CASE STUDY: DESIGN AND CONSTRUCTION OF CONFINED MASONRY HOMES IN INDONESIA

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Initial Efforts

- Build Change began work in Indonesia after the December 26, 2004 Indian Ocean earthquake and tsunami
- In March 2005, Build Change survey identified 4 typical housing types used in Aceh:
  - Confined masonry
  - Timber framed on stilts
  - Timber framed over a masonry “skirt” base
  - Reinforced concrete block masonry
- Survey also identified the availability of building materials and the skill sets of local builders
- Prototype designs were developed for each type by a team of pro-bono structural engineers in the USA
Design Process

- Build Change contracted with the NGO Mercy Corps to build 11 homes as a pilot project.
- The prototype designs were presented to the homeowners to select from. All chose the confined masonry design.
- The confined masonry building was fully engineered by the USA pro-bono team and Build Change’s Indonesian engineers, and constructed in 2006 by local builders trained by Build Change.
The design was further developed and packaged into a design and construction “Blue Book”, published in both English and Indonesian.

The Blue Book was distributed to NGOs working in Aceh and used for the engineering review of housing designs and training for local builders, inspectors, and homeowners in Aceh, Padang, and West Sumatra.
Technical Challenges

Lack of Standards and Codes:

- The Indonesian building code does not include provisions for confined masonry
- Other building codes could not be applied because of differences in construction practice in Indonesia
- Indonesian guidelines were available but were prescriptive in nature and not fully detailed

Solutions:

- Adapted details from available guidelines to the extent possible
- Used masonry provisions from other codes
- Used conservative assumptions on seismic acceleration and material strengths
Technical Challenges

Slender Walls:

- Common practice is to use tall, single wythe walls
  - Common brick size did not allow for multiple wythes, instead only single wythe running bond could be used

Flemish Bond using bricks with typical proportion (top view)

Flemish Bond using Aceh bricks (top view)
Technical Challenges

Slender Walls:

- Tall walls with window openings were highly desired by the homeowners for ventilation

- Typical dimensions:
  - 3 meter wall height
  - 10-11 cm wall thickness

- Height/thickness ratios were 27-30
  - Greatly exceeds maximum ratios allowed by other building codes and guidelines
Technical Challenges

Slender Walls:

- Despite their high height/thickness ratios, out-of-plane failures were rare in Indonesia except in Aceh
- Were the occurrences in Aceh due to the earthquake or the tsunami?
Technical Challenges

Slender Walls:

- **Solutions:**
  - Initially included steel reinforcement in the bed joints
  - Designed the ring beams to resist the out-of-plane forces from the wall
  - Limited the spacing between walls to 3 meters
    - Reduced the ring beam spans
    - Reduced the length the walls had to span horizontally
  - Literature review of out-of-plane behavior of confined masonry walls:
    - Research papers
    - Masonry textbooks
    - Earthquake reconnaissance reports
    - Note differences in behavior compared to URM and framed infill
  - From review, determined an acceptable wall panel size to justify reducing the amount of joint reinforcement
Technical Challenges

Other challenges:
- Masonry gable walls
- Small (11 cm) tie-columns
- No tie-columns at wall openings
- Undeveloped beam and column reinforcing
- Stirrups with 90 degree hooks
- No toothing
Technical Challenges

Solutions:

- Improved details
  - Developed hooks at all concrete connections
  - Dowels from walls to columns
- Builder training
- Quality control by Build Change trained inspectors
- Increased involvement by the homeowner:
  - Responsible for material procurement
  - Engaged in the design
  - Quality control inspections
Non-Technical Challenges

Construction Practices:
- Hand tools are commonly used
- Concrete is mixed and placed manually, mixers were rare and trucks & pumps were non-existent
- Bricks were made at small “mom and pop” kilns with variable quality

Solutions:
- Training for builders, homeowners & material manufacturers
- Emphasis on the 3 “C’s”: Configuration, Connections, and Construction Quality
- Modified details to accommodate construction practice:
  - Used smaller bars that are easier to bend
Non-Technical Challenges

Lack of Familiarity with Confined Masonry:

- Foreign NGO program managers were not familiar with the system
- Engineers, both Indonesian and foreign, were also not familiar with the system
  - Confined masonry buildings in Indonesia are typically not engineered
  - Many foreign engineers were from countries where confined masonry is not common or is not engineered
- Often mistaken for concrete frame with masonry infill systems that managers and engineers were more familiar with

Solution: Training for NGOs and engineers
Technical Challenges

Building Codes:

- Because there were no provisions for confined masonry in the Indonesian code, NGO program managers were reluctant to use it.
- Only willing to use confined masonry if the design strictly followed the guidelines endorsed by the government.

Solution: Provided engineering calculations to justify the design and any deviations from the guidelines.
Non-Technical Challenges

Funding:

- “Enhanced” confined masonry is more expensive to build than unreinforced masonry and confined masonry as it had been typically constructed

- Not a significant issue in Aceh because there was more reconstruction funding available
  - Reconstruction was primarily donor driven

- Was a significant issue in West Sumatra since reconstruction funding was approximately ½ of what was available in Aceh
  - Homeowners often had to supplement the construction with their own funds

Solution: Since some of the engineering enhancements used in Aceh could not be used in West Sumatra, the enhancements were prioritized to maximize the cost benefit (biggest “bang for the buck”)

- Bed joint reinforcement was not used
2016 Aceh Earthquake

- Earthquake epicenter approximately 100 km from the pilot project site
- MMI of IV to V reported at sites (USGS)
  - MMI of IX at epicenter
- Houses constructed as part of the pilot project were found to be in good condition
- Damage was limited to cracks in the plaster and in 2 cases the concrete cover
- Many cracks appear to be the result of foundation settlement prior to the earthquake
QUESTIONS?
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Thank you for your attention