CFSRC COLLOQUIUM

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Incorporating cold-formed steel member and system design into the undergraduate curriculum

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Abstract

Cold-formed steel design, in an ideal scenario, deserves an entire advanced undergraduate or graduate level course. However, this is not practical in many institutions, where a program of study can only include a few courses in hot-rolled steel design due to teaching capacity and ever-expanding program requirements. Thus, instructors with expertise in cold-formed steel and repetitively-framed systems are forced to infuse it into other curricula, or simply not teach it at all. The pervasiveness of repetitively-framed structural systems worldwide motivates not only teaching the fundamentals of member behavior, but also system behavior, to prepare undergraduates for their careers as practicing engineers. This paper highlights efforts at the University of Massachusetts Amherst to do this in two courses: a second course in steel design (CFS members), and a course on structural systems (repetitive and light framed systems). Modularized lesson plans are presented, along with in-class active learning activities, examples of student work, and feedback from students in each of courses. This paper aims to enable effective modular cold-formed steel instruction, leading to significant learning in thin-walled member behavior and repetitively-framed system behavior.

1. Cold-formed steel education at UMass Amherst

At the University of Massachusetts Amherst (UMass), there are two opportunities to learn about cold-formed steel in the classroom. The first is in a course on structural systems called Unified Structural Design, and the second is in a graduate-level steel design course. Currently, no dedicated course on cold-formed steel design is offered at UMass. The dedicated course is rare in the United States, so instructors wishing to expose their students to concepts of thin-walled structural design and repetitively-framed systems must modularize the curriculum and insert it into other courses. This paper provides a brief overview of how we accomplished this at UMass. Fully-solved assignments are provided in Appendices A-H. We provide these as a resource to the community, to aid in the teaching of cold-formed steel to students at every level, around the world.

These materials are provided as a suggestion – something that worked for us, with our students. We expect and look forward to inevitable improvements, and seek to establish a culture of sharing among cold-formed steel educators.

1.1 Unified Structural Design

This course is, loosely, a course on structural systems. Arches, light-framed systems, cable-supported structures, and tall buildings are all a part of the course. The material is divided into modules: each structural system receives two lectures on the history of that system, two lectures on structural analysis of that system, and two design workshops. Correspondingly, each module has readings, analysis, and design assignments associated with it. The course was made up of students ranging from second year undergraduates to PhD students, and had 32 students in total.

1.1.1 Light-framed structural analysis assignment

In choosing light-framed systems to focus our course module on, shear walls represented an accessible point of entry, with little prior knowledge of thin-walled member stability required. Furthermore, the equivalent lateral force procedures defined within ASCE 7-16 [1] provided a means of analyzing a lateral load on a structure without taking focus away from the structural system. These reductions were necessary to keep the material accessible to the undergraduates in the course, many of whom had yet to take a first course in steel design.

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Figure 1 depicts a simple three story building with shear walls acting as the lateral force resisting system. That shear can be distributed among all shear walls in a story was a major learning objective of this segment of the course. Tracing load transfer from the top of the building to the bottom via tributary heights was another. With these two concepts in mind, students could then enter the shear wall design tables (for OSB-sheathed shear walls in Table E1.3-1 in AISI S400) [2] and select a shear wall for each story height.

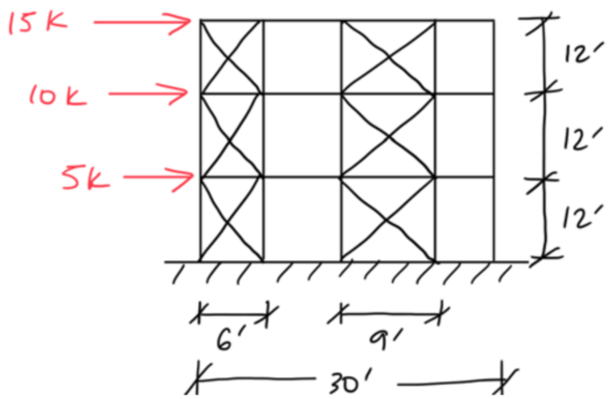


Figure 1: Simple shear wall building system utilized in class and in assignments (Appendix A)

As there are many parameters which influence shear wall capacity, students were encouraged to consider which might increase construction time and material cost. Appendix A provides the analysis assignment while Appendix B provides the solution to that assignment. Students may use any structural analysis program to complete Problem 3 of the assignment. In Problem 3, comparisons to hot-rolled steel frames are encouraged as a springboard from existing knowledge to new knowledge, and to underscore that structural systems are chosen based on unique constraints – some are more suitable than others for a given scenario.

1.1.1 Light-framed design assignment

The design assignment is provided in Appendix C. It builds on the material from the analysis portion of the module by tasking students with designing a building for simplified wind loads with CFS shear walls as the lateral force resisting system. Additional requirements as to siting are provided, and students are expected to submit fully-realized building designs. Appendix D provides the rubric by which the assignment was graded. 50% of the points are for providing adequate explanations for design choices and assumptions; this was intentional, to train students to communicate their designs clearly. No solution is provided as the assignment was open-ended, and any logical and efficient design was acceptable.

1.2 Advanced topics in steel structures

This course is a second, graduate level course in steel design, which typically covers composite members, eccentric connections, plate girders, lateral force resisting systems, and cold-formed steel design. In this course, cold-formed steel occupies approximately four weeks of the semester. In the course sequence, cold-formed steel is last, ensuring students have exposure to plate stability concepts through plate girder design. The plate girder module is slightly modified to ensure this connection is made, and that the fundamental behavior of thin plates is familiar to students. The first lecture in plate girders is a derivation of the critical buckling load for a simply supported plate. Tension field action is explained as post-buckling reserve, the first challenge to the erroneous idea that buckling is failure. Deeper into plate girder design, web crippling is taught as higher mode local buckling. Seeding these ideas earlier in the course provides a foundation for students to expand upon with cold-formed steel.

A background to cold-formed steel members and systems are provided in the first lecture. The next three lectures are structured to teach cross-section stability, culminating in the finite strip method. The remaining four lectures are divided into a CUFSM [3] [4] tutorial, an in-class CUFSM laboratory, a direct strength method [5] design example, and a lecture on the seismic behavior of cold-formed steel buildings. This final lecture aligned with the research expertise of the instructor. Student course evaluations over several years indicated that this research talk is a high point – do not shy away from bringing research into the classroom.

1.2.1 Cold-formed steel mini-project

Each major topic in this course is accompanied by a mini-project, for which students are given four weeks to complete. In this mini-project (Appendix F), students are tasked with a direct strength method calculation of the bending capacity of two back-to-back studs (Figure 2). The capacity is calculated first assuming the studs are not connected, and then assuming they are fastened in their webs.

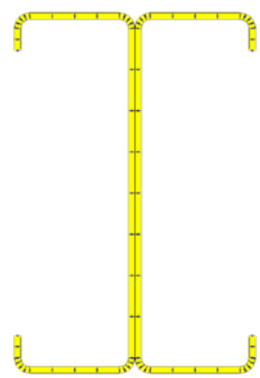


Figure 2: Back-to-back channels (from CUFSM)

The project leverages students' newfound knowledge of the provisions within AISI S100 [5] and of the finite strip method, while expanding their understanding of composite action from earlier in the course. Note that as of publication of this paper, no sample student work is available, but this will be updated when possible.

1.2.1 Cold-formed steel laboratory

Students continually provide positive feedback on finite strip lectures. While producing a signature curve is taught in class, with students following along with the instructor on their own laptops, the expanded functions of CUFSM [4] are taught via a laboratory component, in which students are asked to model a spring or general constraint (to simulate fastening to a deck or sheathing). They are also asked to compare multiple finite strip models, move nodes and elements, and generally explore the program in an environment where they can work in groups and ask questions. To maintain structure to the laboratory, the worksheet in Appendix G is given to the students at the outset (solutions are provided in Appendix H). Students are expected to complete the worksheet during class, and submit their results electronically to the instructor. This is traditionally a very popular lecture, and students are eager to experiment with cross-section shapes, plot buckled shapes in three-dimensions, and see how buckling mode changes with buckling half-wavelength.

While technical challenges are inevitable, the low-stakes environment of the laboratory ensures students do not get frustrated. Troubleshooting technical issues in class ensures they are able to do the same at home.

2. Conclusions

While a dedicated course in cold-formed steel represents the educational ideal, typical undergraduate and graduate curriculum provides significant opportunity to incorporate cold-formed steel into existing core curriculum. In short three-to-four week modules, it is possible to teach fundamental concepts of cross-section stability, repetitive framing, lateral force resisting systems, construction methods, and design code capacity predictions. The materials provided in the appendices to this paper provide a framework for doing the same at your institution.

3. Acknowledgments

The authors gratefully acknowledge our students, who, with their enthusiasm, made teaching this material a joyful experience.

References

[1] American Society of Civil Engineers (ASCE). (2016). *ASCE/SEI 7-16: Minimum Design Loads for Buildings and Other Structures*, ASCE, Reston, VA.

[2] AISI S400-15, North American Specification for Seismic Design of Cold-Formed Steel Structural Systems. Washington, DC, U.S.A.: AISI, 2015.

[3] Z. Li, B.W. Schafer, (2010) "Application of the finite strip method in cold-formed steel member design," *Journal of Constructional Steel Research*, Volume 66, Pages 971-980.

[4] Constrained and Unconstrained Finite Strip Method (CUFSM) available for download at https://www.ce.jhu.edu/cufsm/

[5] AISI S100-16, North American Specification for the Design of Cold-Formed Steel Structural Members. Washington, DC, U.S.A.: AISI, 2016.

Appendix A: Light-framed structural analysis sample assignment (undergraduate)

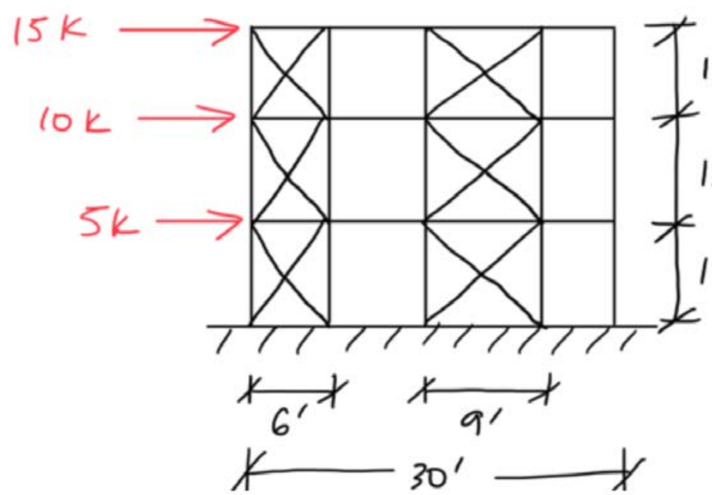
University of Massachusetts Amherst
Dept. of Civil & Environmental Engineering
CEE 497K/597K Unified Structural Design
CEE 211/497P Perspectives on the Evolution of Structures

Analysis #2: Light-Framed
Due at the beginning of class, Wednesday March 4th

Problem 1: Given a 20 psf wind pressure on a three story hotel (100 feet wide, 60 feet deep, with story heights of 15 feet), calculate lateral story demands in both directions. Illustrate your solution on a hand-drawn schematic.

Problem 2:
(a) For the building system below, use Table E1.3-1 from AISI S400 (attached) to design wood structural panel-sheathed shear walls. The design consists of the sheathing material (OSB), the fastener spacing and the chord stud size. You must also report the capacity per lineal foot.

(b) Discuss: is it better to minimize number of fasteners or total steel weight?

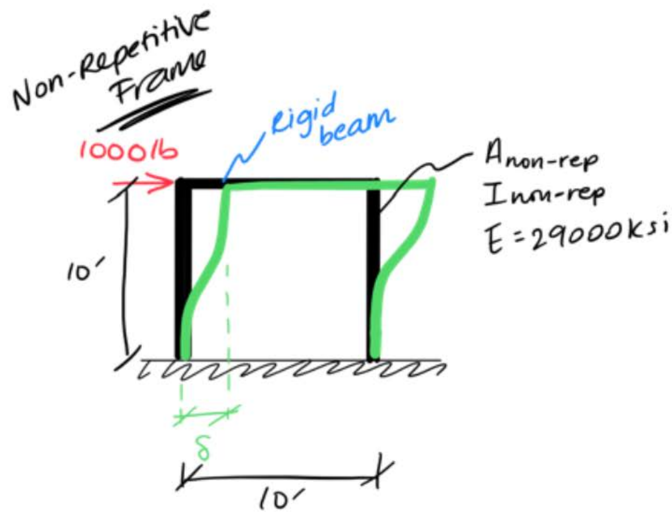


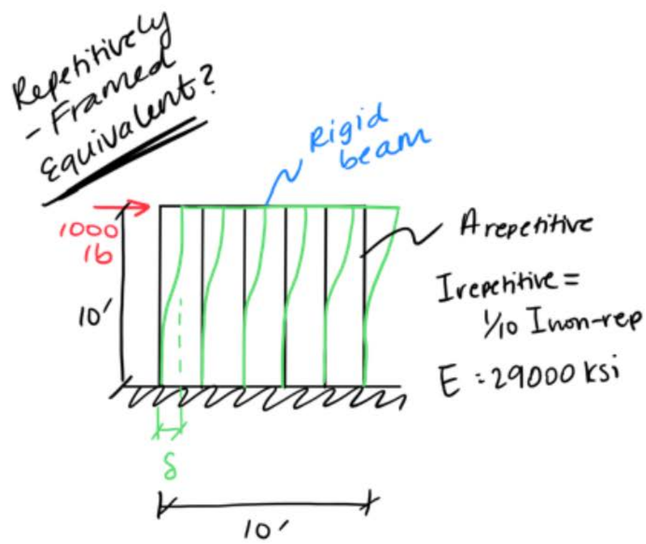
Problem 3: This problem tackles the behavior of non-repetitively framed systems vs. repetitively-framed systems (see drawing below). How many light columns are required to equal the performance of heavy columns? To accomplish this:

(a) Using SAP 2000, model a non-repetitive hot-rolled steel frame laterally loaded with a 1000 lb concentrated load. Assume the frame is 10 feet wide and 10 feet tall. Determine the lateral deflection of the frame, at the load location.

(b) Using SAP 2000, model frames of the same dimension, framed with cold-formed steel (assume $A_{repetitive} = A_{non\text{-}rep}$ and $I_{repetitive} = (1/10)I_{non\text{-}rep}$). How many evenly-spaced columns must you add such that the lateral deflection of the cold-formed frames is equivalent to your result from part (a)? Document all of your cases (you must analyze a minimum of 5 cases, including the correct solution)

(c) Present your results from (b) on a plot of # columns vs. lateral deflection.





columns = 2, 3, 4, 5 ⋯ i

Table E1.3-1
Nominal Shear Strength [Resistance] (v_n) per Unit Length for Seismic and Other In-Plane Loads [1,4]
For Shear Walls Sheathed With Wood Structural Panels on One Side of Wall

U.S. and Mexico (lb/ft)

Assembly Description	Max. Aspect Ratio (h:w)	Fastener Spacing at Panel Edges[2] (in.)				Designation Thickness[5] of Stud and Track (mils)	Minimum Sheathing Screw Size
		6	4	3	2		
15/32" Structural 1 Sheathing (4-ply)	2:1[3]	780	990	-	-	33 or 43	8
	2:1	890	1330	1775	2190	43 or 54	8
						68	10
7/16" OSB	2:1[3]	700	915	-	-	33	8
	2:1[3]	825	1235	1545	2060	43 or 54	8
	2:1	940	1410	1760	2350	54	8
	2:1	1230	1850	2310	3080	68	10

Canada (kN/m)

Assembly Description	Max. Aspect Ratio (h:w)	Fastener Spacing at Panel Edges[2] (mm)			Designation Thickness[5] of Stud and Track (mils)	Required Sheathing Screw Size
		150	100	75		
9.5 mm CSP Sheathing	2:1[3]	8.5	11.8	14.2	43 (min.)	8
12.5 mm CSP Sheathing	2:1[3]	9.5	13.0	19.4	43 (min.)	8
12.5 mm DFP Sheathing	2:1[3]	11.6	17.2	22.1	43 (min.)	8
9 mm OSB 2R24/W24	2:1[3]	9.6	14.3	18.2	43 (min.)	8
11 mm OSB 1R24/2F16/W24	2:1[3]	9.9	14.6	18.5	43 (min.)	8

1. For SI: 1" = 25.4 mm, 1 ft = 0.305 m, 1 lb = 4.45 N. For U.S. Customary Units: 1 mm = 0.0394", 1 m = 3.28 ft, 1 N = 0.225 lb
2. See Section E1.4.1.1 for installation requirements for screws in the field of the panel.
3. See Section E1.3.1.1 for *shear wall* height-to-length aspect ratios (h:w) greater than 2:1, but not exceeding 4:1.
4. See Section E1.3.1.1.2 and Section E1.3.1.1.3 for requirements for sheathing applied to both sides of wall.
5. Only where *Designation Thickness* is specified as a (min) is substitution with a thicker member permitted.

Appendix B: Solutions to sample light-framed analysis assignment

Light-Framed Structural Analysis Solutions

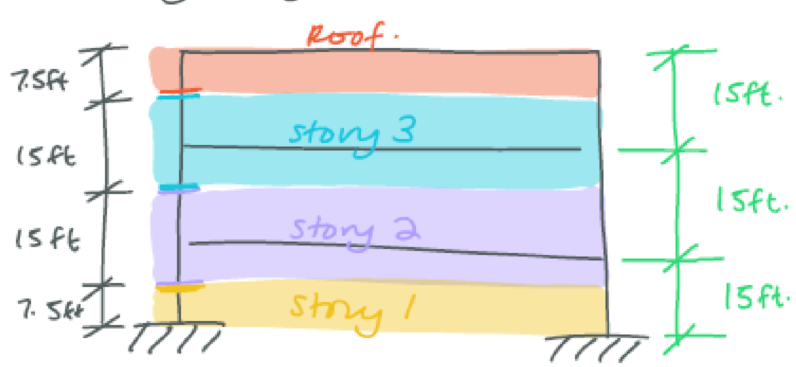
by: Kara Peterman and Sanjay Arwade
UMass Amherst

For publication / distribution at the 2020 OFSRC Colloquium.

Problem 1: 3 story building subject to wind load.

First consider wind on 60ft. side of building. → need tributary heights for each story for an equivalent lateral force calculation.

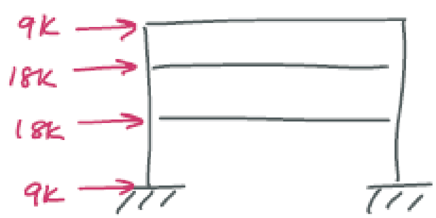
Tributary heights for each story



sample calculation for roof:

$$F_{roof} = (20\ psf)(60\ ft)(7.5\ ft) = 9\ kips$$

Performing this calculation for every story yields:



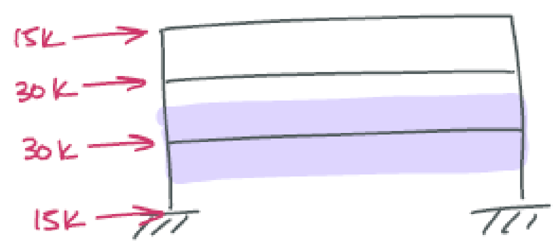
note: 9k at bottom goes directly to the foundation.

Summing loads gives shear wall demands:

story	SW demand (k)
3	9
2	18+9 = 27
1	18+9+18+9 = 45

Next load case: wind on 100 ft side of the building. Tributary heights remain the same, just building width changes.

Resultant lateral forces:



sample calculation for story 2:

(20psf)(100ft)(15ft) = 30k

Story	SW demand (k)
3	15
2	45
1	75

Problem 2:

(a). At each level, there is 15 ft. of available shear wall. Possible shear walls below:

Story	Demand (k)	Demand (lb/ft)	Fastener Spacing (in.)	Stud thick (mils)	Capacity (lbs)
3	15	1000	6	68	1230
2	25	1667	3	54	1760
1	30	2000	2	43/54	2060

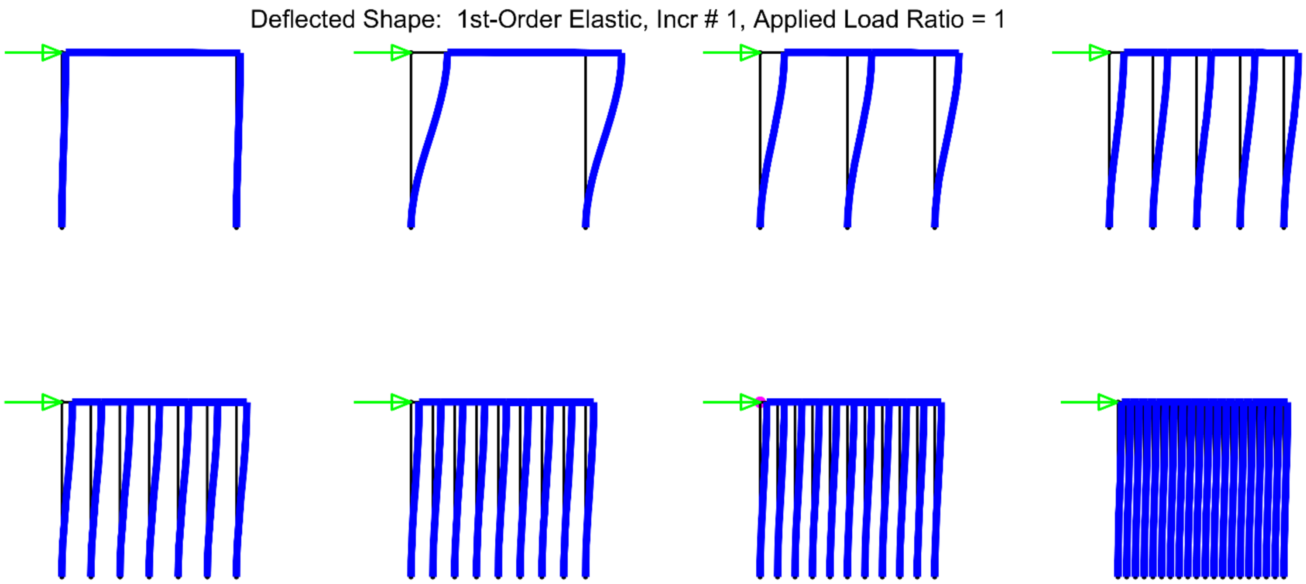
demand increases towards foundation.

fastener spacing has a big impact on capacity!

(b). Considerations:

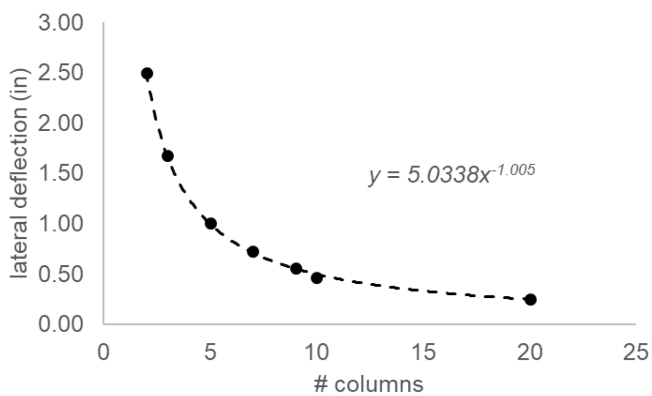
* cost of steel
* cost / # of fasteners
* labor cost / time to install lots of fasteners
* construction speed. ... more ?

Problem 3 (a) and (b) – structural model



Problem 3 (c) – equivalent light-framed wall?

# columns	δ (in)
2	0.27
2	2.50
3	1.68
5	1.01
7	0.72
9	0.56
10	0.46
20	0.25
Equivalent LF	
18.48	0.27



Appendix C: Undergraduate-level light-framed design assignment
University of Massachusetts Amherst
Dept. of Civil & Environmental Engineering
CEE 497K/597K Unified Structural Design
CEE 211/497P Perspectives on the Evolution of Structures

Design #2: Light-Framed Structures
Due at the beginning of class, Wednesday March 11th

You are to design a new classroom building for UMass Amherst using CFS. The site is the lawn to the east of the Campus pond. The required square footage is 85,000 square feet and your building must reach 3 stories over at least some of its floorplan. Note that this is not really an appropriate site for a new building as the lawn and pond are important landscape features with a (somewhat tenuous) connection to the great landscape architect Frederick Law Olmstead.

Your design must consist of the overall form of the building—its windows and doors and its shear walls. You are not responsible for the interior arrangement of spaces except that you may choose to place some shear walls in the interior of the building as opposed to on the perimeter walls.

Your submission must include drawings that show the overall form of the building including windows, doors and shear walls. 3D isometric drawings are nice, but you must include elevations and plans of the building clearly showing the key façade features (windows, doors, shear walls) and the relationship of the building to the site including a plan showing the position relative to the pond, walkways and roads and relative to the slope of the land. Your submission must also clearly indicate the wind speed, pressures and loads, the shear wall demands and the shear wall designs.

The procedures in ASCE 7 for calculating wind loads are correct and appropriate for professional final design, but they obscure the basic physics of how wind interacts with structures. Wind generates load on a structure according to the product of a coefficient related to drag and the square of the wind speed. Use the expression

$p = 0.00256 \times V^2$

to calculate the wind pressure, where p is the pressure in psf and V is the wind speed in mph. You should assume that the pressure is uniform over the height of the building. This is a simplification that is acceptable for this conceptual design exercise. In reality, wind speeds and, therefore, wind pressures, increase with height above ground.

You can obtain information about the site characteristics from google maps, the USGS National Map (https://www.usgs.gov/core-science-systems/national-geospatial-program/national-map) or the Town of Amherst GIS database (http://gis.amherstma.gov/apps/topoextract.htm)

Appendix D: Rubric for design assignment
University of Massachusetts Amherst
Dept. of Civil & Environmental Engineering
CEE 497K/597K Unified Structural Design
CEE 211/497P Perspectives on the Evolution of Structures

Design HW #2: Light-Framed

Grading rubric

Criterion	Reasonable Design/analysis/ "Did you do it?"	Explanation/"How did you present it?"
Building owner requirements		Not applicable (no points)
Overall shape/form		
Elevation View		
Plan View		
Siting		
Topography		
Wind speed		
Wind pressure		
Loads on structure		
Shear wall demands		
Shear wall sizing		

Score /21

Appendix E: Sample light-framed design student submission

University of Massachusetts Amherst
Dept. of Civil & Environmental Engineering
CEE 597K Unified Structural Design

Design HW #2: Repetitively Framed Structure

[redacted]

March 11th, 2020

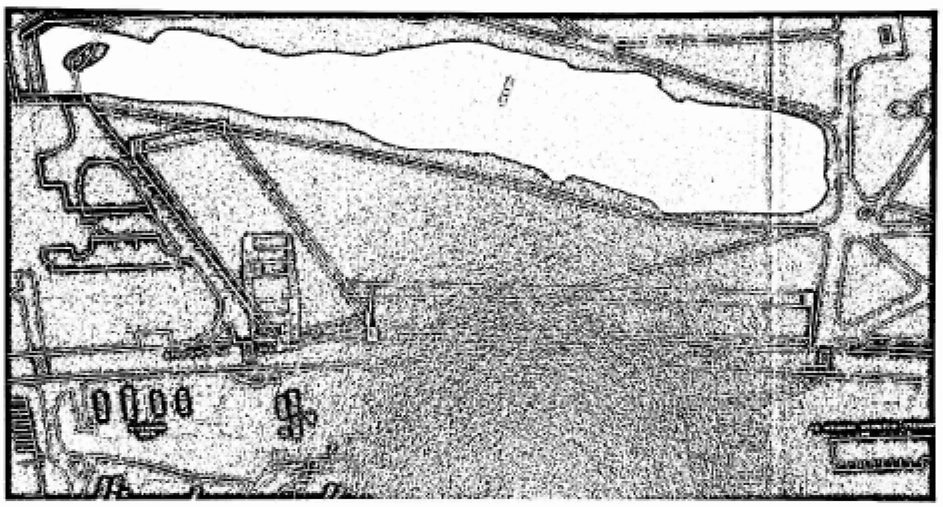


Figure 1: Isometric Wireframe of Proposed Structure

Design Decisions

1. **Geometric Requirements**

   The site was to be located in the lawn east of the campus pond, an area which is of architectural significance. In order to preserve as much of the landscape as possible, a majority of the building is to be buried beneath a green roof that will be at the current elevation of North Pleasant street. The foundation will be 15ft below Pleasant Street, giving a 15ft story height. The client requested the building to be 85,000sf with three stories of elevation. To meet these requirements, the building was split into three wings, North Wing, South Wing, and Tower. The North Wing has an area of 37,330sf, the South Wing has an area of 39,000sf, and the Tower adds two floors over the South Wing, each 5,175sf, totaling in **86,680sf** of floor area and **three stories** of elevation.

2. **Geometric Considerations for Analysis**

   The previous design decisions necessitated the use of some simplifications for analysis of different sections of the building. Each of the three wings were analyzed separately with wind perpendicular to each wing's walls. Each wing was then independently designed to resist shear found in their respective analysis, although the wings will ultimately be part of the same structural system. For example the basement level of the tower is embedded into the South Wing, and the shear walls also extend into the basement directly below the Tower, although, floor diaphragm theory would technically allow for the grouping of shear walls in the basement floor. There are also other internal shear walls aligned with each wing's respective orthogonal grid used in analysis. Additionally, the embedment of most of the building into the landscape would mean that the building would be shielded from wind and would allow for direct bracing of most of the building against the earth, however, shear walls were still designed as if the building was above ground to keep with the spirit of the assignment.

3. **Wind Pressure**

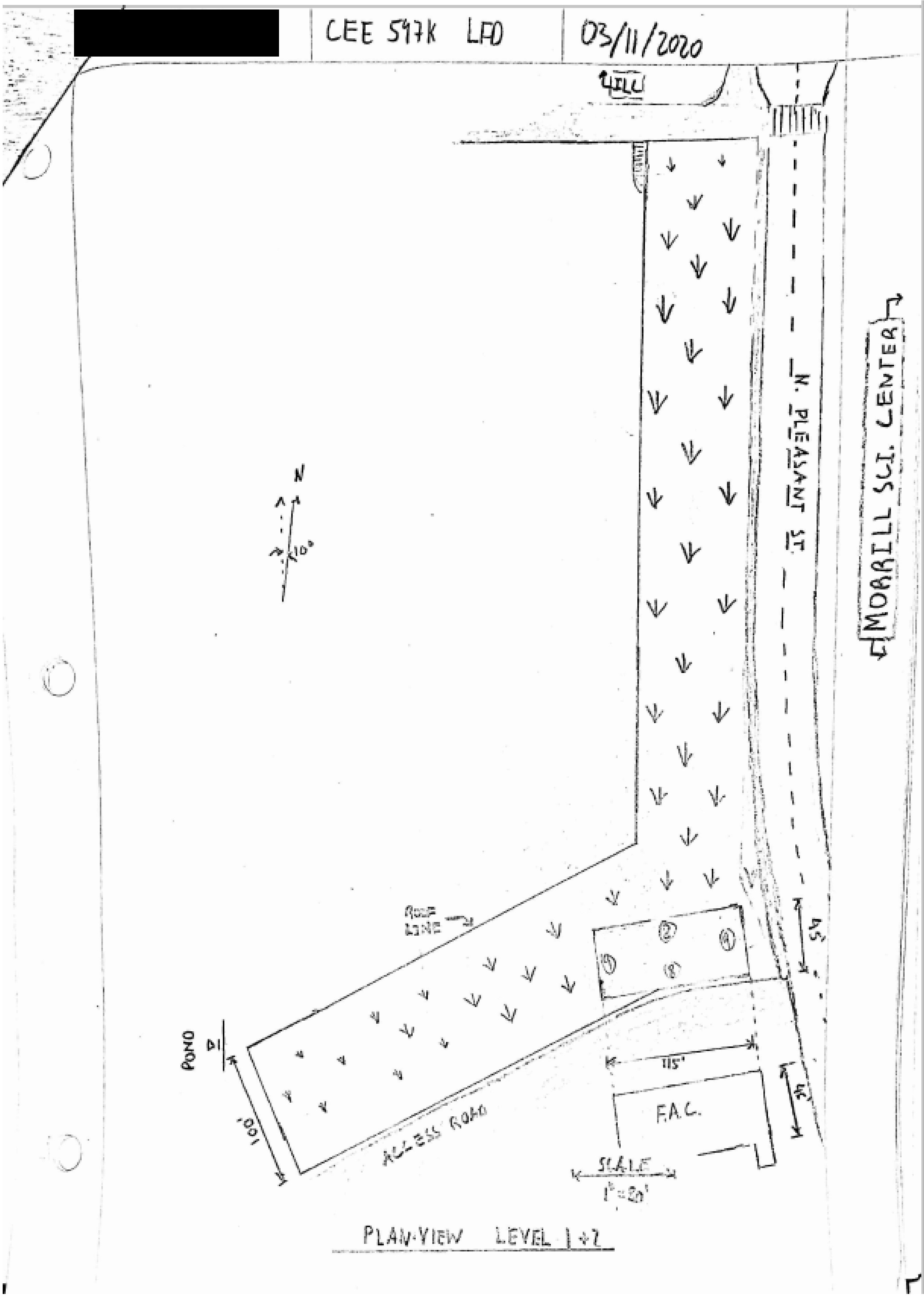
   The wind velocity in Amherst was found to be **105mph** using the ASCE-7 wind velocity web tool. It was then converted to a pressure of **28.2psf** using the given formula $p = 0.00256 \times V^2$. Wind pressure was assumed to be constant over the height of the building.

4. **Loading at Floors**

   The pressure was multiplied by the width of the walls and the height of the tributary area to calculate the amount of wind force that will be transmitted to each floor diaphragm. The shear forces were then summed starting at the roof to find the amount of force each shear wall would need to be designed to resist.This was done on the two orthogonal faces of the respective wings. A summary of the total loads, the shear wall demands and the shear wall designs can be found in Table 1.

Table 1. Strength Calculation Summaries and Shear Wall Designations

Wing	Floor	Wall/Wind Orientation	Total Required Strength (lb)	Total Supplied Strength (lb)	Total Length of Shear Wall	Required Strength (lb/ft)	Supplied Strength (lb/ft)	Designation
Tower	Base	N-S	97,372	98,560	32	3,043	3,080	**OSB, 68 Mil, 2"**
		W-E	38,100	49,280	16	2,381	3,080	**OSB, 68 Mil, 2"**
	1st	N-S	73,029	73,920	24	3,043	3,080	**OSB, 68 Mil, 2"**
		W-E	28,575	29,600	16	1,786	1,850	**OSB, 68 Mil, 4"**
	2nd	N-S	24,343	29,600	16	1,521	1,850	**OSB, 68 Mil, 4"**
		W-E	9,525	11,200	16	595	700	**OSB, 33 Mil, 6"**
North	Base	N-S	16,934	19,680	16	1,058	1,230	**OSB, 68 Mil, 6"**
		W-E	100,802	110,880	48	2,100	2,310	**OSB, 68 Mil, 3"**
South	Base	N-S	66,319	67,760	22	3,015	3,080	**OSB, 68 Mil, 2"**
		W-E	21,168	29,600	16	1,323	1,850	**OSB, 68 Mil, 4"**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CEE 597K LFD
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MORRILL SCI. CENTER
N
ROOF LINE
POND
D1
100'
ACCESS ROAD
45'
115'
34'
F.A.C.
SCALE
1"=20'
PLAN-VIEW LEVEL 1+2

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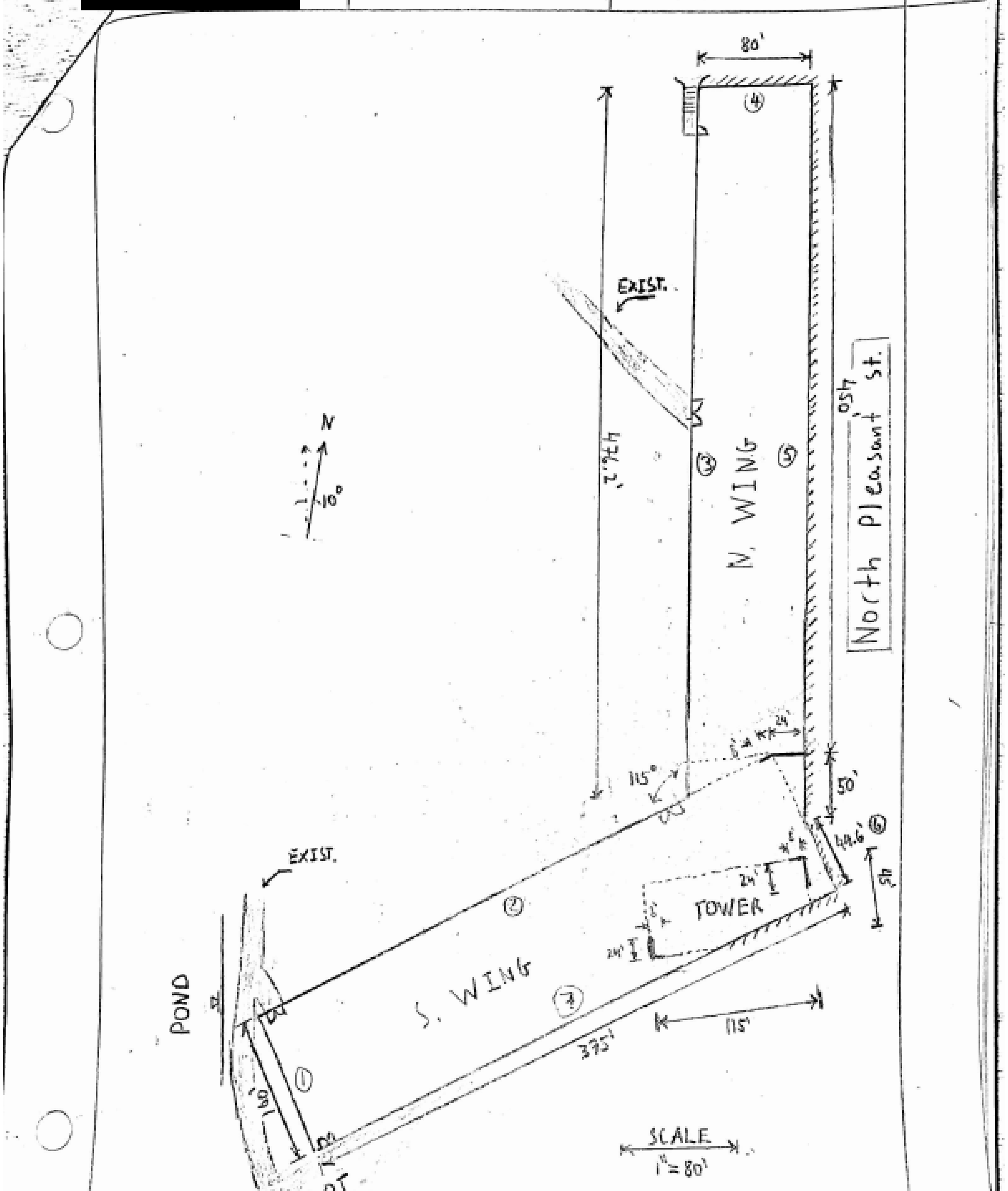

PLAN VIEW – LEVEL 0

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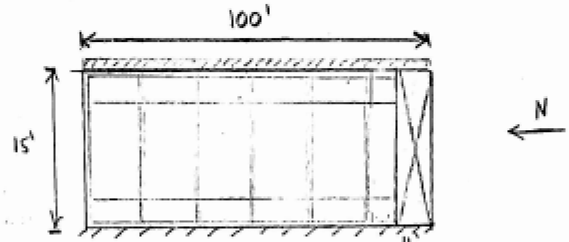
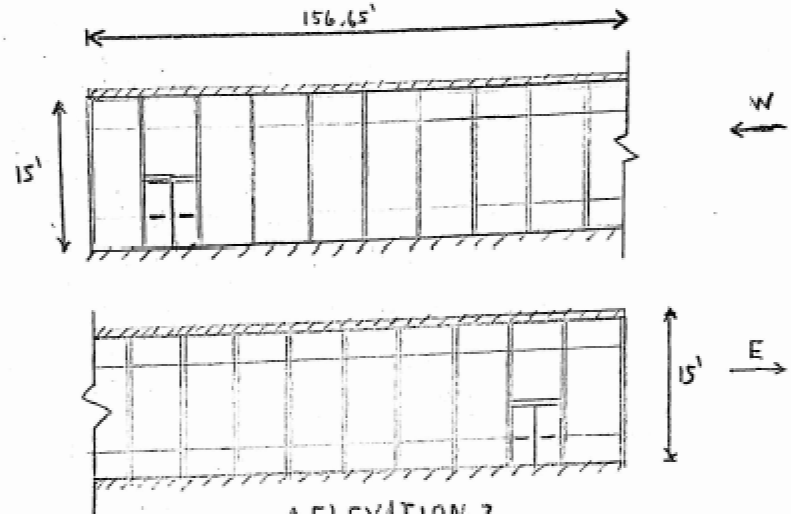
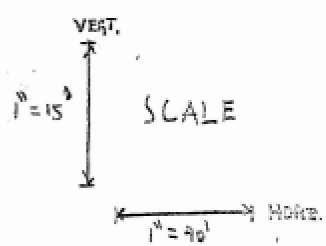


ELEVATION 1



ELEVATION 2



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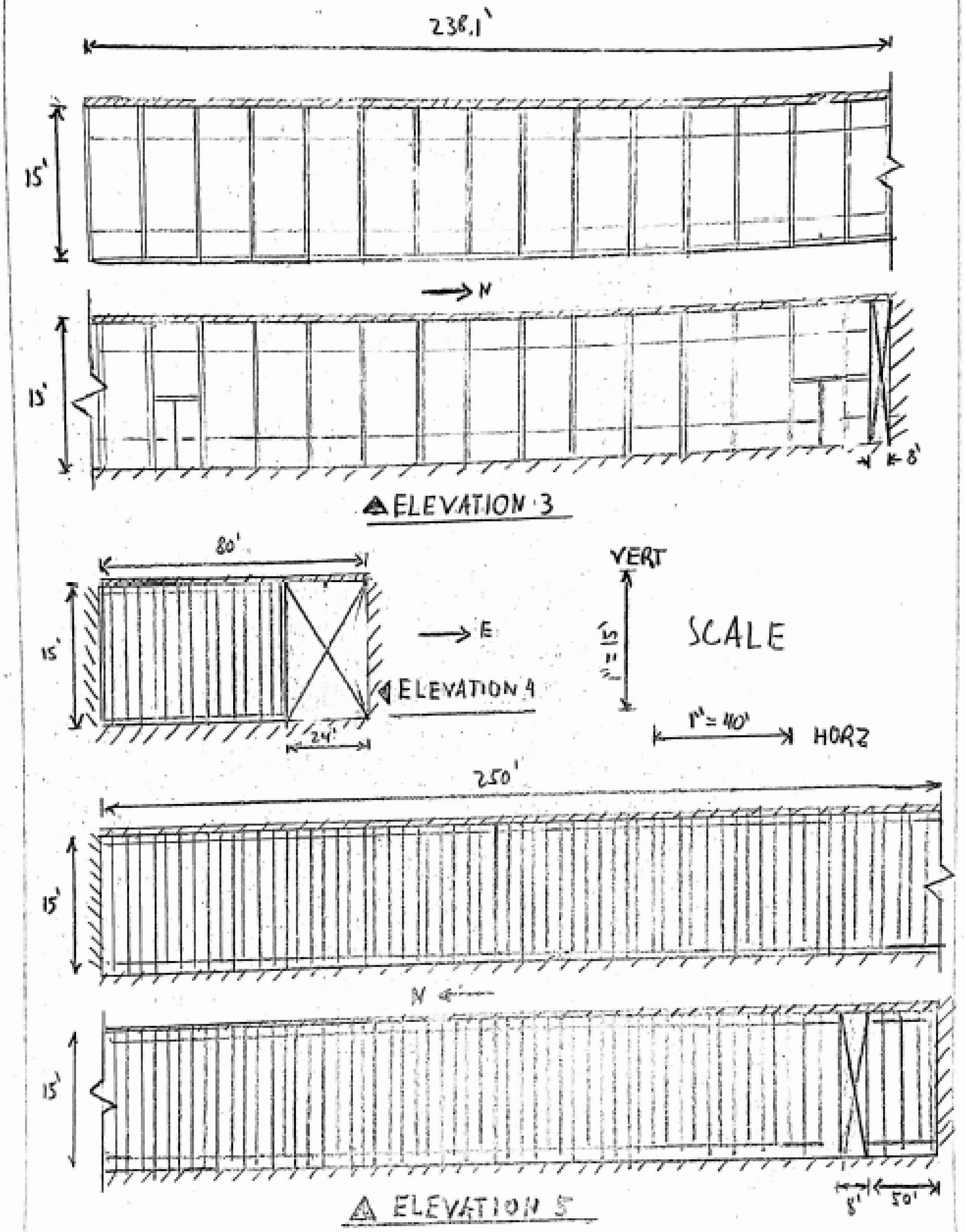
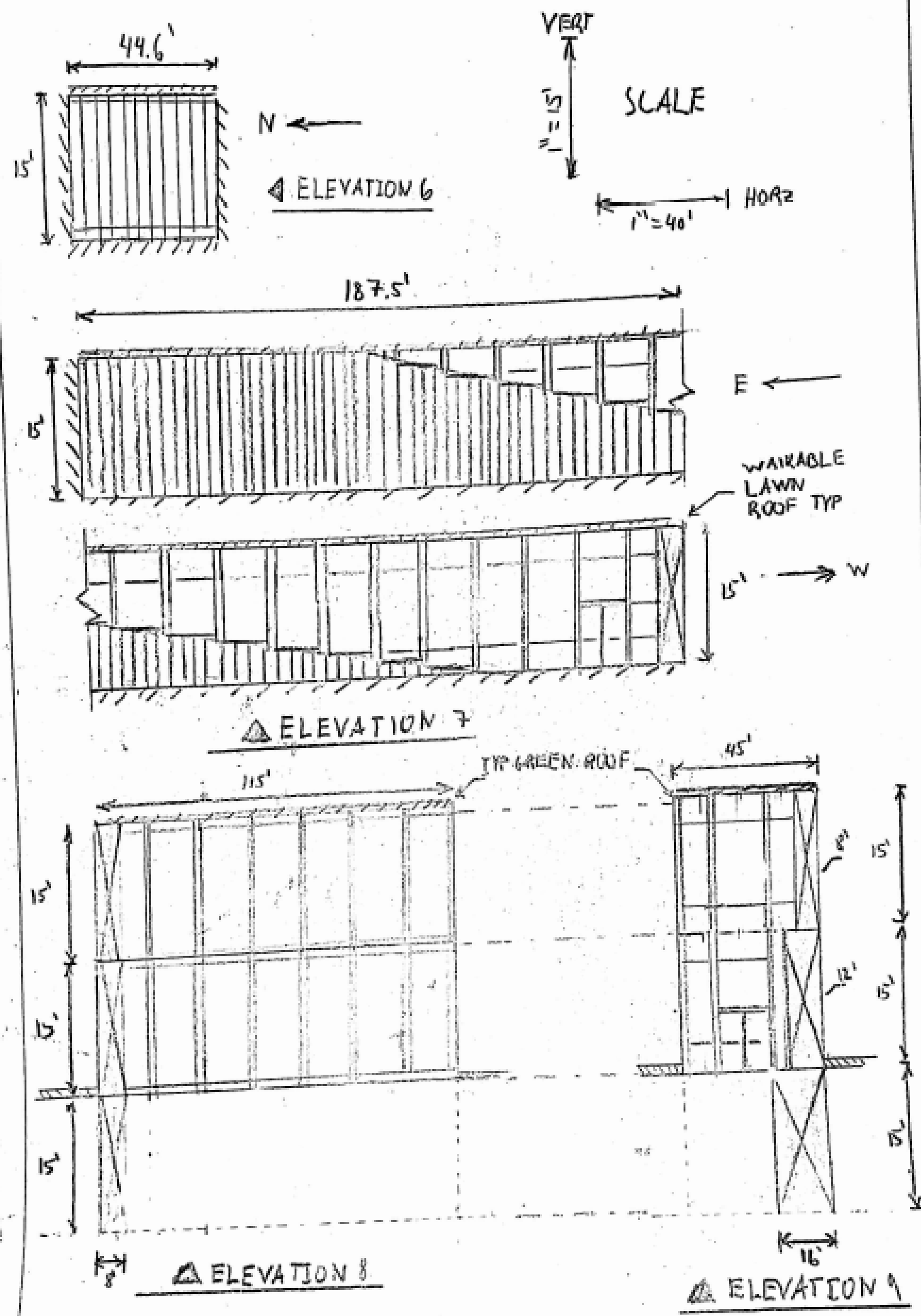


[redacted] | CEE597K LFD | 03/11/2020



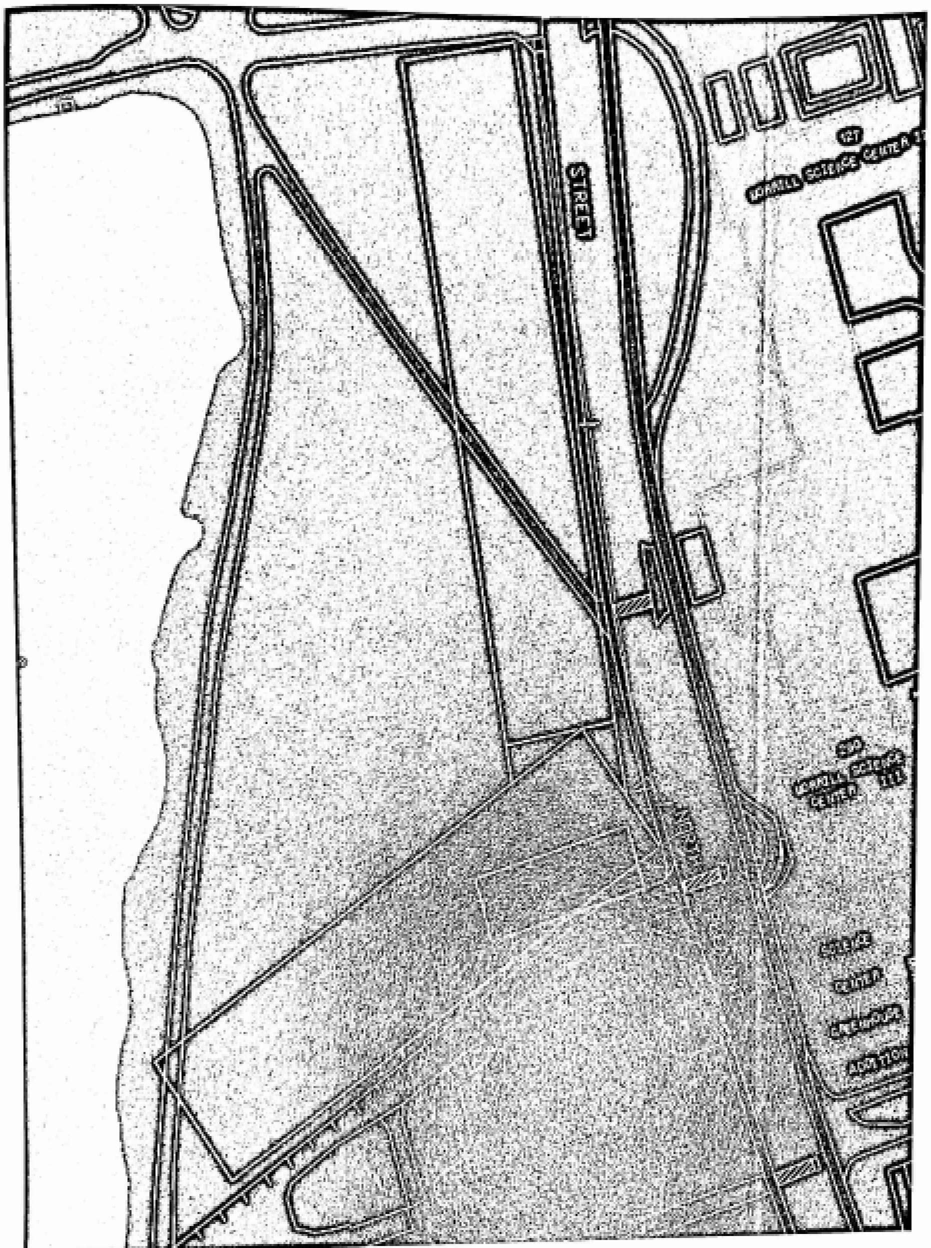


Figure 2: Final Site Layout

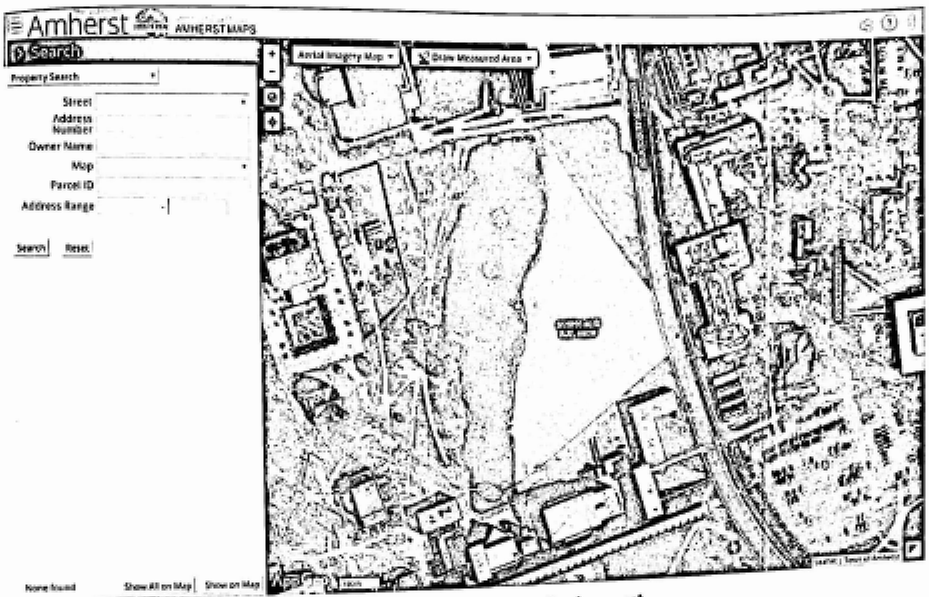


Figure 3: Initial Idea for Site Layout

Figure 4: Initial Idea for Site Layout

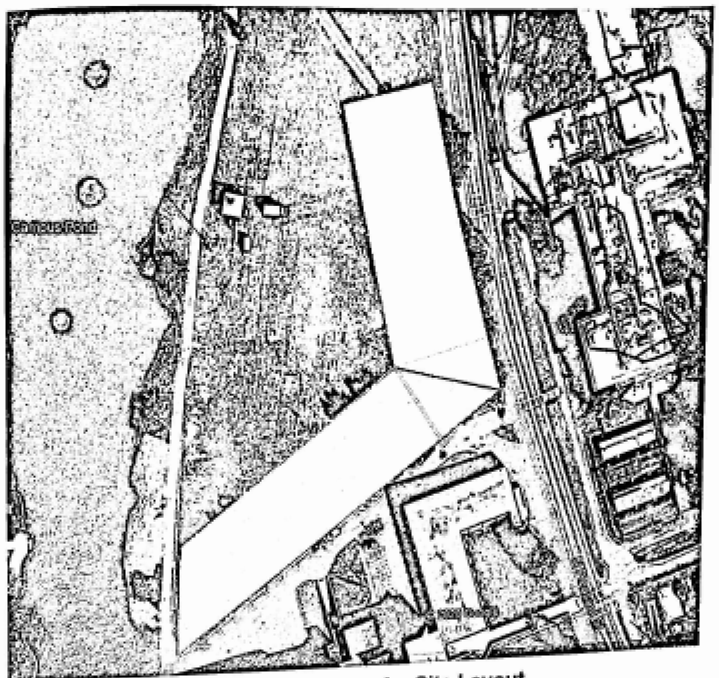


Figure 5: Initial Idea for Site Layout

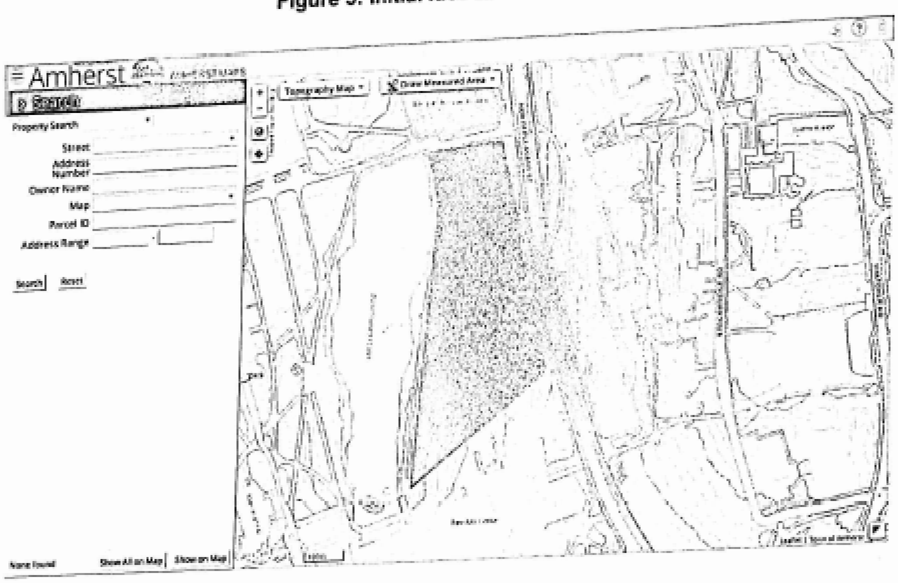
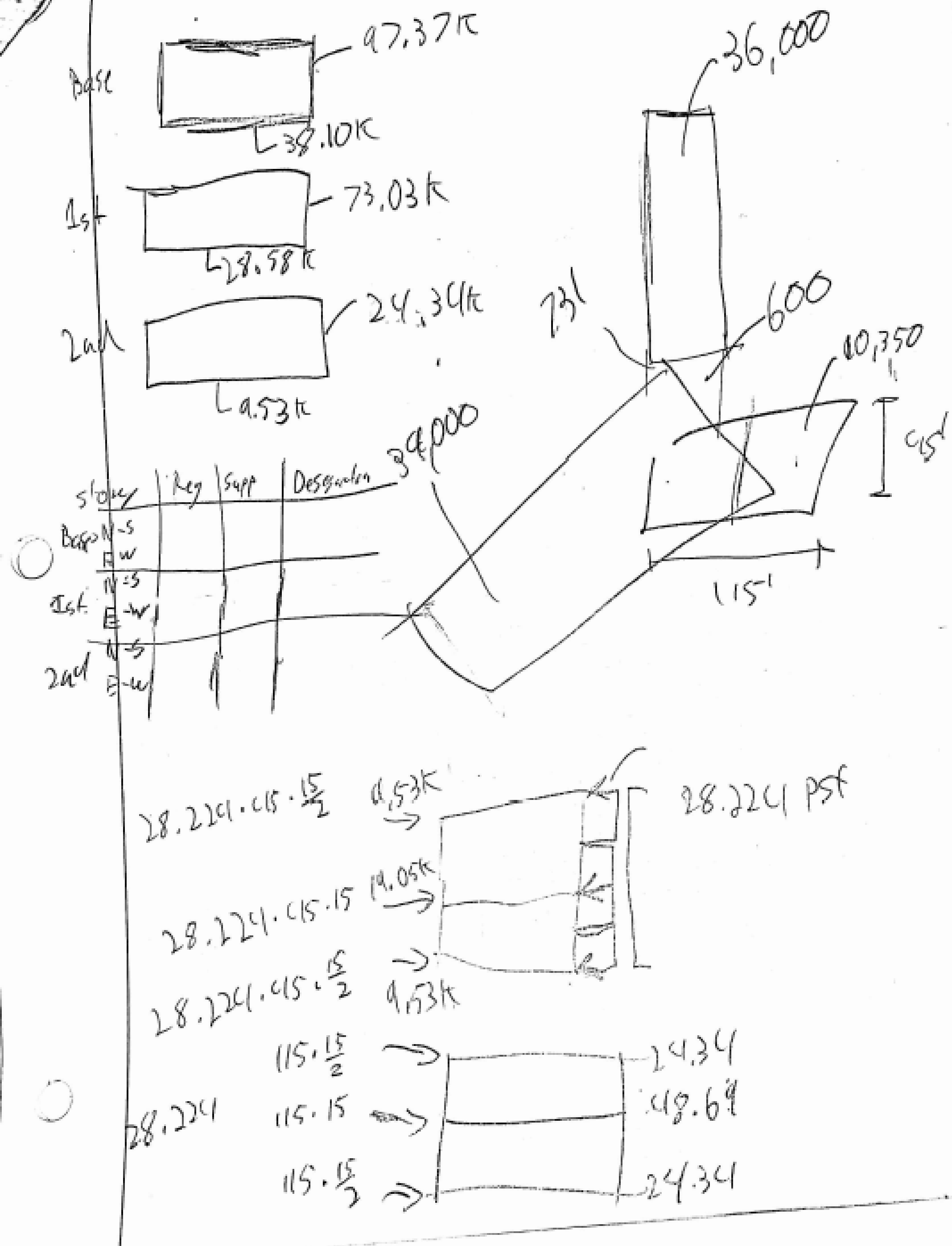


Figure 6: Initial Idea for Site Layout

Appendix 1 | Rough Calcs + Sketches | [redacted]



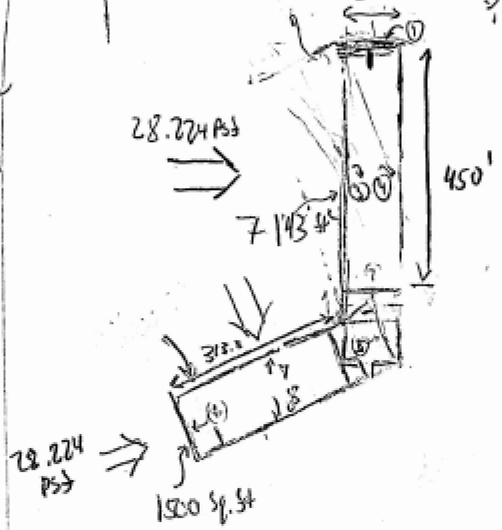
Appendix 1 | Rough Calcs + Sketches [redacted]

Conservative
80.15 = 1200
· 28.224 =
33868.8
÷2 = 16934.4
÷16 = 1058.4 #/ft

or 7.50 ft 2116.8

Shear wall demands
7143 ft² · 28.224 psf
= 201604.032 Pounds
÷2 = 100,802.016 total

1" = 50' ...
1/4" = 10'
1/4" = 2'
1" = 20'
1/4" = 4'
1" = 40'
1/4" = 8'
1" = 80'
1/4" = 16'



① 100802.016 Pounds / 2 / 80'
= 630.0126 #/ft
↳ OSB, 6", 33 min: 700

100802.016/2 / 700 = 72"

② 100802.016 Pounds / 2
over min walls
by 2:1 min 15'/2 = 7.5'
100802.016#/3080 = 16.37'
for wall

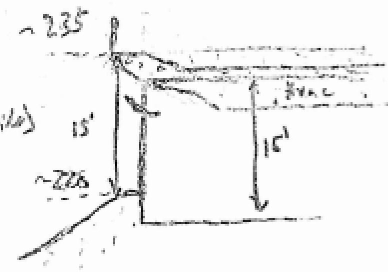
24

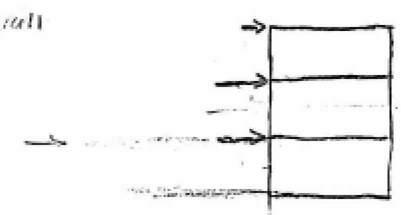
1500 ft² · 28.224 psf = 42,336 Pounds
÷2 = 21168

by 2:1 min → 7.5' per side

21168#/15' = 1411.2 #/ft
/16' = 1323 #/ft
2×8' OSB, 4", 54 min (1 per side)

4700
33.3 · 15 · 28.22 psf = 13263.7
÷2 = 6631.344 to walls
÷200 ft = 331.6 #/ft min
÷3080 = 21.53 ... wall
↳ 10.77' Per wall





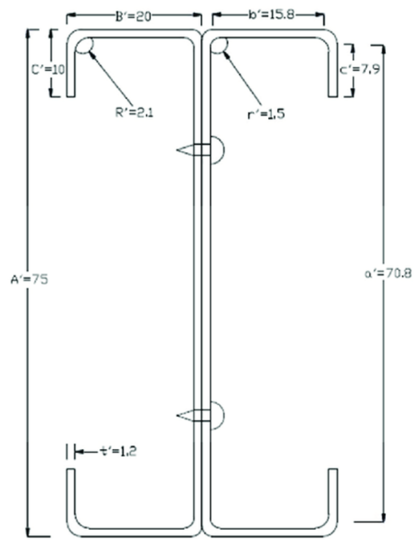
Appendix F: Graduate-level cold-formed steel sample project

Mini-Project 5: Cold-formed steel design

University of Massachusetts Amherst CEE 542

Due April 30th, 2019

Cold-formed steel studs are frequently connected "back-to-back" to increase capacity – these compound members are used primarily as columns, chord studs in shear walls, and floor joists. The figure below illustrates this detail in which two studs are connected via fasteners at the web (ignore dimensions – figure is for illustrative purposes only).



As you can imagine, the web fasteners can create composite action in the back-to-back studs and can be detailed to increase or decrease the degree of composite action.

Using the Direct Strength Method and the provisions in AISI S100-16:

1. What is the capacity of two non-composite back-to-back 600S200-97 [50 ksi] studs in strong axis flexure? For full credit you must provide: input and output of a finite strip analysis, hand calculations, and any assumptions you made. (20 pts)

2. Repeat (1) but now assume the back-to-back studs are connected at two points on the web, spaced 3" from each other. How does the capacity change when you consider this connectivity? (30 pts)

Hint: this paper may provide some guidance

David C. Fratamico, Shahabeddin Torabian, Xi Zhao, Kim J.R. Rasmussen, Benjamin W. Schafer, "Experimental study on the composite action in sheathed and bare built-up cold-formed steel columns," Thin-Walled Structures, Volume 127, 2018, Pages 290-305, ISSN 0263-8231, https://doi.org/10.1016/j.tws.2018.02.002.

Appendix G: Graduate-level in-class sample laboratory (open-ended)

CEE 542 CUFSM Lab – April 16 2019

University of Massachusetts Amherst CEE 542

Email results to Dr. Peterman: kdpeterman@umass.edu

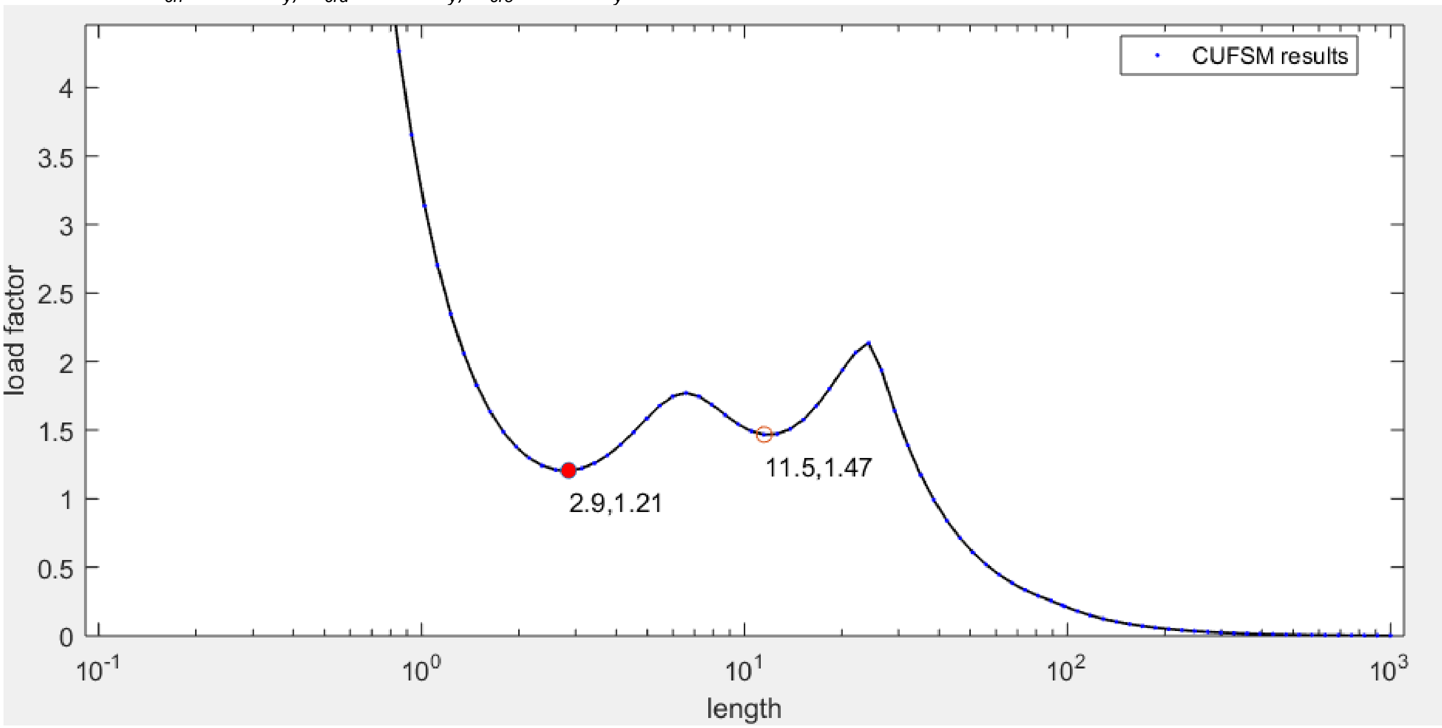
1. Model a simply supported 8' long 362S162-68 [50 ksi] stud under axial compression in CUFSM and produce the signature curve. Identify the design inputs P_{crl}, P_{crd}, and P_{cre}.

2. You wish to increase the distortional buckling capacity of the stud. Modify your cross-section such that Pcrd is increased (provide a comparison plot of the signature curves with the original section and the new section to demonstrate your changes). Do not change the thickness of the cross-section.

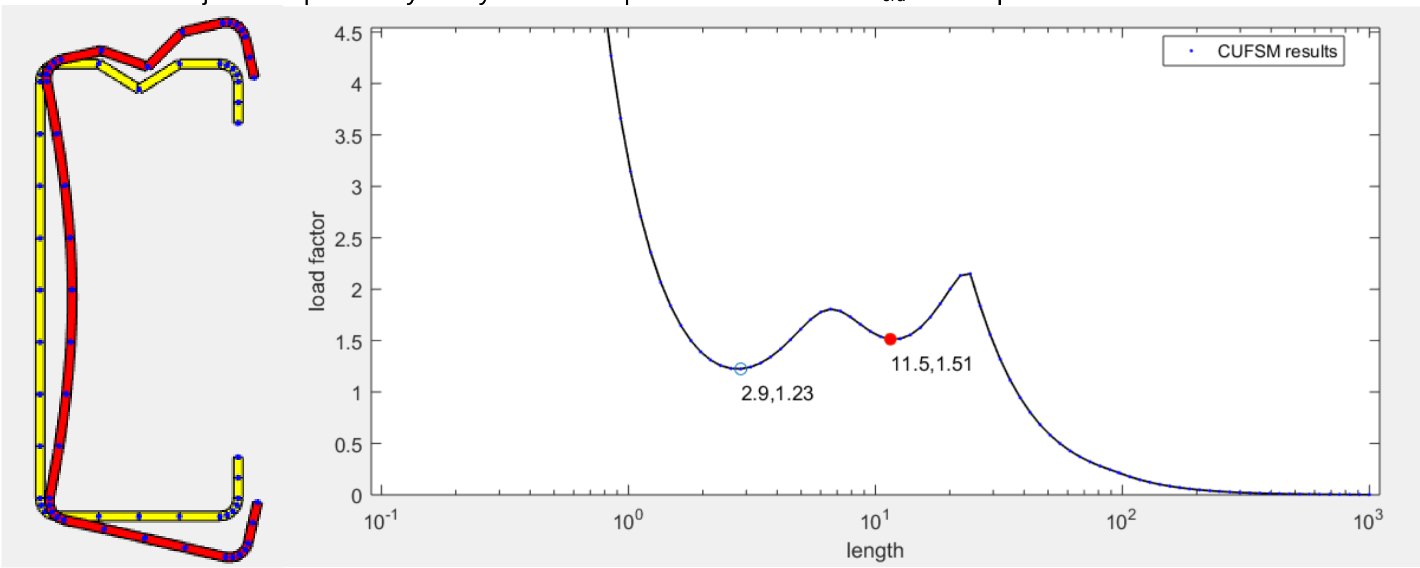
3. Cold-formed sections are frequently fastened at the midpoint of the flanges to other material (sheathing) which restricts their ability to deform (and thus buckle). Model this restraint on your original 362S162-68 [50 ksi] section in CUFSM and state your model inputs. Compare the new signature curve to that of the original section. What do these restraints change?

Appendix H: Possible solutions to in-class laboratory

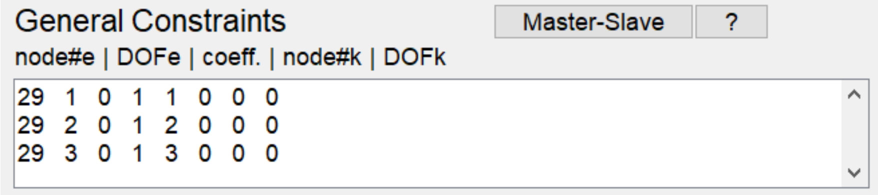
Problem 1: $P_{crl} = 1.21P_y$; $P_{crd} = 1.47P_y$; $P_{cre} = 0.22P_y$

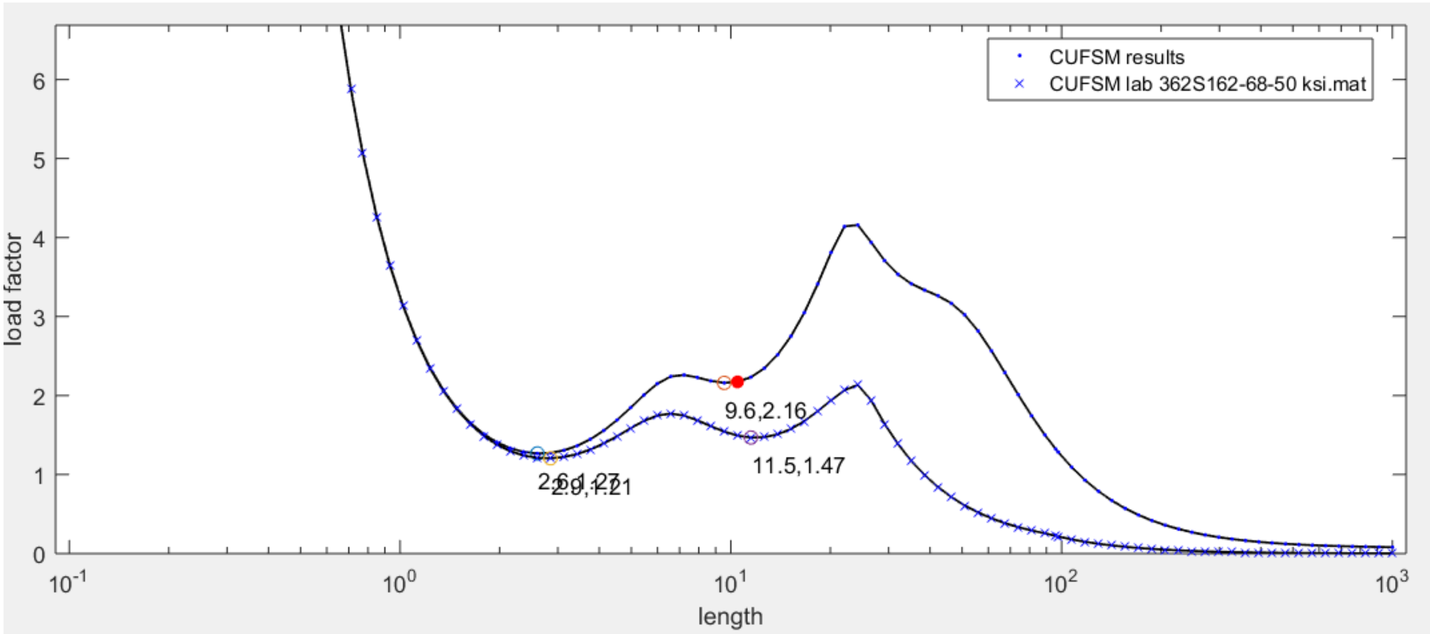


Problem 2: this is just one possibility – any result that produces increased P_{crd} is acceptable.



Problem 3: baseline model from problem 1 used for this – center of top flange (node 29) restrained via General Constraints function. Pcrd increases, Pcre increases (restraint delays formation of global buckling).





CUFSM results
CUFSM lab 362S162-68-50 ksi.mat
load factor
length
9.6,2.16
11.5,1.47
2.6,1.27
2.9,1.21