THE WORLD BANK · GFDRR · Universidad de los Andes · UCL

Date:	9/17/2018
Building Type:	**RC2/LR/LD**
Author:	UNIANDES
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FRAGILITY VULNERABILITY ASSESSMENT

REINFORCED CONCRETE BUILDINGS

GENERAL INFORMATION

Index Building Taxonomy Code: **RC2/LR/LD**/RD/NI/SS/SW/RF/NP/OS/GC/VN

1. Main structural system:……………………………………………	RC1 ☐	RC2 ☒	RC3 ☐	RC4 ☐	RC5 ☐
2. Height range:……………………...……………………..		Low (LR) ☒		Medium (MR) ☐	High (HR) ☐
3. Seismic design level:……………………….…...	Poor (PD) ☐	Low (LD) ☒		Medium (MD) ☐	High (HD) ☐
4. Diaphragm Type:…………………………………….		Flexible diaphragm (FD) ☐	Rigid diaphragm (RD) ☒		
5. Structural Irregularity:……………………………………..	No irreg. (NI) ☒	Hor. (HI) ☐	Vert. (VI) ☐		Hor. and vert. (HV) ☐
6. Span Length:……………………...…………………………..		Short span (SS) ☒	Slender - weak column (SW) ☐		
7. Pier Type:………………………………………………..		Regular column (RO) ☒	Regular column (RO) ☐		
8. Foundation Type and Flexibility:…………….…………………		Rigid foundation (RF) ☒	Flexible foundation (FF) ☐		
9. Seismic Pounding Risk:………………………………………..		No pounding (NP) ☒	Pounding risk (PR) ☐		
10. Seismic Retrofitting:……………...………………………..		Original structure (OS) ☒	Retrofitted structure (RS) ☐		
11. Structural Health Conditions:……………………………….		Good condition (GC) ☒	Poor condition (PC) ☐		
12. Vulnerable Non-Structural Components:……………………..		Non vulnerable (NN) ☐	Vulnerable (VN) ☒		

INTRINSIC CHARACTERISTICS

General Geometry:

Building plane area (m²):…………………...………………...…	304
Building total area (m²):……………………….……………....	304
Number of stories:………………………………………..	1
Story height (m):…………………………………………………	3
Number of spans in X direction:……………………………………	7
Typical span length in X direction (m):………………………	4.5
Number of spans in Y direction (m):………………………………	3
Typical span length in Y direction (m):………...…………………..	3.5
Foundation system:…………………………………………………	CISF
Typical column dimensions (cm x cm):…………….....…………………	25X30
Typical beam dimensions (cm x cm):…………….……...………………	20X30
Typical shear wall dimensions (cm x cm):……………….………………	-
Typical bracing member section (cm x cm):………………………………	-

Material properties:

Concrete:………………….f'c (MPa):	21	Ec (GPa):	21.5
Reinforcement:………….fy (Mpa):	420	Es (GPa):	200
Structural steel:………… fy (Mpa):	-	Es (GPa):	-
Masonry:………………….f'm (MPa):	-	γ:………..	-

Infill walls:

	Interior walls		Facade walls	
Infill type:………………………				
Wall height (m):……………… X	-	Y 3	X 1.5 Y	3
Depth (m):……………………… X	-	Y 0.15	X 0.15 Y	0.15
Isolated from structure:…………. Yes ☐	No ☒	Yes ☐	No ☒	

MODELLING PARAMETERS

3D Numerical model:
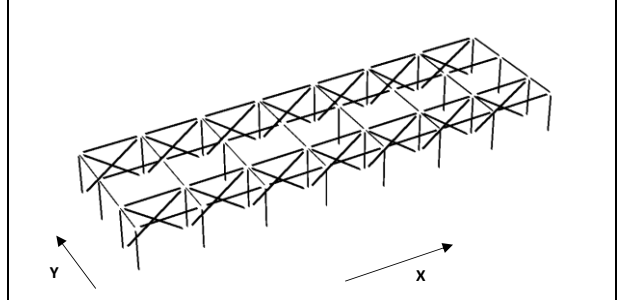
Modelling considerations:

Plasticity model:…………………………	Lumped ☒	Distributed ☐	
Infill walls modelling approach:…………		Equivalent frame	
Roof Diaphragm:…………………………	Rigid ☒	Flexible ☐	
Foundation:………………………………	Rigid ☒	Flexible ☐	
	kv (kN)	kh (kN)	kθ (kN)

Loads:

Over imposed design dead load (D) (kN/m2):……………………	1.2
Design Live load (L) (kN/m2):…………………..………………	2.0
Load combination in non-linear analysis:………………………...	D+0.25L
Average load per square meter (kN/m2):…………………………	4.3

Analysis considerations:

Global P-Delta effects:……………………	Yes ☒	No ☐
Rigid zones:……………….……………..	Yes ☒	No ☐
Initial effective stiffness:…………………… Beams	0.35	Columns 0.30
Analysis direction:…………………………	X ☒	Y ☐
Analysis orientation:………………..………	(+) ☒	(-) ☐

SEISMIC BEHAVIOR

Total weight (D) (kN):…....................……………	514	1st mode mass participation (%):……………………………	98.1
Total weight (L) (kN):…....................……………	783	First floor column area (m2):………………………………	1.75
T₁ uncracked (sec):……………………………	0.05	Total weight (D+L) /columns area (%f'c):…………………	0.21
T₁ cracked (sec):…………...........……………	0.08	Horizontal first story shear column capacity (g):……………	0.23

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SEISMIC BEHAVIOR

Capacity Curve:

IBRC-7 (RC2-LR-LD)

IBRC-7 (RC2-LR-LD)
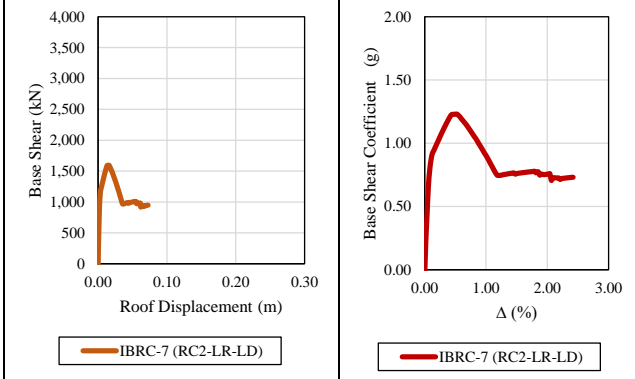
Idealized capacity curve:

Behavior point	Base shear (kN)	Displacement (m)
Yield point:……………..………………	1230	0.01
Maximum capacity:………………	1590	0.21
Ultimate capacity:……..…………	-	-

Collapse mechanism: Excessive flexibility

● IO   ● LS   ● CP
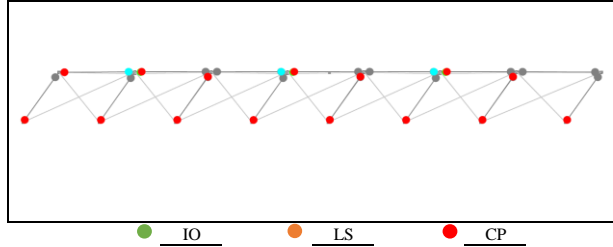
NON-LINEAR ANALYSIS PARAMETERS

Seismic ground motions:

Number of ground motions used:…………………………	22
Soil type:…………………………………………………….	C
Source type:……………………………………………….	Far field
Retrieved from:…………………………….………………	PEER-NGA

Analysis considerations:

Non-linear analysis:…………………………………	Static [X] Dynamic [ ]
Analysis methodology:………………………………	N2
Intensity measure parameter (IM):…………………	Sa[T] (g)
Scaling factor: 0.1 Minimum: 0.1 Maximum: 2	

Ground motion spectra:
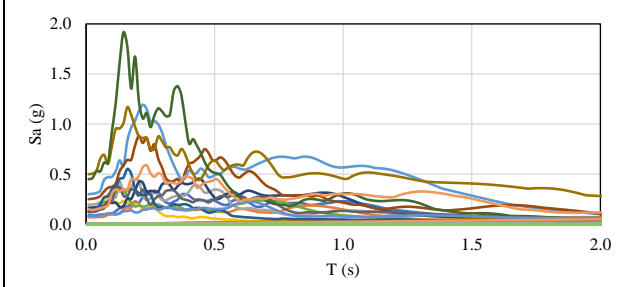
Illustrative EDP:
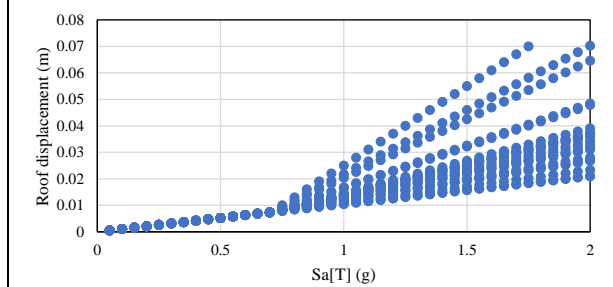
FRAGILITY ASSESSMENT

Damage states (DS):

Intensity Measure:……………………………………	Sa[T] (g)
Slight (SD) -Operational (OP) (%):…………………	0.20
Medium (MD) - Immediate occupancy (IO) (%):….	0.40
Extensive (ED) - Life safety (LS) (%):…………….	0.66
Collapse (CD) - Collapse prevention (CP) (%): ……	1.20
Integration methodology:……………………………	LSM

	OP	IO	LS	CP
Mean:………………	0.56	0.99	1.30	2.09
Deviation:…………	0.15	0.18	0.27	0.48

Fragility function:
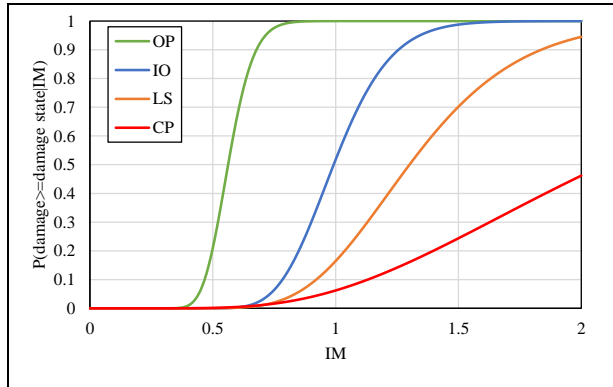
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Component model:

Story	Group	Subgroup	Description	Unit	Quantity	Fragility curve	EDP	Correlation
1	E	C1	Column-one beam	Node	8	B1041.091a	Drift	0
1	E	C2	Column-two beams	Node	21	B1041.091b	Drift	0
1	A	F2	Masorny facade	5m x 3m	14	C1011.006a	Drift	1
1	A	M4	Masonry wall	5m x 3m	6	C1011.006b	Drift	1
1	C	S2	Contents	5m x 5m	13	E2022.010a	Drift	0

Phase I:

Beta model uncertainty:………………………………..………………	0.3
Number of iteration for model uncertainty:………..……………………	20
Number of iterations for damage states uncertainty:………………………	20
Number of iterations for cost and time uncertainty:………………………	20
Scale factor for cost:…………………………………… Yes ☐ No ☒	

Phase II:

Lower intensity to no damage (g/g):…………………………………	0.1
Maximum allowable residual drift for demolition (%):……………………	1.5
Percentage of building replacement value (%):……………………………	100
Bidirectional factor for total cost model:…………………………………	1
Intensity level for building evacuation (g/g):………………………………	2

Vulnerability function:
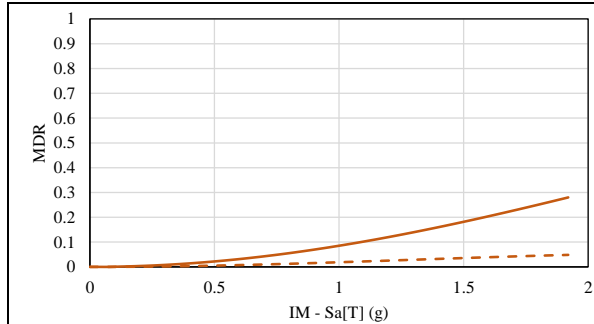
Fragility to vulnerability weighting percentage:

OP (%):	0	IO (%):	20	LS (%):	50	CP (%):	100

GLOSARY

f'c:	Compressive concrete strength	kv:	Spring vertical stiffness	IM:	Intensity measure	
Ec:	Concrete elastic module	kh:	Spring horizontal stiffness	DM:	Damage states	
fy:	Tensile steel strength	kθ:	Spring rotational stiffness	OP:	Operational	
Es:	Steel elastic module	D:	Death load	IO:	Immediate occupancy	
f'm:	Masonry compressive strength	L:	Live load	LS:	Life safety	
γ:	Masonry density	T1:	First mode period	CP:	Collapse prevention	
CISF:	Concrete isolated spread footing	Sa:	Pseudo acceleration	EDP:	Engineering demand parameters	

Horizontal first story shear column capacity (g) = $(\sqrt{f'c}/6)*(A\_col/W)$

PRINCIPAL REFERENCES

Reference project:…………………………………	Global Library of School Infrastructure - GLoSI
Main bibliographical references:……………………	GLoSI Technical Report
	FEMA P-695
	ASCE 41-17
	N2 Method (Fajfar, 2000)
	GEM Analytical Vulnerability Assessment Guideline (D'Ayala et al, 2015)
	FUNVUL (www.ecapra.org)