SEISMIC EVALUATION OF COMBINED FABRIC LIMITED (CFL) – ADMIN BLOCK (HR BUILDING)

January 2019

DEPARTMENT OF EARTHQUAKE ENGINEERING
NED UNIVERSITY OF ENGINEERING AND TECHNOLOGY

EXECUTIVE SUMMARY

This report summarizes the observations and the results of the seismic risk assessment based on multi-tier assessment methodology provided in ASCE 31-03 provisions. Tier-1 vulnerability analysis was conducted for any potential deficiencies that may exist in the structural lateral force resisting system for seismic performance levels corresponding to Life Safety (LS) and Immediate Occupancy (IO).

“ASCE 31-03, Seismic Evaluation of Existing Buildings” is internationally recognized standard which utilizes a three-tiered process for the seismic assessment and evaluation of the existing buildings by identifying the “weak links” in a building’s lateral force resisting system that can lead to significant failure and/or collapse.

The ASCE 31-03 Tier-1 procedure is a preliminary screening tool designed to quickly identify potential seismic deficiencies of the structural lateral-force resisting system and geologic and site hazards. The Tier-1 evaluation procedure utilizes a series of checklists for rapid evaluation of the building while requiring only a minimal level of structural calculations. The checklist statements determine whether each item is compliant or non-compliant. Compliant statements identify conditions that are acceptable. Non-compliant statements identify deficiencies that are in need of further detailed evaluation using the Tier-2 and Tier-3 procedures.

ASCE 31-03 Tier-1 evaluation of the Combined Fabric Limited – Admin Block (HR Building) is completed in conjunction with a comprehensive review of the original design drawings, the information collected during site visits, and detailed analysis using the corresponding clauses for Tier-1 assessment. The identified noncompliant and potential deficient areas are based on the ASCE guidelines and on experience and judgment concerning the performance of this type of structure in past major earthquakes, requiring a more detailed evaluation through the ASCE 31-03 Tier-2 and Tier–3 Analytical Evaluation Phases.

ACKNOWLEDGEMENTS

In order to examine the various facets of the ASCE checklist, detailed field visit to the Combined Fabric Limited – Admin Block (HR Building) was undertaken which involved discussions with the staff members concerned with the maintenance and smooth functioning of the building processes. We would therefore like to express our deepest gratitude not only to these officials who made every effort to arrange field visit, and extended all possible help directly and indirectly, and to provide information and insights.

DISASTER VOCABULARY

Hazard

A hazard is natural or man-made phenomena which may causes physical damage, loss or threaten human life and well-being if it occurs in an area of human settlement, agricultural or industrial activity.

Risk

Risk is defined as the expected losses (lives lost, persons injured, damage to property, economic activities or livelihoods disrupted) to a community when a hazard event occurs. The probability of the loss will occur as the result of an adverse event, given the hazard and vulnerability.

Vulnerability

Vulnerability is defined as the extent to which a community, structure, services or geographic area is likely to be damaged or disrupted by the impact of particular hazard, on account of their nature, construction and proximity to hazardous terrains or a disaster prone area. These long term factors, weaknesses or constraints affect a household or community's ability to absurd losses after disaster or to recover from the damage.

Capacity

Capacity can be defined as resources, means and strengths which exist in households and communities and which enable them to cope with, withstand, prepare for, prevent, mitigate or quickly recover from a disaster. People's capacity can also be taken into account. Capacities could be classified into physical and socio-economic capacities.

Life-Safety (LS) Performance Level

The performance objective is meant to ensure that the building will not collapse and that exit paths from the building will not be blocked, however, the building may be heavily damaged and may be unable to be occupied after a major earthquake. In addition, the building may not be repairable after a major earthquake.

ACRONYMS

ASCE	American Society of Civil Engineers
EERI	Earthquake Engineering Research Institute
LS	Life-Safety Performance Level
IO	Immediate Occupancy Performance Level
NEDUET	NED University of Engineering and Technology
NEHRP	National Earthquake Hazards Reduction Program
R&D	Research and Development

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1. Introduction

Earthquakes are low-probability high-consequence events. Though they may occur only once in the life of a building they can have devastating, irreversible consequences resulting in collapse and loss of life. As Pakistan lies in a seismically active region, therefore the life safety and structural integrity of existing buildings is of great concern and needs to be addressed urgently. Detailed seismic vulnerability evaluation is a technically complex and expensive procedure, with the publication of ASCE 31-03, the American Society of Civil Engineers (ASCE) has produced a document that represents a consensus standard for the seismic evaluation of existing buildings.

The evolution of ASCE 31 over many years has made significant efforts to understand the factors that affect the seismic performance of buildings and offers procedures to manage earthquake risk in existing buildings through identifying the inherent weaknesses in the design of the structure and any components of the structure.

This project, aims to review and assess the structural resilience and weakness of the existing Combined Fabric Limited – Admin Block (HR Building) against probable seismic event in future through ASCE 31-03, Tier-1 checklist evaluation (Rapid Visual Screening Assessment). This assessment of the Building was performed for Life Safety and Immediate Occupancy performance levels.

Observations, analyses, and conclusions contained in this report focus primarily with the risk associated with earthquake. The evaluations included field reconnaissance limited to the general physical status of the building. In most cases, building finishes conceal structural elements. No testing or demolition of finishes to expose the existing structural elements was conducted to determine their material properties or concealed problems with the construction of the buildings.

2. Objectives

This report primarily summarizes the results of site observations, structural drawing reviews, and preliminary projections of structural performance during a major earthquake based on engineering judgment in conjunction with ASCE 31-03, Tier 1 seismic evaluation checklists for the building. The project scope is limited to the following:

- ✓ Tier-1 Seismic Evaluation (Rapid Visual Screening Assessment) with quick checks is performed in accordance with ASCE 31-03.
- ✓ The scope of Tier-1 seismic evaluation, as outlined in ASCE 31-03, is intended to identify deficiencies and to make recommendations for a Tier-2 evaluation, if necessary that could result in losses during the facility's life exposure.
- ✓ To submit a summary report on physical visit observation and propose if further detailed evaluation using the Tier-2 and Tier-3 procedures is needed.

During Tier-1 seismic evaluation process of the building, the key responsibilities of NED University included:

- ✓ NEDUET assessment team will review the available structural and architectural drawings.
- ✓ NEDUET assessment team will determine the regional seismic hazard.
- ✓ NEDUET assessment team will visit and perform the ASCE 31 Tier-1 checklist evaluation.
- ✓ NEDUET assessment team will share a summarized report on physical visit observation and identified non-compliant aspects and deficiencies.

3. Building Checks

This report is based on site visits, review of available structural drawings and preliminary evaluation based on ASCE 31-03 Tier-1 checklist in conjunction with judgment and experience. This assessment is based on the assumption that the Combined Fabric Limited – Admin Block (HR Building) was constructed in accordance with the available existing drawings and that elements used to resist lateral forces are in good condition. The investigation was limited to the visual observation of items not covered by finish material. Other conditions affecting the structure that were not inspected, anticipated, or accessible are beyond the scope of this report.

This assessment is limited to the buildings' primary structural systems. Evaluation of non-structural items such as architectural elements, furnishings and interior equipment, and electrical, mechanical, and plumbing systems are not considered in this evaluation. The professional services have been performed with the degree of care and skill exercised, under similar circumstances, by reputable consultants practicing in this field.

4. Building Description

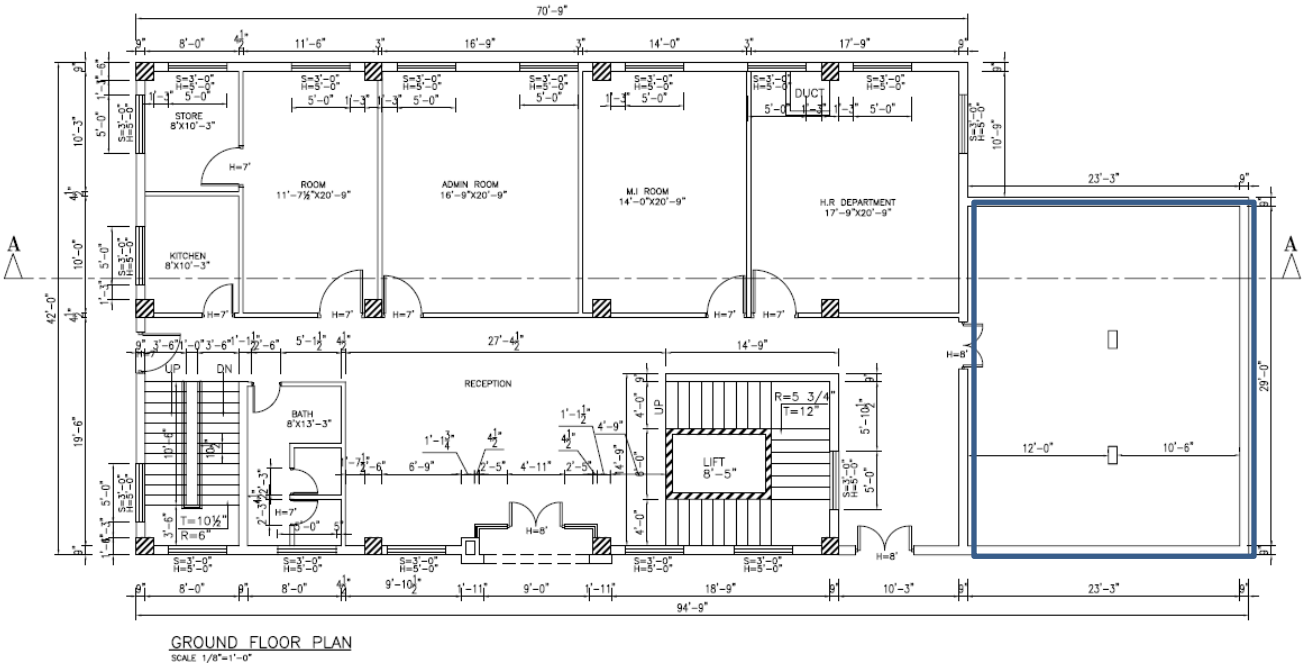
4.1. General Description

The building has ground plus two stories with exterior rectangular dimensions of 94'-0" wide by 40'-6" long (Figure 1). The total height of the building is (33') with 11 feet height for each storey. The structural system of the building mainly consists of Reinforced Concrete Frame with small part of the building comprising of unreinforced load bearing masonry walls. Stairs are present at two side of the building. One lift is present as well. The isolated footings and combined footings are provided as the foundation. The design compressive strength of concrete is 3 ksi for beams and 3.5 ksi for columns and the yield strength of steel of 60 ksi is used.

In accordance with the Building Code of Pakistan, Seismic Provisions, 2007, the city of Lahore is located in Seismic Zone 2A (Figure 2 and Figure 3). Accordingly, the seismic assessment of the building is carried out using seismic zone 2A, i.e. moderate seismic zone. The soil is assumed conservatively to be of class D. This reinforced concrete frame part of the building is evaluated as a reinforced concrete moment frame (Type-C1; refer to Table 2-2 ASCE 31-03) whereas the unreinforced masonry part of the building is subjected to additional checks for building type URMA as per ASCE 31-03. Considering the occupancy type of the building, the seismic assessment exercise is conducted for the performance levels of life safety (LS) and immediate occupancy (IO).

5. Tier-1 Analysis

The first level of the seismic assessment is 'Tier-1 assessment' as specified by ASCE 31-03. The Tier-1 analysis consists of carrying out checks related to various building components, which include geometry, storey details, mass, stresses, existing condition of building for life safety conditions and some supplementary checks which include structural framing and reinforcement details. Furthermore, some checks are modified for Pakistan, which include infill parameters and column aspect ratio. List of all these checks are summarized in **Error! Reference source not found.**.



GROUND FLOOR PLAN
SCALE 1/8"=1'-0"

Figure 1: Architectural Plan of CFL Admin Block Ground Floor (Highlighted Part is showing URM)

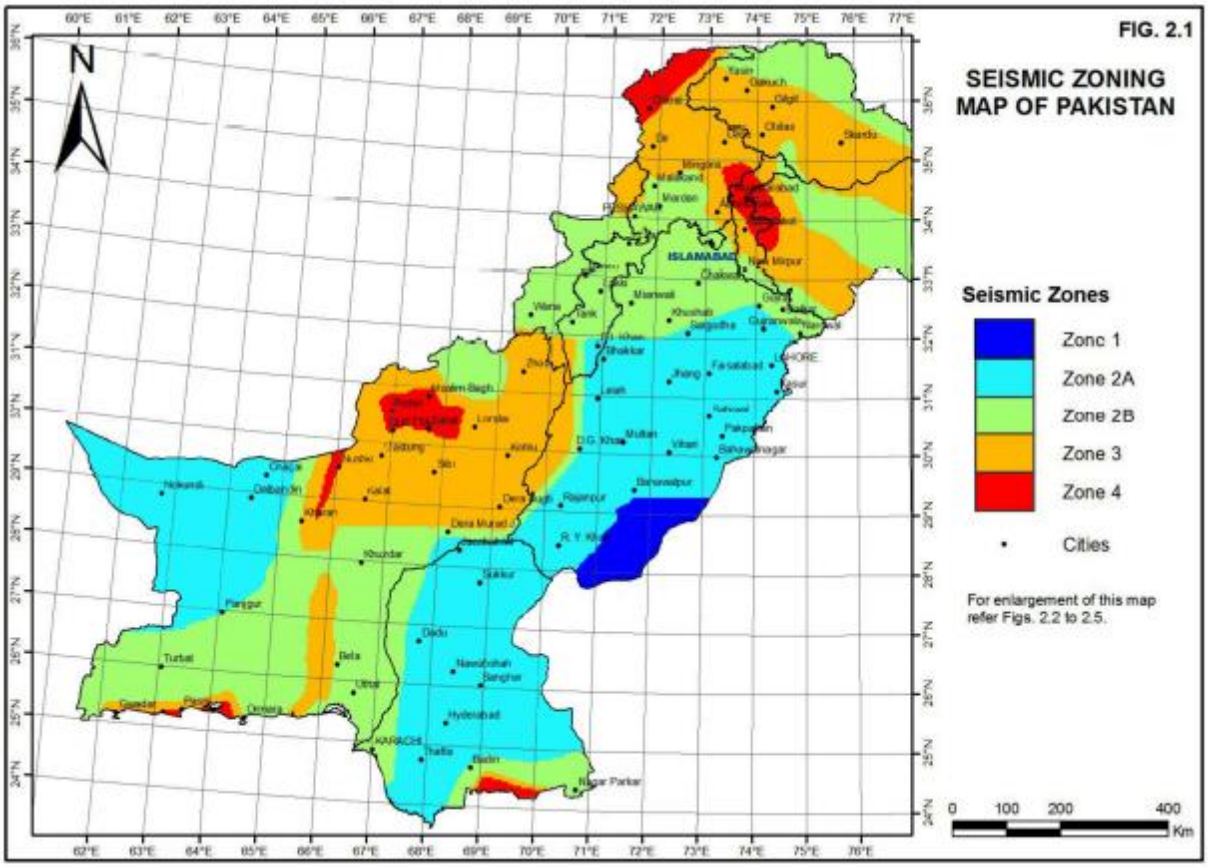


Figure 2: Seismic Zonation Map of Pakistan by Pakistan Building Code, 2007

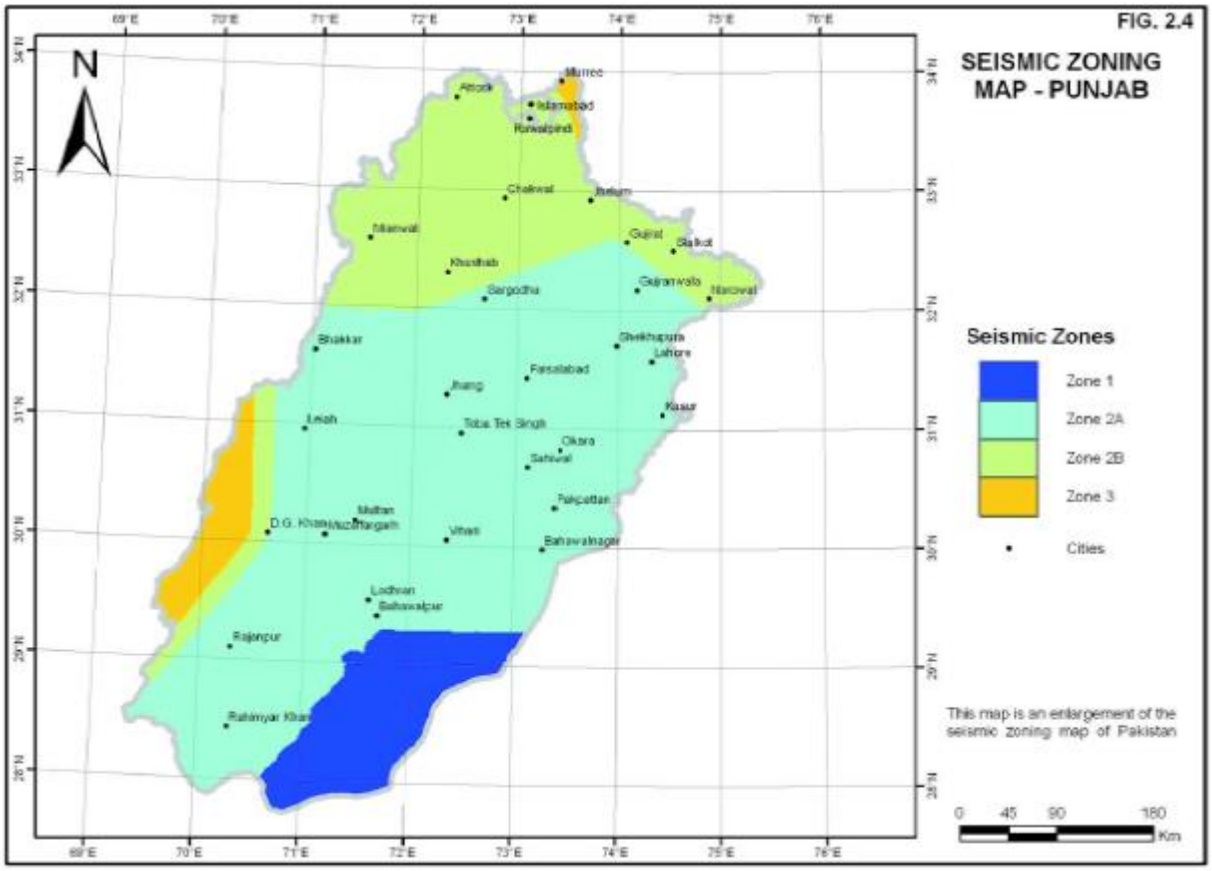


Figure 3: Seismic Zonation Map of Punjab by Pakistan Building Code, 2007

Table 1: Structural checklists for building type C1

BASIC STRUCTURAL CHECKLIST	SUPPLEMENTAL STRUCTURAL CHECKLIST	BASIC STRUCTURAL CHECKLIST MODIFIED FOR PAKISTAN	GEOLOGICAL SEISMIC HAZARD AND FOUNDATION CHECKLIST
Building System	Building System	Building System	Geological Hazard
Load Path	Flat Slab Frames	Proportion of Infill Walls	Liquefaction
Adjacent Building	Pre-stressed Frames	Solid Walls	Slope Failure
Mezzanine	Captive Column	Column Aspect Ratio	Surface Fault Rupture
Weak Storey	No Shear Failures	Transfer to Shear Wall	CONDITION OF FOUNDATION
Soft Storey	Strong Column/ Weak	Construction Quality	Foundation Performance
Geometry	Beam Bars		Deterioration
Vertical Discontinuities	Column-Bar Splices		Pole Foundation
Mass Irregularity	Beam-Bar Splices		Over Turning
Torsion	Column-Tie Spacing		Ties Between Foundation
Deterioration	Stirrup Spacing		Deep Foundation
Post Tensioning Anchors	Joint Reinforcing		Sloping Sites
LATERAL FORCE RESISTING SYSTEM	Joint Eccentricity		
Redundancy	Stirrup and Tie Hooks		
Interfering Wall	Deflection Compatibility		
Shear Stress Check	Flat Slabs		
Axial Stress Check	DIAPHRAGMS		
CONNECTIONS	Diaphragm Continuity		
Concrete Columns	Plan Irregularities		
	Diaphragm Reinforcement		
	CONNECTIONS		
	Uplift at Pile Caps		

6. Site Visits

NEDUET assessment team visited the building located in Lahore on 30th October, 2018. The purpose of the site visits was to review the condition of visible structural elements in the building, confirm that construction generally followed as that shown on structural drawings, and review as-built conditions of items or any other details having changed over a period of time. No destructive demolition testing was performed in order to view items not readily viewable. These items include (but are not limited to foundations) reinforcing steel and wall to roof connections.

7. Building Loads

The building loads, taken into account for simple calculations as required by ASCE 31-03, consist of dead loads, including self-weight of the structural elements, finishes load, wall loads and loads. The live loads on various floors are taken as 50 psf for the offices on the floor and 20 psf for inaccessible roof. Live loads for various floors are taken as per ASCE 7-01. For office use floors, 50 psf is considered and for dining, prayer room and stair 100 psf load is considered whereas for different machines “Light Manufacturing” category is selected as per code and 125 psf load is considered. 25% of the live load is taken to calculate total load as described by UBC section 1630.

8. Summary of Seismic Tier-1 Assessment

The summary of ASCE 31-03 checks for the building is provided in Table 2 and Table 3. The qualitative rating of the assessment checks for the building is provided in Table 4 and Table 5. The detail of the checks for the building is provided in Appendix – B to F.

9. Summary of Qualitative Assessment

The summary of qualitative assessment based on visual inspection and calculations is provided separately in Table 6.

10. Conclusion

The Tier-1 Seismic evaluation of the Building is performed in accordance with ASCE 31-03 requirements, which is a three-tier process. The scope of Tier-1 evaluations is to carryout simple checks based on visual inspection of the building. These checks assist in assessing if the existing

building complies with the minimum requirements of seismic safety. If any of the check indicates non-compliance then detailed investigation is warranted as Tier-2 evaluation, which may further indicate the need to Tier-3 assessment. It needs to be highlighted that Tier-1 assessment of the Building is carried out for two performance levels namely Immediate Occupancy (IO) and Life-Safety (LS). The latter performance level, i.e. Life Safety, is generally deemed relevant in most cases. The important observations/conclusions drawn from the work are listed as under:

1. This building is located within an area with a “Moderate” level of seismicity.

2. This building is classified mainly as Building Type C-1 (CONCRETE MOMENT FRAMES) as per ASCE 31-03. Additional checks for unreinforced masonry structure are conducted considering building type URMA as per ASCE 31-03.

3. In general, emergency lighting and ducts were anchored properly.

4. Building satisfies all the codified provisions corresponding to the Life Safety (LS) requirements.

5. Building does not satisfy the codified provisions corresponding to the Immediate Occupancy (IO) requirements in case of the following stipulated clauses.

    a) Presence of strong beam weak column. In general, the flexural strength of beams is found to be greater than the flexural strength of columns.

    b) Absence of minimum required column-tie spacing and column-bar splices.

    c) Absence of minimum required beam-stirrup spacing.

    d) Joint eccentricity is found to be higher than the allowable eccentricity of 20% in some locations

    e) Shear stress in concrete column exceeds the limits stipulated in the clause for immediate occupancy

    f) Required proportion of the infill walls is not satisfied.

6. For all buildings, the provisions for the joint reinforcement, beam bar splices, liquefaction and foundation deterioration could not be checked due to lack of the required data.

7. For the non-compliant requirements, mentioned in points 5 to 6 above, it is likely that the outcome of Tier-2 and Tier-3 analyses satisfies the required code provisions and any further structural intervention may not be required. The original designer may, however, be consulted for finding adequate solutions of these non-compliances in case the provisions are not satisfied in Tier-2 and Tier-3 assessment.

As mentioned earlier that Tier-1 analysis is only a screening phase that includes some quick checks and simple calculations. As can be seen in the above, several checks in the Tier-1 evaluation indicate non-compliance with the requirements of ASCE 31-03 provision. This, however, must not be construed as a deficient building at this stage. This evaluation only indicates that further study is needed to analyse this building in detail which may call for the need of Tier-2 and Tier-3 evaluation (which are beyond the scope of this report).

11. Recommendation

An ASCE 31-03 Tier-2 or Tier-3 evaluation may be conducted to determine if the non-compliant deficiencies of Tier-1 can be resolved by further analysis or if retrofit will be required.

1. It is strongly recommended that the original designer is consulted to address the above listed deficiencies.

2. Prior to suggesting mitigation and/ or retrofit measures, it is recommended to carryout detailed investigation, in order to seek implications of the deficiencies mentioned in Table 2 to 6 of this report. It is in the experience that some of the deficiencies may be overcome by carrying out Tier-2 or Tier-3 analyses.

3. If any mitigation and/ or retrofit are to be designed, it is advisable to prioritize deficiencies and develop a plan for mitigation.

4. Retrofits (if any) should be designed by a specialist engineer according to the priorities and plan mentioned above.

Table 2: Summary of Tier-1 Assessment for building (C = Compliant, N/C = Non-Complaint, N/A = Not Applicable, I-U = Information Unavailable)

Basic Structural Checklist For Life Safety		**Supplemental Structural Checklist For Immediate Occupancy**		**Basic Structural Checklist Modified For Pakistan**		**Geological Seismic Hazard And Foundation Checklist**	
Building System		Building System		Building System		Geological Hazard	
Load path	C	Flat slab frames	C	Proportion of infill walls	N/C	Liquefaction	I-U
Adjacent building	C	Pre-stressed frames	N/A	Solid wall	C	Slope Failure	C
Mezzanine	N/A	Captive column	N/A	Column aspect ratio	C	Surface Fault rupture	C
Weak storey	C	No shear failures	C	Transfer to shear wall	N/A	Condition of Foundation	
Soft storey	C	Strong column/ weak beam	N/C	Construction quality	C	Foundation Performance	C
Geometry	C	Beam bars	C			Deterioration	I-U
Vertical discontinuities	C	Column-bar splices	N/C			Pole Foundation	N/A
Mass irregular	C	Beam-bar splices	I-U			Over turning	C
Torsion	C	Column-tie spacing	N/C			Ties between Foundation element	C
Post tensioning anchors	N/A	Stirrup spacing	N/C			Deep foundation	N/A
Lateral-Force Resisting System		Joint reinforcing	I-U			Sloping Sites	C
		Joint eccentricity	N/C				
Redundancy	C	Stirrup and tie hooks	C				
Interfering wall	C	Deflection compatibility	N/A				
Shear stress	C	Flat slabs	N/A				
Axial stress	C	Diaphragms					
Connections		Diaphragm continuity	C				
Concrete columns	C	Plan irregularities	N/A				
		Diaphragm R/F at openings	N/A				
		Lateral-Force Resisting System					
		Shear stress	N/C				

Table 3: Basic Structural Checklist for Unreinforced Masonry Part of Building (C = Compliant, N/C = Non-Complaint, N/A = Not Applicable, I-U = Information Unavailable)

Basic Structural Checklist For Life Safety and Immediate Occupancy			
General		Lateral-Force Resisting	
Masonry Units	C	Redundancy	C
Masonry Joints	C	Shear Stress Check	N/C
Unreinforced Masonry Wall Cracks	C		

Table 4: Qualitative Summary of Tier-1 Assessment for the building (P = Poor- Detailed Investigation Needed; F= Fair- As-Built Drawing Missing; G= Good- Almost Everything is in Order; N/A = Not Applicable)

Basic Structural Checklist For Life Safety		**Supplemental Structural Checklist For Immediate Occupancy**		**Basic Structural Checklist Modified For Pakistan**		**Geological Seismic Hazard And Foundation Checklist**	
Building System		Building System		Building System		Geological Hazard	
Load path	G	Flat slab frames	G	Proportion of infill walls	P	Liquefaction	F
Adjacent building	G	Pre-stressed frames	N/A	Solid wall	G	Slope Failure	G
Mezzanine	N/A	Captive column	N/A	Column aspect ratio	G	Surface Fault rupture	G
Weak storey	G	No shear failures	G	Transfer to shear wall	N/A	Condition of Foundation	
Soft storey	G	Strong column/ weak beam	P	Construction quality	G	Foundation Performance	G
Geometry	G	Beam bars	G			Deterioration	F
Vertical discontinuities	G	Column-bar splices	P			Pole Foundation	N/A
Mass irregular	G	Beam-bar splices	F			Over turning	G
Torsion	G	Column-tie spacing	P			Ties between Foundation element	G
Post tensioning anchors	N/A	Stirrup spacing	P			Deep foundation	N/A
Lateral-Force Resisting System		Joint reinforcing	F			Sloping Sites	G
		Joint eccentricity	P				
Redundancy	G	Stirrup and tie hooks	G				
Interfering wall	G	Deflection compatibility	N/A				
Shear stress	G	Flat slabs	N/A				
Axial stress	G	Diaphragms					
Connections		Diaphragm continuity	G				
Concrete columns	G	Plan irregularities	N/A				
		Diaphragm R/F at openings	N/A				
		Lateral-Force Resisting System					
		Shear stress	P				

Table 5: Qualitative Summary of Tier-1 Assessment for Unreinforced Masonry Part of Building (P = Poor- Detailed Investigation Needed; F= Fair- As-Built Drawing Missing; G= Good- Almost Everything is in Order; N/A = Not Applicable)

Basic Structural Checklist For Life Safety and Immediate Occupancy			
General		Lateral-Force Resisting	
Masonry Units	G	Redundancy	G
Masonry Joints	G	Shear Stress Check	P
Unreinforced Masonry Wall Cracks	G		

Table 6: Observation and comments for visual inspection for Building

Provision/Requirement	Rating	Observation	Additional Comments
Proper anchorage of emergency lighting	Good	In general the emergency lightings were anchored properly.	Refer Appendix-A
Proper anchorage of cladding	Good	The claddings were found to be anchored properly.	Refer Appendix-A
Equipment attached properly	Good	In most cases the equipment was anchored properly.	Refer Appendix-A
Piping attached properly	Good	The piping systems were found to be attached properly.	Refer Appendix-A
Light fixtures attached properly	Good	The lighting fixtures were found to be attached properly.	Refer Appendix-A
Deterioration	Good	No deterioration of Concrete and masonry was observed.	Refer Appendix-A

APPENDIX A: PHOTOGRAPHS SHOWING OBSERVATIONS FROM VISUAL INSPECTION OF BUILDING

Figure 4: Proper anchorage of cladding and fixtures

Figure 5: Emergency Exit signs are places appropriately

APPENDIX B: ASCE 31-03 STRUCTURAL CHECKS FOR LIFE SAFETY FOR BUILDING

ASCE 31-03 Section C3.7.8 gives details of checks for life safety performance level. All these checks for the building are described below:

LOAD PATH

Provision: The structure shall contain a minimum of one complete load path for life safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the means to the foundation.

Observation(s)/Finding(s): Complete load paths exist from roof to foundation of building in both direction. Minimum two frames comprise of beams and columns are present in each direction.

Comments: Compliant.

ADJACENT BUILDING

Provision: The clear distance between the buildings being evaluated and any adjacent building shall be greater than 4 percent of the height of the shorter building for life safety and immediate occupancy.

Observation(s)/Finding(s): Minimum clear distance to the adjacent building is greater than 4% of the building's height.

Comment: Compliant

MEZZANINE

Provision: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral –force-resisting elements of the main structure.

Finding: Mezzanine is not present.

Comment: Not Applicable

WEAK STOREY

Provision: The strength of the lateral-force-resisting system in any storey shall not be less than 80 percent of the strength in an adjacent story, above or below, for life safety and Immediate Occupancy.

Observation(s)/Finding(s): The difference between the strength of the storeys is less than 20%.

Method: The flexural strength of each column is determined by performing the sectional analysis and the strength of storey is determined as collective strength of all columns in a particular storey and then compared with the codified provisions.

Comment: Compliant

SOFT STOREY:

Provision: The stiffness of the lateral force resisting system in any story shall not be less than 70 percent of the lateral-forces-resisting system stiffness in an adjacent story above or below, or less than 80 percent of the average lateral-force-resisting system stiffness of the three stories above or below for life safety and immediate Occupancy.

Observation(s)/Finding(s): Stiffness of all stories is found to be compliant for both Life Safety and Immediate Occupancy.

Method: Stiffness of each storey is determined as collective stiffness of all columns in a particular storey and then compared. The stiffness of each column is determined using Equation (1), provided below:

$$K = \frac{6EI}{L^2} \qquad (1)$$

Where

K= stiffness of each column

E= Modulus of elasticity of reinforced concrete.

I= Moment of inertia

L= Height of column.

Comment: Compliant

GEOMETRY

Provision: There shall be no change in horizontal dimension of the lateral-force-resisting system of more than 30 percent in a story relative to adjacent stories for life safety and immediate occupancy, excluding one-story penthouses and mezzanines.

Observation(s)/Finding(s): No difference in x and y dimensions.

Comment: Compliant

VERTICAL DISCONTINUITIES

Provision: All vertical elements in the lateral-force-resisting system shall be continuous to the foundation.

Observation(s)/Finding(s): All the columns are extended to foundations.

Comment: Compliant.

MASS IRREGULAR

Provision: There shall be no change in effective mass more than 50 percent from one story to the next for Life safety and Immediate Occupancy. Light roofs, penthouses, and mezzanines need not be considered.

Observation(s)/Finding(s): Difference between the masses of ground and first storey is 10%.

Method: Mass of each floor is calculated manually. Live loads for various floors are taken as per ASCE 7-01. For office use floors, 50 psf is considered and for dining, prayer room and stair 100 psf load is considered. For different machines “Light Manufacturing” category is considered thus live load of 125 psf load is considered accordingly. 25% of the live load is taken to calculate total load as described by UBC section 1630.

Comment: Compliant.

TORSION

Provision: The estimated distances between the story centre of mass and the story centre of rigidity shall be less than 20 percent of the building width in either plan dimension for Life Safety and Immediate Occupancy.

Observation(s)/Finding(s): Difference between center of rigidity and center of mass is within 20% of the dimension of plan in respective direction.

Method: Centre of rigidity is determined using columns and neglecting the contribution of beams by using Equation (2),

$$X_o = \frac{K_y X_i}{\Sigma K_i} \qquad Y_o = \frac{K_x Y_i}{\Sigma K_i} \qquad (2)$$

Centre of rigidity and centre of mass was calculated for each storey and their difference was compared with the dimension of plan in respective direction.

Comment: Compliant

REDUNDANCY

Provision: The number of lines of moment frames in each principal direction shall be greater than equal to 2 for life safety and Immediate Occupancy. The number of bays of moment frames in each line shall be greater than or equal to 2 for life safety and 3 for Immediate Occupancy.

Observation(s)/Finding(s): More than 2 frames are present in each direction.

Comment: Compliant.

INTERFERING WALL

Provision: All concrete and masonry infill walls placed in moment frames shall be isolated from structural elements.

Observation(s)/Finding(s): Walls are connected with frame by mortar only

Comment: Compliant

SHEAR STRESS CHECK

Provision: The shear stress in the concrete column, calculated using the quick check procedure of section 3.5.3.2, shall be less than the greater of 100 psi or 2√f'c for life safety and Immediate Occupancy.

Observation(s)/Finding(s): All values of average shear stress on each storey are less than the greater of 100 psi or 2√f'c for Life Safety. But for Immediate Occupancy, the shear stress in X-direction for ground storey is higher than 2√f'c.

Method: Shear stresses are calculated using Equation 3, provided below:

$$v_j^{avg} = \frac{1}{m}\left(\frac{n_c}{n_c - n_f}\right)\frac{V_j}{A_c} \qquad (3)$$

Where

n_c = Total number of columns

n_f = Total number of frames in direction of loading

A_c = Area of columns of a storey

V_j = Storey shear

m = modification factor = 2 for LS and 1.3 for IO performance level.

Comment: Compliant for Life-Safety and Non-Compliant for Immediate Occupancy

AXIAL STRESS CHECK

Provision: The axial stress due to gravity loads in columns subjected to overturning forces shall be less than $0.10f_c$ for life safety and immediate occupancy. Alternatively, the axial stresses due to overturning forces alone, calculated using the quick check procedure of section 3.5.3.6, shall be less than $0.30f_c$ for life safety and Immediate Occupancy.

Observation(s)/Finding(s): The axial stresses in columns are less than 0.1f'c for gravity loads in both storeys. The stresses due to overturning moment are less than the limited value of 0.3f'c.

Method: The ratio of total loads of a storey to the summation of cross-sectional area of all columns of the storey was taken to obtain average stress of a column in a particular storey for Life

safety performance level. Equation 4 is used to calculate axial stresses due to overturning moment and compared with the value of 0.3f'c of columns.

$$p_{ot} = \frac{1}{m}\left(\frac{2}{3}\right)\left(\frac{Vh_n}{Ln_f}\right)\left(\frac{1}{A_{col}}\right) \qquad (4)$$

Where

n_f =Total number of frames in the direction of loading.

V = Pseudo lateral force

h_n = total height of building

L = total length of frame

m = modification factor.

A_{col} = Area of end column of frame.

Comment: Compliant

CONCRETE COLUMNS

Provision: All concreted columns shall be doweled into the foundation for life Safety, and the dowels shall be able to develop the tensile capacity of reinforcement in column of lateral-force-resisting system for Immediate Occupancy.

Observation(s)/Finding(s): All columns are doweled into foundation as per provided drawing.

Comment: Compliant

APPENDIX C: ASCE 31-03 SUPPLEMENTARY CHECKLIST OBSERVATIONS FOR BUILDING-1

ASCE 31-03 Section C3.7.8S gives details of checks for immediate occupancy performance level. All these checks for the building are described below:

FLAT SLAB FRAMES

Provision: The lateral-force-resisting system shall not be a frames consisting of columns and a flat slab/plate without beams.

Observation(s)/Finding(s): Frame structure is provided.

Comment: Compliant

CAPTIVE COLUMN

Provision: There shall be no columns at a level with height/depth ratios less than 50 percent of the nominal height/depth ratio of the typical columns at that level for life safety and 75 percent for Immediate Occupancy.

Observation(s)/Finding(s): No Captive columns are present.

Comment: Not Applicable

NO SHEAR FAILURES

Provision: The shear capacity of frame members shall be able to develop the moment capacity at ends of the members.

Observation(s)/Finding(s): The shear capacity of the frame elements is found to be greater than the expected shear stress.

Method: Shear capacity of beams is calculated and compared with the shear obtained by dividing moment capacity of beam by span of frame.

Comment: Compliant

STRONG COLUMN WEAK BEAM

Provision: The sum of moment capacity of the columns shall be 20 percent greater than that of the beams at frame joints.

Observation(s)/Finding(s): Capacity of beams on majority of beam column joints is greater than the column's capacity.

Method: Flexural capacities of column and beams were determined at joints using Response 2000 and compared.

Comment: Non-compliant for most of the cases

BEAM BARS

Provision: At least two longitudinal top and two longitudinal bottom bars shall extend continuously throughout the length of each frame beam. At least 25 percent of the longitudinal bars provided at the joints for either positive or negative moment shall be continuous throughout the length of the members for Life Safety and Immediate Occupancy

Observation(s)/Finding(s): Minimum two bars are provided continuous on top and bottom sides of beams that is more than 25% of the total longitudinal reinforcement.

Comment: Compliant

COLUMN-BAR SPLICES

Provision: All column bar lap splice lengths shall be greater than $35d_b$ for Life Safety and $50d_b$ for Immediate Occupancy, and shall be enclosed by ties spaced at or less than $8d_b$ for Life Safety and Immediate Occupancy. Alternative, column bars shall be spliced with mechanical couplers with a capacity of at least 1.25 times the nominal yield strength of the spliced bar

Observation(s)/Finding(s): Column splice length is at $48d_b$ and ties are spaced at greater than $8d_b$.

Comment: Non-compliant

BEAM-BAR SPLICES

Provision: The lap splices or mechanical couplers for longitudinal beam reinforcing shall not be located within $L_b/4$ of the joints and shall not be located in the vicinity of potential plastic hinge locations.

Observation(s)/Finding(s): Not calculated because no details for the splice lengths are provided.

Comment: No Information

COLUMN-TIE SPACING

Provision: Frame columns shall have ties spaced at or less than d\4 for Life Safety and Immediate Occupancy throughout their length and at or less than $8d_b$ for Life Safety and Immediate Occupancy at all potential plastic hinge locations.

Observation(s)/Finding(s): Ties spacing for columns is #3 bars at 8 inches center to center.

Comment: Non-compliant

STIRRUP SPACING

Provision: All beams shall have stirrups spaced at or less than d/2 for life Safety and Immediate Occupancy throughout their length. At potential plastic hinge locations, stirrups shall be spaced at or less than the minimum of $8d_b$ or d/4 for life Safety and Immediate Occupancy.

Observation(s)/Finding(s): Spacing for stirrup in beam is maximum 7" at mid span and maximum 6" at potential hinge locations.

Comment: Non-compliant

JOINT REINFORCING

Provision: Beam-column joints shall have ties spaced at or less than 8db for life safety and immediate occupancy.

Observation(s)/Finding(s): No information is provided.

Comment: No Information.

JOINT ECCENTRICITY

Provision: There shall be no eccentricities larger than 20 percent of the smallest column plan dimension between girder and column centrelines. This statement shall apply to the Immediate Occupancy Performance level only.

Observation(s)/Finding(s): Only one joint with beam B11 and column C1 shows more than 20% eccentricity.

Comment: Non-Compliant

STIRRUP AND TIE HOOKS

Provision: The beam stirrups and column ties shall be anchored into the member cores with Hooks of 135 or more. This Statement shall apply to the Immediate Occupancy Performance level only.

Observation(s)/Finding(s): Hooks are of 135 degrees

Comment: Compliant

DEFLECTION COMPATIBILITY

Provision: Secondary components shall have the shear capacity to develop the flexural strength of the components for life safety and shall meet the requirement of sections 4.4.1.4.9, 4.4.1.4.10, 4.4.1.4.11 and 4.4.1.4.12 and 4.4.1.4.15 of ASCE31-03 for Immediate Occupancy.

Observation(s)/Finding(s): There is no secondary component present in the structure.

Comment: Not Applicable

FLAT SLABS

Provision: Flat slabs/plates not part of lateral force resisting system shall have continuous bottom steel through the column joints for Life Safety and Immediate Occupancy.

Observation(s)/Finding(s): No flat slabs are present.

Comment: Not applicable

DIAPHRAGM CONTINUITY

Provision: The diaphragms shall not be composed of split- level floor and shall not have expansion joints.

Observation(s)/Finding(s): No expansion joints are present.

Comment: Compliant.

PLAN IRREGULARITIES

Provision: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corner or other location of plan irregularities this statement shall apply to the Immediate Occupancy performance level only.

Observation(s)/Finding(s): No re-entrant corners present in the building

Comment: Not Applicable

DIAPHRAGM REINFORCEMENT AT OPENINGS

Provision: There shall be reinforcement around all diaphragm openings larger than 50 percent of the building width in either major plan dimension. This statement shall apply to the Immediate Occupancy performance level only.

Observation(s)/Finding(s): There is no opening present which is larger than 50% of the building width in either major plan dimension.

Comment: Not applicable

APPENDIX D: MODIFIED STRUCTURAL CHECKLIST FOR PAKISTAN FOR BUILDING

In addition to ASCE 31 screening phase (Tier -1), some additional factors, modified according to local conditions, are designed for Pakistan as discussed below.

PROPORTION OF INFILL WALLS:

Provision: The height-to-thickness ratio of the infill walls at each story shall be less than 9 for life safety in areas of moderate seismicity, 10 for collapse prevention in areas of high seismicity, and 15 for collapse prevention in areas of moderate seismicity.

Observation(s)/Finding(s): Masonry walls of the building are 9 inches and 3 inches thick with height of 8.5 feet. The height-to-thickness ratio of the infill walls is 11 and 34 respectively.

Comment: Non-Compliant

SOLID WALL

Provision: The infill walls shall not be of cavity constructions.

Observation(s)/Finding(s): Masonry walls of the buildings are solid block walls.

Comment: Compliant

COLUMN ASPECT RATIO

Provision: The column clear height divided by the minimum column cross sectional dimension shall be less than 10 for building for the ground story, and less than 14 for the upper stories.

Observation(s)/Finding(s): Columns at ground storey and first storey have aspect ratio of 5.67.

Comment: Compliant

OVER ALL CONSTRUCTION QUALITY

Provision: The construction quality shall be good or fair but not poor.

Observation(s)/Finding(s): Good

Comment: Compliant

APPENDIX E: GEOLOGICAL SITE HAZARD AND FOUNDATION CHECKLIST FOR BUILDING-1

ASCE 31-03 Section C3.8 gives details of checks for geological site hazards and foundations for moderate to high seismicity level. All these checks for the building are described below:

LIQUEFACTION

Provision: 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 feet under the building for life Safety and Immediate Occupancy.

Observation(s)/Finding(s): Carrying out liquefaction checks is beyond the scope of the work.

Comment: No-Information

SLOPE FAILURE

Provision: The building site shall be sufficiently remote from potential earthquake induced slope failures or rock falls to be unaffected by such failures or shall be capable of accommodating any predicted movements without failure.

Observation(s)/Finding(s): The terrain of the building site is level.

Comment: Compliant

SURFACE FAULT RUPTURE

Provision: Surface fault rupture and surface displacement at the building site is not anticipated

Observation(s)/Finding(s): No fault is present in the vicinity of building.

Comment: Compliant

FOUNDATION PERFORMANCE

Provision: There shall be no evidence of excessive foundation movement such as settlement or heave that would affect the integrity or strength of the structure

Observation(s)/Finding(s): The structure does not show evidence of excessive foundation movement as no visual cracking or deformations plinth beam and column joints was observed.

Comment: Compliant

DETERIORATION

Provision: There shall be no evidence that foundation elements have deteriorated due to corrosion, sulphate attack, material breakdown, or other reasons in a manner that would affect the integrity or strength of the structure.

Observation(s)/Finding(s): This could not be observed on site.

Comment: No Information

OVERTURNING

Provision: The ratio of the horizontal dimension of the lateral-force-resisting system at the foundation level to the building height (base/height) shall be greater than $0.6S_{a.}$

Observation(s)/Finding(s): Spectral acceleration ($0.6S_a$) of the building is 0.12g and base to height ratio of the building is 2.1 and 1.2 in X and Y direction, respectively.

Comment: Compliant

TIES BETWEEN FOUNDATION ELEMENTS

Provision: The foundation shall have ties adequate to resist seismic forces where footings, piles and piers are not restrained by beams, slabs or soils classified as Class A, B, or C

Observation(s)/Finding(s): Plinth beams are provided above foundation acting as tie element between foundations.

Comment: Compliant

SLOPING SITES

Provision: The difference in foundation embedment depth from one side of the building to another shall not exceed one story in height. This statement shall apply to the Immediate Occupancy Performance Level only.

Observation(s)/Finding(s): It is found within the specified limits.

Comment: Compliant

APPENDIX F: ASCE 31-03 STRUCTURAL CHECKS FOR UNREINFORCED MASONRY PART OF BUILDING

MASONRY UNITS

Provision: There shall be no visible deterioration of masonry units.

Observation(s)/Finding(s): No visible deterioration was observed in the masonry units.

Comment: Compliant

MASONRY JOINTS

Provision: The mortar shall not be easily scraped away from the joints by hand with a metal tool, and there shall be no areas of eroded mortar.

Observation(s)/Finding(s): The masonry joints were found to be in good condition.

Comment: Compliant.

UNREINFORCED MASONRY WALL CRACKS

Provision: There shall be no existing diagonal cracks in wall elements greater than 1/8 inch for Life Safety and 1/16 inch for Immediate Occupancy or out-of-plane offsets in the bed joint greater than 1/8 inch for Life Safety and 1/16 inch for immediate occupancy, and shall not form an X pattern.

Observation(s)/Finding(s): No diagonal cracks in wall elements and out-of-plane offsets in bed joints were observed.

Comment: Compliant

LATERAL FORCE RESISTING SYSTEM

REDUNDANCY

Provision: There shall be no existing diagonal cracks in wall elements greater than 1/8 inch for Life Safety and 1/16 inch for Immediate Occupancy or out-of-plane offsets in the bed joint greater than 1/8 inch for Life Safety and 1/16 inch for immediate occupancy, and shall not form an X pattern.

Observation(s)/Finding(s): No diagonal cracks in wall elements and out-of-plane offsets in bed joints were observed.

Comment: Compliant

SHEAR STRESS CHECK

Provision: The shear stress in the unreinforced masonry shear walls shall be less than 30 psi for clay units and 70 psi for concrete units for Life Safety and Immediate Occupancy.

Observation(s)/Finding(s): All values of average shear stress are greater than 70 psi.

Method: Shear stresses are calculated using Equation 5, provided below:

$$v_j^{avg} = \frac{1}{m}\left(\frac{V_j}{A_w}\right) \qquad (5)$$

Where

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

V_j = Storey shear

m = Component modification factor

Comment: Non-Compliant