THE WORLD BANK — IBRD·IDA | WORLD BANK GROUP   GFDRR — Global Facility for Disaster Reduction and Recovery   Universidad de los Andes   UCL

Date:	11/12/2018
Building Type:	**UCM-URM1/LR/LD**
Authors:	UCL
Sheet:	1 of 4

FRAGILITY/VULNERABILITY ASSESSMENT

DRY STONE MASONRY INDEX BUILDING

GENERAL INFORMATION

Index Building Taxonomy String: **UCM-URM1/LR(1)/LD**/FD/NI/SP/LO/RF/NP/OS/GC/VN

1. Main structural system:……………………………………..			Dry Stone Masonry (UCM-URM1)				
2. Height range:……………………..……………………..	Low (LR)	X	Medium (MR)	☐	High (HR)	☐	
3. Seismic design level:……………..………………………	Poor (PD)	☐	Low (LD)	X	Medium (MD) ☐		High (HD) ☐
4. Diaphragm Type:………………………………………..	Flexible (FD)	X	Rigid (RD)	☐			
5. Structural Irregularity:……………..……………………..	No (NI)	X	Horizontal (HI)	☐	Vertical (VI) ☐		Both (HV) ☐
6. Wall Panel Length:…………………….………………….	Short (SP)	X	Long (LP)	☐			
7. Wall Openings:…………………………………………….	Small (SO)	☐	Large (LO)	X			
8. Foundation Type and Flexibility:…………………………….	Flexible (FF)	☐	Rigid (RF)	X			
9. Seismic Pounding Risk:………………..………………….	No (NP)	X	Yes (PR)	☐			
10. Seismic Retrofitting:……………..………………………	Original (OS)	X	Retrofitted (RS)	☐			
11. Structural Health Condition:…………………………….	Poor (PC)	☐	Good (GC)	X			
12. Non-Structural Components:……..……………………	Vulnerable (VN)	X	Non Vulnerable (NN)	☐			

INTRINSIC CHARACTERISTICS

General Geometry:

Building Plan Area (m^2):……………………...………………	105
Building Total Floor Area (m^2):…………………...……..	105
Number of Stories:………………………………...…………	1
Story Height (m):……………………………………...………	2.4
Number of Spans in X Direction:…………………...…………	4
Typical Span Length in X Direction (m):………………...…………	5
Number of Spans in Y Direction (m):……………………………	1
Typical Span Length in Y Direction (m):………..…………………	5
Wall Thickness (mm):……………...……………………………	480
Wall Construction:……………………...………………………	Running Bond
No. of Wythes……………………………………………………	Two

Material Properties of Masonry:

Unit Weight, γ (kg/m^2):………………	2200
Modulus of Elasticity, E (MPa):……	7934
Shear Modulus, G (MPa):…………	3173
Compressive Strength, f'm (MPa):…	51.9
Cohesion, c (MPa):………………..	0
Tensile Strength, f$_t$ (MPa):…………	0
Friction Coefficient, μ:……………..	0.65

MODELLING PARAMETERS

3D Model

Longitudinal (X)   Transverse (Y)
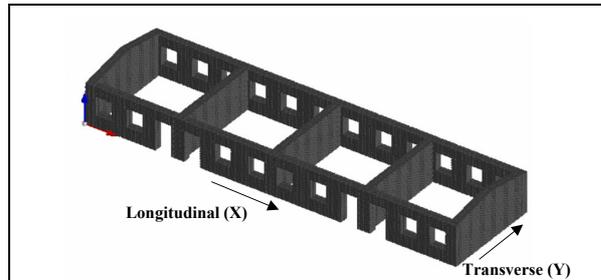
Modelling Consideration

Numerical Model Type:…………………………	3-D Element-by-Element
Masonry Modelling Approach:………………..	Simplified Micro-Modelling

Loads:

Roof Dead Load (D) (kN/m2):…………….........................	0.9
Design Live Load (L) (kN/m^2):……………………………………..	0.0
Load Combination for Seismic Analysis:……………..……........	D+0.25L
Average Load per Square Meter (kN/m^2):……………...……….	0.9

Analysis Considerations:

Global P-Delta Effects:…………………	Yes X	No ☐	
Analysis Direction:………………….….	X X	Y ☐	
Analysis Orientation:……………………	(+) ☐	(-) X	

SEISMIC BEHAVIOR

Seismic Weight of IP Walls (kN):…............................	890	Seismic Weight of OOP Walls (kN):….............................	820
Fundamental Time Period of IP Walls (sec):………….	0.13	Fundamental Time Period of OOP Walls (sec):…………	0.34

**Pushover Curve with Damage State Thresholds:**
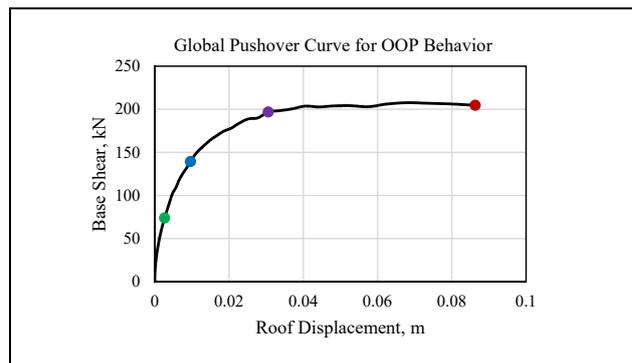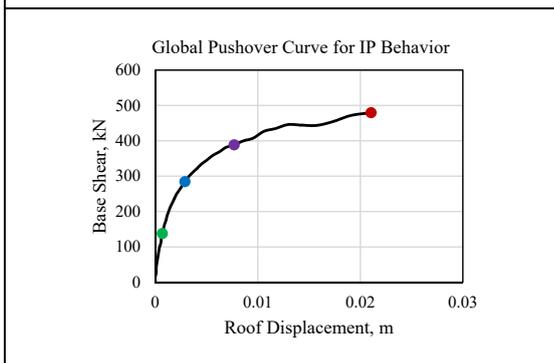
Global Pushover Curve for IP Behavior

Global Pushover Curve for OOP Behavior

IB2_LBM_UCM-URM1_LR_LD

FRAGILITY/VULNERABILITY ASSESSMENT

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Damage (Crack Pattern, Width and Extent) Progression

IP Wall Behavior	**OOP Wall Behavior**
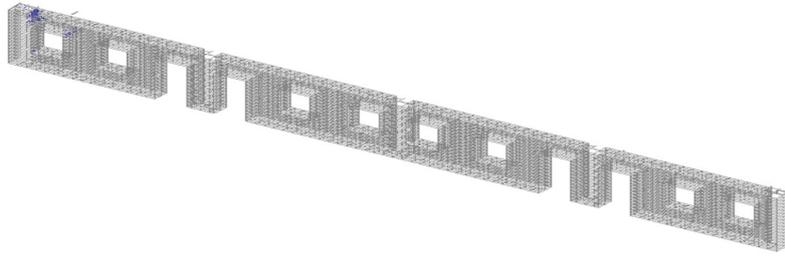
**OP Threshold**: Hairline cracks (blue) of maximum width 0.3 mm appeared at few corners of doors and windows.
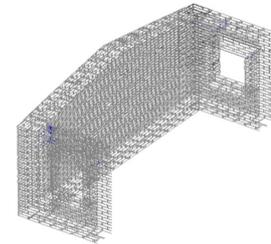

OP Threshold: Hairline cracks (blue) appeared at the top connection with the in plane walls. Max crack width 0.1 mm.
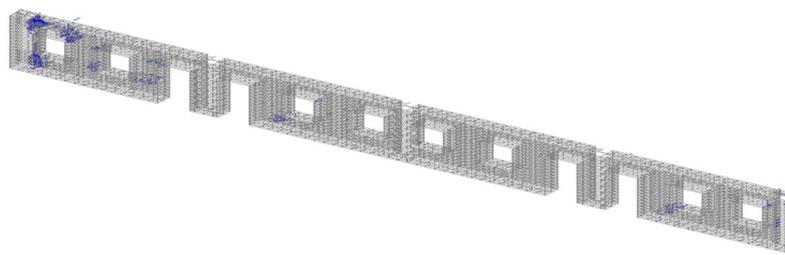

IO Threshold: Hairline to minor cracks (blue) of maximum width 3 mm developed at most of the corners of the openings, few piers and spandrels start to develop shear and flexural cracks, respectively.
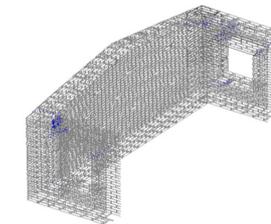

IO Threshold: Minor cracks (blue) start to develop at the IP connection, max crack width 3 mm.
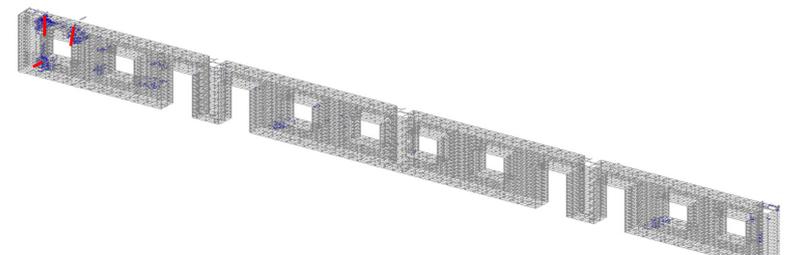

LS Threshold: Right most spandrel and pier start to damage in flexure and shear respectively, with major cracks (red) of 7 mm maximum width.
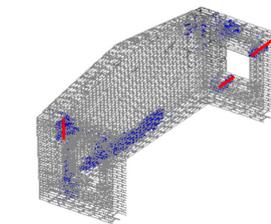
LS Threshold: Major cracks (red) of 10 mm maximum width the IP walls connections. A horizontal crack of maximum opening 1 mm at the bottom appears.
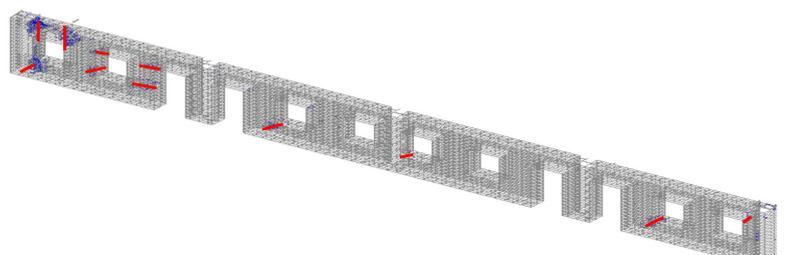
CP Threshold: Most piers start to damage in shear, left most pier and spandrel damaged with extensive cracks (red) of 12 mm maximum width.
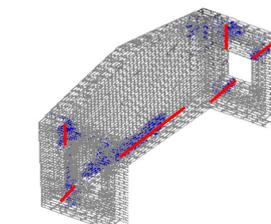
CP Threshold: Top connection with the IP wall damaged with extensive cracks (red) of width more than 12 mm. Horizontal bottom crack (red) extends to full length with a maximum opening of 4 mm.

FRAGILITY/VULNERABILITY ASSESSMENT

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SEISMIC PERFORMANCE ASSESSMENT

### Analysis Considerations:

Analysis Methodology:………………….....……. Static Analysis (N2 Method)

Engineering Demand Parameter (EDP):…………… Roof Drift

Seismic Ground Motions:

Ground Motion Suite:………FEMA P695 - 22 Far Field Ground Motions

Intensity Measure (IM):…….PGA (g)

Scaling Factor:……………. 0.1

Minimum IM:……………… 0

Maximum IM:……………… 2g

Spectra of 22 Far Field Ground Motions

Bilinear Idealization:

ADRS Capacity Curve for IP Behavior

ADRS Capacity Curve for OOP Behavior

EDP Calculation:

N2 Performance Points for IP Behavior

N2 Performance Points for OOP Behavior
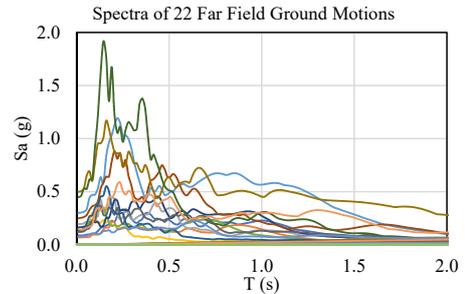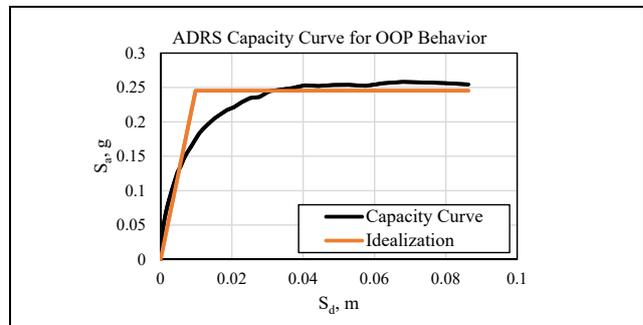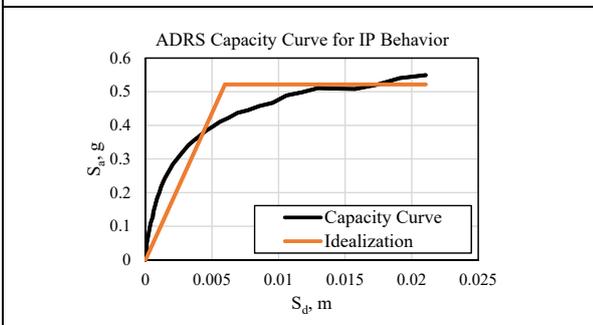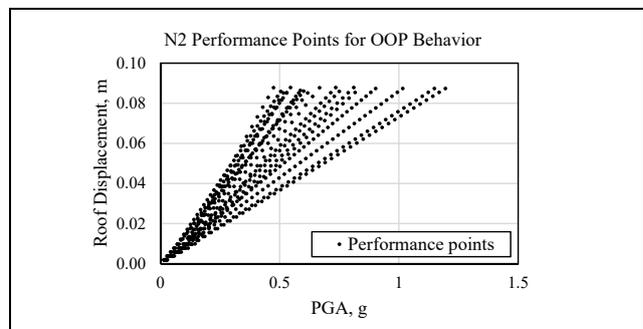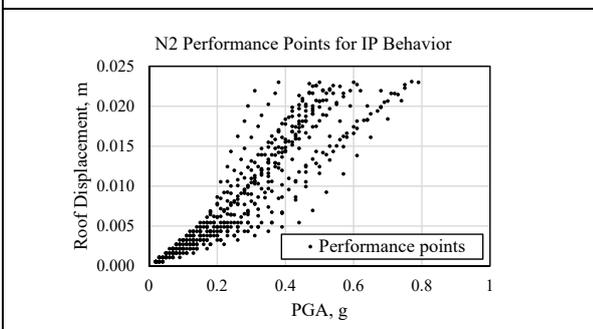
FRAGILITY ASSESSMENT

Integration Methodology:………………..…….. Least Square Method

Fragility Functions:

Fragility Curves for IP Behavior

Fragility Curves for OOP Behavior
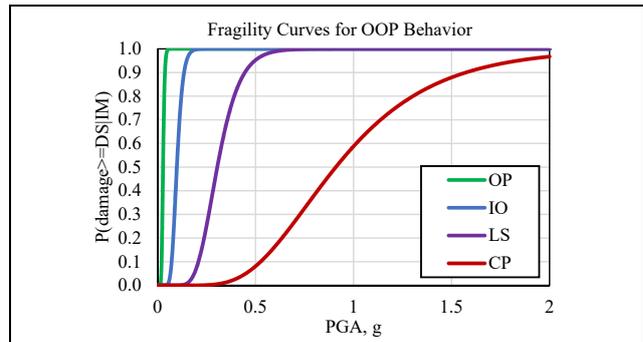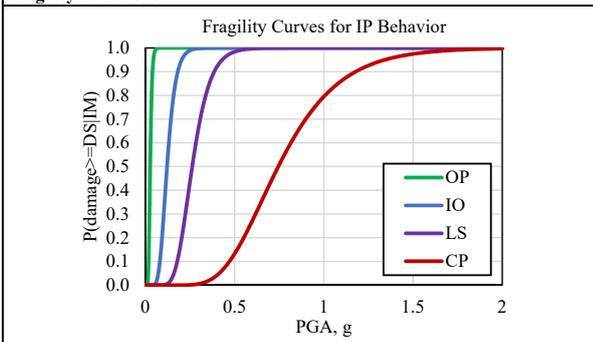
	OP	IO	LS	CP		OP	IO	LS	CP
Mean:………………	0.03	0.12	0.26	0.74	Mean:………………	0.03	0.10	0.30	0.91
Standard Deviation:..	0.31	0.32	0.30	0.36	Standard Deviation:..	0.24	0.25	0.30	0.43

IB2_LBM_UCM-URM1_LR_LD

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VULNERABILITY ASSESSMENT

Damage to Loss Function:

OP (%): 2   IO (%): 10   LS (%): 43.5   CP (%): 100

Vulnerability Function:
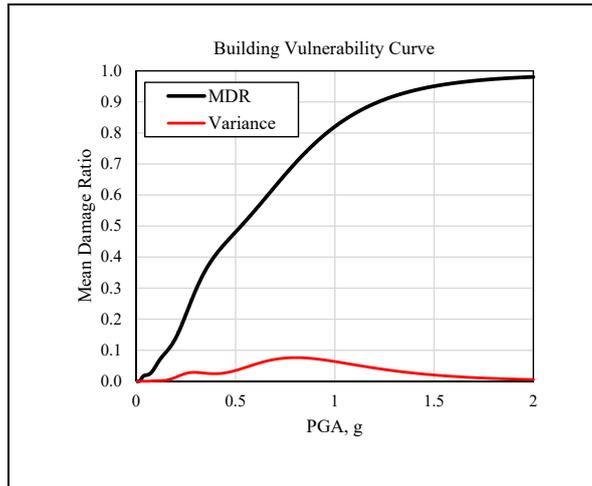
GLOSARY

IP = In Plane   OOP = Out of Plane
OP = Operational   IO = Immediate Occupancy   LS = Life Safety   CP = Collapse Prevention
IM = Intensity Measure   EDP = Engineering Demand Parameter
ADRS = Acceleration Displacement Response Spectra
Sa = Spectral Acceleration   Sd = Spectral Displacement
PGA = Peak Ground Acceleration
T (s) = Time (second)

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)