Rating form completed by: **MAFFEI STRUCTURAL ENGINEERING**
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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

Natural Sciences Building 2, University of California Santa Cruz

CAAN #7179
560 Red Hill Road, Santa Cruz, CA 95064
UCSC Campus: Main Campus

REGISTERED PROFESSIONAL ENGINEER JOSEPH RICHARD MAFFEI No. 3694 STRUCTURAL STATE OF CALIFORNIA

DATE: 2018-12-31

Rating summary	Entry	Notes
UC Seismic Performance Level (rating)	V (Poor)	
Rating basis	Tier 1	ASCE 41-17[1]
Date of rating basis	2018	
Recommended list assignment (UC Santa Cruz 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	Building previously rated III but does not have a documented review.
Further evaluation recommended?	Tier 3 NLRHA	

[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

- Original construction drawings by Anshen & Allen Architects, "Natural Sciences Unit 2," dated 1967-02-25 (131 sheets with architectural, structural, MEP drawings). Structural drawings by T.Y. Lin, Kulka, Yang & Associates (sheets S-1 to S-12 for Natural Sciences 2 Main Building).
- Retrofit drawings by Wildman & Morris Architects & Engineers, "Seismic Upgrade Natural Sciences 2," dated 1998-03-11 (54 sheets with architectural, structural, MEP drawings). Structural sheets S-1 to S-11.
- Letter by Wildman & Morris, "Review of Natural Sciences Unit II Following the October 17, 1989 Earthquake," dated 1989-12-08 (2 pages).
- Letter by Degenkolb Engineers, "Post-Earthquake Inspection Natural Sciences II," dated 1989-12-04 (3 pages).
- Letter UCSC Campus Architect with conceptual details and construction cost estimate, "Damage Survey Report," dated 1990-05-18 (7 pages).
- University of California building database information, "Natural Sciences 2," provided by Jose Sanchez (UCSC) on 2018-12-12.

Additional building information known to exist

- None

Scope for completing this form

Reviewed structural drawings for original construction and carried out ASCE 41-17 Tier 1 evaluation. Did not make site visit or evaluate non-structural life-safety hazards but discussed with UCSC staff who know the building.

Brief description of structure

Natural Sciences 2 is a four-story building, approximately 96 feet (north-south) by 247 feet (east-west) in plan, approximately 88,000 square feet. The building is built into a hill such that grade is at the 1st Floor level on the south side of the building, and grade is at the 2nd Floor level on the north side of the building.

Structural system for vertical (gravity) load: The floor and roof system consists of precast lightweight concrete T-beams spaced at 10 feet on center, spanning north-south between exterior precast normal-weight concrete columns and cast-in-place concrete walls running east-west at the center of the building. There is a 3.5-inch lightweight concrete topping slab with reinforcement. At the 4th Story, the perimeter supports become concrete wall piers rather than precast columns.

Between the east-west concrete walls at the center of the building (on Lines D and E), there is an open mechanical space that runs the full height of the building, separating the north and south portions of the diaphragm at the 3rd and 4th Floors; at the 2nd Floor, the north and south portions of the diaphragm are also separated, except that there is a concrete floor between Lines D and E located 6'-2" below the 2nd Floor level.

Structural system for lateral forces: Reinforced concrete walls are located along the center of the building (on Lines D and E) and around stair and elevator cores at the east and west ends of the building. Concrete walls are typically 10-inches thick with #4@16" on center reinforcement each face, each way. The concrete wall on Line D is discontinuous at the 1st story, supported on columns.

Seismic retrofitting constructed in the late 1990s includes exterior steel braced frame buttresses added on the north and south sides of the building to provide seismic resistance in the north-south direction. The braced frame buttresses consist of welded steel rectangular tube sections, and they are founded on concrete drilled piers. Steel collectors (rectangular tube sections) extend from the buttresses into the building, connected to the underside of T-beam flanges. On the north side, the braced frame buttresses exist at the 2nd and 3rd Stories (because the 1st Story is below-grade on the north side of the building); on the south side, the braced frames exist at the 1st, 2nd, and 3rd Stories, and they include east-west braces at the 1st Story. At the 4th Story, retrofitting includes interior X-braces in the north-south direction constructed from steel WT shapes. Steel angles (L6x4x3/8) are added at the north and south edges of the 2nd, 3rd, and 4th Floor diaphragms as chord reinforcement.

Foundation System: Concrete walls and perimeter columns are supported on strip footings. Interior columns are supported on spread footings.

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:

- Discontinuous longitudinal wall on Line D at the 1st Story. Concrete columns (12"x24") beneath this wall are flexure/shear-governed, with #4@12" ties.
- Numerous openings in longitudinal concrete walls on Lines D and E just below each floor level. (See wall elevations Sheet S-8.) These openings are expected to reduce shear strength of the walls and cause shear damage to the short piers between the openings.
- Plan torsion at the 1st story. The north side of the building is built into the hill and has a significant amount of longitudinal concrete wall at the 1st Story; the south side of the building has very little lateral resistance. The only lateral resistance at the south side of the building is the steel retrofit braces, which are expected to be more flexible than the concrete walls.
- Precast concrete columns at the building perimeter have short clear height at the 2nd and 3rd Stories because of deep spandrels and are subject to shear-governed behavior.
- Connections of precast T-beams to column corbels experienced damage in the 1989 Loma Prieta Earthquake. Letters following the earthquake indicate that a metal bracket was being designed to improve these connections. We did not find documentation of these metal brackets in the retrofit drawings.

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)	Y
Load path	N	Liquefaction	N
Adjacent buildings	N	Slope failure	N
Weak story	Y	Surface fault rupture	N
Soft story	N	Masonry or concrete wall anchorage at flexible diaphragm	N
Geometry (vertical irregularities)	Y	URM wall height-to-thickness ratio	N
Torsion	Y	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]

None known by those familiar with the building. We did not visit the building interior.

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

[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.

Discussion of rating

The building is reported to have been the most severely-damaged building on campus in the 1989 Loma Prieta Earthquake, which was a smaller earthquake than that which is considered by current standards for evaluating existing buildings. Letters following that earthquake indicate that the building was "poor" or "very poor," and strongly recommended retrofitting. The steel braced frame retrofit, designed in 1998, improves the building's seismic behavior by addressing the most critical deficiency: lack of lateral force resistance in the north-south direction. However, it is not clear that the 1998 retrofit provides sufficient lateral resistance and ductility to withstand the demands for a Risk Category III existing structure according to current UC Seismic Policy. In our opinion, the building is near the margin between a IV (Fair) and V (Poor) rating, so we recommend a V (Poor) rating at this time, which could be improved to IV (Fair) if supported by more detailed investigation and analysis.

Recommendations for further evaluation or retrofit

We recommend that the University perform a more detailed seismic evaluation to evaluate the behavior of the steel braced frames acting in combination with concrete walls, the effects of plan torsion, deformation demands on concrete columns, and the connection of T-beams to column corbels.

Potential retrofit measures could include:

- Adding concrete wall and/or FRP wrapping columns beneath the discontinuous wall on Line D.
- Improvement of connections of T-beams to column corbels (depending on what improvements were carried out following the 1989 Loma Prieta Earthquake).
- Providing lateral resistance in the east-west direction on the south side of the building.
- Improve shear behavior and gravity support of perimeter precast columns, such as by FRP wrapping or supplemental steel support.
- Adding concrete walls or braced frames in the north-south direction (if analysis indicates that that existing steel retrofit braced frame buttresses and existing concrete walls do not have adequate combined lateral resistance).

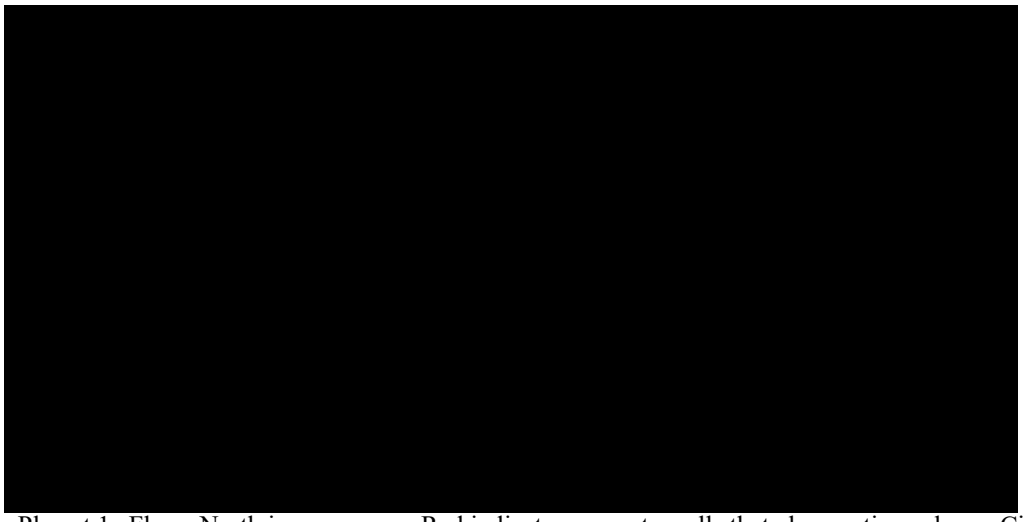
Additional building data	Entry	Notes
Latitude	36.998535	
Longitude	-122.06049	
Are there other structures besides this one under the same CAAN#	No	
Number of stories above lowest perimeter grade	4	
Number of stories (basements) below lowest perimeter grade	0	1st Story is below-grade on the north side of the building, above-grade on the south side of the building.
Building occupiable area (OGSF)	87716	
Risk Category per 2016 CBC Table 1604.5	III	Occupant load > 500 (campus to confirm) and contains educational occupancy above 12th grade.
Estimated fundamental period	0.39 sec	Estimated using ASCE 41-17 equation 4-4 and 7-18
Building height, h_n	52 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
Exponent for period, β	0.75	Estimated using ASCE 41-17 equation 4-4 and 7-18
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	1.29	
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: 1969 Code: 1964 UBC	Code specified construction drawing General Notes
Applicable code for partial retrofit	See full retrofit	
Applicable code for full retrofit	1991 UBC	Retrofit drawings dated 1998 reference 1991 UBC. No performance objective is stated. Letters from 1989-1990 indicate that the intention was likely to "repair to good rating" following damage in 1989 Loma Prieta Earthquake.
FEMA P-154 data		
Model building type North-South	PC2: Precast concrete frames with shear walls	
Model building type East-West	PC2: Precast concrete frames with S2 steel braced frame retrofit	
FEMA P-154 score	N/A	Not included here because we performed ASCE 41 Tier 1 evaluation.

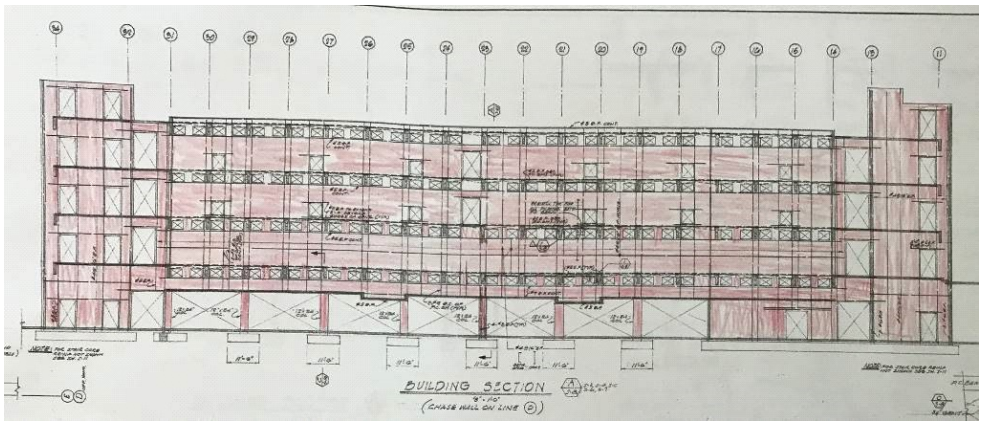
[4] Determination of site class and assessment of geotechnical hazards are based on correspondence with Pacific Crest Geotechnical Engineers and Nolan, Zinn, and Associates Geologists. [*Revised Geology and Geologic Hazards, Santa Cruz Campus, University of California*, Job # 04003-SC 13 May 2005]. Site 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 that are applicable to Site Class D, and which per Exception 2 would result in an effective F_V factor of 2.72 (1.5 times larger). At the Santa Cruz main campus this only affects structures with T>0.69 seconds. We understand that the appropriateness of this requirement of Section 11.4.8 might be reviewed by UCOP.

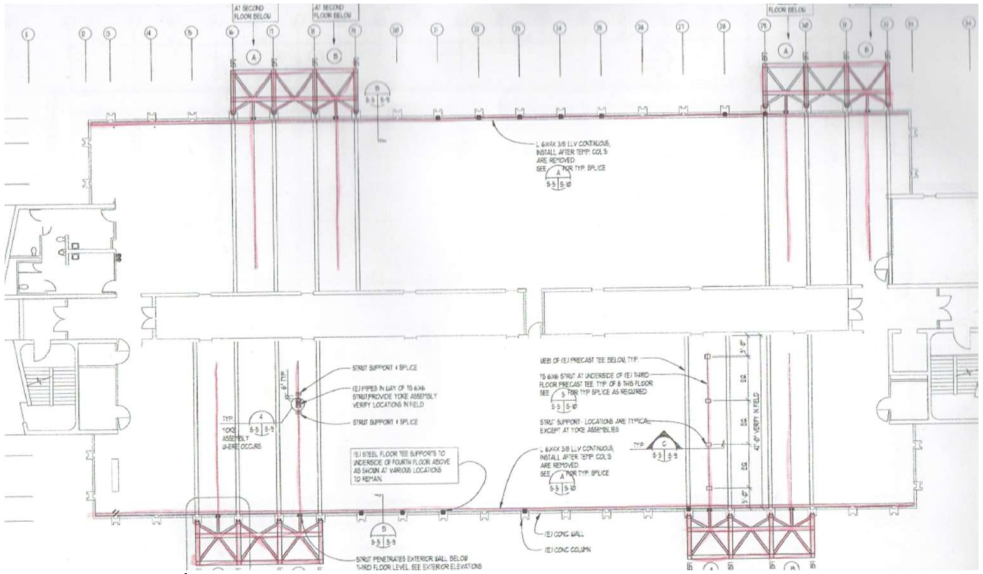
Previous ratings		
Most recent rating	Good	From UCSC building database.
Date of most recent rating	1998 (assumed)	We are not aware of a basis for this rating. We assume that it is because the building was retrofitted in 1998.
2nd most recent rating	Very Poor	From UCSC building database.
Date of 2nd most recent rating	1989 (assumed)	We are not aware of a basis for this rating. We assume that it is because letters following the 1989 Loma Prieta Earthquake indicate that the building was the most severely-damaged building on campus, and that seismic upgrading (beyond repair of damage) was recommended.
3rd most recent rating	-	
Date of 3rd most recent rating	-	
Appendices		
ASCE 41 Tier 1 checklist included here?	Yes	Refer to attached checklist file



Plan at 1 Floor. North is up on page. Red indicates concrete walls that also continue above. Circled column is one of seven columns on Line D below a discontinuous concrete wall.



Wall elevation Line D (looking south).



1998 retrofit. (3rd floor shown.) Red indicates exterior steel braced frame buttresses (rectangular tube sections), steel collectors extending into the building (rectangular tube sections), and steel chord reinforcement (angle sections) added along the north and south edges of the diaphragm.

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ASCE 41-17
Collapse Prevention Basic Configuration Checklist

LOW SEISMICITY

BUILDING SYSTEMS - *GENERAL*

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

BUILDING SYSTEMS - *BUILDING CONFIGURATION*

C	NC	N/A	U	Description
○	●	○	○	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:** 4th Story has concrete wall piers at the perimeter (in place of columns) that do not exist at the lower stories. One of the two main longitudinal wals (Line D) is discontinuous at the 1st Story.
●	○	○	○	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:**
○	●	○	○	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:** Discontinuous wall at 1st Floor on Line D. Interior braces (retrofit) exist only at the 4rth Story.

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

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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) **Comments:** Discontinuous wall at 1st Floor on Line D.
☒	☐	☐	☐	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:**
☐	☒	☐	☐	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:** At the 1st Story, the building has limited lateral resistance on the south side (to resist east-west earthquake). The primary lateral resistance on the south side are the steel (retrofit) braces, which are expected to be much more flexible than the long concrete walls on the north side of the building.

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

GEOLOGIC SITE HAZARD

C	NC	N/A	U	Description
☒	☐	☐	☐	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:**
☒	☐	☐	☐	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:**
☒	☐	☐	☐	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:**

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Collapse Prevention Basic Configuration Checklist

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

FOUNDATION CONFIGURATION

	Description
C ◉ NC ○ N/A ○ U ○	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:**
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) **Comments:** Site class assumed to be C, similar to other buildings on campus.

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Collapse Prevention Structural Checklist For Building Type PC2

LOW AND MODERATE SEISMICITY

SEISMIC-FORCE-RESISTING SYSTEM

	Description
C NC N/A U ● ○ ○ ○	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:**
C NC N/A U ● ○ ○ ○	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 ○ ● ○ ○	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 is used to approximately check combination of retrofit braced frames with existing concrete walls. If all seismic force is assumed to be taken by concrete walls, north-south D/C ratio exceeds 2.0 at all levels. If load is shared between braced frames and concrete walls, D/C ratio is approximately 1.5 at 1st Story. Also, there are many openings in the concrete walls on Lines D and E just below each floor level, which are expected to reduce east-west shear capacity.
C NC N/A U ● ○ ○ ○	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:**

DIAPHRAGMS

	Description
C NC N/A U ● ○ ○ ○	TOPPING SLAB: Precast concrete diaphragm elements are interconnected by a continuous reinforced concrete topping slab with a minimum thickness of 2 in. (51 mm). (Commentary: Sec. A.4.5.1. Tier 2: Sec. 5.6.4) **Comments:** Topping slab 3.5 inches thick.

CONNECTIONS

	Description

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C	NC	N/A	U	
●	○	○	○	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:**
●	○	○	○	TOPPING SLAB TO WALLS OR FRAMES: Reinforced concrete topping slabs that interconnect the precast concrete diaphragm elements are doweled for transfer of forces into the shear wall or frame elements. (Commentary: Sec. A.5.2.3. Tier 2: Sec. 5.7.2) **Comments:**
●	○	○	○	FOUNDATION DOWELS: Wall reinforcement is doweled into the foundation. (Commentary: Sec. A.5.3.5. Tier 2: Sec. 5.7.3.4) **Comments:**
○	○	○	●	GIRDER–COLUMN CONNECTION: There is a positive connection using plates, connection hardware, or straps between the girder and the column support. (Commentary: Sec. A.5.4.1. Tier 2: Sec. 5.7.4.1) **Comments:** Letters from 1989 indicate that a metal bracket detail was developed to address damage to corbels supporting precast T-beam s on columns. We did not find details of this improvement in the retrofit drawings.

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 ●	PRECAST FRAMES: For buildings with concrete shear walls, precast concrete frame elements are not considered as primary components for resisting seismic forces. (Commentary: Sec. A.3.1.5.2. Tier 2: Secs. 5.5.2.4, 5.5.2.5.1, and 5.5.2.5.2) **Comments:** Prior to 1998 retrofit, earthquake damage indicated that precast concrete frame elements were participating for resisting seismic forces. 1998 retrofit intends to address this in the north-south direction, and to some extent in the east-west direction at the 1st Story. However, we expect that precast frames may still participate, particularly at the south side of the building.
C ● NC ○ N/A ○ U ○	PRECAST CONNECTIONS: For buildings with concrete shear walls, the connection between precast frame elements, such as chords, ties, and collectors in the seismic-force-resisting system, develops the capacity of the connected members. (Commentary: Sec. A.3.1.5.3. Tier 2: Sec. 5.6.1.1) **Comments:** 1998 retrofit added chords at north and south edges of diaphragms, and north-south collectors to steel braced frame buttresses.

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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	
☐	☒	☐	☐	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:** Columns below the discontinuous wall on Line D are flexure/shear-governed. Precast columns at the perimeter of the building have limited clear height because of deep spandrels; columns are shear-governed at 2nd and 3rd Stories, flexure/shear-governed at 1st Story.
☒	☐	☐	☐	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:**

DIAPHRAGMS

				Description
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. 5.5.3.3.1) **Comments:** At levels 3 and 4 there is a shaft between the longitudinal walls on Lines D and E. Walls at stairs and elevator cores are partially outside the main floor diaphragm.

CONNECTIONS

				Description
C	NC	N/A	U	
☐	☐	☒	☐	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:**
☒	☐	☐	☐	CORBEL BEARING: If the frame girders bear on column corbels, the length of bearing is greater than 3 in. (76 mm) (Commentary: Sec. A.5.4.3. Tier 2: Sec. 5.7.4.3) **Comments:**
☐	☐	☐	☒	CORBEL CONNECTIONS: The frame girders are not connected to corbels with welded elements. (Commentary: Sec. A.5.4.4. Tier 2: Sec. 5.7.4.3) **Comments:** Letters from 1989 indicate that a metal bracket detail was developed to address damage to corbels supporting precast T-beam s on columns. We did not find details of this improvement in the retrofit drawings.

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ASCE 41-17
Collapse Prevention Structural Checklist For Building Type S2-S2A

LOW SEISMICITY

SEISMIC-FORCE-RESISTING SYSTEM

	Description
C ● NC ○ N/A ○ U ○	REDUNDANCY: The number of lines of braced frames in each principal direction is greater than or equal to 2. (Commentary: Sec. A.3.3.1.1. Tier 2: Sec. 5.5.1.1) **Comments:**
C ○ NC ○ N/A ○ U ○	COLUMN AXIAL STRESS CHECK: The axial stress caused by gravity loads in columns subjected to overturning forces is less than $0.10F_y$. Alternatively, the axial stress caused by overturning forces alone, calculated using the Quick Check procedure of Section 4.4.3.6, is less than $0.30F_y$. (Commentary: Sec. A.3.1.3.2. Tier 2: Sec. 5.5.2.1.3) **Comments:** Braced frames do not carry gravity load.
C ○ NC ● N/A ○ U ○	BRACE AXIAL STRESS CHECK: The axial stress in the diagonals, calculated using the Quick Check procedure of Section 4.4.3.4, is less than $0.50F_y$. (Commentary: Sec. A.3.3.1.2. Tier 2: Sec. 5.5.4.1) **Comments:** Quick check is used to approximately check combination of retrofit braced frames with existing concrete walls. If all seismic force is assumed to be taken by braced frames, D/C ratio is approximately 2.5. If load is shared between braced frames and concrete walls, D/C ratio is approximately 1.5.

CONNECTIONS

	Description
C ○ NC ○ N/A ○ U ○	TRANSFER TO STEEL FRAMES: Diaphragms are connected for transfer of seismic forces to the steel frames. (Commentary: Sec. A.5.2.2. Tier 2: Sec. 5.7.2) **Comments:**
C ● NC ○ N/A ○ U ○	STEEL COLUMNS: The columns in seismic-force-resisting frames are anchored to the building foundation. (Commentary: Sec. A.5.3.1. Tier 2: Sec. 5.7.3.1) **Comments:**

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Collapse Prevention Structural Checklist For Building Type S2-S2A

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

SEISMIC-FORCE-RESISTING SYSTEM

	Description
C ☐ NC ☒ N/A ☐ U ☐	REDUNDANCY: The number of braced bays in each line is greater than 2. (Commentary: Sec. A.3.3.1.1. Tier 2: Sec. 5.5.1.1) **Comments:**
C ☐ NC ☐ N/A ☐ U ☒	CONNECTION STRENGTH: All the brace connections develop the buckling capacity of the diagonals. (Commentary: Sec. A.3.3.1.5. Tier 2: Sec. 5.5.4.4) **Comments:**
C ☒ NC ☐ N/A ☐ U ☐	COMPACT MEMBERS: All brace elements meet compact section requirements in accordance with AISC 360, Table B4.1. (Commentary: Sec. A.3.3.1.7. Tier 2: Sec. 5.5.4) **Comments:**
C ☒ NC ☐ N/A ☐ U ☐	K-BRACING: The bracing system does not include K-braced bays. (Commentary: Sec. A.3.3.2.1. Tier 2: Sec. 5.5.4.6) **Comments:**

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 ☐	COLUMN SPLICES: All column splice details located in braced frames develop 50% of the tensile strength of the column. (Commentary: Sec. A.3.3.1.3. Tier 2: Sec. 5.5.4.2) **Comments:**

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ASCE 41-17
Collapse Prevention Structural Checklist For Building Type S2-S2A

C	NC	N/A	U	
●	○	○	○	SLENDERNESS OF DIAGONALS: All diagonal elements required to carry compression have *Kl/r* ratios less than 200. (Commentary: Sec. A.3.3.1.4. Tier 2: Sec. 5.5.4.3) **Comments:**
○	○	○	●	CONNECTION STRENGTH: All the brace connections develop the yield capacity of the diagonals. (Commentary: Sec. A.3.3.1.5. Tier 2: Sec. 5.5.4.4) **Comments:**
○	●	○	○	COMPACT MEMBERS: All brace elements meet section requirements in accordance with AISC 341, Table D1.1, for moderately ductile members. (Commentary: Sec. A.3.3.1.7. Tier 2: Sec.5.5.4) **Comments:**
○	○	●	○	CHEVRON BRACING: Beams in chevron, or V-braced, bays are capable of resisting the vertical load resulting from the simultaneous yielding and buckling of the brace pairs. (Commentary: Sec. A.3.3.2.3. Tier 2: Sec. 5.5.4.6) **Comments:**
●	○	○	○	CONCENTRICALLY BRACED FRAME JOINTS: All the diagonal braces frame into the beam–column joints concentrically. (Commentary: Sec. A.3.3.2.4. Tier 2: Sec. 5.5.4.8) **Comments:**

DIAPHRAGMS (STIFF OR FLEXIBLE)

	Description
C NC N/A U ○ ○ ● ○	OPENINGS AT FRAMES: Diaphragm openings immediately adjacent to the braced frames extend less than 25% of the frame length. (Commentary: Sec. A.4.1.5. Tier 2: Sec. 5.6.1.3) **Comments:**

FLEXIBLE DIAPHRAGMS

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

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ASCE 41-17
Collapse Prevention Structural Checklist For Building Type S2-S2A

C	NC	N/A	U	
☐	☐	☐	☐	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:**
☐	☐	☐	☐	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:**
☐	☐	☐	☐	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:**
☐	☐	☐	☐	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:**

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

MAFFEI STRUCTURAL ENGINEERING

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

SEISMIC EVALUATION OF EXISTING BUILDINGS - TIER 1 SCREENING

ASCE 41-17 Chapter 4

General			Reference	Location
Architect	Anshen & Allen Architects			
Structural Engineer	Original: TY Lin, Kulka, Yang; Retrofit: Wildman & Morris.			
Location	560 Red Hill Road, Santa Cruz, CA 95064			
Design date	Original 1967; Retrofit 1998			
Latitude	36.998535		(Google Earth)	
Longitude	-122.06049		"	
Stories above grade	4			

Seismic parameters					
Risk Category	III	2016 CBC Table 1604.5			
Site Class	C	https://earthquake.usgs.gov/hazards/urban/sfbay/soiltype/		(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}	1.307	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}	0.585	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}	1.286	For BSE-2E hazard level		(ASCE 41-17 Table 2-2)	Copied at right
S_{X1}	0.885	For BSE-2E hazard level		(ASCE 41-17 Table 2-2)	Copied at right

Scope			
Performance level	Limited Safety	(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	PC2: Precast concrete frames with shear walls	(ASCE 41-17 Table 3-1)	Copied at right

Material properties				Notes		
Concrete	f'_c	3000	psi	Specified on drawings, NWC	(ASCE 41-17 Table 10-4)	See ASCE 41
Reinf.	f_y	60	ksi	Column vertical bars A432	(ASCE 41-17 Table 10-4)	See ASCE 41
	f_y	40	ksi	All other bars Intermediate grade	(ASCE 41-17 Table 10-4)	See ASCE 41
Steel	F_y	46	ksi	Steel braced frame retrofit HSS	(ASCE 41-17 Table 9-1)	See ASCE 41

Checklists

Benchmark building	No	(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
	17.15 Collapse Prevention Structural Checklist for Building Type PC2	(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	18133	kip	$V = Cs_a W$ = 1.29W	(ASCE 41-17 Eq 4-1)	See ASCE 41
W	14100	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	1.29	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	story ht	h	wh^k	F_{story}	F_{story}	V_{story}
	kip	ft	ft			kip	kip
Roof	3000		52	156000	0.33	6060	
4	3700	12.0	40	148000	0.32	5749	6060
3	3700	12.0	28	103600	0.22	4024	11809
2	3700	12.0	16	59200	0.13	2300	15833
1		16.0	0				18133
Total	14100			466800	1.0	18133	
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)

MAFFEI STRUCTURAL ENGINEERING

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	20016	90240	81	18	0.7	0.2
3	14640	63360	215	50	2.0	0.5
2	14640	63360	288	67	2.6	0.6
1	22704	56940	213	85	1.9	0.8
Total						
M_s	3.75			(ASCE 41-17 Table 4-8)		

Copied at right

v_{limit} 110 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)

Axial stress in diagonal braces (ASCE 41-17 4-9) (ASCE 41-17 4-9)

Story	$A_{br\,N\text{-}S}$ in^2	$A_{br\,E\text{-}W}$ in^2	$(L/s)_{br\,N\text{-}S}$ ft	$(L/s)_{br\,E\text{-}W}$ ft	$N_{br\,N\text{-}S}$	$N_{br\,E\text{-}W}$	f_{NS}^{avg} ksi	f_{EW}^{avg} psi	D/C_{NS}	D/C_{EW}
Roof										
4							#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
3	21		2.8		16		24	#DIV/0!	1.0	#DIV/0!
2	21		2.0		16		23	#DIV/0!	1.0	#DIV/0!
1	21	21	2.0	1.9	8	8	52	48	2.3	2.1
Total										
M_s	4.22			(ASCE 41-17 Table 4-9)						

f_{limit} 23 ksi $f_{limit} = 0.5F_y$

$f^{avg} = (1/M_S)(V_{story}/sN_{br})(L_{br}/A_{br})$ (ASCE 41-17 Eq 4-9)

M-factor for diagonal braces per Table 4-9

			M_s
F_y	46	ksi	
F_{ye}	58	ksi	
$90/\sqrt{F_{ye}}$	12		5.75
$190/\sqrt{F_{ye}}$	25		3.00
d/t	19		**4.22**