

FRAGILITY/VULNERABILITY ASSESSMENT

Date:	11/12/2018
Building Type:	UCM-URM5/LR/PD
Authors:	UCL
Sheet:	1 of 4

RUBBLE STONE MASONRY IN CEMENT MORTAR INDEX BUILDING

GENERAL INFORMATION

Index Building Taxonomy String:

UCM-URM5/LR(1)/PD/FD/NI/SP/SO/RF/NP/OS/PC/VN

Rubble Stone in Cement Mortar Masonry (UCM-URM5)

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

INTRINSIC CHARACTERISTICS

General Geometry:

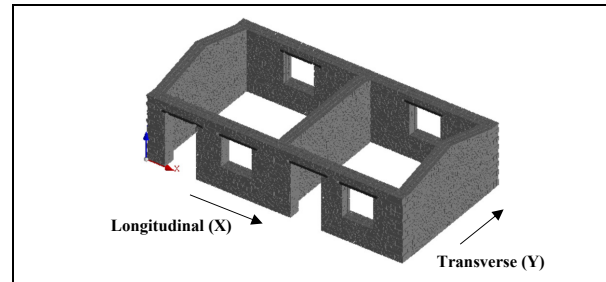
Building Plan Area (m ²):.....	37
Building Total Floor Area (m ²):.....	37
Number of Stories:.....	1
Story Height (m):.....	2.3
Number of Spans in X Direction:.....	2
Typical Span Length in X Direction (m):.....	4.5
Number of Spans in Y Direction (m):.....	1
Typical Span Length in Y Direction (m):.....	4
Wall Thickness (mm):.....	420
Wall Construction:.....	Running Bond
No. of Wythes:.....	Two

Material Properties of Masonry:

Unit Weight, γ (kg/m ³):.....	2200
Modulus of Elasticity, E (MPa):.....	4629
Shear Modulus, G (MPa):.....	1200
Compressive Strength, f_m (MPa):.....	37
Cohesion, c (MPa):.....	0.36
Tensile Strength, f_t (MPa):.....	0.12
Friction Coefficient, μ :.....	0.63

MODELLING PARAMETERS

3D Model



Modelling Consideration

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

Loads:

Roof Dead Load (D) (kN/m ²):.....	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

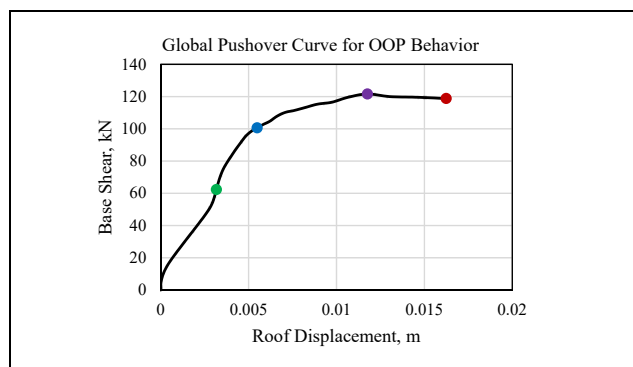
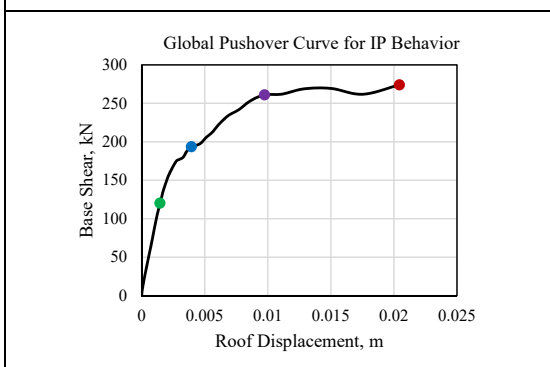
Analysis Considerations:

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

SEISMIC BEHAVIOR

Seismic Weight of IP Walls (kN):.....	380	Seismic Weight of OOP Walls (kN):.....	390
Fundamental Time Period of IP Walls (sec):.....	0.13	Fundamental Time Period of OOP Walls (sec):.....	0.4

Pushover Curve with Damage State Thresholds:



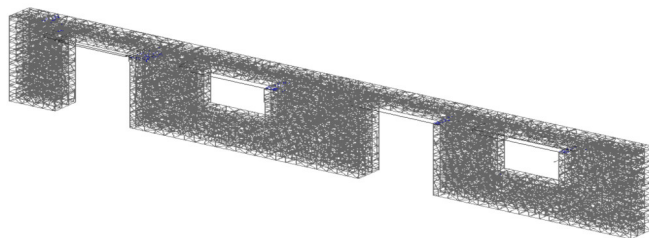
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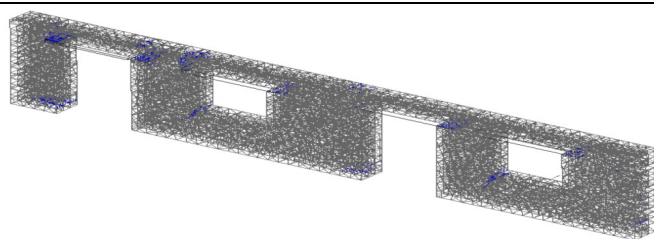
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Damage (Crack Pattern, Width and Extent) Progression

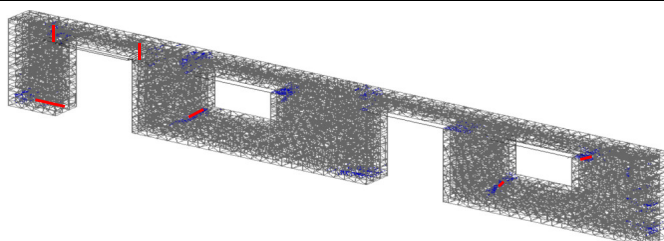
IP Wall Behavior



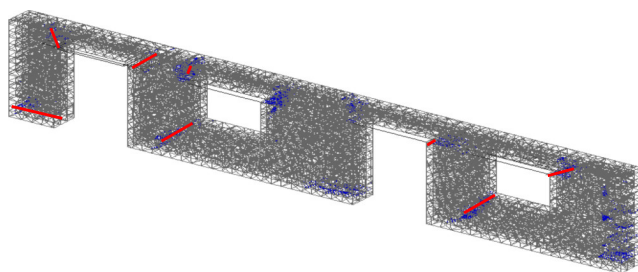
OP Threshold: Hairline cracks (blue) of maximum width 0.1 mm appeared at few corners of doors and windows.



IO Threshold: Hairline to minor cracks of maximum width 0.5 mm developed at most of the corners of the openings, few piers and spandrels start to develop shear and flexural cracks, respectively.

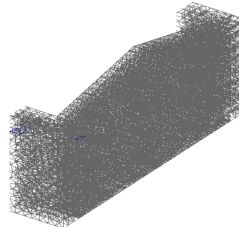


LS Threshold: Left most pier start to damage in flexure with major cracks of 5 mm maximum width. Other piers also start to develop shear and flexural cracks.

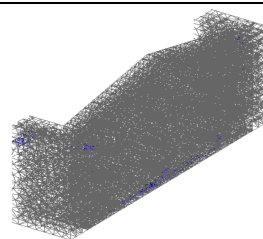


CP Threshold: Most piers and spandrels start to damage in shear/flexure with major cracks (red) of width of more than 5 mm.

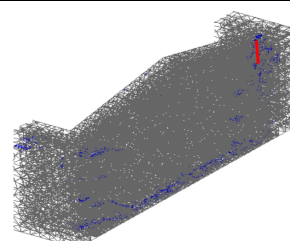
OOP Wall Behavior



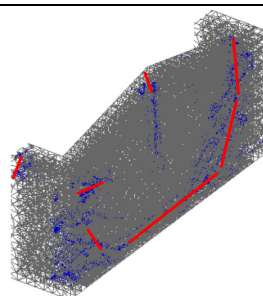
OP Threshold: Hairline cracks appeared at the connection with the in plane walls. Max crack width 0.1 mm.



IO Threshold: Minor cracks (blue) start to extend downwards at the IP connection with a maximum crack width of 2 mm. A horizontal crack (blue) of maximum opening 1 mm appears at the bottom.



LS Threshold: Major cracks (red) of 4 mm maximum width developed at the IP walls connections. A horizontal crack (blue) of maximum opening 1 mm appears at the bottom.



CP Threshold: Wall on the verge of collapse. Well shaped major cracks of average width more than 4 mm (red) appeared through out as U shaped mechanism.

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SEISMIC PERFORMANCE ASSESSMENT

Analysis Considerations:

Analysis Methodology:..... Static Analysis (N2 Method)
Engineering Demand Parameter (EDP):..... Roof Drift

Seismic Ground Motions:

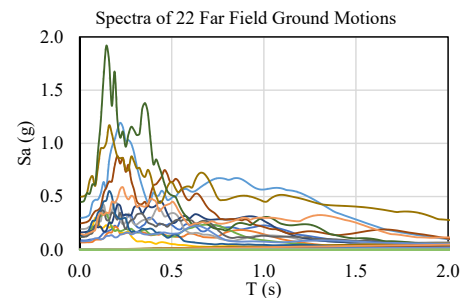
Ground Motion Suite:..... FEMA P695 - 22 Far Field Ground Motions

Intensity Measure (IM):..... PGA (g)

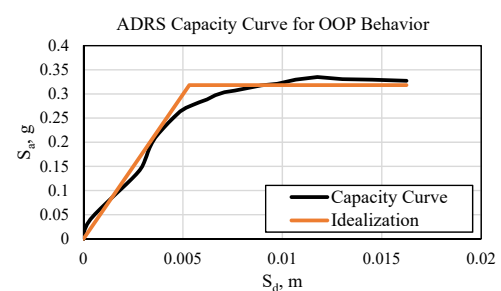
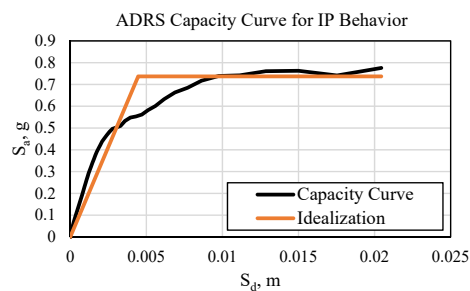
Scaling Factor:..... 0.1

Minimum IM:..... 0

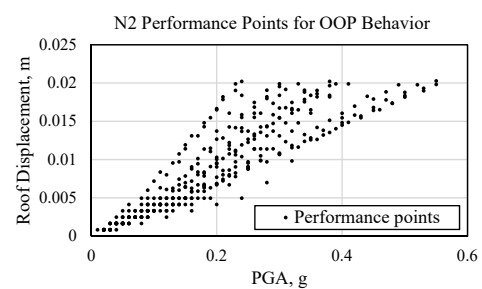
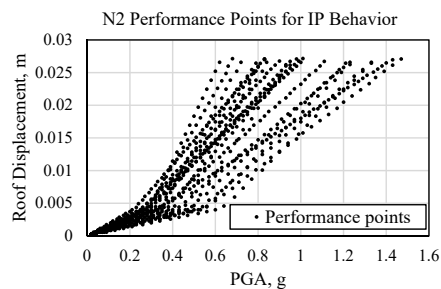
Maximum IM:..... 2g



Bilinear Idealization:



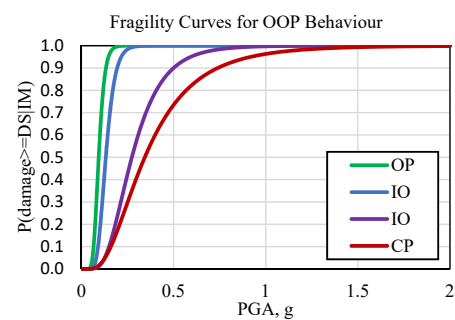
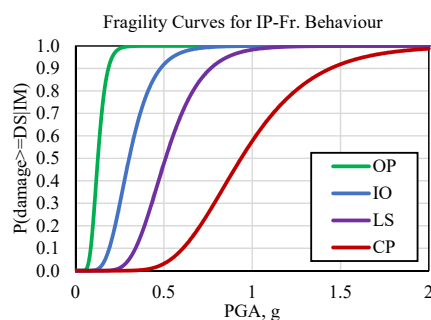
EDP Calculation:



FRAGILITY ASSESSMENT

Integration Methodology:..... Least Square Method

Fragility Functions:



	OP	IO	LS	CP
Mean:.....	0.13	0.30	0.51	0.94
Standard Deviation:..	0.30	0.36	0.32	0.34

	OP	IO	LS	CP
Mean:.....	0.09	0.13	0.27	0.34
Standard Deviation:..	0.27	0.30	0.47	0.60

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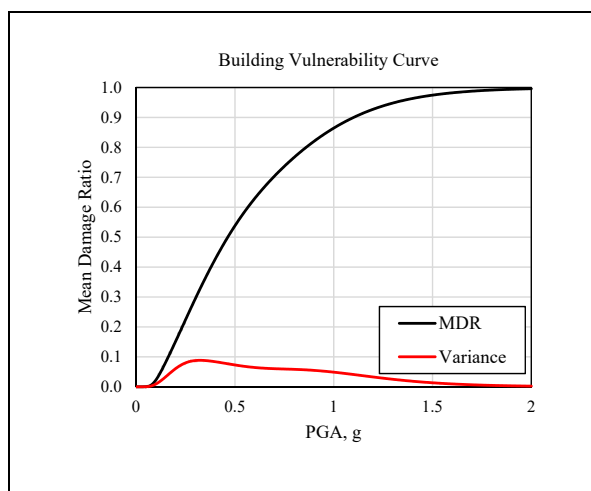
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VULNERABILITY ASSESSMENT

Damage to Loss Function:

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

Vulnerability Function:



GLOSSARY

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)