EARTHQUAKE-RESISTANT CONFINED MASONRY CONSTRUCTION

Prof. Sudhir K. Jain  
Department of Civil Engineering  
Indian Institute of Technology  
Kanpur, India

Dr. Svetlana Brzev  
Department of Civil Engineering  
British Columbia Institute of Technology  
Vancouver, Canada
EARTHQUAKES HAPPEN

...and they can be very destructive
Recent Deadly Earthquakes in the World

- 1993 Latur, Maharashtra, India – 8000 deaths
- 1999 Ducze, Turkey – 20000 deaths
- 2001 Bhuj, Gujarat, India – 14000 deaths
- 2003 Boumerdes, Algeria – 3000 deaths
- 2004 The Great Sumatra Earthquake and Tsunami in Indonesia, Thailand, Sri Lanka, and India – 270,000 deaths
- 2005 Kashmir Earthquake in Pakistan and India – 100000 deaths

- 2001 in India
  - 270,000 deaths
- 2005 in India
  - 100000 deaths
Building Construction Affected by Earthquakes

- Both low-rise and high-rise construction
- Both rural and urban construction
- Both masonry and concrete construction
CONFINED MASONRY:

an opportunity for improved seismic performance both for unreinforced masonry and reinforced concrete frame construction in low- and medium-rise buildings
Confined Masonry Construction: An Alternative to Reinforced Concrete Frame Construction

An example from Chile (Source: Ofelia Moroni)
Confined Masonry Construction: An Alternative to Unreinforced Masonry Construction

An example from Indonesia (Source: C. Meisl, EERI)
Confined Masonry Construction: a Definition

Confined masonry is a construction system where the walls are built first, and RC columns and beams are cast afterwards.
A difference between the confined masonry and reinforced concrete frames = construction sequence

Confined Masonry
- Walls first
- Concrete later

Reinforced Concrete Frame
- Concrete first
- Walls later

Source: Tom Schacher
Reinforced Concrete Frame Construction
Confined Masonry Construction
Key Components of a Confined Masonry Building

Key structural components of a confined masonry building are:

- **Masonry walls** made either of clay brick or concrete block units
- **Tie-columns** = vertical RC confining elements which resemble columns in reinforced concrete frame construction.
- **Tie-beams** = horizontal RC confining elements which resemble beams in reinforced concrete frame construction.
Components of a Confined Masonry Building
Key Elements – Layout Rules

tie-column spacing ≤ 4.0m

thickness ≥ 100mm

tie-columns at wall ends and intersections

tie-columns at openings
Typical Floor Plans – Examples from Chile

Source: O. Moroni and M. Astroza
Typical Floor Plans – Examples from Chile

Source: O. Moroni and M. Astroza
Confined Masonry – Opportunity for Phased Construction

Source: M. Blondet
Confined Masonry: Construction Process

Source: Tom Schacher
Confined Masonry: Construction Process

Indonesia (C.Meisl)  Slovenia (Lutman and Tomazevic)
Confined Masonry Under Construction – Worldwide
Confined Masonry: Construction Details

*Good connections are of critical importance!*

**SOLUTION:** Sufficient Anchoring
Poor Connections => Poor Earthquake Performance

27 May 2006 Central Java Earthquake

Build Earthquake Resistant Houses
Change Construction Practice Permanently
The Importance of Quality Construction

Key points:
- Qualified construction labour
- Good quality building materials (bricks, cement, sand, steel, etc.)
- Good detailing according to recognized construction guidelines
- Regular site inspection by qualified inspectors

Source: M. Blondet
Earthquake Performance

Confined masonry construction has been practiced in countries/regions with very high seismic risk, such as

- Latin America (Mexico, Chile, Peru, Argentina),
- Mediterranean Europe (Italy, Slovenia),
- South Asia (Indonesia),
- Middle East (Iran) and
the Far East (China).
Confined masonry construction has been exposed to several destructive earthquakes:

- 1985 Lloeleo, Chile (magnitude 7.8)
- 1985 Mexico City, Mexico (magnitude 8.0)
- 2001 El Salvador (magnitude 7.7)
- 2003 Tecoman, Mexico (magnitude 7.6)
- 2007 Pisco, Peru (magnitude 8.0)
- 2004 The Great Sumatra Earthquake and Tsunami, Indonesia (magnitude 9.0)
- 2003 Bam, Iran (magnitude 6.6)

Confined masonry buildings performed very well in these major earthquakes – some buildings were damaged, but no human losses.
Confined Masonry Performs Very Well in Earthquakes

A six-storey confined masonry building remained undamaged in the August 2007 Pisco, Peru earthquake (Magnitude 8.0) while many other masonry buildings experienced severe damage or collapse.
Confined Masonry Performs Very Well in Earthquakes

Confined masonry buildings in town of Santa Cruz Analquito still standing, while the surrounding adobe construction was destroyed in the 2001 El Salvador earthquakes (magnitudes 7.7 and 6.6) which killed 1100 people.
Newly Built Confined Masonry Buildings Generally Performed Well in the 27 May 2006 Central Java Earthquake

→ Confined masonry house without damage or cracks, on the edge of heavy damaged Pleret

Build Earthquake Resistant Houses
Change Construction Practice Permanently
Earthquake Resistance of Confined Masonry Building Has Been Tested using Earthquake Simulation Facilities

Shake-Table Testing of a 3-storey Confined Masonry Building at UNAM, Mexico (Credit: Sergio Alcocer and Juan Arias)
Conclusions

- Confined masonry construction can be practiced as a viable alternative to reinforced concrete frame construction for low-rise and medium-rise buildings.
- Minor changes in construction practice can lead to significant improvement in earthquake performance.
- Many lives can be saved and people can continue to inhabit their homes after an earthquake.
Further Reading

New NICEE Publication
December 2007

To obtain a copy, contact

nicee@iitk.ac.in

Or order online at

www.nicee.org
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