


Seismic Design of Masonry Structures

Prof. Richard E. Klingner
AEI Student Chapter Seminar

The University of Texas at Austin
October 7, 2009

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Main points

1. Modern masonry structures are not the same as old - fashioned , unreinforced masonry
2. Wall - type masonry structures are simpler to design than framed structures
3. Low - rise masonry structures designed and constructed according to the MSJC Code and Specification can resist very strong earthquakes

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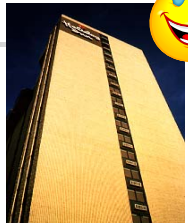



a dynamic treat . . .



almost
3 g !

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1. Modern masonry structures are not the same as old - fashioned , unreinforced masonry



Loma Prieta (SF) , 1989

Northridge (LA) , 1994

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2. Wall - type masonry structures are simpler to design than framed structures

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Steps in simplified design of masonry structures

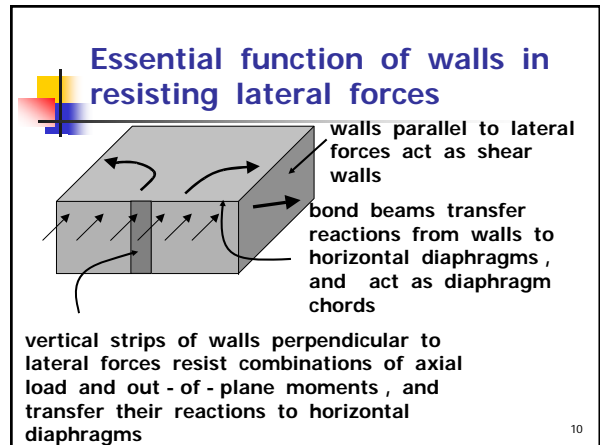
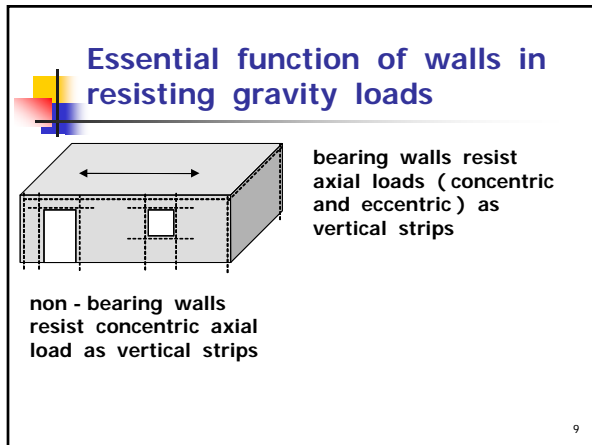
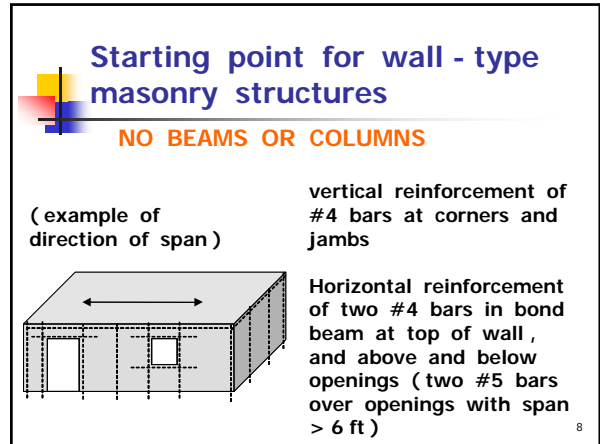
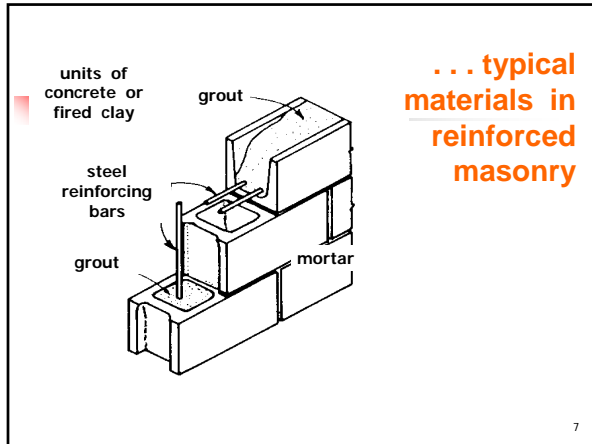
- starting point for design
- design of vertical strips in walls perpendicular to lateral loads
- design of walls parallel to lateral loads
- design of lintels
- simplified analysis for lateral loads
- design of diaphragms
- detailing

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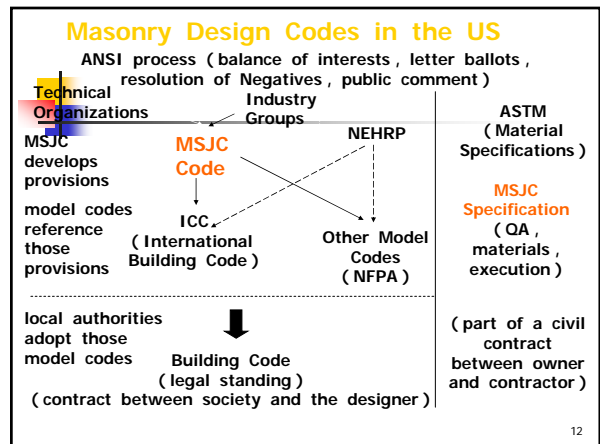
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3. Low - rise masonry structures designed and constructed using the MSJC Code and Specification can resist very strong earthquakes

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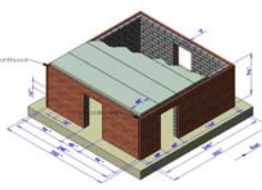
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Seismic design of masonry is state - of - the - art

- NSF - NEES small - group project
- October 2006 through September 2009
- involves four universities plus masonry industry
- headed by UT Austin



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important results so far

- low-rise reinforced concrete masonry buildings with clay masonry veneer (meeting MSJC Code and Specification for SDC D) resist earthquakes above MCE without collapse
- seismic response of buildings and veneer is generally consistent with performance expectations
- seismic response is well predicted by nonlinear dynamic analysis and static design tools

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what's coming

- project objectives
- project participants
- seismic response of low - rise buildings
- reinforced concrete masonry with clay masonry veneer
 - experimental and analytical work
 - key observations
 - important points

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project objectives

- performance - based design of new masonry and masonry veneer
 - study seismic performance of masonry veneer and veneer connectors
 - examine inelastic behavior of low - rise reinforced concrete masonry structures
 - propose refinements to performance - based design provisions for new masonry and masonry veneer
 - educate the profession and the public

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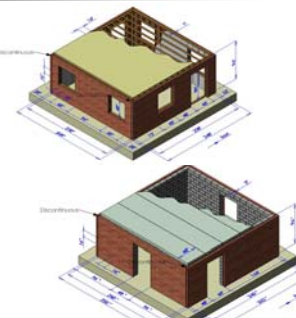
project participants

- University of Texas at Austin
 - Richard E. Klingner , Seongwoo Jo (GRA)
- University of California at San Diego
 - Benson Shing , Hussein Okail (GRA)
- Washington State University
 - Char Grimes , Katherine Keane , David McLean
- North Carolina A&T State University
 - Mark McGinley , Eric Johnson (GRA)
- Help from masonry industry

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structures studied

- backing system of wood-stud frames or reinforced concrete masonry (CMU)
- clay masonry veneer (attached to backing system using connectors) improves esthetics and thermal, acoustic and water - penetration resistance



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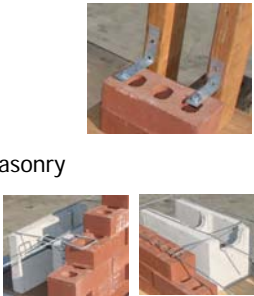
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masonry veneer connectors

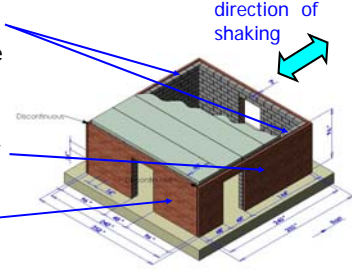
- wood - stud frames
 - corrugated connectors
 - rigid connectors
- reinforced concrete masonry
 - adjustable connectors
 - tri-wire connectors



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seismic response

- in - plane CMU walls govern the seismic response of the building
- in - plane veneer slides and rocks
- out - of - plane veneer acts as added mass



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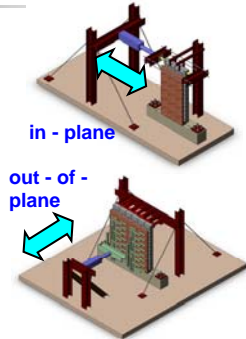
reinforced concrete masonry with clay masonry veneer

- experimental work
- analytical work
- key observations
- future work
- important points

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experimental work (1)


- quasi - static tests of wall segments (UT Austin)
- shaking - table tests of wall segments
- shaking - table tests of complete structure



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experimental work (2)


- quasi - static tests of wall segments
- shaking - table tests of wall segments (UCSD)
- shaking - table tests of complete structure



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experimental work (3)

- quasi - static tests of wall segments
- shaking - table tests of wall segments
- shaking - table tests of complete structure (UCSD)



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analytical work (OpenSees)

- develop nonlinear analytical models for each element
 - reinforced concrete masonry
 - clay masonry veneer
 - veneer connectors
- predict quasi - static and shaking - table response
- refine models using quasi - static and shaking - table results (in progress)


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a construction treat . . .



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a dynamic treat . . .



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