ERICKSON ANCHORAGE OF ROOF-TOP EQUIPMENT
PROJECT ID: CEEN_2018CPST_002

by

B RAY Engineering

Brandon Roberts
Roman Calderon
Ammon Hymas
Yejezkel Jimenez

A Capstone Project Final Report

Submitted to

Bahaar Taylor & Joshua Peterson
Erickson Structural

Department of Civil and Environmental Engineering
Brigham Young University

April 15, 2019

Executive Summary

PROJECT TITLE: ERICKSON ANCHORAGE OF ROOF-TOP EQUIPMENT
PROJECT ID: CEEN_2018CPST_002
PROJECT SPONSOR: ERICKSON STRUCTURAL
TEAM NAME: B RAY ENGINEERING

Project Objectives:

Create Excel spreadsheet appropriate for calculating gravity and lateral anchorage of rooftop equipment (including solar panels, mechanical units, etc.)

Create AutoCAD details to depict typical connections of rooftop equipment to the building structure.

Create template proposal for use for such projects (similar examples will be provided). Constraints & Goals: Excel spreadsheet should be automated as much as possible to accommodate several different scenarios such as pitched roofs, varying sizes of equipment, different wind and seismic loading requirements, snow drift loading, etc.

Constraints & Goals: AutoCAD details should be easily customizable as far as possible. Engineering Specialty: Structural

Deliverables:

Excel Spreadsheet

AutoCAD Model

Proposal Template

Table of Contents

List of Figures

Introduction

The anchorage of rooftop equipment is a structural analysis focused project for Erickson Structural Consulting Engineers. Which is a company that focuses upon working with existing structures, including forensic investigations of building structures and failures, assessments of, and remediation designs for, distressed building structures, structural analysis of existing buildings, design of structural renovations and modifications to existing buildings, evaluation of insurance claims involving structural loss, and seismic evaluation and rehabilitation of existing buildings. Hence, in order to make their jobs easier this company has asked us to create an Excel spreadsheet that uses the equations and standards and codes from the ASCE minimum design loads for buildings and other structures manual, to calculate seismic design force, displacements any other seismic demands, and to calculate wind loads on structures and building appurtenances. Along with the calculations on the spreadsheet we need to create and AutoCAD file that depicts typical rooftop connections and equipment that goes on the buildings structure and create template proposal for use for such projects.

Schedule

*****We need to update this to match this semester's work*****

10 September 2018	Formed capstone group in class
10 September 2018	Received capstone assignment
10 September 2018	Met with Dr. Borden, the team's faculty advisor.
5 October 2018	Did a video call with the team's sponsors, Bahaar Taylor and Joshua Peterson from Erikson Structural Consulting Engineers.
12 November 2018	Created a basic outline in Excel demonstrating the template of the team's spreadsheet and sent it to the sponsors for feedback.
12 November 2018	Conference call with sponsors. Discussed details concerning the spreadsheet and the ASCE codes we will need to complete the project.
7 December 2018	Conference call with sponsors.
7 January 2019	Kick-off meeting for winter semester
24 January 2019	Obtained ASCE 7-10 codes
26 January 2019	Started working on the seismic load calculations on the spreadsheet.
8 March 2019	Met with Mr. Oxborrow for assistance on the project
9 March 2019	Started working on the various load scenario calcualtions
18 March 2019	Met with Dr. Lee for additional assistance on the project
1 April 2019	Finalized spreadsheet
3 April 2019	Finished and turned in the poster
11 April 2019	Final presentation in the ASCE seminar

Assumptions & Limitations

Assumptions the team had to make included the following:

- A user interface will need to be created with Visual Basic code, so structural analyses can be streamlined
- All formulas found in ASCE 7-16 will be included in the final product
- AutoCAD models will be similar to those in the examples provided
- The AutoCAD models and proposal template will need to allow for user input

Limitations the team encountered included:

- The sponsors reside out-of-state, creating difficulties with communication.
- Sponsors have been very busy with their work, so it has been hard to keep in contact with them.

Design, Analysis & Results

After having talked to Bahaar Taylor and Josh Peterson, we understood that we needed to get the manual called "Minimum Design Loads for Buildings and Other Structures" in order to find out the formulas needed to calculate seismic demands and wind loads. We read and analyzed section 13 called "seismic design requirements for nonstructural components" from the manual to find those formulas out. We were able to identify some of the key formulas that will be used in the spread sheet in order to calculate seismic demands and wind loads. Some of these formulas are the following:

To determine the horizontal seismic design force, Fp. It shall be applied at the component's center of gravity and distributed relative to the component's mass distribution.

$$F_P = \frac{0.4 a_p S_{DS} W_p}{\left(\frac{R_p}{I_p}\right)}\left(1+2\frac{z}{h}\right) \qquad (13.3\text{-}1)$$

F_p is not required to be taken as greater than

F_p is not required to be taken as greater than $F_p = 1.6 S_{DS} I_p W_p$ (13.3-2)

and F_p shall not be taken as less than $F_p = 0.3 S_{DS} I_p W_p$ (13.3-3)

Where:

- F_p= seismic design force
- S_{DS}= spectral acceleration, short period, as determined from Section 11.4.4
- a_p= component amplification factor that varies from 1.00 to 2.50 (select appropriate value from Table 13.5-1 or 13.6-1)
- I_p= component importance factor that varies from 1.00 to 1.50 (see Section 13.1.3
- W_p= component operating weight
- R_p= component response modification factor that varies from 1.00 to 12 (select appropriate value from Table 13.5-1 or 13.6-1)

- z = height in structure of point of attachment of component with respect to the base. For items at or below the base, z shall be taken as 0. The value of z/h need not exceed 1.0
- h = average roof height of structure with respect to the base

13.3.2 Seismic Relative Displacements

$D_{pI} = D_p I_e$

where

- I_e = the importance factor in Section 11.5.1
- D_p = displacement determined in accordance with the equations set forth in Sections 13.3.2.1 and 13.3.2.2.

We have not used all of the formulas listed above in our spread sheet. This is because we spent some time reading and trying to understand all these formulas in this particular section.

Figure 1 shows how the seismic design force is calculated.

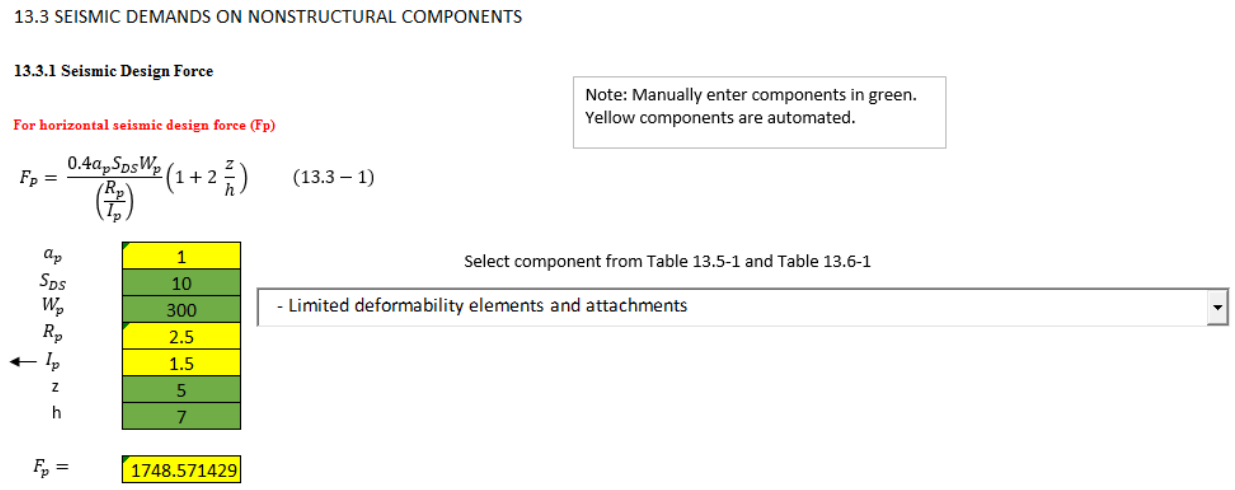

Figure 1: Seismic Design Force, Fp

Figure 1 shows how the seismic design force is calculated. The cells in color green represent the values that have to be entered manually and the cells in color yellow represent the values that are automated. Also, the formula used to calculate the seismic design force, Fp is shown at the top left corner of the spreadsheet. On the right side of colored cells, there is a dropdown list where you must select the appropriate component from the Coefficients for Architectural Components list from tables 13.5-1 and 13.6.-1. For example, in figure 1, the selected component is "Limited deformability elements and attachments' which gives the following values: component amplification factor , $a_p = 1$, component response modification factor, $R_P = 2.5$, component importance factor, $I_p = 1.5$. Also, on the right side of the dropdown list, all of the variables are defined. In this way, the user will know what each variable mean and so be able to input the right value for it.

Figure 2 shows an example of a rectangular mechanical unit where the height at which the seismic design force acts as wells as its angle at which it acts are customizable.

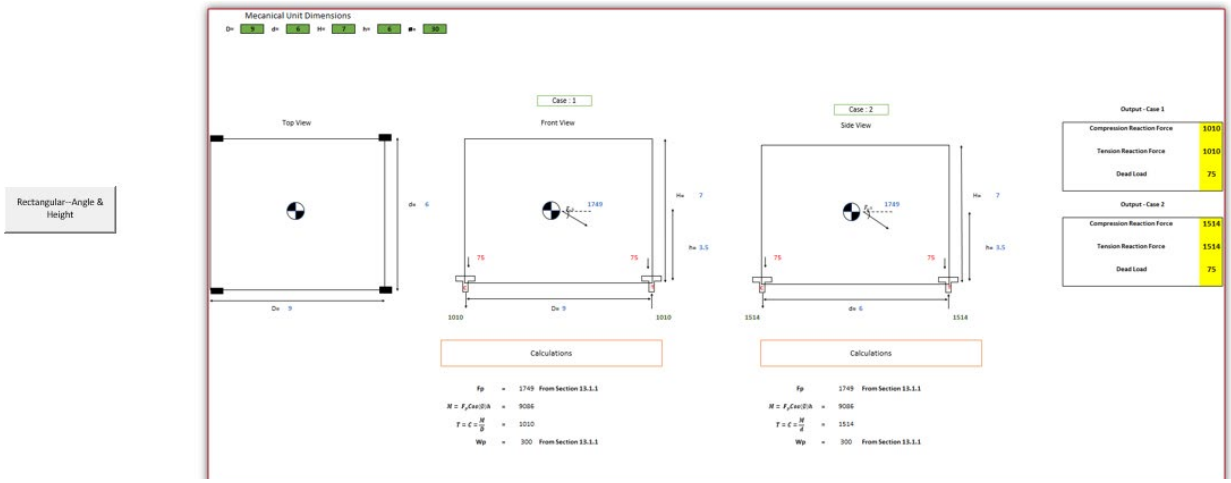

Figure 2 Rectangular Mechanical Unit

Figure 2 shows an example of one of the different possible scenarios that can be chosen by the user. In this particular example, a rectangular mechanical unit is shown where it is possible to customize the height at which the seismic design Force, Fp acts as well as the position of the angle at which this force acts. To be able to go to this case, it is necessary to click on the button that is located to the side that has the title "Rectangular-Angle & Height". In this worksheet it is possible to calculate the dead loads as well as the reaction forces at the anchors of the mechanical unit. In order to calculate all these, it is necessary to first input the dimensions of the mechanical unit. These can be input in the green cells found on the top left corner as shown in Figure 2. For example, in Figure 2, a 9 X 6 X 7 rectangular mechanical unit is shown. In the same way, the height at which the seismic design force, Fp acts as well as the position of the angle at which it acts can be input. For instance, in Figure 2, the height and the angle at which force Fp acts are 6 ft and 30 degrees respectively. All the dimensions previously input are also display on the mechanical unit pictures. This helps the user to double check that the dimensions of the mechanical unit are correct. Once all the dimensions are input, the spreadsheet will automatically calculate the dead loads as well as the reaction at the anchors. The dead loads are shown in color read on the mechanical unit pictures, located next to the arrows pointing downwards. Also, inside the anchors figures, it is possible to see which of these two is in compression and which is in tension. For example, Figure 2 shows that the anchor on the left is in compression and the one on the right is in tension. Underneath the anchors, the reaction forces acting on them are shown in color green. In addition, on the right side of the figures as shown in Figure 2, it is possible to find all the calculated values. Also, below the figures as shown in Figure 2, the formulas necessary to calculate all the values found are shown.

On the other hand, the assumptions made to calculate these values are the following: the anchors are located right on the corners, the seismic design force, Fp is always acting right in the middle of the mechanical unit and the mechanical unit has only four anchors.

Lessons Learned

Our team has learned a few things from our progress so far on this project. We have learned the importance of effective and efficient communication. Our sponsors reside in another state and are naturally busy with their day to day whirlwind of work. We could only communicate with them through email and telephone so learning how to use that precious time with them wisely was crucial. We had some trouble understanding what was expected for the project initially and since our only communication is emails and short telephone calls we still had some confusion throughout the duration of the project. Another thing that we learned is how fast a deadline can approach whether you're ready or not. It is important to schedule your time wisely and spread out your workload before it becomes too late. There were times when we were rather busy with other school work and didn't prioritize the project. This came back to harm us in the end as we fell behind. We also learned that in the professional world, others won't hold your hand and guide you through your work. Oftentimes it is up to you to figure out what you need to do and ask the important questions to help you out. We are starting to understand how to be more independent and accountable in the workplace.

As we started to make progress on the project we learned some useful Microsoft Excel skills that will need in our future careers. We learned that sometimes a client wants you to create something based off your own design. They trust you to make something acceptable and we learned to not hesitate so much when we don't know exactly how something should be.

Conclusions

This project is focused on structural analysis of seismic design forces, displacements, and wind loads. The two deliverables are an Excel spreadsheet for the automated calculations for different scenarios and an AutoCAD drawing along with the written proposals.

An automated spreadsheet was developed to calculate gravity and lateral anchorage loads of rooftop equipment (including solar panels, mechanical units, ect.). The spreadsheet was automated to accommodate several different scenarios such as varying sizes of equipment and different seismic loading requirements. Using AutoCAD, the team created details to depict typical connections of rooftop equipment to the building structure.

Recommendations

This spreadsheet is based on the ASCE 7-10 manual codes, chapter 13, which calculates seismic anchorage, and chapter 29 which calculates the wind load. The same topics and formulas were revised on the IBC 2006, IBC 2015 and IBC 2018 manual codes, so any data, variables, codes or differences were added to the spreadsheet. Therefore, those manuals and codes are the limitation, if the engineer needs to have more equations calculated or new codes to be covered, the spreadsheet would need to be updated.

Another thing to consider in this project is that the spreadsheet can only calculate the seismic and wind loads for certain cases. The spreadsheet was designed for rectangular shapes and squared unit equipment, so another recommendation would be to update the spreadsheet to any other specific shape or unit size that needs to be calculated. Overall, the recommendation is to build upon this automated tool to have more options and a more extensive list of codes and reactions to be calculated.

Appendix A—Résumés

BYU | CIVIL & ENVIRONMENTAL ENGINEERING
IRA A. FULTON COLLEGE

CAPSTONE

Brandon Roberts

brandon.b.roberts@gmail.com • 480.432.4234 • linkedin.com/in/brandon-b-roberts

Professional Experience

Land Development Intern May 2018 - July 2018

EPS Group Inc. *Mesa, AZ*

- Prepared cross-sectional flow modeling for presentation to 5+ stakeholders
- Designed base maps and roadway striping plans in AutoCAD/Civil 3D 2018
- Ensured correct referencing and quality of plans and reports
- Executed post-design construction activities including contractor requests for information and deliverables
- Supported 1 Senior Project Manager and 2 Project Managers in 2+ project simultaneously
- Collaborated with 6 team members and 10+ external consultant groups on project development

Inventory Supervisor May 2017 - July 2017

Pinto Creek Co. LLC (Grower, Packer, Shipper of Fresh Vegetables) *Eloy, AZ*

- Coordinated packing of vegetables for retail and wholesale orders using real-time industry specific software system
- Coordinated shipping process with sales department and freight carriers
- Oversaw shipping of 15 Semi Loads of product per day to retail and wholesale customers in United States and Canada
    - (Customers included: Walmart, Costco, Safeway, Supervalu, Meijer, Bashas, Target)
- Worked with team in fast paced, dynamic, and stressful environment where accuracy and timeliness were paramount

Student Piano Technician October 2015 - Present

BYU School of Music Piano Shop *Provo, UT*

- Diagnose and remedy regulation problems among 1200+ parts
- Trusted to handle $250,000 pianos and take care of assigned pianos
- Tune pianos within 5 cents of accuracy
- Perform maintenance work on 6+ pianos weekly

Volunteer Work

Volunteer Representative Aug 2013 - Aug 2015

The Church of Jesus Christ of Latter-day Saints *Villahermosa, Mexico*

- Increased effectiveness by training 3 other representatives over 3-month period each
- Prepared and taught training meetings to 8+ representatives weekly
- Presented 20+ lessons of self-improvement and behavioral changes in community
- Analyzed and reported performance indicators weekly

Awards and Skills

Advanced Spanish fluency (reading, writing, speaking)

Engineering related software: AutoCAD/ Civil 3D 2018, FLO-2D, Extensive knowledge of Microsoft Office, ArcGIS

Eagle Scout

Education

Bachelor of Science in Civil Engineering Apr 2020

Brigham Young University *Provo, UT*

- Cumulative GPA: 3.32
- Extracurricular: Tau Beta Pi Honor Society, American Society of Civil Engineering, Earthquake Engineering Research Institute
- Relevant Coursework: Engineering Mechanics (Statics, Dynamics, Materials), Hydraulics and Fluid Flow Theory, Soil Mechanics, Engineering Applications of GIS, Structural Analysis, Capstone (currently enrolled)

Ammon Hymas

7809 E 122nd Pl, Thornton CO, 80602 | (303) 875-3166 | akhymas@gmail.com

Profile

- Senior in college with an emphasis and interest in transportation engineering. Hard working, driven, and committed to delivering high quality results.

Education

CIVIL ENGINEERING | 2013-2020 | BRIGHAM YOUNG UNIVERSITY

- Cumulative GPA: 3.09

Skills, Abilities, & Service

SKILLS

- Has experience using Microsoft Excel, Microsoft Word, AutoCAD Civil 3D, Visual Basic, and MicroStation. Can fluently speak and write Indonesian.

LEADERSHIP

- Organized and lead an Eagle Scout project. Team leader in the varsity wrestling and football teams in high school. Served as a district leader on a religious mission in Indonesia; leading up to 9 other missionaries.

SERVICE

- Served as a full-time, volunteer missionary in Indonesia for two years. Worked with at risk youth, performed ecclesiastical functions, and managed service projects.

Experience

INTERN | ROCKSOL CONSULTING GROUP | SUMMER 2018

- Assisted in quality assurance for a project replacing a bridge and fixing drainage issues on a road in Nebraska.
- Completed alignments, corridors, and section views for a project proposal for Pena Blvd in Colorado.

INTERN | HDR ENGINEERING INC | SUMMER 2012, SUMMER 2013

- Learned from and worked with experienced transportation and traffic engineers.
- Assisted engineers on project revision/completion, delivered documents, and provided relevant insights.

CASHIER/FLOORING ASSOCIATE | HOME DEPOT | OCTOBER 2016 - PRESENT

- Gained skills interacting with customers and helping them meet their needs. Learned to maintain composure under pressure.
- Nominated as cashier of the month in December 2016 and July 2017.

Yejezkel Jiménez

602 E 600 N #419, Provo, UT 84604 || C: (801)-836-3238 yejezkeljd@hotmail.com

Education

Civil Engineering
Minor: Business Management
Brigham Young University
Expected - April 2019

Associate Degree in Business
LDS Business College
Winter 2013

Work experience

Intern – Salem City Engineering Department — Oct/2018 - Present

- Designed storm water system for a church facility and analyzed multiple design storms.
- Worked on and updated city codes and standards, write requests for proposals, participate in meetings with developers' and city officials, solve a variety of different engineering problems from different disciplines, other engineering and public works tasks

Translator - BYU Political Science Department — Jan/2018 - Oct/2018

- Translated documents for the nonprofit organization: Impact Evidence, who has developed a website to help public policy makers. Website: (http://ie.byu.edu/)

Social Media and Marketing Specialist - BYUtv International — Jun/2015 - Jan/2018

- Increased viewership by 350% analyzing and capturing social media data, insights and best practices.
- Lead a team on creation and designing of marketing and communication platforms.
- Designed logos and edited pictures and videos for social media content.

Intern - Academy for Creating Enterprise — Jan/2015 - Apr/2015

- worked with the CEO and the presidents of ACE (non profit organization) in Mexico to gather information to create, design and write a manual in Spanish for an incentive program, that the company has recently opted to run in Peru.

Teller - Wells Fargo — Nov/2012 - Aug/2013

- Worked in a fast-paced environment while providing excellent customer service and helping resolve their concerns in a timely fashion. Handle big amounts of cash, processing account transactions effectively and following proper procedures to minimize errors and reduce fraud.

Skills

- **Bilingual** Spanish / English
- **CAD:** Revit, Catia and Autocad
- Excel VBA coding

Roman Calderon

rcp_calderon@hotmail.com (352)-722-1148

EDUCATION

B.S. Civil Engineering — Dec 2019
Brigham Young University — *Provo, UT*

- Minors in Math, and Business Management
- 3.52/4.0 GPA
- Relevant Course Work: Computational methods; Metals, Woods, & Composites; Concrete, Masonry, & Asphalt; Mechanics of Materials; Elementary Soil Mechanics; Intro to Transportation Engr; Hydraulics & Fluid Flow Theory; Structural analysis; Geometric Design of Highways

Associate's Degree in Business with an accounting certificate — Apr 2015
LDS Business Collage — *Salt Lake, UT*

- 3.93/4.0 GPA

WORK EXPERIENCE

Custodian — May 2015 - Current
Brigham Young University — *Provo, UT*

- Supervise a group of 5 students to clean and maintain some BYU buildings in excellent conditions
- Assist with training of new staff in work methods and procedures
- Developed a new system of teamwork resulting in a remarkable improvement in performance and effectiveness of each team member

Custodian — Aug 2014 - Apr 2015
The Church of Jesus Christ of Latter-Day Saints — *Salt Lake, UT*

- Worked with a multidisciplinary team for the possible implementation of new equipment
- Developed an outstanding ability to coordinate maintenance activities with management and other custodial staff
- Improved and documented all SOP (Standard Operating Procedures) concerning custodial duties

LEADERSHIP AND SERVICE

Boxing Club President — May 2015 – Dec 2016
Brigham Young University — *Provo, UT*

- Increased the total number of active members by 200%
- Planned and organized several activities such as: info sessions, community service projects and mentorship sessions.

Student Committee Coordinator — Jul 2010 – Apr 2011
Polytechnic University of Pachuca — *Pachuca, Mexico*

- Motivated over 250 students to overcome their fear of sharing their ideas to school administrators
- Responsible for performance measures and well-being of more than 100 students.

SKILLS

- Modeling/Rendering: AutoCAD CIVIL 3D, NX10
- Computer: MS Office
- Programming: Visual Basic for Applications
- QuickBooks

Foreign Language

- Spanish: Native and English: Proficient
- Portuguese

Appendix B—Figures