

Based on this evaluation and ASD's commitment to evaluating and upgrading all their facilities, ASD created a *Seismic Evaluation and Retrofit Guide* (ASD Seismic Guide) for all their existing schools in 2014. This guide was updated in 2021 to the ASCE 41-17 standard, and as of this writing, ASD has used this guide to complete Tier 1 evaluations of every facility in the district.

2018 Earthquake and School Closure

On Friday, November 30, 2018, a magnitude 7.1 earthquake occurred at 8:29 am, Alaska Standard Time. At the time of the earthquake, there were no accelerometer recording stations in Eagle River; a station in nearby Chugiak recorded a maximum spectral acceleration of 0.47g for short periods (0.2 seconds), and in Anchorage, the maximum recorded short-period acceleration was 1.49g (Dutta et al., 2019). For perspective, the mapped MCE_R, 5 percent damped, spectral response acceleration parameter for short periods at this site is 1.5g. Gruening Middle School is located on Site Class D soils and within Seismic Design Category D.

Beginning the day of the earthquake, engineers walked through and evaluated all the buildings in the district. Engineers first evaluated Gruening on Sunday, December 2, 2018, and then visited three more times in the next three weeks. As a result, the building was red-tagged per ATC-20-1 *Field Manual – Postearthquake Safety Evaluation of Buildings* (ATC-20). Damage observations included cracked masonry, leaning of the two-story CMU gym wall, stairway to column connection damage, bent gym curtain support beam, cracked drywall, acoustic ceiling tile failures, and gypsum-board ceiling failures. Repairs of minor masonry cracking and ceiling tiles began immediately; the leaning two-story CMU gym wall was shored along with similar two-story CMU walls at the MPR.

Students at Gruening Middle School did not return to school after the one-week shutdown of all schools in the district. Instead, Gruening students and staff temporarily relocated to the nearby high school for the next two and a half years.

Performance Objective	Seismic Hazard Level	Spectral Response Acceleration Parameter at Short Periods (S_S)
Damage Control	BSE-1E	0.783
Limited Safety	BSE-2E	1.299
Damage Control	BSE-1N	1
Limited Safety	BSE-2N	1.5

Table 1. ASCE 41 Performance Objectives

Repair, Retrofit, and Redesign

In spring 2019, design began on the Gruening Middle School Earthquake Recovery Project. ASD separated the project into three parts to accommodate multiple sources of funding: earthquake repair, seismic mitigation, and programming upgrades. Engineers referenced ASCE 41 and ASCE 7-10 Minimum Design Loads for Buildings and Other Structures (ASCE 7) for structural design.

Engineers used the following ASCE 41 Performance Objectives in evaluating the existing structure and the design of repairs and upgrades, per a Risk Category III building and the ASD Seismic Guide (*Table 1*).

Earthquake Repair

The most urgent structural earthquake damage at Gruening was the leaning of the two-story CMU wall in the gym. Upon further observation, engineers determined that the top of the CMU wall had detached from the roof diaphragm via splintering of the wood top plate (*Figure 2*). Detachment occurred along 110 linear feet of wall, and a similar connection existed along 700 linear feet of wall throughout the building.

To repair the damaged top of CMU wall connections, and reduce the risk of failure in future earthquakes, a new connection for the top of the wall had to be developed. The new top-of-wall connection was designed to resist out-of-plane seismic forces per ASCE 7. Engineers designed two different top-of-wall connections to remediate the existing condition: (1) a two-sided connection using steel bent plates on both sides of the wall, and (2) a single-sided connection using a single steel plate on one side of the wall, anchored to the CMU wall using a through-bolt. The engineer, architect, and contractor coordinated throughout the design and construction process to determine which of the two connections would be best suited at each location. Once all

Figure 2. Top of CMU Wall Damage

700 feet of new connections were installed, the contractor removed the temporary shoring of the tall gym and MPR walls.

Top of interior CMU wall to diaphragm connection is not an ASCE 41 Tier 1 screening item; the Checklist for Building Type RM1 includes a wall anchorage check, but only for *exterior* concrete or CMU walls. However, Gruening does not have any exterior concrete or CMU walls. Therefore, a Tier 2 deficiency-based evaluation would not have detected the deficient top of interior CMU wall connection, but a Tier 3 systematic evaluation may have.

During the post-earthquake evaluations, extensive damage was observed to the CMU walls and the masonry veneer. Of particular concern was the damage at CMU wall intersections. At approximately 120 corner T-intersections, engineers detailed a connection to rigidly attach the intersecting walls. Face shells were demolished as required, and L-shaped (bent) reinforcement was post-installed into the existing CMU. At 15 of these intersections, the existing CMU walls had tube steel columns embedded. At these locations, engineers detailed a connection to rigidly attach the intersecting CMU walls to the steel columns.

Immediately following the earthquake, ASD's contractors temporarily repaired the damaged stairway to column connection. The permanent solution to this damage was to rigidly connect the stairs to the adjacent wood stud wall. This was done using horizontal tension ties with lag screws.

In the gym, 40 feet of the curtain support beam was bent during the earthquake (*Figure 3*). After coordination with Gruening's architect and staff, the contractor removed the damaged portion. As part of the reprogramming of the school, the damaged length of curtain wall support was no longer needed. However, the remaining beam length lacked lateral bracing in the longitudinal direction. Engineers designed an open-channel strut bracing the beam in the longitudinal direction.

Seismic Retrofit

ASD elected to incorporate voluntary seismic upgrades per ASCE 41 in addition to repairing the earthquake damage. Before beginning ASCE 41 upgrades, engineers, in coordination with the architect, decided to remove the existing masonry veneer from the exterior of the building. This decision was significant because it removed substantial seismic weight from the building, reducing seismic design loads. The existing veneer weight was 63 pounds per square foot; the new siding weight is less than five pounds per square foot; removing the veneer removed 1,200 tons of seismic weight (Figure 4). In addition to reducing weight, removing the masonry veneer and replacing it with a new, lightweight, blue-insulated metal panel siding gave the school a refreshed look. The new look helps to give the public a visual differentiation between the old and new Gruening Middle School.

During the Tier 1 screening, engineers flagged the wood shear walls at Gruening as *Non-Compliant* per the SHEAR STRESS CHECK of the Tier 1 Type W2 Checklist. As part of the seismic retrofit of Gruening, engineers evaluated the existing shear walls for ASCE 41 Tier 2 compliance. Linear static procedures (LSP) were used. Since all the floor and roof diaphragms in the building are flexible and limited drag struts were observed in the existing building, loads were distributed to the wood and masonry shear walls based on total length. All wood shear walls that were non-compliant per an ASCE 41 Tier 2 deficiency-based evaluation were upgraded to meet Damage Control at the BSE-1N Seismic Hazard Level and Limited Safety at the BSE-2N Seismic Hazard Level; this included approximately 300 linear feet of wall.

Existing single-sided wood shear walls were upgraded to double-sided wood shear walls, with nailing/staples on the new sheathing equal to that of the existing. One of the challenges of this upgrade was determining the existing nailing patterns. Original drawings called for nailing, but in some cases, engineers discovered that staples were used in place of nails. This was not documented in the original or corrective drawings. Per the *National Design Specifications* (NDS) for Wood Construction, "for shear walls sheathed with the same construction and materials on opposite sides of the same wall, the combined nominal shear capacity shall be permitted to be taken as twice the nominal unit shear capacity for an equivalent shear wall sheathed on one side." Therefore, engineers needed to know the existing capacity of the shear walls to determine the new, double-sided wall capacity. Using selective demolition of finishes, Reid Middleton was able to determine a representative sample of the size, spacing, and pattern for the shear wall nailing/stapling throughout the building.

Gruening's second level is open to the ground floor below in many locations. This provides an open concept and allows natural light throughout the hallways. However, during the Tier 1 screening, engineers noted that the flexible wood diaphragm openings on the second level had re-entrant corners that were not reinforced/strapped horizontally and did not align with the existing lateral-force resisting elements. In addition, the wood ledgers adjacent to these diaphragm openings were not adequately attached to the existing CMU walls. To alleviate these issues at diaphragm openings, Simpson holdowns were installed in horizontal pairs at 49 locations.

Figure 3. Damaged Curtain Support Beam

As a follow-up to the Tier 1 screening non-compliant checklist item, DIAGONALLY SHEATHED AND UNBLOCKED DIAPHRAGMS, all flexible wood diaphragms were evaluated for ASCE 41 Tier 2 compliance. Over 21,000 square feet of diaphragms were strengthened as part of this project. The diaphragms were strengthened by adding blocking (where not present) or adding a new layer of wood sheathing atop existing sheathing. Floor diaphragm strengthening was done from below (due to existing concrete topping over the wood sheathing), whereas roof diaphragm strengthening was done from above in conjunction with the reroofing. All roofing was removed and replaced down to the sheathing, which provided convenient timing to upgrade the roof diaphragms.

As part of this project, engineers reviewed the existing CMU walls compared to current design and detailing standards. Although the ASCE 41 Tier 1 screening compares CMU wall reinforcing to a maximum spacing of 48 inches on-center, current *Masonry Standards Joint Committee* (MSJC) *Building Code* requirements do not allow 48-inch spacing for stack bond masonry, or for Special Reinforced Masonry Shear Walls, which are required in Seismic Design Category D. Current MSJC code requires a minimum spacing of 24-inch spacing for both vertical and horizontal reinforcement. The spacing of the existing masonry reinforcing at Gruening was 32-inches vertical and 48-inches horizontal; the existing CMU walls at Gruening did not meet the minimum spacing requirements of MSJC. In addition, existing unbraced CMU walls greater than 17 feet high were determined to have insufficient out-of-plane bending capacity.

Reid Middleton evaluated multiple solutions to address the CMU wall deficiencies: inserting traditional reinforcing steel (rebar) into the walls, overlaying the CMU with Simpson FRCM, or overlaying bi-directional fabric-reinforced polymer (FRP). In collaboration with Simpson engineers, Reid Middleton and ASD elected to use FRCM on all existing CMU walls in the building. The use of FRCM accomplished two objectives: upgrading existing stack bound CMU walls to meet current MSJC reinforcing requirements and strengthening tall walls to meet out-of-plane bending capacity requirements.


Figure 4. Removal of Masonry Veneer

FRCM combines a high-performance sprayable mortar with a carbon-fiber grid to create a thin structural layer that does not add significant weight or volume to the project. FRCM had never been used in Alaska prior to this project. Reid Middleton and the Simpson team worked closely during the design and construction phases to ensure the installation went smoothly. In addition, Simpson engineers aided in detail development, including end-of-wall anchorage, as well as specifications.

The FRCM application process was as follows (*Figure 5*):

Figure 5. Fabric-Reinforced Cementitious Matrix (FRCM)

1. Remove finishes from single (or both) sides of masonry shear walls as noted on plans.
2. Remove paint from the surface.
3. Fill the existing CMU flutes and place the fabric matrix. The anticipated added thickness to the CMU wall is a maximum of ½ inch.
4. Trowel finish and paint as shown on Architectural Drawings.

With close collaboration between the contractor, Simpson, and the engineer, the FRCM installers could place the FRCM ahead of schedule. The installers covered approximately 36,000 square feet of wall with FRCM per the structural drawings. Most of the FRCM was single-sided, except at the tall walls of the MPR, where FRCM was required on both faces of the wall to address deficient out-of-plane bending reinforcing.

Returning to School

Students returned to Gruening Middle School on August 17, 2021. On October 14, 2021, the principal of Gruening Middle School, Mr. Bobby Jefts, the ASD superintendent, Dr. Deena Bishop, Alaska's governor, Governor Mike Dunleavy, along with students, parents, and the design and construction team celebrated the ribbon cutting at Gruening. Students proudly gave tours of their revitalized school, which has been upgraded to receive excellent marks during the next earthquake pop quiz.▪

Full references are included in the online version of the article at **STRUCTUREmag.org**.

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Project Team

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