Shaking table testing

and

Finite Element Analysis

techniques applied to

Masonry structures

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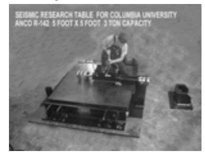
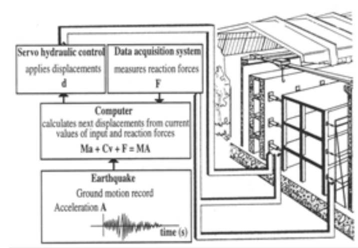
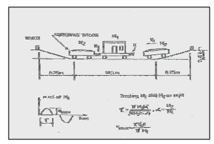
Experimental techniques



- High Performance Seismic Simulator
- Pseudo-Dynamic
- Static monotonic and Quasi static
- Impact Table
- Underground Explosions






Shaking table study of single masonry story houses; University of California, Berkeley USA

This investigation was part of a research program entitled, "Laboratory studies of the seismic behavior of single story masonry buildings in seismic zone 2 of the U.S.A.", sponsored by the department of housing and urban development (HUD).

- The three simulated earthquakes were the 1940 El Centro, 1952 Taft and 1971 Pacoima Dam accelerograms.
- Response was measured and recorded by means of a large number of transducers.

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Important findings

- Typical single-story masonry houses are so rigid that they do not develop very complicated dynamic response mechanisms during an earthquake.
- The motions of the test structures followed the shaking table motions very closely, with distortions generally being proportional to, and in-phase with the base accelerations.

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- For this reason, the frequency characteristics of the earthquake input are not a major factor in its tendency to induce damage in a masonry house.
- The peak acceleration value of the ground motion is the dominant quantity controlling response to earthquakes.
- The amplification factor at the top of the walls was in the range between 1.0 and 1.5.

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- No cracking was observed in any major unreinforced wall unit for tests with peak accelerations less than 0.2g.
- The lowest intensity shaking that caused cracking of non-bearing in plane wall occurred during tests with peak accelerations of 0.21g
- the minimum intensity to cause cracking of an out of plane wall was 0.25g.

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- Unreinforced out-of-plane walls continued to perform satisfactorily after cracking for several tests of increased intensity, but the displacements of these walls generally became excessive during tests with peak accelerations in excess of 0.4g.

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- The study concluded that for PGA of 0.1g, the minimum length of an unreinforced shear resisting element should be 6 ft;
- whereas for PGA of 0.2g the minimum length of an unreinforced shear-resisting element should be 9ft or there may be two 6ft elements.
- Shear resisting element which is a panel of a masonry wall must extend from floor to ceiling without any penetrations, openings, or discontinuities.

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Limitations

- The study was carried out specifically on block masonry building system prevailing in a USA state. There can be drastic difference in the materials and field practice.

- The roof of the models was a timber truss, which is significantly different from the rigid concrete slab. In the later case the roof acts as a rigid diaphragm and connects the walls to form a box type structure.

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Numerical modeling of masonry

- The existing numerical models for masonry have been divided into two groups: the heterogeneous and the homogenous models.

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- The heterogeneous models analyze the masonry walls discretizing bricks and mortar separately through finite element and/or interface elements.

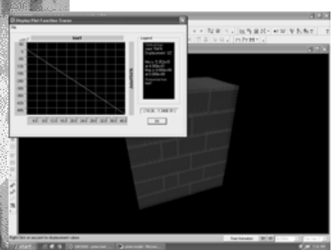
- A suitable constitutive relationship is then assumed for each component. In this way it is possible to take into account, with particular accuracy, the characteristics of mortar joints, which play a very important role in the global behavior of masonry.

- The principal limitation of these models consists of the high computational effort they require, especially when a real wall or building must be analyzed

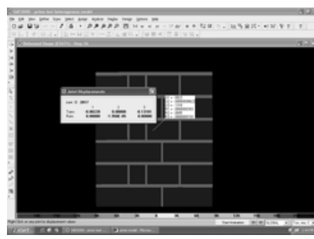
- In the homogenous models, masonry is assumed as a continuum material: its properties are either obtained from in-situ lab tests or empirical equations.

- In this way, real masonry buildings can be studied with reasonable computational effort

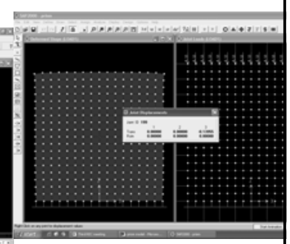
3-D Heterogeneous
8-Noded Solid Elements



3-D Heterogeneous
Shell Elements



3-D Homogeneous
Shell Elements



- A best numerical model is the one that represents the maximum characteristics of the physical model/actual object.
- The process of representation of an actual object into a numerical model in a particular finite element software environment needs continuous refinement.
- This can be best achieved when sufficient experimental data of the relevant parameters of the model is available for validation against the results of numerical model

Case Study

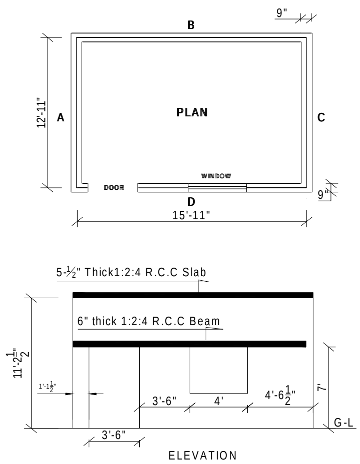


Table 1

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 (τ_o)	14 Psi
10	Coefficient of friction μ	1.0

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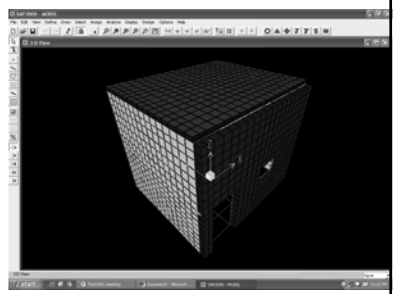
FE Based Numerical Study of the Str Model (contd)

FE representation of the structural model

- **Shell element** and **3-D homogenous model** having **composite brick masonry assemblage properties** were used for the design of **FE model**
- **Length, width and height of the FE model** were **identical** to the field model
- **E = 300 ksi** as obtained from lab tests
- Excitation source: **The ground acceleration record obtained in the tests was used for as input time history load.**



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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

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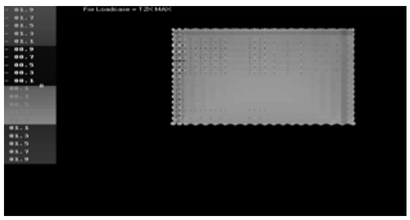

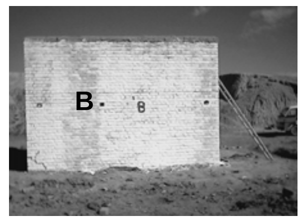

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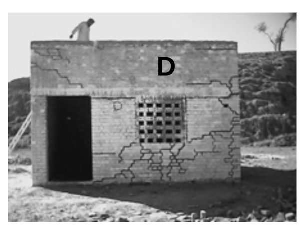

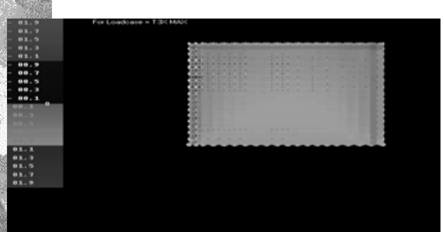

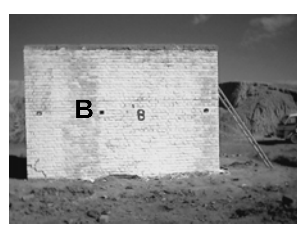

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Conclusions

- Shake table test must represent the prototype as closely as possible. For example the brick and mortar type, roof etc. of the model shall be similar to the prototype; other wise results will not be reliable.

- FE technique using 3-D homogenous, linear elastic models can be used for studying the behavior of masonry. However using non-linear inelastic models would be more realistic.

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The End

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