Rating form completed by:
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Text in green is to be part of UC Santa Cruz building database and may be part of UCOP database

UC Santa Cruz building seismic ratings

Theater Arts Foundry Building

CAAN #7405
410 Foundry Road, Santa Cruz, CA 95064
UCSC Campus: Main Campus

DATE: 2019-06-30

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]	Medium ($50-$200/sf)	See recommendations on further evaluation and retrofit.
Is 2018-2019 rating required by UCOP?	Yes	Building was not previously rated
Further evaluation recommended?	No	

[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 UC Seismic Policy and Method B of Section 321 of the 2016 California Existing Building Code.

[2] Per Section 3.A.4.i of the Seismic Program Guidebook, 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

- Site visit on 2019-06-13

Additional building information known to exist

- None

Scope for completing this form

No structural drawings were available for this building. We carried out a site visit to investigate the lateral-resisting-system. An ASCE 41-17 Tier 1 evaluation was completed. We did not perform an ASCE 41 Tier 1 nonstructural evaluation, but we looked for potentially hazardous nonstructural components during our site visit.

Brief description of structure

The Theater Arts Foundry building is a single-story structure that contains approximately 2000 square feet. The structure is a Butler Building with steel moment frames in the transverse direction and metal panels in the longitudinal direction.

Identification of levels: Level 1 (at grade), Roof

Foundation system: The site is flat. No foundation is visible, and no drawings were available at time of this review. Level 1 is slab on grade.

Structural system for vertical (gravity) load: The roof is framed with steel joists spanning to steel moment frames. A crane is hung from the steel moment frames.

Structural system for lateral forces: The structure is a Butler Building with steel moment frames in the transverse direction and metal panels in the longitudinal direction. The moment frame column is a W8 shape, the moment frame beam appears to be a W10 or W12. The metal wall panels are attached to an edge beam at the roof, to horizontal girts at third points along the height of the wall, and to an angle at the bottom of the wall that is attached to the slab on grade. Fasteners are visible at joints in the metal panel at approximately 12" o.c. Our visual inspection found that the moment frames appeared in good condition but the metal wall panels were rusted and water-damaged.

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:

- The metal paneling on the exterior walls of the building is rusted and deteriorated at several locations, thus compromising the lateral load path to the foundation.

Structural deficiency	Affects rating?	Structural deficiency	Affects rating?
Lateral system stress check (wall shear, column shear or flexure, or brace axial as applicable)	N	Openings at shear walls (concrete or masonry)	N
Load path	Y	Liquefaction	N
Adjacent buildings	N	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 non-structural life-safety concerns, including at exit routes.[3]

We walked through the building. We did not perform the Tier 1 nonstructural evaluation, but we looked for potentially hazardous nonstructural components during our site visit on 13 June 2019. There is a crane suspended from the roof beams, and the anchorage of the crane to the beams is unknown and should be inspected. Besides the crane, as shown below, we found no major nonstructural concerns.

UCOP non-structural checklist item	Life safety hazard?	UCOP non-structural 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	None observed
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

Discussion of rating

The rating of V (Poor) is due to the poor condition of the building, namely the rusted wall panel connections to the foundation. If further inspection of the walls finds the connection to the foundation to be mostly intact, or if the metal panels are replaced, the rating may be raised to IV (Fair).

Recommendations for further evaluation or retrofit

We recommend that the Campus perform a more detailed inspection of the metal wall panels, and replace as needed to provide a connection to the foundation.

Peer review of rating

This seismic evaluation was discussed in a peer review meeting on 24 June 2019. Reviewers present were Bret Lizundia of R+C and Jay Yin of Degenkolb. Comments from the reviewers have been incorporated into this report. The reviewers agreed with the assigned rating.

Additional building data	Entry	Notes
Latitude	36.99583	
Longitude	-122.062046	
Are there other structures besides this one under the same CAAN#	No	
Number of stories above lowest perimeter grade	1	
Number of stories (basements) below lowest perimeter grade	0	
Building occupiable area (OGSF)	1984 sq. ft.	
Risk Category per 2016 CBC Table 1604.5	II	Educational occupancy (classroom)
Building structural height, h_n	15' +/-	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	0.11 sec	Estimated using ASCE 41-17 equation 4-4 and 7-18

[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 the type and location of potential non-structural hazards.

Site data		
975 yr hazard parameters S_s, S_1	1.286, 0.488	
Site class	D	
Site class basis[4]	Geotech	See footnote below
Site parameters F_a, F_v[5]	1, 1.81	
Ground motion parameters S_{cs}, S_{c1}	1.286, 0.885	
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	Constructed: 1975 Code: 1973 UBC	Code inferred based on year of construction, as documented on UCSC FacilitiesLink
Applicable code for partial retrofit	None	None
Applicable code for full retrofit	None	None
Model building data		
Model building type North-South	S3 – Steel Light Frames	
Model building type East-West	S3 – Steel Light Frames	
FEMA P-154 score	N/A	Not included here. Tier 1 evaluation.
Previous ratings		
Most recent rating	None	
Date of most recent rating	-	
2nd most recent rating	-	
Date of 2nd most recent rating	-	

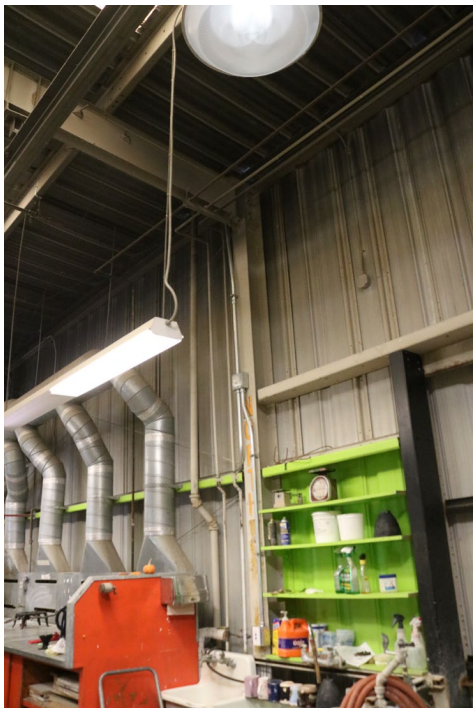
[4] Determination of site class and assessment of geotechnical hazards are based on correspondence with Pacific Crest Geotechnical Engineers and Nolan, Zinn, and Associates Geologists. [*Revised Geology and Geologic Hazards, Santa Cruz Campus, University of California*, Job # 04003-SC 13 May 2005]. Site 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

[5] F_V factor used does not include the requirements of Section 11.4.8-3 of ASCE 7-16, which per Exception 2 would result in an effective F_V factor of 2.72 (1.5 times larger). We are doing this intentionally as we understand that the appropriateness of the requirements of Section 11.4.8 is under review by UCOP.

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

Moment frame at roof

Moment frame beam-column joint, metal wall panels



West wall

East wall, water damage visible

West wall, water damage visible

UC Campus:	UC Santa Cruz			Date:	6/30/2019		
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Building Name:	Kerr Hall			Initials:	NY	Checked:	JM
Building Address:	500 Kerr Road, Santa Cruz CA 95064			Page:	1	of	3

ASCE 41-17
Collapse Prevention Basic Configuration Checklist

LOW SEISMICITY

BUILDING SYSTEMS - *GENERAL*

	Description
C NC N/A U ● ○ ○ ○ **NC**	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:** Collectors to walls are not provided. Caisson reinforcement is developed only 20db into pier caps versus current ACI 318-14 development length of 28db. .
C NC N/A U ○ ○ ○ ○ **C**	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:** C - No adjacent buildings
C NC N/A U ○ ○ ○ ○ **C**	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:** C - No mezzanines

BUILDING SYSTEMS - *BUILDING CONFIGURATION*

	Description
C NC N/A U ○ ○ ○ ○ **C**	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:** C – wall length/thickness increases with height.
C NC N/A U ○ ○ ○ ○ **C**	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:** C

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

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Collapse Prevention Basic Configuration Checklist

C	NC	N/A	U	
○	○	○	○	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)
C				**Comments:** C – interior walls are continuous to foundation.
C	NC	N/A	U	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)
	NC			**Comments:** NC – Level 1 has more than 30% increase in wall length versus Level 2. This is due to the wall added at the north end of the building for retaining soil.
C	NC	N/A	U	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)
C				**Comments:** C – There is a 44% change in mass between Level 3 (larger floor footprint) and Level 4 (smaller floor footprint).
C	NC	N/A	U	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)
	NC			**Comments:** NC – Level 1 has significantly more wall at the north end of the building, resulting in the eccentricity between center of mass and center of rigidity in the north-south direction.

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

GEOLOGIC SITE HAZARD

	Description
C NC N/A U	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)
C	**Comments:**
C NC N/A U	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)
C	**Comments:**

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ASCE 41-17
Collapse Prevention Basic Configuration Checklist

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

GEOLOGIC SITE HAZARD

C	NC	N/A	U	
○	○	○	○	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)
C				**Comments:**

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

FOUNDATION CONFIGURATION

C	NC	N/A	U	Description
○	○	○	○	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)
	NC			**Comments: NC – At stair core, wall is 16' long and 65' high (including basement depth), so 16'/65' = 0.25 < 0.6Sa = 0.6*1.28 = 0.77**
C	NC	N/A	U	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)
○	○	○	○	
C				**Comments:** C – tie beams are provided

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

Low And Moderate Seismicity

Seismic-Force-Resisting System

	Description
C NC N/A U NA	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:** NA – no frames provided
C NC N/A U 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:**
C NC N/A U 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:** NC – walls in north-south direction are overstressed at Level 2 where the building footprint increases but wall length do not increase proportionally.
C NC N/A U 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: C**

Connections

	Description
C NC N/A U NA	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: NA – rigid diaphragm at floor and roof**
C NC N/A U NC	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:** NC – no collectors provided

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

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: C**
C				

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

Seismic-Force-Resisting System

C	NC	N/A	U	Description
○	○	○	○	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:** NC – gravity columns do not have shear capacity to develop their flexural strength, at levels 3 and below.
NC				
○	○	○	○	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:**
C				
○	○	○	○	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:**
C				

Diaphragms (Stiff Or Flexible)

C	NC	N/A	U	Description
○	○	○	○	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:**
C				
○	○	○	○	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:**
C				

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

Flexible Diaphragms

C NC N/A U	Description
NA	CROSS TIES: There are continuous cross ties between diaphragm chords. (Commentary: Sec. A.4.1.2. Tier 2: Sec. 5.6.1.2) **Comments:**
NA	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:**
NA	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:**
NA	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:**
NA	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:**

Connections

C NC N/A U	Description
NC	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:** NC – pile caps have top reinforcement, but pile reinforcement is inadequately developed into pile cap (development length is specified 20db and not 28db as required by ACI 318-14)

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Project:_____
Subject:_____
By:_____
Date:_____

SEISMIC EVALUATION OF EXISTING BUILDINGS - TIER 1 SCREENING

ASCE 41-17 Chapter 4

General				Reference	Location
Building	Kerr Hall				
Architect	Germano, Milono & Associates				
Structural Engineer	T.Y. Lin, Kulka, Yang & Associate				
Location	513 Cowell Service Road, Santa Cruz, CA 95064				
Design date	1969				
Latitude	36.99699			https://hazards.atcouncil.org/	
Longitude	-122.06210			"	
Stories above grade	4				

Seismic parameters					
Risk Category	II	2016 CBC Table 1604.5			
Site Class	D			(ASCE 41-17 2.4.1.6, ASCE 7-16 Chapter 20)	See ASCE 7
Liquefaction hazard	Low	http://data-sccgis.opendata.arcgis.com/datasets/77d380d355934b38a44894154377e28d_62		(ASCE 41-17 3.3.4)	See ASCE 41
Landslide hazard	Low	http://data-sccgis.opendata.arcgis.com/datasets/7984aabd55ec4a4794ae33d7919bd9c7_133			
S_{DS}	0.85	https://hazards.atcouncil.org/	Based on ASCE 7-16 DE, used to determine "Level of Seismicity"	(ASCE 41-17 Eq 2-4)	See ASCE 41
S_{D1}	0.59	https://hazards.atcouncil.org/	Based on ASCE 7-16 DE, used to determine "Level of Seismicity"	(ASCE 41-17 Eq 2-5)	See ASCE 41
S_{XS}	1.281	For BSE-2E hazard level	https://hazards.atcou	(ASCE 41-17 Table 2-2)	Copied at right
S_{X1}	0.88	For BSE-2E hazard level	https://hazards.atcouncil.org/	(ASCE 41-17 Table 2-2)	Copied at right

Scope				
Performance level	Collapse Prevention	(ASCE 41-17 Table 2-2)	Copied at right	
Seismic hazard level	BSE-2E	(ASCE 41-17 Table 2-2)	Copied at right	
Level of seismicity	High	(ASCE 41-17 Table 2-4)	Copied at right	
Building type	C2: Concrete shear walls with rigid diaphragms	(ASCE 41-17 Table 3-1)	Copied at right	

Material properties				Notes		
Concrete	f'_c	4000	psi	Specified on drawings, NWC	(ASCE 41-17 Table 10-4)	See ASCE 41
Reinf.	f_y	40	ksi	Specified on Drawings for #5 and smaller	(ASCE 41-17 Table 10-4)	See ASCE 41
		60	ksi	Specified on Drawings for #6 and larger		
Steel	F_y	N/A	ksi	N/A	(ASCE 41-17 Table 9-1)	See ASCE 41

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Checklists

Benchmark building	No	Retrofit also pre-benchmark	(ASCE 41-17 Table 3-2)	Copied at right
Checklist(s) req'd	17.1.2 Basic Configuration		(ASCE 41-17 Table 4-6)	Copied at right
	17.12 Structural Checklist for Building Types C2a		(ASCE 41-17 Table 4-6)	Copied at right
	~~17.19 Nonstructural Checklist~~	(not performed)	(ASCE 41-17 Table 4-6)	Copied at right

Seismic forces

V	16589	kip	$V = Cs_a W$	= 1.28W	(ASCE 41-17 Eq 4-1)	See ASCE 41
W	12950	kip	building weight		(ASCE 41-17 4.4.2.1)	See ASCE 41
C	1.0		Convert linear elastic to inelastic disp.		(ASCE 41-17 Table 4-7)	Copied at right
S_a	1.28	g	$S_a = S_{x1}/T \le S_{XS}$		(ASCE 41-17 Eq 4-3)	See ASCE 41
T	0.39	sec	$T = C_t h_n^{\beta}$		(ASCE 41-17 Eq 4-4)	See ASCE 41
C_t	0.020				(ASCE 41-17 Eq 4-4)	Copied at right
β	0.75				(ASCE 41-17 Eq 4-4)	Copied at right
h_n	52	ft	building height		(ASCE 41-17 Eq 4-4)	Copied at right

Story Forces (ASCE 41-17 4-2a) (ASCE 41-17 4-2b)

Story	w kip	story ht ft	h ft	wh^k	F_{story}	F_{story} kip	V_{story} kip
Roof	2069		52	107588	0.29	4828	
4	2447	13.0	39	95433	0.26	4283	4828
3	4385	13.0	26	114010	0.31	5116	4828
2	4049	13.0	13	52637	0.14	2362	14227
1		13.0	0				16589
Total	12950			369668	1.0	16589	

k 1.00 k = 1.0 for T < 0.5, 2.0 for T > 2.5, linear interpolation between

$F_{story} = V(wh^k)/(\Sigma wh^k)$ (ASCE 41-17 4-2a)

$V_{story} = \Sigma_{above} F_{story}$ (ASCE 41-17 4-2b)

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Shear stress in shear walls (ASCE 41-17 4-8) (ASCE 41-17 4-8)

Story	$A_{w\,N\text{-}S}$ in^2	$A_{w\,E\text{-}W}$ in^2	v_{NS}^{avg} psi	v_{EW}^{avg} psi	D/C_{NS}	D/C_{EW}
Roof						
4	11220	18860	96	57	0.8	0.4
3	13464	20760	80	52	0.6	0.4
2	17735	26208	178	121	1.4	1.0
1	48936	48480	75	76	0.6	0.6
Total						

M_s 4.50 (ASCE 41-17 Table 4-8)

v_{limit} 126 psi $v_{limit} = 2\sqrt{f_c'} \geq 100$ psi

$v^{avg} = (1/M_S)(V_{story}/A_w)$ (ASCE 41-17 Eq 4-8)

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SHEAR STRENGTH OF CONCRETE ELEMENTS

FEMA 306 Section 5.3.6

Input

f'_{ce}	4000	psi	concrete expected strength
λ	1.00		lightweight aggregate factor = 1.0 NWC, 0.85 sand LWC, 0.75 LWC
μ	1.4	λ	per ACI 318 11.7.4 = 1.4 monolithic, 1.0 roughened, 0.6 not roughened, 0.7 bars
$f_{ye\_transverse}$	46	ksi	expected transverse steel yield strength
$f_{ye\_longitudina}$	70	ksi	expected shear friction steel yield strength
b_w	32.0	in	width
l_w	24.0	in	length of wall (depth of beam or column)
h_w	12.3	ft	clear height of wall or column (length of beam or spandrel)
ρ_n	0.00115		transverse reinforcement ratio
A_s	8.0	in^2	longitudinal reinforcement area
P	600	kip	axial load
M_{n_1}	645	k-ft	moment strength at one end of element (e.g. top)
M_{n_2}	645	k-ft	moment strength at other end of element (e.g. bottom)
c	12.5	in	distance from extreme compressive fiber to neutral axis
θ	35	degrees	35 degrees unless limited to larger angles by the potential corner to corner crack

for corner to corner crack, use θ= max(35, atan(l_w/h_w))= 35

Behavior Mode

Flexure/ Diagonal

$V_{n\_flexure} = (M_{n1} + M_{n2})/h$ =	105	kip	
$V_{n\_diagonal\_tension\_at\_low\_ductility\_demand}$ =	170	kip	($\mu \le 2$)
$V_{n\_diagonal\_tension\_at\_high\_ductility\_demand}$ =	91	kip	($\mu \ge 5$)
$V_{n\_sliding\_shear}$ =	614	kip	

Diagonal Tension Shear

	$\mu \le 2$	$\mu \ge 5$		
				flexural ductility demand
$V_{n\_diagonal}$	170	91	kip	$= V_c + V_s + V_p$
V_c	96	17	kip	$= \alpha\beta k_{rc} (f'_{ce})^{1/2} b_w (0.8 l_w)$
V_s	28	28	kip	$= \rho_n f_{ye} b_w h_d$
V_p	46	46	kip	$= ((l_w - c)\, N_u) / (2M/V)$
k_{rc}	3.5	0.6		
α	1.0	1.0		$= 3 - M/(0.8 l_w V)$ ($1.0 \le \alpha \le 1.5$)
β	0.708	0.708		$= 0.5 + 20\rho_g$ (≤ 1.0)
ρ_g	0.01042	0.01042		longitudinal reinforcement ratio
M/V	74.0	74.0	in	$= h_w/2$ assumes that beams/floors are stiffer than column (fixed- Adjust M/V calculation for other conditions.
h_d	16.4	16.4	in	$= (l_w - c)\cot\theta$ ($\le h_w$)
N_u	600	600	k	axial load
$2M/V$	147.96	147.96	in	$= h_w$ assumes that beams/floors are stiffer than column (fixed- Adjust M/V calculation for other conditions.

Sliding Shear

$V_{n\_sliding}$	614	kip	$= A_{vf} f_y \mu$ ($\le 0.2 f_c A_c$, $800 A_c$)

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A_{vf}	8.0 in^2	area of shear friction reinforcement