ASCE 41-13 SEISMIC EVALUATION
Of

City of Inglewood Civic Center - Library

101 W. Manchester Blvd
Inglewood, CA 90301

Prepared by:

Nabih Youssef Associates
Structural Engineers
550 South Hope Street, Suite 1700
Los Angeles, California 90071
NYA Job # 16167.00

June 8, 2018

TABLE OF CONTENTS

0.0 EXECUTIVE SUMMARY

The objective of this report is to present the results of seismic evaluation on the Main Library building for the City of Inglewood. Tier 1 screening as well as Tier 2 deficiency-based evaluation have been conducted per ASCE 41-13 Standard for Seismic Evaluation and Retrofit of Existing Buildings.

Main Library building was constructed circa 1971 along with two adjacent buildings, Police Department and City Hall. Library building consists of 4 stories above grade with additional mechanical penthouse at roof level.

The property was visited by NYA staff to observe the general condition of the visible portions of the property. Overall, the building appeared to be in good condition.

The site is located within an established Alquist-Priolo Earthquake Fault Zone and thus subject to the jurisdiction of the Alquist-Priolo (A-P) Special Studies Zone Act.

The Geotechnical Consultation indicates that there is a potential for surface rupture at the site from fault plane displacement propagating to the ground surface due to the mapped trace of the active Newport-Inglewood fault. Surface rupture during major earthquakes that produce significant ground deformations associated with differential movement along the ruptured fault can severely damage structures that cross the fault. Large movements caused by fault rupture generally cannot be mitigated economically.

Although there is a potential for surface rupture at the site, it is noted that this is a rare event. The Tier 1 and Tier 2 evaluation does not assess the impact of the associated differential ground displacement on structural performance, and the proposed strengthening does not address mitigation of the hazard. A site-specific fault rupture hazard investigation would need to be performed to map the fault trace and zones of influence through the site and to estimate magnitudes of vertical and/or horizontal displacements consistent with seismic hazard levels in order to further assess the hazard.

Based on Tier 1 and Tier 2 evaluation and analysis, the subject building consists of several significant structural deficiencies listed below:

- Insufficient shear strength of several columns at base through 2nd floor
- Insufficient flexural strength of most beams at all levels (as beams were not originally designed for seismic load resistance)
- Insufficient shear strength of 4 beams at Lecture Hall portion
- Insufficient shear and flexural strength on narrow wall piers at all levels

To satisfy the required seismic performance level, the proposed retrofit/strengthening concepts consist of the following:

- Add new concrete shear walls at all levels in both directions
- Add new grade beams between (E) spread footings to support new shear walls
- Enlarge (E) spread footings that support (N) concrete walls with addition of top and bottom bars
- Strengthen (E) beams in shear by widening at underside of Lecture Hall portion

1.0 INTRODUCTION

1.1 General

The objective of this report is to present the results of seismic evaluation of the Main Library for the City of Inglewood. Tier 1 screening as well as Tier 2 deficiency-based evaluation have been conducted per ASCE 41-13 Standard for Seismic Evaluation and Retrofit of Existing Buildings.

The property was visited by *Nabih Youssef Associates* (NYA) staff to observe the general condition of the visible structural portions of the property. A general review of the structural and non-structural elements was performed during the site visit to develop an understanding of the building's construction.

This evaluation of the structural systems represents the opinion of NYA based on the site review and the available information from the existing architectural and structural drawings of the building.

1.2 Scope of Work

The following tasks outline the scope of work for the structural evaluation of the building:

1. Review existing architectural and structural drawings of the structure.
2. Perform limited walk-through of the structure including the attic to visually confirm that the existing drawings generally correspond to actual conditions.
3. Acquire material test data results from the existing structure and geotechnical data reports from Accu-Test and AMEC.
4. Evaluate required seismic performance level based on ASCE 41-13 Tier 1 and Tier 2.
5. Develop professional opinion of the adequacy of the structure to resist seismic forces and identify structural and nonstructural components that are not compliant to the evaluation standard.
6. Provide report summarizing the result of the structural evaluation and analysis of the structure as well as proposed strengthening schemes for structural deficiencies identified.

This report has been prepared for the sole and exclusive use of *City of Inglewood – Public Works Department* and shall not be relied upon by or transferred to any other party, or used for any other purpose, without the express written authorization of NYA. Further, it is understood that NYA is not liable for the accuracy and/or adequacy of the structural design performed by others.

2.0 EVALUATION REQUIREMENTS

2.1 Building Description

Library building was constructed circa 1971 along with two adjacent buildings, Police Department and City Hall. Library building consists of 4 stories above grade with additional mechanical penthouse at roof level. The building's main tower plan is typically 144'-0" by 144'-0", and it maintains square floor plan throughout full building height except at second and third levels where re-entrant corner exists. The first level shares larger floor plate with outdoor plaza area and lecture hall. The lecture hall is its own structural system that is different from the main library building portion, but they share the common first level diaphragm above grade.

The gravity system consists of two-way reinforced concrete slabs and beams at all levels. The beams span to reinforced concrete columns which continue down to spread footings typically. There are beams spanning both orthogonal directions, and typical bay spacing is 36'-0" at the main library portion. The lecture hall has reinforced concrete bearing wall on all four sides of the room with reinforced concrete roof slab and beams. At roof level over the penthouse, the gravity system consists of steel framing with composite deck.

The lateral force resisting system consists of five rows of non-ductile (reinforced) concrete moment frames in both orthogonal directions along full building height for the main library portion. Only the lecture hall portion consists of reinforced concrete shear walls at first level that are not continuous down to the foundation. Typical level consists of rigid diaphragm with reinforced concrete slab that is doweled into moment frame members or shear walls. The composite deck at roof diaphragm is also rigid diaphragm; however, it's not directly doweled into concrete moment frames.

2.2 Building Performance Criteria

Main Library building has Risk Category II per ASCE 7-10. With target structural performance level of Life Safety, seismic hazard level for Tier 1 and Tier 2 evaluations are at BSE-1E per Table 2-1 of ASCE 41-13, shown below. BSE-1E hazard level indicates Basic Safety Earthquake-1 associated with Basic Performance Objective for Existing Buildings, taken as a seismic hazard with a 20% probability of exceedance in 50 years at a site. According to the USGS's design map for the subject site, the design short-period spectral response acceleration parameter, S_{XS}, and the design spectral response acceleration parameter at a 1-s period, S_{X1}, for BSE-1E Seismic Hazard Level, are 0.842g and 0.461g respectively.

Table 2.1 – Basic Performance Objective for Existing Buildings (BPOE)

	Tier 1[a]	Tier 2[a]	Tier 3	
Risk Category	BSE-1E	BSE-1E	BSE-1E	BSE-2E
I & II	Life Safety Structural Performance Life Safety Nonstructural Performance (3-C)	Life Safety Structural Performance Life Safety Nonstructural Performance (3-C)	Life Safety Structural Performance Life Safety Nonstructural Performance (3-C)	Collapse Prevention Structural Performance Nonstructural Performance Not Considered (5-D)
III	See footnote *b* for Structural Performance Position Retention Nonstructural Performance (2-B)	Damage Control Structural Performance Position Retention Nonstructural Performance (2-B)	Damage Control Structural Performance Position Retention Nonstructural Performance (2-B)	Limited Safety Structural Performance Nonstructural Performance Not Considered (4-D)
IV	Immediate Occupancy Structural Performance Position Retention Nonstructural Performance (1-B)	Immediate Occupancy Structural Performance Position Retention Nonstructural Performance (1-B)	Immediate Occupancy Structural Performance Position Retention Nonstructural Performance (1-B)	Life Safety Structural Performance Nonstructural Performance Not Considered (3-D)

[a]For Tier 1 and 2 assessments, seismic performance for the BSE-2E is not explicitly evaluated.
[b]For Risk Category III, the Tier 1 screening checklists shall be based on the Life Safety Performance Level (S-3), except that checklist statements using the Quick Check procedures of Section 4.5.3 shall be based on MS-factors and other limits that are an average of the values for Life Safety and Immediate Occupancy.

Reference: Seismic Evaluation and Retrofit of Existing Buildings, Table 2-1 [ASCE/SEI 41, 2013]

The level of seismicity is determined with the response acceleration parameters associated with BSE-1N per ASCE 41-13 Section 2.5. BSE-1N indicates Basic Safety Earthquake-1 for use with the Basic Performance Objective Equivalent to New Building Standards, taken as two-thirds of the ground shaking based on the Risk-Targeted Maximum Considered Earthquake (MCE_R) per ASCE 7 at a site. According to the USGS's design map for the subject site, the design short-period spectral response acceleration parameter, S_{DS}, and the design spectral response acceleration parameter at a 1-s period, S_{D1}, for BSE-1N Seismic Hazard Level, are 1.166g and 0.641g respectively. Because S_{DS} exceeds 0.5g and S_{D1} exceeds 0.2g, the level of seismicity is defined as High per Table 2-5 of ASCE 41.

USGS Design Maps Summary Report

User–Specified Input

Report Title	City of Inglewood Civic Center Fri July 7, 2017 01:00:56 UTC
Building Code Reference Document	ASCE 41-13 Retrofit Standard, BSE-1E (which utilizes USGS hazard data available in 2008)
Site Coordinates	33.96177°N, 118.35514°W
Site Soil Classification	Site Class D – "Stiff Soil"

USGS–Provided Output

$S_{S,20/50}$	0.664 g	$S_{XS,BSE-1E}$	0.842 g
$S_{1,20/50}$	0.240 g	$S_{X1,BSE-1E}$	0.461 g

USGS Design Maps Summary Report

User–Specified Input

Report Title	City of Inglewood Civic Center Sat July 8, 2017 01:06:53 UTC
Building Code Reference Document	ASCE 41-13 Retrofit Standard, BSE-1N (which utilizes USGS hazard data available in 2008)
Site Coordinates	33.96177°N, 118.35514°W
Site Soil Classification	Site Class D – "Stiff Soil"

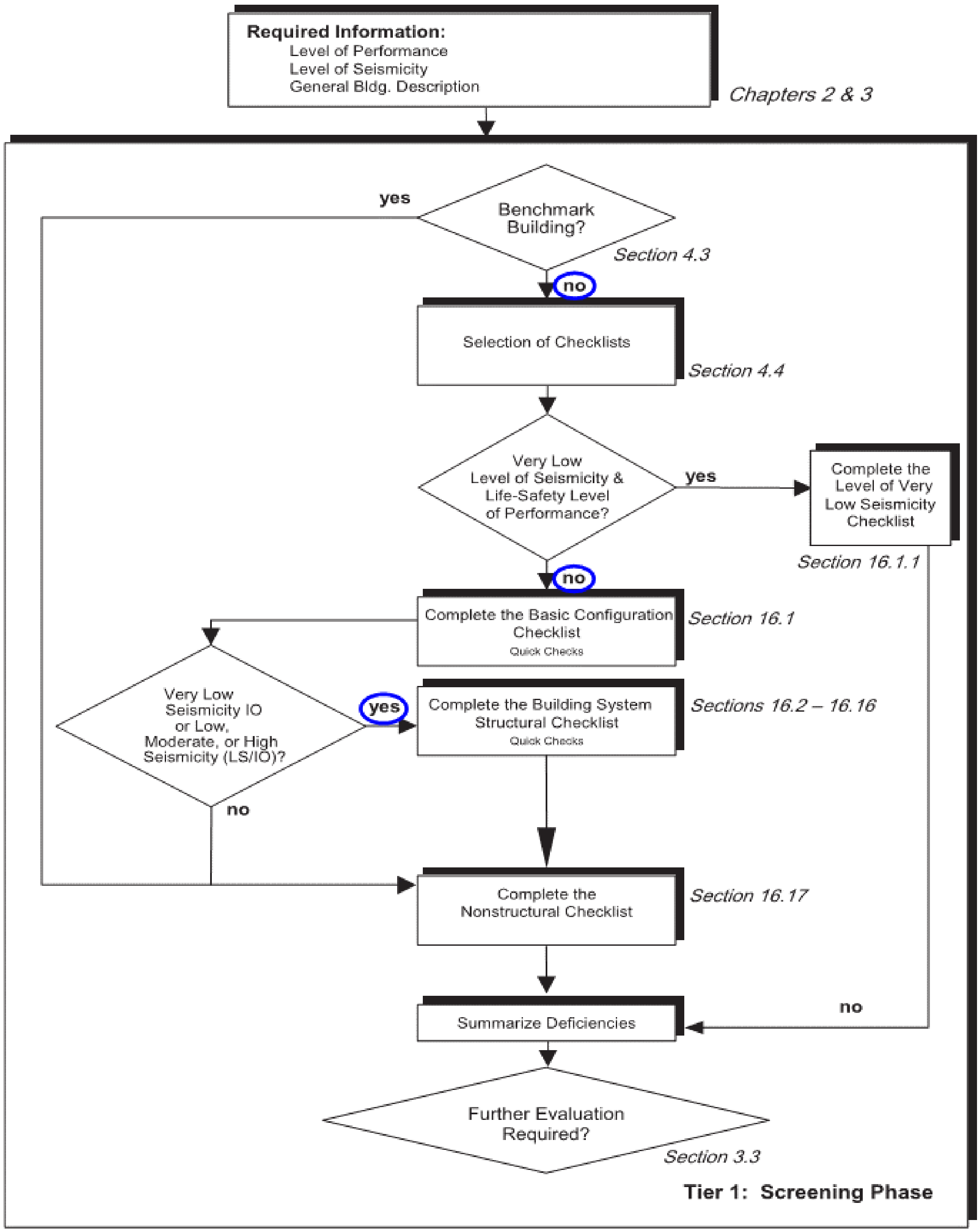
USGS–Provided Output

$S_{XS,BSE-1N}$	1.166 g
$S_{X1,BSE-1N}$	0.641 g

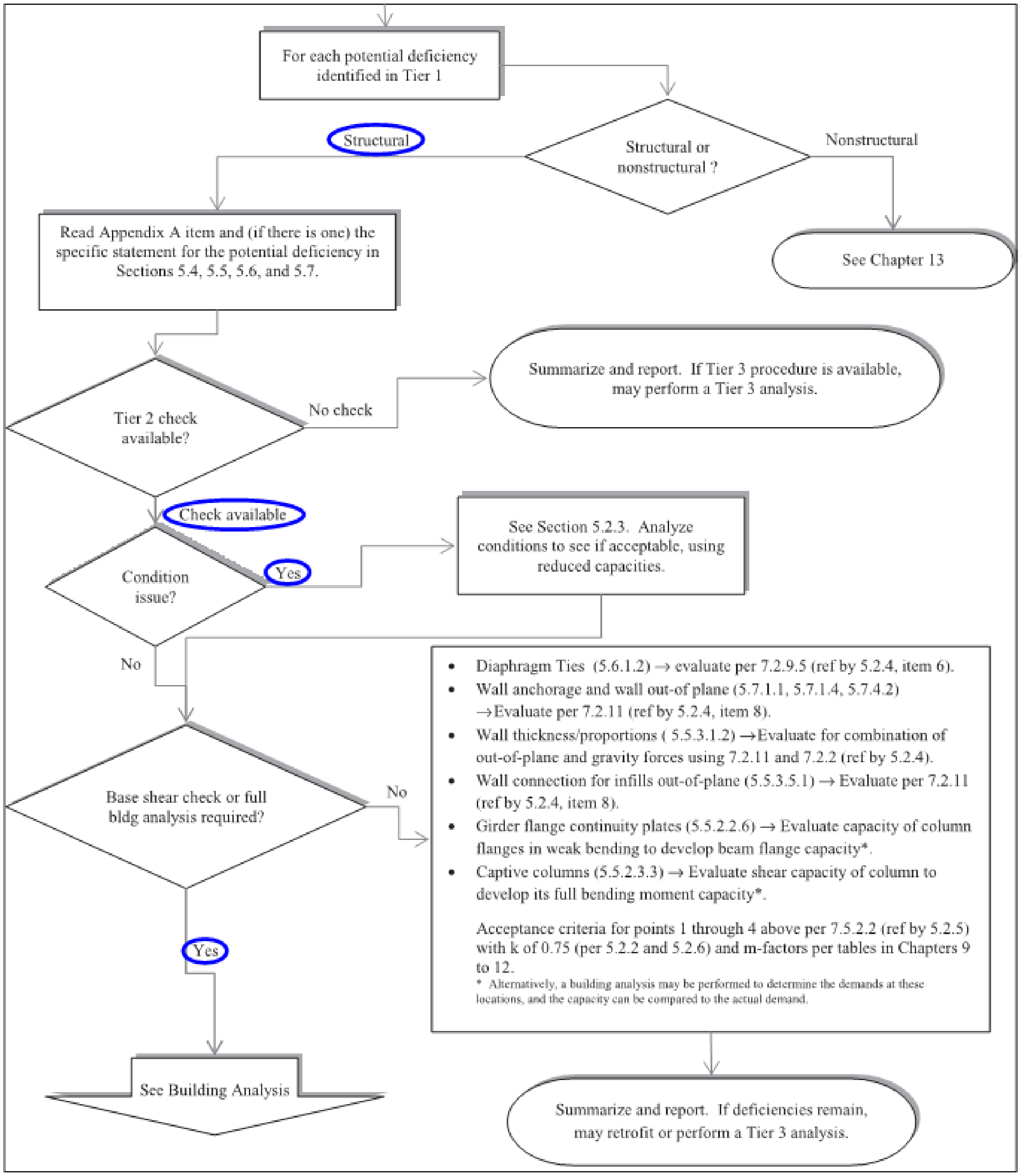
Reference: U.S. Geological Survey – Seismic Design Map [earthquake.usgs.gov]

2.3 ASCE 41-13 Flowcharts

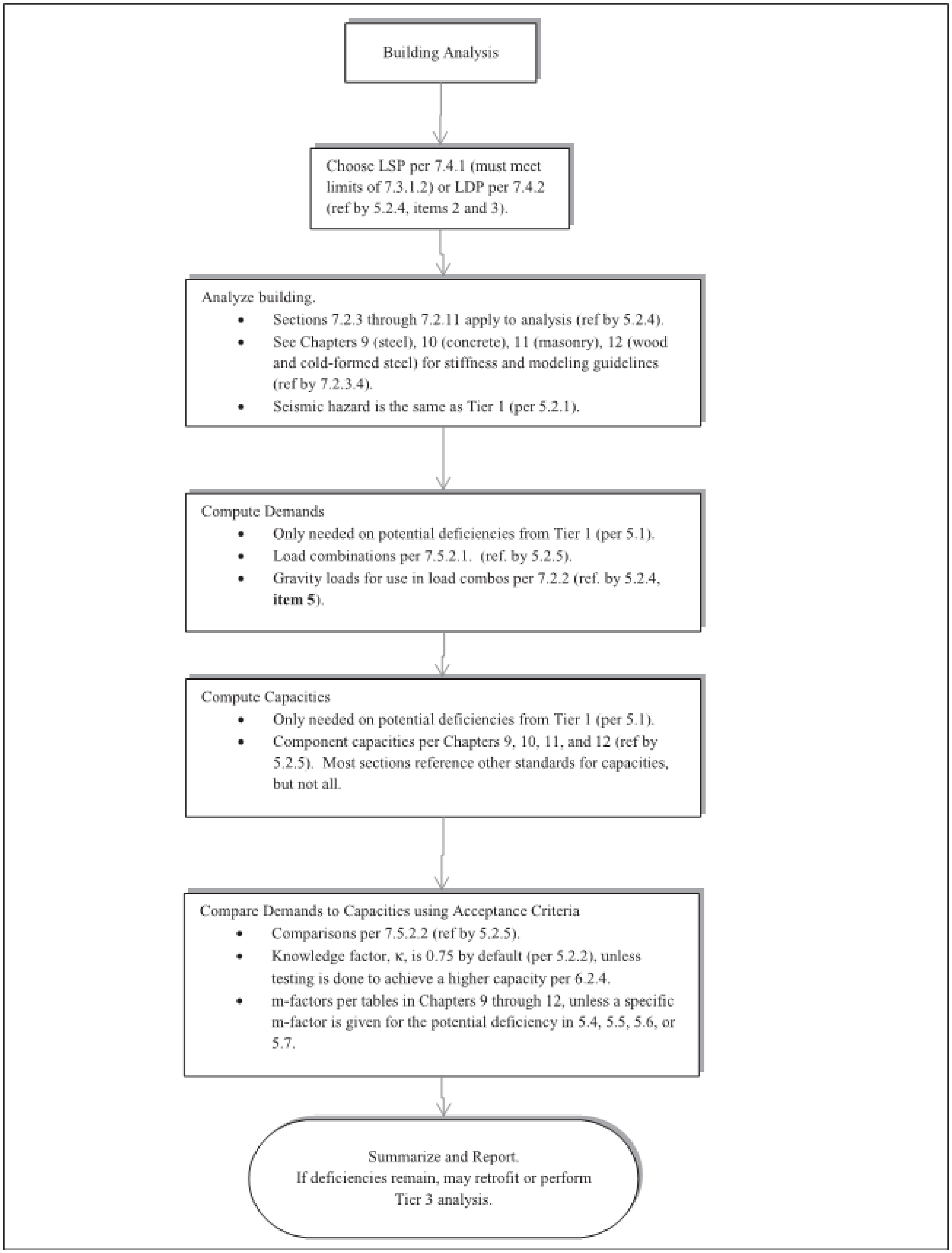
The following flowcharts describe the evaluation process for both Tier 1 and Tier 2. These flowcharts are indicated in Figure 4-1 and Figure 5-1 of ASCE 41-13.



Reference: Seismic Evaluation and Retrofit of Existing Buildings, Figure 4-1 [ASCE/SEI 41, 2013]



Reference: Seismic Evaluation and Retrofit of Existing Buildings, Figure 5-1 [ASCE/SEI 41, 2013]



Reference: Seismic Evaluation and Retrofit of Existing Buildings, Fig. 5-1 (Continued) [ASCE/SEI 41, 2013]

3.0 GEOLOGIC SITE HAZARDS

Geologic site hazards are a function of the seismic hazard and the site conditions – some hazards may only be relevant during very strong seismic shaking. Certain geologic and local site conditions can lead to structural damage in the event of an earthquake. Earthquake induced hazards include liquefaction, landsliding and fault rupture. The effects of these hazards on the subject property are discussed below.

3.1 Liquefaction

Liquefaction is the sudden loss of bearing strength that can occur when saturated, cohesionless soils (sands and silts) are strongly and repetitively vibrated. Damage from liquefaction results primarily from horizontal and vertical displacement of the ground. These displacements occur because sand/water mixtures in a liquefied condition have virtually no strength and provide little or no resistance to compaction, lateral spreading, or down slope movement. This movement of the land surface can damage buildings, and buried utilities, such as gas mains, water lines and sewers, particularly at their connection to the building.

Examination of the *Earthquake Zones of Required Investigation (EZRIM) Inglewood Quadrangle*, prepared by the California Geological Survey, indicates that the site is not located in an area recognized by the State of California where historic occurrence of liquefaction, or local geological, geotechnical and groundwater conditions indicate a potential for permanent ground displacement. The *Report of Geotechnical Consultation Proposed Seismic Evaluation*, prepared by Amec Foster Wheeler, indicates that the materials beneath the site consists of generally dense older alluvial deposits, previous explorations at the site did not encounter groundwater within 77 feet below grade, and historic-high groundwater level is approximately 50 feet below grade. And thus, the potential for liquefaction and associated ground deformation beneath the site is considered low.

3.2 Slope Failure

A landslide is the downhill movement of masses of earth under the force of gravity. Earthquakes can trigger landslides in areas that are already landslide prone. Landslides are most common on slopes of more than 15 degrees and can generally be anticipated along the edges of mesas and on slopes adjacent to drainage courses.

Review of the Inglewood EZRIM indicates that the site is not located in an area recognized by the State of California with a potential for slope instability or landsliding. The Geotechnical Consultation indicates that there are no known landslides near the site, and the site is not in the path of any known or potential landslides. The site is relatively flat, thus the potential for landslides to affect the site is considered low.

3.3 Surface Fault Rupture

Ground fault rupture is the direct manifestation of the movement along a fault, projected to the ground surface. It consists of a concentrated, permanent deformation of the ground surface, which in major earthquakes can extend many miles along the trace of the fault. This deformation can be in either horizontal and/or vertical direction. A ground-surface rupture involving more than a few inches of movement within a concentrated area can result in major damage to structures that cross it. Large movements caused by fault rupture generally cannot be mitigated economically.

Review of the Inglewood EZRIM indicates that the site is located within an established Alquist-Priolo Earthquake Fault Zone and thus subject to the jurisdiction of the Alquist-Priolo (A-P) Special Studies Zone Act.

The purpose of the act is to prevent the construction of buildings used for human occupancy on the surface trace of active faults. A geologic investigation is required for proposed new construction (single family wood-frame and steel-frame dwellings up to two stories not part of a development of four units or mare are exempt) within an established fault zone to demonstrate that the buildings will not be constructed across active faults – the building must be set back (generally 50 feet) from the fault.

Per California Public Resource Code, Division 2, Chapter 7.5, Section 2621.7(b), any development or structure in existence prior to May 4, 1975 is exempt from the requirements of the A-P Act, except for alteration or addition to a structure that exceeds 50 percent of the value of the structure.

The Geotechnical Consultation indicates that due to the mapped trace of the active Newport-Inglewood fault, there is a potential for surface rupture at the site from fault plane displacement propagating to the ground surface.

Although there is a potential for surface rupture at the site, it is noted that this is a rare event. A site-specific fault rupture hazard investigation would need to be performed to map the fault trace and zones of influence through the site and to estimate magnitudes of vertical and/or horizontal displacements consistent with seismic hazard levels in order further assess the hazard.

4.0 TIER 1 SCREENING

4.1 Benchmark Building

A site visit was made on June 28, 2017 to assess the actual field conditions of the subject building by Sinhui Chang of *Nabih Youssef Associates*. The majority of the structural framing and connections was covered by acoustic ceilings and wall finishes. Observation was limited to the visible areas of the structure. In general, the structural components of the building appeared to be in good condition. The quality of construction appears to be good.

Main Library building is classified as Concrete Moment Frames (Type C1) per ASCE 41-13 Table 3-1. The subject building was constructed in 1971. Benchmark building year for Type C1 is 2000 designed per IBC. Therefore, Library building does not meet the benchmark building and is subjected to the seismic evaluation.

4.2 Tier 1 Checklists

Per Table 4-7 of ASCE 41-13, Tier 1 Evaluation requires the following checklists for Life Safety performance level at a high seismic region:

- Life Safety Basic Configuration Checklist (Section 16.1.2 of ASCE 41)
- Life Safety Structural Checklist (Section 16.9LS)
- Life Safety Nonstructural Checklist (Section 16.17)

The following tables indicate all required checklist items with appropriate mark on the left column as one of four applications: Compliant (C), Non-Compliant (NC), Unknown (U), Not Applicable (N/A). Each of the checklist item also has following explanation.

Life Safety Basic Configuration Checklist
(Section 16.1.2 of ASCE41)

Building System – General	
C	LOAD PATH: The structure shall contain a complete, well-defined load path, including structural elements and connections that serve to transfer the inertial forces associated with the mass of all elements of the building to the foundation.
N/A	ADJACENT BUILDINGS: The clear distance between the building being evaluated and any adjacent building is greater than 4% of the height of the shorter building. • Adjacent structures are pedestrian bridges to different buildings with seismic separations.
N/A	MEZZANINES: Interior mezzanine levels are braced independently from the main structure or are anchored to the seismic force-resisting elements of the main structure. • There are no interior mezzanine levels.
Building System – Building Configuration	
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. • See calculations in appendix.
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. • See calculations in appendix.
NC	VERTICAL IRREGULARITIES: All vertical elements in the seismic-force-resisting system are continuous to the foundation. • The concrete shear walls at the lecture hall are not continuous to the foundations. They are supported by discontinuous reinforced concrete columns between the first level and the foundation level.
C	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. • The change in the net horizontal dimension of the seismic-force-resisting system is less than 30% of the adjacent story.
NC	MASS: There is no change in effective mass more than 50% from one story to the next. Light roofs, penthouses, and mezzanines need not be considered. • The first level above grade has 50% more mass than the level above due to the inclusion of the lecture hall.
C	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. • The main library portion of the building is in rectangular shape and symmetrical in both directions. By inspection, 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 dimensions. The lecture hall has its own center of rigidity and may or may not affect torsional behavior at the first level. Further study is required during Tier 2 analysis with 3D model.
Geologic Site Hazards	
C	LIQUEFACTION: Liquefaction susceptible, saturated, loose granular soils that could jeopardize the building's seismic performance shall not exist in the foundation soils at depths within 50 ft under the building.
C	SLOPE FAILURE: The building site is sufficiently remote from potential earthquake-induced slope failures or rock falls to be unaffected by such failures or is capable of accommodating any predicted movements without failure.
NC	SURFACE FAULT RUPTURE: Surface fault rupture and surface displacement at the building site are not anticipated. • According to geotechnical report, there is a potential for surface rupture due to Newport-Inglewood fault at the site. A site-specific fault rupture hazard investigation will be required for new site developments as well as modernization projects per geotechnical engineer.
Foundation Configuration	
C	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 0.6 Sa. • See calculations in appendix.
N/A	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. • The subject building has soil Site Class D.

Life Safety Structural Checklist
For Building Type C1 – Concrete Moment Frames
(Section 16.9LS of ASCE41)

Seismic Force Resisting System	
C	REDUNDANCY: The number of lines of moment frames in each principal direction is

	greater than or equal to 2. The number of bays of moment frames in each line is greater than or equal to 2. • There are 4 bays of moment frames in each line. And there are 5 moment frame lines in each principal direction. [Reference: S3.3]
C	COLUMN AXIAL STRESS CHECK: The axial stress caused by unfactored gravity loads in columns subjected to overturning forces because of seismic demands is less than 0.20f'c. Alternatively, the axial stress caused by overturning forces alone, calculated using the Quick Check procedure of Section 4.5.3.6, is less than 0.30f'c. • See calculations in appendix.
C	INTERFERING WALLS: All concrete and masonry infill walls placed in moment frames are isolated from structural elements. • There are no interfering walls within the moment frames of the library portion.
NC	COLUMN SHEAR STRESS CHECK: The shear stress in the concrete columns, calculated using the Quick Check procedure of Section 4.5.3.2, is less than the greater of 100 psi or $2\sqrt{f'c}$. • Columns at all levels do not meet shear stress check. See calculations in appendix.
N/A	FLAT SLAB FRAMES: The seismic-force-resisting system is not a frame consisting of columns and a flat slab or plate without beams. • The structural system consists of reinforced beams and columns. [Reference: S3.3]
N/A	PRESTRESSED FRAME ELEMENTS: The seismic-force-resisting frames do not include any prestressed or posttensioned elements where the average prestress exceeds the lesser of 700 lb/in^2 of f'c/6 at potential hinge locations. The average prestress is calculated in accordance with the Quick Check procedure of Section 4.5.3.8. • No prestressed elements have been used in this building.
C	CAPTIVE COLUMNS: There are no columns at a level with height/depth ratios less than 50% of the nominal height/depth ratio of the typical columns at that level. • There are not deep beams in the subject building. Typical beam depths are 30", whereas typical story height is 14'-0". Columns on each level are consistent in dimension; typically, the column is 24x24. No columns' height/depth ratios are less than 50% than nominal height/depth ratio.
C	NO SHEAR FAILURES: The shear capacity of frame members is able to develop the moment capacity at the ends of the members. • All beam and column members are adequate. See calculations in appendix.
NC	STRONG COLUMN-WEAK BEAM: The sum of the moment capacity of the columns is 20% greater than that of the beams at frame joints. • Most interior and perimeter columns at third floor and few interior columns at second floor do not meet this criterion. • See calculations in appendix.
C	BEAM BARS: At least two longitudinal top and two longitudinal bottom bars extend continuously throughout the length of each frame beam. At least 25% of the longitudinal bars provided at the joints for either positive or negative moment are continuous throughout the length of the members. • There are minimum of two bars at top and bottom continuous along the full length of beam members typically. Both top and bottom bars extend to column centerline at minimum typically. Top and bottom rebars are minimum (2) - #7 per beam schedule. [Reference: S4.3]
NC	COLUMN-BAR SPLICES: All column-bar lap splice lengths are greater than $35d_b$ and are enclosed by ties spaced at or less than $8d_b$. Alternatively, column bars are spliced with mechanical couplers with a capacity of at least 1.25 times the nominal yield

	strength of the spliced bar. • All column vertical rebar lap splice lengths are 30-bar diameter, less than 35 times bar diameter. Ties enclosed are spaced at 6" o.c. which is less than 8 times the diameter of the smallest longitudinal bar of #11. [Reference: 8/S4.2]
C	BEAM-BAR SPLICES: The lap splices or mechanical couplers for longitudinal beam reinforcing are not located within $l_b/4$ of the joints and are not located in the vicinity of potential plastic hinge locations. • All the beam bar lap splices are located at member length/3 from the joint. [Reference: S4.3]
NC	COLUMN-TIE SPACING: Frame columns have ties spaced at or less than d/4 throughout their length and at or less than $8d_b$ at all potential plastic hinge locations. • Column ties are typically spaced at 8" o.c. at middle length. 12" exceeds d/4 and $8d_b$ typically. [Reference: 1/S4.2]
NC	STIRRUP SPACING: All beams have stirrups spaced at or less than d/2 throughout their length. At potential plastic hinge locations, stirrups are spaced at or less than the minimum of $8d_b$ or d/4. • Typical stirrup spacing at midspan is 12" o.c. At potential plastic hinge locations, stirrup spacing is mostly 6" o.c. In most beams, they do not meet this criterion. [Reference: S4.3]
C	JOINT TRANSVERSE REINFORCING: Beam-column joints have ties spaced at or less than $8d_b$. • The typical tie spacing at column-beam joints is 6" on center, which is less than typical column's $8*d_b$. [Reference: 1/S4.2]
N/A	DEFLECTION COMPATIBILITY: Secondary components have the shear capacity to develop the flexural strength of the components. • There are no secondary components above grade.
N/A	FLAT SLABS: Flat slabs or plates not part of the seismic-force-resisting system have continuous bottom steel through the column joints. • No flat slab/plates are part of the SRFS in the structure.
Connections	
C	CONCRETE COLUMNS: All concrete columns are doweled into the foundation with a minimum of 4 bars. • Concrete columns are doweled into the foundation with minimum of 4 bars. [Reference: 1/S4.2]
N/A	UPLIFT AT PILE CAPS: Pile caps have top reinforcement, and piles are anchored to the pile caps. • There's no pile caps used in the foundation.
Diaphragms	
C	DIAPHRAGM CONTINUITY: The diaphragms are not composed of split-level floors and do not have expansion joints. • The diaphragms are not composed of split-level floors and do not have expansion joints.

Life Safety Nonstructural Checklist
(Section 16.17 of ASCE41)

Life Safety Systems	
U	FIRE SUPPRESSION PIPING: Fire suppression piping is anchored and braced in accordance with NFPA-13.
U	FLEXIBLE COUPLINGS: Fire suppression piping has flexible couplings in accordance with NFPA13.
U	EMERGENCY POWER: Equipment used to power or control life safety systems is

	anchored or braced.
U	STAIR AND SMOKE DUCTS: Stair pressurization and smoke control ducts are braced and have flexible connections at seismic joints.
U	SPRINKLER CEILING CLEARANCE: Penetrations through panelized ceilings for fire suppression devices provide clearances in accordance with NFPA-13.
Hazardous Materials	
U	HAZARDOUS MATERIAL EQUIPMENT: Equipment mounted on vibration isolators and containing hazardous material is equipped with restraints or snubbers.
U	HAZARDOUS MATERIAL STORAGE: Breakable containers that hold hazardous material, including gas cylinders, are restrained by latched doors, shelf lips, wires, or other methods.
U	HAZARDOUS MATERIAL DISTRIBUTION: Piping or ductwork conveying hazardous materials is braced or otherwise protected from damage that would allow hazardous material release.
U	SHUT-OFF VALVES: Piping containing hazardous material, including natural gas, has shut-off valves or other devices to limit spills or leaks.
U	FLEXIBLE COUPLINGS: Hazardous material ductwork and piping, including natural gas piping, has flexible couplings.
U	PIPING OR DUCTS CROSSING SEISMIC JOINTS: Piping or ductwork carrying hazardous material that either crosses seismic joints or isolation planes or is connected to independent structures has couplings or other details to accommodate the relative seismic displacements.
Partitions	
N/A	UNREINFORCED MASONRY: Unreinforced masonry or hollow-clay tile partitions are braced at a spacing of at most 10 ft in Low or Moderate Seismicity, or at most 6 ft in High Seismicity.
N/A	HEAVY PARTITIONS SUPPORTED BY CEILINGS: The tops of masonry or hollow-clay tile partitions are not laterally supported by an integrated ceiling system.
U	DRIFT: Rigid cementitious partitions are detailed to accommodate the following drift ratios: in steel moment frame, concrete moment frame, and wood frame buildings, 0.02; in other buildings, 0.005.
Ceilings	
N/A	SUSPENDED LATH AND PLASTER: Suspended lath and plaster ceilings have attachments that resist seismic forces for every 12 ft^2 of area.
U	SUSPENDED GYPSUM BOARD: Suspended gypsum board ceilings have attachments that resist seismic forces for every 12 ft^2 of area.
Light Fixtures	
U	INDEPENDENT SUPPORT: Light fixtures that weigh more per square foot than the ceiling they penetrate are supported independent of the grid ceiling suspension system by a minimum of two wires at diagonally opposite corners of each fixture.
Cladding and Glazing	
N/A	CLADDING ANCHORS: Cladding components weighing more than 10 psf are mechanically anchored to the structure at a spacing equal to or less than the following: for Life Safety in Moderate Seismicity, 6 ft; for Life Safety in High Seismicity and for Position Retention in any seismicity, 4 ft.
N/A	CLADDING ISOLATION: For steel or concrete moment frame buildings, panel connections are detailed to accommodate a story drift ratio of at least the following: for Life Safety in Moderate Seismicity, 0.01; for Life Safety in High Seismicity and for Position Retention in any seismicity, 0.02.
N/A	MULTI-STORY PANELS: For multistory panels attached at more than one floor level, panel connections are detailed to accommodate a story drift ratio of at least the following: for Life Safety in Moderate Seismicity, 0.01; for Life Safety in High Seismicity and for Position Retention in any seismicity, 0.02.

U	PANEL CONNECTIONS: Cladding panels are anchored out of plane with a minimum number of connections for each wall panel, as follows: for Life Safety in Moderate Seismicity, 2 connections; for Life Safety in High Seismicity and for Position Retention in any seismicity, 4 connections.
N/A	BEARING CONNECTIONS: Where bearing connections are used, there is a minimum of two bearing connections for each cladding panel.
U	INSERTS: Where concrete cladding components use inserts, the inserts have positive anchorage or are anchored to reinforcing steel.
U	OVERHEAD GLAZING: Glazing panes of any size in curtain walls and individual interior or exterior panes more than 16 ft^2 in area are laminated annealed or laminated heat-strengthened glass and are detailed to remain in the frame when cracked.
Masonry Veneer	
N/A	TIES: Masonry veneer is connected to the backup with corrosion-resistant ties. There is a minimum of one tie for every 2-2/3 ft^2, and the ties have spacing no greater than the following: for Life Safety in Low or Moderate Seismicity, 36 in.; for Life Safety in High Seismicity and for Position Retention in any seismicity, 24 in.
N/A	SHELF ANGLES: Masonry veneer is supported by shelf angles or other elements at each floor above the ground floor.
N/A	WEAKENED PLANES: Masonry veneer is anchored to the backup adjacent to weakened planes, such as at the locations of flashing.
N/A	UNREINFORCED MASONRY BACK UP: There is no unreinforced masonry backup.
N/A	STUD TRACKS: For veneer with metal stud backup, stud tracks are fastened to the structure at a spacing equal to or less than 24 in. on center.
N/A	ANCHORAGE: For veneer with concrete block or masonry backup, the backup is positively anchored to the structure at a horizontal spacing equal to or less than 4 ft along the floors and roof.
Parapets, Cornices, Ornamentation, and Appendages	
N/A	URM PARAPETS OR CORNICES: Laterally unsupported unreinforced masonry parapets or cornices have height-to-thickness ratios no greater than the following: for Life Safety in Low or Moderate Seismicity, 2.5; for Life Safety in High Seismicity and for Position Retention in any seismicity, 1.5.
N/A	CANOPIES: Canopies at building exits are anchored to the structure at a spacing no greater than the following: for Life Safety in Low or Moderate Seismicity, 10 ft; for Life Safety in High Seismicity and for Position Retention in any seismicity, 6 ft.
N/A	CONCRETE PARAPETS: Concrete parapets with height-to-thickness ratios greater than 2.5 have vertical reinforcement.
N/A	APPENDAGES: Cornices, parapets, signs, and other ornamentation or appendages that extend above the highest point of anchorage to the structure or cantilever from components are reinforced and anchored to the structural system at a spacing equal to or less than 6 ft. This checklist item does not apply to parapets or cornices covered by other checklist items.
Masonry Chimneys	
N/A	URM CHIMNEYS: Unreinforced masonry chimneys extend above the roof surface no more than the following: for Life Safety in Low or Moderate Seismicity, 3 times the least dimension of the chimney; for Life Safety in High Seismicity and for Position Retention in any seismicity, 2 times the least dimension of the chimney.
N/A	ANCHORAGE: Masonry chimneys are anchored at each floor level, at the topmost ceiling level, and at the roof.
Stairs	
N/A	STAIR ENCLOSURES: Hollow clay tile or unreinforced masonry walls around stair enclosures are restrained out of plane and have height-to-thickness ratios not greater than the following: for Life Safety in Low or Moderate Seismicity, 15-to-1; for Life Safety in High Seismicity and for Position Retention in any seismicity, 12-to-1.

U	STAIR DETAILS: In moment frame structures, the connection between the stairs and the structure does not rely on shallow anchors in concrete. Alternatively, the stair details are capable of accommodating the drift calculated using the Quick Check procedure of Section 4.5.3.1 without including any lateral stiffness contribution from the stairs. • Stairs are concrete filled pan treads. The connections may not be capable to accommodate drift. [Reference: 2/S6.2]
Contents and Furnishings	
U	INDUSTRIAL STORAGE RACKS: Industrial storage racks or pallet racks more than 12 ft high meet the requirements of ANSI/RMI MH 16.1 as modified by ASCE 7 Chapter 15.
U	TALL NARROW CONTENTS: Contents more than 6 ft high with a height-to-depth or height-to-width ratio greater than 3-to-1 are anchored to the structure or to each other.
U	FALL-PRONE CONTENTS: Equipment, stored items, or other contents weighing more than 20 lb whose center of mass is more than 4 ft above the adjacent floor level are braced or otherwise restrained.
Mechanical and Electrical Equipment	
U	FALLPRONE EQUIPMENT: Equipment weighing more than 20 lb whose center of mass is more than 4 ft above the adjacent floor level, and which is not in-line equipment, is braced.
U	IN-LINE EQUIPMENT: Equipment installed in-line with a duct or piping system, with an operating weight more than 75 lb, is supported and laterally braced independent of the duct or piping system.
U	TALL NARROW EQUIPMENT: Equipment more than 6 ft high with a height-to-depth or height-to-width ratio greater than 3-to-1 is anchored to the floor slab or adjacent structural walls.
U	MECHANICAL DOORS: Mechanically operated doors are detailed to operate at a story drift ratio of 0.01.
Elevators	
U	RETAINER GUARDS: Sheaves and drums have cable retainer guards.
U	RETAINER PLATE: A retainer plate is present at the top and bottom of both car and counterweight.

4.3 Summary of Tier 1 Structural Deficiencies

Below list all structural deficiencies identified through the Tier 1 procedure that will require further analysis verification with Tier 2 procedure.

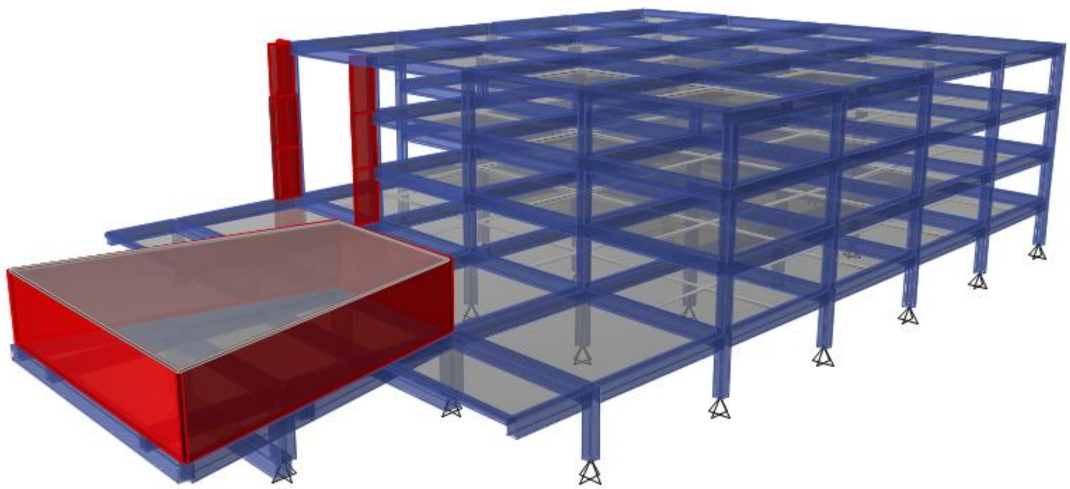
- Life Safety Basic Configuration Checklist
  - Vertical Irregularities [ASCE 41-13 §5.4.2.3] – Evaluate the elements below the vertical discontinuities as force-controlled elements.
- Life Safety Structural Checklist
  - Mass Irregularity [ASCE 41-13 §5.4.2.5] – Evaluate the seismic-force-resisting elements using the linear dynamic procedure.
  - Column Shear Stress Check [§5.5.2.1.4] – Evaluate the adequacy of frame elements using linear procedure.
  - Strong Column-Weak Beam [§5.5.2.1.5] – The ability of columns to resist demands to be evaluated using m-factor of 2.0 for concrete moment frames.
  - Column-Bar Splices [§5.5.2.3.6] – Evaluate the flexural demands at noncompliant column splice locations with smaller m-factors to account for potential lack of ductility.
  - Column-Tie Spacing [§5.5.2.3.7] - Evaluate the demands at noncompliant columns with smaller m-factors to account for potential lack of ductility.
  - Beam Stirrup Spacing [§5.5.2.3.7] - Evaluate the demands at noncompliant beams with smaller m-factors to account for potential lack of ductility.

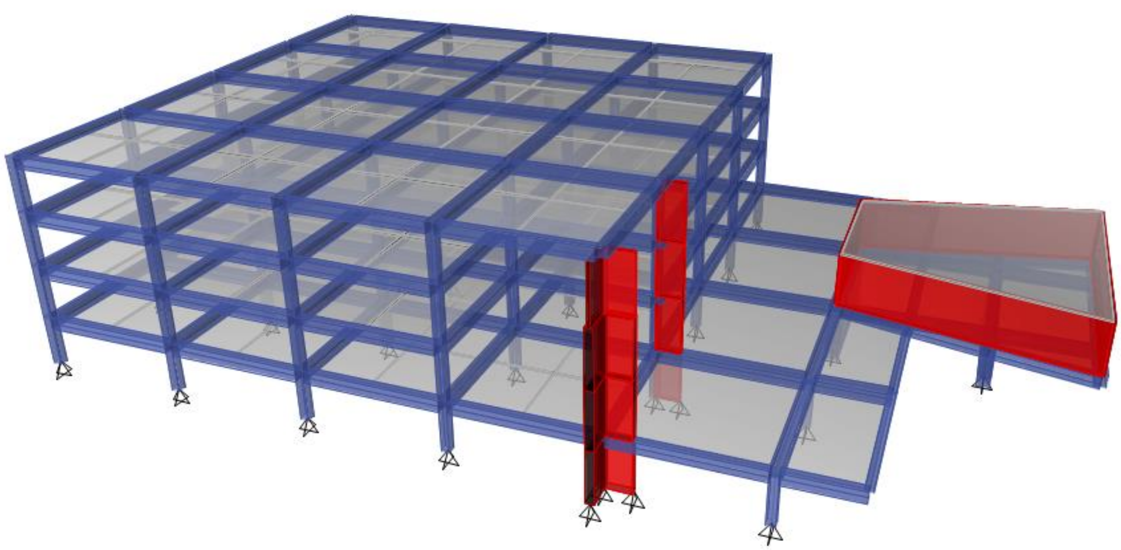
5.0 TIER 2 DEFICIENCY-BASED EVALUATION

5.1 Structural Analysis and Modeling Assumptions

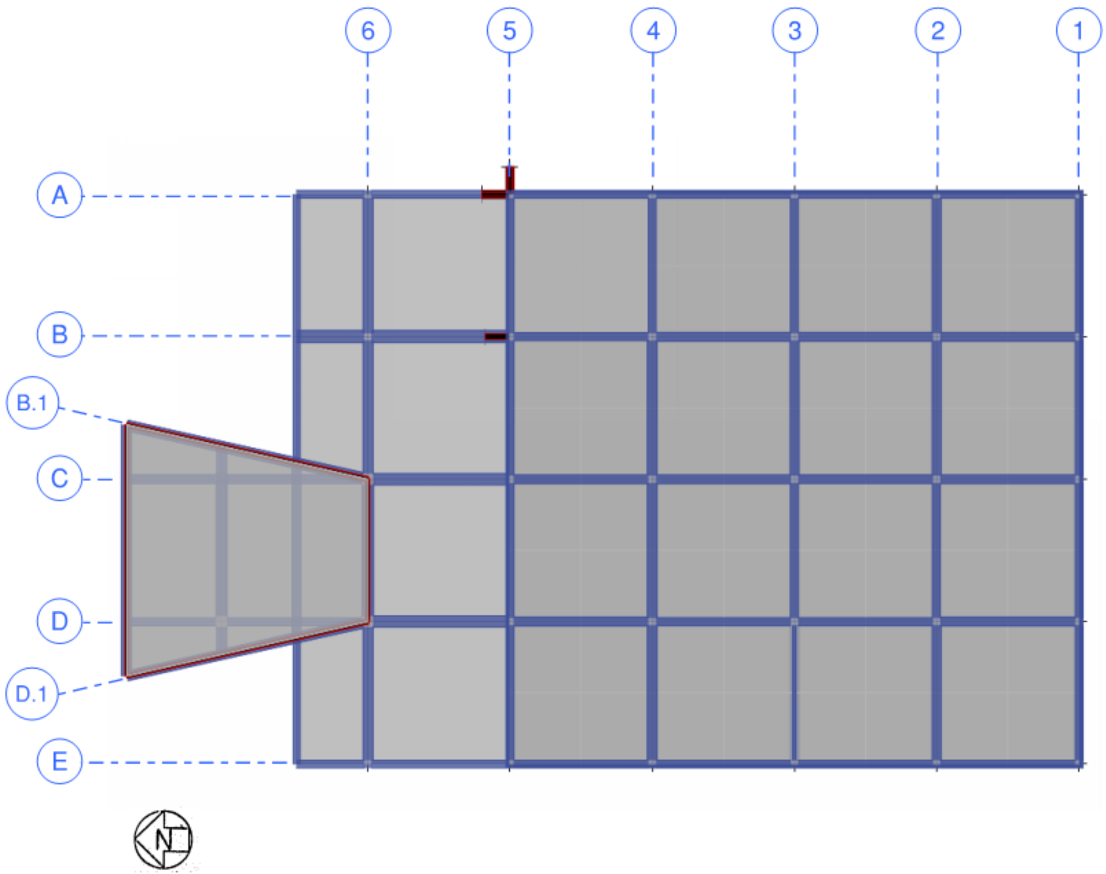
ETABS software is used to create a 3D model for linear analysis. The modeling assumptions follow the requirements of ASCE 41-13 §7.2.3.

Due to mass irregularity in the building, the structural analysis requires linear dynamic procedure as noted on the previous section.





Below shows the framing plan with gridlines.



Following is the gravity loads assigned in the ETABS model.

Penthouse Roof		
SIDL =	63 psf	(to be distributed to column loads per trib area)
LL =	20 psf	(roof - to be distributed to column loads per trib area)
Penthouse Floor / Concrete Roof		
SIDL =	33 psf	(SIDL of penthouse floor)
LL 1 =	125 psf	(storage LL for penthouse floor)
LL 2 =	20 psf	(typ roof)
3rd & 2nd Floors		
SIDL =	30 psf	(typ floor)
LL =	150 psf	(for library with stacked books)
1st Floor / Plaza Deck		
SIDL 1=	26 psf	(typ interior; not seismic mass)
SIDL 2=	4.5 psf	(typ exterior; not seismic mass)
LL 1 =	100 psf	(for library with stacked books/lobby)
LL 2 =	100 psf	(for assembly)
Lecture Hall - Roof		
SIDL =	82 psf	(typ roof)
LL =	20 psf	(typ roof)
Lecture Hall - Floor		
SIDL =	16 psf	(typ interior + seats)
LL =	60 psf	(for fixed seats)

Partition Seismic Mass	
Penthouse Floor / Concrete Roof =	5 psf
3rd & 2nd & 1st Floors =	10 psf

Total seismic weight of the building is 18,128 kips.

Material Properties

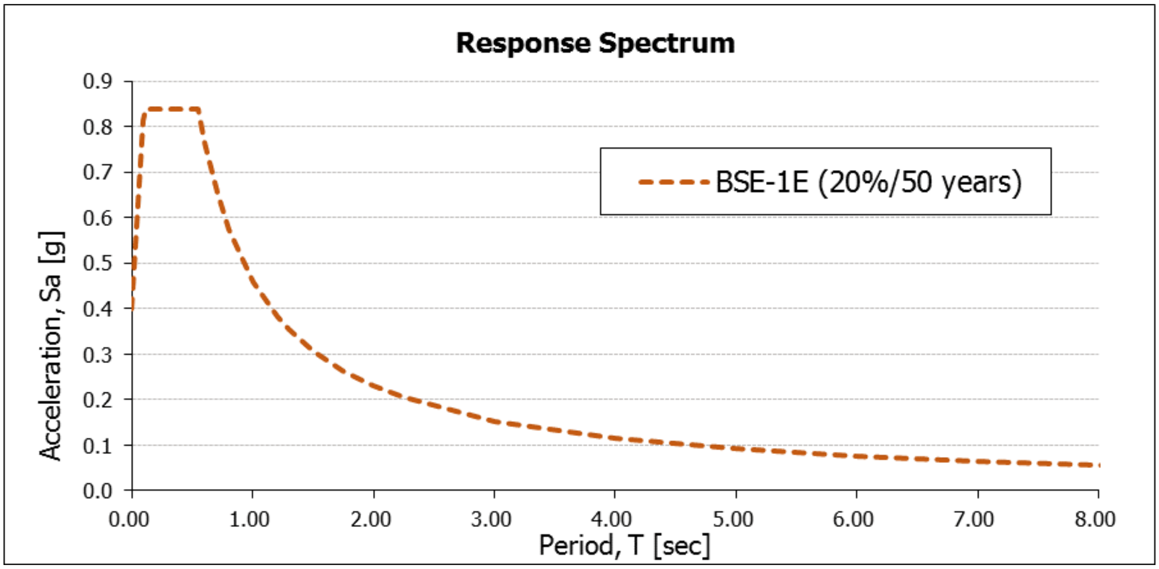
Based on results from Accu-Test material testing & ASCE 41-13 §7.5.1.4 & §10.2.2.3.1,

Typical Slab & Beams:	f'ce =	4390	psi
	Ec per f'ce =	3777	ksi
	Coefficient of Variation =	20.2%	> 20%
	k, knowledge factor =	1.00	
	f'c,LB =	4390	psi
Typical Column (at Library only):	f'ce =	4543	psi
	Ec per f'ce =	3842	ksi
	Coefficient of Variation =	24.1%	> 20%
	k, knowledge factor =	1.00	
	f'c,LB =	4543	psi
Typical Wall:	f'ce =	5287	psi
	Ec per f'ce =	4144	ksi
	Coefficient of Variation =	21.3%	> 20%
	k, knowledge factor =	1.00	
	f'c,LB =	5287	psi
Primary Reinforcement:	fy =	73	ksi
	Coefficient of Variation =	10.6%	< 20%
	k, knowledge factor =	1.00	
	fy,LB =	65	ksi
Stirrup Reinforcement:	fy =	40	ksi
	k, knowledge factor =	0.75	

Flexural stiffness modifiers are used according to ASCE 41-13 Table 10-5.

- Beams: 0.3
- Columns: 0.7 for columns with axial stress greater than 0.5*A*f'c & 0.3 for columns with axial stress less than 0.1*A*f'c; linear interpolation used for columns with axial stress ranging between the limits
- Walls & Slabs: 0.5 (in-plane) & 0.1 (out-of-plane)

Below is the response spectrum used for the linear dynamic procedure.



Load combinations for gravity loads are per ASCE 41-13 §7.2.2:

- Q_{G1} = 1.1*(DL + 0.25*LL)
- Q_{G2} = 0.9*(DL)

Load combinations for component forces are per ASCE 41-13 §7.5.2.1:

- $Q_{UD} = Q_G + Q_E$ for deformation-controlled action
- $Q_{UF} = Q_G + Q_E/(C_1C_2J)$ for force-controlled action, where $C_1C_2J = 2.0$.

Tier 2 acceptance criteria for linear procedures are the following per ASCE 41-13 §7.5.2.2:

- For Deformation-Controlled Actions, $m\kappa Q_{CE} > Q_{UD}$
  - Actions that correspond to deformation-controlled approach include:
    - Flexure in beams
    - Flexure and shear in walls
- For Force-Controlled Actions, $\kappa Q_{CL} > Q_{UF}$
  - Actions that correspond to force-controlled approach include:
    - Shear in beams
    - Axial and shear in columns
    - Shear in beam-to-column joints
    - Axial in walls
    - Axial, shear, and moment in all connections
    - Axial, shear, and moment in diaphragms

5.2 Structural Analysis Results

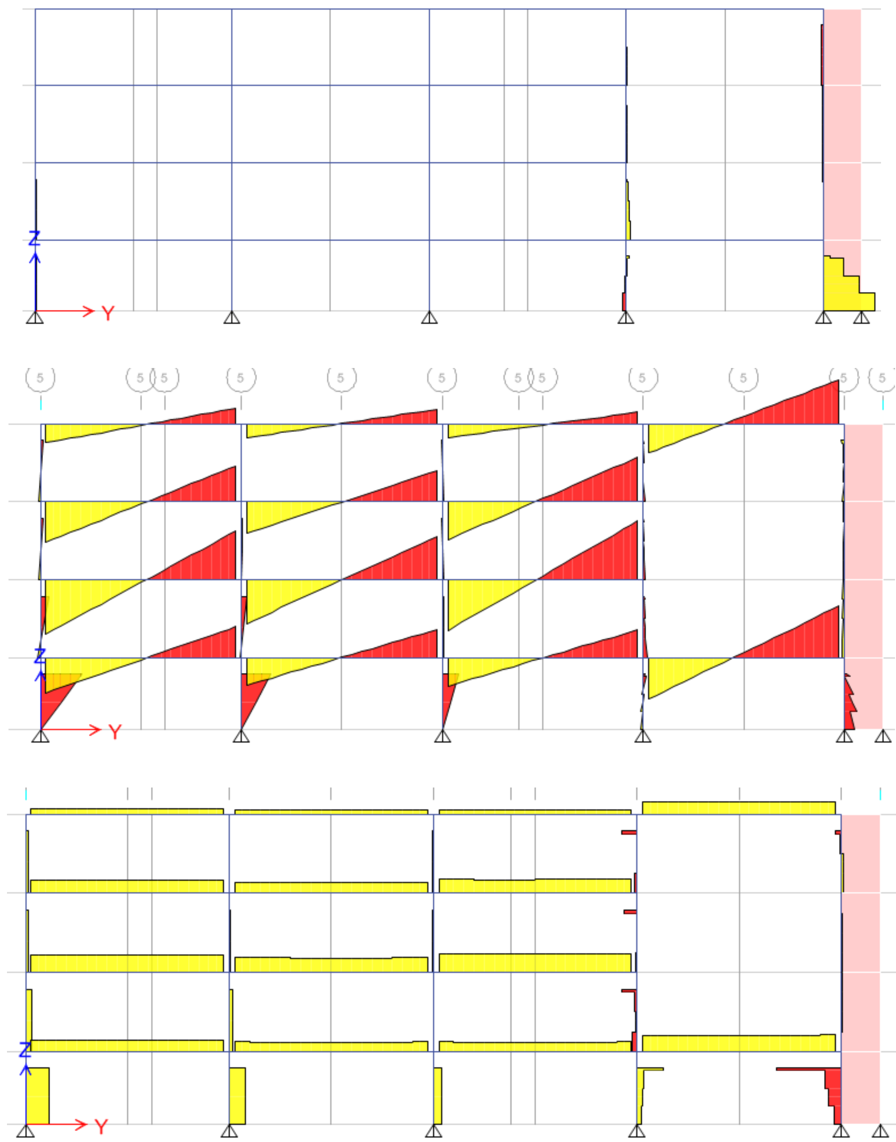
Base shear from linear dynamic analysis for the subject building is:

- 4,563 kips in north-south direction (X-direction in the model)
- 3,848 kips in east-west direction (Y-direction in the model)

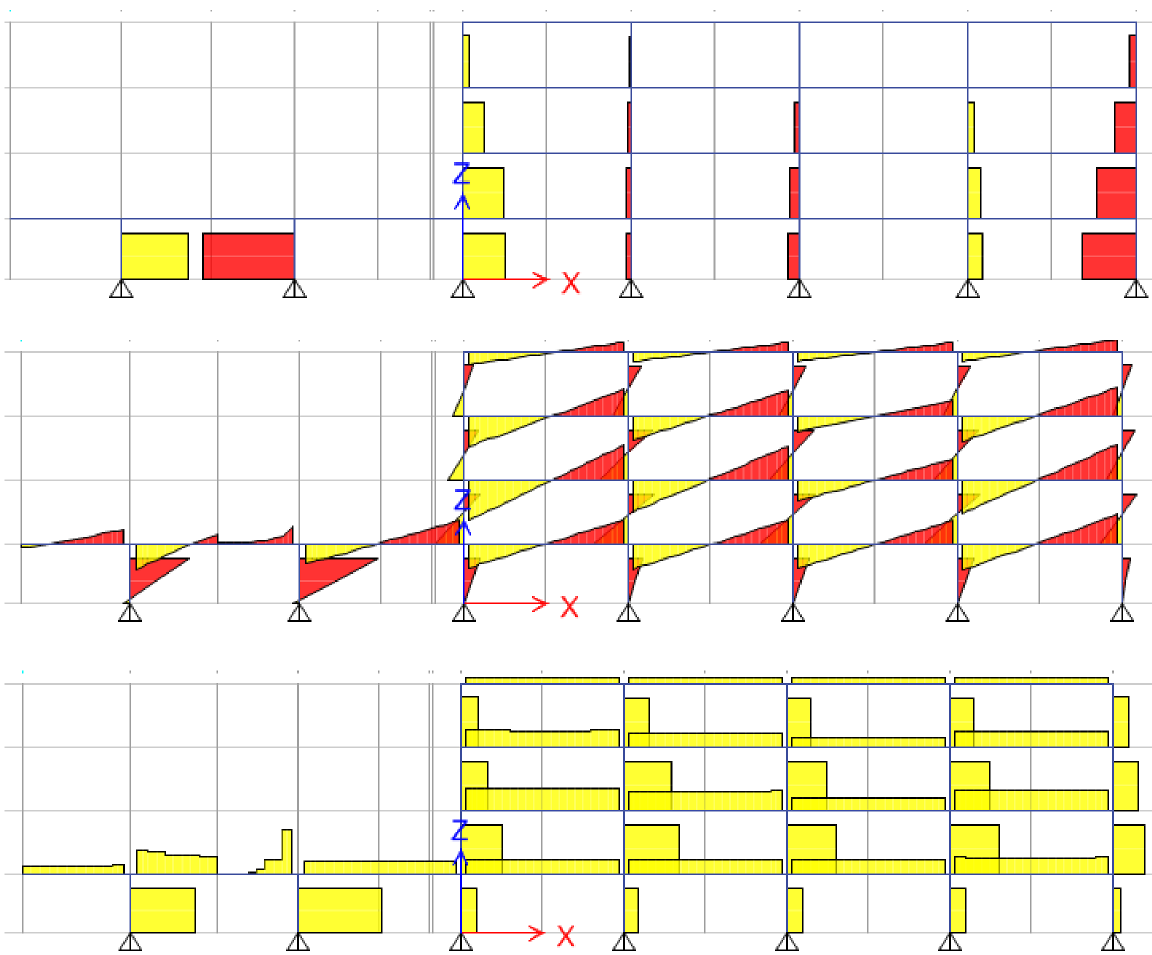
Building period for the subject building is:

- 1.29 seconds in north-south direction (X-direction in the model)
- 1.69 seconds in east-west direction (Y-direction in the model)

The following elevation diagrams indicate demands on the frame members under a static seismic load case as an example for various dynamic load cases used in the complete analysis process.



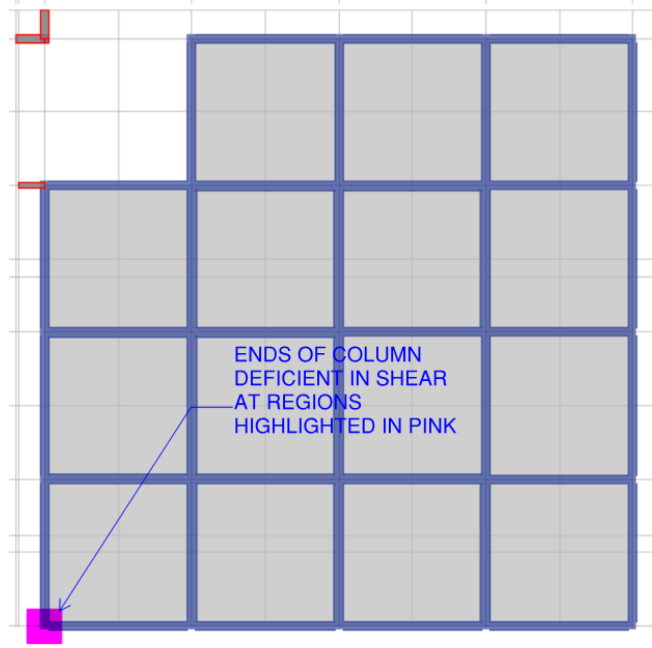
Axial, moment, and shear diagrams on typical exterior frame respectively



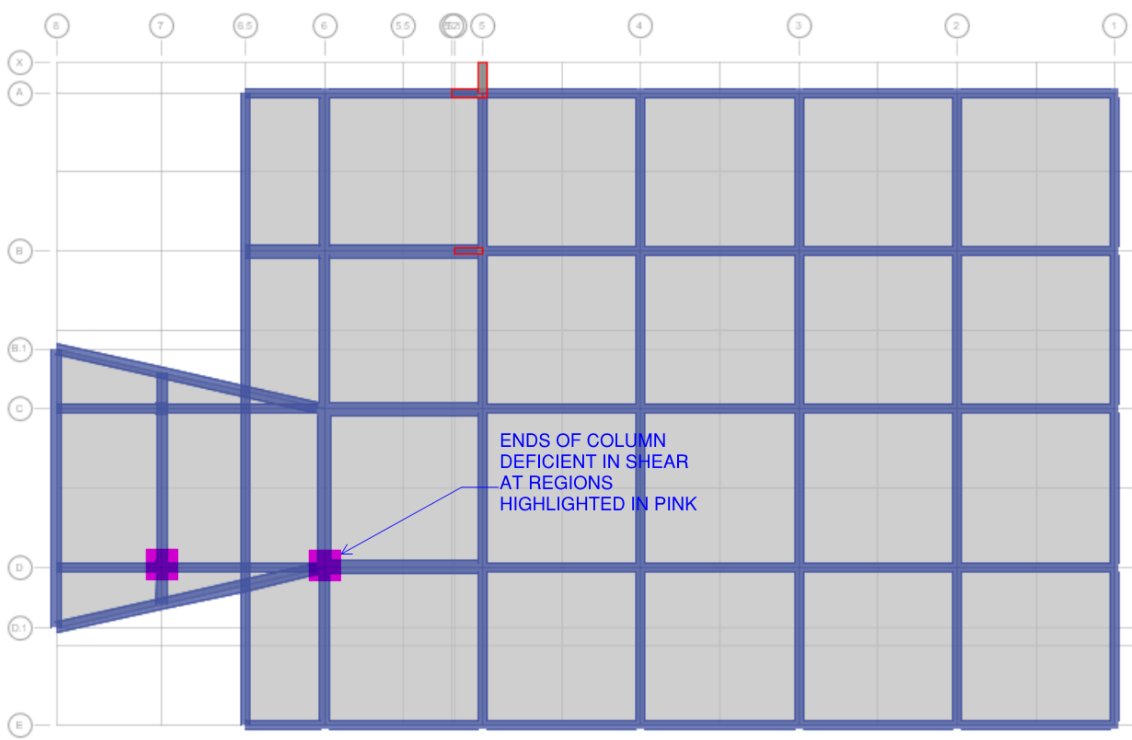
Axial, moment, and shear diagrams on typical interior frame respectively

Columns:

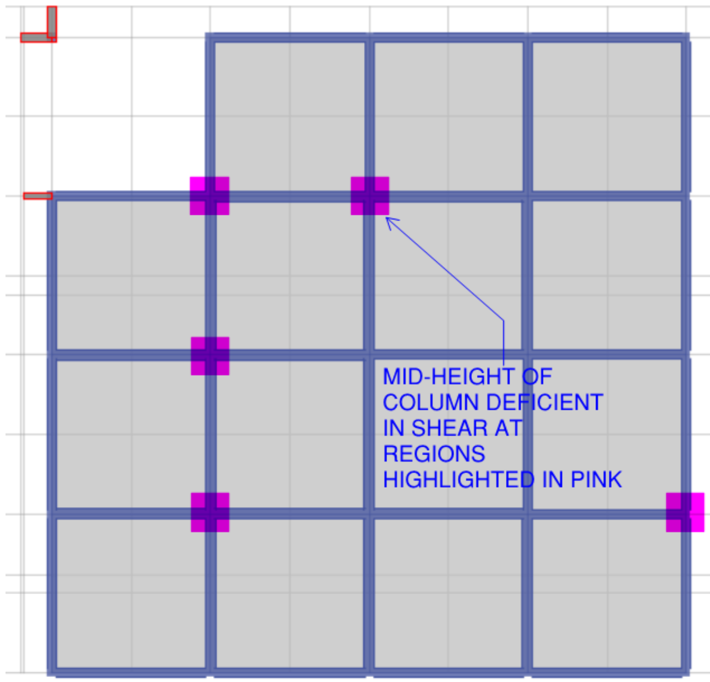
- All columns are sufficient in flexural strength under all load combinations.
- Few columns at first two levels are deficient in shear strength at column ends. More columns at all levels are deficient in shear strength at mid-height.



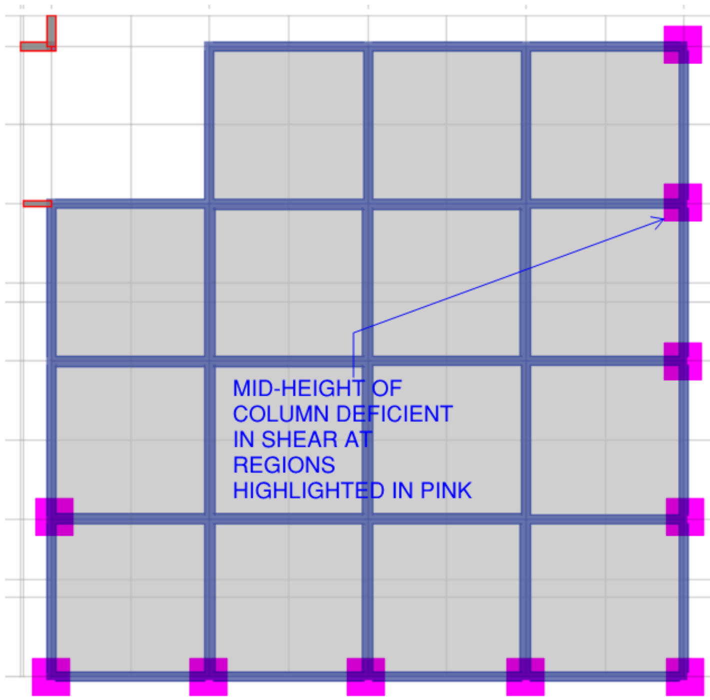
BELOW 2ND FLOOR PLAN



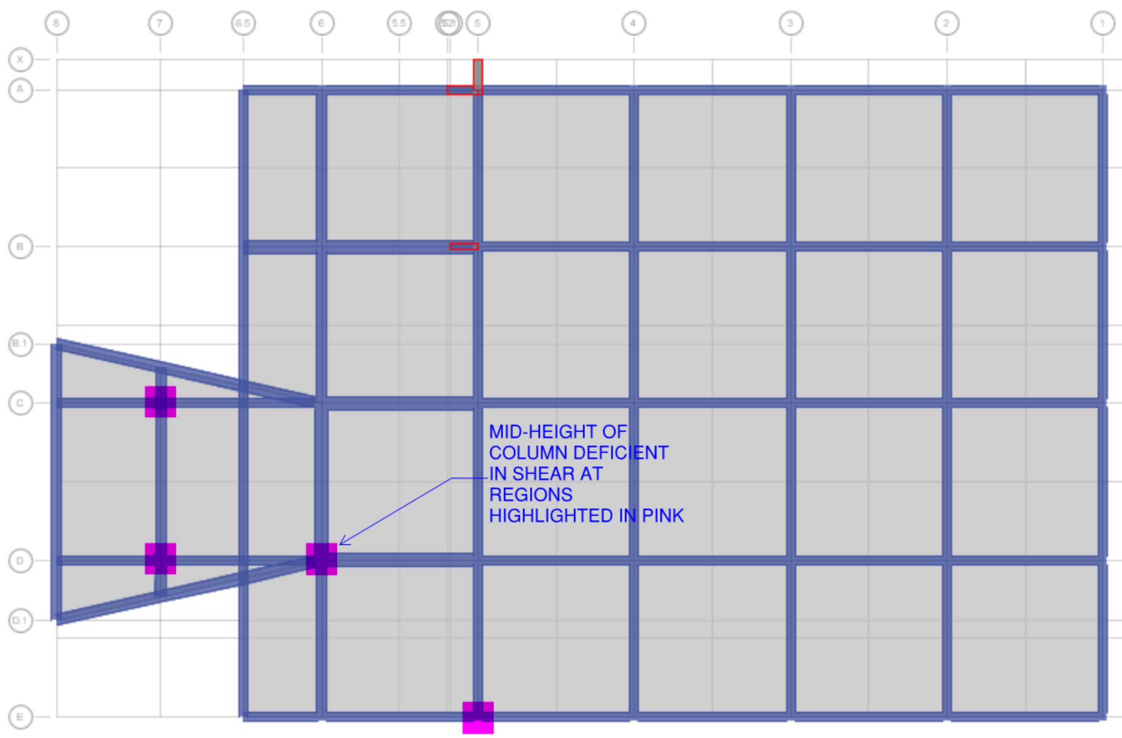
BELOW 1ST FLOOR PLAN



BELOW 3RD FLOOR PLAN



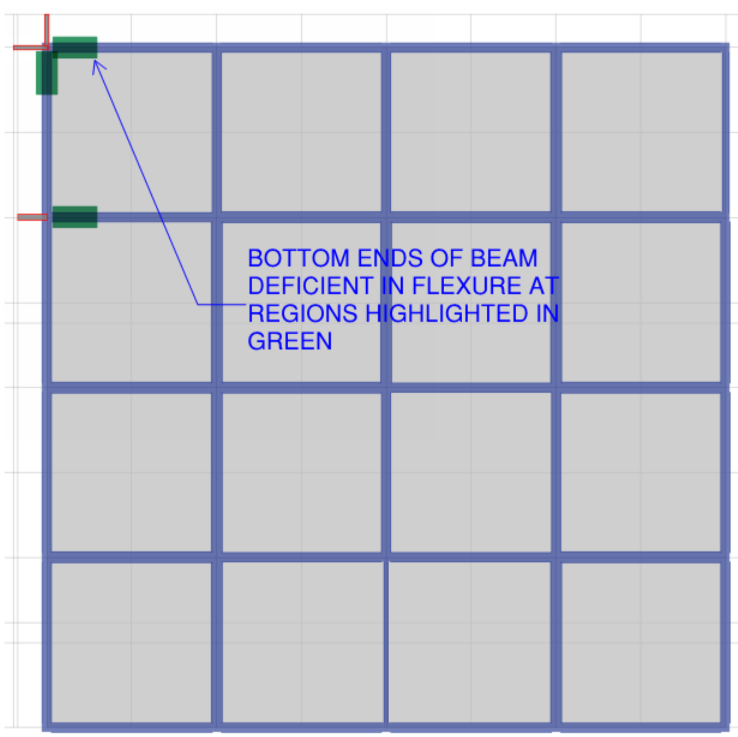
BELOW 2ND FLOOR PLAN



BELOW 1ST FLOOR PLAN

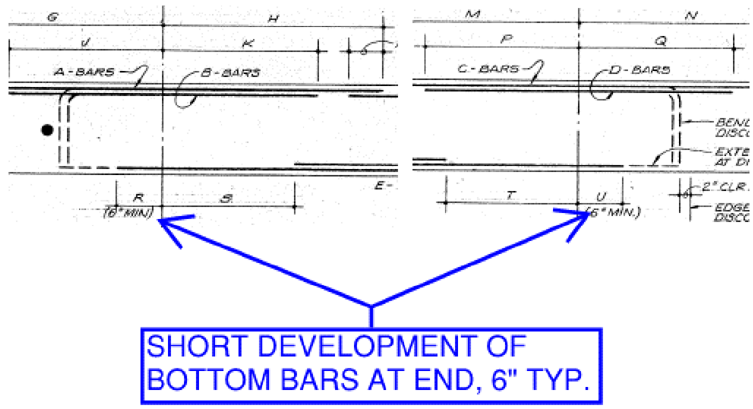
Beams:

- Several beams at roof adjacent to narrow wall piers near main entrance of the library are deficient in flexure at member ends.

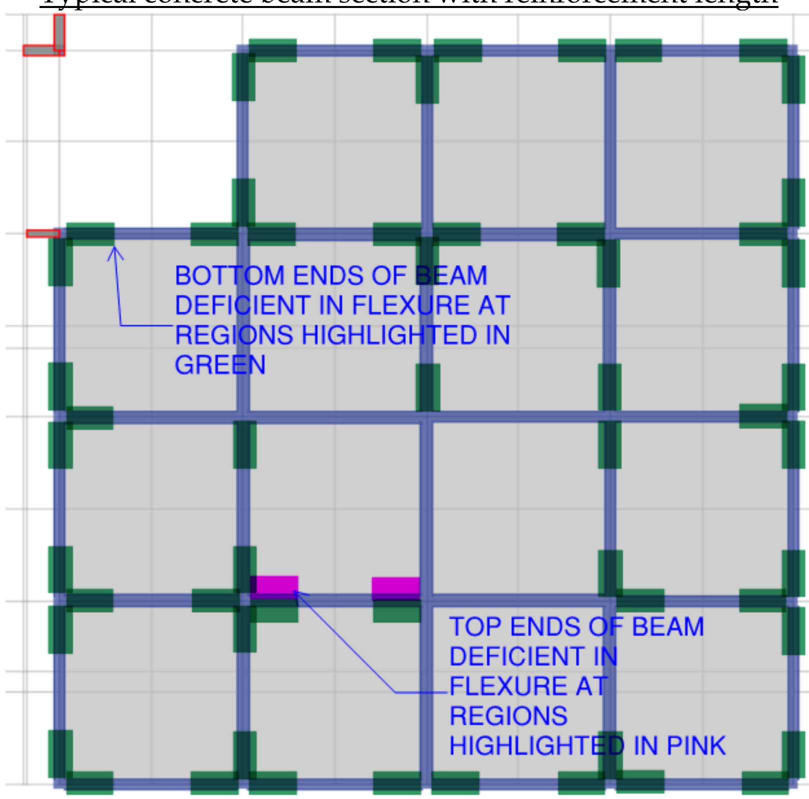


ROOF PLAN

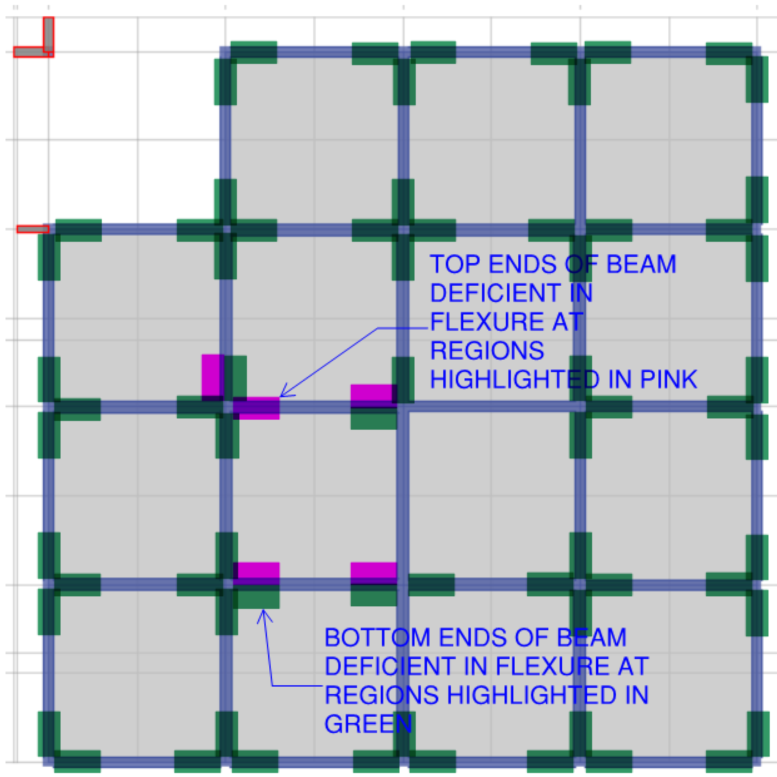
- Most of the exterior and interior beams are deficient in flexure at member ends as the beams were not originally designed for seismic demand in the frames. All beams have bottom longitudinal bars that extend 6" beyond the column centerline, causing the reinforcement not being able to develop in tension.
- Few beams at underside of Lecture Hall are deficient in shear strength along member length.



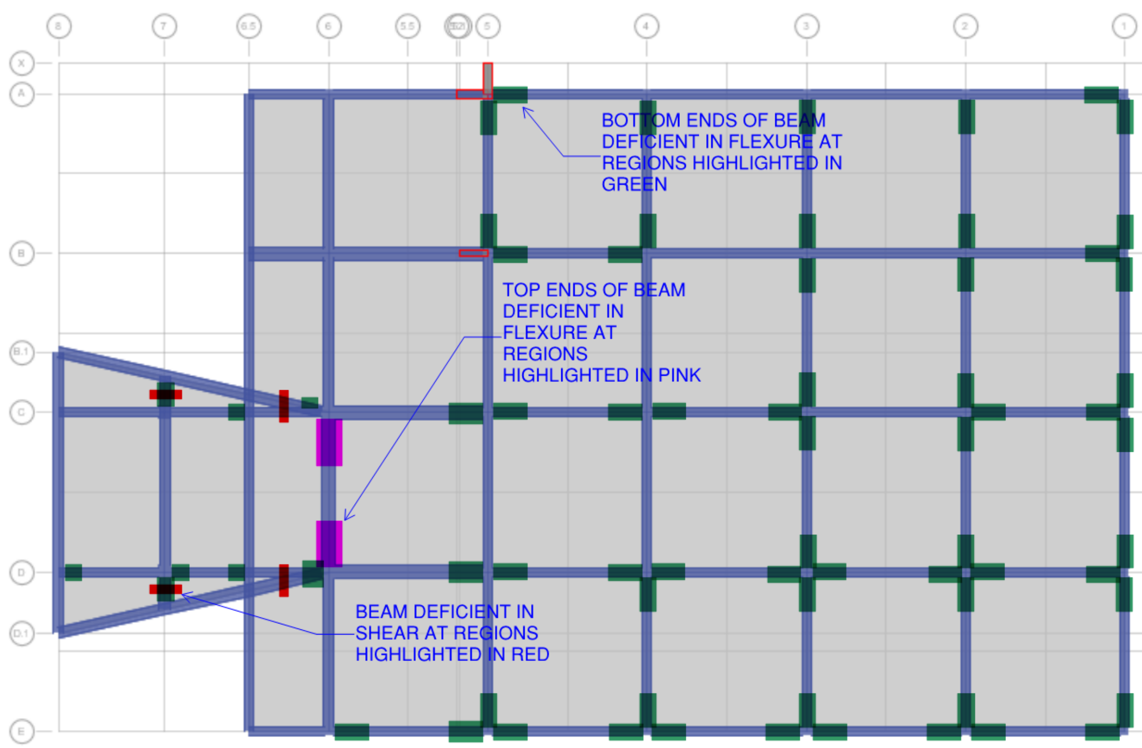
Typical concrete beam section with reinforcement length



3RD FLOOR PLAN



2ND FLOOR PLAN



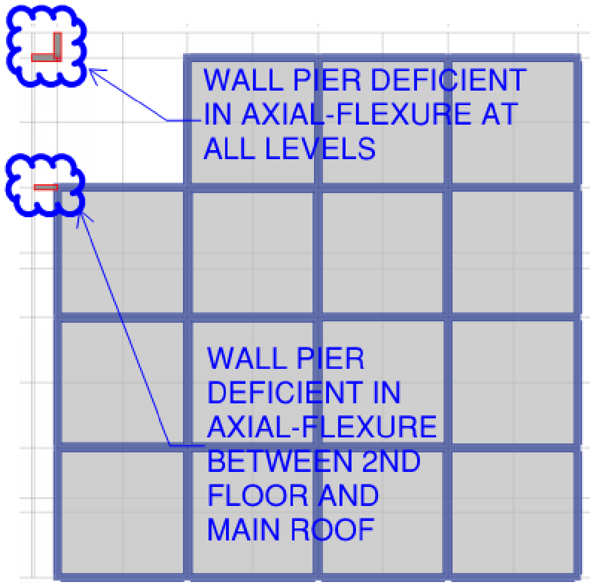
1ST FLOOR PLAN

Frame joints:

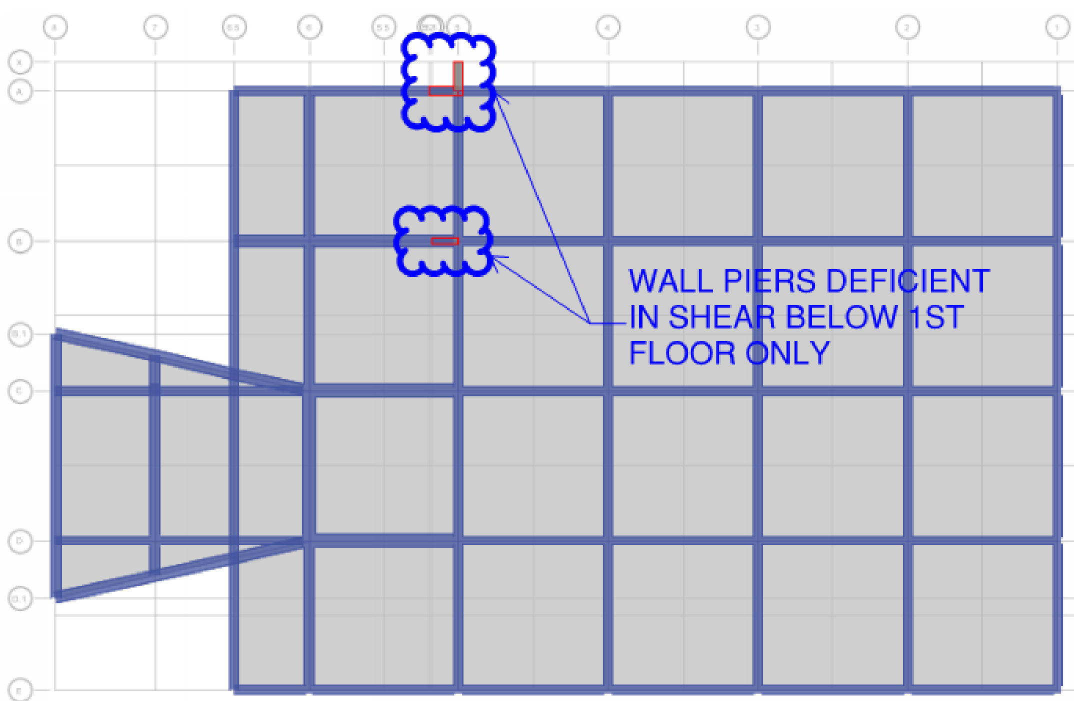
- Instead of capacity-based joint shear check, ASCE 41-13 allows demand-based joint shear analysis. Based on the demands, all of the exterior and interior joints are sufficient in shear strength.

Wall components:

- Narrow wall piers near main entrance of the building are deficient in flexure and shear.



AT ALL FLOORS



BELOW 1ST FLOOR PLAN

Foundation components:

- With the existing moment frame system, all the existing spread foundation are adequate in bearing, flexural, and shear strength. There is no indication of uplift force from the main columns to the foundation.

5.3 Summary of Tier 2 Deficiencies

The following lists summary of structural deficiencies identified in the subject building.

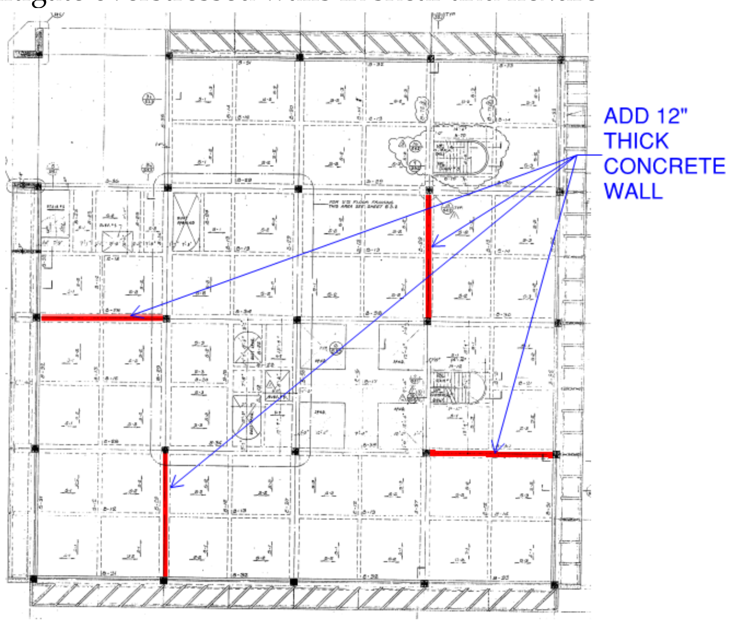
- Column shear strength
    - 5 column locations above 2^{nd} floor
    - 10 column locations above 1^{st} floor
    - 4 column locations above grade level
- Beam flexural strength - ends
    - Beams at main roof adjacent to (E) wall piers
    - Almost all beams at 2^{nd} and 3^{rd} floors
    - Most of beams at 1^{st} floor
    - Two of the (E) grade beams
- Beam shear strength
    - 4 beams at 1^{st} floor at Lecture Hall portion of building
- Wall shear strength
    - 2 narrow wall piers below 1^{st} floor
- Wall flexure strength
    - L-shape wall pier at all levels
    - Straight narrow wall pier between 2^{nd} floor and main roof

6.0 RETROFIT RECOMMENDATIONS

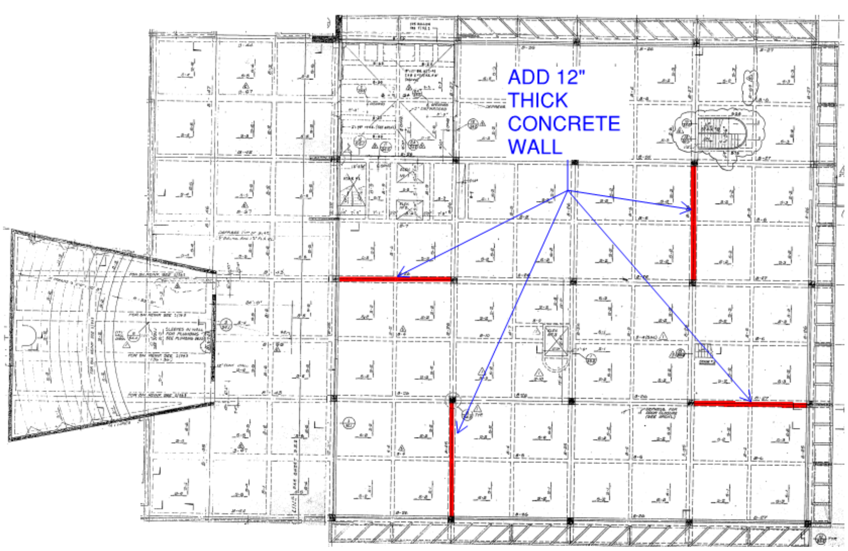
6.1 Strengthening Concepts and Sketches

Change Main Seismic Force Resisting System Overall to Shear Wall:

- Adding new shear walls at all levels
  - Provide redundant proper seismic-force-resisting system
  - Mitigate shear deficient columns at all levels
  - Mitigate flexurally deficient beams at all levels
  - Joint shear deficiencies are no longer issue due to wall system
  - Mitigate overstressed walls in shear and flexure

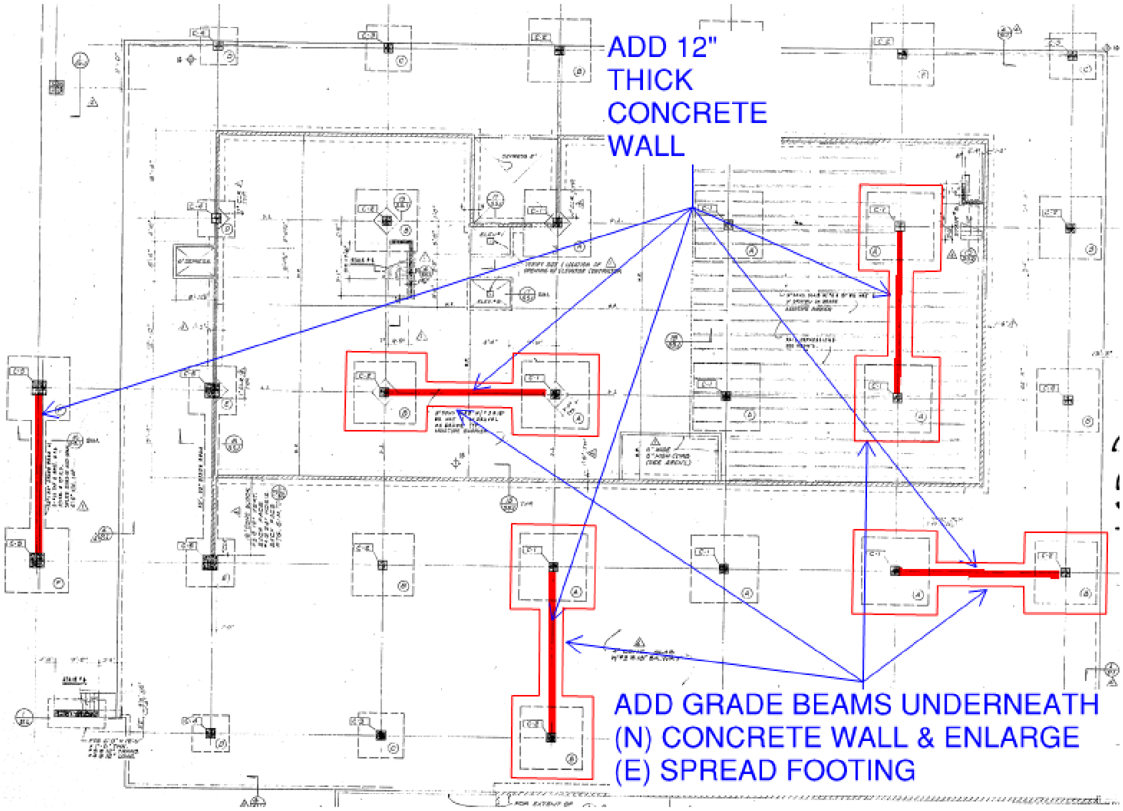


2ND & 3RD FLOOR PLAN

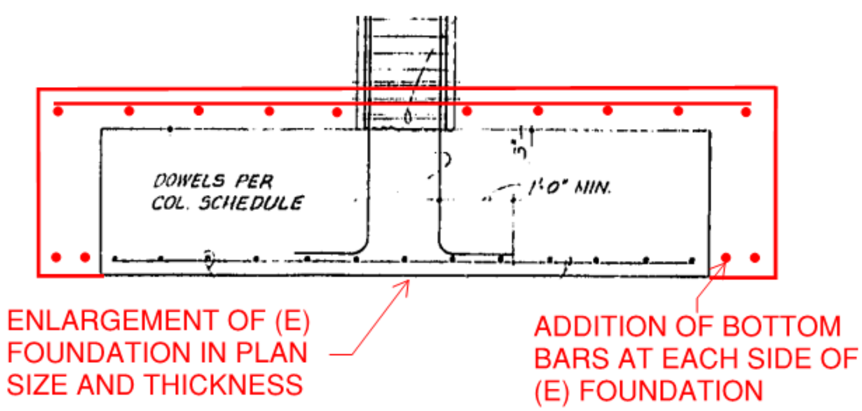


1ST FLOOR PLAN

- Adding new grade beams between (E) spread footings to support new shear walls (4 locations)
- Enlarge (E) spread footings that support (N) concrete shear walls with addition of top and bottom bars for uplift resistance and flexural strengthening

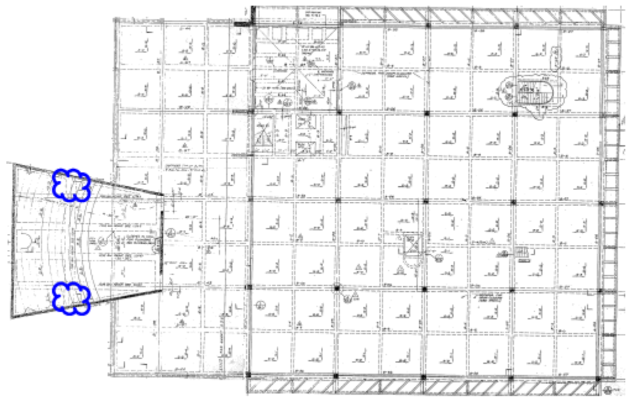


FOUNDATION / GROUND FLOOR PLAN

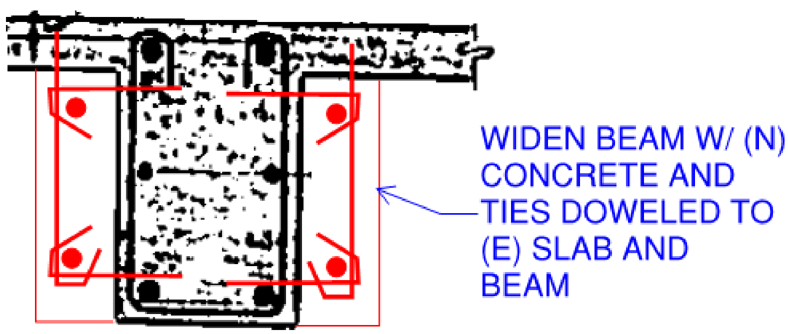


STRENGTHENING OF FOUNDATION

Strengthen (E) beams for shear underside of Lecture Hall



1ST FLOOR KEY PLAN



6.2 Rough Order of Magnitude

APPENDIX