Seismic Retrofit and Structural Improvement of a Camp Facility for Children with Life-Altering Medical Conditions

I. Project Description

Introduction

Camp X provides year-round programs for children with serious medical conditions. The camp's Executive Director approached our university requesting us to evaluate the building currently used as an activity space for campers and lodging for camp volunteers. Specifically, they requested that we perform a seismic evaluation of the building, make it universally accessible, and remodel some of the facilities within the building. During the 2022-23 academic year a team of four civil engineering seniors successfully completed this work as their capstone project under the supervision of three civil engineers (2 PEs and 1 SE) from a local structural engineering company and a faculty advisor.

Background of the Facility

Camp X (hereafter also referred to as the lodge) was started by a family in mid-2000 in memory of their child who was lost to cancer at a young age. The camp provides year-round programs to children and families affected by life-altering medical conditions so they can experience the joy of camp.

Built in 1968, the lodge is a three-story, wood-framed building originally constructed as a summer camp for a different organization. The current facility has a total floor area of approximately 7,000 sq. ft. Various views of the structure are shown in Fig 1.

Figure 1. Views of Camp X from southwest (top left), east (top right), south (bottom left) and north (bottom right)

Project Scope

Camp X requested the student team to accomplish the following:

- The team produce **engineering drawings** of the building from their site visit as these drawings were missing from Camp X's records.

- The lodge was built before seismic provisions were in place. The team perform a **seismic evaluation** of the lodge and recommend retrofits for any deficiency.
- The team perform some **non-seismic improvements** to the lodge to **make it universally accessible**: The improvements address the following problems: i) to access the main floor where primary activities take place, one has to take a few steps down from the main entryway; the main floor needs to be made universally accessible, ii) none of the stalls in the main floor bathroom are ADA (American Disability Act) compliant and the bathroom itself is congested and needs redesign, iii) the current kitchenette to be converted into a full-size kitchen.
- Perform a **cost estimate** for the above improvements.

Project Implementation

Development of Engineering Drawings of the Lodge

During the site visit, the team took physical measurements and 3D scan images of the inside of the building. Using these the team developed the engineering drawings of the building using AutoCAD. The floor plans of the building developed by the team are shown in Figure 2.

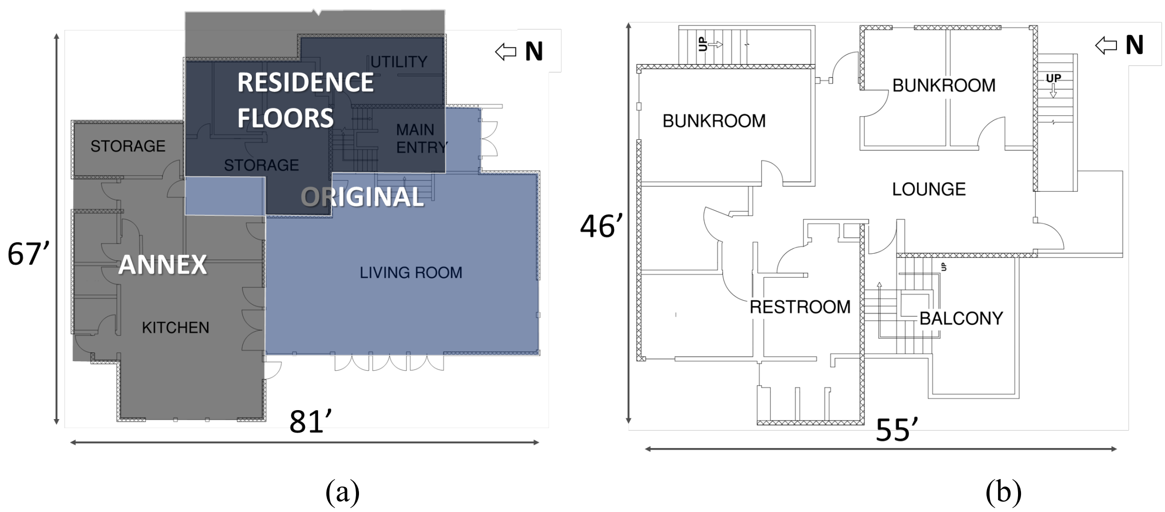


Figure 2. Floor Plans of the Lodge: a) main floor, b) second and third floors

The original building was constructed in 1968 and has an open ceiling up to the roof. In 1994 an annex was added as shown in Figure 2a. The mezzanine area at the east end of the main floor has a residence area (Figure 2a). The second and third stories have the same floor plan and consist of sleeping quarters, a lounge, and a communal restroom for the campers (Figure 2b). The engineering drawings were helpful in the analysis and development of options for the seismic retrofits and non-seismic improvements. The poster shows various inside views of the lodge taken using a 3D scan camera during one of the site visits which will help the reader better visualize the interior of the lodge.

Seismic Analysis, Deficiencies and Retrofits

The team identified seismic deficiencies in the lodge by carrying out a Tier 1 analysis as specified in ASCE 41-17 (*Seismic Evaluation and Retrofit of Existing Buildings*). This involved visual inspection of the structure followed by seismic analysis and evaluation.

The team analyzed the lodge as category II (*ie. residential structure*), seismic hazard BSE-2E (*ie. 5% probability of exceedance in 50 years*) and for a structural performance objective of collapse prevention (*ie. occupants will be able to exit the building safely in a design level earthquake*). Using these parameters and the building characteristics, the team calculated the forces acting at the floor diaphragms of the lodge in the event of an earthquake. This is shown in Figure 3.

Based on the above, the team identified deficiencies and made recommendations that would improve the lodge's seismic performance. These are described below. *Due to space constraints some of the retrofits are described in this portion of the submittal and the rest are presented in the poster.*

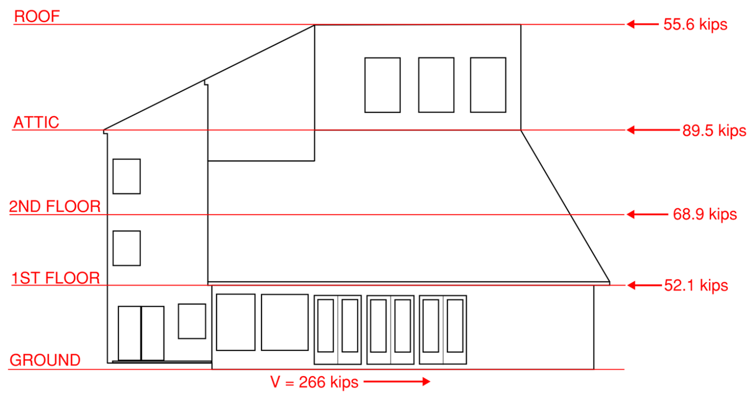
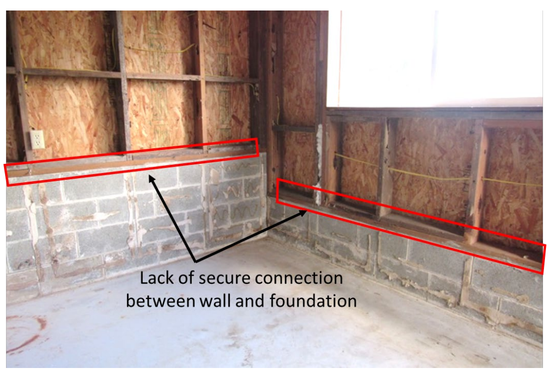
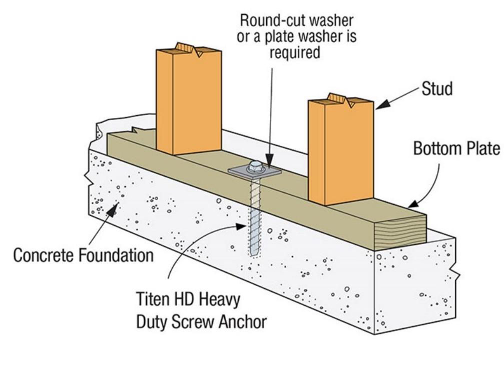


Figure 3. Seismic forces at Floor Levels of Lodge

Timber wall members lacked secure connections to the foundations as shown in Fig 4a. During a seismic event this may result in shear failure at the wall-foundation interface. To overcome this deficiency, the team designed wood sill bolts, shown in Figure 4b, using the Simpson Strong-tie Anchor Designer software. Titan HD screws, 3/4" diameter and 4" long, were recommended to be installed at a center-to-center spacing of six feet.



(a)



(b)

Figure 4. Wall panel-foundation: a) Seismic Deficiency and b) Retrofit Recommendation

The team found that in the event of an earthquake the mezzanine may rotate about the wall and/or slide against the wall as indicated in Figure 5. To resist rotational motion, Simpson Strong-Tie HDU2 Holdowns were added at each corner of the mezzanine connecting it to the wall with anchors penetrating the wall studs. To resist sliding, the team recommended adding two ¼" diameter Simpson Strong-Tie SDS Heavy Duty Connector Screws at each wall stud through the rim of the mezzanine-wall connection.

To prevent the wall from crushing when the mezzanine pushes into it, the wall studs at each end of the mezzanine were strengthened using 2x6 Douglas-Fir Larch graded No.1 or higher. These retrofits are shown in Figure 6.

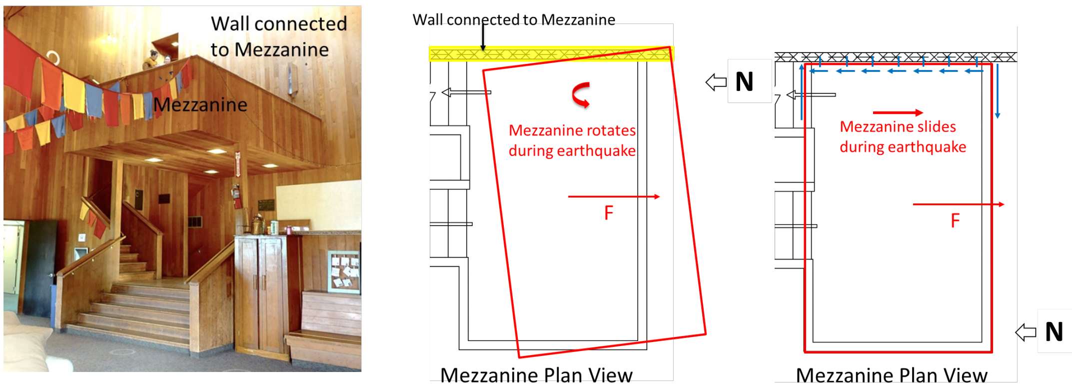


Figure 5. Mezzanine and its Failure Modes During a Seismic Event

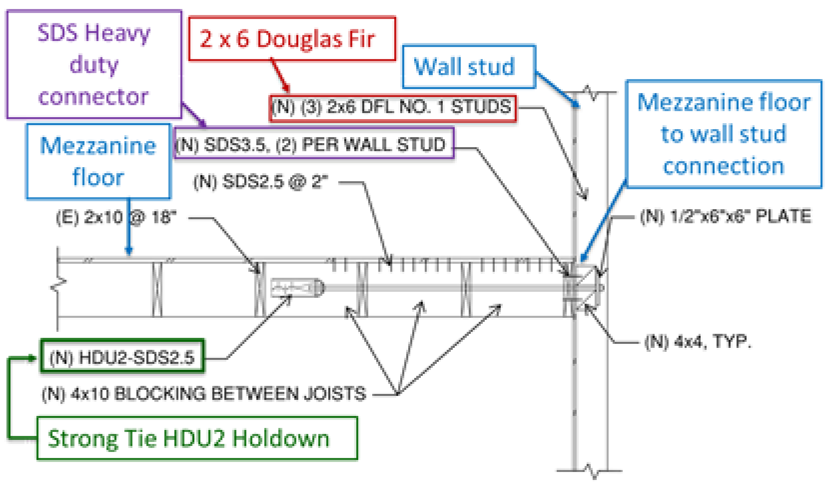


Figure 6. Elevation View of Mezzanine Seismic Retrofit

Roof chords longer than 20 ft had to be strengthened so that the roof deflection is minimized. In addition, the building had several narrow shear walls that resist earthquake forces. These walls had to be strengthened against a seismic event. Roof chord and shear wall deficiencies and their retrofit recommendations are explained in the poster.

Non-seismic Structural Improvements

Per the client's request, the team investigated selected non-structural improvements to the lodge which are listed under the project scope (see page 2, third bullet). Some of these improvements are explained below while the rest are presented in the poster.

The lodge currently has a small kitchenette, shown in Figure 7, that does not meet the needs of the facility. Camp X requested that this be converted to a full-size kitchen. Working with an architectural firm, the team developed preliminary design for a new kitchen.

a) b)

Figure 7. Lay out of the Existing Kitchenette; a) Floor Plan, b) Elevation View

The new design shown in Figure 8 involves removing an east-west running load-bearing wall and replacing it with two 4x6 Douglas-Fir Larch columns and a 5-1/2” x 7-1/2” glue-laminated lumber beam. Two partition walls and doors will be removed, and a window added, making space for a breakfast nook.

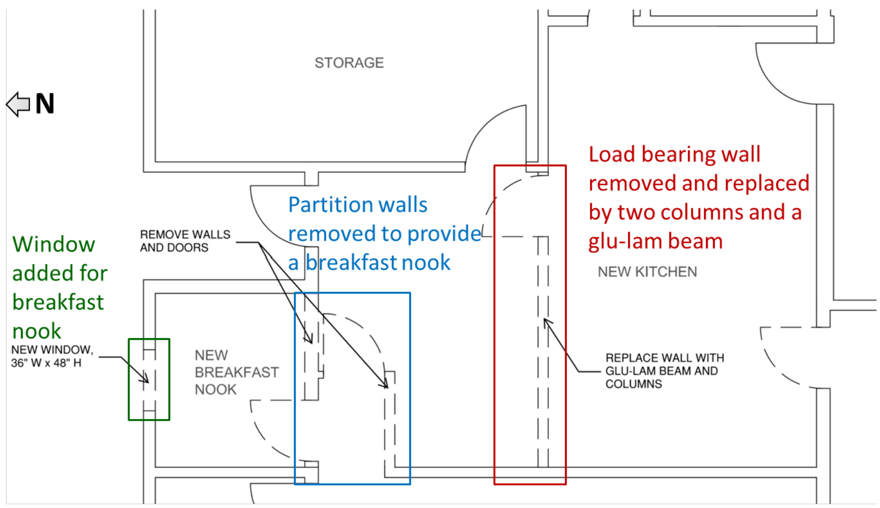


Figure 8. Floor Plan of Preliminary Design for the Full-Size Kitchen and Breakfast Nook

The poster offers insights into how the team ensured the bathroom and entryway to the main floor were made universally accessible.

Cost Estimate

The team consulted with a construction company to arrive at a cost estimate for the project. The team found that the project could be completed in an estimated time of eight weeks with six full-time laborers for a total cost of $365,000. Of this total cost, $170,000 will be for labor, $149,400 for materials, $11,000 for Simpson Strong Tie products and $35,000 for subcontractors.

II. Collaboration of Faculty, Students and Licensed Professional Engineers

All engineering students are required to successfully complete a team-based, industrially sponsored, year-long capstone project. The team for the above project consisted of four students and was supervised by a faculty member. A local engineering firm served as the owner representative and three engineers from that firm (two PEs, and one SE) provided technical guidance to the team. This team of three engineers is hereafter referred to as liaison engineers. A licensed civil engineering faculty member (PE) taught the senior design course and provided feedback on the project throughout the year.

The students met with their faculty advisor and the liaison engineers weekly. The faculty advisor and the senior design instructor provided technical assistance throughout the project, provided feedback on several drafts of the proposal in fall quarter and the final report in spring quarter.

Our department has an active advisory board consisting of about a dozen local licensed civil engineering practitioners. The board meets twice a year to provide feedback on curriculum, employment opportunities and to discuss other industry-academic issues. The student team made an oral presentation to the board in early winter quarter describing their project scope and plan of action and received valuable feedback. The spring quarter presentation covered their final design and recommendations to the client.

All civil engineering capstone teams participate in an annual American Society of Civil Engineers (ASCE) local section presentation competition. These presentations were judged by a panel of five civil engineering practitioners (4 PEs and 1 EIT). The format for this competition is a 15-minute oral presentation followed by questions and answers.

III. Benefit to Public Health, Safety and Welfare

The mission of Camp X had a huge impact on the team. The project showed the team how engineers could be involved in worthy social causes. Seismic retrofits will bring the lodge up to current safety standards. The remodel of the bathrooms and the design of a wheelchair lift from the entryway to the main floor *(both described in the poster)* will make the building universally accessible.

IV. Multidiscipline or Allied Professional Participation

This project required expertise in structural and seismic engineering, architecture, cost estimation and engineering drafting. The team met with two architects for assistance with the non-seismic structural improvements. The architects provided guidance on the code requirements for universal accessibility of the lodge and requirements for the kitchen remodel. The team also worked with a construction company to arrive at a cost estimate for the construction.

V. Skills Gained

Students developed a range of skills through this project: technical skills, oral and written communication skills, project management and leadership skills, ability to work in a team setting and to interact with a non-engineering client.

a) Technical skills

The students learned how to carry out a client's dream from the conceptual stage through architectural drawings to engineering design. Through the design process they acquired the skill to use the following tools:

- Design Manuals: ASCE 41-17 (*Seismic Evaluation and Retrofit of Existing Buildings*), ASCE 7-16 (*Minimum Design Loads and Associated Criteria for Buildings and other Structures*), IEBC 2018 *(International Existing Building Code*), 2018 American Wood Council (AWC) National Standards
- Computer aided drafting (AutoCAD 2023)
- Design Software: Simpson Strong-tie Anchor Designer software

b) Communication skills

The students submitted a written proposal to the client at the end of fall quarter, outlining their understanding of the project, scope of work, plan of implementation, and schedule. At the end of spring quarter, they submitted a final report describing the work done, engineering calculations, drawings and other deliverables as initially agreed.

The students had the experience of working for a non-engineering client. The students had to translate the client's "language" of needs and functional requirements to engineering "language" of design parameters and constraints. Then, the team had to prioritize the functional requirements of the client and convert them into measurable parameters prior to the design.

The students were required to make oral presentations to the class twice a quarter and each student had to make at least one presentation each quarter. The academic year concluded with a conference style event, where the team presented its work to the entire university community, sponsors of all the senior capstone projects, prospective sponsors, friends, and alumni.

c) Project Management and Leadership skills

Each team member served as the project manager for part of the academic year. The project manager was responsible for setting up team meetings, developing meeting agendas, conducting the meetings, assigning tasks to the team members and following up on action items. The project manager was also responsible for contacting the client, the liaison engineers, and the faculty advisor, as needed.

d) Awareness of Social Issues in Engineering

Students were made aware of how engineers could be involved in valuable social causes. The camp facility relies on donors to implement improvements, and the engineering drawings developed by the team will be used for fund-raising by the camp facility.

VI. Summary

A team of four civil engineering seniors carried out the seismic assessment and universal accessibility improvement of Camp X that serves as a haven for children with life-altering medical conditions. The project was supervised by two faculty members (one of them a PE), three civil engineers (two PEs and one SE) from a local civil engineering company. The project will improve seismic safety standards and make the facility universally accessible. This project provided the students an opportunity to provide engineering services to a worthy cause while developing marketable skills.