16WCEE 2017 36SS- Global Implementation of confined masonry construction technology for seismic risk reduction: challenges and opportunities

DEVELOPMENT OF CONFINED MASONRY SEISMIC CONSIDERATIONS, RESEARCH AND DESIGN CODES IN PERU

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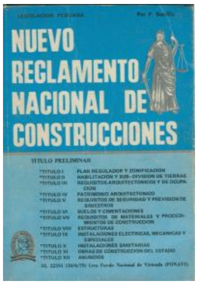
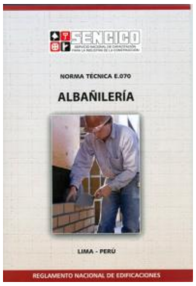
Masonry Codes “Norma E.070-Albañilería”

1970	1977	1982	2006
			

New Masonry Committee started 2016.

Before any Code

- Plain masonry (unreinforced) 20th Century
- Masonry with some columns ~1950
- Walls t=0.25m, solid bricks

Building Code 1970

Some masonry specifications
Seismic Force: H = U C1 P

Masonry resistance ?
Stresses in masonry ?

1970 EQ. M7.8 - importance of confinement

Seismic Building Code 1977

- Chapter 3 deal with masonry
- σ (allowable), but σ(act) not specified.
- Confined and reinforced masonry were covered

…Seismic Building Code 1977

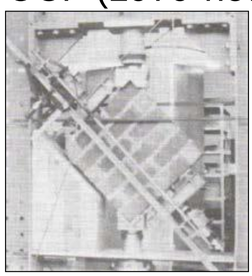
Allowable stresses

- Compression by flexure: 0.3 f'm
- Tension by flexure
  (⊥ layers): 1 kg/cm^2 = 0.098 MPa
  (|| layers): 2 kg/cm^2 = 0.196 MPa
- Shear
  plain masonry: 0.15 $\sqrt{f'm}$ < 1.1 kg/cm^2
  confined masonry: 0.30 $\sqrt{f'm}$ < 2.2 kg/cm^2
- Axial compression
  (still valid!)

$$f_m = 0.2 f'_m \left[1-\left(\frac{h}{35t}\right)^2\right]$$

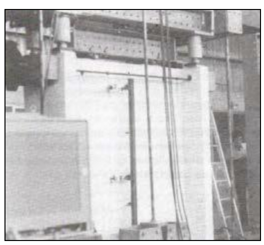
Laboratory Tests (1978-1982)

Structures Laboratory at PUCP (1979-now)



Walletes

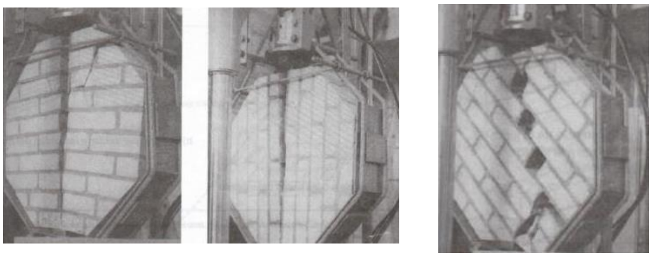
Prof. San Bartolomé (+2014)



Full scale walls

Laboratory Tests (1979-1982)

Private research using PUCP Lab:



Prof. Gallegos, Casabonne

Octagonal small walls varying the load angle.

Masonry Code of 1982

Design based on allowable stresses.

For confined masonry:

- Shear stress v_m:

Mortar with lime	1.8+0.18 fd < 3.3 kg/cm^2
Mortar without lime	1.2+0.18 fd < 2.7 kg/cm^2

- Tension by flexure

Mortar with lime	1.33 kg/cm^2
Mortar without lime	1.00 kg/cm^2 (0.098 MPa)

- Tie columns and beams dimensions, and reinforcement As depend on wall shear force V.

Laboratory Tests (1982-2000)

San Bartolomé led many experimental projects:

- Effect of reinforcement (H, V), vertical load+cyclic lateral load, in-plane slenderness in half scale walls.

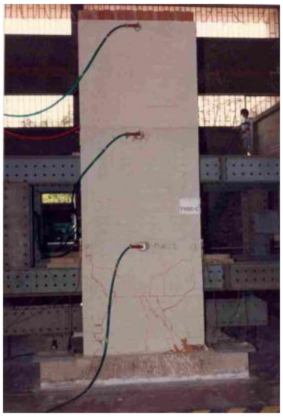
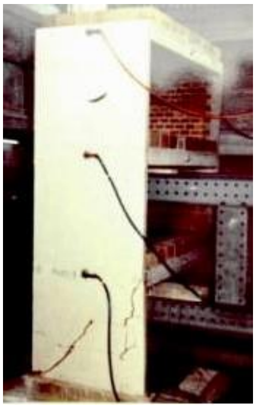


A new approach for design of confined masonry was proposed, based on shear strength (5th NAMC 1990)

… Laboratory Tests (1982-2000)

Shaking table test on 3-story scale walls showed that tension cracks appear, but shear failure occurs.

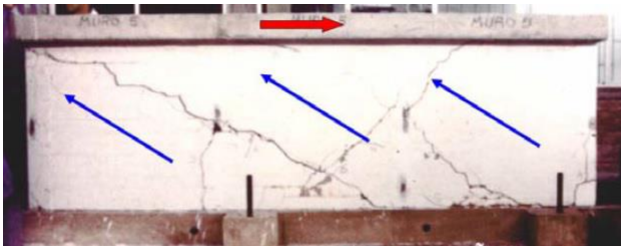
(10 WCEE 1992).

… Laboratory Tests (1982-2000)

Effect of RC beams in coupled walls

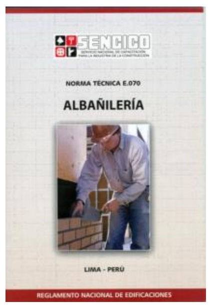
Effect of number of wall panels,



Comparison between toothed connection and vertical connection with wires (RC column - masonry wall), planned after the 1985 Chile EQ.

Effect of testing procedure (dynamic-static), joint project between PUCP and UNI-CISMID (see 10WCEE, 1992).

Masonry Code of 2006



Code draft document by San Bartolomé in 1999.

Papers in 10 NAMC (2007), 14 IBBMAC (2008).

Update of materials (solid brick allowed to have 30% holes)

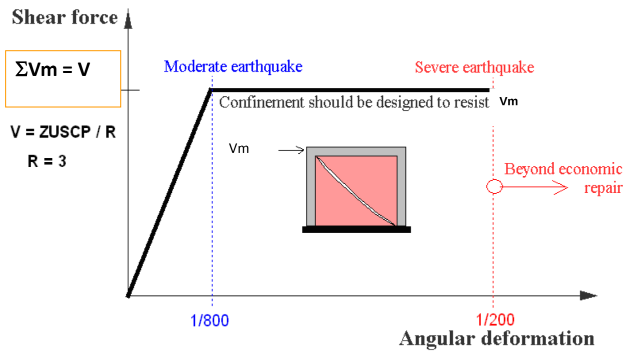
Confined masonry walls in low-rise buildings under severe earthquakes have a shear failure. The tie-columns have to be designed to resist the diagonal cracking force.

Masonry Code of 2006

Performance based-design of masonry walls for two stages:

- Elastic behavior under moderate earthquakes
- Repairable shear failure for severe earthquakes

  lateral drifts < 1/200=0.005



Masonry Code of 2006

Design procedure includes:

1) Minimum wall density within building plan
2) Design for vertical loads, Ash=? if $\sigma_{(ver)} > 0.05\, f'_m$
3) Seismic analysis for <u>moderate</u> earthquake forces (half of severe EQ, or R=6); wall shall not crack: Ve < 0.55 Vm.
4) Calculate the shear force capacity Vm for every wall in each story.

Clay and concrete units: $V_m = 0.5\, v'_m\, \alpha\, t\, L + 0.23\, P_g$

Silica lime units: $V_m = 0.35\, v'_m\, \alpha\, t\, L + 0.23\, P_g$

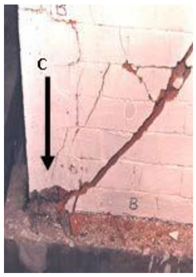
$$1/3 \le \alpha = \frac{V_e L}{M_e} \le 1$$

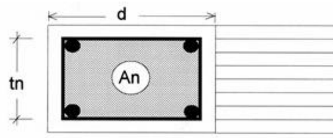
… Masonry Code of 2006

5) Design the wall for <u>severe</u> earthquakes

All walls in first story have diagonal shear failure (=Vm)

- Check shear capacity of first story $V < \Sigma V_m$
- Amplification of elastic values Ve, Me, for walls in the upper stories ($2 < V_{m1}/V_{e1} < 3$), check if these walls reach shear capacity (or not).
- Calculate internal forces (V, T, C) in first story tie-col and tie-beams.
- Concrete design.





Masonry Code of 2006

UNI-CISMID (Zavala,et.al)

Pseudo dynamic test in model house, low quality bricks.

Drift 1/200 showed repairable stage.

Collapse reached for drift 1/65.

Challenges for the Masonry Code

- Self construction, low quality materials, poor hand work.
- Lack of control by national and local authorities.
- Wrong construction practice, bad structural configurations.
- Recent EQ Pisco 2007 showed many defects.
- Simplified design is required (new Masonry Code under discussion).

Popular bricks not allowed

Paper 2883 Quiun-Santillán

THANK YOU!!

Perú

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