Rating form completed by:

RUTHERFORD + CHEKENE
ruthchek.com
Evaluator: CLP/EFA/BL
Date: 06/28/2019

Text in green is to be part of UC Santa Cruz building database and may be part of UCOP database

REGISTERED PROFESSIONAL ENGINEER
BRET LIZUNDIA
No. S3950
Exp. 12-31-20
STRUCTURAL
STATE OF CALIFORNIA
06-28-19

DATE: 2019-06-28

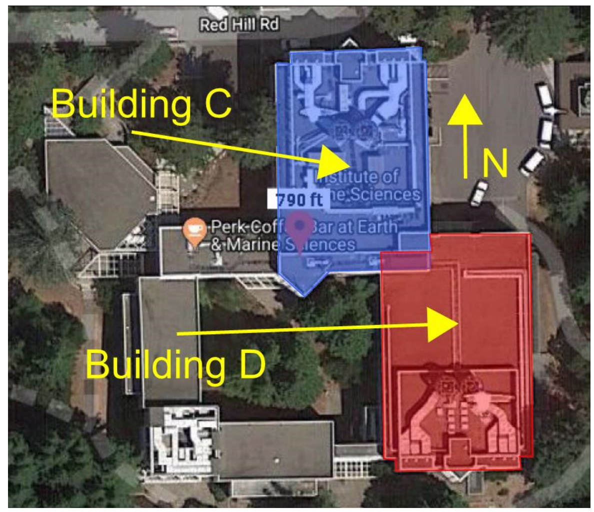
UC Santa Cruz building seismic ratings

Earth & Marine Sciences (Concrete Shear Wall Lab Blocks C & D)

CAAN #7775
552 Red Hill Road, Santa Cruz, CA 95064
UCSC Campus: Main Campus

Building C (North Elev. Building D (East Elev.)

Plan



Rating summary	Entry	Notes
UC Seismic Performance Level (rating)	V (Poor)	
Rating basis	Tier 1	ASCE 41-17[1]
Date of rating	2019	
Recommended UC Santa Cruz priority category for retrofit	Priority B	Priority A=Retrofit ASAP Priority B=Retrofit at next permit application
Ballpark total construction cost to retrofit to IV rating[2]	High ($200-400/sf)	See recommendations on further evaluation and retrofit.
Is 2018-2019 rating required by UCOP?	Yes	1998 Revised Rating was Good (3 checklists, 2 reports)
Further evaluation recommended?	Yes	Tier 2 or 3 evaluation of concrete shear wall capacity.

[1] We translate this Tier 1 evaluation to a Seismic Performance Level rating using professional judgment. Non-compliant items in the Tier 1 evaluation do not automatically put a building into a particular rating category, but we evaluate such items along with the combination of building features and potential deficiencies, focused on the potential for collapse or serious damage to the gravity supporting structure that may threaten occupant safety. See Section III.B of the 19 May 2017 *UC Seismic Safety Policy* and Method B of Section 321 of the 2016 *California Building Code*.

[2] Per Section III.A.4.i of the 26 March 2019 *UC Seismic Program Guidebook, Version 1.3*, the cost includes all construction cost necessitated by the seismic retrofit, including restoration of finishes and any triggered work on utilities or accessibility. It does not include soft costs such as design fees or campus costs. The cost is in 2019 dollars.

Building information used in this evaluation

- Architectural drawings by McLellan & Copenhagen, Executive Architects, and Zimmer Gunsul Frasca Partnership, "Earth and Marine Sciences Building, University of California, Santa Cruz," as-built set dated 16 August 1991, Sheets A0.1 to A8.4.3 (165 sheets). Drawings are for whole complex; relevant sheets for concrete shear wall buildings are for "North and South Lab Blocks."
- Structural drawings by Rutherford + Chekene, Structural and Civil Engineers, "Earth and Marine Sciences Building, University of California, Santa Cruz," reference set dated 16 August 1991, Sheets S0.1 to S8.1 (45 sheets). Drawings are for whole complex; relevant sheets for concrete shear wall buildings are for "North and South Lab Blocks."
- Structural Calculations by Rutherford+ Chekene, three volumes obtained from R+C archive dated February 1990.
- UCSC 1998 Seismic Assessment, 2 reports by R+C.

Additional building information known to exist

Original Civil, Electrical, Mechanical, Plumbing, Fire Alarm, Honeywell shop drawings not reviewed.

Scope for completing this form

Reviewed architectural and structural drawings for original construction, reviewed original 1990 structural calculations, reviewed 1998 Seismic Assessment, made brief site visit on 3 June 2019, and carried out ASCE 41-17 Tier 1 evaluation.

Brief description of structure

The Earth and Marine Sciences Building is a complex with seven independent structures that include two concrete shear wall laboratory buildings, four steel moment frame office buildings, and one steel braced frame lecture hall. The buildings are arranged around a central courtyard on a site that slopes to the south and are typically separated by 2" or 3" seismic gaps. This report addresses the two concrete shear wall Lab Block Buildings C and D that are classified as Model Building Type C2.

The two 4-story Lab Blocks C and D have perimeter concrete shear walls perforated with numerous window and door openings. Although each building contains four levels of framing, the floor levels are offset by one level, so the roof of Lab Block C is one story above the roof of Lab Block D. The elevators serve both structures and have five elevator levels in order to provide access to the roof of Lab Block D. The framing in the interior consists of 26" deep concrete waffle slabs spanning to concrete columns with drop panels. The two buildings are oriented at 90 degrees with an interlocking reentrant corner at the southeast corner of Lab Block C. Stairs at the building perimeters are triangular in plan with full height glazing and located at the north and south ends of Lab Block C and the south end of Lab Block D. A loading dock is located at the north end of Lab Block D.

<u>Building Condition:</u> The building appeared to be well maintained for a structure of this vintage. We did not observe any signs of structural deterioration that would influence the rating.

<u>Identification of levels:</u> The original drawings identify five levels labeled Levels 0 to Level 4 but the Lab Blocks each have four structural levels. The site slopes down from the north to the south and some portions of the complex are below grade. The bottom of footing at the north end of Lab Block C is at 777'; the bottom of footing at the south end of Lab Block D is at 747.5'. The south end of Lab Block C has lower footings than the north end. These Lab Block buildings are basically rectangular in plan and oriented at 90 degrees to each other, joined to the Atrium on the north side and via bridge structures to Office A1 on the south side. The floor levels of the Lab Blocks and Office buildings are slightly misaligned at Levels 1 and 3, so the bridges on the south at these two levels are sloped.

<u>Foundation system:</u> The Lab Blocks C and D have continuous wall footings at the perimeter shear walls and a mix of individual spread footings, larger group footings, and tie beams for some of the interior columns. The last bay at the north end of Lab Block D has a mat footing. The N-S wall footings are stepped to accommodate the slope to the south.

<u>Structural system for vertical (gravity) load:</u> The Lab Block buildings typically have 26" concrete waffle slabs that span to the perimeter shear walls and to interior columns with drop panels. The roof has a 10" flat slab that spans to

columns and to a limited number of concrete beams. Limited steel framing was used in the 3 stair towers and for the bridges that connect to Office A1.

Structural system for lateral forces: The Lab Block buildings were designed as concrete shear walls with all the lateral load taken by concrete shear walls. The design was done per the 1988 UBC using an allowable stress design lateral load of V=0.183W and an R_w value of 6. Each structure has two lines of shear walls at or near the perimeter walls. The walls are typically 13.5" thick with two curtains of #5@12" in each direction. All the walls are perforated with numerous openings, so the walls consist largely of deep spandrel beams and short piers between openings that are shear critical. Piers are generally well detailed with relatively tight confinement reinforcing.

Brief description of seismic deficiencies and expected seismic performance including mechanism of nonlinear response and structural behavior modes

Identified seismic deficiencies of the building include the following:

- Due to the many wall openings, the shear walls appear to have inadequate shear capacity at the three lower levels in both directions using the ASCE 41-17 Quick Check procedure. The peak demand-to-capacity ratio is 2.0. The walls are basically deep spandrels with narrow piers between windows.
- The 2" seismic gap between the concrete Lab Blocks is inadequate by current standards, but the buildings are relatively stiff, and the floors are aligned at three levels, so this may result in pounding but not expected to cause severe damage.

Structural deficiency	Affects rating?	Structural deficiency	Affects rating?
Lateral system stress check (wall shear, column shear or flexure, or brace axial as applicable)	Y	Openings at shear walls (concrete or masonry)	N
Load path	N	Liquefaction	N
Adjacent buildings	Y	Slope failure	N
Weak story	N	Surface fault rupture	N
Soft story	N	Masonry or concrete wall anchorage at flexible diaphragm	N
Geometry (vertical irregularities)	N	URM wall height-to-thickness ratio	N
Torsion	N	URM parapets or cornices	N
Mass – vertical irregularity	N	URM chimney	N
Cripple walls	N	Heavy partitions braced by ceilings	N
Wood sills (bolting)	N	Appendages	N
Diaphragm continuity	N		

Summary of review of nonstructural life-safety concerns, including at exit routes.[3]

The Lab Blocks C and D include a large mechanical floor at the lowest level of Building D and scientific laboratories with seemingly hazardous materials. Limited lab areas were observed at the time of our site visit and included a mix of restrained, poorly restrained, and unrestrained hazardous items. Unrestrained gas cylinders and a cryotank were observed in one lab area. Laterally unrestrained piping (service unknown) was observed in Lab Block D on the roof and in the mechanical basement. We are flagging the issue so that a subsequent evaluation confirms whether the unbraced piping corresponds to any type of gas piping or ventilation for hazardous compounds whose failure may pose a life safety hazard.

[3] For these Tier 1 evaluations, we do not visit all spaces of the building; we rely on campus staff to report to us their understanding of if and where nonstructural hazards may occur.

UCOP nonstructural checklist item	Life safety hazard?	UCOP nonstructural checklist item	Life safety hazard?
Heavy ceilings, feature or ornamentation above large lecture halls, auditoriums, lobbies or other areas where large numbers of people congregate	None observed	Unrestrained hazardous materials storage	Yes
Heavy masonry or stone veneer above exit ways and public access areas	None observed	Masonry chimneys	None observed
Unbraced masonry parapets, cornices or other ornamentation above exit ways and public access areas	None observed	Unrestrained natural gas-fueled equipment such as water heaters, boilers, emergency generators, etc.	None observed

Basis of rating

A Seismic Performance Level rating of V is assigned to the C2 buildings based on the deficiencies identified by the Tier 1 check. The concrete shear walls have numerous openings, strong spandrel-weak pier geometry, and inadequate shear capacity using these procedures. Small seismic gaps may allow pounding between adjacent buildings.

Recommendations for further evaluation or retrofit

We recommend performing a nonlinear Tier 3 evaluation to obtain a more refined quantification of wall behavior mechanisms and deformation capability to see if acceptance criteria are satisfied via the use of more advanced calculations and expected strengths.

Peer review of rating

This seismic evaluation was discussed in a peer review meeting on 24 June 2019. Reviewers present were Joe Maffei of Maffei Structural Engineering and Jay Yin of Degenkolb Engineers. Comments from the reviewers have been incorporated into this report. The reviewers agreed with the assigned rating.

Additional building data	Entry	Notes
Latitude	36.997938	
Longitude	-122.059722	
Are there other structures besides this one under the same CAAN#	Yes	
Number of stories above lowest perimeter grade	4	
Number of stories (basements) below lowest perimeter grade	0	
Building occupiable area (OGSF)	105,000	Computed from footprint of C & D and Atrium Level 1 (Total from UCSC Database for #7775 is 152,080).
Risk Category per 2016 CBC Table 1604.5	II	
Building structural height, h_n	57 ft	Structural height defined per ASCE 7-16 Section 11.2
Coefficient for period, C_t	0.020	Estimated using ASCE 41-17 equation 4-4 and 7-18
Coefficient for period, β	0.75	Estimated using ASCE 41-17 equation 4-4 and 7-18
Estimated fundamental period	0.41 sec	Estimated using ASCE 41-17 equation 4-4 and 7-18
Site data		
975-year hazard parameters S_s, S_1	1.283, 0.487	From OSHPD/SEAOC website
Site class	D	

Site class basis	Geotech[4]	See footnote below
Site parameters F_a, F_v	1.0, 1.813	From OSHPD/SEAOC website
Ground motion parameters S_{cs}, S_{c1}	1.283, 0.882	From OSHPD/SEAOC website
S_a at building period	1.28	
Site V_{s30}	900 ft/s	
V_{s30} basis	Estimated	Estimated based on site classification of D.
Liquefaction potential	Low	
Liquefaction assessment basis	County map	See footnote below
Landslide potential	Low	
Landslide assessment basis	County map	See footnote below
Active fault rupture identified at site	No	
Fault rupture assessment basis	County map	See footnote below
Site-specific ground motion study?	No	
Applicable code		
Applicable code or approx. date of original construction	Built: 1993 Code: 1988 UBC	
Applicable code for partial retrofit	None	No partial retrofit.
Applicable code for full retrofit	None	No full retrofit
FEMA P-154 data		
Model building type – north-south	C2 Concrete Shear Wall	
Model building type – east-west	C2 Concrete Shear Wall	
FEMA P-154 score	N/A	Not included here because we performed ASCE 41 Tier 1 evaluation.
Previous ratings		
Most recent rating	Good	UCSC 1998 Seismic Survey #7775.
Date of most recent rating	1998	
2nd most recent rating	-	
Date of 2nd most recent rating	-	

4 Determination of site class and assessment of geotechnical hazards are based on correspondence with Pacific Crest Geotechnical Engineers and Nolan, Zinn, and Associates Geologists. [*Revised Geology and Geologic Hazards, Santa Cruz Campus, University of California*, Job # 04003-SC 13 May 2005]. Site class is taken as D throughout the main campus of UC Santa Cruz. The following links provide hazard maps for liquefaction, landslide, and fault rupture:
https://gis.santacruzcounty.us/mapgallery/Emergency%20Management/Hazard%20Mitigation/LiquifactionMap2009.pdf
https://gis.santacruzcounty.us/mapgallery/Emergency%20Management/Hazard%20Mitigation/LandslideMap2009.pdf
https://gis.santacruzcounty.us/mapgallery/Emergency%20Management/Hazard%20Mitigation/FaultZoneMap2009.pdf

3rd most recent rating	-	
Date of 3rd most recent rating	-	
Appendices		
ASCE 41 Tier 1 checklist included here?	Yes	Refer to attached checklist file.

Rating form completed by:

RUTHERFORD + CHEKENE
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Evaluator: CLP/EFA/BL

Date: 06/28/2019

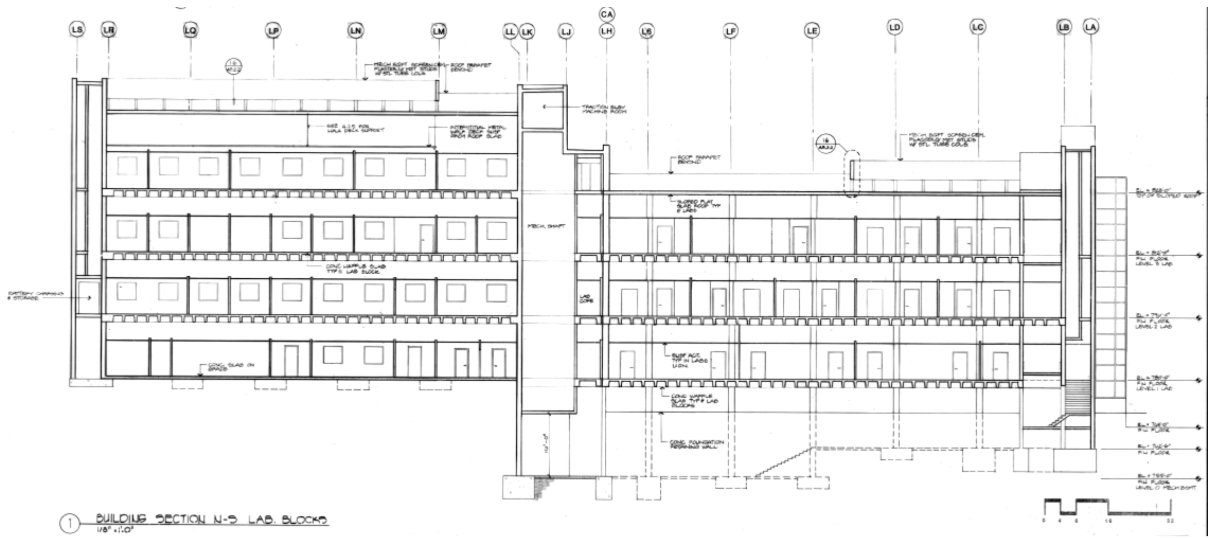
Site Plan for Orientation

[redacted]

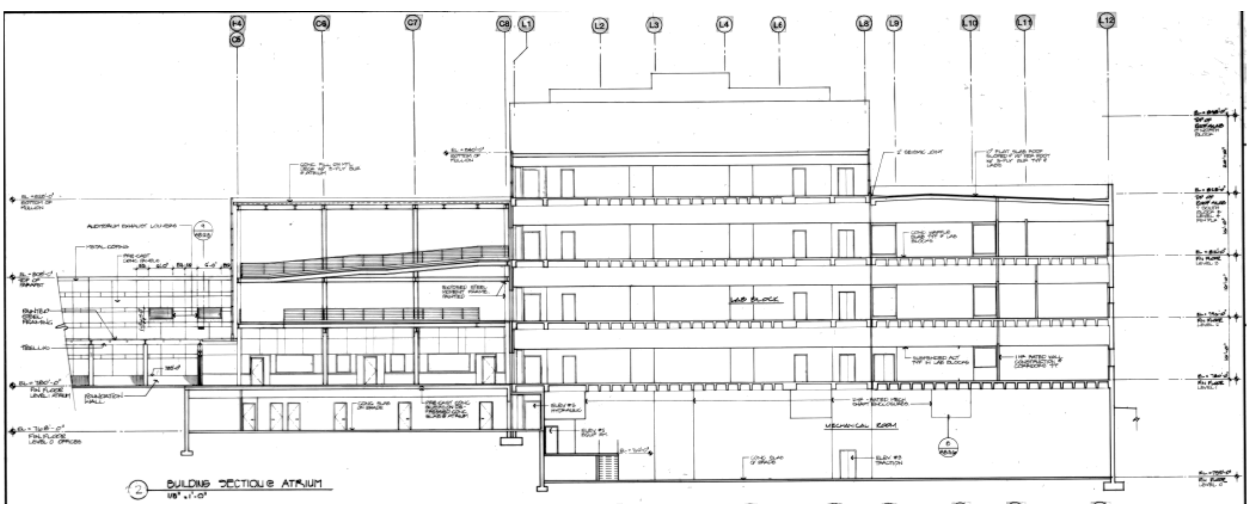
Structural Plan Level 1 Sheet S2.2.1 (North at Right)

[redacted]

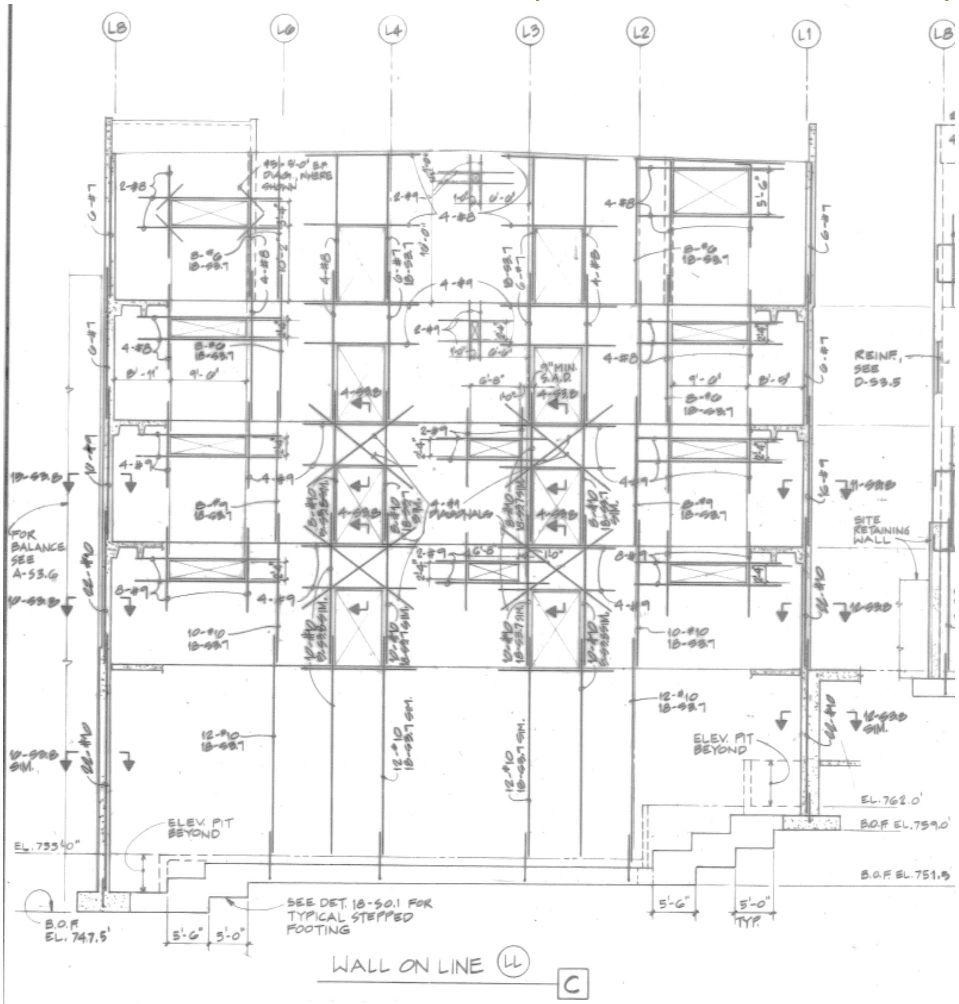
Architectural Section thru Lab Blocks (Looking East, Block C Left, Block D Right, note floors offset by one level)



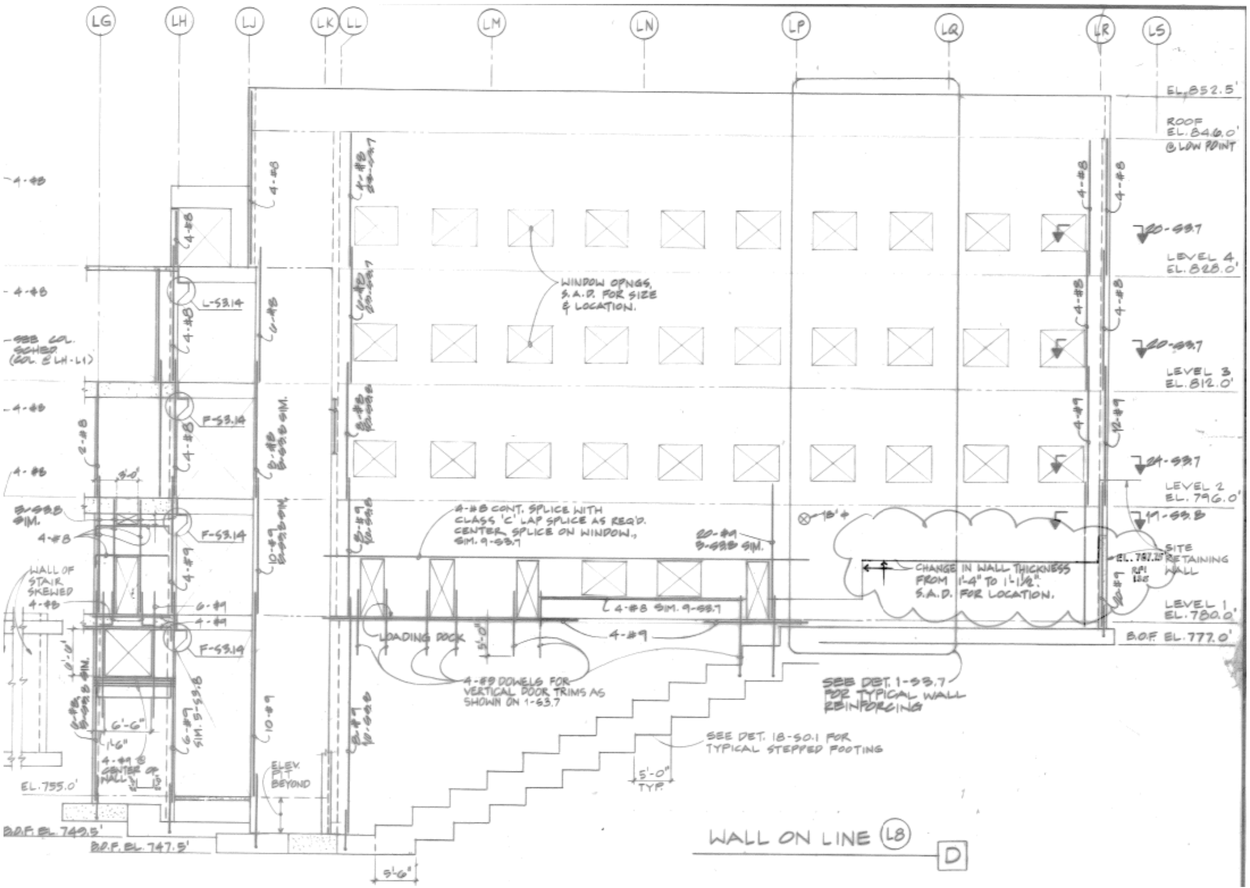
Architectural Section thru B, Atrium and Lab Blocks (Looking North, B206 Far Left, Atrium Left, Block C Right, Block D Far Right)



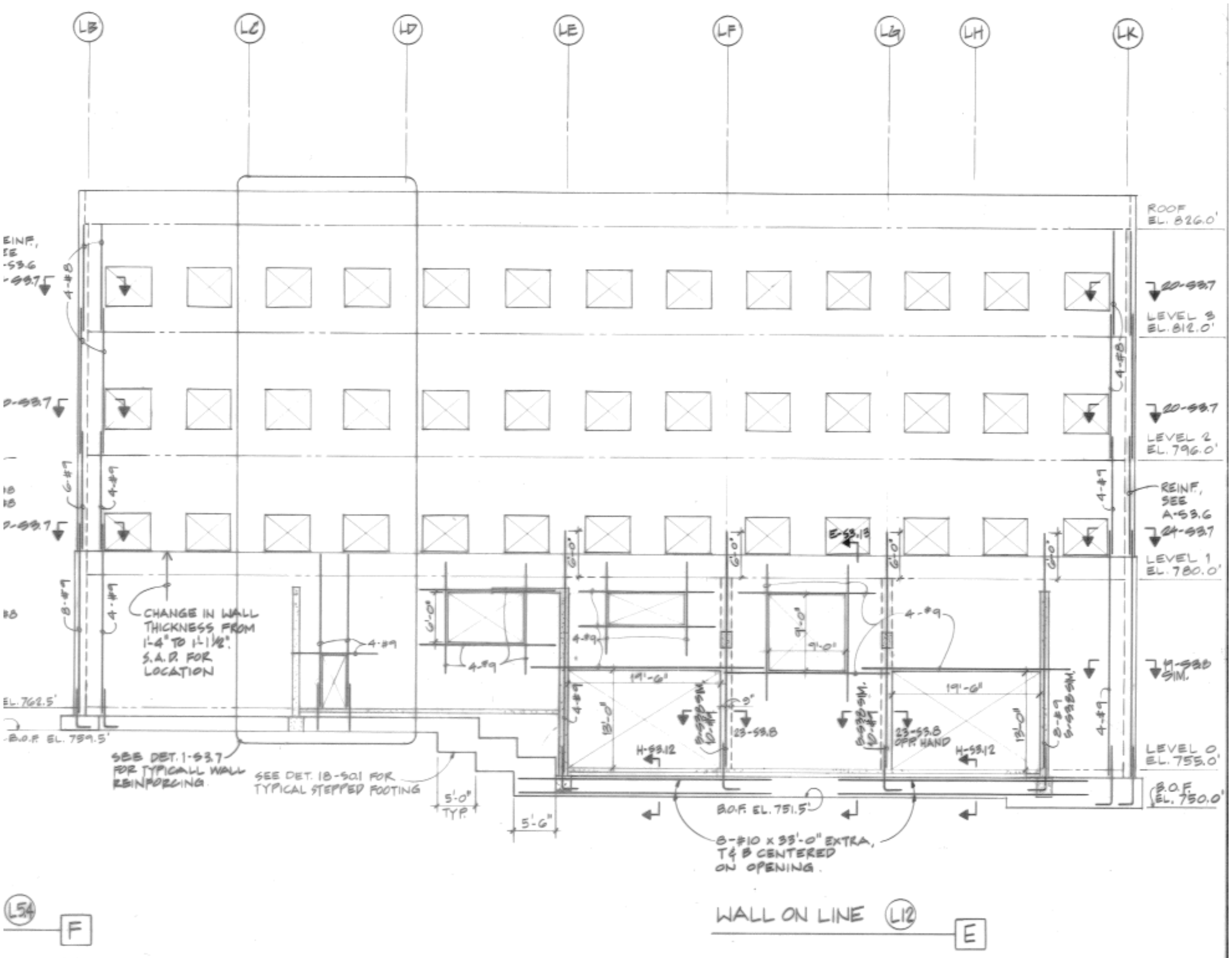
Transverse Shear Wall Elevation Line LL (C/S3.5, South Wall Lab Block C)



Longitudinal Shear Wall Elevation Line L8 (D/S3.5, East Wall Lab Block C)



Longitudinal Shear Wall Elevation Line L12 (E/S3.6, East Wall Lab Block D)



APPENDIX A

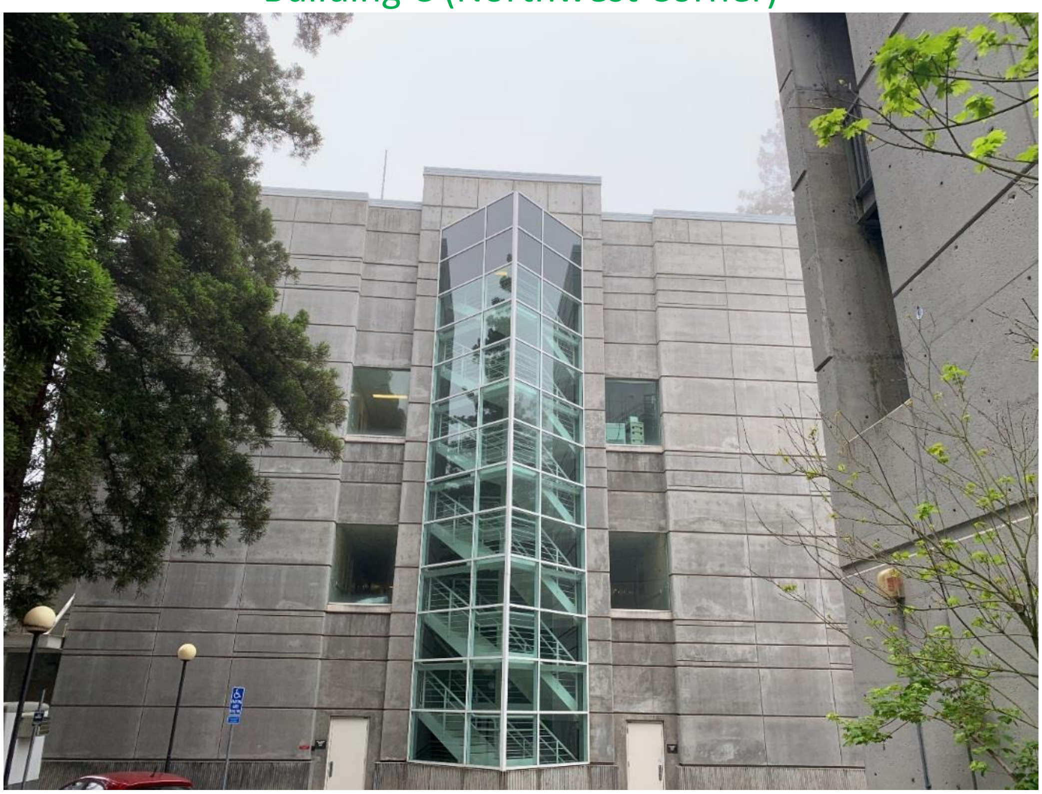
Additional Photos

Building Name: EARTH & MARINE SCIENCES (C2)
Evaluator: R+C
CAAN ID: 7775
Date: 6/28/19

[redacted]

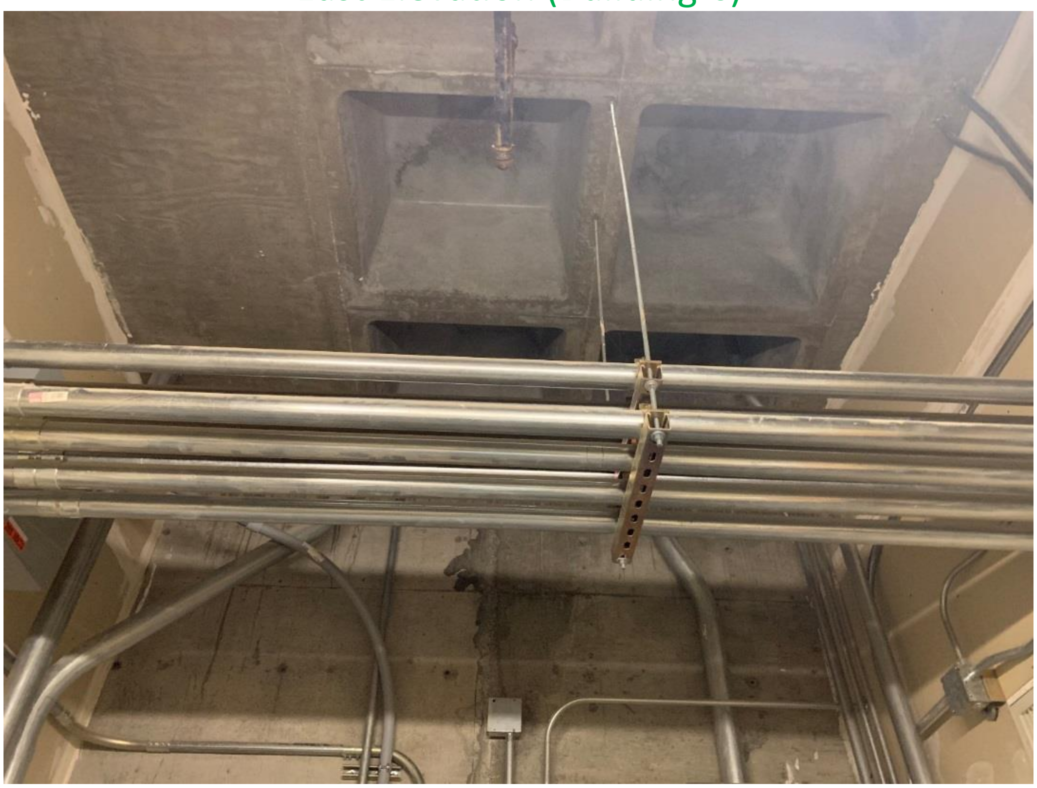
Plan Showing Building Designations (Buildings C and D are C2 Concrete Shear Wall Buildings)

Building C (Northwest Corner)



North Elevation (Building C)

East Elevation (Building C)

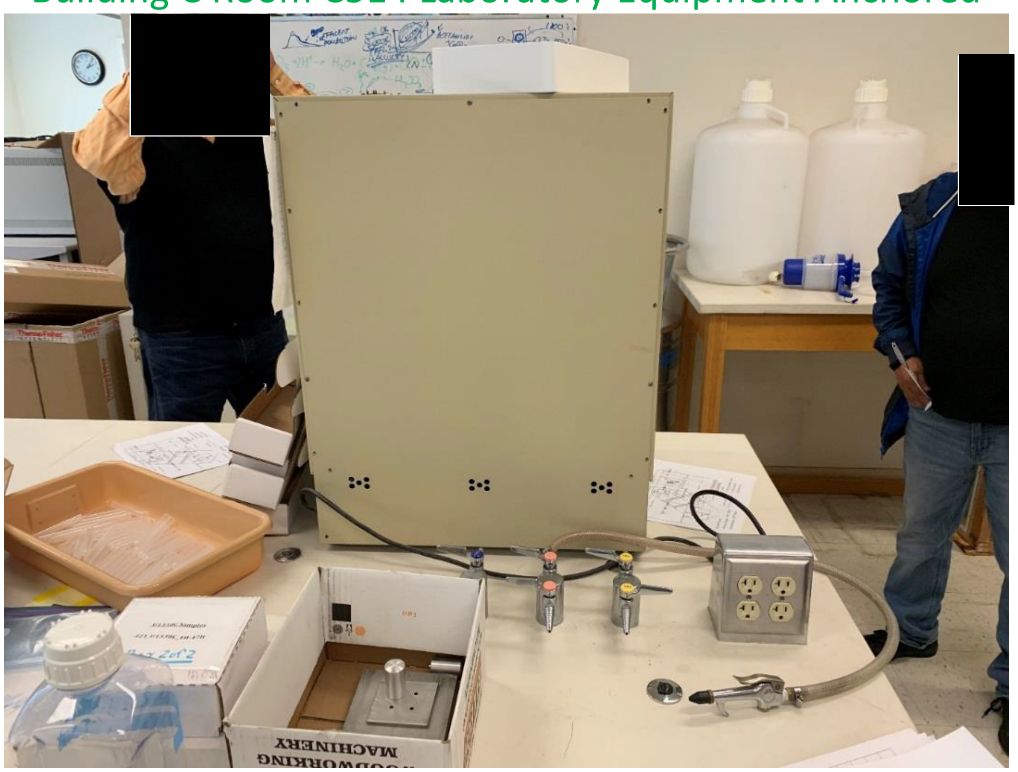


Building C (View Above Ceiling in Corridor near C300)

Building C (Typical View Above Ceiling)

Building C Room C514 (3 Cylinders Anchored to Wall, One Anchored to Dolly, One Unanchored)

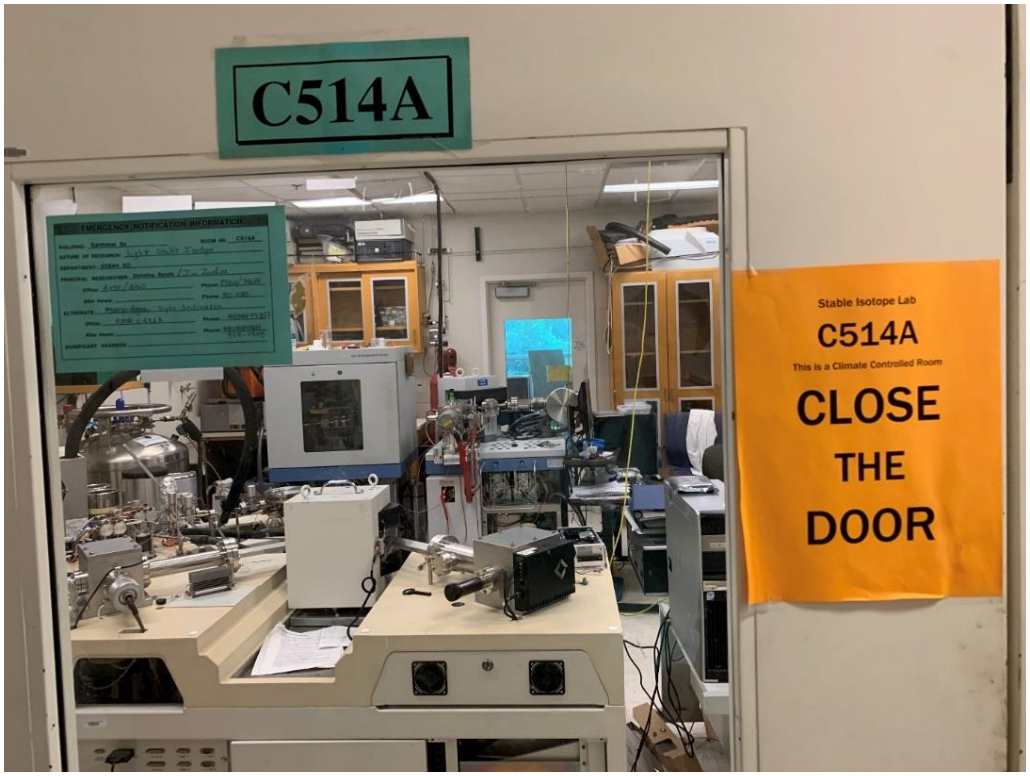
Building C Room C514 Laboratory Equipment Anchored



Building C Room C514 Laboratory Equipment Unanchored

Building C Room C514 Toolbox Unanchored

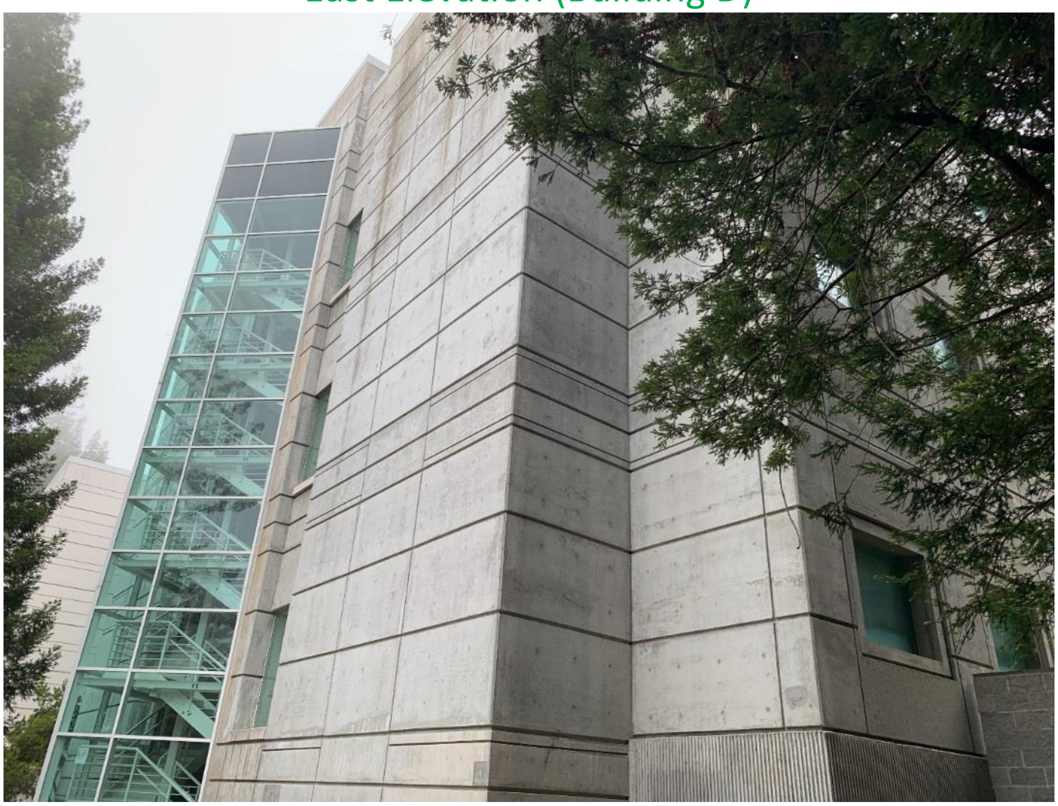
Building C Room C514 Tall Cabinet Unanchored



Building C Room C514A Unanchored Laboratory Equipment

North Elevation Building D (Left), East Elevation Building C (Right)

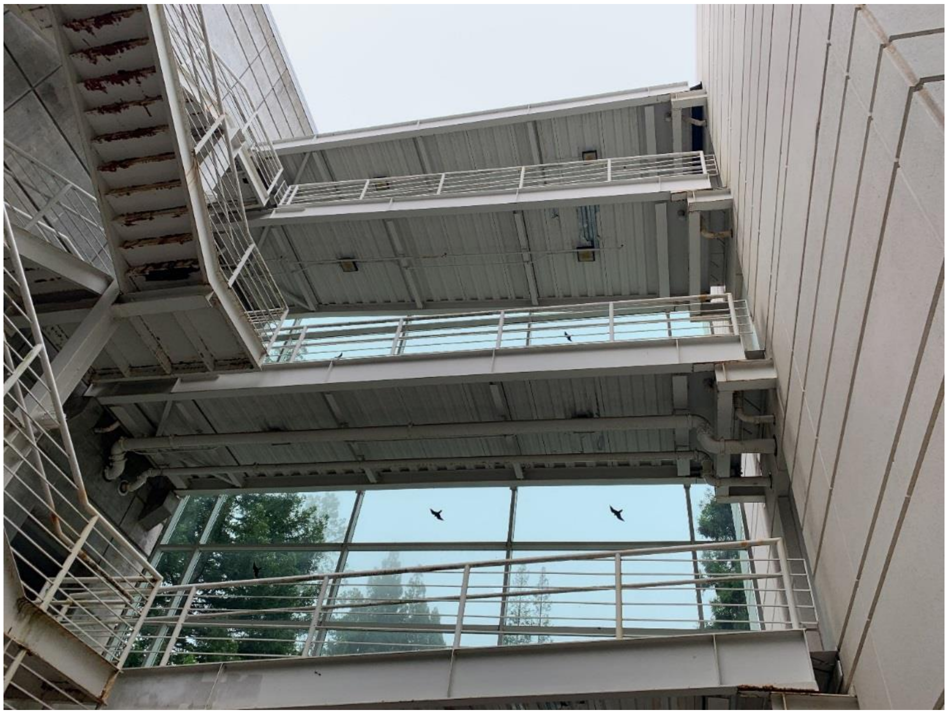
East Elevation (Building D)



Southeast Corner (Building D)

South Elevation (Building A1 Left, Bridge at Center, Building D Right)

North Elevation of Bridge Lower Portion (Looking South from Courtyard, Building D at Left)



North Elevation of Bridge Upper Portion (Looking South from Courtyard, Building D at Left, Building A1 at Right)

Bridge Support Detail (Looking South, Building A1 at Right)

Bridge Support Detail (Looking North, Anchored to Building D at Right)

View Above Ceiling at Cable Trays Braced with Unistrut (Corridor Near Building D300)

View Above Ceiling in Corridor near D300 with Partitions Anchored at Top (Building D)

Wall Anchored Milli-Q Tank (Building D360)

Anchored Fume Hood (Building D360)

Restraints at Top of Cabinet (Building D360)

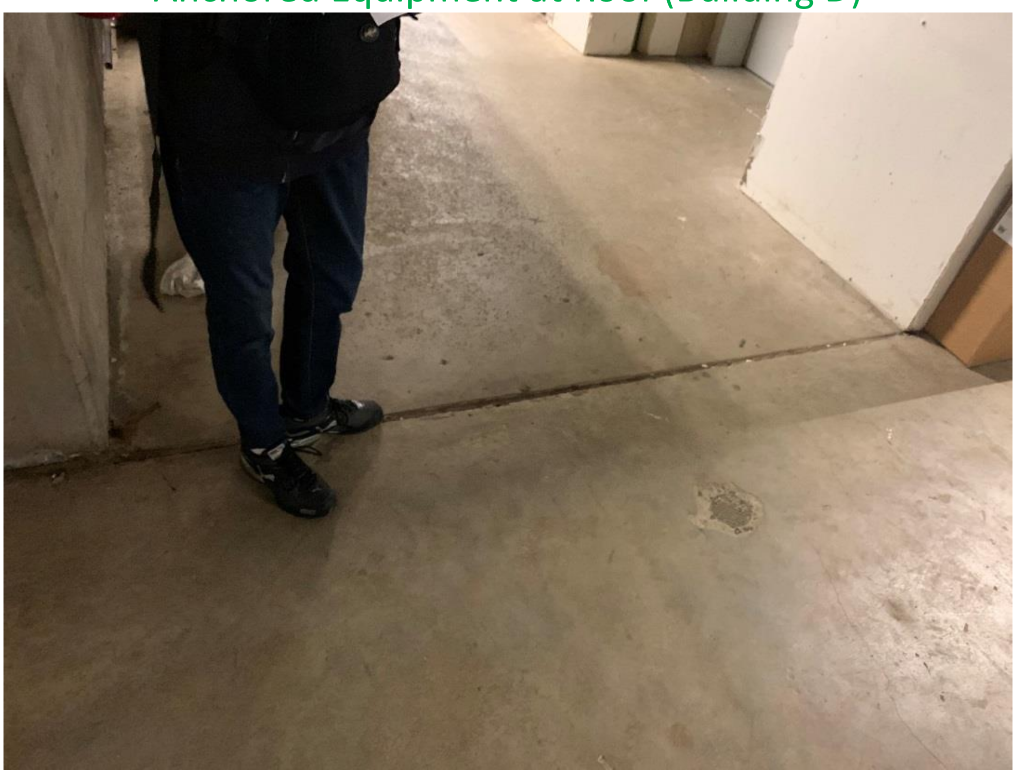
Laterally Unrestrained Pipes at Roof (Building D)

Restrained Cooling Towers at Roof (Building D)

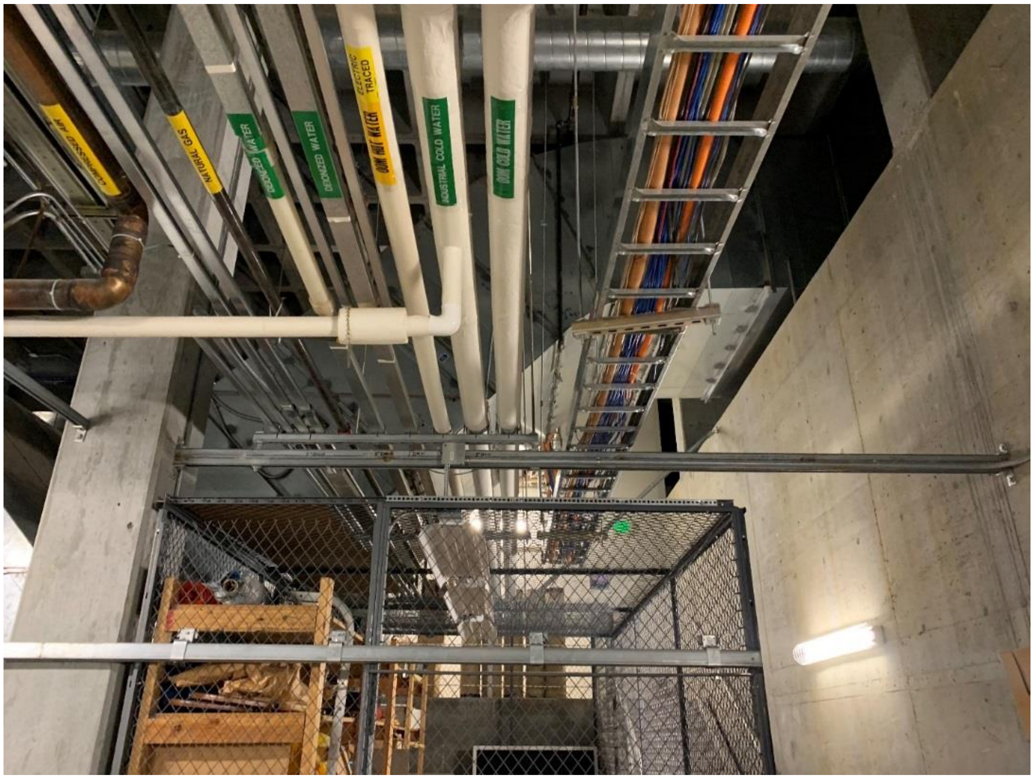
Laterally Unrestrained Pipes and Ducts at Roof (Building D)

Laterally Unrestrained Pipes and Ducts at Roof (Building D)

Anchored Equipment at Roof (Building D)



Basement Separation 1” Between Building D and Building C



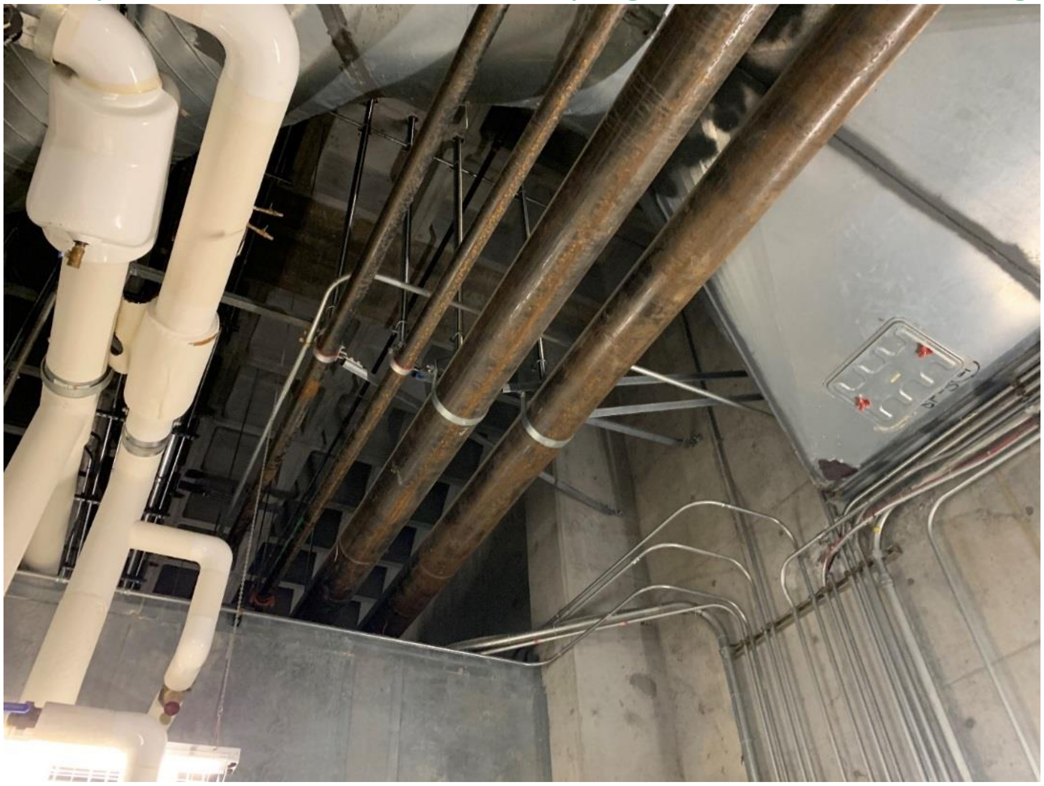
Laterally Unrestrained Pipes and Cable Trays at Basement (Building D)

Anchored Tank with Isolators at Basement (Building D)

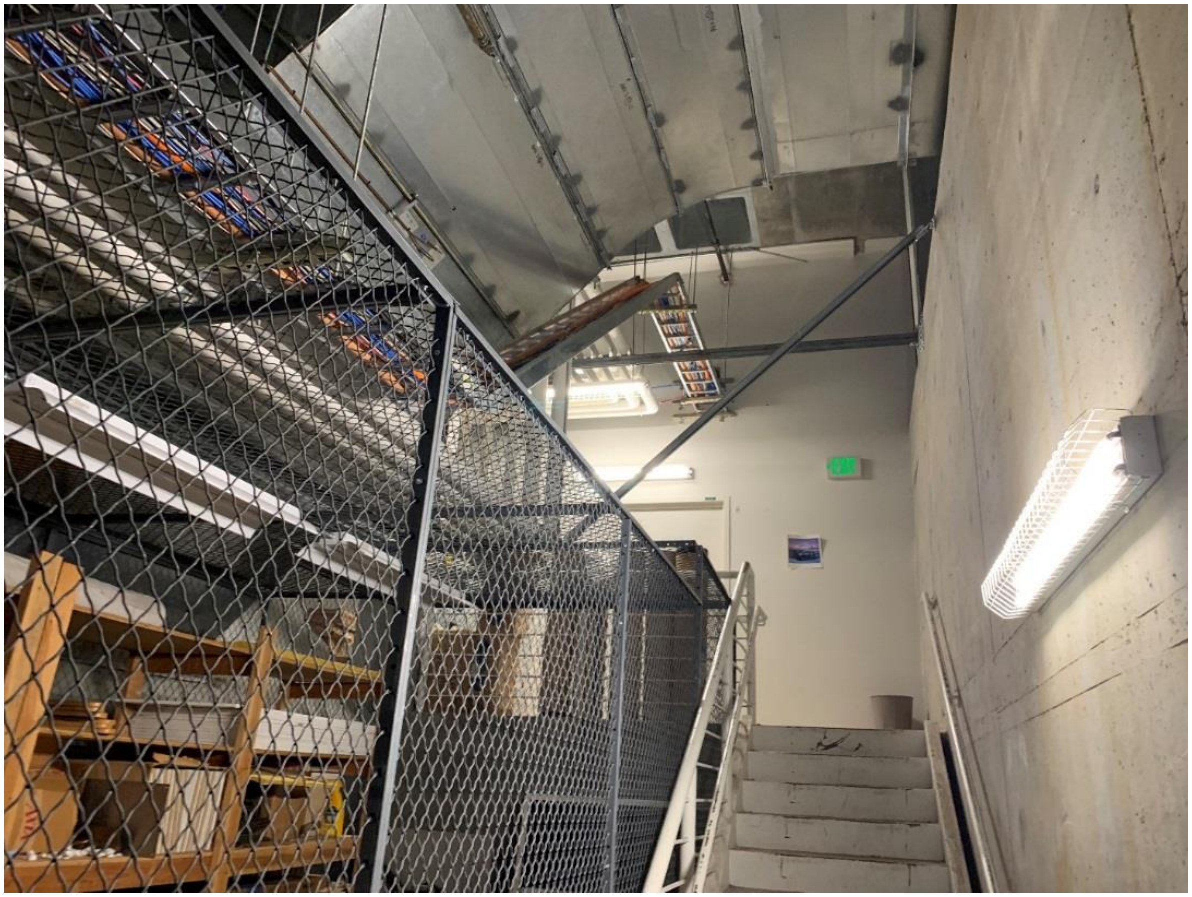
Anchored Tank at Basement (Building D)

Anchored Equipment at Basement (Building D)

Laterally Unrestrained Ducts and Piping at Basement (Building D)



Laterally Unrestrained Ducts and Piping at Basement (Building D)



Unrestrained and Restrained Materials in Cage at Basement (Building D)

APPENDIX B

ASCE 41-17 Tier 1 Checklists (Structural)

UC Campus:	Santa Cruz			Date:	06/28/2019		
Building CAAN:	7775	Auxiliary CAAN:		By Firm:	Rutherford + Chekene		
Building Name:	Earth & Marine Sciences (C & D)			Initials:	CLP, EFA	Checked:	WAL/BL
Building Address:	552 Red Hill Road, Santa Cruz, CA 95064			Page:	1	of	3

ASCE 41-17
Collapse Prevention Basic Configuration Checklist

LOW SEISMICITY

BUILDING SYSTEMS - *GENERAL*

C NC N/A U	Description
C (selected)	LOAD PATH: The structure contains a complete, well-defined load path, including structural elements and connections, that serves to transfer the inertial forces associated with the mass of all elements of the building to the foundation. (Commentary: Sec. A.2.1.1. Tier 2: Sec. 5.4.1.1) **Comments:** General comment: Original design by R+C and structural calculations available for review.
NC (selected)	ADJACENT BUILDINGS: The clear distance between the building being evaluated and any adjacent building is greater than 0.25% of the height of the shorter building in low seismicity, 0.5% in moderate seismicity, and 1.5% in high seismicity. (Commentary: Sec. A.2.1.2. Tier 2: Sec. 5.4.1.2) **Comments:** Gap required is 57'x12"*0.015=10.3". Gap provided is 2"
N/A (selected)	MEZZANINES: Interior mezzanine levels are braced independently from the main structure or are anchored to the seismic-force-resisting elements of the main structure. (Commentary: Sec. A.2.1.3. Tier 2: Sec. 5.4.1.3) **Comments:** There are no mezzanine levels.

BUILDING SYSTEMS - *BUILDING CONFIGURATION*

C NC N/A U	Description
C (selected)	WEAK STORY: The sum of the shear strengths of the seismic-force-resisting system in any story in each direction is not less than 80% of the strength in the adjacent story above. (Commentary: Sec. A2.2.2. Tier 2: Sec. 5.4.2.1) **Comments:**. Similar wall layout at each level.
C (selected)	SOFT STORY: The stiffness of the seismic-force-resisting system in any story is not less than 70% of the seismic-force-resisting system stiffness in an adjacent story above or less than 80% of the average seismic-force-resisting system stiffness of the three stories above. (Commentary: Sec. A.2.2.3. Tier 2: Sec. 5.4.2.2) **Comments:** Similar wall layout at each level.
C (selected)	VERTICAL IRREGULARITIES: All vertical elements in the seismic-force-resisting system are continuous to the foundation. (Commentary: Sec. A.2.2.4. Tier 2: Sec. 5.4.2.3) **Comments:** Similar wall layout at each level; all walls continuous to foundation.

Note: **C =** Compliant **NC =** Noncompliant **N/A =** Not Applicable **U =** Unknown

UC Campus:	Santa Cruz		Date:	06/28/2019		
Building CAAN:	7775	Auxiliary CAAN:	By Firm:	Rutherford + Chekene		
Building Name:	Earth & Marine Sciences (C & D)		Initials:	CLP, EFA	Checked:	WAL/BL
Building Address:	552 Red Hill Road, Santa Cruz, CA 95064		Page:	2	of	3

ASCE 41-17
Collapse Prevention Basic Configuration Checklist

C NC N/A U	
C (selected)	GEOMETRY: There are no changes in the net horizontal dimension of the seismic-force-resisting system of more than 30% in a story relative to adjacent stories, excluding one-story penthouses and mezzanines. (Commentary: Sec. A.2.2.5. Tier 2: Sec. 5.4.2.4) **Comments:** Similar wall layout at each level; all walls continuous to foundation.
C (selected)	MASS: There is no change in effective mass of more than 50% from one story to the next. Light roofs, penthouses, and mezzanines need not be considered. (Commentary: Sec. A.2.2.6. Tier 2: Sec. 5.4.2.5) **Comments:** Similar floor layout at each level.
C (selected)	TORSION: The estimated distance between the story center of mass and the story center of rigidity is less than 20% of the building width in either plan dimension. (Commentary: Sec. A.2.2.7. Tier 2: Sec. 5.4.2.6) **Comments:**. Similar wall layout at each level; no torsion issues.

MODERATE SEISMICITY (COMPLETE THE FOLLOWING ITEMS IN ADDITION TO THE ITEMS FOR LOW SEISMICITY)

GEOLOGIC SITE HAZARD

C NC N/A U	Description
C (selected)	LIQUEFACTION: Liquefaction-susceptible, saturated, loose granular soils that could jeopardize the building's seismic performance do not exist in the foundation soils at depths within 50 ft (15.2m) under the building. (Commentary: Sec. A.6.1.1. Tier 2: 5.4.3.1) **Comments:** There is no mapped liquefaction on https://gis.santacruzcounty.us/mapgallery/Emergency%20Management/Hazard%20Mitigation/LiquifactionMap2009.pdf.
C (selected)	SLOPE FAILURE: The building site is located away from potential earthquake-induced slope failures or rockfalls so that it is unaffected by such failures or is capable of accommodating any predicted movements without failure. (Commentary: Sec. A.6.1.2. Tier 2: 5.4.3.1) **Comments:** There are no mapped landslides on https://gis.santacruzcounty.us/mapgallery/Emergency%20Management/Hazard%20Mitigation/LandslideMap2009.pdf.
C (selected)	SURFACE FAULT RUPTURE: Surface fault rupture and surface displacement at the building site are not anticipated. (Commentary: Sec. A.6.1.3. Tier 2: 5.4.3.1) **Comments:** There are no faults at the project site per https://gis.santacruzcounty.us/mapgallery/Emergency%20Management/Hazard%20Mitigation/FaultZoneMap2009.pdf.

Note: **C =** Compliant **NC =** Noncompliant **N/A =** Not Applicable **U =** Unknown

UC Campus:	Santa Cruz		Date:	06/28/2019		
Building CAAN:	7775	Auxiliary CAAN:	By Firm:	Rutherford + Chekene		
Building Name:	Earth & Marine Sciences (C & D)		Initials:	CLP, EFA	Checked:	WAL/BL
Building Address:	552 Red Hill Road, Santa Cruz, CA 95064		Page:	3	of	3

ASCE 41-17
Collapse Prevention Basic Configuration Checklist

HIGH SEISMICITY (COMPLETE THE FOLLOWING ITEMS IN ADDITION TO THE ITEMS FOR MODERATE SEISMICITY)

FOUNDATION CONFIGURATION

C NC N/A U	Description
C (selected)	OVERTURNING: The ratio of the least horizontal dimension of the seismic-force-resisting system at the foundation level to the building height (base/height) is greater than $0.6S_a$. (Commentary: Sec. A.6.2.1. Tier 2: Sec. 5.4.3.3) **Comments:** Transverse Frame width B = 91', Building Height is H = 57', B/H = 1.6 Sa = 1.283g per ATC at BSE-2E 0.6 x Sa = 0.77 B/H > 0.6 Sa
C (selected)	TIES BETWEEN FOUNDATION ELEMENTS: The foundation has ties adequate to resist seismic forces where footings, piles, and piers are not restrained by beams, slabs, or soils classified as Site Class A, B, or C. (Commentary: Sec. A.6.2.2. Tier 2: Sec. 5.4.3.4) **Comments:** Site Class D assumed. All foundation elements tied together with continuous strip footings and slab is doweled to and restrains the footings.

Note: **C =** Compliant **NC =** Noncompliant **N/A =** Not Applicable **U =** Unknown

UC Campus:	Santa Cruz		Date:	06/28/2019		
Building CAAN:	7775	Auxiliary CAAN:	By Firm:	Rutherford + Chekene		
Building Name:	Earth & Marine Sciences (Lab Blocks C & D)		Initials:	CLF/EFA	Checked:	WAL/BL
Building Address:	552 Red Hill Road, Santa Cruz, CA 95064		Page:	1	of	3

ASCE 41-17
Collapse Prevention Structural Checklist For Building Type C2-C2A

Low And Moderate Seismicity

Seismic-Force-Resisting System

C / NC / N/A / U	Description
NC	COMPLETE FRAMES: Steel or concrete frames classified as secondary components form a complete vertical-load-carrying system. (Commentary: Sec. A.3.1.6.1. Tier 2: Sec. 5.5.2.5.1) **Comments:** Gravity framing is a complete system.
C	REDUNDANCY: The number of lines of shear walls in each principal direction is greater than or equal to 2. (Commentary: Sec. A.3.2.1.1. Tier 2: Sec. 5.5.1.1) **Comments:** Shear is resisted by four perimeter walls.
NC	SHEAR STRESS CHECK: The shear stress in the concrete shear walls, calculated using the Quick Check procedure of Section 4.4.3.3, is less than the greater of 100 lb/in.^{2} (0.69 MPa) or $2\sqrt{f'_c}$. (Commentary: Sec. A.3.2.2.1. Tier 2: Sec. 5.5.3.1.1) **Comments:** Quick Check fails for Lab Block C and D at lower 3 floors in both directions; ok at top level only. Highest D/C ratio is 2.0.
C	REINFORCING STEEL: The ratio of reinforcing steel area to gross concrete area is not less than 0.0012 in the vertical direction and 0.0020 in the horizontal direction. (Commentary: Sec. A.3.2.2.2. Tier 2: Sec. 5.5.3.1.3) **Comments:** Typical steel ratio 0.0021

Connections

C / NC / N/A / U	Description
N/A	WALL ANCHORAGE AT FLEXIBLE DIAPHRAGMS: Exterior concrete or masonry walls that are dependent on flexible diaphragms for lateral support are anchored for out-of-plane forces at each diaphragm level with steel anchors, reinforcing dowels, or straps that are developed into the diaphragm. Connections have strength to resist the connection force calculated in the Quick Check procedure of Section 4.4.3.7. (Commentary: Sec. A.5.1.1. Tier 2: Sec. 5.7.1.1) **Comments:** No flexible diaphragms.
C	TRANSFER TO SHEAR WALLS: Diaphragms are connected for transfer of seismic forces to the shear walls. (Commentary: Sec. A.5.2.1. Tier 2: Sec. 5.7.2) **Comments:** Concrete slabs connected to shear walls.

Note: **C** = Compliant **NC** = Noncompliant **N/A** = Not Applicable **U** = Unknown

UC Campus:	Santa Cruz		Date:	06/28/2019		
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Building Name:	Earth & Marine Sciences (Lab Blocks C & D)		Initials:	CLF/EFA	Checked:	WAL/BL
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ASCE 41-17
Collapse Prevention Structural Checklist For Building Type C2-C2A

C NC N/A U	
(●) C ( ) NC ( ) N/A ( ) U	FOUNDATION DOWELS: Wall reinforcement is doweled into the foundation with vertical bars equal in size and spacing to the vertical wall reinforcing directly above the foundation. (Commentary: Sec. A.5.3.5. Tier 2: Sec. 5.7.3.4) **Comments:** Dowels match wall steel.

High Seismicity (Complete The Following Items In Addition To The Items For Low And Moderate Seismicity)

Seismic-Force-Resisting System

	Description
C NC N/A U (●) C ( ) NC ( ) N/A ( ) U	DEFLECTION COMPATIBILITY: Secondary components have the shear capacity to develop the flexural strength of the components. (Commentary: Sec. A.3.1.6.2. Tier 2: Sec. 5.5.2.5.2) **Comments:** Building is very rigid; gravity columns are expected to have adequate capacity.
C NC N/A U ( ) C ( ) NC (●) N/A ( ) U	FLAT SLABS: Flat slabs or plates not part of the seismic-force-resisting system have continuous bottom steel through the column joints. (Commentary: Sec. A.3.1.6.3. Tier 2: Sec. 5.5.2.5.3) **Comments:** 10” flat slab at roof is detailed as part of system
C NC N/A U (●) C ( ) NC ( ) N/A ( ) U	COUPLING BEAMS: The ends of both walls to which the coupling beam is attached are supported at each end to resist vertical loads caused by overturning. (Commentary: Sec. A.3.2.2.3. Tier 2: Sec. 5.5.3.2.1) **Comments:** Geometry more like deep spandrel and short piers; structural drawings show extra vertical steel at all wall openings.

Diaphragms (Stiff Or Flexible)

	Description
C NC N/A U (●) C ( ) NC ( ) N/A ( ) U	DIAPHRAGM CONTINUITY: The diaphragms are not composed of split-level floors and do not have expansion joints. (Commentary: Sec. A.4.1.1. Tier 2: Sec. 5.6.1.1) **Comments:** No split level floors. Floors of Blocks C & D offset one level but are aligned.
C NC N/A U (●) C ( ) NC ( ) N/A ( ) U	OPENINGS AT SHEAR WALLS: Diaphragm openings immediately adjacent to the shear walls are less than 25% of the wall length. (Commentary: Sec. A.4.1.4. Tier 2: Sec. 5.6.1.3) **Comments:** No large diaphragm openings at shear walls.

UC Campus:	Santa Cruz			Date:	06/28/2019	
Building CAAN:	7775	Auxiliary CAAN:		By Firm:	Rutherford + Chekene	
Building Name:	Earth & Marine Sciences (Lab Blocks C & D)			Initials:	CLF/EFA	Checked: WAL/BL
Building Address:	552 Red Hill Road, Santa Cruz, CA 95064			Page:	3	of 3

ASCE 41-17
Collapse Prevention Structural Checklist For Building Type C2-C2A

Flexible Diaphragms

C / NC / N/A / U	Description
N/A	CROSS TIES: There are continuous cross ties between diaphragm chords. (Commentary: Sec. A.4.1.2. Tier 2: Sec. 5.6.1.2) **Comments:** No flexible diaphragms.
N/A	STRAIGHT SHEATHING: All straight-sheathed diaphragms have aspect ratios less than 2-to-1 in the direction being considered. (Commentary: Sec. A.4.2.1. Tier 2: Sec. 5.6.2) **Comments:** No flexible diaphragms.
N/A	SPANS: All wood diaphragms with spans greater than 24 ft (7.3 m) consist of wood structural panels or diagonal sheathing. (Commentary: Sec. A.4.2.2. Tier 2: Sec. 5.6.2) **Comments:** No flexible diaphragms.
N/A	DIAGONALLY SHEATHED AND UNBLOCKED DIAPHRAGMS: All diagonally sheathed or unblocked wood structural panel diaphragms have horizontal spans less than 40 ft (12.2 m) and aspect ratios less than or equal to 4-to-1. (Commentary: Sec. A.4.2.3. Tier 2: Sec. 5.6.2) **Comments:** No flexible diaphragms.
N/A	OTHER DIAPHRAGMS: Diaphragms do not consist of a system other than wood, metal deck, concrete, or horizontal bracing. (Commentary: Sec. A.4.7.1. Tier 2: Sec. 5.6.5) **Comments:** No flexible diaphragms.

Connections

C / NC / N/A / U	Description
N/A	UPLIFT AT PILE CAPS: Pile caps have top reinforcement, and piles are anchored to the pile caps. (Commentary: Sec. A.5.3.8. Tier 2: Sec. 5.7.3.5) **Comments:** No piles or pile caps.

APPENDIX C

UCOP Seismic Safety Policy Falling Hazards Assessment Summary

UC Campus:	Santa Cruz			Date:	06/28/2019	
Building CAAN:	7775	Auxiliary CAAN:		By Firm:	Rutherford + Chekene	
Building Name:	Earth & Marine Sciences (C and D)			Initials:	CLP, EFA	Checked:	WAL/BL
Building Address:	552 Red Hill Road, Santa Cruz, CA 95064			Page:	1	of	1

UCOP SEISMIC SAFETY POLICY
Falling Hazard Assessment Summary

	Description
P ☐ N/A ☒	**Heavy ceilings, features or ornamentation above large lecture halls, auditoriums, lobbies, or other areas where large numbers of people congregate (50 ppl or more)** **Comments:** There are no heavy ceilings, features, or ornamentation
P ☐ N/A ☒	**Heavy masonry or stone veneer above exit ways or public access areas** **Comments:** There is no masonry or stone veneer.
P ☐ N/A ☒	**Unbraced masonry parapets, cornices, or other ornamentation above exit ways or public access areas** **Comments:** There are no masonry parapets, cornices or other ornamentation.
P ☒ N/A ☐	**Unrestrained hazardous material storage** **Comments:** Laboratory building assumed to have many hazardous materials. Observed both anchored and unanchored gas cylinders and an unanchored Cryotank in Stable Isotope Lab in Room C514. Recommend survey to identify and anchor hazardous material cabinets, gas cylinders, and lab equipment housing hazardous materials.
P ☐ N/A ☒	**Masonry chimneys** **Comments:** There are no masonry chimneys.
P ☐ N/A ☒	**Unrestrained natural gas-fueled equipment such as water heaters, boilers, emergency generators, etc.** **Comments:** Mechanical equipment located in basement of Building C. Major equipment we observed was anchored but observed laterally unrestrained overhead piping.
P ☒ N/A ☐	**Other:**. Observed limited lab areas with unanchored or poorly anchored tall cabinet, unanchored refrigerators, tool box, etc. **Comments:**. Recommend survey to identify and anchor tall and overhead items in laboratory areas.
P ☒ N/A ☐	**Other:** Laterally unrestrained piping and ducts in basement of Building C and long runs of piping and ducts at roof of Building D. **Comments:**. Recommend survey of basement and roof areas to identify laterally unrestrained overhead gas lines, or other ducts, piping and cable trays that are not adequately braced and anchored.
P ☒ N/A ☐	**Other:** Full height glazing in Lobby and Atrium above exits and at three exterior staircases and adjacent to bridges on south side of complex. **Comments:** Recommend review of glazing details

Falling Hazards Risk: Moderate

Note: P= Present, N/A = Not Applicable

APPENDIX D

Quick Check Calculations

Rating form completed by:

RUTHERFORD + CHEKENE
ruthchek.com
Evaluator: CLP/EFA/WAL/BL
Date: 06/28/2019

Unit Weights:

Unit weight were not calculated because we had the original design calcualtions shown below

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a california corporation

303 Second Street, Suite 800 North
San Francisco, California 94107
Tel: (415) 495-4222 Fax: (415) 546-7536

Project: EMS
Subject: North Lab
Job No.: 88017S By: HF
Date: 8-30-89 Sheet: NL 2

BUILDING WEIGHT

Roof ⇒	(158+10)psf × [(137' × 93') − (2 × 10' × 7')]	= 2117^k
	+ (158+10) psf × 30' × 15.5'/2	= 39
	Mech. = 50psf × 63' × 72'	= 227
	Screen = 50psf × 8' × (63' + 63' + 72')	= 79
	Wall @ LL = 150pcf × 1' × 18/2 × 80'	= 108
	Wall @ LJ = 150pcf × 1' × 93' × 9' × 13.5/20'	= 85
	+ 150pcf × .79' × 5.5' × 93'	= 61
	Wall @ LR = 150 × 1' × 9' × 57'	= 77
	+ 150 × .79 × 5.5' × 93'	= 61
	Wall @ LS = 150 × 1.125' × 9' × 70'	= 106
	+ 150 × .79' × 5.5' × 110'	= 72
	Walls L1 & L8 = 150 × .79' × 6.5' × 128' × 2	= 197
	+ 150 × 1.125' × 10' × 13'/18 × 128 × 2	= 312
	+ 150 × 1.125' × 5' × 5.5'/18 × 136'	= 35
	+ 150 × 1.125' × 3' × 1.5/18 × 128' × 2	= 11
	W_R	= 3587^k
4th: 3rd Sim.	220psf × [(137' × 93') − (2 × 10' × 7')]	= 2772
	+ 220 × 30 × 15.5/2	= 51
	Wall @ LL = 150 × 1' × (19' + 16')/2 × 80'	= 210
	Wall @ LR = 150 × 1 × (19' + 16')/2 × 57'	= 150
	Wall @ LS = 150 × 1.125 × (19' + 16')/2 × 70'	= 207
	Walls L1 & L8 = 150 × 1.125 × 10' × 5/18 × 128 × 2	= 120
	+ 150 × 1.125 × 5 × 12.5/18 × 136	= 80
	+ 150 × 1.125 × 3 × 16.5/18 × 128 × 2	= 119
	+ 150 × 1.125 × 8' × 12/16 × 256	= 259
	+ 150 × 1.125 × 5 × 5.5/16 × 136	= 39
	+ 150 × 1.125 × 3 × 1.5/16 × 250	= 12
	W_4	= 4019K

Rating form completed by:

RUTHERFORD + CHEKENE
ruthchek.com

Evaluator: CLP/EFA/WAL/BL

Date: 06/28/2019

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a california corporation

303 Second Street, Suite 800 North
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Tel: (415) 495-4222 Fax: (415) 546-7536

Project: EMS
Subject: North Lab
Job No.: 880175
By: LF
Date: 8-30-89
Sheet: NL3

2nd = Floor same as 4th = 2772

= 51

Wall @ LL = 150 pcf × 1' × 16' × 80' = 192

Wall @ LR = 150 pcf × 1' × 16' × 57' = 137

Wall @ LS = 150 × 1.125' × 16' × 70' = 189

Walls L1 & L8 = 150 × 1.125 × 8' × 4/16 × 250 = 86

+ 150 × 1.125 × 5 × 10.5/16 × 136 = 75

+ 150 × 1.125 × 3 × 14.5/16 × 250 = 115

+ 150 × 1.125 × 8' × 173' = 234

+ 150 × 1.125 × 8' × 12/16 × 83' = 84

W2 = 3935 k

W Base = 3587 + 4019 + 4019 + 3935 = 15560 k

Story Weights

This is the summary of the story weight obtained from calculations

Building C		
Floor	Weight (kip)	Total weight (kip)
roof	3587	
4	4019	
3	4019	
2	3935	
		15560

Period

Period is calculated using Mathcad and is attached with the Mathcad calculations below

BSE-2E Response Spectrum

ATC Hazards by Location

Search by Address | Search by Coordinate

36.997938 | -122.059722 | Search

Wind | Snow | Tornado | Seismic

Hazard Level BSE-2E

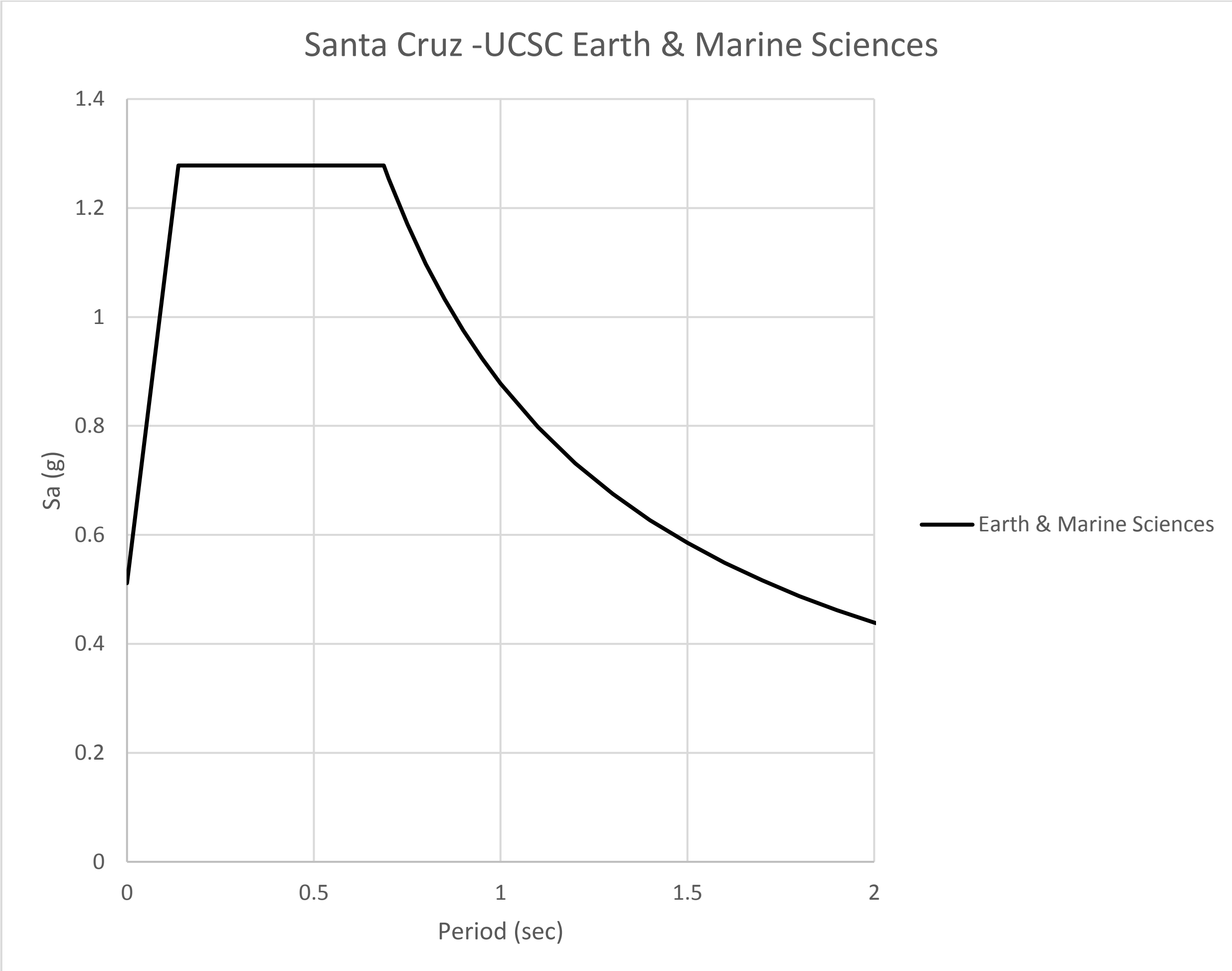
Name	Value	Description
S_S	1.283	MCE_R ground motion (period=0.2s)
F_a	1	Site amplification factor at 0.2s
S_{XS}	1.283	Site modified spectral response (0.2s)
S_1	0.487	MCE_R ground motion (period=1.0s)
F_v	1.813	Site amplification factor at 1.0s
S_{X1}	0.882	Site modified spectral response (1.0s)

Rating form completed by:

RUTHERFORD + CHEKENE
ruthchek.com

Evaluator: CLP/EFA/WAL/BL

Date: 06/28/2019



Calculations required for checklists were performed using the program Mathcad, and are attached in the following pages

Concrete building C check

Shear stress in the wall check

Period Calculation

Calculation of total shear force

Calculation of Ratio of steel

Shear stress in wall

4.4.3.3 Shear Stress in Shear Walls. The average shear stress in shear walls, v_j^{avg}, shall be calculated in accordance with Eq. (4-8).

$$v_j^{avg} = \frac{1}{M_s}\left(\frac{V_j}{A_w}\right) \qquad (4\text{-}8)$$

where

V_j = Story shear at level j computed in accordance with Section 4.4.2.2;

A_w = Summation of the horizontal cross-sectional area of all shear walls in the direction of loading. Openings shall be taken into consideration where computing A_w. For masonry walls, the net area shall be used. For wood-framed walls, the length shall be used rather than the area; and

M_s = System modification factor; M_s shall be taken from Table 4-8.

Table 4-8. M_s Factors for Shear Walls

Wall Type	Level of Performance CP[a]	LS[a]	IO[a]
Reinforced concrete, precast concrete, wood, reinforced masonry, and cold-formed steel	4.5	3.0	1.5
Unreinforced masonry	1.75	1.25	1.0

[a] CP = Collapse Prevention, LS = Life Safety, IO = Immediate Occupancy.

$M_s := 4.5$

Period calculation

4.4.2.4 Period. The fundamental period of a building, in the direction under consideration, shall be calculated in accordance with Eq. (4-4).

$$T = C_t h_n^\beta \quad (4\text{-}4)$$

where

T = Fundamental period (s) in the direction under consideration;
C_t = 0.035 for moment-resisting frame systems of steel (Building Types S1 and S1a);
= 0.018 for moment-resisting frames of reinforced concrete (Building Type C1);
= 0.030 for eccentrically braced steel frames (Building Types S2 and S2a);
= 0.020 for all other framing systems;
h_n = Height (ft) above the base to the roof level;

β = 0.80 for moment-resisting frame systems of steel (Building Types S1 and S1a);
= 0.90 for moment-resisting frame systems of reinforced concrete (Building Type C1); and
= 0.75 for all other framing systems.

$C_t := 0.02 \qquad h_{tot} := 52\frac{ft}{ft} \qquad \beta := 0.75$

$$T_1 := C_t \cdot h_{tot}^{\beta} = 0.387$$

$S_{x1} := 0.882$

$S_{a1} := \frac{S_{x1}}{T_1} = 2.277$ Larger than 1.283g use 1.283g

$S_a := 1.283$

Building C		
Floor	Weight (kip)	Total weight (kip)
roof	3587	
4	4019	
3	4019	
2	3935	
		15560

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Project: EMS
Subject: North Lab
Job No. 88017S By: HF
Date: 8-30-89 Sheet: NL3

2nd = Floor same as 4th = 2772

= 51

Wall @ LL = 150 pcf × 1' × 16' × 80' = 192
Wall @ LR = 150 pcf × 1' × 16' × 57' = 137
Wall @ LS = 150 × 1.125' × 16' × 70' = 189
Walls L1 & L8 = 150 × 1.125 × 8' × 4/16 × 250' = 86
+ 150 × 1.125 × 5 × 10.5/16 × 136 = 75
+ 150 × 1.125 × 3 × 14.5/16 × 250 = 115
+ 150 × 1.125 × 8' × 173' = 234
+ 150 × 1.125 × 8' × 12/16 × 83' = 84

W_2 = 3935^k

W_{Base} = 3587 + 4019 + 4019 + 3935 = 15560^k

Table 4-7. Modification Factor, *C*

Building Type[a]	Number of Stories 1	2	3	≥4
Wood and cold-formed steel shear wall (W1, W1a, W2, CFS1) Moment frame (S1, S3, C1, PC2a)	1.3	1.1	1.0	1.0
Shear wall (S4, S5, C2, C3, PC1a, PC2, RM2, URMa) Braced frame (S2) Cold-formed steel strap-brace wall (CFS2)	1.4	1.2	1.1	1.0
Unreinforced masonry (URM) Flexible diaphragms (S1a, S2a, S5a, C2a, C3a, PC1, RM1)	1.0	1.0	1.0	1.0

[a] Defined in Table 3-1.

From R+C original calcs

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San Francisco, California 94107
Tel: (415) 495-4222 Fax: (415) 546-7536

Project: EMS
Subject: North Lab
Job No.: 880175
By: HF
Date: 8-30-89
Sheet: NL 2

BUILDING WEIGHT

Roof ⇒ (158+10)psf × [(37' × 93') − (2 × 10' × 7')] = 2117^k
+ (158+10)psf × 30' × 15.5'/2 = 39
Mech. = 50psf × 63' × 72' = 227
Screen = 50psf × 8' × (63' + 63' + 72') = 79
Wall @ LL = 150pcf × 1' × 18/2 × 80' = 108
Wall @ LJ = 150pcf × 1' × 93' × 9' × 13.5/20' = 85
+ 150pcf × .79' × 5.5' × 93' = 61
Wall @ LR = 150 × 1' × 9' × 57' = 77
+ 150 × .79 × 5.5' × 93' = 61
Wall @ LS = 150 × 1.125' × 9' × 70' = 106
+ 150 × .79' × 5.5' × 110' = 72
Walls L1 & L8 = 150 × .79' × 6.5' × 128' × 2 = 197
+ 150 × 1.125' × 10' × 13/18 × 128 × 2 = 312
+ 150 × 1.125' × 5' × 5.5/18 × 136' = 35
+ 150 × 1.125' × 3' × 1.5/18 × 128' × 2 = 11
W_R = 3587^k

4th: 220psf × [(137' × 93') − (2 × 10' × 7')] = 2772
3rd Sim. + 220 × 30 × 15.5/2 = 51
Wall @ LL = 150 × 1' × (19' + 16')/2 × 80' = 210
Wall @ LR = 150 × 1 × (19 + 16')/2 × 57' = 150
Wall @ LS = 150 × 1.125 × (19' + 16')/2 × 70' = 207
Walls L1 & L8 = 150 × 1.125 × 10' × 5/18 × 128 × 2 = 120
+ 150 × 1.125 × 5 × 12.5/18 × 136 = 80
+ 150 × 1.125 + 3 × 16.5/18 × 128 × 2 = 119
+ 150 × 1.125 × 8' × 12/16 × 256 = 259
+ 150 × 1.125 × 5 × 3.5/16 × 136 = 39
+ 150 × 1.125 × 3 × 1.5/16 × 250 = 12
W_4 = 4019K

Calculation of total shear force

$C_{mod} := 1$

$w_1 := 3935kip$ $w_2 := 4019kip$ $w_3 := 4019kip$ $w_4 := 3589kip$

$W_{total} := w_1 + w_2 + w_3 + w_4 = 15562 \cdot kip$

$V_{total} := C_{mod} \cdot S_a \cdot W_{total} = 19966 \cdot kip$

$h_1 := 16ft$ $h_2 := 32ft$ $h_3 := 48ft$ $h_4 := 57ft$

4.4.2.2 Story Shear Forces. The pseudo seismic force calculated in accordance with Section 4.4.2.1 shall be distributed vertically in accordance with Eqs. (4-2a and 4-2b). For buildings six stories or fewer high, the value of k shall be permitted to be taken as 1.0.

$$F_x = \frac{w_x h_x^k}{\sum_{i=1}^{n} w_i h_i^k} V \qquad \text{(4-2a)}$$

$$V_j = \sum_{x=j}^{n} F_x \qquad \text{(4-2b)}$$

where

V_j = Story shear at story level j;
n = Total number of stories above ground level;
j = Number of story levels under consideration;
W = Total seismic weight, per Section 4.4.2.1;
V = Pseudo seismic force from Eq. (4-1);
w_i = Portion of total building weight W located on or assigned to floor level i;
w_x = Portion of total building weight W located on or assigned to floor level x;

h_i = Height (ft) from the base to floor level i;
h_x = Height (ft) from the base to floor level x; and
k = 1.0 for $T \leq 0.5$ s and 2.0 for $T > 2.5$ s; linear interpolation shall be used for intermediate values of k.

For buildings with stiff or rigid diaphragms, the story shear forces shall be distributed to the lateral-force-resisting elements based on their relative rigidities. For buildings with flexible diaphragms (Types S1a, S2a, S5a, C2a, C3a, PC1, RM1, and URM), story shear shall be calculated separately for each line of lateral resistance.

$k_{0.5} := 1$ $\quad k_{2.5} := 2$

$k_{inter} := 1$ no interpolation needed but kept nomenclature from previous sheet

$\left(\frac{h_1}{ft}\right)^{k_{inter}} = 16$ $\quad \left(\frac{h_2}{ft}\right)^{k_{inter}} = 32$ $\quad \left(\frac{h_3}{ft}\right)^{k_{inter}} = 48$ $\quad \left(\frac{h_4}{ft}\right)^{k_{inter}} = 57$

$$F_1 := \left[\frac{w_1 \cdot ft \cdot \left(\frac{h_1}{ft}\right)^{k_{inter}} \cdot V_{total}}{\left[w_1 \cdot ft \cdot \left(\frac{h_1}{ft}\right)^{k_{inter}} + w_2 \cdot ft \cdot \left(\frac{h_2}{ft}\right)^{k_{inter}} + w_3 \cdot ft \cdot \left(\frac{h_3}{ft}\right)^{k_{inter}} + w_4 \cdot ft \cdot \left(\frac{h_4}{ft}\right)^{k_{inter}}\right]}\right] = 2.134 \times 10^3 \cdot kip$$

$$F_2 := \left[\frac{w_2 \cdot ft \cdot \left(\frac{h_2}{ft}\right)^{k_{inter}} \cdot V_{total}}{\left[w_1 \cdot ft \cdot \left(\frac{h_1}{ft}\right)^{k_{inter}} + w_2 \cdot ft \cdot \left(\frac{h_2}{ft}\right)^{k_{inter}} + w_3 \cdot ft \cdot \left(\frac{h_3}{ft}\right)^{k_{inter}} + w_4 \cdot ft \cdot \left(\frac{h_4}{ft}\right)^{k_{inter}}\right]}\right] = 4.359 \times 10^3 \cdot kip$$

$$F_3 := \left[\frac{w_3 \cdot ft \cdot \left(\frac{h_3}{ft}\right)^{k_{inter}} \cdot V_{total}}{\left[w_1 \cdot ft \cdot \left(\frac{h_1}{ft}\right)^{k_{inter}} + w_2 \cdot ft \cdot \left(\frac{h_2}{ft}\right)^{k_{inter}} + w_3 \cdot ft \cdot \left(\frac{h_3}{ft}\right)^{k_{inter}} + w_4 \cdot ft \cdot \left(\frac{h_4}{ft}\right)^{k_{inter}}\right]}\right] = 6.539 \times 10^3 \cdot kip$$

$$F_4 := \left[\frac{w_4 \cdot ft \cdot \left(\frac{h_4}{ft}\right)^{k_{inter}} \cdot V_{total}}{\left[w_1 \cdot ft \cdot \left(\frac{h_1}{ft}\right)^{k_{inter}} + w_2 \cdot ft \cdot \left(\frac{h_2}{ft}\right)^{k_{inter}} + w_3 \cdot ft \cdot \left(\frac{h_3}{ft}\right)^{k_{inter}} + w_4 \cdot ft \cdot \left(\frac{h_4}{ft}\right)^{k_{inter}}\right]}\right] = 6.934 \times 10^3 \cdot kip$$

$V_{check} := F_1 + F_2 + F_3 + F_4 = 19966 \cdot kip$ $\quad\quad V_{total} = 19966 \cdot kip$

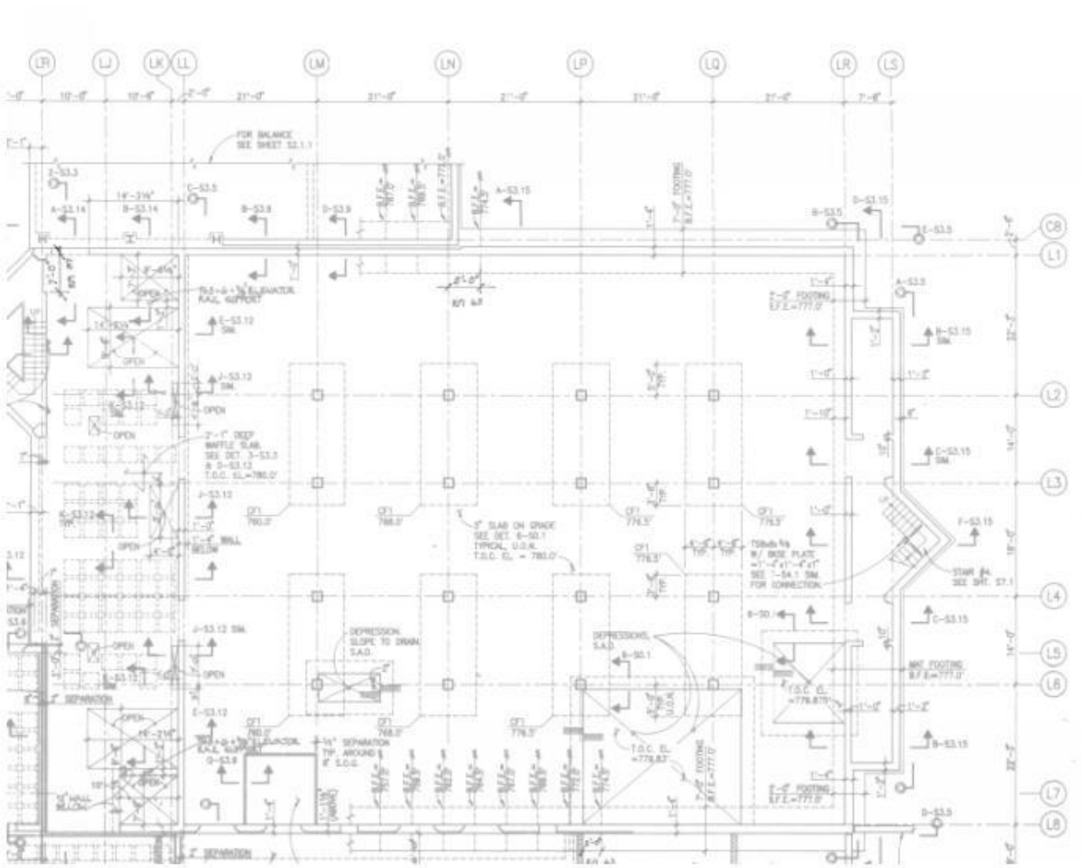
$V_1 := F_1 + F_2 + F_3 + F_4 = 19966 \cdot kip$

$V_2 := F_2 + F_3 + F_4 = 17832 \cdot kip$

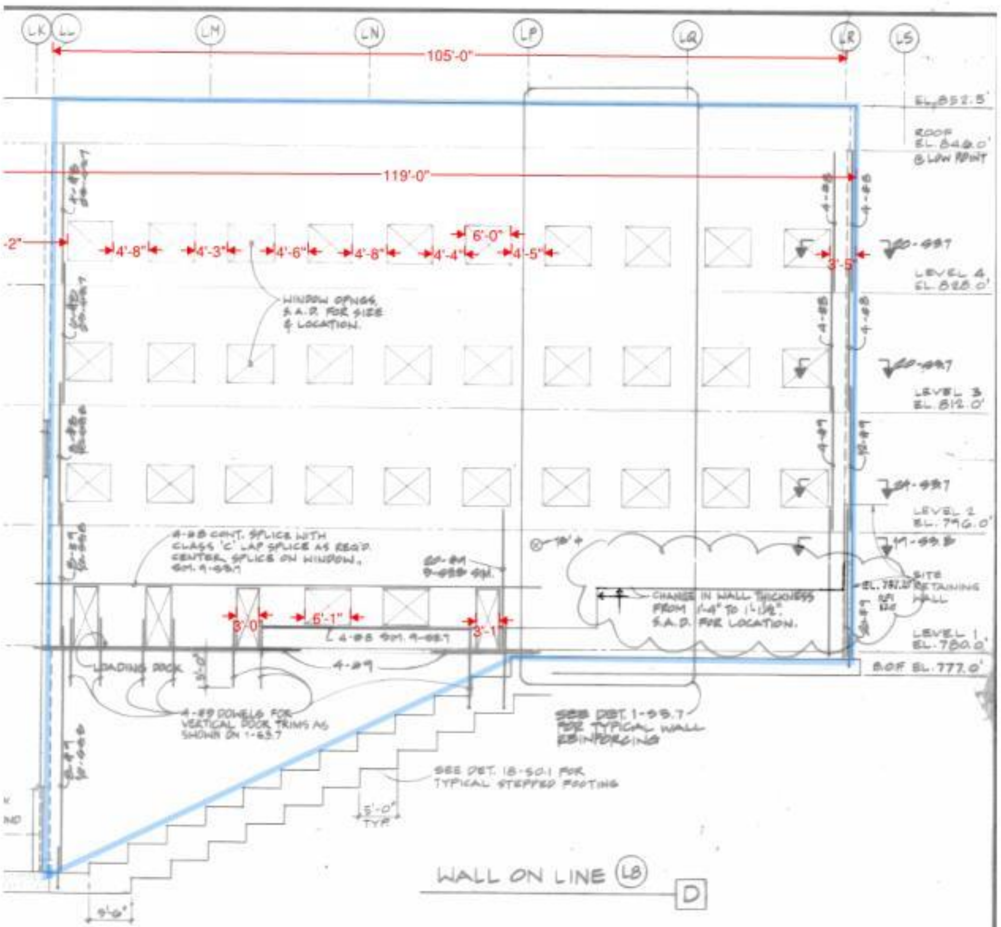
$V_3 := F_3 + F_4 = 13473 \cdot kip$

$V_4 := F_4 = 6934 \cdot kip$

Calculation of shear stress per wall



Line L8



Line L8

$Length_{L84th} := 119ft - 10 \cdot 6ft = 708 \cdot in$

$Length_{L83rd} := Length_{L84th} = 708 \cdot in$

$Length_{L82nd} := Length_{L84th} = 708 \cdot in$

$Length_{L81st} := 119ft - 4 \cdot 3ft - 2 \cdot 6ft = 1140 \cdot in$

$t_{wall} := 13.5in$

$Awall_{L84th} := Length_{L84th} \cdot t_{wall} = 9558 \cdot in^2$

$$Awall_{L83rd} := Length_{L83rd} \cdot t_{wall} = 9558 \cdot in^2$$

$$Awall_{L82nd} := Length_{L82nd} \cdot t_{wall} = 9558 \cdot in^2$$

$$Awall_{L81st} := Length_{L81st} \cdot t_{wall} = 15390 \cdot in^2$$

$$S_{limit1} := 2\sqrt{4000}psi = 126.491 \cdot psi$$ or 100psi use 126.5psi

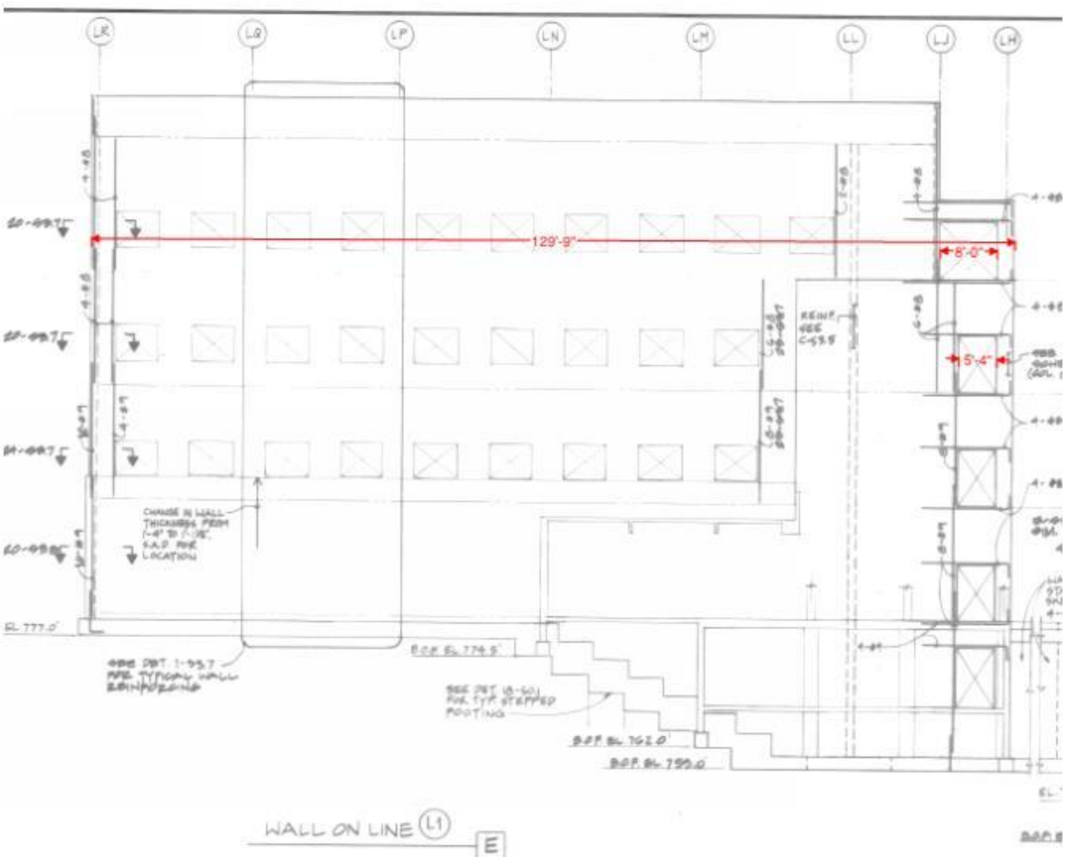
$$Swall_{L84th} := \frac{V_4}{2 \cdot M_s \cdot Awall_{L84th}} = 80.608 \cdot psi$$

$$Swall_{L83rd} := \frac{V_3}{2 \cdot M_s \cdot Awall_{L83rd}} = 156.621 \cdot psi$$ Larger than 126.5psi does not comply

$$Swall_{L82nd} := \frac{V_2}{2 \cdot M_s \cdot Awall_{L82nd}} = 207.296 \cdot psi$$ Larger than 126.5psi does not comply

$$Swall_{L81st} := \frac{V_1}{2 \cdot M_s \cdot Awall_{L81st}} = 144.149 \cdot psi$$ Larger than 126.5psi does not comply

Line L1



Line L1

$$Length_{L14th} := 119ft - 10 \cdot 6ft - 8ft = 612 \cdot in$$

$$Length_{L13rd} := 129.66ft - 5.33ft - 9 \cdot 6ft = 843.96 \cdot in$$

$$Length_{L12nd} := Length_{L13rd} = 843.96 \cdot in$$

$$Length_{L11st} := 129.66ft - 5.33ft = 1492 \cdot in$$

$$t_{wall} = 13.5 \cdot in$$

$$Awall_{L14th} := Length_{L14th} \cdot t_{wall} = 8262 \cdot in^2$$

$$Awall_{L13rd} := Length_{L13rd} \cdot t_{wall} = 11393 \cdot in^2$$

$$Awall_{L12nd} := Length_{L12nd} \cdot t_{wall} = 11393 \cdot in^2$$

$$Awall_{L11st} := Length_{L11st} \cdot t_{wall} = 20141 \cdot in^2$$

$$S_{limit1} = 126.491 \cdot psi$$

or 100psi use 126.5psi

$$Swall_{L14th} := \frac{V_4}{2 \cdot M_s \cdot Awall_{L14th}} = 93.252 \cdot psi$$

$$Swall_{L13rd} := \frac{V_3}{2 \cdot M_s \cdot Awall_{L13rd}} = 131.389 \cdot psi$$

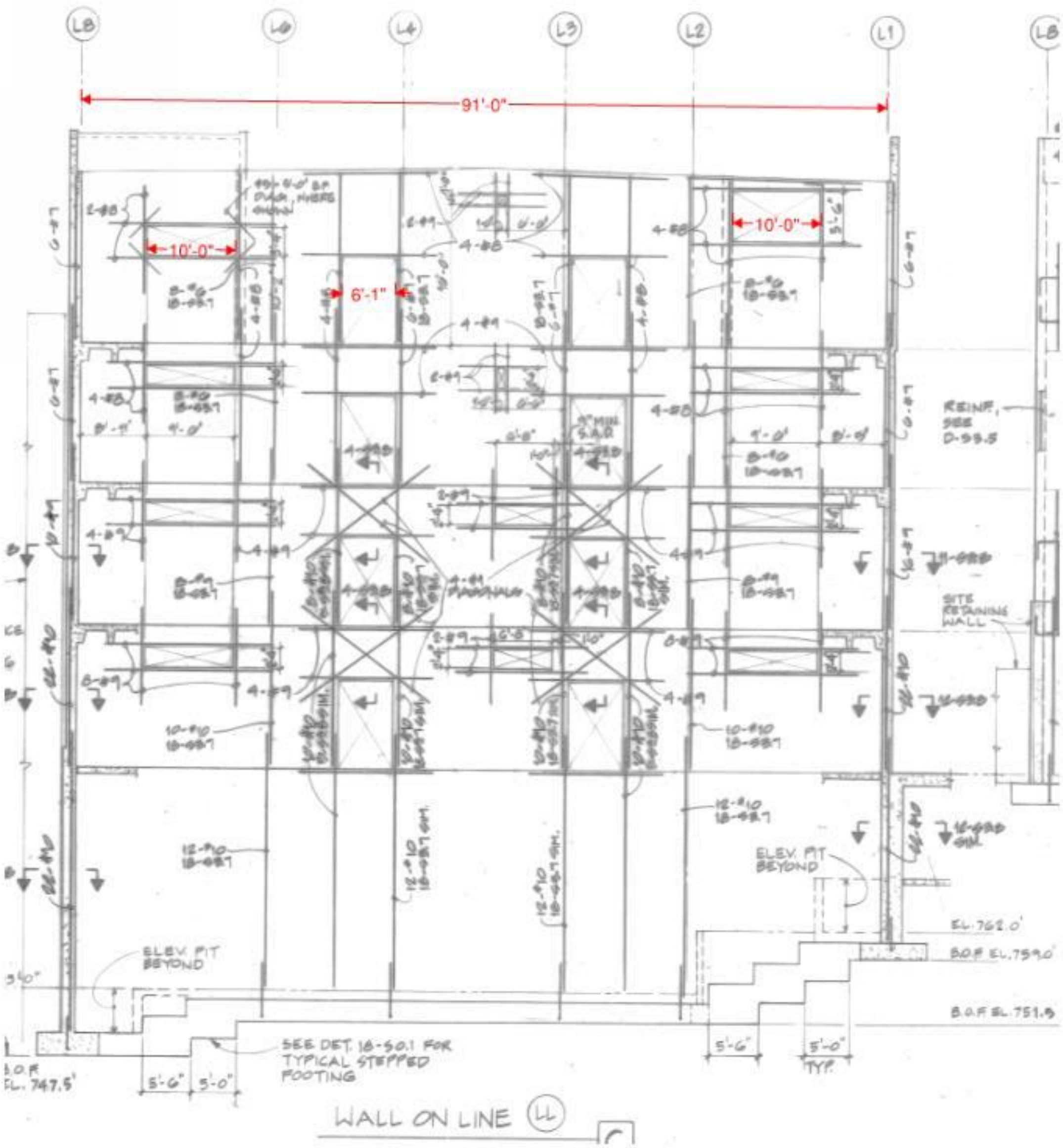
Larger than 126.5psi does not comply

$$Swall_{L12nd} := \frac{V_2}{2 \cdot M_s \cdot Awall_{L12nd}} = 173.901 \cdot psi$$

Larger than 126.5psi does not comply

$$Swall_{L11st} := \frac{V_1}{2 \cdot M_s \cdot Awall_{L11st}} = 110.143 \cdot psi$$

Line LL


91'-0"
10'-0"
10'-0"
6'-1"
REINF., SEE D-53.5
SITE RETAINING WALL
ELEV. PIT BEYOND
ELEV. PIT BEYOND
EL. 762.0'
B.O.F. EL. 759.0'
B.O.F. EL. 751.5
SEE DET. 18-50.1 FOR TYPICAL STEPPED FOOTING
5'-6"
5'-0"
5'-6"
5'-0" TYP.
WALL ON LINE (LL)

Line LL

$Length_{LL4th} := 91ft - 2 \cdot 10ft - 2 \cdot 6ft = 708 \cdot in$

$Length_{LL3rd} := 91ft - 2 \cdot 10ft - 2 \cdot 6ft = 708 \cdot in$

$Length_{LL2nd} := 91ft - 2 \cdot 10ft - 3 \cdot 6ft = 636 \cdot in$

$Length_{LL1st} := 91ft - 2 \cdot 10ft - 3 \cdot 6ft = 636 \cdot in$

$t_{wall} = 13.5 \cdot in$

$Awall_{LL4th} := Length_{LL4th} \cdot t_{wall} = 9558 \cdot in^2$

$Awall_{LL3rd} := Length_{LL3rd} \cdot t_{wall} = 9558 \cdot in^2$

$Awall_{LL2nd} := Length_{LL2nd} \cdot t_{wall} = 8586 \cdot in^2$

$Awall_{LL1st} := Length_{LL1st} \cdot t_{wall} = 8586 \cdot in^2$

$Slimit1 := 2\sqrt{4000}psi = 126.491 \cdot psi$ or 100psi use 126.5psi

$Swall_{LL4th} := \frac{V_4}{2 \cdot M_s \cdot Awall_{LL4th}} = 80.608 \cdot psi$

$Swall_{LL3rd} := \frac{V_3}{2 \cdot M_s \cdot Awall_{LL3rd}} = 156.621 \cdot psi$ Larger than 126.5psi does not comply

$Swall_{LL2nd} := \frac{V_2}{2 \cdot M_s \cdot Awall_{LL2nd}} = 230.763 \cdot psi$ Larger than 126.5psi does not comply

$Swall_{LL1st} := \frac{V_1}{2 \cdot M_s \cdot Awall_{LL1st}} = 258.38 \cdot psi$ Larger than 126.5psi does not comply

Check Ratio of steel for shear walls

Typical reinforcement #5 @12 in OC EW EF

$t_{wall} := 13.5in$

In a 12 in lenght we have 1 #5 bar $As_{5bar} := 0.31in^2$

$A_c := 12in \cdot t_{wall} = 162 \cdot in^2$

$$\rho_{steel} := \frac{2 \cdot As_{5bar}}{A_c} = 0.0038$$

$\rho_{minhorz} := 0.002$ $\rho_{minvert} := 0.0012$

ρsteel is bigger than both ok