



NAZARBAYEV  
UNIVERSITY

# **Assessment of Seismic Vulnerability of Building Structures in Almaty, Kazakhstan**

**Presenter:**

**Muhammad Sajjad**

**Research Supervisors:**

**Dr. Dichuan Zhang**

**Dr. Sung-Woo Moon**



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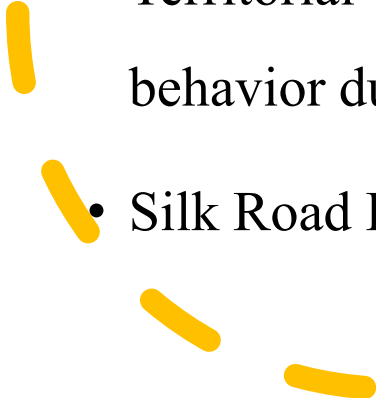


# Introduction



# Rationale for Project

- Earthquake is one of the most destructive phenomena among all natural disasters.
- Building performance is key to access the vulnerability associated with seismic event.
- Territorial scale is necessary to devise standards to better approximate building behavior during earthquake.
- Silk Road Economic Belt



# Rationale for Project

- This research is aimed especially at Kazakhstan as Kazakhstan's southern and south-eastern areas are in a seismically active zone.
- High seismic zones cover around 42.9 percent of Kazakhstan's land area. Over 7 million people reside here, more than 40% of the country's industrial capacity is concentrated here, and over 400 communities are situated here including the country's major industrial and cultural hub, Almaty, with a population of more than 1.7 million [1].



# Hypothesis

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Several types of building structures in Almaty region are vulnerable to earthquakes.

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Pre-cast emulated moment frame buildings constructed in 1970s to 1990s may not have sufficient capacity to resist large earthquakes.

# Objectives

- **Macroseismic Assessment**
  - To categorize the buildings as per EMS-98
  - To develop vulnerability curves based on Macroseismic assessment.
- **Analytical Assessment**
  - To evaluate the seismic performance of pre-cast emulated frame buildings through incremental dynamic analyses.
  - To develop seismic fragility curves for pre-cast emulated moment frame buildings based on incremental dynamic analyses results for
    - a) Immediate Occupancy
    - b) Life Safety and
    - c) Collapse Prevention



# Literature Review

# Seismicity in Almaty

- There were no significant earthquakes in Kazakhstan in the last century. The last significant earthquake, which largely damaged Almaty, occurred in 1911, more than a century ago.
- The city sits on a significant seismically active fault zone in the northern Tien Shan Mountain range called Almaty fault or Tien Shan fault.
- It is challenging to discover and examine faults that never reach the Earth's surface, which is common in areas where convergent activity is forming mountains. One example is the mountain-front fault, which is thought to have caused the Verney (Almaty) earthquake of 1887 of magnitude 7.3.
- The Chilik earthquake of 1889 occurred in Kazakhstan on a fault that had likely been immobile for thousands of years prior. [2]

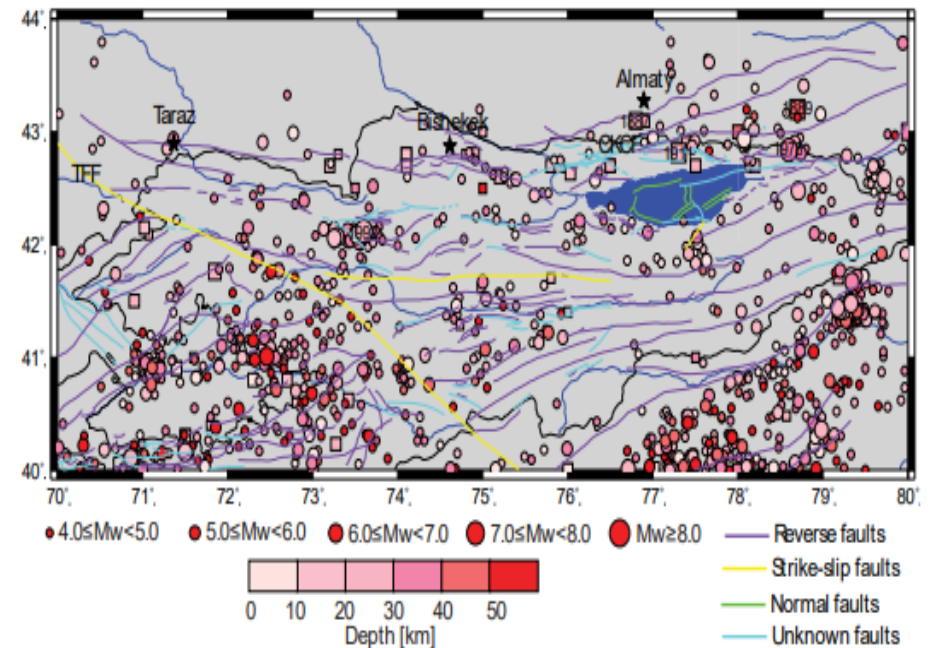


Fig: 1 Seismic map of south and south-east of Kazakhstan [3,4]

# Construction Practices in Almaty

- The development of the building regulatory system for seismic design in Kazakhstan was performed based on the analytical findings of Soviet researchers. Over the past 50 years, the Kazakhstani regulations for construction in seismic regions have been reissued six times [5]. However, due to the complexity of this document, it did not receive a comprehensive application from local experts.
- The first building norms and rules of the Republic of Kazakhstan, entitled Construction in Seismic Regions (SNIIP) [6], for the construction in seismic regions were issued in 1998. For that time, SNIIP represented a progressive regulatory document providing methods for determining seismic loads for designing buildings and structures in seismic regions [7].
- Compared to the former norms of the Soviet Union the seismic design code experienced several modifications, which were motivated by the aim of increasing the seismic safety of the designed structures, and the document was reissued in 2001 and 2006 [8].

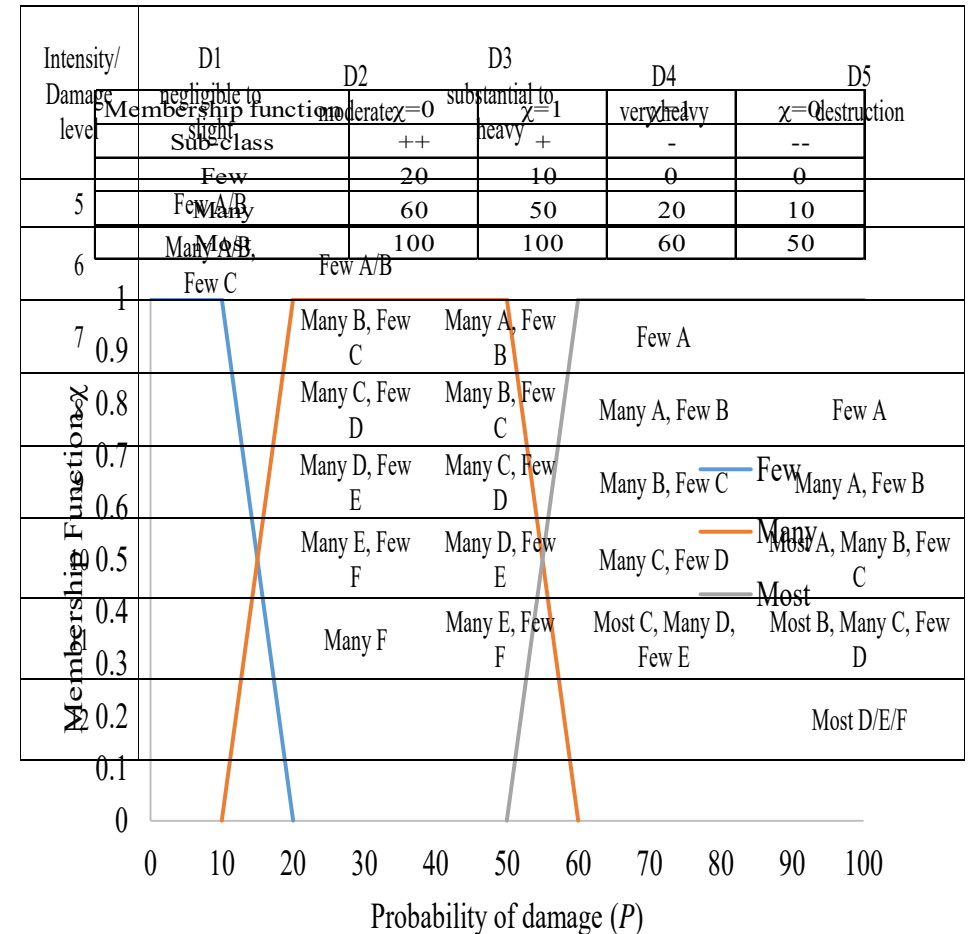
# Seismic Assessment Methods

1. Empirical Methods	1.1 P25 Scoring Method (Ihsan [9], F. G. Gülay and Semih S. Tezcan [10])	
	1.2 Vulnerability index methods	1.2.1 GNDT approach (Manjip Shakya[11], Faccioli [12])
		1.2.2 <a href="#">European Macro-Seismic (EMS) approach</a> (Bernardini, Rosa Nappi in Italy [13], Tariq Masood in Asia Pacific region [14])
1.3 Rapid Visual screening assessment methods (Wallace and Miller[15] , M.C. Ningthoujam in Manipur [16], Sudhir K. Jain in India [17], Daniele Perrone for hospitals [18])		
2. Analytical methods [4]	2.1 Non-Linear Static Analysis (M. Polese [19], L.C. Pagnini [20], M.N. Fardis [21])	
	2.2 <a href="#">Non-Linear Time History Analysis</a> (Sobhan [22], Moazam [23] and Asgarian [24])	

# EMS-98

- Classification of building typologies into six vulnerability classes (A to F), ranging from the most vulnerable to the least vulnerable.
- Used five degrees of damage levels marked by the letters D1, D2, D3, D4, and D5, ranging from minor damaged to completely collapsed
- Based on the assessment of historical earthquake structural damages, an implicit Damage Probability Matrix (DPM) is built using descriptive language ("Few", "Many", "Most") to relate the degree of damage to earthquake intensities for various vulnerability classes.
- Using fuzzy set theory, the language terms "few," "many," and "most" were transformed into quantitative counterparts on a scale of one (1) to hundred (100).

**Table 1 Damage probability for Class B**



**Fig 2 Membership Function  $\chi$**

# EMS-98

- For the likelihood of damage at each damage level, a binomial density function was introduced.

$$p(k) = \frac{5!}{k!(5-k)!} \left(\frac{\mu_D}{5}\right)^k \left(1 - \frac{\mu_D}{5}\right)^{5-k}$$

- By plugging the values of k and p(k) into above Equation, it is possible to determine the mean damage value ( $\mu_D$ ) for each vulnerability class at a variety of intensities and probable sub-classes, as depicted in table 2.

**Table 2 Damage probability for Class B**

Intensity	DPM	Sub-class ++			Sub-class +			Sub-class -			Sub-class --		
		p (k)	Damage level (k)	$\mu_D$	p (k)	Damage level (k)	$\mu_D$	p (k)	Damage level (k)	$\mu_D$	p (k)	Damage level (k)	$\mu_D$
5	Few D1	20	D1	0.2	10	D1	0.1	0	D1	0.0	0	D1	0.0
6	Many D1, Few D2	20	D2	1.0	10	D2	0.6	20	D1	0.2	10	D1	0.1
7	Many D2, Few D3	20	D4	1.8	10	D4	1.3	20	D3	1.0	10	D3	0.6
8	Many D3, Few D4	20	D5	2.7	10	D5	2.2	20	D4	1.8	10	D4	1.3
9	Many D4, Few D5	20	D5	3.6	10	D5	3.2	20	D5	2.7	10	D5	2.2
10	Many D5	60	D5	4.5	50	D5	4.4	20	D5	3.6	10	D5	3.2

A low-angle, upward-looking photograph of several modern skyscrapers with glass facades. The buildings are arranged in a way that they converge towards the top center of the frame, creating a strong sense of height and scale. The sky is a vibrant blue with scattered white clouds. A bright sun is visible near the top center, creating a lens flare effect. The overall color palette is dominated by blues and whites.

# Macroseismic Assessment

# Building Structures in Almaty



Fig: 3 Pre-cast Concrete Emulated Moment Frame



Fig: 4 Unreinforced Masonry with adobe bricks



Fig: 5 Pre-cast Concrete Wall Panels



Fig: 6 Reinforced Concrete

# Categorization of Buildings

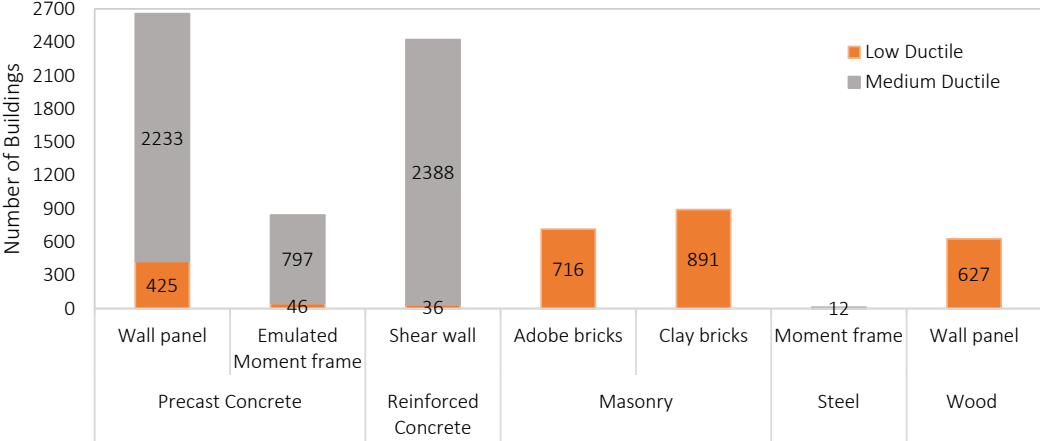


Fig: 7 Categorization of Residential Buildings

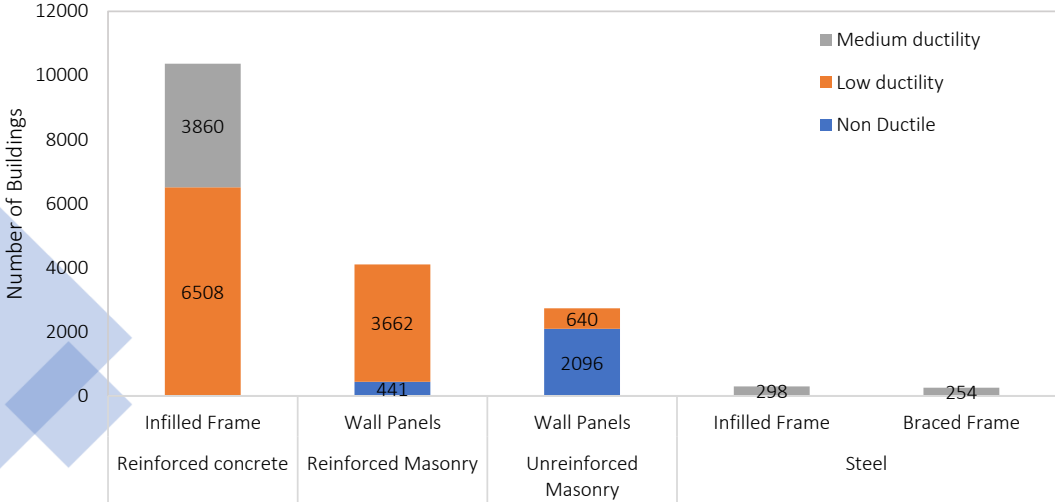


Fig: 9 Categorization of Commercial Buildings

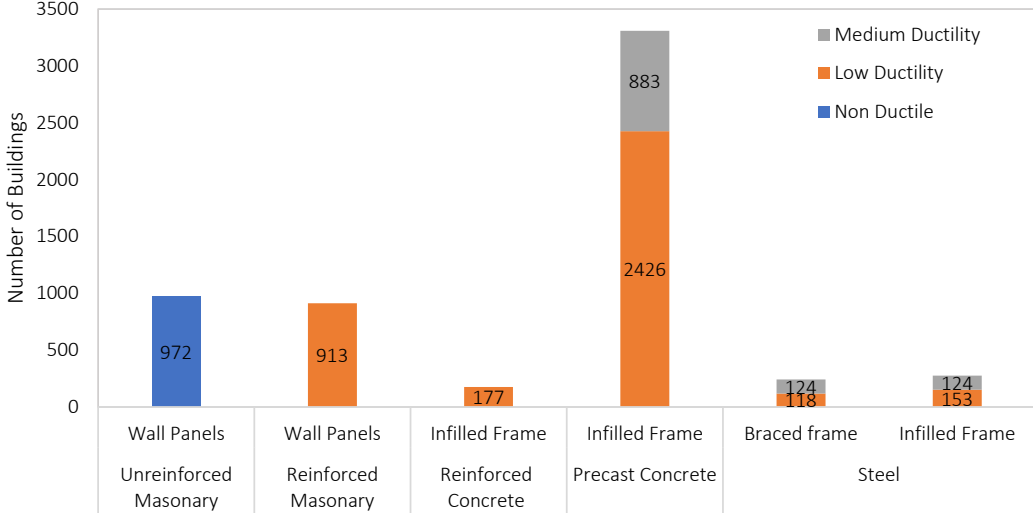


Fig: 8 Categorization of Industrial Buildings

# Vulnerability and Ductility Index

- In this study, we employ curve-fitting to find the best match between the discrete points in Figure 10 and the mean damage-intensity curves using the equation given below.

$$\mu_D = 2.5 \left[ 1 + \tanh \left( \frac{I + 6.25V - 13.1}{Q} \right) \right]$$

Table 3 Earthquake Intensity versus mean damage of each class

Vulnerability Index (V)	Vulnerability Class					
	A	B	C	D	E	F
Sub-class ++	0.98	0.86	0.7	0.54	0.38	0.21
Sub-class +	0.91	0.78	0.62	0.46	0.29	0.13
Sub-class -	0.86	0.7	0.53	0.38	0.22	0.05
Sub-class --	0.78	0.62	0.45	0.29	0.14	-0.03
Average	0.88	0.74	0.58	0.42	0.26	0.1
Ductility Index (Q)	1.7	2.1	2.1	2.2	2.2	2.3

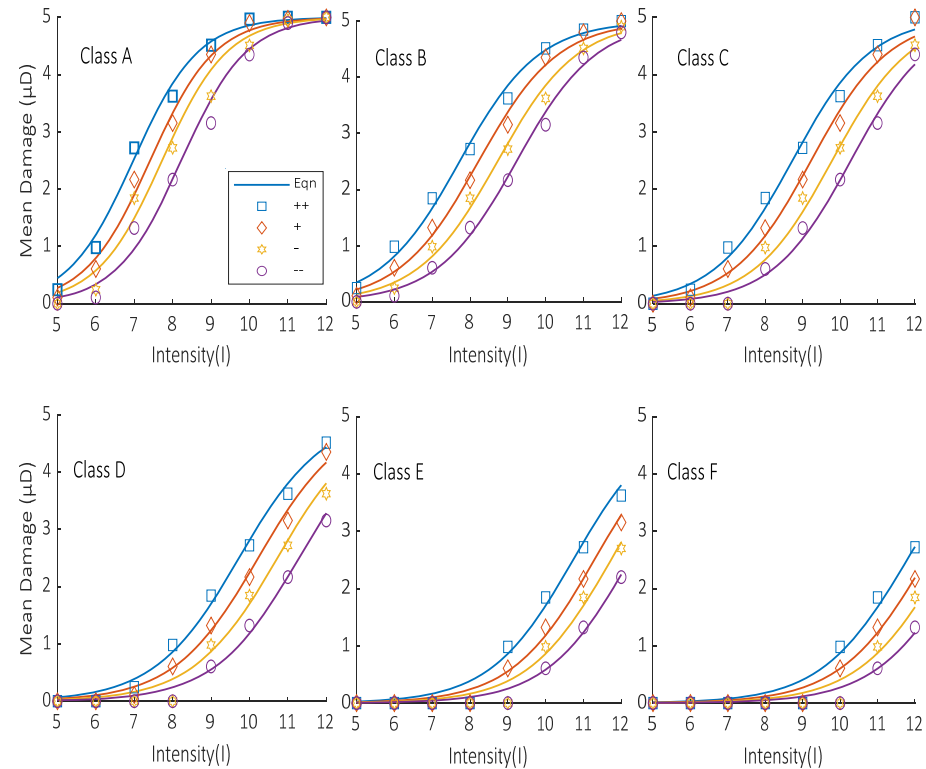


Fig 10 Earthquake Intensity versus mean damage of each class

# Mapping of Residential Buildings to EMS-98 damage grades

Table 4 Mapping of Residential Buildings to EMS-98

Residential buildings in Almaty			EMS-98 scale		Mapping		
Construction Materials	Lateral Force Resisting Systems	Ductility	Type of Structures	Vulnerability Class Ranges	Assigned Vulnerability Class	V	Q
Precast Concrete	Wall Panels	Low	Wall without ERD	B-D	B+	0.78	2.1
		Medium	Wall with moderate level of ERD	C-E	C++	0.7	2.1
	Emulated Moment Frames	Low	Frame without ERD	A-D	B	0.74	2.1
		Medium	Frame with moderate level of ERD	B-E	C+	0.62	2.1
Reinforced concrete	Shear Walls	Low	Wall without ERD	B-D	B-	0.7	2.1
		Medium	Wall with moderate level of ERD	C-E	D++	0.54	2.2
Unreinforced Masonry	Adobe Walls	Low	Adobe (earthquake brick)	A-B	A++	0.98	1.7
	Brick Walls	Low	Unreinforced with RC floors	B-D	B++	0.86	2.1
Steel	Moment Frames	Medium	Steel structures	C-F	D+	0.46	2.2
Wood	Wall Panels	Low	Timber structures	B-E	B++	0.86	2.1

# Mapping of Industrial Buildings to EMS-98 damage grades

Table 5 Mapping of Industrial Buildings to EMS-98

Industrial buildings in Almaty			EMS-98 scale		Mapping		
Construction Materials	Lateral Force Resisting Systems	Ductility	Type of Structures	Vulnerability Class Ranges	Assigned Vulnerability Class	V	Q
Reinforced concrete	Infilled Frame	Low	Frame with moderate level of ERD	B-E	B	0.74	2.1
Precast Concrete		Low			B+	0.78	2.1
		Medium			C+	0.62	2.1
Reinforced masonry	Wall Panels	Low	Reinforced or Confined	C-E	C	0.575	2.1
Unreinforced masonry		None	Unreinforced with RC floors	B-D	B	0.74	2.1
Steel	Braced frame	Low	Steel structures	C-F	C-	0.53	2.1
		Medium			D-	0.38	2.2
	Infilled Frame	Low			C+	0.62	2.1
		Medium			D	0.415	2.2

# Mapping of Commercial Buildings to EMS-98 damage grades

Table 6 Mapping of Commercial Buildings to EMS-98

Commercial buildings in Almaty			EMS-98 scale		Mapping		
Construction Materials	Lateral Force Resisting Systems	Ductility	Type of Structures	Vulnerability Class Ranges	Assigned Vulnerability Class	V	Q
Reinforced concrete	Infilled Frame	Low	Frame with moderate level of ERD	B-E	B	0.74	2.1
		Medium			C+	0.62	2.1
Reinforced Masonry	Wall Panels	None	Reinforced or Confined	C-E	C++	0.7	2.1
		Low			C	0.575	2.1
Unreinforced Masonry	Wall Panels	None	Unreinforced with RC floors	B-D	B	0.74	2.1
		Low			B-	0.7	2.1
Steel	Infilled Frame	Medium	Steel structures	C-F	D	0.415	2.2
	Braced Frame				D-	0.38	2.2

# Vulnerability Curves of Residential Buildings

$$\mu_D = 2.5 \left[ 1 + \tanh \left( \frac{I + 6.25V - 13.1}{Q} \right) \right]$$

$$PGA = e^{\left( \frac{I - 9.82}{1.72} \right)} \text{ if } I > 5$$

- Unreinforced masonry, and wooden structures, both DBE and MCE predict a high likelihood of total destruction.

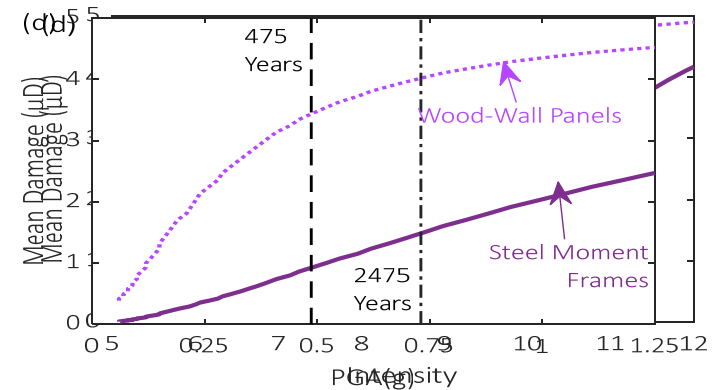
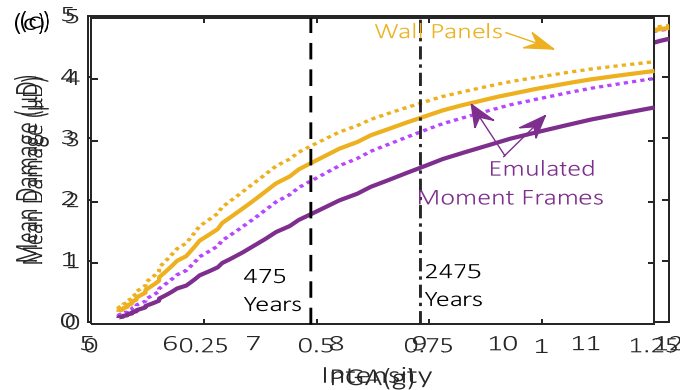
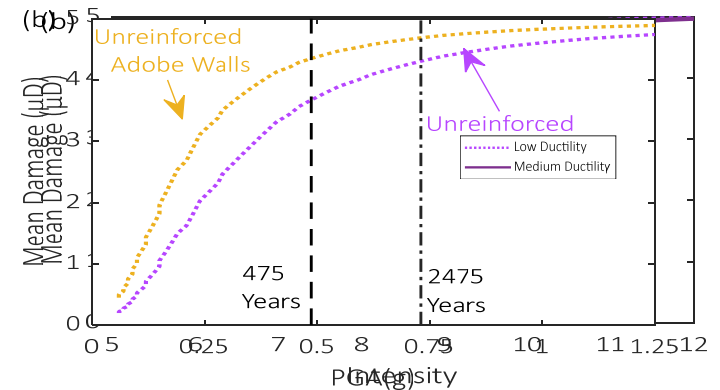
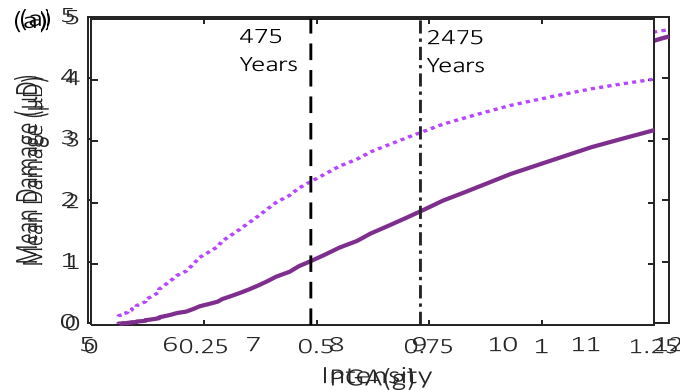


Fig. 12 Mean damage vs. PGA for different groups of residential buildings: (a) reinforced concrete; (b) unreinforced adobe walls; (c) masonry or precast concrete; (d) wood and steel.

# Vulnerability Curves of Industrial Buildings

$$\mu_D = 2.5 \left[ 1 + \tanh \left( \frac{I + 6.25V - 13.1}{Q} \right) \right]$$

unreinforced masonry,  
 reinforced concrete, and  
 precast concrete with low  
 ductility structures, both  
 DBE and MCE predict a  
 high likelihood of heavy to  
 very heavy damage.

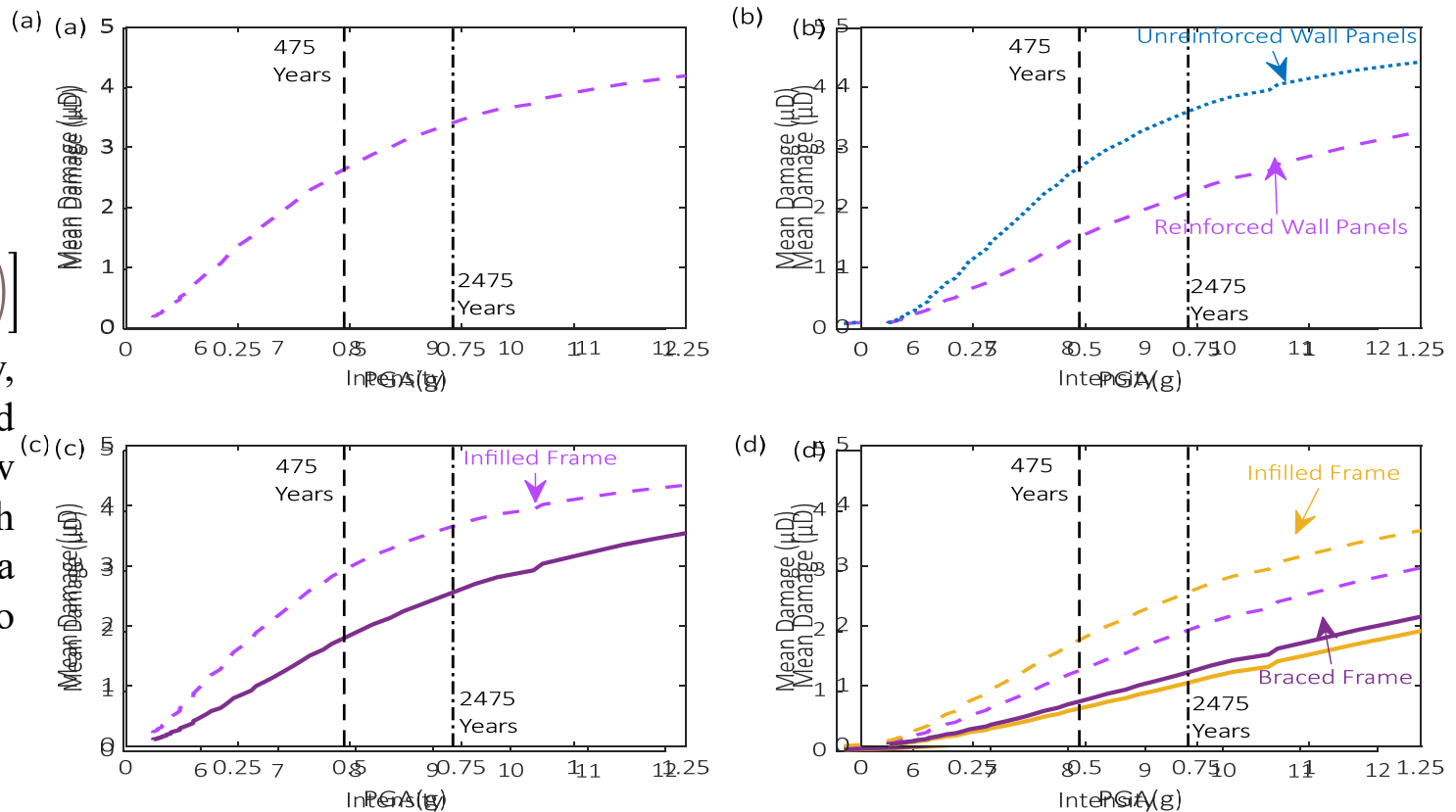


Fig. 14 Mean damage vs. Intensity for different types of industrial buildings: (a) reinforced concrete infilled wall, (b) masonry, (c) precast concrete, (d) steel.

# Vulnerability Curves of Commercial Buildings

$$\mu_D = 2.5 \left[ 1 + \tanh \left( \frac{I + 6.25V - 13.1}{Q} \right) \right]$$

- unreinforced masonry with no ductility and reinforced concrete with low ductility structures, both DBE and MCE predict a high likelihood of moderate to heavy damage.

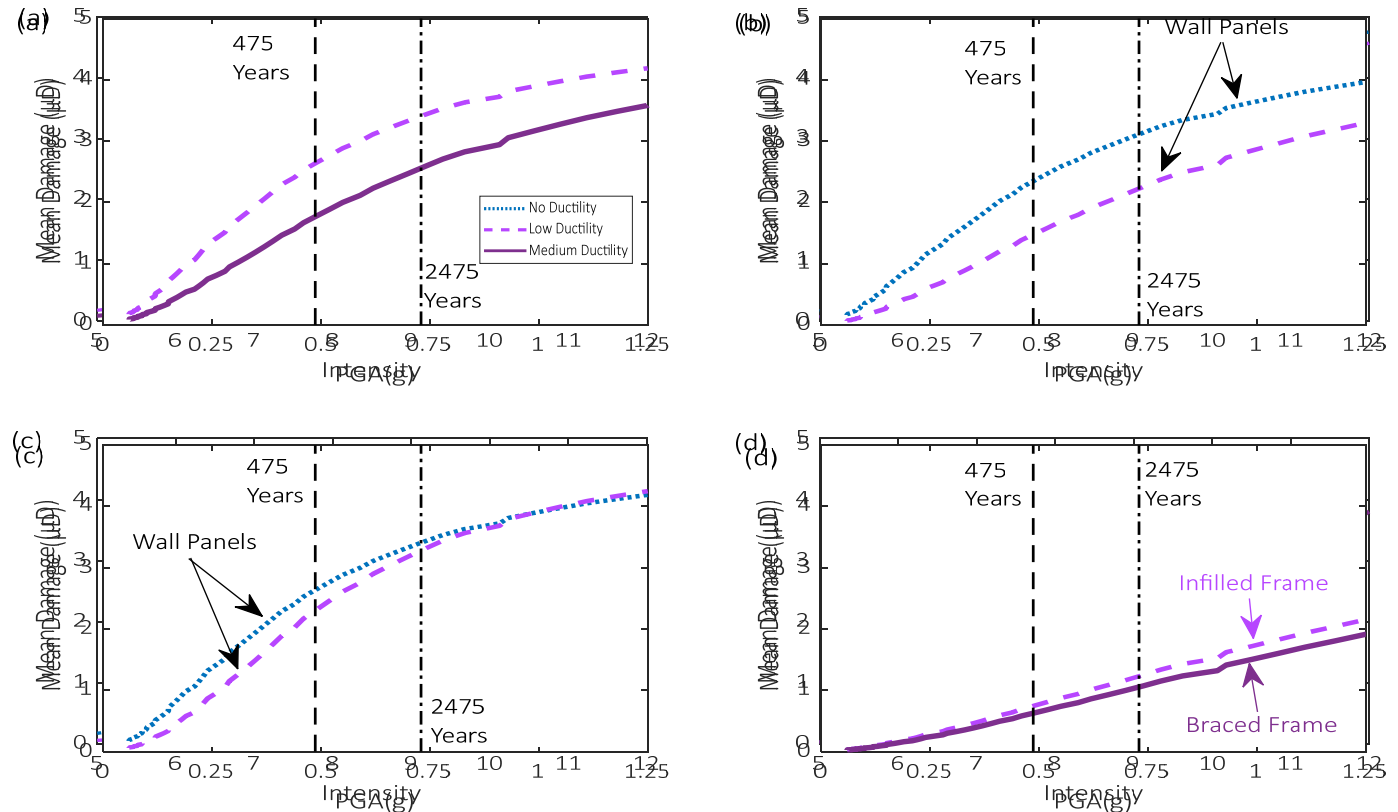
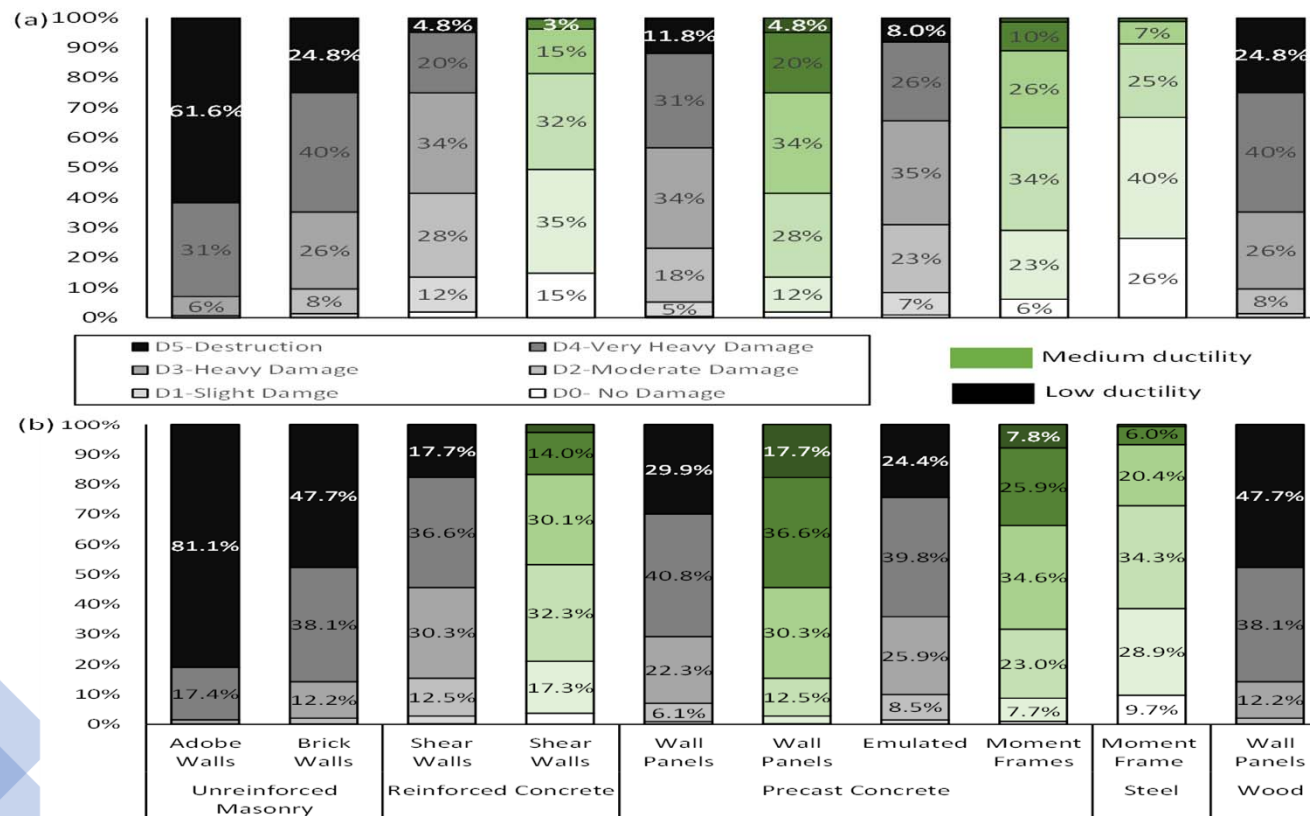


Fig. 16 Mean damage vs. PGAs for different groups of commercial buildings: (a) reinforced concrete infilled wall (b) unreinforced masonry (c) unreinforced masonry (d) steel.

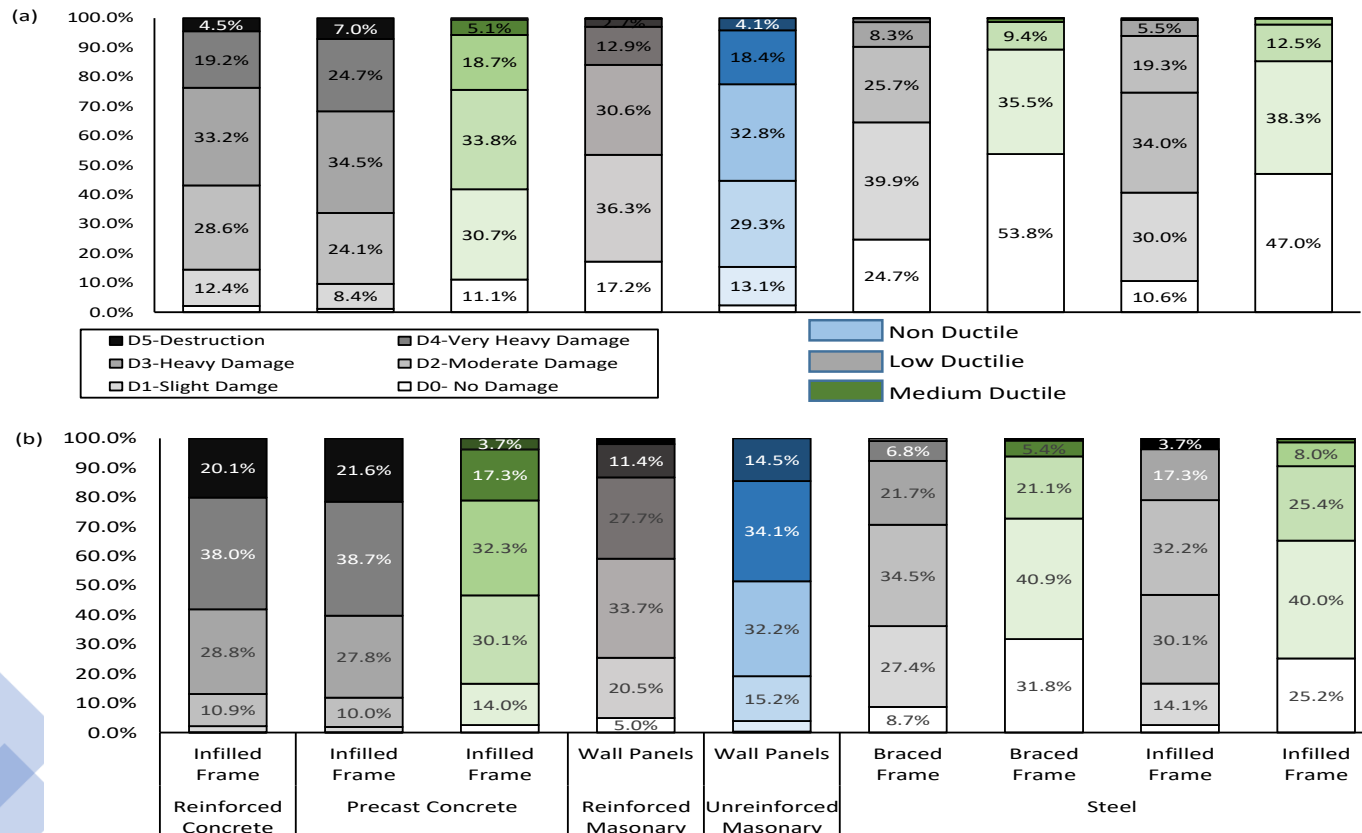
# Damage Probability for each damage grade of Residential buildings



- Unreinforced masonry, and wooden structures, both DBE and MCE predict a high likelihood of total destruction. Nevertheless, the danger of destruction is substantial, exceeding 20% under DBE and 40% under MCE.

Fig. 17 Residential buildings damage probabilities at (a) DBE (return period of 475 years) and (b) MCE (return period of 2475 years).

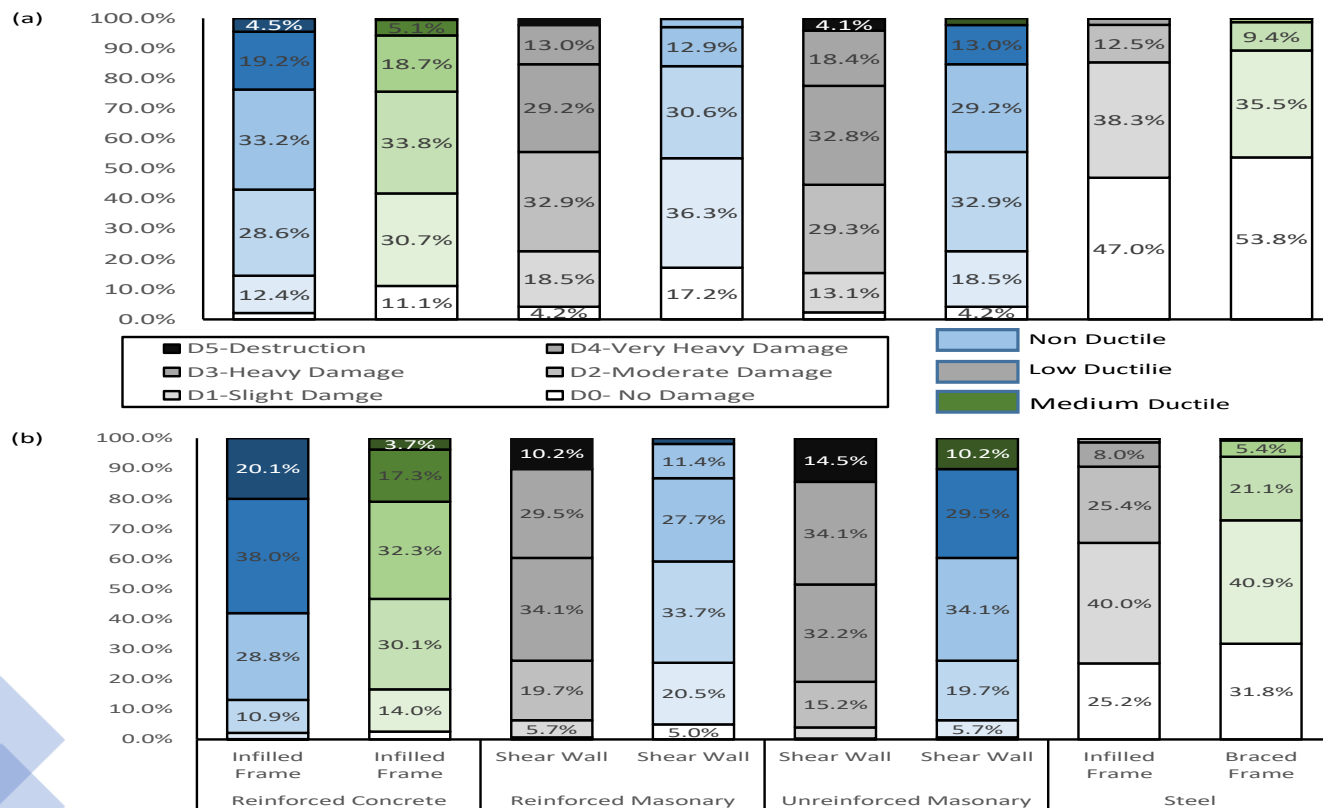
# Damage Probability for each damage grade of Industrial buildings



- Unreinforced masonry, reinforced concrete, and precast concrete with low ductility structures, both DBE and MCE predict a high likelihood of heavy to very heavy damage. Nonetheless, the risk of heavy damage is high, topping 18% in DBE and 34% in MCE.

Fig. 18 Industrial buildings damage probabilities at (a) DBE (return period of 475 years) and (b) MCE (return period of 2475 years).

# Damage Probability for each damage grade of Commercial buildings



- Unreinforced masonry with no ductility and reinforced concrete with low ductility structures, both DBE and MCE predict a high likelihood of moderate to heavy damage. Nonetheless, the risk of heavy damage is high, exceeding 25% in DBE and 32% in MCE.

Fig 19 Commercial buildings damage probabilities at (a) DBE (return period of 475 years) and (b) MCE (return period of 2475 years).

# Macroseismic Assessment Results

1. Unreinforced masonry and concrete with low ductility → Residential
2. Precast concrete → Industrial
3. Reinforced concrete → Commercial
4. For residential buildings, unreinforced masonry, and wood structures, both DBE and MCE predict a high likelihood of total destruction. Nevertheless, the danger of destruction is substantial, exceeding 20% under DBE and 40% under MCE.
5. For industrial buildings unreinforced masonry, reinforced concrete, and precast concrete with low ductility structures, both DBE and MCE predict a high likelihood of heavy to very heavy damage. Nonetheless, the risk of heavy damage is substantial, exceeding 18% in DBE and 34% in MCE.
6. For commercial buildings unreinforced masonry with no ductility and reinforced concrete with low ductility structures, both DBE and MCE predict a high likelihood of moderate to heavy damage. Nonetheless, the risk of moderate damage is high, exceeding 30% in DBE and 30% in MCE.

# Pre-cast Emulated Moment Frame

- Pre-cast emulated moment frame buildings have a high probability of sustaining heavy damage to collapse of the structure and constitute of more than 10% of the residential buildings. Therefore these buildings are selected for detailed assessment.



# Analytical Assessment

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# Selected Building Series

## 1. VT Series

Estimated time construction from 1970s to 1980s



## 2. VP Series

Estimated time construction from 1980s to 1990s



# Geometry of Building

## 1. VT Series

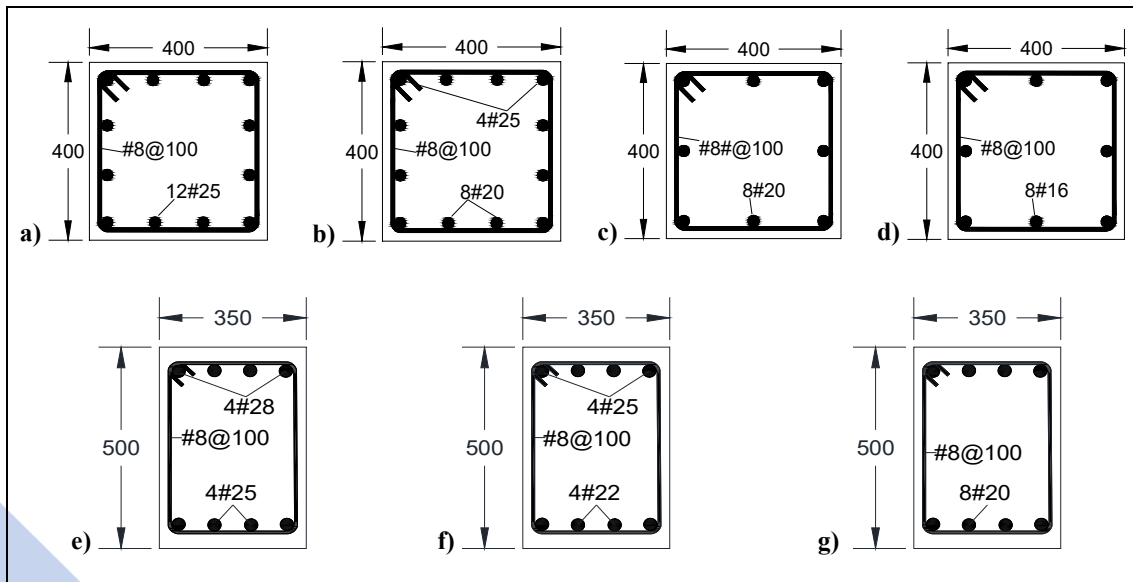


Fig. 22 Cross Section Details of VP Series a) Column of 1st floor b) Column of 2nd floor c) Column of 3rd floor d) Column of 4th and 5th floor e) Beam of 1st floor f) Beam of 2nd and 3rd floor and g) Beam of 4th and 5th floor.

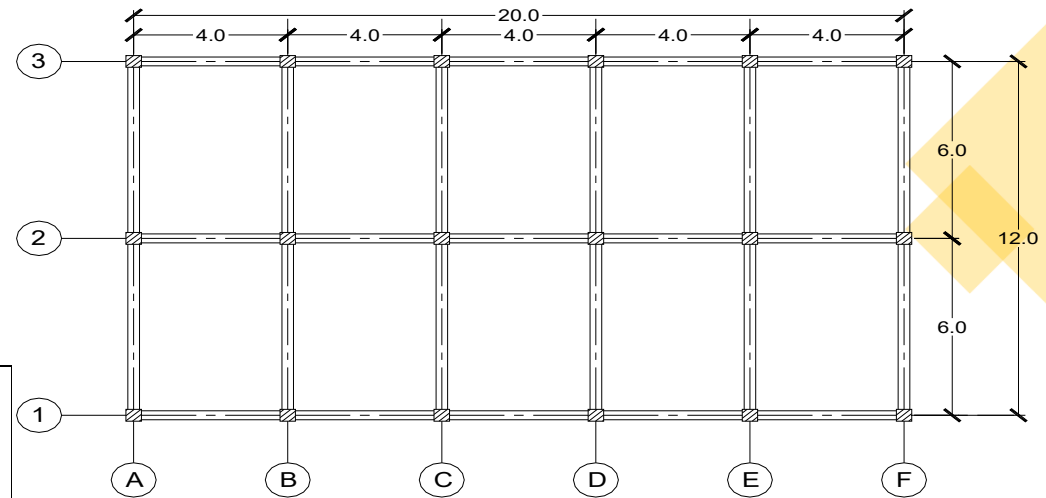


Fig. 20 Plan view

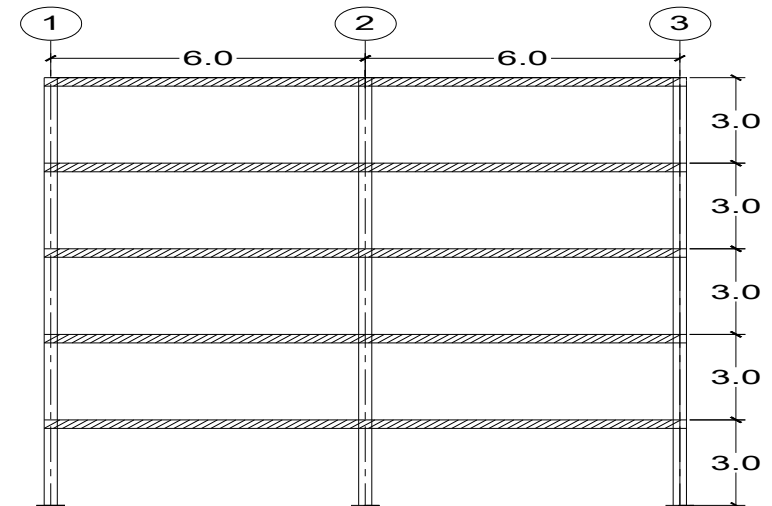


Fig. 21 Elevation view

# Geometry of Building

## 2. VP Series

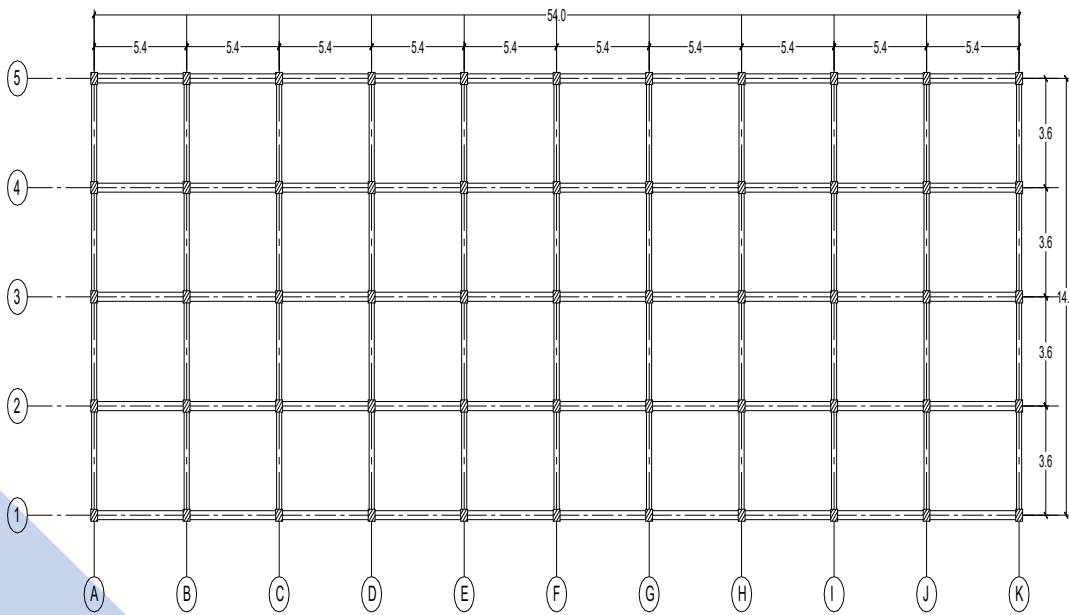


Fig. 23 Plan view

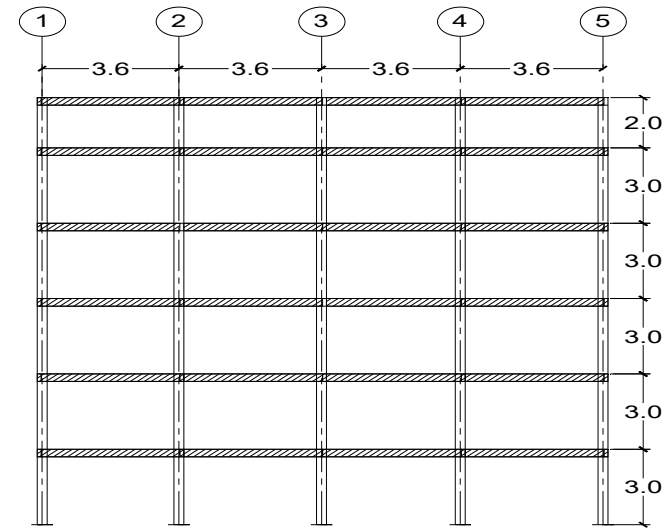


Fig. 24 Elevation view

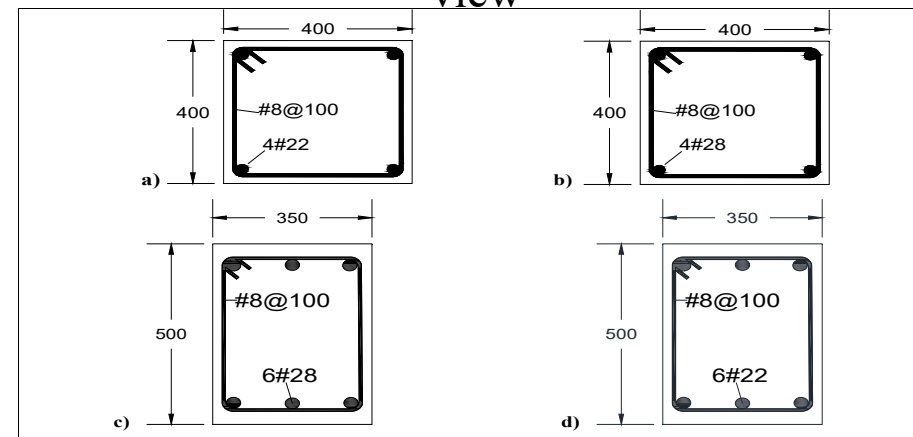


Fig. 25 Cross Section Details of VP Series a) Column of 1st to 5th floor b) Column of the technical floor c) Beam 1st of 5th floor and d) Beam technical floor.

# Design Strength

## 1. VT Series

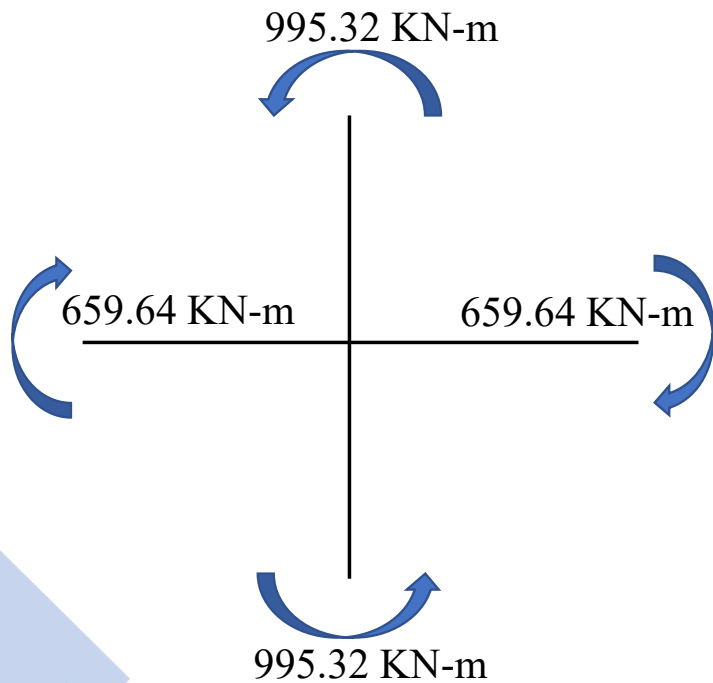


Fig. 26 Design Moment strength of 1<sup>st</sup> Floor

Table 7 Nominal Shear and Moment Strength of VT series buildings

	Floor Level	Nominal Shear $V_n$ (KN)	Nominal Moment $M_{nc}$ (KN-m)		Floor Level	Nominal Shear $V_n$ (KN)	Nominal Moment $M_{nb}$ (KN-m)	$\Sigma M_{nc}$ (KN-m)	$\Sigma M_{nb}$ (KN-m)	$\Sigma M_{nc} / \Sigma M_{nb}$	Strong Column weak Beam
Column	1st	297.25	541.66	Beams	1st	261.98	368.66	995.32	659.64	1.51	Satisfied
	2nd	297.25	453.66		2nd	261.98	290.98	768.38	581.96	1.32	Satisfied
	3rd	297.25	314.72		3rd	261.98	290.98	533.46	501.80	1.06	Not Satisfied
	4th	297.25	218.74		4th	261.98	210.82	381.06	421.63	0.90	Not Satisfied
	5th	297.25	162.32		5th	261.98	210.82	324.64	421.63	0.77	Not Satisfied

# Design Strength

## 2. VP Series

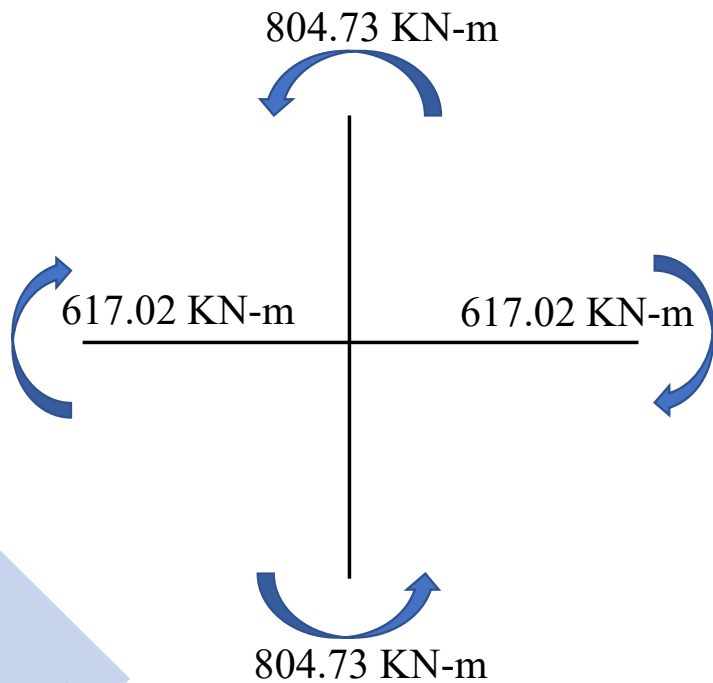


Fig. 27 Design Moment strength of 1<sup>st</sup> Floor

Table 8 Nominal Shear and Moment Strength of VP series buildings

	Floor Level	Nominal Shear $V_n$ (KN)	Nominal Moment $M_{nc}$ (KN-m)		Floor Level	Nominal Shear $V_n$ (KN)	Nominal Moment $M_{nb}$ (KN-m)	$\Sigma M_{nc}$	$\Sigma M_{nb}$	$\Sigma M_{nc} / \Sigma M_{nb}$	Strong Column weak Beam
Columns	1st	286.35	420.01	Beams	1st	264.12	308.51	804.73	617.02	1.30	Satisfied
	2nd	286.35	384.71		2nd	264.12	308.51	730.58	617.02	1.18	Not Satisfied
	3rd	286.35	345.86		3rd	264.12	308.51	649.40	617.02	1.05	Not Satisfied
	4th	286.35	303.54		4th	264.12	308.51	561.46	617.02	0.91	Not Satisfied
	5th	286.35	257.92		5th	264.12	308.51	386.10	500.24	0.77	Not Satisfied
	Technical	286.35	128.17		Technical	264.12	191.73	256.35	383.47	0.67	Not Satisfied

# Opensees Model

## 1. VP Series

### Considered Parameters

- ∨ Damping = 2%
- ∨ P-delta
- ∨ Gravity Load
- ∨ Rayleigh damping: 1<sup>st</sup> and 3<sup>rd</sup> mode
- ∨ Implicit Newmark Method

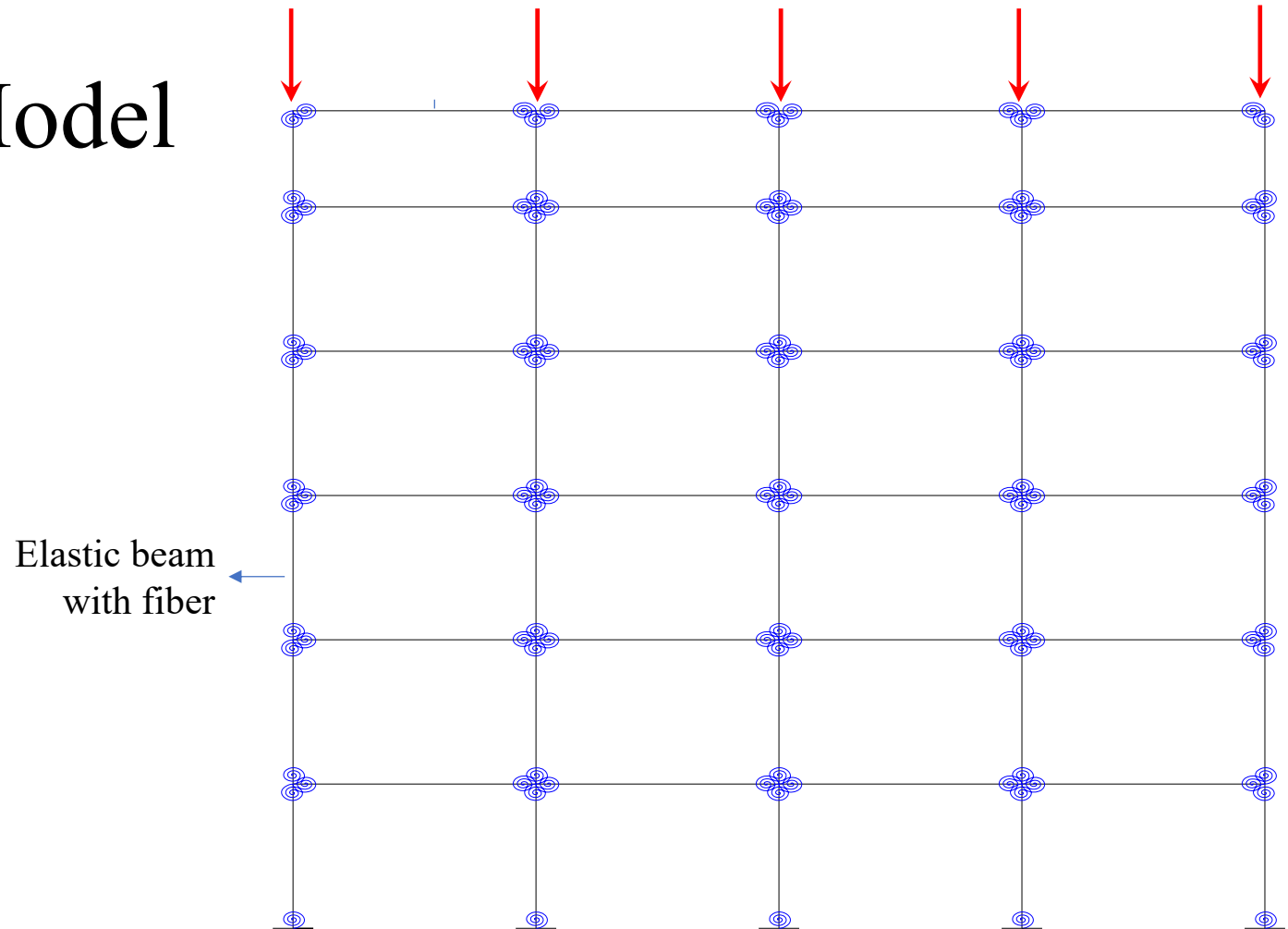
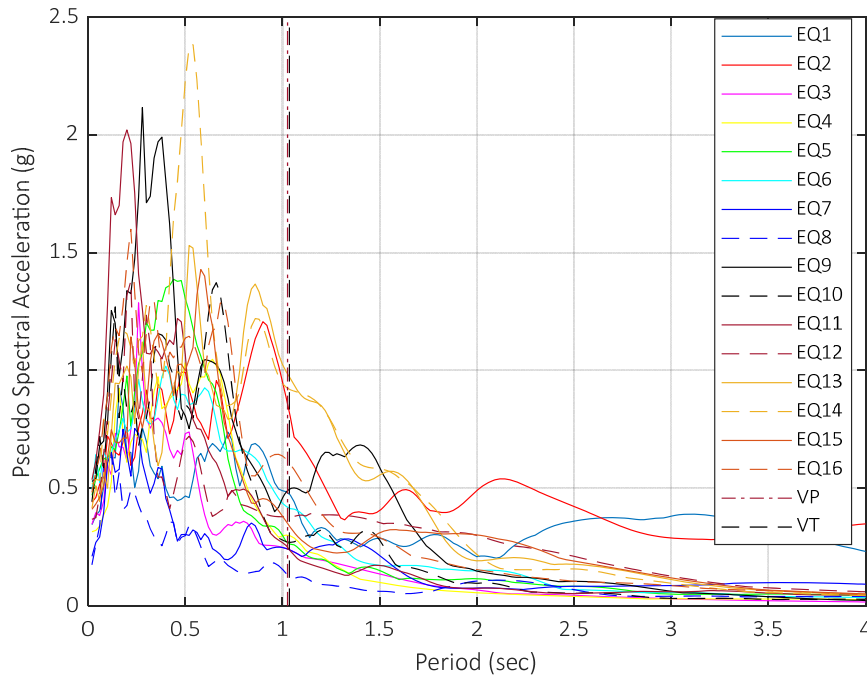


Fig. 28 Two-dimensional model of the VP Series

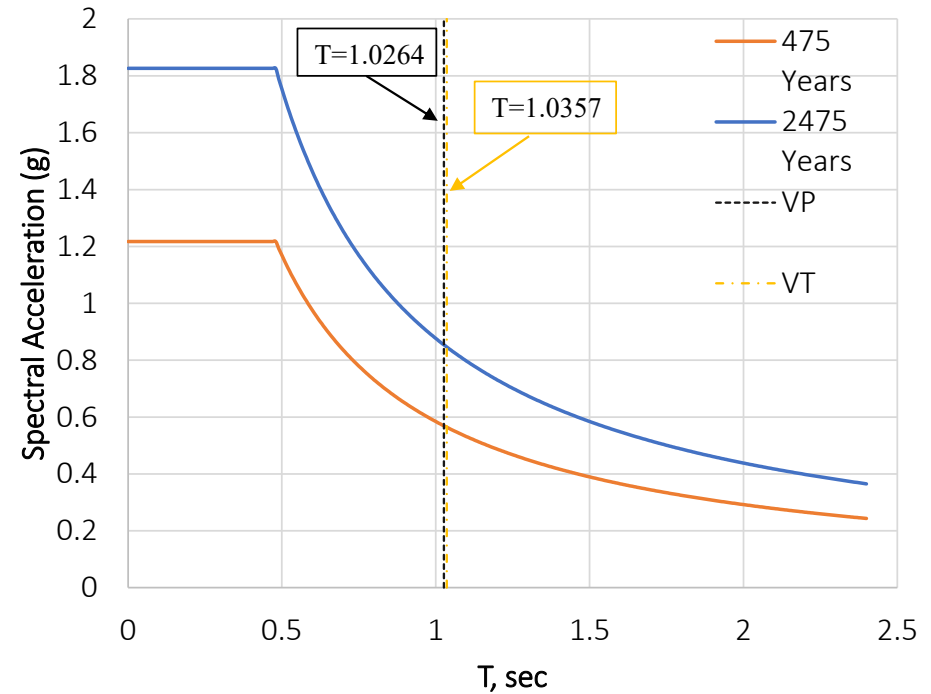
# Ground Motions

ID	Event	Magnitude	Year	Record	Component	Fault Type
1	Chi-Chi Taiwan	7.6	1999	CHY100	E - W	Reverse
2	Chi-Chi Taiwan	7.6	1999	CHY101	N - S	Reverse
3	Friuli Italy	6.5	1976	Tolmezzo	TMZ000	Reverse
4	Friuli Italy	6.5	1976	Tolmezzo	TMZ270	Reverse
5	Chi-Chi Taiwan	7.6	1999	TCU045	E - W	Reverse
6	Chi-Chi Taiwan	7.6	1999	TCU045	N - S	Reverse
7	San Fernando	6.6	1971	LA - Hollywood Stor FF	PEL090	Reverse
8	San Fernando	6.6	1971	LA - Hollywood Stor FF	PEL180	Reverse
9	Loma Prieta	6.9	1989	Capitola	CAP000	Reverse Oblique
10	Loma Prieta	6.9	1989	Capitola	CAP090	Reverse Oblique
11	Loma Prieta	6.9	1989	Gilroy Array #3	G03000	Reverse Oblique
12	Loma Prieta	6.9	1989	Gilroy Array #3	G03090	Reverse Oblique
13	Northridge	6.9	1994	Beverly Hills - 14145 Mulhol	MUL009	Reverse
14	Northridge	6.9	1994	Beverly Hills - 14145 Mulhol	MUL279	Reverse
15	Northridge	6.9	1994	Canyon Country - W Lost Cany	LOS000	Reverse
16	Northridge	6.9	1994	Canyon Country - W Lost Cany	LOS090	Reverse

- Response Spectrum of Earthquakes



- Design Response Spectrum of Almaty



- Spectral acceleration with increment of 0.05g is introduced to model for each earthquake until it reaches the performance limit of collapse prevention

# General Results

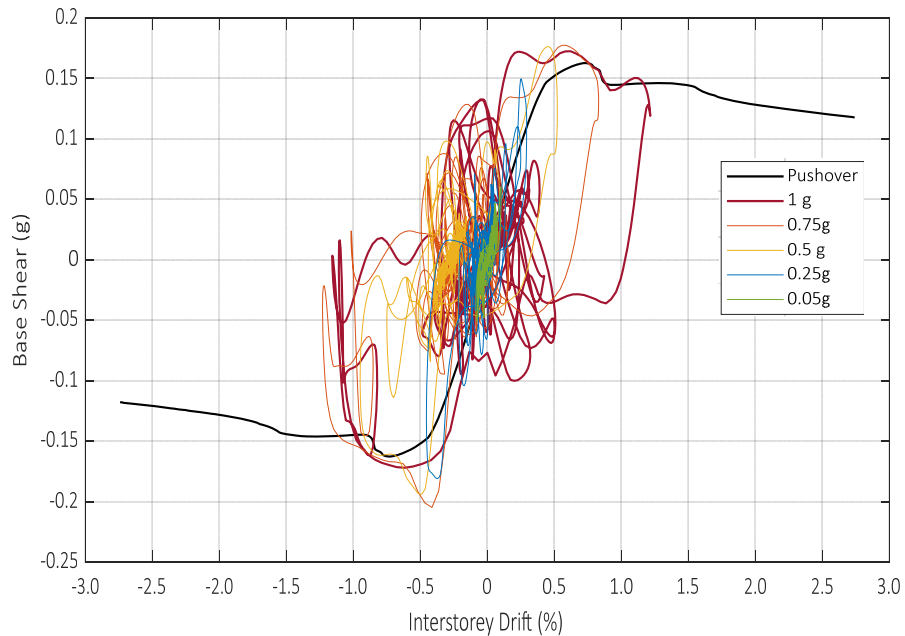


Fig. 29 Hysteresis Plot of VP series at various values of Sa

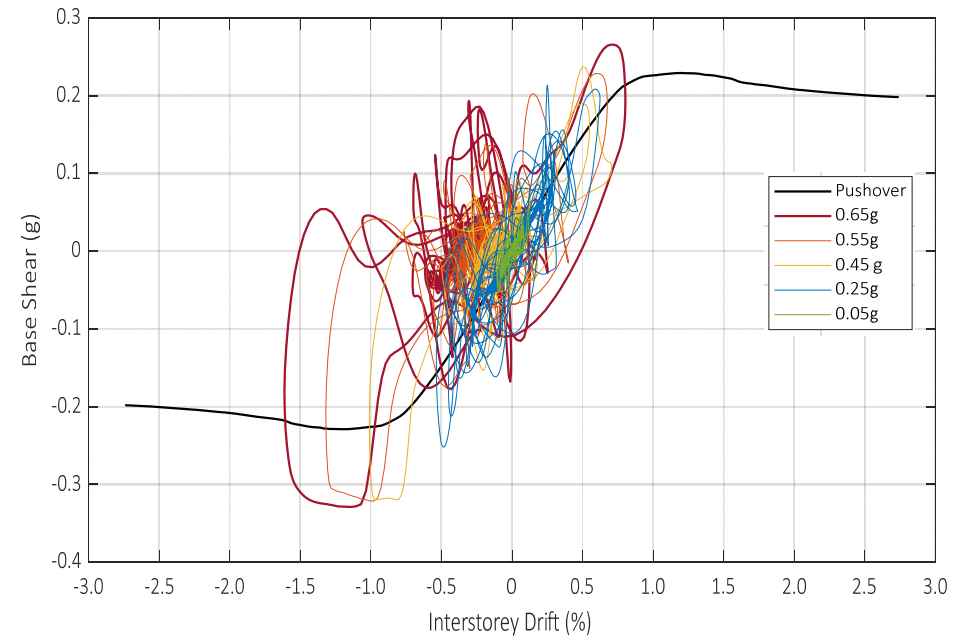


Fig 30 Hysteresis Plot of VT series at various values of Sa

# General Results

## ❖ Plastic Hinge Formation

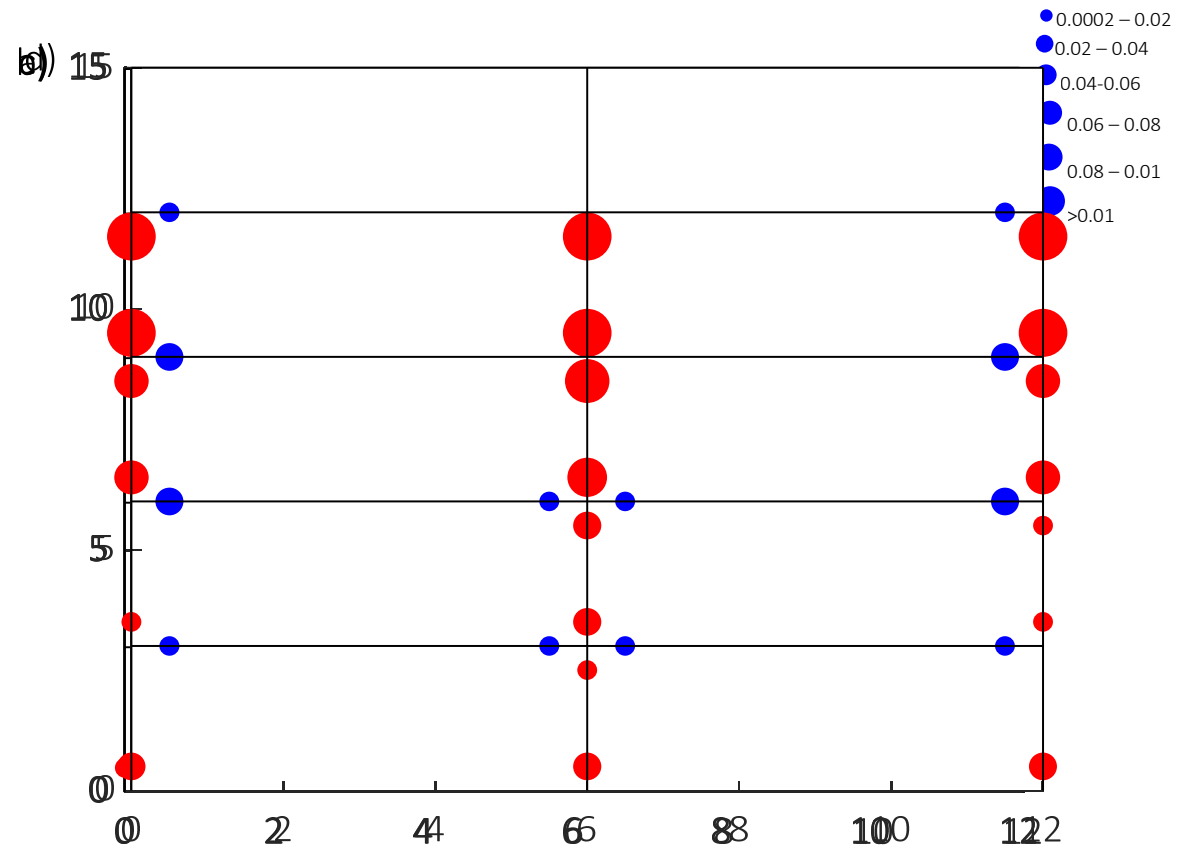


Fig. 3.23 Plastic Hinge Formation of WT Series at 0.25g

# General Results

## ❖ Plastic Hinge Formation

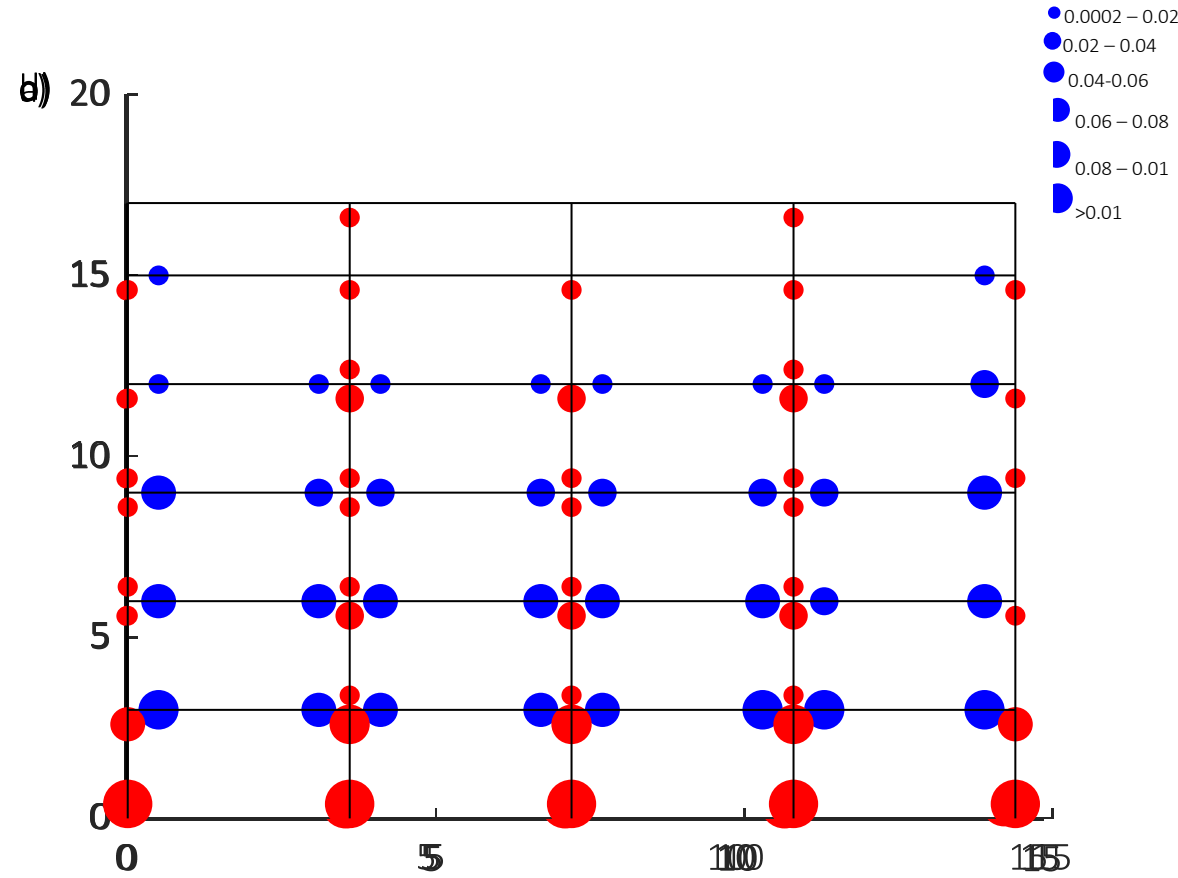


Fig. 38 Plastic Hinge Formation of VP Series at d) 0.25 g

# General Results

## ❖ Maximum Interstorey Drift

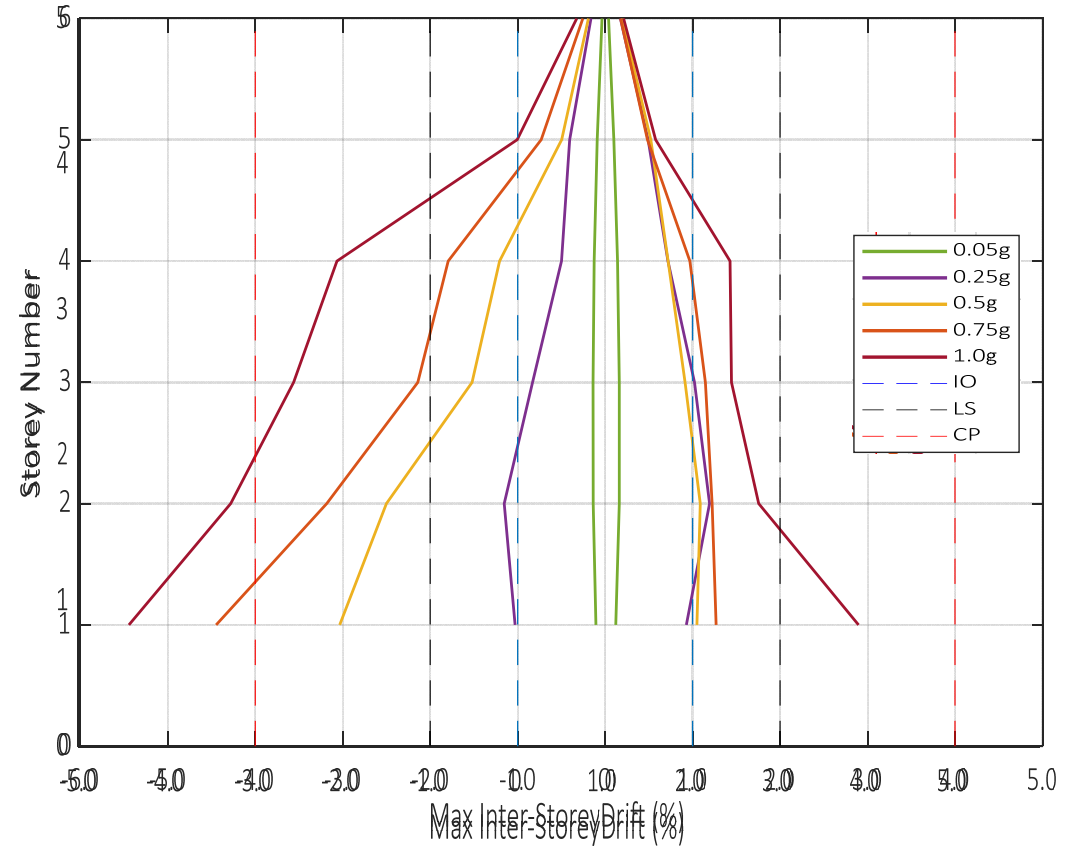


Fig 49 Maximum Inter-storey Drift of each Floor of VP series



# Parametric Results

❖ Global Failure

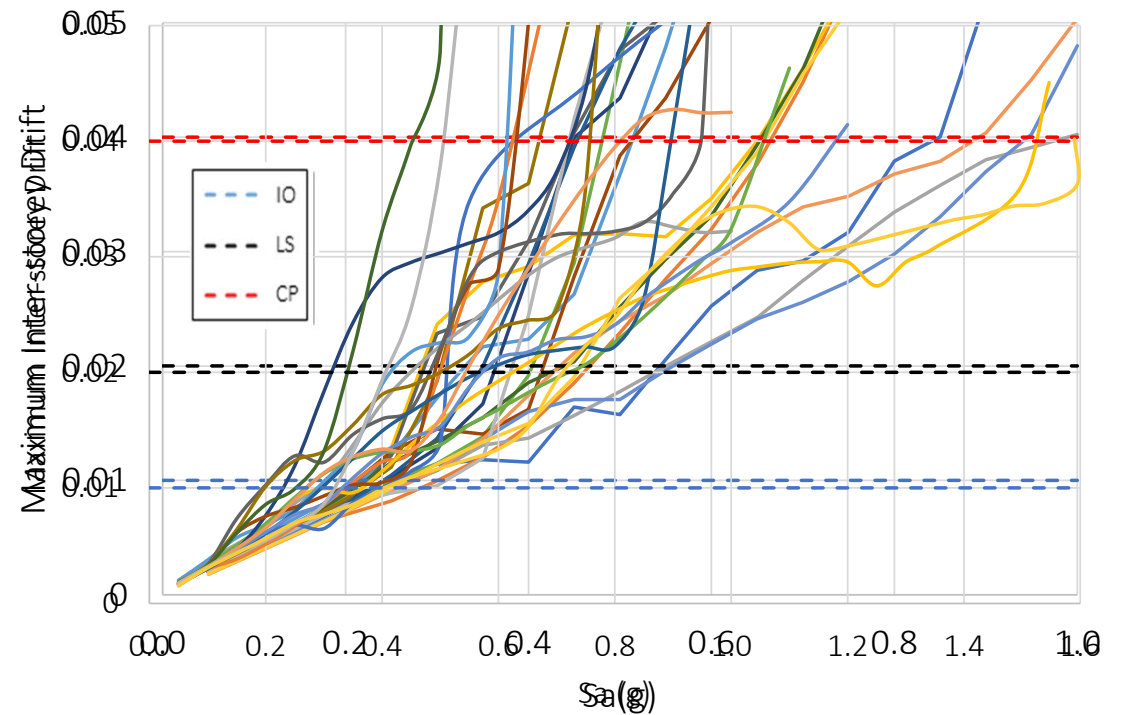
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Table 9 Performance Limits for Inter-storey Drift as per FEMA 356

<b>Sr. #</b>	<b>Performance Level</b>	<b>Performance Limit</b>
1	Immediate Occupancy	1%
2	Life Safety	2%
3	Collapse Prevention	4%

# Parametric Results

❖ Global Failure



Maximum Inter-storey Drift of VT series  
Maximum Inter-storey Drift of VP series

# Parametric Results

## ❖ Global Failure

A future earthquake with return period of 475 years shows a very high probability of moderate damage of approximately 90% and 46% probability of severe damage/collapse while at MCE the probability of severe damage increases up to 86%.

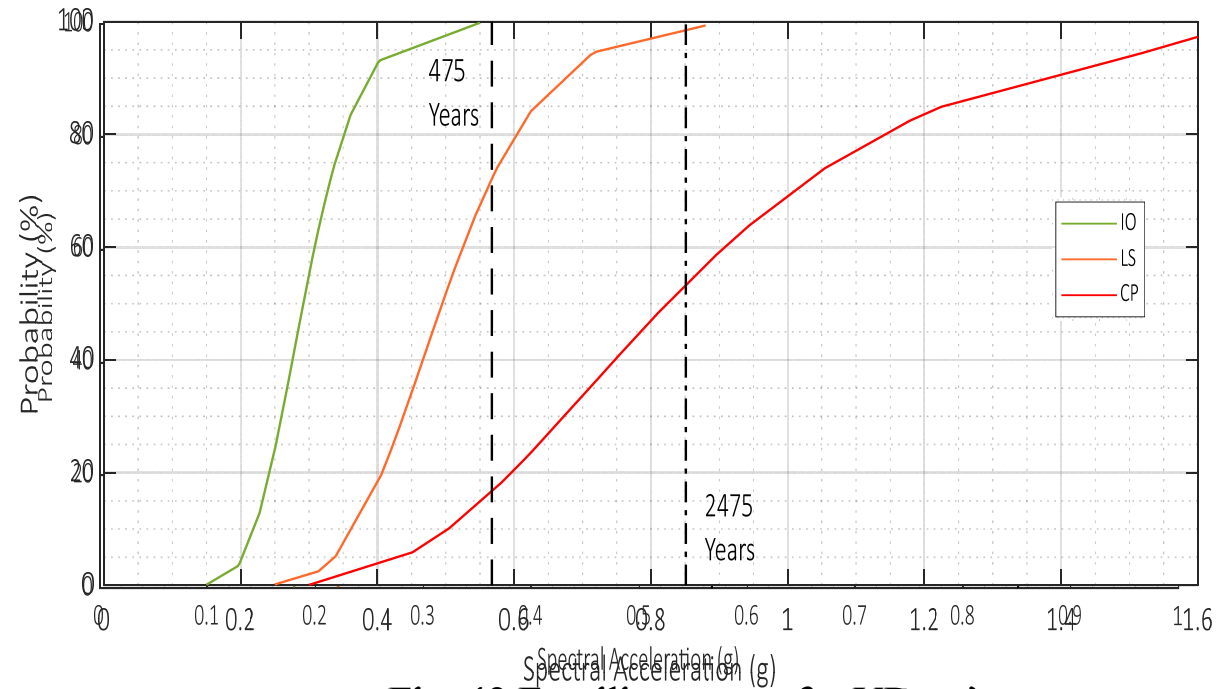


Fig. 42 Fragility curves for VP series

# Parametric Results

❖ Local Failure

Table 10 Plastic Rotation Values for RC columns and beams

<b>Building Series</b>	<b>Element</b>	<b>IO</b>	<b>LS</b>	<b>CP</b>
VT Series	Column	0.0043	0.014	0.018
	Beam	0.010	0.020	0.025
VP Series	Column	0.0038	0.013	0.017
	Beam	0.010	0.020	0.025

# Parametric Results

❖ Local Failure

## ✓ Plastic Rotation

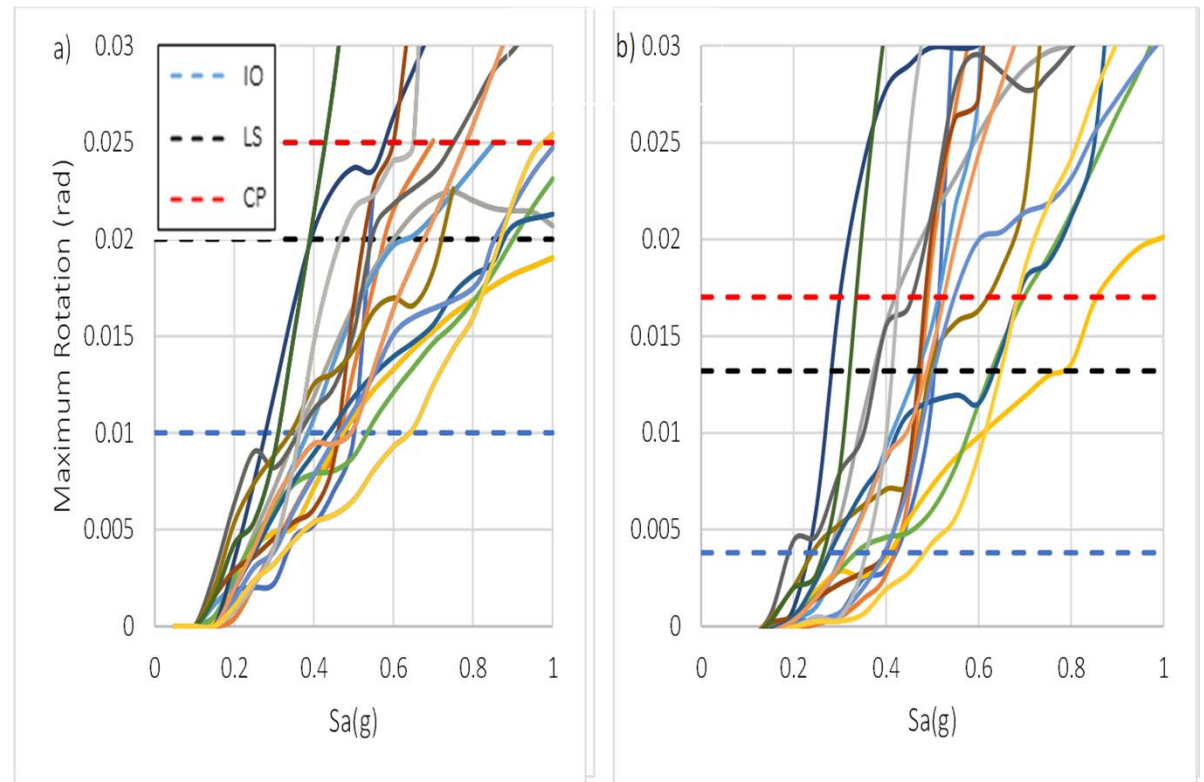


Fig. 44 Maximum rotation in structural components of VP series a) beams b) columns

# Parametric Results

## ❖ Local Failure

A future earthquake with return period of 475 years shows very high probability for both collapse of the building and severe damage exceeding 90% chances of collapse of the building.

## ✓ Fragility Curves

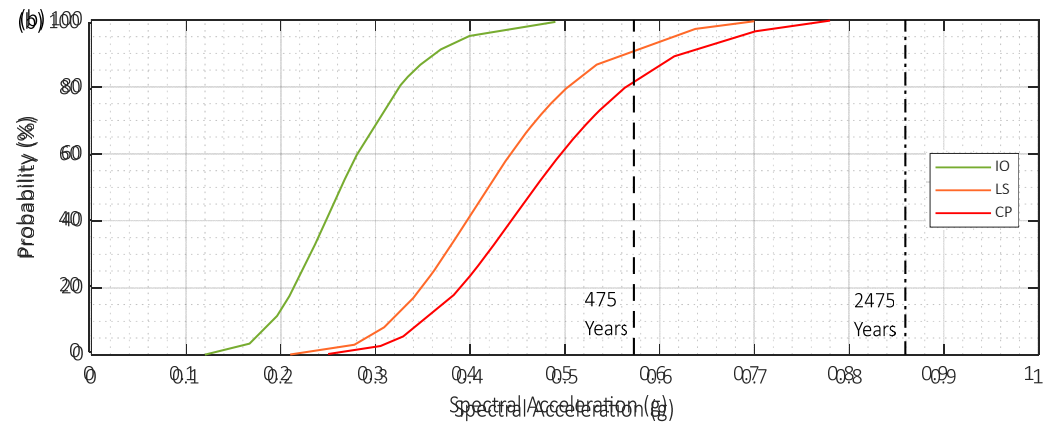
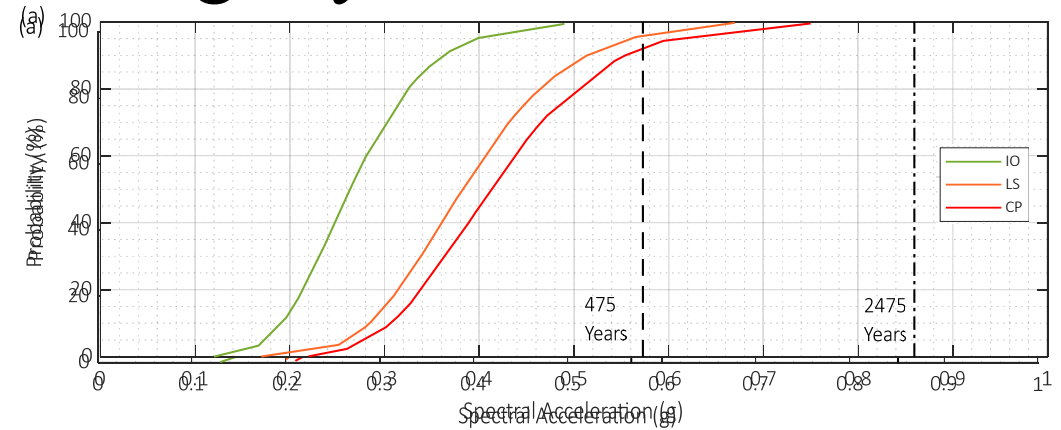


Fig. 46 Fragility curve for Local failure of structural elements of VP series a) columns b) beams

# Conclusion

## Macroseismic Assessment

- Both the DBE and the MCE suggest that there is a high risk of destruction of residential buildings, made of unreinforced masonry, and wood. Yet, there is a significant risk of damage, one that exceeds 20% under DBE and 40% under MCE. It is therefore proposed that these structures undergo substantial strengthening or demolition, with the decision being made based on the outcomes of following financial assessments.
- For industrial and commercial buildings made of unreinforced masonry and concrete shows a high probability of moderate to very heavy damage for both DBE and MCE. The likelihood of heavy damage lies between 20% to 30%.

# Conclusion

- **Analytical Assessment**

- A future earthquake with return period of 475 years shows a very high probability of moderate damage of approximately 70% and 15% probability of severe damage/collapse while at MCE the probability of severe damage increases up to 50%.
- No major disaster has happened in Almaty in the last century despite the facts that buildings have probabilities of sustaining moderate to severe damages at DBE and MCE is because the city has not been hit by a major earthquake in the last century. But this might lead to misinterpretation, that it will not be hit by one in future, which will lead towards a major disaster. Nonetheless, these evaluation results can be used by government decision-makers to formulate policies to mitigate future seismic disasters to avoid such disaster.

# References

- [1] N. v. Silacheva, U. K. Kulbayeva, and N. A. Kravchenko, “Probabilistic seismic hazard assessment of Kazakhstan and Almaty city in peak ground accelerations,” *Geod Geodyn*, vol. 9, no. 2, pp. 131–141, 2018, doi: 10.1016/j.geog.2017.11.002.
- [2] C. Grützner et al., “Assessing the activity of faults in continental interiors: Palaeoseismic insights from SE Kazakhstan,” *Earth Planet Sci Lett*, vol. 459, pp. 93–104, Feb. 2017, doi: 10.1016/j.epsl.2016.11.025.
- [3] N. v. Silacheva, U. K. Kulbayeva, and N. A. Kravchenko, “Probabilistic seismic hazard assessment of Kazakhstan and Almaty city in peak ground accelerations,” *Geod Geodyn*, vol. 9, no. 2, pp. 131–141, 2018, doi: 10.1016/j.geog.2017.11.002.
- [4] K. Anderson, G. Capannelli, E. Ginting, and K. Taniguchi, “Kazakhstan: Accelerating Economic Diversification,” 2018.
- [5] Bespayev, A.A. About the transition from SP RK 2.03–30–2017\* to design according to SP RK EN 1998-1:2004/2012. Вестник Национальной Инженерной Академии Республики Казахстан 2019
- [6] SNiP RK B.1.2-4-98; Construction in Seismic Regions. KazNIISA: Almaty, Kazakhstan, 1998.
- [7] Zhunusov, T.; Taubaev, A.; Itskov, I.; Mikhailova, N.; Nurmagambetov, A. Seismic Hazard and Building Vulnerability in Kazakhstan. In *Seismic Hazard and Building Vulnerability in Post-Soviet Central Asian Republics*; Springer: Dordrecht, The Netherlands, 1999.
- [8] Zhanabayeva, A.; Moon, S.W.; Ocheme, J.I.; Yeraly, S.; Khomyakov, V.A.; Kim, J.; Satyanaga, A. Comparative analysis of seismic design codes adhering to the Kazakhstani and European approaches. *Sustainability* 2023, 15, 615.
- [9] Bal, İ.E., Gülay, F.G. and Tezcan, S.S. (2010) “Use of analytical tools for calibration of parameters in P25 preliminary assessment method,” *Computational Methods in Applied Sciences*, pp. 559–582. Available at: [https://doi.org/10.1007/978-94-007-0053-6\\_25](https://doi.org/10.1007/978-94-007-0053-6_25).

# References

- [12] Faccioli E, Pessina V, Calvi G, Borzi B. A study on damage scenarios for residential buildings in Catania city. *J Seismolog* 1999;3:327–43.
- [13] Lantada N, Irizarry J, Barbat A, Goula X, Roca A, Susagna T, et al. Seismic hazard and risk scenarios for Barcelona, Spain, using the Risk-UE vulnerability index method. *Bull Earthq Eng* 2010;8:201–29.
- [14] T. Maqsood, J. Schwarz, and M. Edwards, “Application of European Macroseismic Scale -1998 in the Asia-Pacific region.,” ResearchGate, Aug. 2013, [Online]. Available: <https://www.researchgate.net/publication/276060158>
- [15] Wallace NM, Miller TH. Seismic screening of public facilities in Oregon’s western counties. *Pract Period Struct Des Constr* 2008;13:189–97.
- [16] M.C. Ningthoujam, Radhikesh P. Nanda, Rapid visual screening procedure of existing building based on statistical analysis, *International Journal of Disaster Risk Reduction*, Volume 28, 2018, Pages 720-730, ISSN 2212-4209, <https://doi.org/10.1016/j.ijdr.2018.01.033>.

# References

- [19] Polese M, Verderame GM, Mariniello C, Iervolino I, Manfredi G. Vulnerability analysis for gravity load designed RC buildings in Naples–Italy. *J Earthquake Eng* 2008;12:234–45
- [20] Pagnini LC, Vicente R, Lagomarsino S, Varum H. A mechanical model for the seismic vulnerability assessment of old masonry buildings. *Earthq Struct* 2011;2:25–42.
- [21] Fardis MN, Papailia A, Tsionis G. Seismic fragility of RC framed and wall frame buildings designed to the EN-Eurocodes. *Bull Earthq Eng* 2012;10:1767–93.
- [22] Sobhan M, Rofooei F, Attari NK. Buckling behavior of the anchored steel tanks under horizontal and vertical ground motions using static pushover and incremental dynamic analyses. *Thin-Walled Struct* 2017;112:173–83.
- [23] Moazam AM, Hasani N, Yazdani M. Incremental dynamic analysis of small to medium spans plain concrete arch bridges. *Eng Fail Anal* 2018;91:12–27.
- [24] Asgarian B, Sadrinezhad A, Alanjari P. Seismic performance evaluation of steel moment resisting frames through incremental dynamic analysis. *J Constr Steel Res* 2010;66:178–90.



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