

## FRAGILITY/VULNERABILITY ASSESSMENT

Date: 11/12/2018  
Building Type: UCM-URM7/LR/LD  
Authors: UCL  
Sheet: 1 of 4

### RECTANGULAR BLOCK IN CEMENT MORTAR MASONRY INDEX BUILDING

#### GENERAL INFORMATION

##### Index Building Taxonomy String:

UCM-URM7/LR(1)/LD/FD/NI/LP/SO/RF/NP/OS/GC/VN

##### Rectangular Block in Cement Mortar Masonry (UCM-URM7)

- |  |   |  |   |
|--|---|--|---|
| 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 type="checkbox"/>                 | Long (LP) <input checked="" 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:

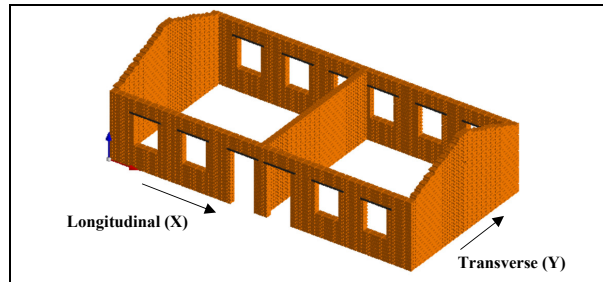
Building Plan Area (m <sup>2</sup> ):.....	60
Building Total Floor Area (m <sup>2</sup> ):.....	60
Number of Stories:.....	1
Story Height (m):.....	2.8
Number of Spans in X Direction:.....	2
Typical Span Length in X Direction (m):.....	5.7
Number of Spans in Y Direction (m):.....	1
Typical Span Length in Y Direction (m):.....	5.3
Wall Thickness (mm):.....	250
Wall Construction:.....	English Bond
Thickness:.....	One Brick

##### Material Properties of Masonry:

Unit Weight, $\gamma$ (kg/m <sup>3</sup> ):.....	1920
Modulus of Elasticity, E (MPa):.....	263
Shear Modulus, G (MPa):.....	158
Compressive Strength, $f_m$ (MPa):.....	4.14
Cohesion, c (MPa):.....	0.069
Tensile Strength, $f_t$ (MPa):.....	0.069
Friction Coefficient, $\mu$ :.....	0.6

#### 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

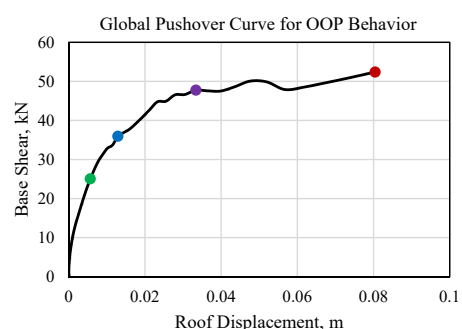
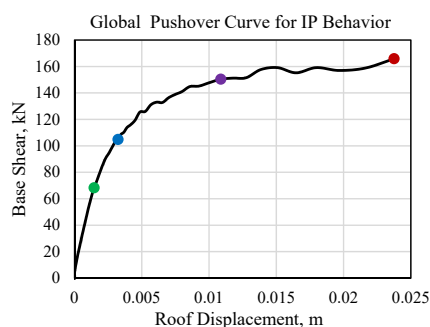
##### Analysis Considerations:

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

#### SEISMIC BEHAVIOR

Seismic Weight of IP Walls (kN):.....	271	Seismic Weight of OOP Walls (kN):.....	275
Fundamental Time Period of IP Walls (sec):.....	0.15	Fundamental Time Period of OOP Walls (sec):.....	0.5

##### Pushover Curve with Damage State Thresholds:



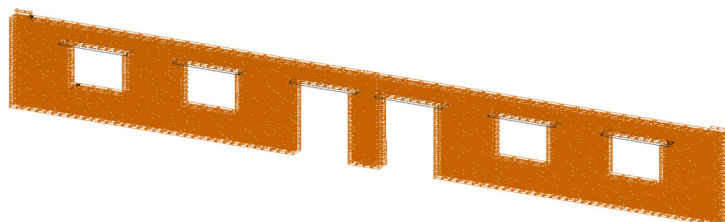
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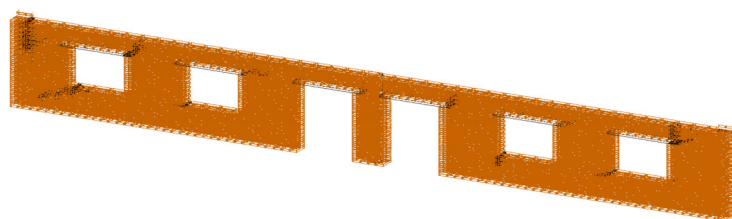
### RECTANGULAR BLOCK IN CEMENT MORTAR MASONRY INDEX BUILDING

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

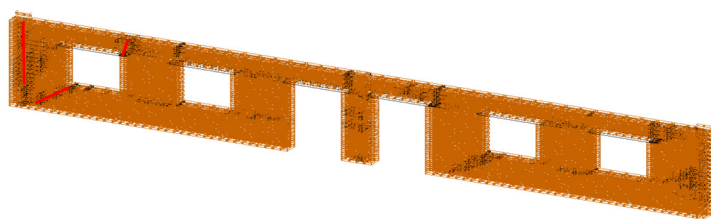
##### IP Wall Behavior



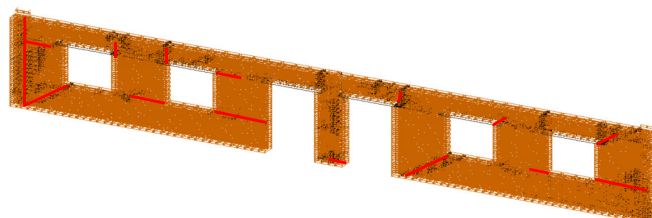
**OP Threshold:** Hairline cracks (black) of maximum width 0.35 mm appeared at few corners of openings.



**IO Threshold:** Hairline to minor cracks (black) of maximum width 1 mm developed at most of the corners of the openings, left most pier and spandrel start to develop shear and flexural cracks, respectively.

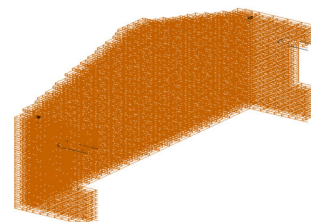


**LS Threshold:** Left most pier has developed extensive shear crack (red) of 12.5 mm maximum width. The left most spandrel also develop an extensive flexural crack (red). Major shear cracks (red) of maximum width 10 mm as well as horizontal (flexural) cracks (red) with a maximum opening of 2 mm appear through most of piers.

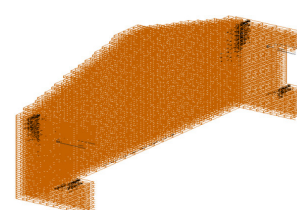


**CP Threshold:** Most piers and spandrels developed extensive shear cracks (of more than 12.5 mm maximum width) and flexural cracks (of 4 mm maximum crack opening) (red). The left most pier and spandrel are on the verge of collapse.

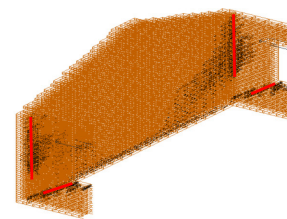
##### OOP Wall Behavior



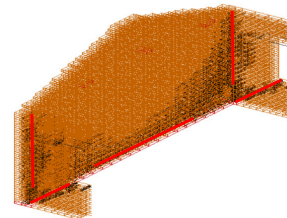
**OP Threshold:** Minor cracks (black) of 0.5 mm maximum width appeared at the connection with the in-plane wall.



**IO Threshold:** Minor cracks (black) with maximum width of 3 mm started to extend downwards at the connection between IP walls, minor shear cracks (black) of 1 mm started in the IP walls.



**LS Threshold:** Full combined mechanism started with major cracks (red) of 12.5 mm maximum width at the IP walls connections through half of the wall height and shear cracks (red) of 12.5 mm width developed in IP walls. A minor horizontal crack at the bottom layer extended to full length, with maximum crack opening of 1 mm.



**CP Threshold:** The cracks (vertical, red) at the IP wall connection becomes extensive with maximum width of more than 12.5 mm and extends through full wall height. Extensive shear crack (diagonal, red) with a width of more than 12.5 mm developed in the IP walls. A horizontal crack extended through the wall with a maximum crack opening of 4 mm.

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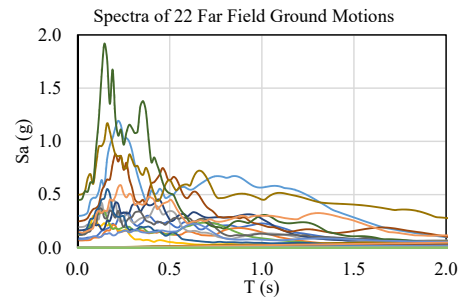
### SEISMIC PERFORMANCE ASSESSMENT

#### Analysis Considerations:

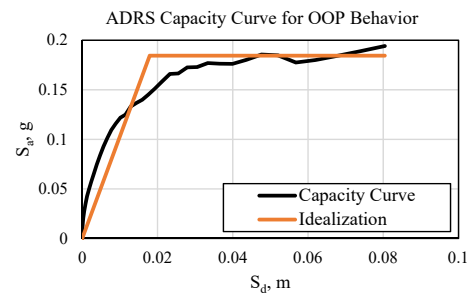
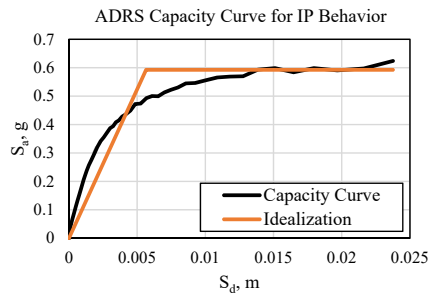
Analysis Methodology:..... Static Analysis (N2 Method)  
Engineering Demand Parameter (EDP):..... Roof Drift

#### Seismic Ground Motions:

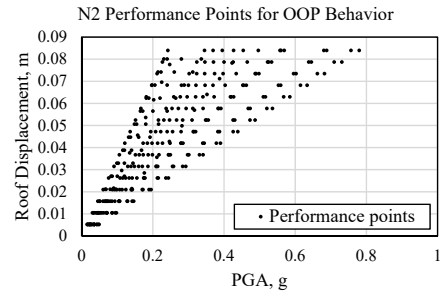
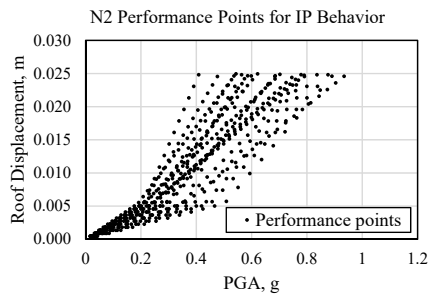
Ground Motion Suite:..... FEMA P695 - 22 Far Field Ground Motions  
Intensity Measure (IM):..... PGA (g)  
Scaling Factor:..... 0.1  
Minimum IM:..... 0  
Maximum IM:..... 2g



#### Bilinear Idealization:



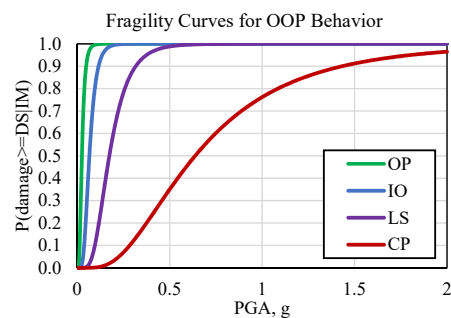
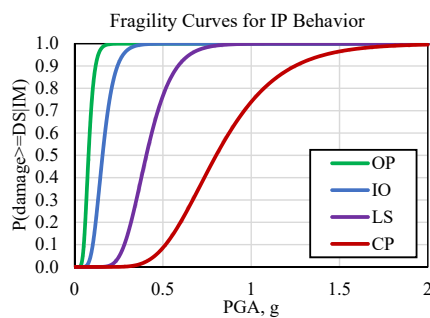
#### EDP Calculation:



### FRAGILITY ASSESSMENT

Integration Methodology:..... Least Square Method

#### Fragility Functions:



	OP	IO	LS	CP
Mean:.....	0.08	0.16	0.41	0.80
Standard Deviation:..	0.32	0.33	0.29	0.34

	OP	IO	LS	CP
Mean:.....	0.03	0.07	0.17	0.64
Standard Deviation:..	0.51	0.44	0.47	0.63

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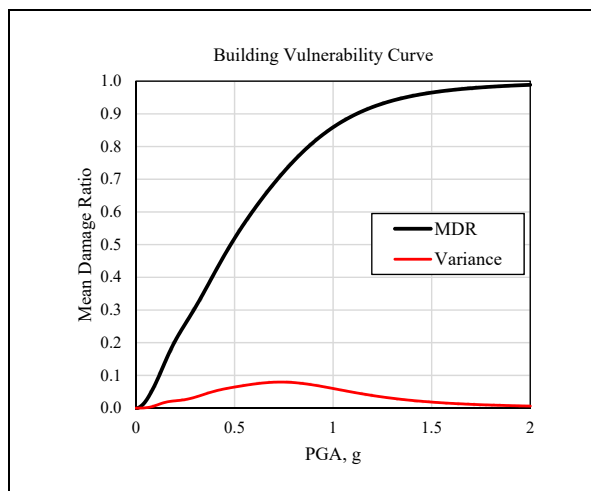
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#### VULNERABILITY ASSESSMENT

##### Damage to Loss Function:

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

##### Vulnerability Function:



#### 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)