

# FRAGILITY VULNERABILITY ASSESSMENT

Date: 9/17/2018  
 Building Type: RC1/MR/LD  
 Author: UNIANDES  
 Sheet: 1 de 3

## REINFORCED CONCRETE BUILDINGS

### GENERAL INFORMATION

#### Index Building Taxonomy Code:

- Main structural system:.....
- Height range:.....
- Seismic design level:.....
- Diaphragm Type:.....
- Structural Irregularity:.....
- Span Length:.....
- Pier Type:.....
- Foundation Type and Flexibility:.....
- Seismic Pounding Risk:.....
- Seismic Retrofitting:.....
- Structural Health Conditions:.....
- Vulnerable Non-Structural Components:.....

#### RC1/MR/LD/RD/NI/SS/SW/RF/NP/OS/GC/VN

|                |                                     |                         |                                     |                            |                                     |                     |                          |     |                          |
|----------------|-------------------------------------|-------------------------|-------------------------------------|----------------------------|-------------------------------------|---------------------|--------------------------|-----|--------------------------|
| RC1            | <input checked="" type="checkbox"/> | RC2                     | <input type="checkbox"/>            | RC3                        | <input type="checkbox"/>            | RC4                 | <input type="checkbox"/> | RC5 | <input type="checkbox"/> |
|                |                                     | Low (LR)                | <input type="checkbox"/>            | Medium (MR)                | <input checked="" type="checkbox"/> | High (HR)           | <input type="checkbox"/> |     |                          |
| Poor (PD)      | <input type="checkbox"/>            | Low (LD)                | <input checked="" type="checkbox"/> | Medium (MD)                | <input type="checkbox"/>            | High (HD)           | <input type="checkbox"/> |     |                          |
|                |                                     | Flexible diaphragm (FD) | <input type="checkbox"/>            | Rigid diaphragm (RD)       | <input checked="" type="checkbox"/> |                     |                          |     |                          |
| No irreg. (NI) | <input checked="" type="checkbox"/> | Hor. (HI)               | <input type="checkbox"/>            | Vert. (VI)                 | <input type="checkbox"/>            | Hor. and vert. (HV) | <input type="checkbox"/> |     |                          |
|                |                                     | Short span (SS)         | <input checked="" type="checkbox"/> | Slender - weak column (SW) | <input type="checkbox"/>            |                     |                          |     |                          |
|                |                                     | Regular column (RO)     | <input checked="" type="checkbox"/> | Regular column (RO)        | <input type="checkbox"/>            |                     |                          |     |                          |
|                |                                     | Rigid foundation (RF)   | <input checked="" type="checkbox"/> | Flexible foundation (FF)   | <input type="checkbox"/>            |                     |                          |     |                          |
|                |                                     | No pounding (NP)        | <input checked="" type="checkbox"/> | Pounding risk (PR)         | <input type="checkbox"/>            |                     |                          |     |                          |
|                |                                     | Original structure (OS) | <input checked="" type="checkbox"/> | Retrofitted structure (RS) | <input type="checkbox"/>            |                     |                          |     |                          |
|                |                                     | Good condition (GC)     | <input checked="" type="checkbox"/> | Poor condition (PC)        | <input type="checkbox"/>            |                     |                          |     |                          |
|                |                                     | Non vulnerable (NN)     | <input type="checkbox"/>            | Vulnerable (VN)            | <input checked="" type="checkbox"/> |                     |                          |     |                          |

### INTRINSIC CHARACTERISTICS

#### General Geometry:

|  |       |
|--|-------|
| Building plane area (m <sup>2</sup> ):.....    | 304   |
| Building total area (m <sup>2</sup> ):.....    | 608   |
| Number of stories:.....                        | 2     |
| Story height (m):.....                         | 3     |
| Number of spans in X direction:.....           | 7     |
| Typical span length in X direction (m):.....   | 4.5   |
| Number of spans in Y direction (m):.....       | 3     |
| Typical span length in Y direction (m):.....   | 3.5   |
| Foundation system:.....                        | CISF  |
| Typical column dimensions (cm x cm):.....      | 25X30 |
| Typical beam dimensions (cm x cm):.....        | 25X30 |
| Typical shear wall dimensions (cm x cm):.....  | -     |
| Typical bracing member section (cm x cm):..... | -     |

#### Material properties:

|  |     |                       |      |
|--|-----|-----------------------|------|
| Concrete:..... f <sub>c</sub> (MPa):         | 21  | E <sub>c</sub> (GPa): | 21.5 |
| Reinforcement:..... f <sub>y</sub> (Mpa):    | 420 | E <sub>s</sub> (GPa): | 200  |
| Structural steel:..... f <sub>y</sub> (Mpa): | -   | E <sub>s</sub> (GPa): | -    |
| Masonry:..... f <sub>m</sub> (MPa):          | -   | γ:                    | -    |

#### Infill walls:

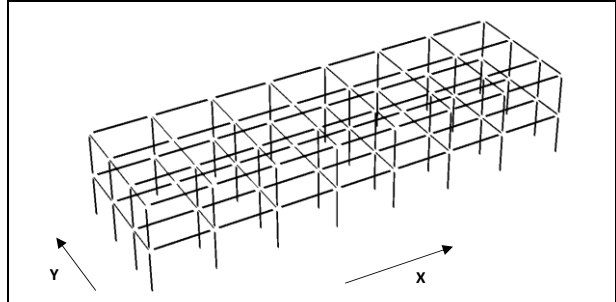
|   |   |                             |   |                             |
|---|---|-----------------------------|---|-----------------------------|
| Infill type:.....   | <b>Interior walls</b>                   |                             | <b>Facade walls</b>                     |                             |
| Wall height (m):..... X <input type="checkbox"/> - Y <input type="checkbox"/> | <input type="checkbox"/>                | 3                           | X <input type="checkbox"/>              | 1.5                         |
| Depth (m):..... X <input type="checkbox"/> - Y <input type="checkbox"/>       | <input type="checkbox"/>                | 0.15                        | X <input type="checkbox"/>              | 0.15                        |
| Isolated from structure:.....   | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/> | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/> |

### SEISMIC BEHAVIOR

|                                      |      |
|--------------------------------------|------|
| Total weight (D) (kN):.....          | 3833 |
| Total weight (L) (kN):.....          | 966  |
| T <sub>1</sub> uncracked (sec):..... | 0.92 |
| T <sub>1</sub> cracked (sec):.....   | 1.16 |

### MODELLING PARAMETERS

#### 3D Numerical model:



#### Modelling considerations:

|                                       |  |                                      |
|---------------------------------------|--|--------------------------------------|
| Plasticity model:.....                | Lumped <input checked="" type="checkbox"/> | Distributed <input type="checkbox"/> |
| Infill walls modelling approach:..... | -  |                                      |
| Roof Diaphragm:.....                  | Rigid <input checked="" type="checkbox"/>  | Flexible <input type="checkbox"/>    |
| Foundation:.....                      | Rigid <input checked="" type="checkbox"/>  | Flexible <input type="checkbox"/>    |
|                                       | k <sub>v</sub> (kN) _____                  | k <sub>h</sub> (kN) _____            |

#### Loads:

|  |         |
|--|---------|
| Over imposed design dead load (D) (kN/m <sup>2</sup> ):..... | 1.2     |
| Design Live load (L) (kN/m <sup>2</sup> ):.....              | 2.0     |
| Load combination in non-linear analysis:.....                | D+0.25L |
| Average load per square meter (kN/m <sup>2</sup> ):.....     | 7.9     |

#### Analysis considerations:

|                                   |   |                                       |
|-----------------------------------|---|---------------------------------------|
| Global P-Delta effects:.....      | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>           |
| Rigid zones:.....                 | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/>           |
| Initial effective stiffness:..... | Beams <input type="checkbox"/> 0.35     | Columns <input type="checkbox"/> 0.30 |
| Analysis direction:.....          | X <input checked="" type="checkbox"/>   | Y <input type="checkbox"/>            |
| Analysis orientation:.....        | (+) <input checked="" type="checkbox"/> | (-) <input type="checkbox"/>          |

|   |      |
|---|------|
| 1st mode mass participation (%):.....                     | 80.4 |
| First floor column area (m <sup>2</sup> ):.....           | 2.88 |
| Total weight (D+L) /columns area (%f <sub>c</sub> ):..... | 0.16 |
| Horizontal first story shear column capacity (g):.....    | 0.45 |

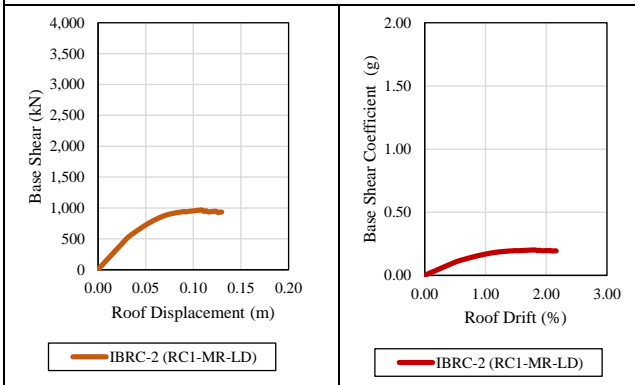
# FRAGILITY VULNERABILITY ASSESSMENT

|                |           |
|----------------|-----------|
| Date:          | 9/17/2018 |
| Building Type: | RC1/MR/LD |
| Author:        | UNIANDÉS  |
| Sheet:         | 2 de 3    |

## REINFORCED CONCRETE BUILDINGS

### SEISMIC BEHAVIOR

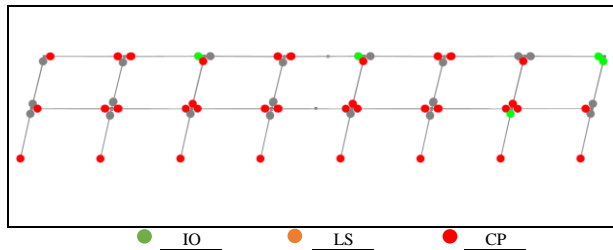
#### Capacity Curve:



#### Idealized capacity curve:

| Behavior point          | Base shear (kN) | Displacement (m) |
|-------------------------|-----------------|------------------|
| Yield point:.....       | 758             | 0.06             |
| Maximum capacity:.....  | 1000            | 0.29             |
| Ultimate capacity:..... | -               | -                |

**Collapse mechanism:** Excessive flexibility



### NON-LINEAR ANALYSIS PARAMETERS

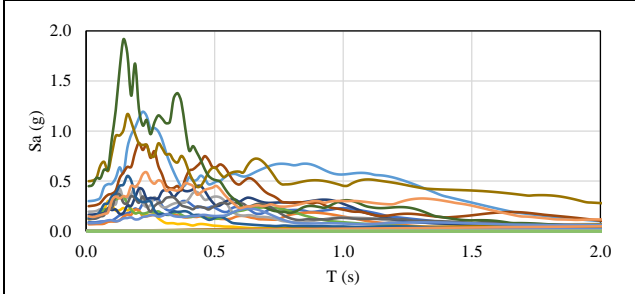
#### Seismic ground motions:

|                                     |           |
|-------------------------------------|-----------|
| Number of ground motions used:..... | 22        |
| Soil type:.....                     | C         |
| Source type:.....                   | Far field |
| Retrieved from:.....                | PEER-NGA  |

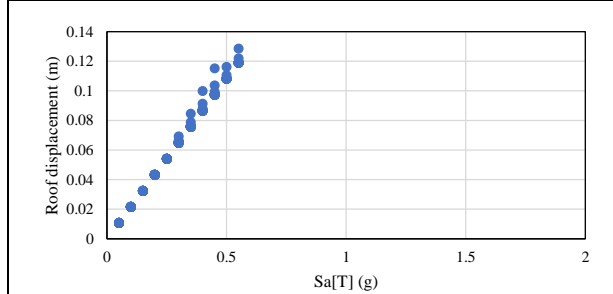
#### Analysis considerations:

|  |  |                                  |
|--|--|----------------------------------|
| Non-linear analysis:.....              | Static <input checked="" type="checkbox"/> | Dynamic <input type="checkbox"/> |
| Analysis methodology:.....             | N2   |                                  |
| Intensity measure parameter (IM):..... | Sa[T] (g)                                  |                                  |
| Scaling factor:.....                   | 0.1  | Minimum: 0.1 Maximum: 2          |

#### Ground motion spectra:



#### Illustrative EDP:



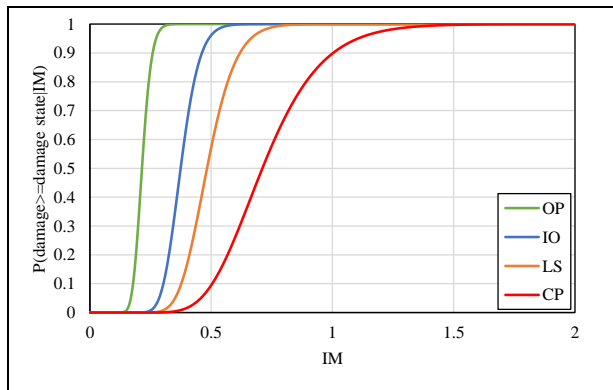
### FRAGILITY ASSESSMENT

#### Damage states (DS):

|  |           |  |  |  |
|--|-----------|--|--|--|
| Intensity Measure:.....                            | Sa[T] (g) |  |  |  |
| Slight (SD) -Operational (OP) (%):.....            | 0.75      |  |  |  |
| Medium (MD) - Immediate occupancy (IO) (%):.....   | 1.30      |  |  |  |
| Extensive (ED) - Life safety (LS) (%):.....        | 1.75      |  |  |  |
| Collapse (CD) - Collapse prevention (CP) (%):..... | 2.30      |  |  |  |
| Integration methodology:.....                      | LSM       |  |  |  |

|                 | OP   | IO   | LS   | CP:  |
|-----------------|------|------|------|------|
| Mean:.....      | 0.21 | 0.37 | 0.48 | 0.71 |
| Deviation:..... | 0.15 | 0.17 | 0.19 | 0.27 |

#### Fragility function:



# FRAGILITY VULNERABILITY ASSESSMENT

|                |           |
|----------------|-----------|
| Date:          | 9/17/2018 |
| Building Type: | RCI/MR/LD |
| Author:        | UNIANDES  |
| Sheet:         | 3 de 3    |

## REINFORCED CONCRETE BUILDINGS

### VULNERABILITY ASSESSMENT

#### Component model:

| Story | Group | Subgroup | Description      | Unit    | Quantity | Fragility curve | EDP   | Correlation |
|-------|-------|----------|------------------|---------|----------|-----------------|-------|-------------|
| 1     | E     | C1       | Column-one beam  | Node    | 8        | B1041.091a      | Drift | 0           |
| 1     | E     | C2       | Column-two beams | Node    | 21       | B1041.091b      | Drift | 0           |
| 1     | A     | F2       | Masonry facade   | 5m x 3m | 14       | C1011.006a      | Drift | 1           |
| 1     | A     | M4       | Masonry wall     | 5m x 3m | 6        | C1011.006b      | Drift | 1           |
| 1     | C     | S2       | Contents         | 5m x 5m | 13       | E2022.010a      | Drift | 0           |
| 2     | E     | C1       | Column-one beam  | Node    | 8        | B1041.091a      | Drift | 0           |
| 2     | E     | C2       | Column-two beams | Node    | 21       | B1041.091b      | Drift | 0           |
| 2     | A     | F2       | Masonry facade   | 5m x 3m | 14       | C1011.006a      | Drift | 1           |
| 2     | A     | M4       | Masonry wall     | 5m x 3m | 6        | C1011.006b      | Drift | 1           |
| 2     | C     | S2       | Contents         | 5m x 5m | 13       | E2022.010a      | Drift | 0           |

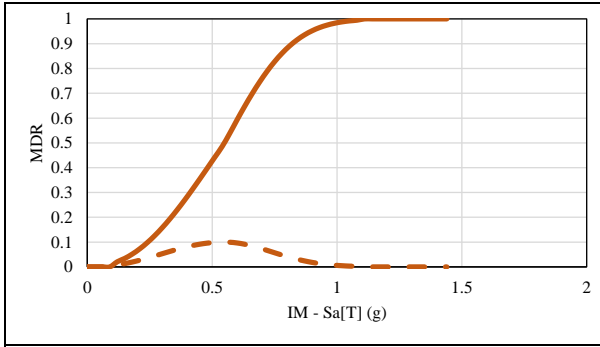
#### Phase I:

|  |   |
|--|---|
| Beta model uncertainty:.....                             | 0.3   |
| Number of iteration for model uncertainty:.....          | 20  |
| Number of iterations for damage states uncertainty:..... | 20  |
| Number of iterations for cost and time uncertainty:..... | 20  |
| Scale factor for cost:.....                              | Yes <input type="checkbox"/> No <input checked="" type="checkbox"/> |

#### Phase II:

|   |     |
|---|-----|
| Lower intensity to no damage (g/g):.....                  | 0.1 |
| Maximum allowable residual drift for demolition (%):..... | 1.5 |
| Percentage of building replacement value (%):.....        | 100 |
| Bidirectional factor for total cost model:.....           | 1   |
| Intensity level for building evacuation (g/g):.....       | 2   |

#### Vulnerability function:



#### Fragility to vulnerability weighting percentage:

|         |    |         |    |         |    |         |     |
|---------|----|---------|----|---------|----|---------|-----|
| OP (%): | 10 | IO (%): | 35 | LS (%): | 65 | CP (%): | 100 |
|---------|----|---------|----|---------|----|---------|-----|

#### GLOSSARY

|  |                                 |                                    |
|--|---------------------------------|------------------------------------|
| fc: Compressive concrete strength      | kv: Spring vertical stiffness   | IM: Intensity measure              |
| Ec: Concrete elastic module            | kh: Spring horizontal stiffness | DM: Damage states                  |
| fy: Tensile steel strength             | kθ: Spring rotational stiffness | OP: Operational                    |
| Es: Steel elastic module               | D: Death load                   | IO: Immediate occupancy            |
| fm: Masonry compressive strength       | L: Live load                    | LS: Life safety                    |
| γ: Masonry density                     | T1: First mode period           | CP: Collapse prevention            |
| CISF: Concrete isolated spread footing | Sa: Pseudo acceleration         | EDP: Engineering demand parameters |

Horizontal first story shear column capacity (g) =  $\sqrt{(f_c)/6} * (A_{col}/W)$

#### 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)   |