BYU ENGINEERING
Civil & Construction Engineering

CAPSTONE

# TIMBER FASTENERS
# PROJECT ID: CEEN_CPST_013

**by**

**ADW Engineering**
**Wyatt Payne**
**Alex Winward**
**Decker Ure**

**A Capstone Project Final Report**

**Submitted to**

**Kip Apostol**
**Of Euclid Timber Frames**

**Department of Civil and Construction Engineering**
**Brigham Young University**

**April 11, 2022**

# Executive Summary

**PROJECT TITLE:** TIMBER FASTENERS
**PROJECT ID:** CEEn_CPST_013
**PROJECT SPONSOR:** Euclid Engineering
**TEAM NAME:** ADW Engineering

The object of this project was to perform static lateral load testing on cross laminated timber (CLT) walls. The four tested walls were 10 feet tall and 8 feet wide and used wood screw connections. Two of the specimens also included dovetail members so as to compare the effect of dovetails on a walls' strength. For this project, our team was tasked to construct a testing frame and apparatus as well as develop a testing procedure to determine the strength parameters of the wall. After testing, the team was also tasked with performing both numerical and visual analysis of data collected to present to the project sponsor. Completion of these tasks will be determined by evaluation of a final report and presentation presented to the sponsor.

The ADW Engineering team tested two CLT walls with dovetail members and two standard CLT walls for control. The walls were tested over a 6-week period between January 11, 2022 and February 17, 2022. During this time, preliminary data analysis was performed so as to ensure our test results were meaningful and fell within an expected range of values. From February 21, 2022, to March 21, 2022, the shear test data was aggregated, and a more comprehensive data analysis was performed. Our final results were presented to Euclid Timber Frames on April 11, 2022, in the form of a final report and presentation.

The final report, included below, will provide all test results, mathematical and visual analysis, an explanation of testing methods used, as well as all assumptions made during testing. After a presentation of our findings, ADW engineering will also present structural recommendations to the sponsor.

The sponsor presentation will also be provided to the sponsor on April 11, 2022. The sponsor presentation will include a brief overview of the project, discuss project details, as well as detail challenges faced during testing. The presentation will also include a brief analysis of the test results, summarize the team's conclusions, and present all design recommendations from ADW Engineering. During the presentation, the sponsor will also be able to ask questions and challenge any aspect of the project, including testing, design, and analysis. A copy of the presentation will also be provided to the sponsor in the form of a PowerPoint file provided sponsor representative.

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# Introduction

The project was to run a lateral load test on a variety of timber walls in order to prove the efficacy of CLT walls in residential applications on behalf of Euclid Timber Frames. CLT walls are large-scale, prefabricated, solid engineered wooden panels. They are lightweight, strong, and produce little on-site construction waste, making CLT panels an alternative to conventional building materials and practices in multifamily and commercial construction. CLT panels consist of several layers of kiln-dried lumber boards stacked together in alternating directions and are generally not used in shear applications. As CLT technology has become increasingly popular in construction, its use as a shear wall element has come into question. Generally, CLT shear walls have not been used due to the lack of an economic connection type that does not compromise the structural integrity of the wall. This test aims to explore effective base connections, prove whether the sponsor's dovetail geometry fulfills this need as well, as establishing the general structural parameters of a variety of Euclid Timber Frames' CLT walls.

In order to establish the strength parameters of the CLT walls, ADW engineering was tasked with designing and building a testing apparatus capable of racking several sample walls provided by the sponsor and testing them in shear. The ADW team developed a stiff steel frame to restrain the base of the shear wall and prevent out of plane movement. Steel connections were used to transfer lateral load from a hydraulic actuator to the top of the shear wall. For each test, the specimens were instrumented with string potentiometers to measure displacement and ensure that no excessive out of plane movement occurred, while the hydraulic actuator's internal mechanisms provided load and lateral displacement measurements.

Testing was performed on four timber walls from January 24, 2021 to February 11, 2022, two of which were tested as a control. After testing, an in depth numerical and visual analysis was performed on the test wall data to ascertain the structural parameters of each wall. The ADW engineering team performed numerical analysis to develop load-deflection curves for each wall specimen tested. ADW engineering also made note of the moisture content, species, and grade of each wall specimen, though in-depth analysis of said parameters was beyond the scope of our analysis.

After receiving our first timber wall shipment from the sponsor, ADW engineering found that the original frame design needed revision. The original specimen had an overhang used in the field by Euclid Timber Frames to install the wall in the field. The overhang was normally inserted over a wooden base which added extra support and strength at the connection. Due to the constraints of ADW Engineering's original frame design and to be as economical as possible, ADW Engineering and sponsor agreed to cut off the overhang so as to adhere to the original frame design. After the first test, it was found that the shear wall failed first at the bottom, near the points of connection. It was also observed that there was little to no deformation of the actual screw connections attaching the frame to the wall. This failure led ADW engineering to believe that the connection type was suboptimal and influenced the results of our tests, warranting redesign of the testing frame. After discussion with the sponsor, the sponsor provided a new set of walls with the installation plate already inserted. ADW revised their testing frame design, adding Simpson Strong Ties (STHD8) at the bottom connection at either end of the testing apparatus to more closely represent the infield conditions of the wall. Both parties agreed to continue testing with more confidence in the data; however, the next test found that the readily available metal straps were too weak and the straps were the failing point of the next test. Euclid provided thicker, high strength straps (STHD14) for the last wall test, which failed in the same manner as the third wall test. As such, the data from each wall is under a different set of conditions and are not comparable. Even though the data across the different tests is not comparable, ADW engineering believes that the tests still provided meaningful data and insights into the general strength parameters of the wall types. The ADW team recommends more testing to make further analysis.

# Schedule

The schedule starts in December and runs through April.

December 8th; The team met with Dave Anderson to determine when testing can be performed

December 8th – December 15th; Team created initial testing framework

December 15th - January 5th; No work done for Finals and Christmas break

January 5th – January 18th; Design review with Euclid, Initial design changes

January 24th; First shear wall test. Initial issue discussion

January 24th – January 31st; Testing frame redesign and approval

January 31st – February 11th; Continuation of shear wall testing

February 12th – March 28th; Data analysis

March 29th - April 8th; Presentation development and project write-up

April 11th; Presentation of results to Euclid

# Assumptions & Limitations

While developing our testing frame and procedure, ADW made a variety of assumptions to simplify design and calculations. Namely, we assumed that there was no out of plane movement of the wall and that our testing frame restrained it effectively. To achieve this result, the wall was braced on the top and bottom in metal sleeves and was loaded only in the lateral direction. This assumption was proven to be acceptable because our out of plane string potentiometers measured almost no displacement. We also assumed 100% efficiency in our testing frame and that all lateral loading was transferred to the test walls. In reality, some energy would be lost from the actuator to the actual wall because of the frame geometries and the mechanical inefficiency of the hydraulic actuator. This assumption affects our calculations as it assumes that a slightly larger than actual load value would produce the displacement at failure. We believe this assumption to be acceptable as the actual inefficiencies in our system were expected to be low. Any uncertainty due to this assumption can be accounted for in field applications by the use of a factor of safety in the calculations.

The connection point of the testing frame is the biggest limiting factor for our testing apparatus. As mentioned earlier in the Introduction section, the connection between the wall and the testing had direct impacts on our tests. In the first test, the large screws connecting the testing frame to the wall added strength at the base and skewed our results larger as proven by the lower strength results in subsequent tests. This phenomenon is also highlighted in Figure 2A below showing that the screws pulled out of wall one after failure experienced little to no deformation, suggesting that the actual connector was not the direct cause of failure. To reduce any possible influence the connector had on lab test data, smaller screws were used in subsequent tests as seen in Figure 3A below.

Each other wall test also failed at the bottom, near the connectors, denoting that the bottom of the wall was the weakest section. However the wall may have failed prematurely in this region due to the differences between lab and field conditions. While the ADW engineering team went through several iterations of the testing frame, we could not perfectly match in field conditions and so the strength values measured were not wholly representative. We would expect the maximum strength values measured in lab tests were lower than those exhibited in the field.

Apart from the limitations listed above, our experiment was also limited by the number of tests performed. We performed two tests on walls with standard timber connections and two tests with the dovetail members. Wood walls have more variability in their general strength than walls built from other materials due to the fact that wood is not an engineered materials and can contain defects and other minor differences between samples. The strength values measured in this report relate specifically to the walls tested and can only be used to determine an approximate understanding of the strength parameters of the given wall type and design. The ADW engineering team did not perform enough tests to develop a statistically average set of strength parameters.

# Design, Analysis & Results

The ADW engineering team began our testing frame design by holding several meetings with the BYU structural lab team and brainstorming several possible frame designs that could apply the desired loading to our wall samples. We expected to need to apply at least 40 kips to our wall to induce failure because of literature reviews conducted by the ADW Engineering team (See Figure 1A). Ultimately the team settled on a pair of sleeves on the top and bottom of the wall to serve as the connection pieces from our wall to an already existing testing frame in the BYU structural lab. To use this testing frame design, the ADW engineering team had to make several alterations to the walls provided by the sponsor. The first two walls delivered to ADW Engineering had an overhang used in the field to better facilitate connections to a concrete base structure. After discussion with Euclid, the overhang was decided to be non-essential and was cut off. ADW Engineering also routed ¼" off either outside face of the CLT wall with Euclid's consent in order to fit the BYU structures lab's readily available sleeves. Both of these changes were adopted so as to be economical and expedite the testing process, and allow for installation of the walls into the existing steel members. Without these changes, new steel members would have had to be manufactured at significant expense to ADW Engineering and slowing down the testing process. This preliminary design can be seen in Figure 2 below.

**Figure 1: Wall 1 After Modifications**

**Figure 2: Preliminary Testing Frame Design**


After selecting our initial design, ADW Engineering performed several calculations to ensure the frame was strong enough to restrain the wall and resist any load applied to the wall, including calculations to select an appropriate size pin to connect our actuator to the top sleeve. After our initial series of calculations, the testing frame members were accepted, and the frame was built.

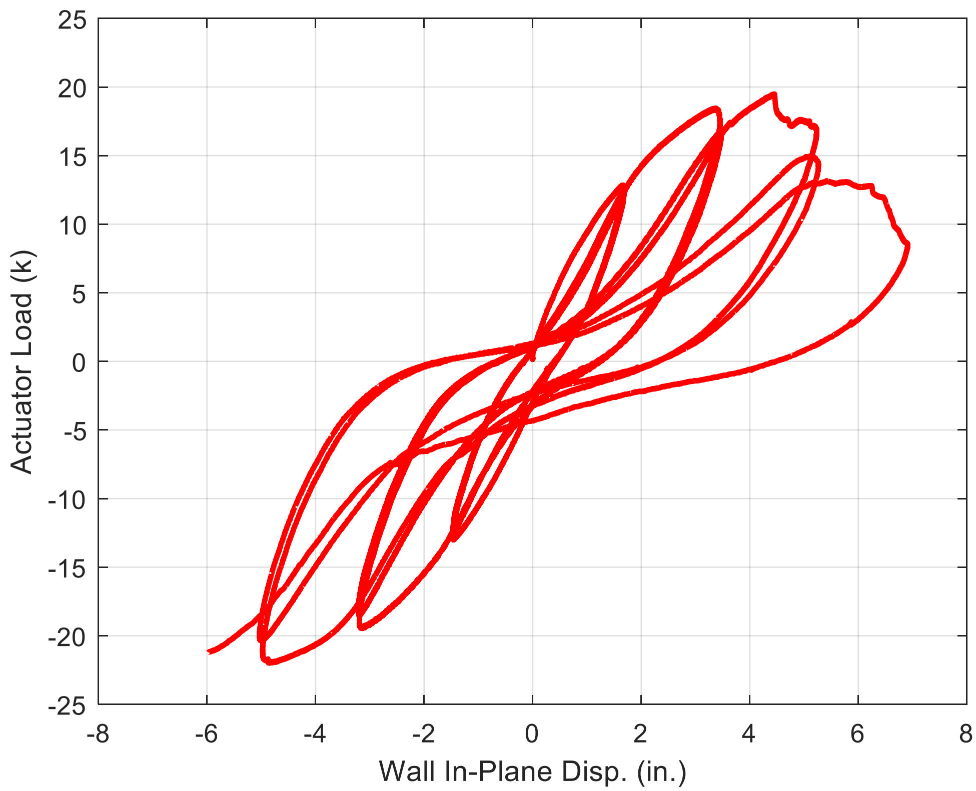
After the initial wall test, the ADW Engineering team recorded the data and photographed the failure plane as seen in Figure 3 below.

**Figure 3: First Wall Failure Mode**

**Figure 4: Wall Test 1 Pull-Out**

The first CLT Timber wall failed at the bottom plate. From our initial inspection of the failure, the ADW Engineering team concluded that the given plane of failure was at the bottom plate and that the results may have been skewed by the large screw connectors embedded in the material which did not accurately represent in field conditions. This was alluded to in both Figures 3 and 2A as the screws themselves exhibited little to no deformation despite being directly adjacent to the failure plane. The maximum strength measured from this test was approximately 20 kips (See Figure 5). The displacement of the wall at failure was approximately 4.5 in.

**Figure 5: Wall 1 Load vs. Displacement**




This measurement is likely significantly higher than the actual strength of the wall due to the added stiffening of the large screw connectors. As such, the wall was redesigned to correct this issue. The ADW Engineering team identified several adaptions to account for the overhang and other flaws in the current iteration of the wall design, and so the testing frame was altered to reflect these changes.

For the second wall, the wooden base traditionally used by the sponsor in practice was placed in the overhang to better reflect the infield conditions of the CLT frame walls and to eliminate any issues caused by said overhang. There were also several alterations made to the testing frame. ADW Engineering changed the design to only use lag screws in each vertical member, mirroring common practice for Euclid Timber Frames in the field. ADW also redesigned their connectors, using 61 4" lag bolts in the bottom member for similar reasons. Most importantly, the team screwed into the wall laterally instead of vertically, as done in wall 1. Although some minor alterations were made to the testing frame, the testing procedure remained the same (see Figure 4A in Appendix). After running the test, the ADW Engineering team noticed a similar failure plane along the bottom of the wall. The maximum strength measured for wall number two was approximately 8 kips. (See Figure 6) The displacement of the wall at failure was about 3 in. The measured strength was much lower than that of wall one, confirming to ADW Engineering that the first wall's strength had been affected by the first wall frame design. During the testing phase, the wall exhibited significant rocking, which would affect the results of the test. Since the wall failed prematurely, ADW Engineering returned to the design process to improve the frame-wall connection for future tests.

**Figure 6: Wall 2 Load vs. Displacement**

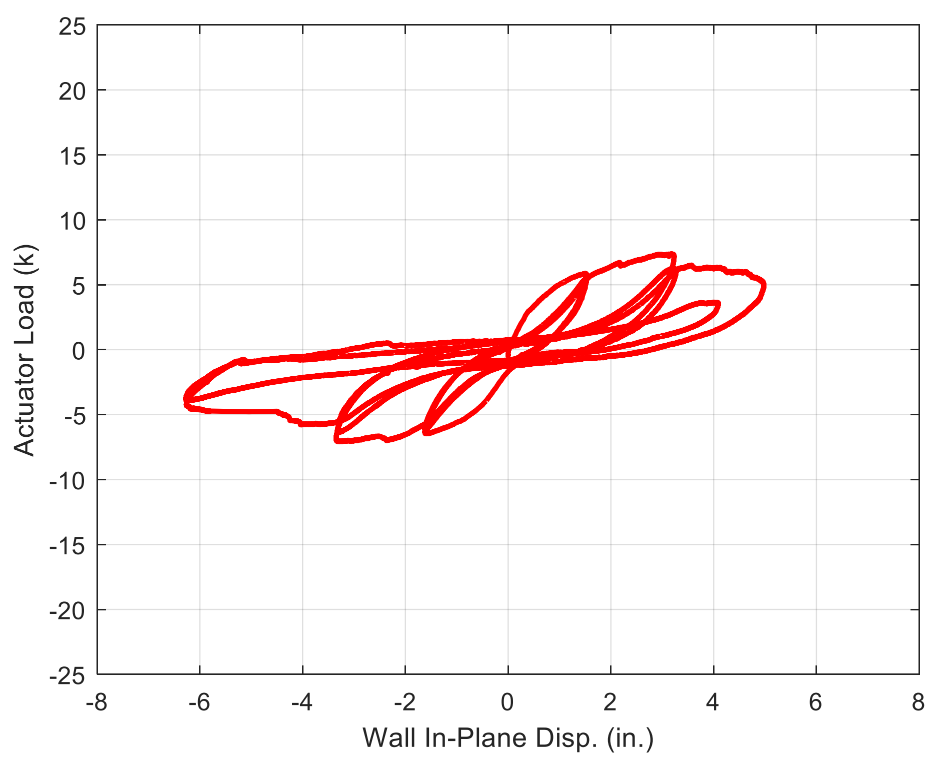


**Figure 7: Wall 2 Lateral Screws Before Installation**

**Figure 8: Wall 2 Testing Frame**

**Figure 9: Wall 2 Failure Mode**

The third CLT timber wall testing frame was redesigned including (2) STHD8 steel straps on either side of the bottom of the testing frame to add extra support rocking. The redesigned testing apparatus can be seen in Figure 10 below.

**Figure 10: Third Wall Frame Alteration**

The testing procedure was again held constant during the third wall test. This test was much shorter than the previous two wall tests, and the wall failed first at the straps, which broke clean through (See Figure 12). This would affect our results by lowering the maximum measured strength of the wall. The approximate measured strength was 17 kips (See Figure 11). The displacement of the wall at failure was approximately 4.8 in. After discussion, the ADW Engineering team and Euclid engineering concluded that thicker metal straps may resolve this issue. The sponsor provided a second set of (STHD14) metal straps which were used for our final shear wall test.

**Figure 11: Third Wall Primary Failure Mode**

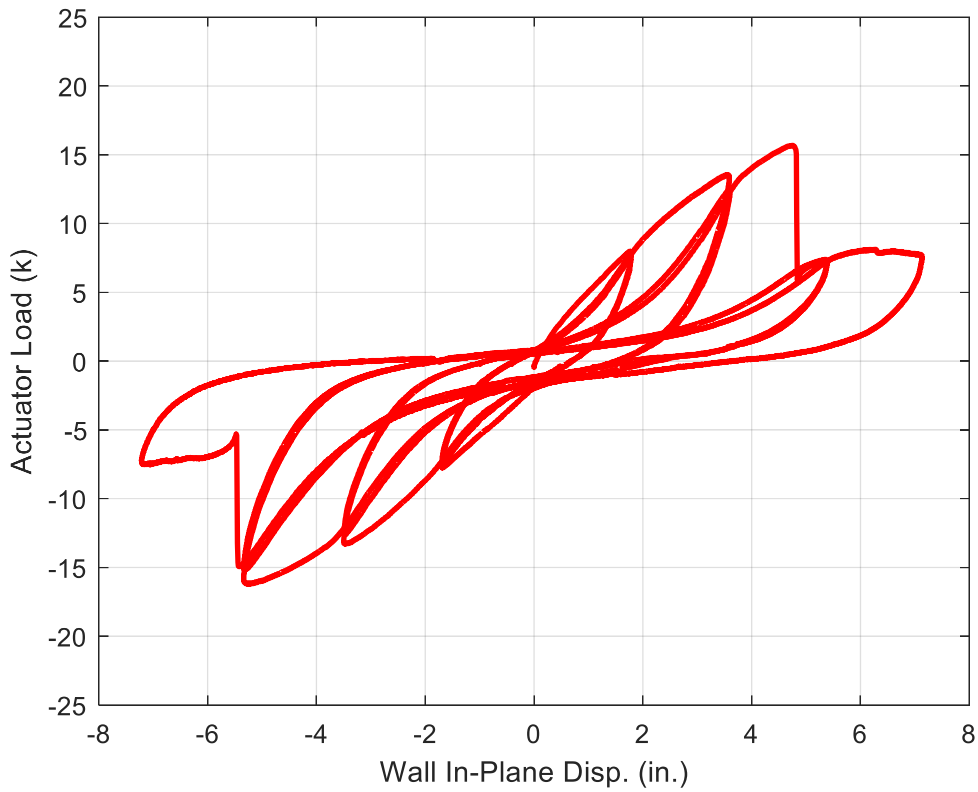


**Figure 12: Third Wall Primary Failure Mode**


**Figure 13: Third Wall Secondary Failure Mode**

The fourth wall test was performed using the same frame design as seen in Figure 10. The thicker steel straps can be seen below in Figure 14. The same testing procedure was followed with the fourth test and the wall was loaded till failure. The last shear wall also failed at the metal straps. The maximum strength of the wall was measured to be about 14 kips. (See Figure 15). The maximum displacement at failure was approximately 4 inches. Since the wall failed first at the metal strap connections, the ADW Engineering team concluded that the actual strength of the wall is higher than that measured.

**Figure 14: Wall 4 STHD14 Straps**

**Figure 15: Wall 4 Load vs. Displacement**

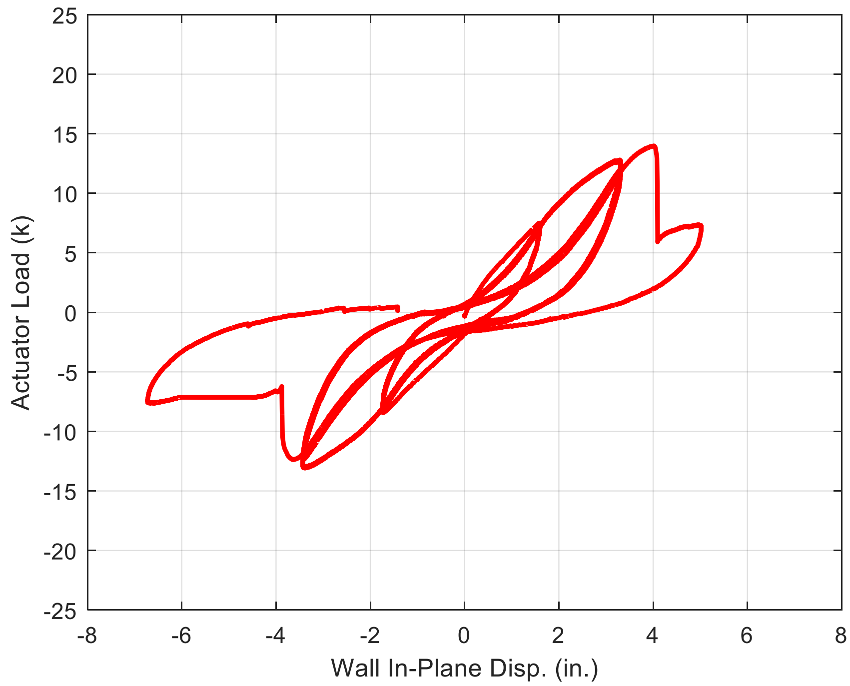



**Figure 16: Wall 4 Failure Mode**

After comparing the four tests, the ADW engineering team concluded that the tests are not truly comparable. This is because each wall was tested under slightly different conditions, with only the testing procedure held constant. Less confidence can be placed in the results of the first two tests as the first two iterations of the frame design did not account for the overhang in the test walls. The sponsor can have some confidence in the second two tests; however, the exact strength parameters of the walls cannot be determined from the current suite of tests. Because the first two tests results' are in question, it is also difficult to compare the dovetail and standard connection walls.

# Related Issues

There are several impacts that our project could have on the greater community, mainly in increasing the efficiency and sustainability of prefabricated construction. CLT walls have little to no waste compared to traditional wooden manufacturing products. They also have excellent thermal performance, cutting heating and cooling costs in building using said systems.  Researching and testing the strength parameters of these walls can inform the public about the efficacy and strength of CLT timber walls and increase their popularity and adoption. This could improve the sustainability of the construction industry overall, and reduce reliance on expensive building materials like concrete.

CLT timber walls have high fire and seismic performance. Implementing CLT walls in construction applications will increase the safety of all those living within those buildings. The buildings will be more resilient to disasters and their effects, resulting in less loss of life and property. If CLT walls can be applied in shear situations more easily, this can expand its uses in construction and allow contractors to maximize CLT walls' intrinsic safety capabilities.

CLT timber walls are also an excellent choice for prefabricated construction. Prefabricated construction is an innovative construction technique, saving on on-site labor costs, and allowing for efficient and easy construction. Prefabricated CLT timber walls are constructed off-site with cost efficient manufacturing, and then shipped to the location. This and the on-site labor saving from their modular design combine to bring significant cost savings to the industry as a whole. Along with saving on costs, the increased construction speed resulting from the use of prefabricated members could allow firms to take on more projects, benefiting the community as a whole.

CLT timber walls are beginning to be adopted in shear applications; however, there is significantly less data on such systems when compared to traditional systems. Currently accepted research and data purports that CLT timber walls may be used in shear application as long as strong inter-panel connections are used. If the results were more readily comparable, this test would have given the sponsor useful information about the efficacy of their current timber connection design, informing them on whether the walls' shear capacity was improved. As it stands, the data provided serves as a strong starting off point for greater research to improve the dovetail member geometry and overall shear strength of CLT timber walls.

# Lessons Learned

The ADW Engineering team grew personally and professionally while working on this project. Our first lesson was in the value of industry knowledge, especially from those in direct contact with the work. The BYU structural lab team, headed by Dave Anderson, and Johnn Judd, were integral to the planning and design behind the whole testing system. As young engineers, the ADW team needed a lot of help to get started and understand the intricacies of building a testing frame and system. Our lab manager was a vocal mentor and advisor, explaining what they had seen in the past and what had worked in their previous experience. Because the ADW Engineering team followed their advice, we were able to begin our tests quickly and had time to make changes to our design and still meet project deadlines.

The ADW Engineering team also learned how important advanced planning is to the success of the project. As mentioned previously, we were able to accept delays and take enough time to fully consider each problem we considered and plan an efficient response. We also were able to work around difficult schedules, both within and without of the team. The ADW Engineering team was able to perform our tests within the overall structures lab schedule without disrupting any other tests because we were able to prioritize important tasks and work requirements that were necessary to keep our project moving forward. Without that, we might have run over time and affected other projects.

ADW Engineering also found how important literature review and study is for the sake of a project. Even though we had some experience in the form of structural engineering classes, we were not prepared to design a test on our own. The ADW engineering team recognized our inexperience and reached out to all sources for information on how to complete the project. During that experience, the ADW team found several wall racking tests (See Figure 1A in Appendix A) and from that were able to build an effective testing procedure. We also found examples of steel member calculations, and so we were able to check our calculations against examples and move forward with confidence even though two of our team members had not previously taken steel design classes.

# Conclusions and Recommendations

The results of the project were generally mixed. The ADW team found that the general strength of the traditional CLT timber walls were 14 kips. Conversely, we found that the dovetail members had an average strength of about 15.5 kips. Both of these values had significant amounts of uncertainty and require further testing. The team arrived at this conclusion by averaging the strength values measured for each wall type. Those values were found by analyzing the stress strain data as seen in Figures 4A, 6A – 8A. We believe that the results presented are justified as we used best industry practice to perform our analysis.

Our team recommends further testing to confirm the team's findings and build upon the current information. The ADW engineering team ran into several issues that significantly affected the results from the given wall tests. (Described in the Design, Analysis and Results section) As such, it is difficult to draw concrete conclusions from the current data. However, most issues in the testing frame have been worked out and the sponsor could use the final design when conducting future tests. The sponsor could also take the average strength values computed to inform them on the lower bound of strength values expected from each type of wall for future construction purposes.

# Appendix A

**Figure 1A: Literature Reviewed During Design**

**Literature Reviewed**

Decker, Brandon Todd. "In-Plane Lateral Load Capacities of Vertically Oriented Interlocking Timber Panels." *Brigham Young University*, Department of Civil and Environmental Engineering, 2014.

Pozza, Luca, et al. "Cyclic Response of CLT Post-Tensioned Walls: Experimental and Numerical Investigation." *Construction and Building Materials*, vol. 308, 2021, https://doi.org/10.1016/j.conbuildmat.2021.125019.

Tran, Dang Khai, and Gi Young Jeong. "Nonlinear and Elasto-Plastic Behaviors of Cross-Laminated Timber (CLT) Walls under Lateral Loads." *Construction and Building Materials*, vol. 295, 2021, https://doi.org/https://doi.org/10.1016/j.conbuildmat.2021.123632.

**Figure 2A: Connection Screws After First Wall Failure and Disassembly**

**Figure 3A: Change in Connection Screws After First Test**

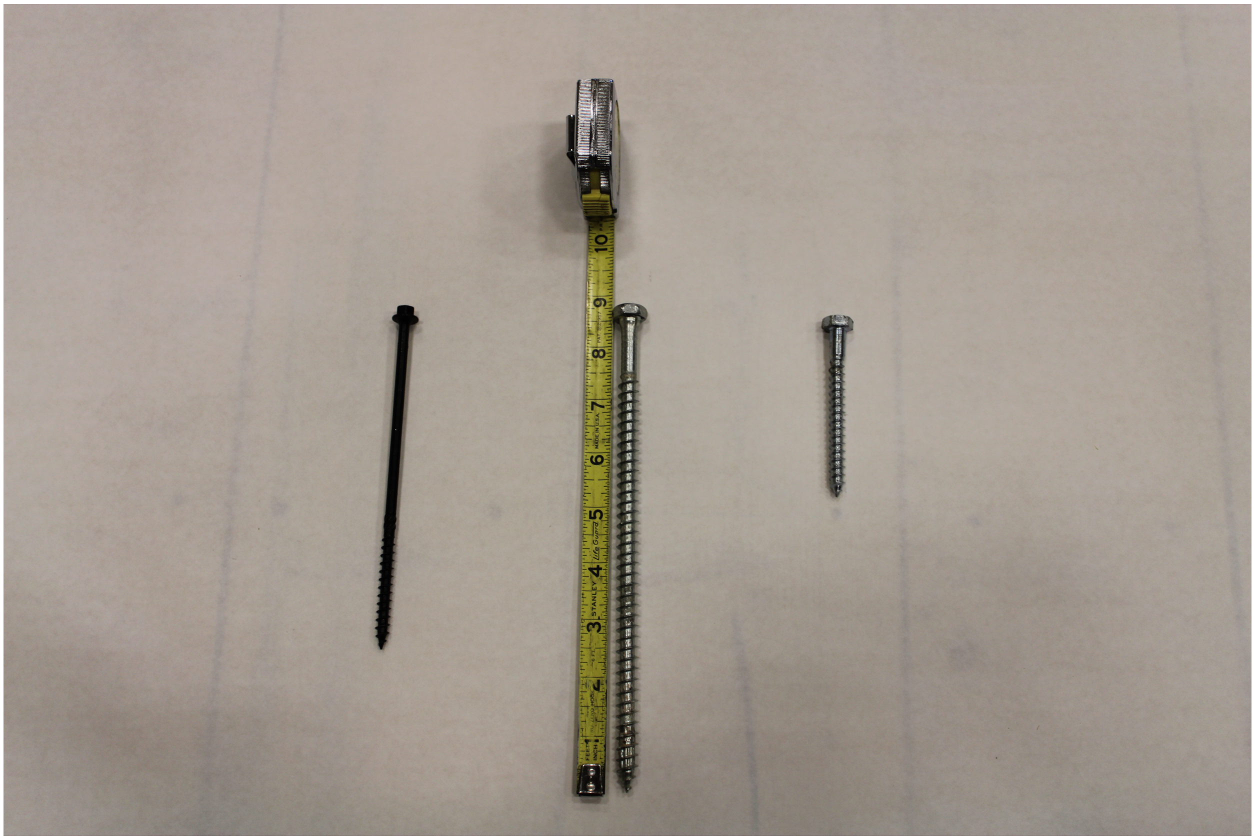


**Figure 4A: Testing Procedure**

1.The wall shall be initially loaded laterally at a strain rate of 2”/minute
2.The wall shall be loaded at that rate until it reaches an initial deflection of 2” forward from the actuator, and then reset to the base position.
3.After resetting, the actuator shall pull the wall backwards at the same rate until the wall reaches -2” deflection.
4.This process shall be repeated once at the given deflection point, providing two cycles at a given deflection.
5.After two cycles at a given deflection, the process will be repeated again at the same strain rate, adding 2” to the allowable deflection. (i.e. 2” followed by 4” followed by 6” and so on.)
6.This procedure will be repeated until failure.

# Alex Winward

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## EDUCATION

**Brigham Young University** Dec 2022
Bachelor of Engineering: Civil and Environmental, Emphasis in Environmental Provo, UT

- Applicable Certifications received at BYU
- Member of the ASCE, and AAEES
- Related Course Work: Geo-Environmental. Environmental Chemistry, Fluid Flow, Geology, Hydrology, Materials, Soils and VBA

## PROJECTS/RESEARCH

**Capstone Project** Apr 2022
*Team Member* Provo, UT

- Linear Shear Test on a Cross Laminated Timber walls.
    - Worked with a real-world client in a very time efficient manner

## EXPERIENCE

**Bayer AG** May 2020-Aug 2020, May 2021-Aug 2021, May 2022-
*Environmental Engineering Intern* Soda Springs, ID

- Worked on 2020 and 2021 Global Reporting Initiative (GRI)
- Worked on 2020 and 2021 Toxic Release Inventory (TRI)
- Ran "Stack Tests" in 2020, to determine if correct pollutant levels were being counted in past/future TRI reports
- Performed Carbon Monoxide tests on industrial kiln

**J.M Mechanical** May 2018- 2020
*Installer* Hyde Park, UT

- Installed duct work in 25+ Commercial buildings in 10 States
- Constructed 100's of parts for use in installation process

## VOLUNTEER EXPERIENCE

**The Church of Jesus Christ of Latter-day Saints** Aug 2015-Aug 2017
*Volunteer service in Texas and New Mexico* Southern United States

- Dedicated 20 hours a week to cleaning the local communities
- Investigated for family records for dozens of individuals, found over 1,200 individuals to add to Familysearch's database.

## SKILLS/INTERESTS/ACHIEVEMENTS/ABILITIES

- Proficient in WMS, VBA coding, GIS, and Revit
- Hunting, hiking around Southern Idaho, and being with my family.

# Wyatt Payne

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Wpayne397@gmail.com
linkedin.com/in/wyatt-payne-155ab8158

## Education

**Degree Goal-** Bachelors in Civil Engineering by June 2022

- Current: 3.5 GPA
- Member of ASCE for BYU
- Former member of "Engineer's without Borders" organization for SUU
- Sterling Scholar Region Winner for Applied Science and Technology

## Work Experience

**Draftsman, Surveyor, and Materials Tester:** Current Employee for Johansen and Tuttle Engineering, Castle Dale, UT. (Started March 2020)

- Created a variety of proposals for campsite designs in Moab, UT.
- Created road alignments and profiles for possible new roads
- Drafted easements for Emery Telecom fiber optic projects
- Surveyed property for landowners and for the Bureau of Land Management
- Inspector of Chip-Seal, Curb and Gutter, and City Street projects.
- Assisted in bidding for job proposals

**Draftsman and Welder:** Former employee for South Shop Steel, Orem, UT. (May 2019-March 2020)

- Used AutoCAD to create construction plans for warehouses
- Created cost estimates for job proposals
- Operated heavy equipment

**Surveyor,** Former employee for Platt & Platt Inc. Civil Engineering and Land Surveying, Cedar City, UT. (January 2018-May 2019)

- Surveyed on construction sites, property lines, etc.
- Assisted with legal descriptions, submitting completed work, job proposals, etc.

## Qualifications Summary

- Knowledgeable in AutoCAD/Civil 3D
- Assisted with in-field inspecting on construction sites
- Knowledgeable in land surveying, asphalt testing, and concrete testing
- Served a 2-year LDS Church mission in Seattle, WA.

# Decker Ure

Phone: 385-271-3019 E-Mail: deckerure@gmail.com
https://www.linkedin.com/in/decker-ure-6559b4163/

## EDUCATION

**BS, Civil and Environmental Engineering** Minor in Languages of Business — April 2022
*Brigham Young University*, Provo, UT
GPA: 3.41
Related Coursework: Computational Methods, Sustainable Infrastructure, Geomatics, Metals,Woods,+ Composites, Hydraulics & Fluid Flow Theory, Structural Analysis, Soil Mechanics, Seepage & Slope Stability, Deep Foundations
Skills: Autocad, Civil3D, Revit, ArcGIS, Python
Language: Mandarin

## RELEVANT EXPERIENCE

*Asset Management Intern,* Central Utah Water Conservancy District, Provo, UT — August 2021 - January 2022
- Created over 500 entries in an online asset management system to track the lifecycle of existing and future water delivery infrastructure and to guide future O&M planning
- Performed field work, including assisting in formal and internal inspections of water infrastructure
- Assist in project management through construction meeting notetaking and reviewing design drawings, submittals, and invoices
- Collaborated with GIS analysts to create a digital map service

*Airfield Paving QC Specialist,* HHI Corporation, Hill Air Force Base, Layton, UT — May 2021 - August 2021
- Liaised with government QA officials during inspections of the jobsite.
- Processed government correspondence daily and distributed relevant information to subcontractors.
- Organized third party testing information for each phase of an airfield paving project, and ensured each test was performed following stringent government requirements.
- Inspected the jobsite daily and ensured all work was performed to government standards.

*Teaching Assistant*, BYU, CEEN 203-Mechanics of Materials, Provo, UT — January 2021 - April 2021
- Review weekly lectures with students to help students process complex material
- Develop homework helps for each assignment and teach students one on one as questions arise

BYU Concrete Canoe Hull Design Team — August 2020 - Present
- Collaborate with other BYU students to design and build a concrete canoe to compete in annual ASCE concrete canoe competition

BYU Greenhouse Predesign Competition Lead — January 2021 - April 2021
- Lead a team of young engineers in designing and prototyping a portable greenhouse for use by the Utah Winter Farmers Association
- Manage the team to ensure deadlines are being met and ensure a high quality product at RMC 2021
- Publish a professional project proposal and report to a panel of judges at RMC 2021

## ADDITIONAL EXPERIENCE

Committee Member, Utah 2021 Infrastructure Report Card — November 2019 - February 2020
- Conducted research and data collection under the direction of an industry professional
- Compiled and edited findings to be used in the Utah 2021 infrastructure report card

## RECOGNITION

*First Place*, RMC 2021 BYU Predesign Competition — April 2021
- Prepared and presented the highest quality project proposal for an efficient greenhouse design made of recycled material