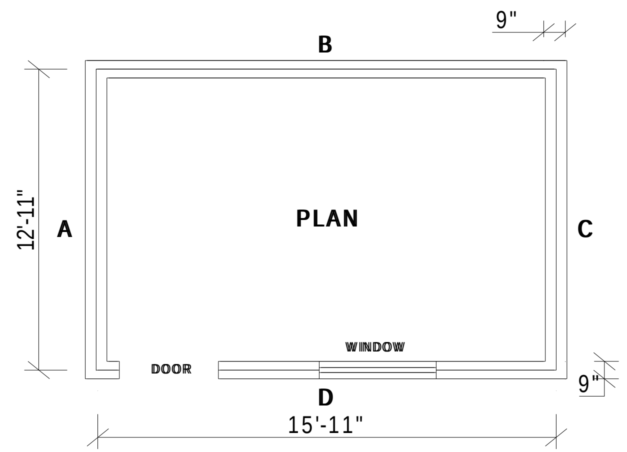
Presentation Title

# Shear Damage Studies of Brick Masonry Structures
# Experimental and Numerical Observations

Continue

# Simulated Earthquake Vibration test on URM structural model

## Details of The Field Model



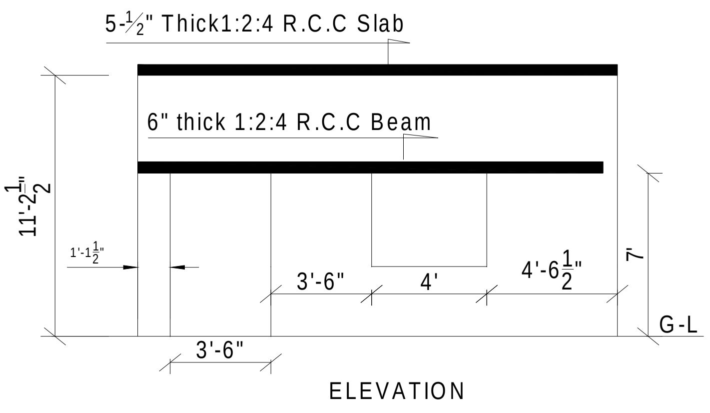
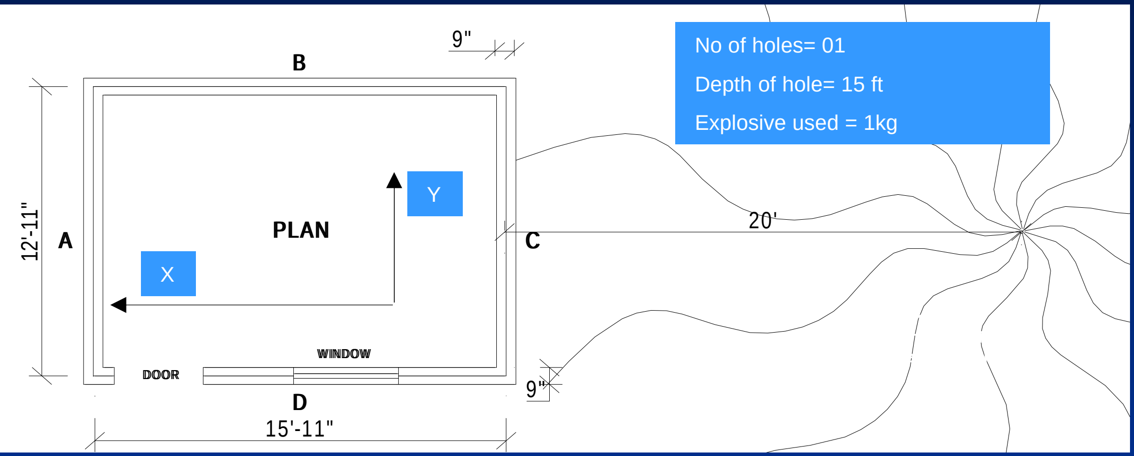



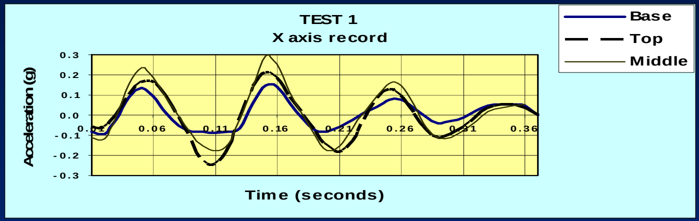

**Table 1**

**Properties of Brick, Mortar and Brick Mortar Assemblage**

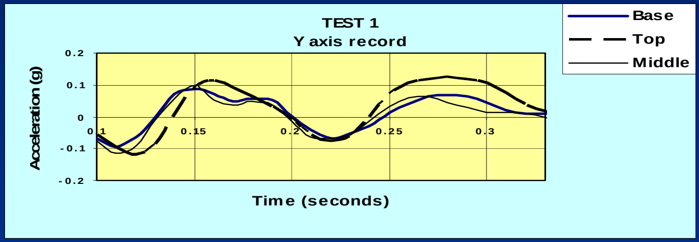
| No: | Material Properties | |
|---|---|---|
| 1 | Water Absorption of Brick Unit | 22% |
| 2 | Initial Rate of Absorption of Brick Unit (IRA) | 1.7kg/min/m$^2$ |
| 3 | Compressive Strength of Brick Unit | 2500 Psi |
| 4 | Modulus of Elasticity of Brick Unit | 600 Ksi |
| 5 | Compressive strength of mortar (Cube Strength of mortar CSK 144, w/c = 1.6) | 900 Psi |
| 6 | Compressive Strength of Masonry Assemblage | 700 Psi |
| 7 | Modulus of Elasticity of Masonry Assemblage | 290 Ksi |
| 8 | Masonry Bond Strength in Tension | 20 Psi |
| 9 | Masonry Bond Strength in Shear ($\tau_o$) | 14 Psi |
| 10 | Coefficient of friction $\mu$ | 1.0 |

**SEVT (contd): TEST-1** was designed with the objective **to evaluate the dynamic characteristics of the masonry** model. The explosive was placed in 4 inch diameter bore hole drilled to a depth of 15 ft.

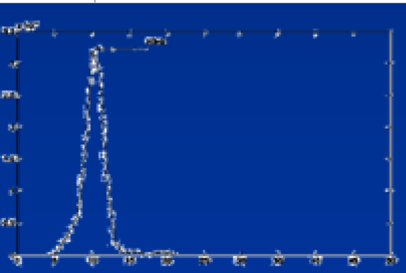


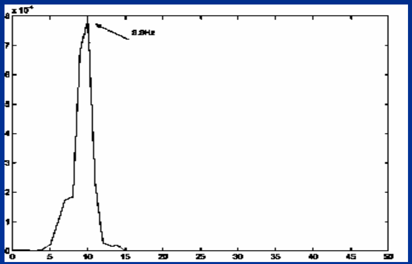

(a): X-axis record for Base, middle and Top



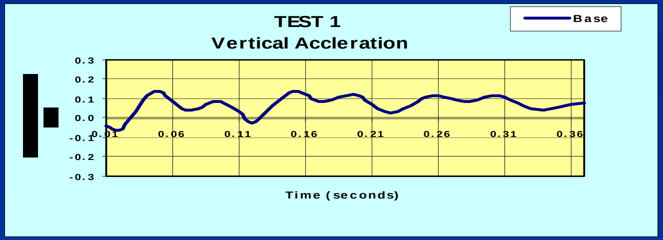

(b): Y-axis record for Base, middle and Top



(a): X axis



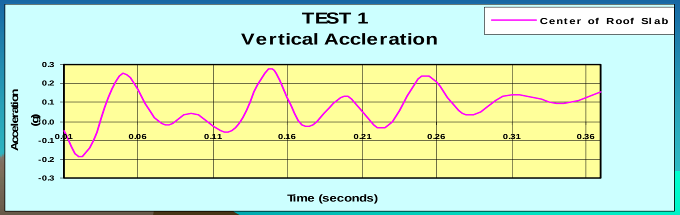

(b): Y axis




(c): Vertical Acceleration at Base of model

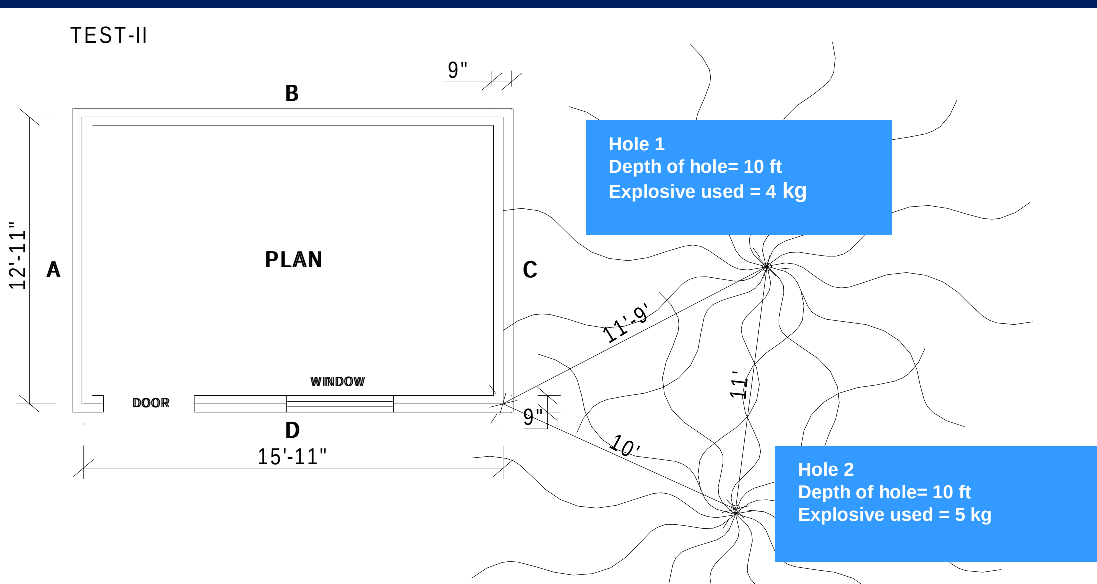
**Table 1**
**Summarized Results of test 1**

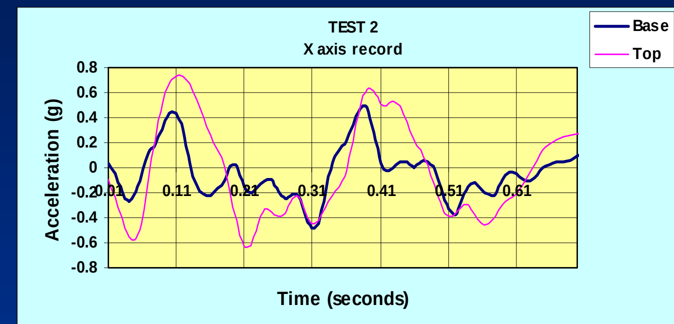
| | |
|---|---|
| Peak Ground Acceleration along X-axis | 0.1487g |
| Peak Response Acceleration along X-axis (model top) | 0.2382g |
| Amplification factor | 1.6 |
| Natural Period of the model along X-axis (longer walls) | 0.1 second |
| Peak Ground Acceleration along Y-axis | 0.09g |
| Peak Response Acceleration along Y-axis (model top) | 0.125g |
| Amplification factor | 1.39 |
| Natural Period of the model along Y-axis (shorter walls) | 0.1second |
| Damping ratio of the model | 0.07 |



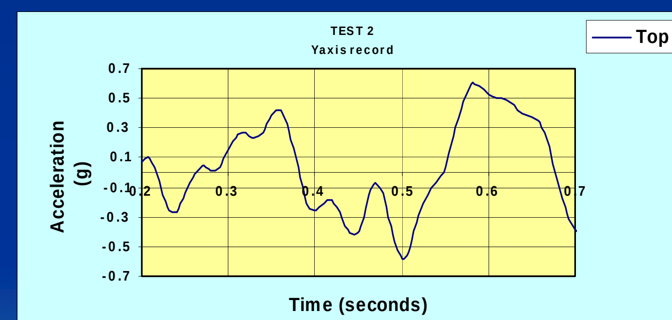

(d): Vertical Acceleration at center of roof slab

# SEVT (contd): TEST-2: The holes were fired from hole 1 to 2 with 250 millisecond delay to increase the duration of shaking. The explosion was designed such that to produce simulated earthquake vibration in both X and Y directions simultaneously, a severe case of earthquake.




(a): X-axis record for model base and top




(b) : Y-axis record for model top only

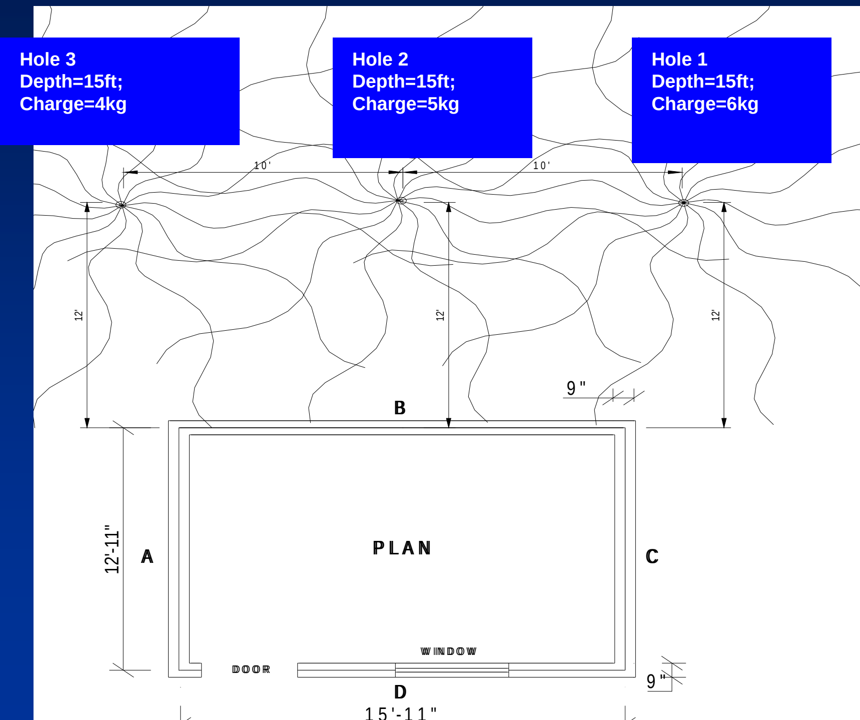
**Table 2**

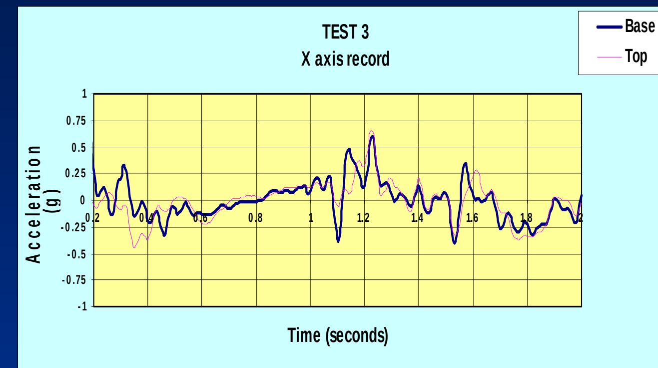
**Peak Ground and Response Acceleration along X and Y axes; TEST 2**

| | |
|---|---|
| Peak Ground Acceleration along X-axis | 0.48g |
| Peak Response Acceleration along X-axis (model top) | 0.73g |
| Amplification Factor | 1.52 |
| Peak Ground Acceleration along Y-axis | __* |
| Peak Response Acceleration along Y-axis (model top) | 0.6g |

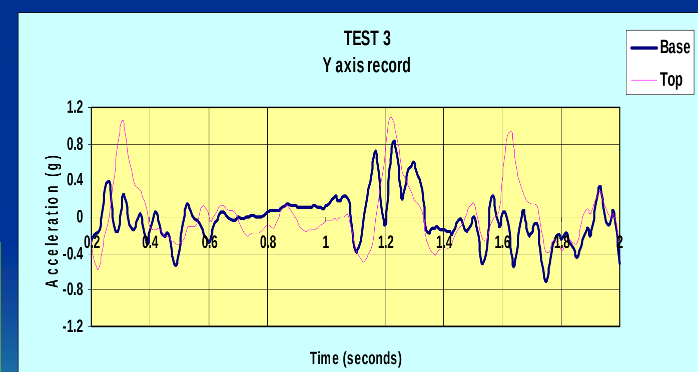
* PGA along Y-axis for test 2 could not be recorded.

**SEVT (contd): TEST-3: The holes were fired from 1 to 2 to 3 with 750 and 250 millisecond delays** to increase the duration of shaking. The direction of excitation was also changed, (the shorter walls) Y axis being the major direction of excitation this time




(a): Along X-axis




(b): Along Y-axis

**Table 3**
**Peak Ground and Response Acceleration along X and Y axes; TEST 3**

| | |
|---|---|
| Peak Ground Acceleration along X-axis | 0.69g |
| Peak Response Acceleration along X-axis (model top) | 0.63g |
| Amplification factor | 0.91 |
| Peak Ground Acceleration along Y-axis | .836g |
| Peak Response Acceleration along Y-axis (model top) | 1.097g |
| Amplification factor | 1.3 |

# FE Based Numerical Study of the Str Model (contd)

## Comparison of experimental and numerical model results

### Period and model top accelerations

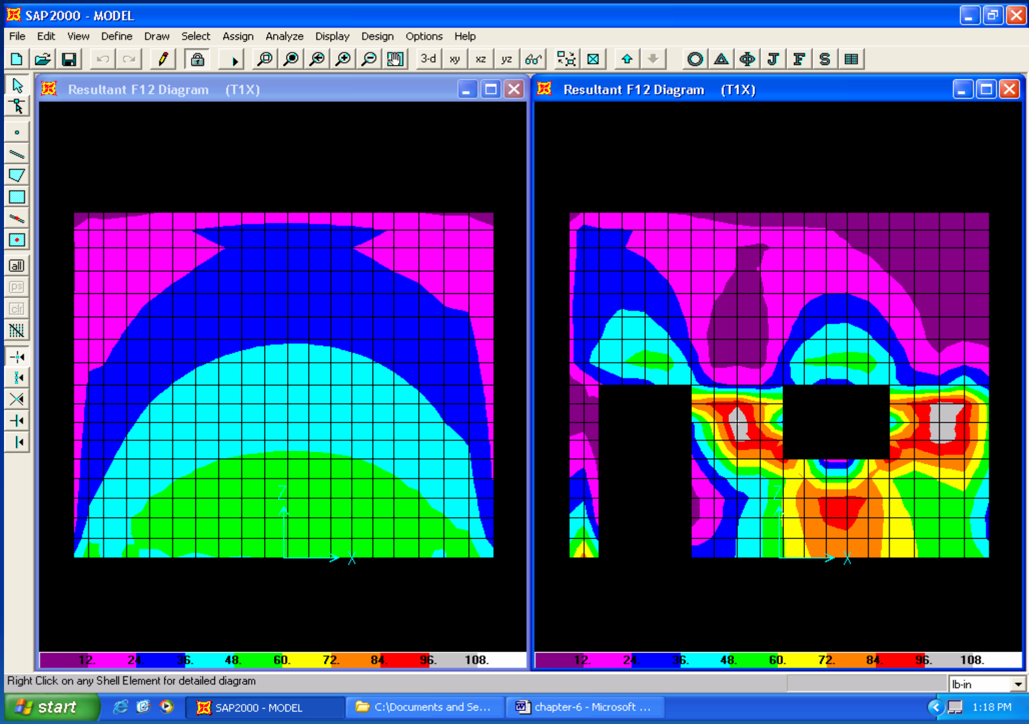
| | TEST values | FE model |
|---|---|---|
| Period along longer direction | 0.1 second | 0.07 seconds |
| Period along shorter direction | 0.1 second | .08seconds |
| Roof acceleration along longer wall TEST 1 | 0.24g | 0.245g |
| Roof acceleration along shorter wall TEST 1 | 0.15 | 0.207 |
| Roof acceleration along longer wall TEST 2 | 0.73g | 0.6g |
| Roof acceleration along longer wall TEST 3 | 0.63g | 0.104g |
| Roof acceleration along shorter wall TEST 3 | 1.097g | 1.63g |

# Seismic performance evaluation through shear damage index study

- Stress results from numerical model can be used for identifying shear damage zones in the model
- Shear Damage Index (SDI) at any particular location of the model
- =Shear Stress/shear strength (at that location)

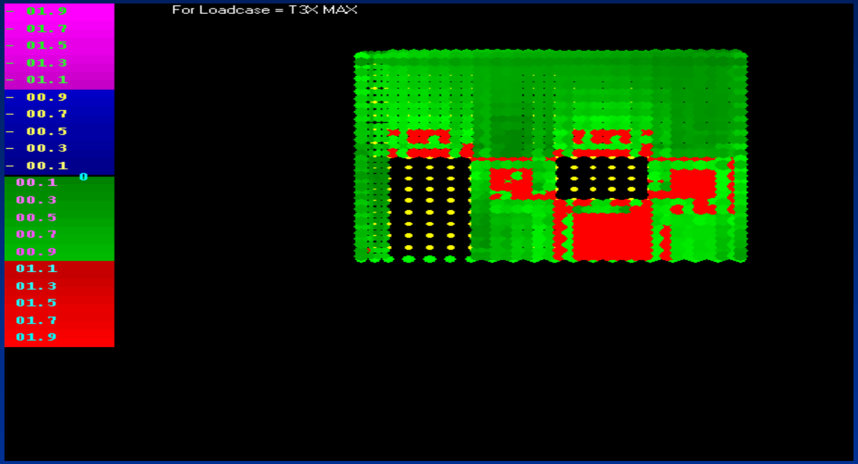
  When the SDI >1.0 at any particular location, the model will suffer some damage at that portion of the model.

  Based on this concept software SDI has been developed, which helps in evaluation of seismic performance of URM buildings through identifying zones susceptible to shear damage under a given state of stresses.

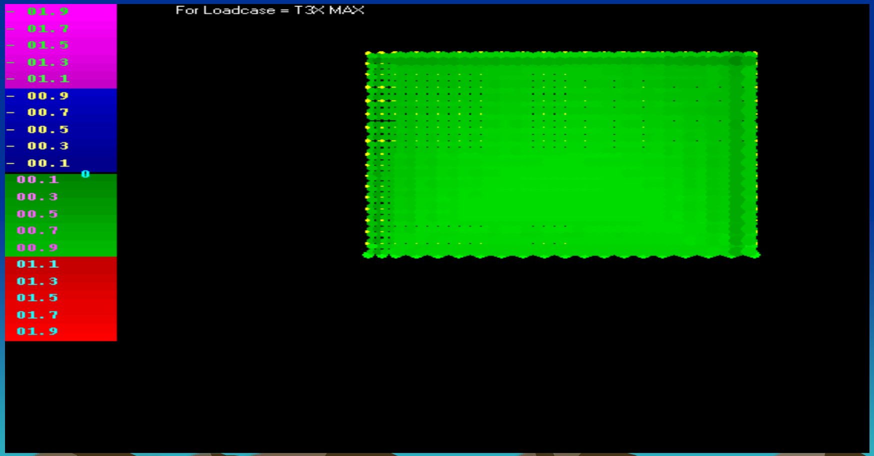


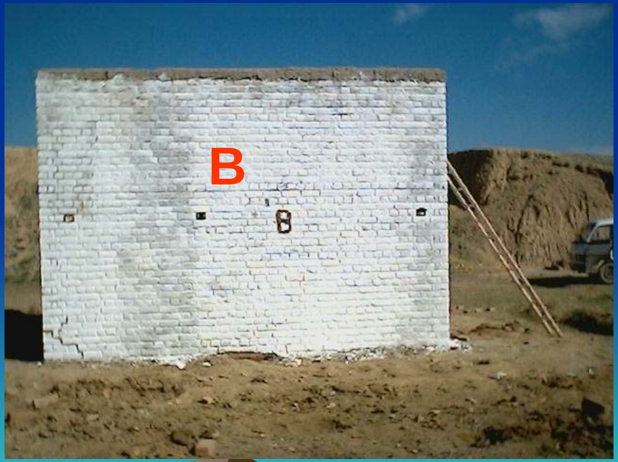

**Shear strength of masonry $\tau_i = \tau_o + \mu f_m = 14 + 1.0 f_m$**

# SDI study (contd): Comparison of the damage zones observed in actual tests and as given by the software; TEST 3







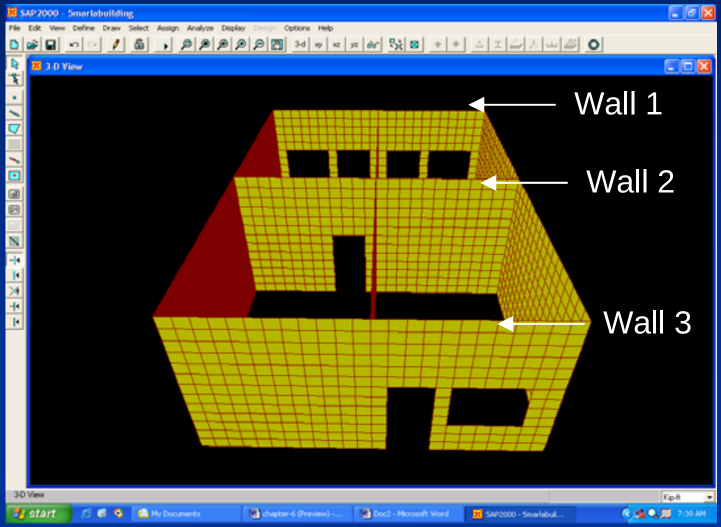
# SDI STUDY (contd);

**CASE STUDY:** A typical **single storey** building situated in **zone 2b** of the UBC seismic risk zones

**No: of rooms** = 04

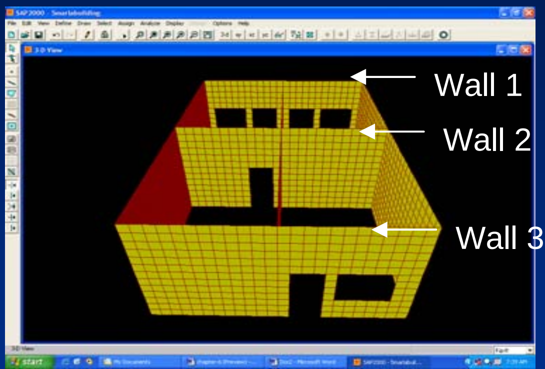
All rooms are of same size with **length and width equal to 17 and 12 ft** respectively.

The **height of the rooms is 13 ft**. The **roof** of the building is a **6 inch thick R.C slab**. To see the inner details of the building the roof slab is however not shown

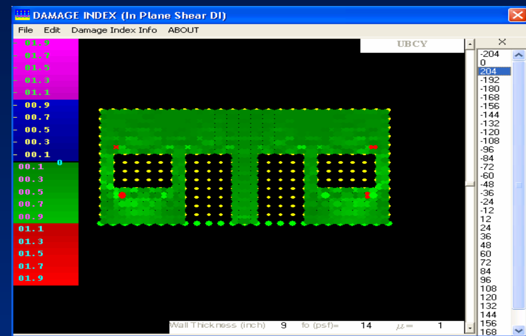



**3-D view of the building**

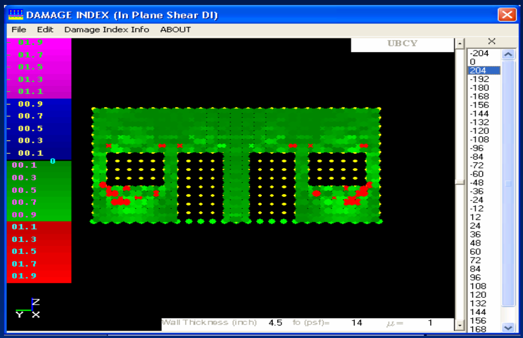
# SDI STUDY (contd); Shear Damage Contours for Walls of the Building Corresponding To Bond Strength of 14 Psi and μ of 1.0.



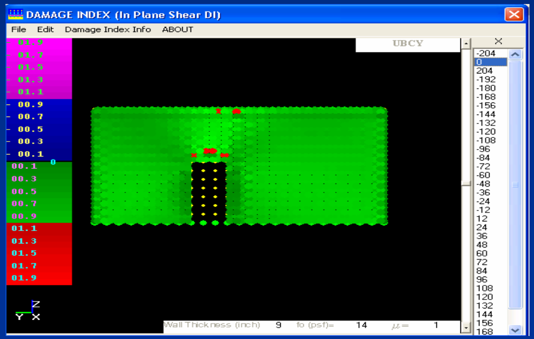

**3-D view of the building**



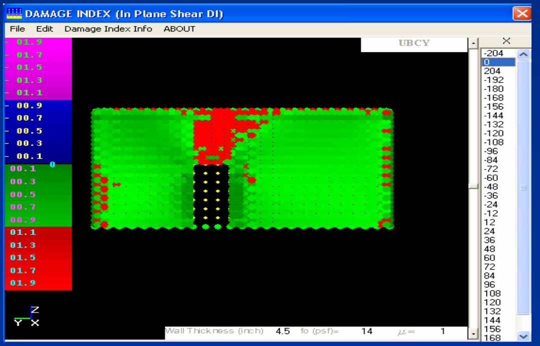

(a) SDI for wall 1, 9inch thick



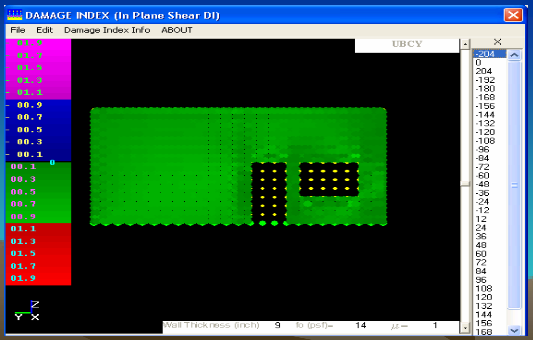

(d) SDI for wall 1, 4.5inch thick



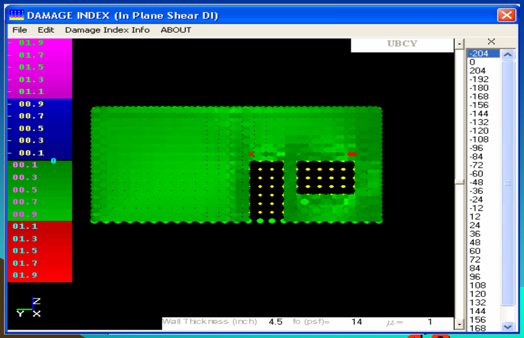

(b) SDI for wall 2, 9inch thick




(e) SDI for wall 2, 4.5inch thick




(c) SDI for wall 3, 9inch thick




(f) SDI for wall 3, 4.5inch thick

# Conclusions from shear damage study of the numerical models

- Generally, 9 inch thick brick masonry walls subjected to seismic demand equivalent to **zone 2b** of the UBC will **remain intact**, provided that some minimum shear strength parameters are achieved. The **minimum shear strength parameters** suggested by this study corresponds to bond strength of **14 Psi and μ of 1.0**. Study of the shear strength parameters for various mortars implies that all mortars **except CS 18** fulfils these minimum requirements.

- Use of only **4.5 inch thick brick walls** as main structural load carrying elements in a masonry structure shall be **avoided** being constructed of common range of mortars studied in this report. However, **4.5 thick walls** with **mortar CK 16** or equivalent strength can be used as a load bearing wall in combination with some walls having thickness of 9 inch or more in a building system.

- **Shear sliding** at **the interface of RC components** and **masonry work** was observed in all cases of experimental and numerical models and therefore **proper shear anchorages/stirrups** shall be used in these portions.

- The portions around the openings i.e. **spandrels and piers are highly vulnerable**. It is recommended that **mortar CK 16 or equivalent mortars shall be used** for enhancing the shear resistance of these portions.

- Depending upon the geometry of walls, material properties of the masonry work and seismic excitation to which the structure is subjected, zones of damage in the walls of a particular masonry building will significantly vary. Therefore any specific recommendations regarding strengthening of walls of a particular building can only be made after **the numerical model and SDI plots of that structure under the given conditions are thoroughly investigated.**