

FRAGILITY VULNERABILITY ASSESSMENT

Date:	9/17/2018
Building Type:	RC2/MR/PD
Author:	UNIANDES
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REINFORCED CONCRETE BUILDINGS

GENERAL INFORMATION

Index Building Taxonomy Code:

- Main structural system:.....
- Height range:.....
- Seismic design level:.....
- Diaphragm Type:.....
- Structural Irregularity:.....
- Span Length:.....
- Pier Type:.....
- Foundation Type and Flexibility:.....
- Seismic Pounding Risk:.....
- Seismic Retrofitting:.....
- Structural Health Conditions:.....
- Vulnerable Non-Structural Components:.....

RC2/MR/PD/RD/NI/SS/SW/RF/NP/OS/GC/VN

RC1 ☐	RC2 ☒	RC3 ☐	RC4 ☐	RC5 ☐
	Low (LR) ☐		Medium (MR) ☒	High (HR) ☐
Poor (PD) ☒	Low (LD) ☐		Medium (MD) ☐	High (HD) ☐
	Flexible diaphragm (FD) ☐		Rigid diaphragm (RD) ☒	
No irreg. (NI) ☒	Hor. (HI) ☐	Vert. (VI) ☐		Hor. and vert. (HV) ☐
	Short span (SS) ☒		Slender - weak column (SW) ☐	
	Regular column (RO) ☒		Regular column (RO) ☐	
	Rigid foundation (RF) ☒		Flexible foundation (FF) ☐	
	No pounding (NP) ☒		Pounding risk (PR) ☐	
	Original structure (OS) ☒		Retrofitted structure (RS) ☐	
	Good condition (GC) ☒		Poor condition (PC) ☐	
	Non vulnerable (NN) ☐		Vulnerable (VN) ☒	

INTRINSIC CHARACTERISTICS

General Geometry:

Building plane area (m ²):.....	299.25
Building total area (m ²):.....	598.5
Number of stories:.....	2
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):.....	20X20
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):	17	E _c (GPa):	19
Reinforcement:..... f _y (Mpa):	420	E _s (GPa):	200
Structural steel:..... f _y (Mpa):	-	E _s (GPa):	-
Masonry:..... f _m (MPa):	-	γ:	-

Infill walls:

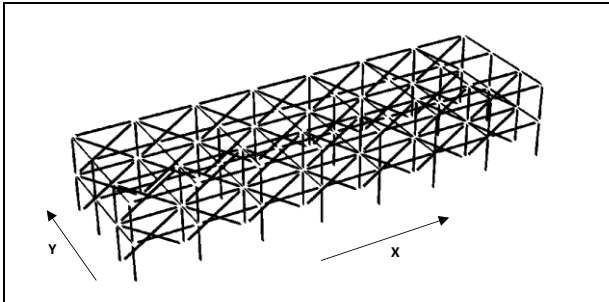
Infill type:.....	Interior walls		Facade walls	
Wall height (m):..... X ☐ - Y ☐	3	X ☐ 1.5 Y ☐	3	
Depth (m):..... X ☐ - Y ☐	0.15	X ☐ 0.15 Y ☐	0.15	
Isolated from structure:.....	Yes ☒ No ☐	Yes ☒ No ☐		

SEISMIC BEHAVIOR

Total weight (D) (kN):.....	2551
Total weight (L) (kN):.....	173.3
T ₁ uncracked (sec):.....	0.123
T ₁ cracked (sec):.....	0.1462

MODELLING PARAMETERS

3D Numerical model:



Modelling considerations:

Plasticity model:.....	Lumped ☒ Distributed ☐
Infill walls modelling approach:.....	Equivalent frame
Roof Diaphragm:.....	Rigid ☒ Flexible ☐
Foundation:.....	Rigid ☒ Flexible ☐
	k _v (kN) _____ k _h (kN) _____ k _θ (kN) _____

Loads:

Over imposed design dead load (D) (kN/m ²):.....	1.2
Design Live load (L) (kN/m ²):.....	1.0
Load combination in non-linear analysis:.....	D+0.25L
Average load per square meter (kN/m ²):.....	4.6

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:.....	(+) ☒ (-) ☐

1st mode mass participation (%):.....	93.62
First floor column area (m ²):.....	1.28
Total weight (D+L) / columns area (%f _c):.....	20.31
Horizontal first story shear column capacity (g):.....	0.32

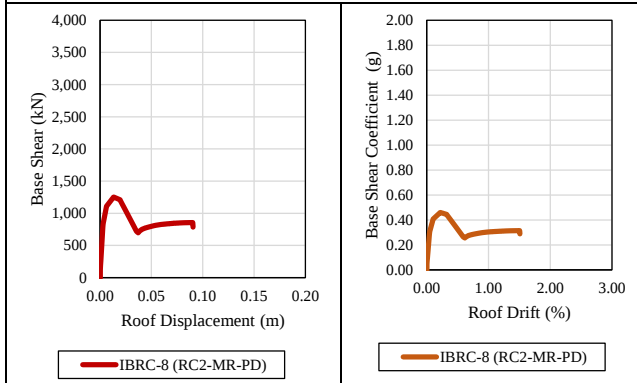
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SEISMIC BEHAVIOR

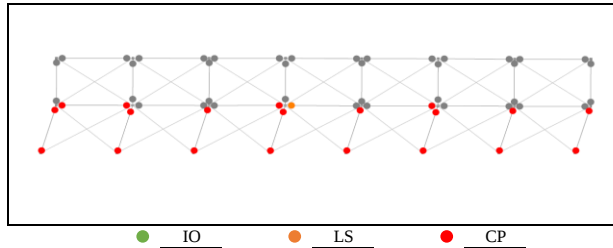
Capacity Curve:



Idealized capacity curve:

Behavior point	Base shear (kN)	Displacement (m)
Yield point:.....	1100	0.006
Maximum capacity:.....	1275	0.0160
Ultimate capacity:.....	700	0.037

Collapse mechanism: Soft story



NON-LINEAR ANALYSIS PARAMETERS

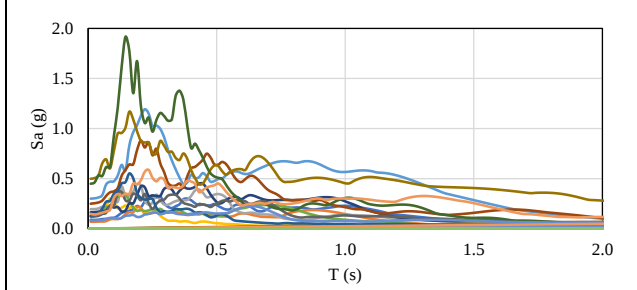
Seismic ground motions:

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

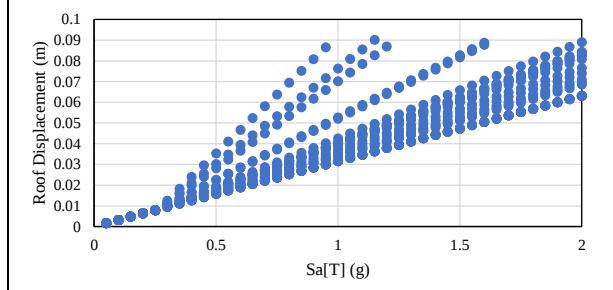
Analysis considerations:

Non-linear analysis:.....	Static ☒ 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:



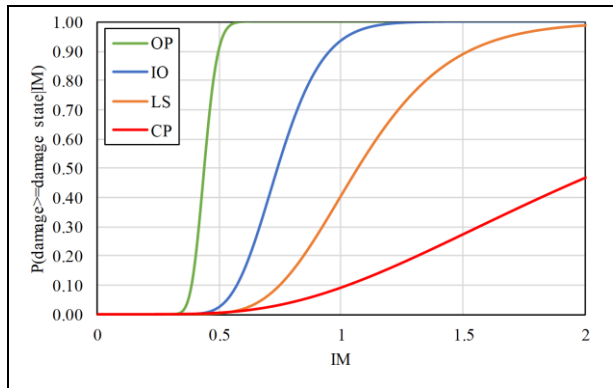
FRAGILITY ASSESSMENT

Damage states (DS):

Intensity Measure:.....	Sa[T] (g)
Slight (SD) - Operational (OP) (%):.....	0.25
Medium (MD) - Immediate occupancy (IO) (%):.....	0.45
Extensive (ED) - Life safety (LS) (%):.....	0.70
Collapse (CD) - Collapse prevention (CP) (%):.....	1.10
Integration methodology:.....	LSM

Mean:.....	OP	IO	LS	CP:
	0.44	0.74	1.07	2.09
Deviation:.....	0.10	0.20	0.28	0.55

Fragility function:



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VULNERABILITY ASSESSMENT

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	Masonry 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
2	E	C1	Column-one beam	Node	8	B1041.091a	Drift	0
2	E	C2	Column-two beams	Node	21	B1041.091b	Drift	0
2	A	F2	Masonry facade	5m x 3m	14	C1011.006a	Drift	1
2	A	M4	Masonry wall	5m x 3m	6	C1011.006b	Drift	1
2	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

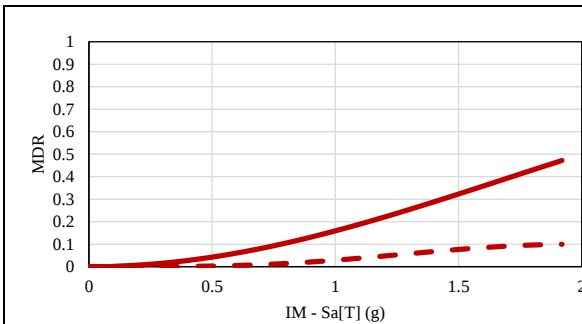
Maximum allowable residual drift for demolition (%):..... 1.5

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

GLOSSARY

f _c : Compressive concrete strength	k _v : Spring vertical stiffness	IM: Intensity measure
E _c : Concrete elastic module	k _h : Spring horizontal stiffness	DM: Damage states
f _y : Tensile steel strength	k _θ : Spring rotational stiffness	OP: Operational
E _s : Steel elastic module	D: Death load	IO: Immediate occupancy
f _m : Masonry compressive strength	L: Live load	LS: Life safety
γ: Masonry density	T ₁ : First mode period	CP: Collapse prevention
CISF: Concrete isolated spread footing	S _a : Pseudo acceleration	EDP: Engineering demand parameters

Horizontal first story shear column capacity (g) = $(\sqrt{f_c}/6) \cdot (A_{col}/W)$

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)