A Brief History of Confined Masonry and the Development of Guidelines

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Why Confined Masonry?

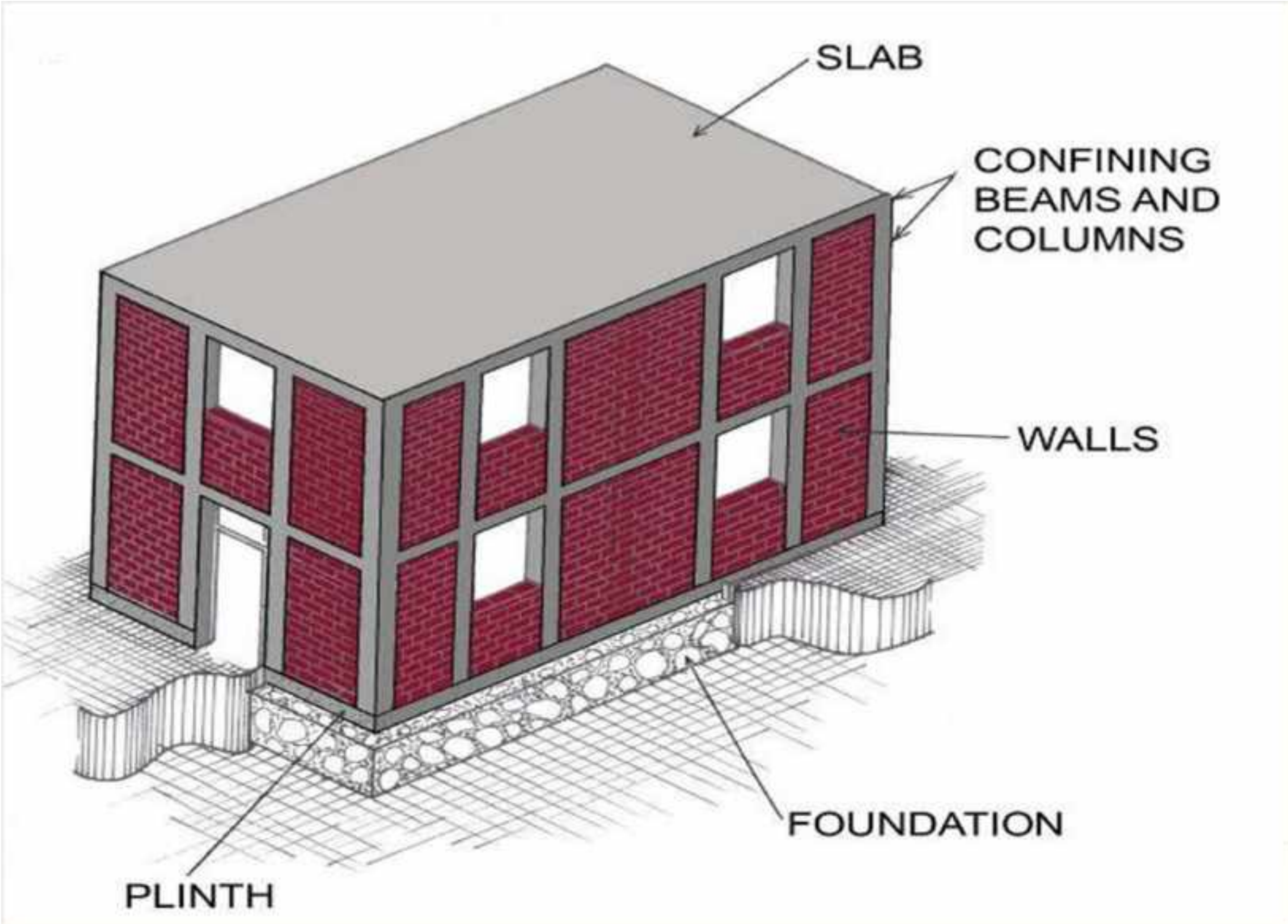
- Poor performance of unreinforced masonry and non-ductile reinforced concrete (RC) frame construction caused unacceptably high human and economic losses in past earthquakes
- This prompted a need for developing and/or promoting alternative building technologies
- Confined masonry is an opportunity for improved seismic performance both for unreinforced masonry and reinforced concrete frame construction in low and medium rise buildings.

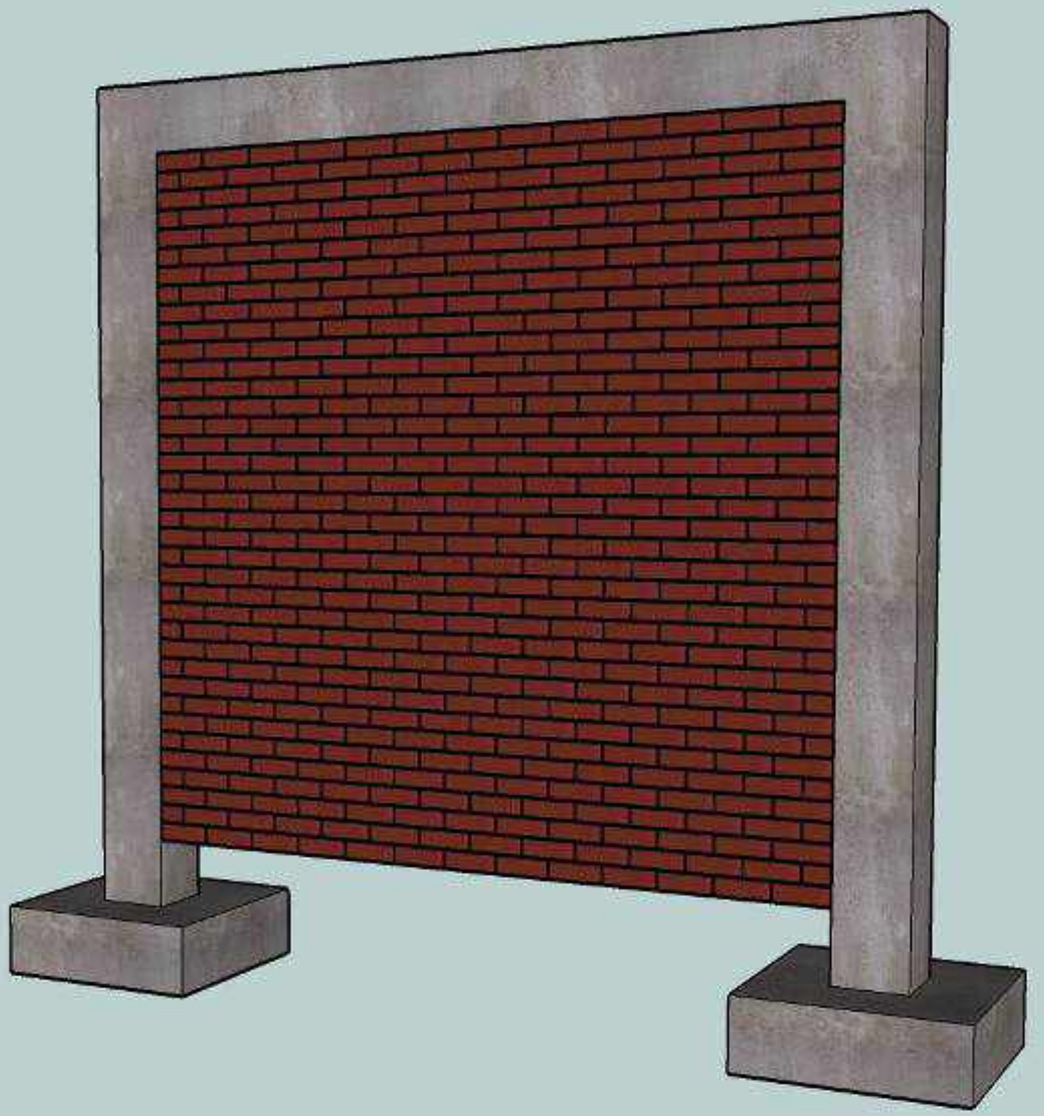
The goal is to achieve enhanced seismic performance using technologies which require similar level of construction skills and are economically viable

Beginnings

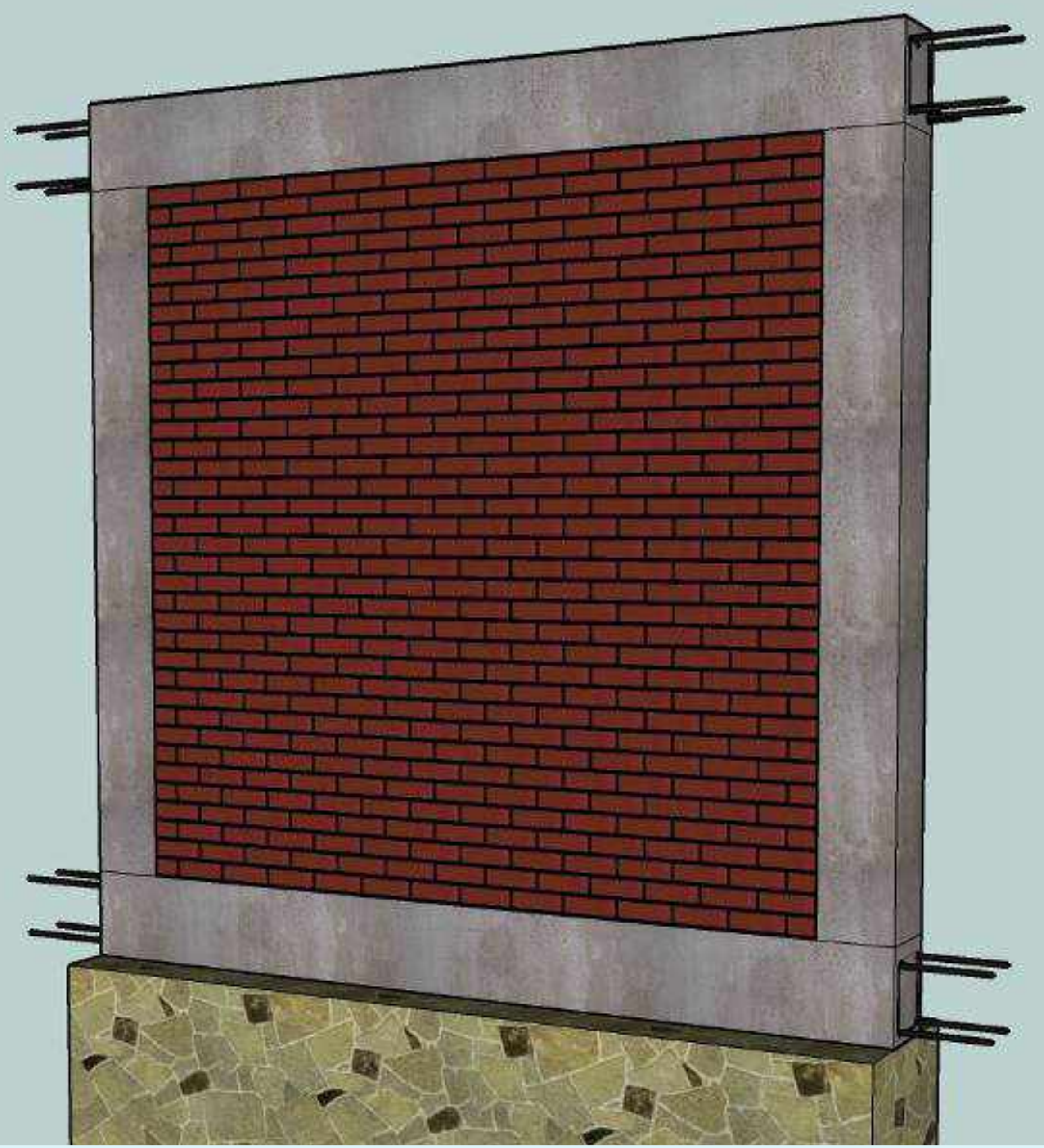
- Evolved though an informal process based on its satisfactory performance in past earthquakes
- The first reported use in the reconstruction after the 1908 Messina, Italy earthquake (M 7.2) – death toll 70,000
- Practiced in Chile and Columbia since 1930’s and in Mexico since 1940’s
- Currently practiced in several countries/regions with high seismic risk, including Latin America, Mediterranean Europe, Middle East (Iran), South Asia (Indonesia), and the Far East (China)

Components of a Confined Masonry Building





Reinforced Concrete Framed Infill Construction



Confined Masonry Construction

Confined Masonry Network

- First organized in 2008
- Experts from 15 countries
- Development of guidelines (2009–)
- Publishing papers at key conferences
- Maintain an online repository of resources related to confined masonry technology and its application in various countries
  - Research papers, earthquake reconnaissance reports, codes, and guidelines
- www.confinedmasonry.org

Guidelines for Confined Masonry

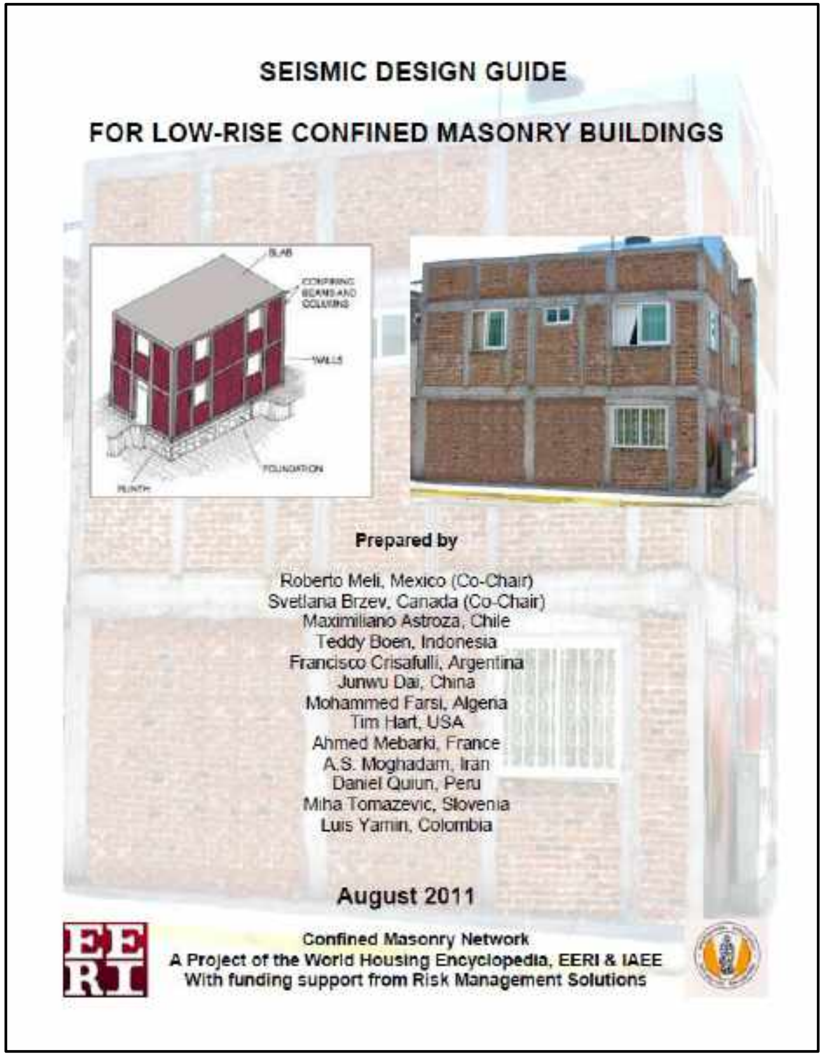
- Seismic Design Guide for Low-Rise Confined Masonry Buildings
  - Published in August 2011
- Construction Guide for Low-Rise Confined Masonry Buildings
  - Final Draft sent out for review in May 2014
- Engineering Design Guide for Confined Masonry Buildings
  - Currently in development

Design Guide Objectives

- To explain the mechanism of seismic response of confined masonry buildings for in- and out-of-plane seismic effects and other relevant seismic response issues;
- To recommend prescriptive design provisions related to low-rise non-engineered buildings (1 and 2-stories high), and;
- To provide a summary of the seismic design provisions for confined masonry buildings from relevant international codes;

Design Guide Contents

- Chapter 1 – Introduction
  - General System Behavior
- Chapter 2 – General Requirements
  - Material Types
- Chapter 3 – Specific Requirements
  - Prescriptive Guidelines
- Appendices
  - Simplified Method for Wall Density Calculations
  - Special Inspection Recommendations



SEISMIC DESIGN GUIDE

FOR LOW-RISE CONFINED MASONRY BUILDINGS

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Design Guide Examples

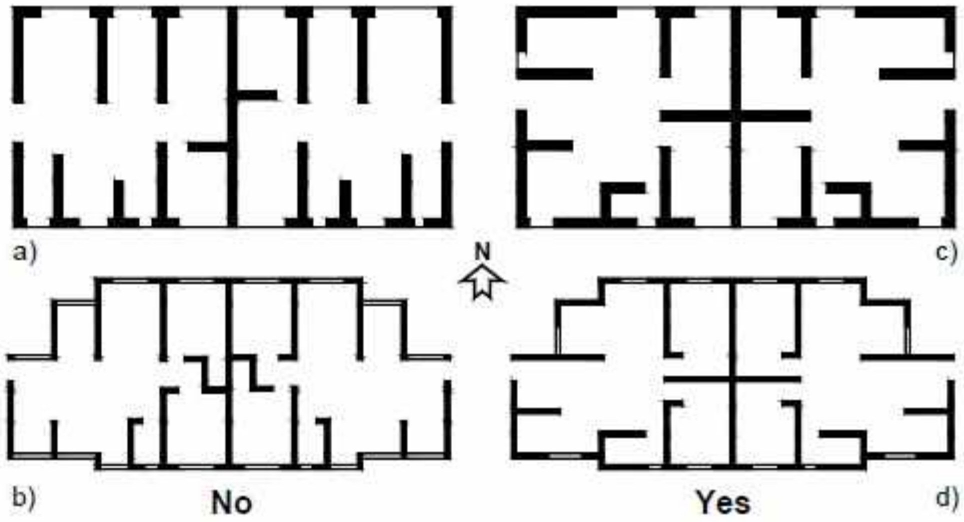


Figure 32. Wall distribution in plan: a) and b) not enough walls in the E-W direction; c) and d) possibly adequate wall lengths in both N-S and E-W directions (note a few strong walls on the perimeter of the plan).

5) The walls should always be placed continuously, directly over one another. Figure 33 (left) shows walls that are offset, while Figure 33 (right) shows vertically continuous walls.

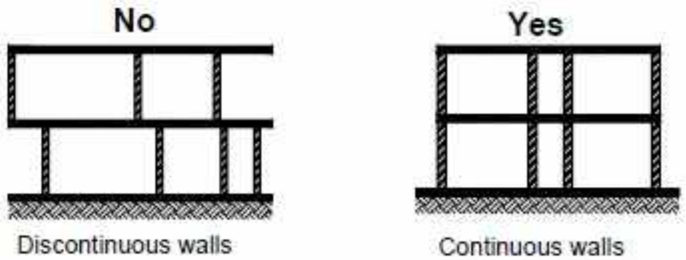


Figure 33. Continuity of walls between storeys (vertical sections shown).

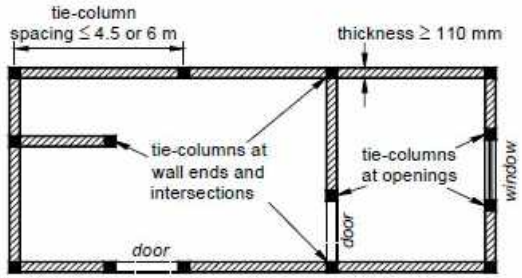


Figure 45. Typical floor plan illustrating the placement of RC tie-columns (Brzev, 2008).

3.1.2.2 Minimum Dimensions

- Tie-column Size (Depth x Width): 150 mm x t, where t denotes the wall thickness
- Tie-beam Size: same as tie-column size

3.1.2.3 Reinforcement Requirements

Longitudinal Reinforcement (Tie-beams and Tie-columns):

- Minimum 4 reinforcing bars
- Bar sizes:
  - deformed reinforcing bars of minimum 10-mm diameter (metric sizes) or #3 bars (3/8" diameter in Imperial units), or
  - smooth reinforcing bars of 12 mm diameter (when deformed bars are not available).

To ensure the effectiveness of tie-beams in resisting earthquake loads, longitudinal bars should have a 90° hooked anchorage at intersections, as shown in Figure 46.

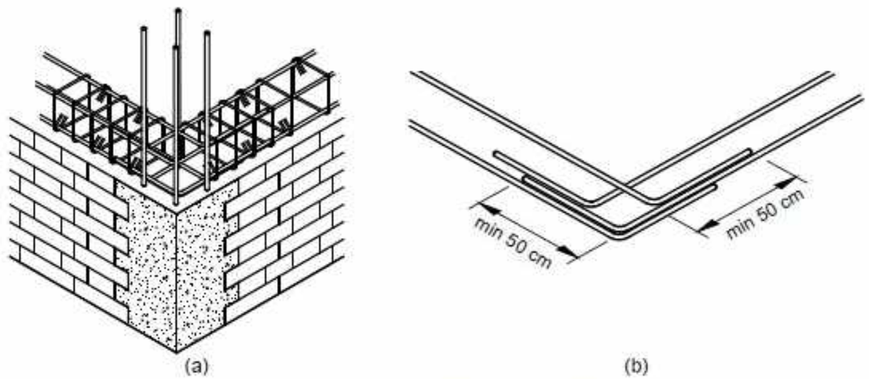
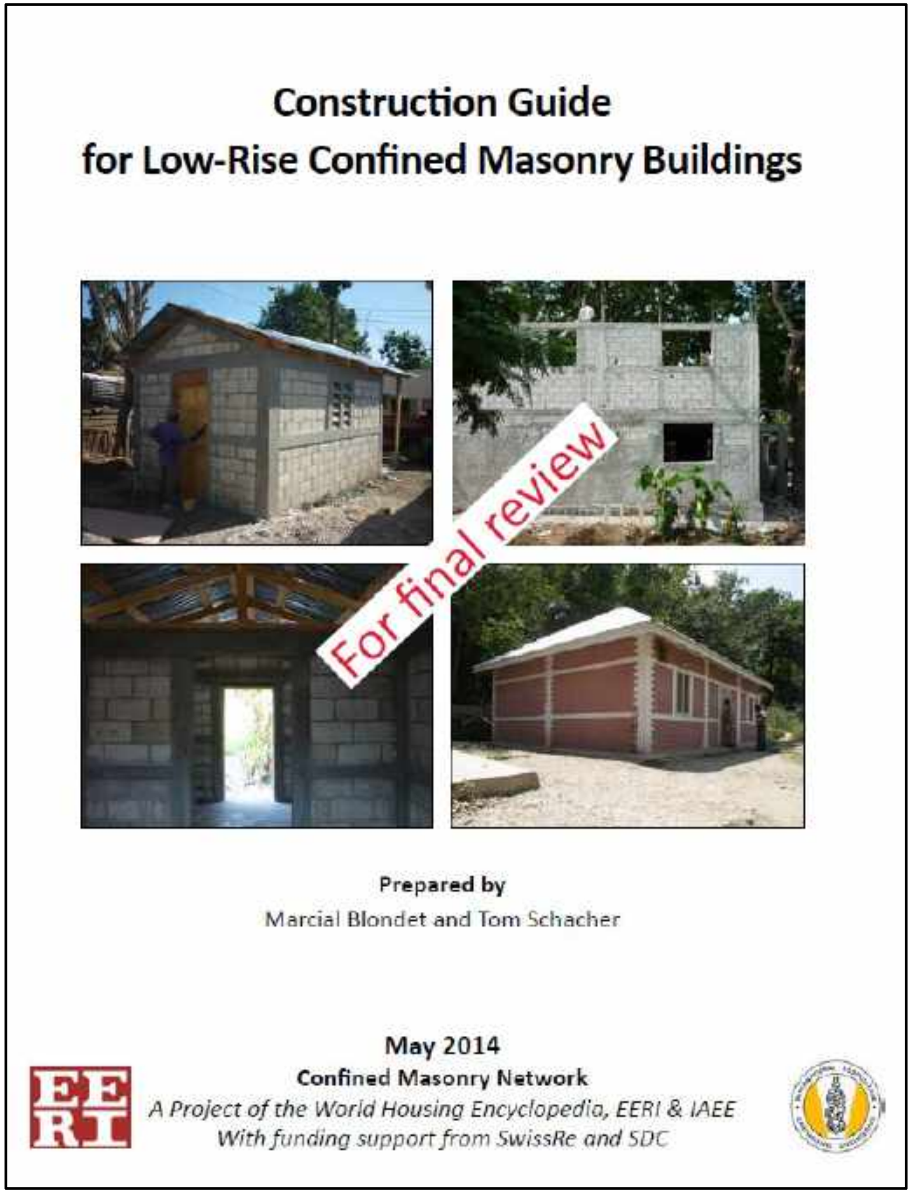


*Figure 46. Tie-beam construction: a) wall intersections; b) hooked anchorage for longitudinal reinforcement is a **must** (Brzev, 2008).*

Construction Guide Objectives

- Compile the best construction practices into one document that can then be adapted for use in specific countries
- Written primarily for builders of confined masonry buildings
- Focus is on the practical aspects of confined masonry



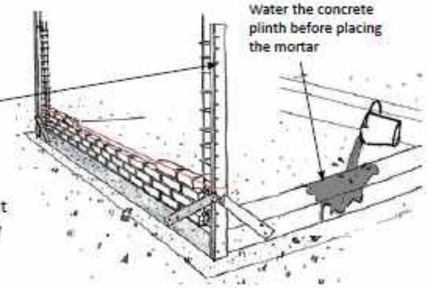
Construction Guide Contents

- Chapter 1 – General Aspects
  - General building rules
- Chapter 2 – Confined Masonry Step by Step
  - Site and foundations
  - Construction tie elements
  - Masonry walls
- Chapter 3 – Additional Issues
  - Lightweight roofs
- Appendices
  - Concrete, mortar & plaster mixes
  - Wall density calculations

Construction Guide Examples

7.5 Laying the bricks

Place vertical timber boards. These boards will ensure the verticality of the wall and allow for the fixing of the strings which will help with the alignment and level of each layer of bricks.



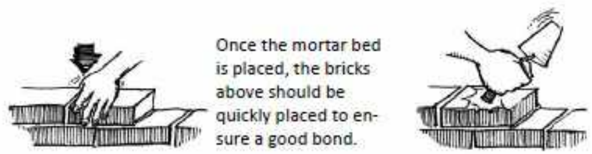
Place mortar uniformly over the plinth using a bricklayer's trowel. Bricks should be saturated but surface dry. Set the bricks over the mix and verify that their edges touch the strings that connect the guides.

Figure 143: Vertical boards for level strings

A mortar bed should not be allowed to sit on the plinth beam or bricks for longer than 15 minutes.

Before placing the next layer, fill the vertical joints completely. Use a small wooden board to prevent the escape of mortar at the joints.

Once the mortar bed is placed, the bricks above should be quickly placed to ensure a good bond.



To better set the brick, hit it lightly with the handle of the trowel.

Figures 143: Placing the mortar and bricks

Do not make joints thicker than 10 - 15 mm (1/2 in.) (little finger). Joints that are too thick will weaken the wall.

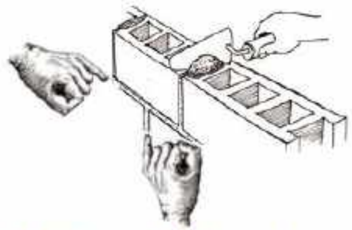


Figure 144: Maximum joint thickness is 10 to 15 mm (1/2 in.)

Engineering Guide Objectives

- Provide recommendations for the design of confined masonry buildings three stories and taller, as well as irregular buildings with configurations that require a detailed engineered design instead of a prescriptive approach
- Provide design methodologies that can be used with local building codes, both those with confined masonry provisions (e.g. Mexico, Peru) & those that don’t (e.g. Haiti, Indonesia)

Engineering Guide Outline

- I. Seismic Design Factors
  - Ductility
  - R-factor
- II. Wall Design
  - In-plane shear & flexure
  - Out-of-plane flexure
  - Wall openings
- III. Confining Elements
  - Tie-columns & tie-beams
- IV. Foundations

Engineering Guide Outline

- IV. Analysis Methods
  - Static & dynamic analysis
  - Periods & mode shapes
  - Computer/FEM modeling
- V. Special Conditions
  - Half-wythe walls
  - Hollow concrete blocks
  - Large wall openings
- VI. Construction
  - Construction documents
  - Procedures
  - Quality control & assurance

Conclusions (1/2)

- Confined masonry offers an opportunity for improved seismic safety over unreinforced masonry & RC frame systems
- Currently practiced in several countries/regions with high seismic risk
- Confined Masonry Network
  - International consortium formed in 2008
  - 1 guideline published
  - 2 guidelines under development

Conclusions (2/2)

- All 3 guidelines explain the mechanism of seismic response of confined masonry buildings
- Design guidelines contain prescriptive design provisions for low-rise non-engineered buildings (1 and 2-stories high)
- Construction guidelines recommend construction practices & focus on the practical aspects of confined masonry
- Engineering guidelines will have recommendations for the design of confined masonry buildings 3 stories & taller as well as for buildings that require a detailed engineered design

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