

# FRAGILITY/VULNERABILITY ASSESSMENT

Date:	11/12/2018
Building Type:	UCM-URM3/LR/LD
Authors:	UCL
Sheet:	1 of 4

## DRESSED STONE IN MUD MORTAR MASONRY INDEX BUILDING

### GENERAL INFORMATION

#### Index Building Taxonomy String:

UCM-URM3/LR(1)/LD/FD/NI/SP/SO/RF/NP/OS/PC/VN

#### Dressed Stone in Mud Mortar Masonry (UCM-URM3)

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

### INTRINSIC CHARACTERISTICS

#### General Geometry:

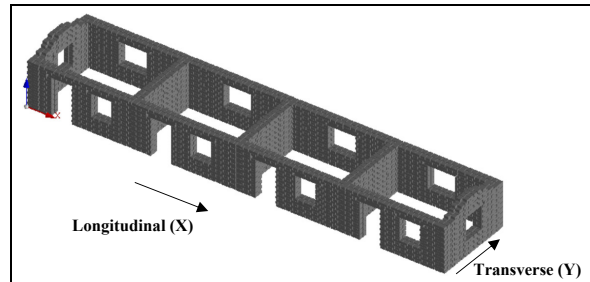
Building Plan Area (m <sup>2</sup> ):.....	88
Building Total Floor Area (m <sup>2</sup> ):.....	88
Number of Stories:.....	1
Story Height (m):.....	2.3
Number of Spans in X Direction:.....	4
Typical Span Length in X Direction (m):.....	5
Number of Spans in Y Direction (m):.....	1
Typical Span Length in Y Direction (m):.....	4.2
Wall Thickness (mm):.....	480
Wall Construction:.....	Running Bond
No. of Wythes:.....	Two

#### Material Properties of Masonry:

Unit Weight, $\gamma$ (kg/m <sup>3</sup> ):.....	2200
Modulus of Elasticity, E (MPa):.....	240
Shear Modulus, G (MPa):.....	96
Compressive Strength, $f_m$ (MPa):.....	1.8
Cohesion, c (MPa):.....	0.048
Tensile Strength, $f_t$ (MPa):.....	0.048
Friction Coefficient, $\mu$ :.....	0.5

### 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 <sup>2</sup> ):.....	0.9
Design Live Load (L) (kN/m <sup>2</sup> ):.....	0.0
Load Combination for Seismic Analysis:.....	D+0.25L
Average Load per Square Meter (kN/m <sup>2</sup> ):.....	0.9

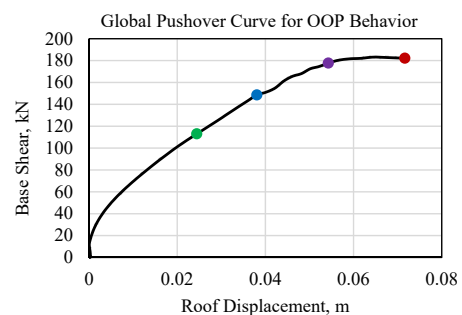
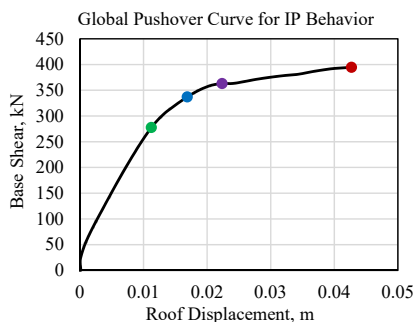
#### Analysis Considerations:

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

### SEISMIC BEHAVIOR

Seismic Weight of IP Walls (kN):.....	860	Seismic Weight of OOP Walls (kN):.....	525
Fundamental Time Period of IP Walls (sec):.....	0.27	Fundamental Time Period of OOP Walls (sec):.....	0.67

#### Pushover Curve with Damage State Thresholds:



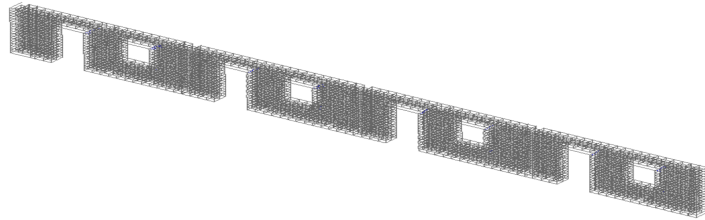
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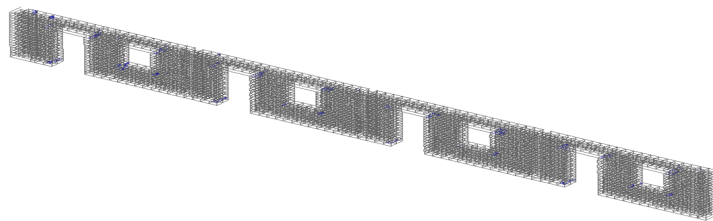
## DRESSED STONE IN MUD MORTAR MASONRY INDEX BUILDING

### Damage (Crack Pattern, Width and Extent) Progression

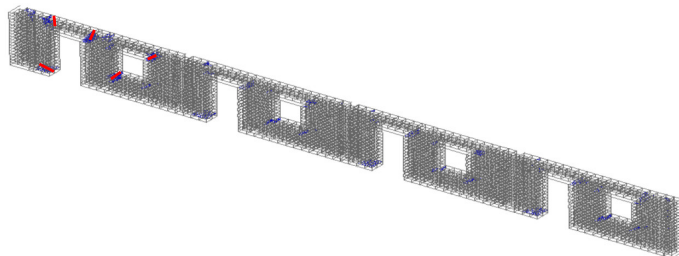
#### IP Wall Behavior



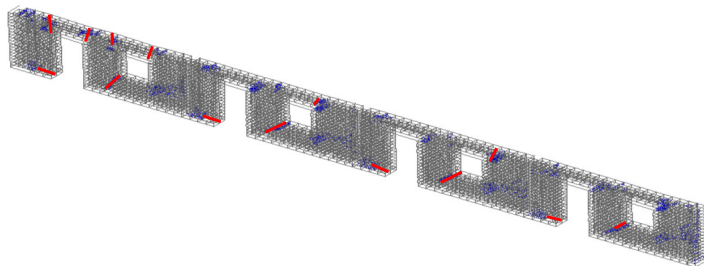
**OP Threshold:** Hairline cracks (blue) of maximum width 0.5 mm appeared at few corners of doors and windows.



**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.

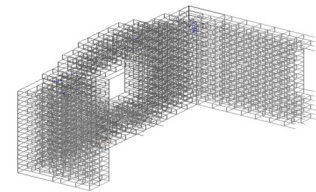


**LS Threshold:** Left pier and spandrel start to damage in shear and flexure with extensive cracks (red) of 12 mm maximum width. Other piers also start to develop extensive shear and flexural cracks.

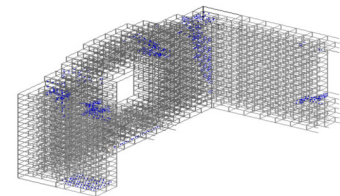


**CP Threshold:** Left pier and spandrel start to damage in shear and flexure with extensive cracks (red) of 12 mm maximum width. Other piers also start to develop extensive shear and flexural cracks.

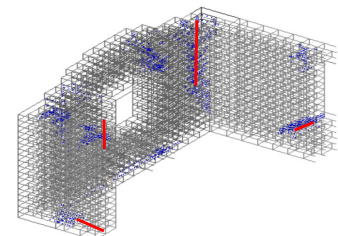
#### OOP Wall Behavior



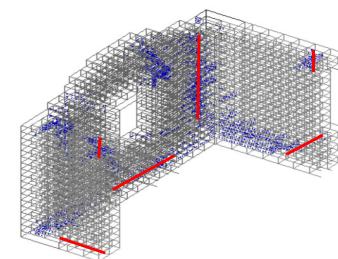
**OP Threshold:** Hairline cracks (blue) appeared at the connection with the in plane walls. Max crack width 0.5 mm.



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



**LS Threshold:** Major cracks (red) of 12 mm maximum width at the IP walls connection. A horizontal crack of maximum opening 2 mm at the bottom appears.



**CP Threshold:** Major cracks (red) of 12 mm maximum width at the IP walls connection. A horizontal crack of maximum opening 2 mm at the bottom appears.

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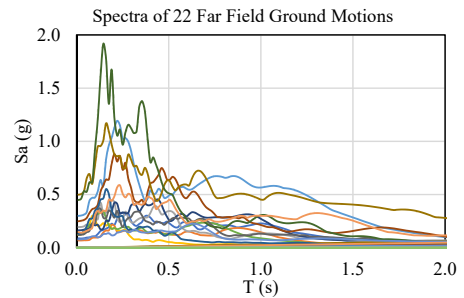
### SEISMIC PERFORMANCE ASSESSMENT

#### Analysis Considerations:

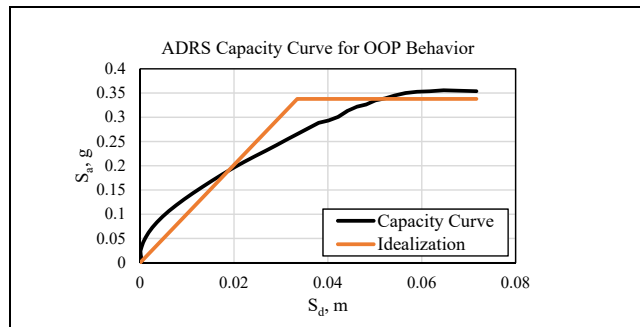
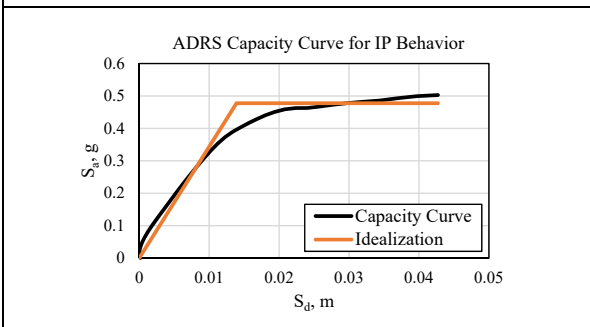
Analysis Methodology:..... Static Analysis (N2 Method)  
 Engineering Demand Parameter (EDP):..... Roof Drift

#### Seismic Ground Motions:

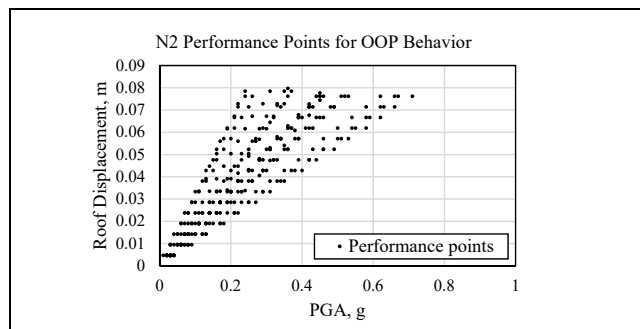
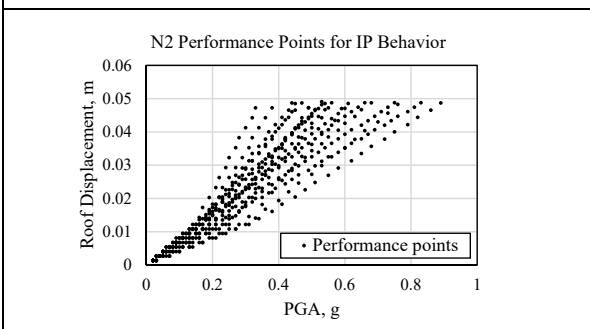
Ground Motion Suite:..... FEMA P695 - 22 Far Field Ground Motions  
 Intensity Measure (IM):..... PGA (g)  
 Scaling Factor:..... 0.1  
 Minimum IM:..... 0  
 Maximum IM:..... 2g



#### Bilinear Idealization:



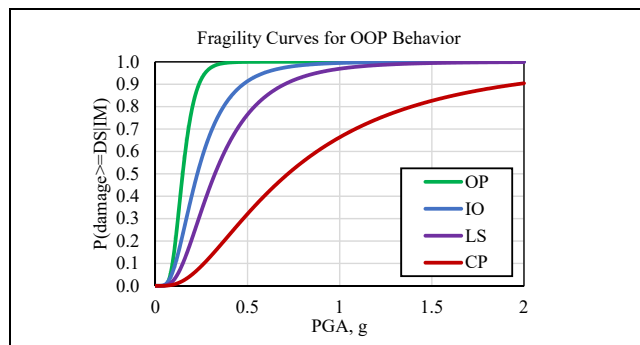
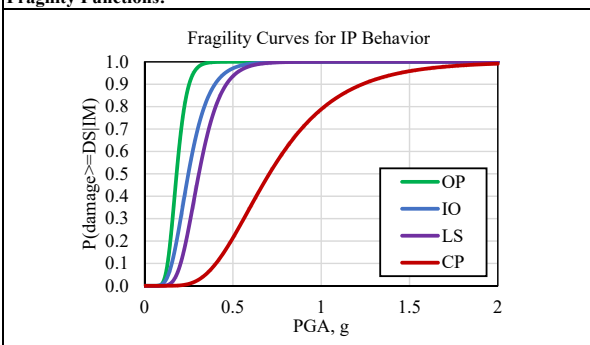
#### EDP Calculation:



### FRAGILITY ASSESSMENT

Integration Methodology:..... Least Square Method

#### Fragility Functions:



Mean:.....	<u>OP</u>	<u>IO</u>	<u>LS</u>	<u>CP</u>
	0.18	0.25	0.31	0.71
Standard Deviation:..	0.26	0.37	0.32	0.44

Mean:.....	<u>OP</u>	<u>IO</u>	<u>LS</u>	<u>CP</u>
	0.15	0.23	0.32	0.72
Standard Deviation:..	0.36	0.58	0.60	0.78

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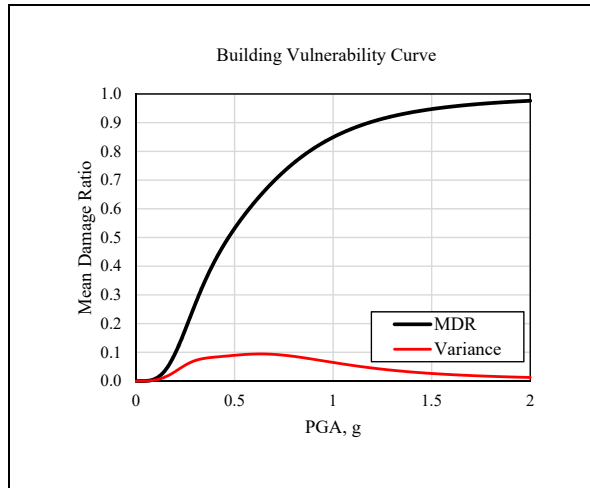
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### VULNERABILITY ASSESSMENT

#### 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 ( <a href="http://www.ecapra.org">www.ecapra.org</a> )