

# FRAGILITY/VULNERABILITY ASSESSMENT

Date:	09/12/2018
Building Type:	CM/LR/HD
Authors:	UCL
Sheet:	1 of 4

## CONFINED MASONRY INDEX BUILDING

### GENERAL INFORMATION

#### Index Building Taxonomy String:

- Main structural system:.....
- Height range:.....
- Seismic design level:.....
- Diaphragm Type:.....
- Structural Irregularity:.....
- Wall Panel Length:.....
- Wall Openings:.....
- Foundation Type and Flexibility:.....
- Seismic Pounding Risk:.....
- Seismic Retrofitting:.....
- Structural Health Condition:.....
- Non-Structural Components:.....

CM/LR(1)/HD/FD/NI/SP/LO/RF/NP/OS/GC/NN

#### Confined Masonry in Cement Mortar (CM)

- |                                                   |                                                         |                                               |
|---------------------------------------------------|---------------------------------------------------------|-----------------------------------------------|
| Low (LR) <input checked="" type="checkbox"/>      | Medium (MR) <input type="checkbox"/>                    | High (HR) <input type="checkbox"/>            |
| Poor (PD) <input type="checkbox"/>                | Low (LD) <input type="checkbox"/>                       | Medium (MD) <input type="checkbox"/>          |
| Flexible (FD) <input checked="" type="checkbox"/> | Rigid (RD) <input type="checkbox"/>                     | High (HD) <input checked="" type="checkbox"/> |
| No (NI) <input checked="" type="checkbox"/>       | Horizontal (HI) <input type="checkbox"/>                | Vertical (VI) <input type="checkbox"/>        |
| Short (SP) <input checked="" type="checkbox"/>    | Long (LP) <input type="checkbox"/>                      | Both (HV) <input type="checkbox"/>            |
| Small (SO) <input type="checkbox"/>               | Large (LO) <input checked="" type="checkbox"/>          |                                               |
| Flexible (FF) <input type="checkbox"/>            | Rigid (RF) <input checked="" type="checkbox"/>          |                                               |
| No (NP) <input checked="" type="checkbox"/>       | Yes (PR) <input type="checkbox"/>                       |                                               |
| Original (OS) <input checked="" type="checkbox"/> | Retrofitted (RS) <input type="checkbox"/>               |                                               |
| Poor (PC) <input type="checkbox"/>                | Good (GC) <input checked="" type="checkbox"/>           |                                               |
| Vulnerable (VN) <input type="checkbox"/>          | Non Vulnerable (NN) <input checked="" type="checkbox"/> |                                               |

### INTRINSIC CHARACTERISTICS

#### General Geometry:

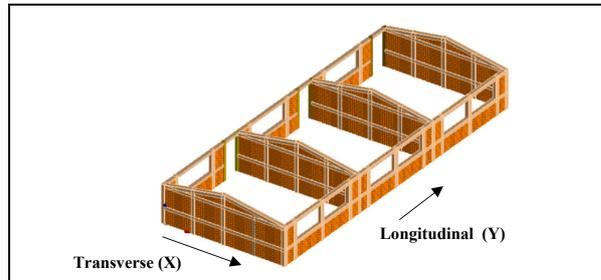
Building Plan Area (m <sup>2</sup> ):.....	146
Building Total Floor Area (m <sup>2</sup> ):.....	146
Number of Stories:.....	1
Story Height (m):.....	2.8
Number of Spans in X Direction:.....	3
Typical Span Length in X Direction (m):.....	6.5
Number of Spans in Y Direction (m):.....	1
Typical Span Length in Y Direction (m):.....	7.5
Wall Thickness (mm):.....	170
Wall Construction:.....	Running Bond
No. of Wythes:.....	Half Brick

#### Material Properties:

	Masonry	Concrete
Unit Weight, $\gamma$ (kg/m <sup>3</sup> ):.....	1300	2500
Modulus of Elasticity, E (MPa):.....	960	17400
Shear Modulus, G (MPa):.....	440	6960
Compressive Strength, $f_m$ (MPa):.....	4.06	21
Cohesion, c (MPa):.....	0.39	
Tensile Strength, $f_t$ (MPa):.....	0.11	
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> ):.....	0.3
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> ):.....	0.3

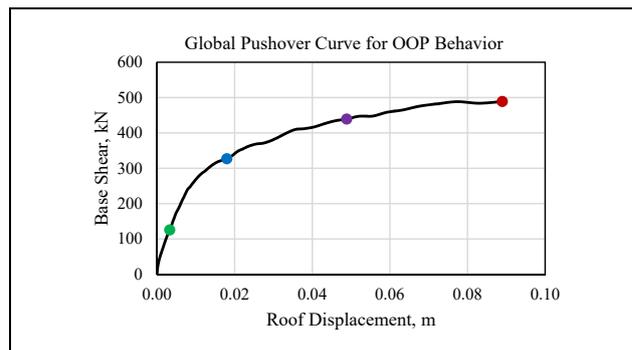
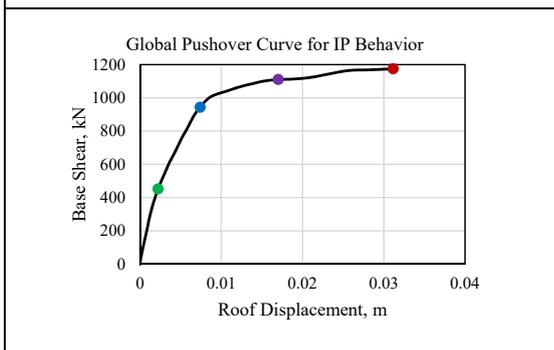
#### Analysis Considerations:

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

### SEISMIC BEHAVIOR

Seismic Weight of IP Walls (kN):.....	435	Seismic Weight of OOP Walls (kN):.....	400
Fundamental Time Period of IP Walls (sec):.....	0.1	Fundamental Time Period of OOP Walls (sec):.....	0.2

#### Pushover Curve with Damage State Thresholds:



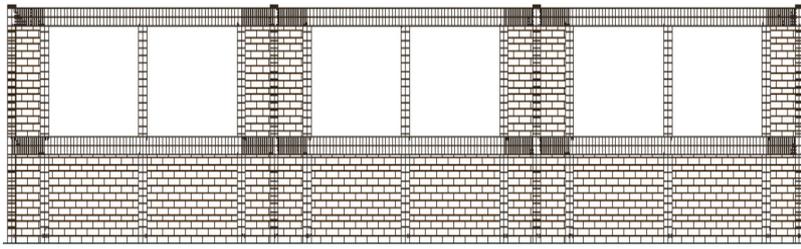
# FRAGILITY/VULNERABILITY ASSESSMENT

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## CONFINED MASONRY INDEX BUILDING

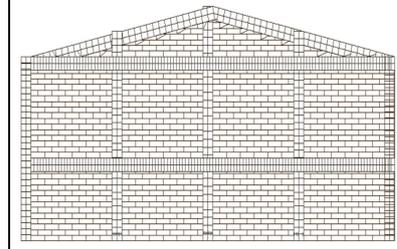
### Damage (Crack Pattern, Width and Extent) Progression

#### IP Wall Behavior

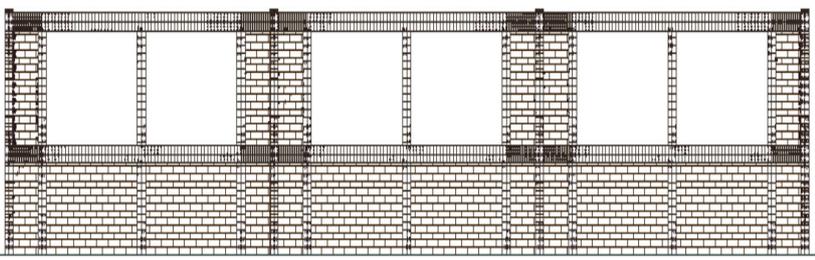


**OP Threshold:** Hairline cracks (black) appeared in some beam column connections and at the base of columns, maximum crack width less than 0.2 mm.

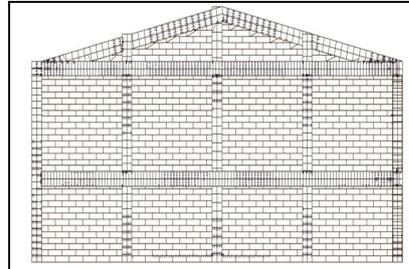
#### OOP Wall Behavior



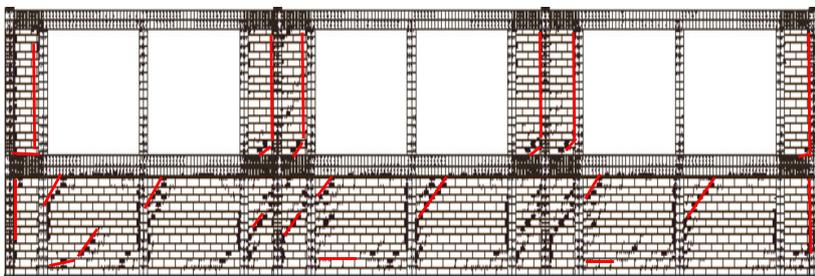
**OP Threshold:** Hairline cracks (black) appeared at the base the middle columns, maximum crack width is less than 0.2 mm.



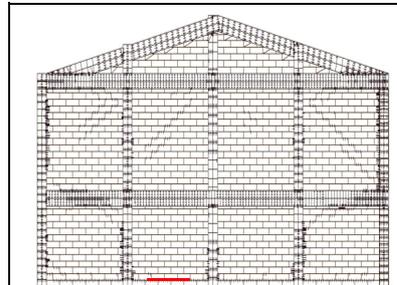
**IO Threshold:** Hairline cracks (black) appeared in all the beam column connections, vertical cracks of maximum width 2 mm start to appear at the connection between upper slender piers and columns, columns in the upper part develop shear cracks due to short column effect. Flexural hairline cracks also appeared in all of the column base.



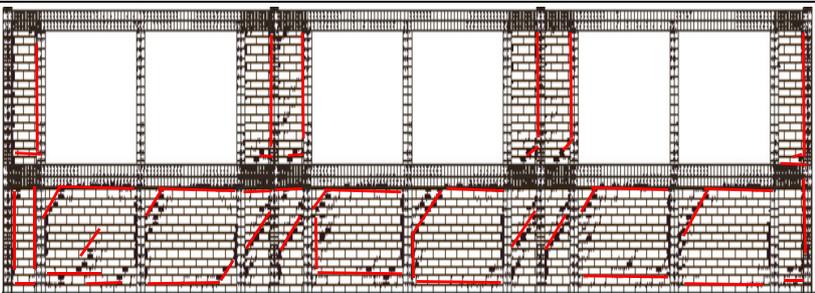
**IO Threshold:** Hairline to minor cracks (black) appeared at the base of central walls and columns with maximum crack opening of 0.5 mm.



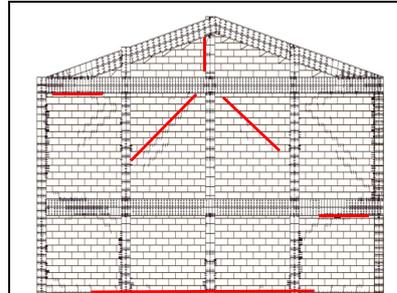
**LS Threshold:** Major flexural cracks (red) developed at base and side of the slender wall piers extending up to full height with crack width of 12 mm at the sides and 6 mm at the base and top. Upper columns have developed more shear cracks extending over 1/3rd of height. Flexural cracks extend upward at the column base. Major diagonal shear and flexural cracks (red) started to develop in all of the lower large walls with maximum width of 12 mm.



**LS Threshold:** Minor flexural cracks extended through full length of wall at the base (black), with a max crack opening 4.5 mm, several panels develop diagonal shear cracks (black) of 2 mm maximum width.



**CP Threshold:** Upper slender walls are rocking within the tie beam-column frame, their base and side is completely detached (14 mm wide cracks (red) at sides and 6 mm opening (red) at the base), lower large walls have failed in combined shear-sliding mechanism with maximum crack (red) width of more than 12 mm, lower slender walls have damaged in shear with maximum crack width (red) of more than 12 mm, major shear cracks at the column base, many of the rebars in column base and at the tie beam-column joints have yielded.



**CP Threshold:** Wall base and column damaged in flexure with a wide horizontal crack (red) at the base of more than 4.5 mm maximum opening. One portion of gable pushed out due to torsion, major diagonal shear and flexural cracks (red) appear in several panels, with maximum crack width 4.5 mm.

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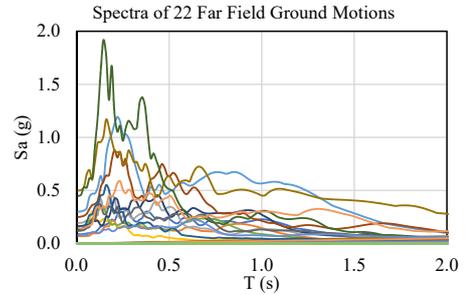
### SEISMIC PERFORMANCE ASSESSMENT

#### Analysis Considerations:

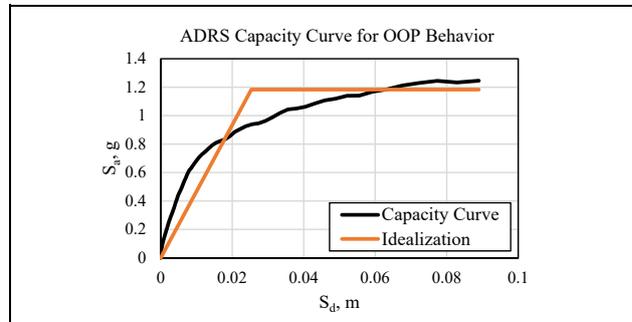
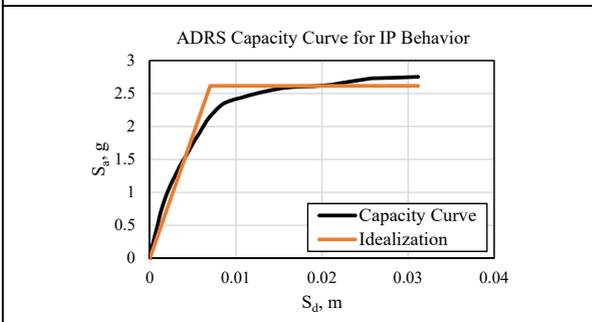
Analysis Methodology:..... Static Analysis (N2 Method)  
 Engineering Demand Parameter (EDP):..... Roof Drift

#### Seismic Ground Motions:

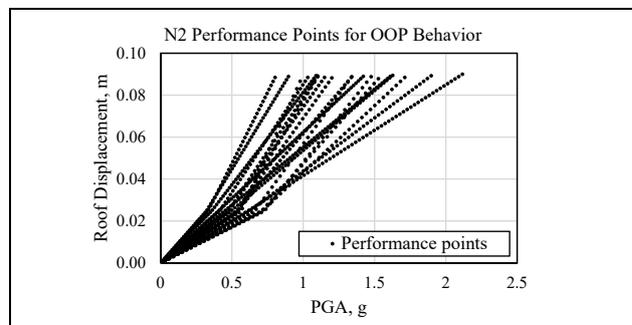
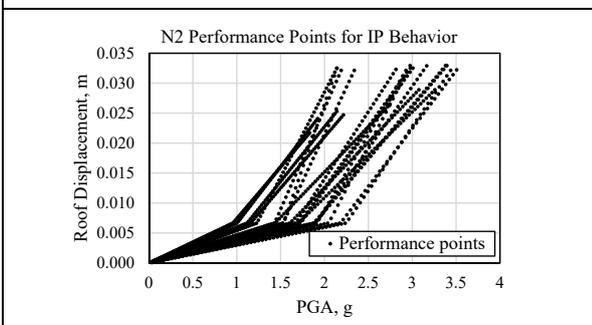
Ground Motion Suite:..... FEMA P695 - 22 Far Field Ground Motions  
 Intensity Measure (IM):..... PGA (g)  
 Scaling Factor:..... 0.05  
 Minimum IM:..... 0  
 Maximum IM:..... 4g



#### Bilinear Idealization:



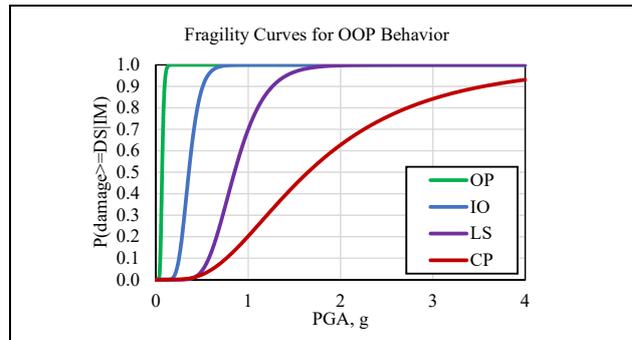
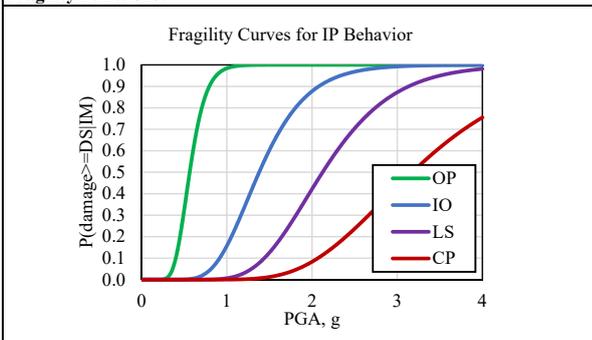
#### EDP Calculation:



### FRAGILITY ASSESSMENT

Integration Methodology:..... Least Square Method

#### Fragility Functions:



Mean:.....	<u>0.56</u>	<u>1.38</u>	<u>2.12</u>	<u>3.18</u>
Standard Deviation:..	<u>0.27</u>	<u>0.32</u>	<u>0.31</u>	<u>0.33</u>

Mean:.....	<u>0.07</u>	<u>0.36</u>	<u>0.85</u>	<u>1.65</u>
Standard Deviation:..	<u>0.27</u>	<u>0.28</u>	<u>0.31</u>	<u>0.60</u>

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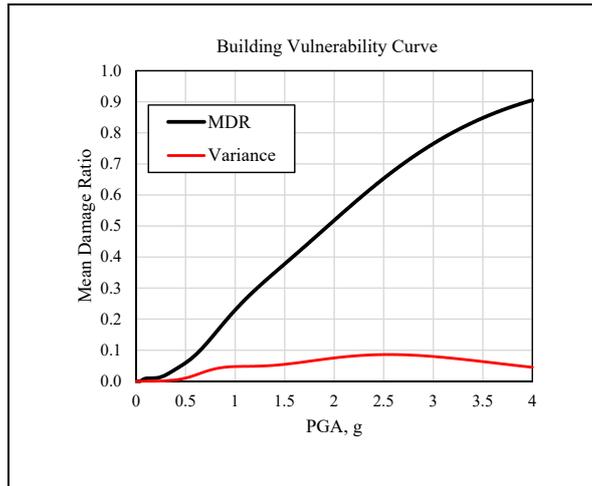
## CONFINED MASONRY INDEX BUILDING

### 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:.....	<u>Global Library of School Infrastructure - GLoSI</u>
Main Bibliographical References:.....	<u>GLoSI Technical Report</u>
	<u>FEMA P-695</u>
	<u>ASCE 41-17</u>
	<u>N2 Method (Fajfar, 2000)</u>
	<u>GEM Analytical Vulnerability Assessment Guideline (D'Ayala et al., 2015)</u>
	<u>FUNVUL (www.ecapra.org)</u>