Confined Masonry in the Reconstruction Process after the October 2005 earthquake in Pakistan

Case History

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BACKGROUND, SEISMIC HAZARD AND PREVALENCE OF CONFINED MASONRY

The M 7.6 earthquake of 8 October 2005 killed 88,000 people, injured 75,000 and left 4 million people homeless (USGS 2005). It was estimated that about half a million houses had been heavily damaged or destroyed.

In the aftermath of the quake SDC, together with UN Habitat, assisted the Pakistani Earthquake Rehabilitation and Reconstruction Authority ERRA in the setup of a training programme on para-seismic construction methods for artisans and house owners. The official training programme included only RC frames and reinforced masonry ‘Indian style’. The initial training material had been prepared by the Nepalese Society for Earthquake Technology NSET.

We soon discovered that some rare contractors were building houses using a simplified version of confined masonry. That is, they had some basic knowledge of this technology but still made several serious mistakes of detailing and execution. Confined Masonry however didn’t seem to be a known standard in the country.

As we were not convinced that RC frames should be taught to unqualified workers (it’s a ‘hi-tech technology’ where too many factors must be observed correctly to make the structures behave as planned by the engineers), and as the newly introduced reinforced masonry, though much appreciated by the people, faced serous difficulties with the different standards of bricks and cement blocks in Pakistan, we were keen on getting confined masonry included in the training programme.

We developed a step-by-step manual where the most important construction details were explained in a graphical way. This manual was to be distributed during the training where each picture was explained in detail.

A major difficulty we faced was to get this construction technique officially recognised by the consulting engineers to ERRA. They had never heard of confined masonry and we had difficulties of providing them with relevant scientific literature. They considered Confined Masonry as a type of RC frame, and expected that we applied the same calculation rules, and therefore the same quantity of rebars and sections of concrete. In fact, when the technique finally got approved, it was only for housing. Schools still had to be calculated as RC frames, even if they were, conceptually speaking, confined masonry.

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[1] SDC: Swiss Agency for Development and Cooperation

RELEVANT AND APPLICABLE CODES AND GUIDELINES

There was no official seismic code for Pakistan when we started work. The Sarhad Interim Seismic Building Code[2] valid for NWFP[3] was produced in March 2006. The only other document available was the Field Practice Manual[4] developed after the quake by the Earthquake Engineering Centre of Engineering and Technology of Peshawar. This booklet contained illustrations on both RC frames and Confined Masonry, without however making a clear distinction between the two techniques.

The building code most used by Pakistani engineers apparently is the American Uniform Building Code. However, according to some engineers, this code is not ideal for the Pakistani context, as it deals very little with the typical brick constructions prevalent in the country.

The only guidelines on confined masonry available were the Blondet manual[5], the Colombian LaRed manual[6] , a web based training course from Colombia[7], the web based document from the City University London[8] and my own draft manual developed the previous year[9].

PERFORMANCE IN RECENT EARTHQUAKES

As Confined Masonry seems to have been unknown in the country before our training, no local information is available with regard to its earthquake performance.

ARCHITECTURAL, CULTURAL AND CLIMATE CONSIDERATIONS

The aim of introducing Confined Masonry is to replace the RC frames as a para-seismic construction method in a non-engineered environment. It is important that people come away from their belief that RC frames are 'strong' just because they make use of two 'strong' materials, concrete and steel.

From an architectural point of view, this replacement has little significance, except perhaps for the elimination of the wall-less open-surface ground-floors.

With regard to climatic considerations confined masonry in itself cannot improve the disastrous modern building standard where walls are too thin to offer any thermal insulation and where concrete slab roofs work as powerful heat accumulators during summer. It is sad to hear from people that their old houses were much better from a climatic point of view, warmer in winter and cooler in summer. But modern houses are 'modern', a sign of economic and social success, their deficiencies are happily accepted as the price to pay, much as in other countries high-heel shoes are worn to show off and not for comfort.

As for cultural acceptance, it seems that people are quite happy to pick up this new earthquake resistant building method. According to information from former colleagues, 60 to 80% of new houses are now built according to the principles of confined masonry. It is

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[2] UET-P (2006), *Sarhad Interim Seismic Building Code, Version 2*, prepared by the Earthquake Engineering Centre, University of Engineering and Technology of Peshawar (UET-P), Government of NWFP, Pakistan

[3] NWFP: North West Frontier Province, Pakistan

[4] Ali Q (2006) *Field Practice Manual*, Urdu version: February 2006; English version: July 2007

[5] Blondet M (2005), *Construction and maintenance of Masonry Houses, for Masons and Craftsmen*, Pontificia Universidad Catolica del Perú

[6] LaRed (>2001), *Manual de Construcción, Evaluación y Rehabilitación Sismo Resistentes de Mampostería*, Associación Colombiana de Ingeniería Sísmica, Colombia

[7] SENA (2001), *Guia de estudio No. 5, Componentes estructurales que garantizan la sismoresistencia*, Centro national de la construccion, Antioquia, Colombia

[8] CITY (?) *Confined Brick Masonry*, Web document, City University London, http://www.staff.city.ac.uk/earthquakes/MasonryBrick/ConfinedBrickMasonry.htm

[9] Schacher T (2006), *Confined Masonry for one and two Storey Buildings, a Construction handbook*, (unpublished)

however impossible to say today whether this is due to the government subsidies a house owner receives if official reconstruction rules are observed, or if people are really convinced of the advantages of the method. An answer to this question will only be possible the day government subsidies have stopped.

BUILDING MATERIALS AND PROPERTIES

Depending on the area, bricks of cement blocks are used.

Bricks are burned in traditional kilns and their average quality is quite acceptable. All bricks have frogs, usually with the brand name of the manufacturer. Their size is approximately (LxWxH) 21.5x10x6cm (9”x4”x2.5”).

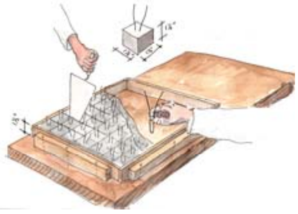
Hollow cement blocks measure (LxWxH) 18”x6”x8” (45x15x20cm). They are produced by local small scale producers. Their quality is mostly insufficient as they are usually let in the sun to dry. Also, the grading of the aggregates is rather casual. Finally, the 6” (15cm) wide standard is dramatically insufficient for seismic requirements. There were long discussions about how quality could be controlled and ensured, but the only solution found was the production of a double faced A4 explanatory leaflet. The new standard imposes a minimum width of 8” (20cm). We recommended that such hollow blocks are not used in confined masonry. However, in the Urdu version of the Confined Masonry Handout this recommendation had to be removed (in the English version it still is present).

Full cement blocks do exist in two varieties: an industrial block of excellent quality having the same dimensions as bricks (but which is rarely used because of its cost), and a block made by local small scale producers, measuring (LxWxH) 12”x8”x8” (30x20x20cm). This standard doesn’t have ideal proportions which becomes apparent in the corner assemblies: a block should be twice as long as wide to ensure an optimal overlap.

Cement is widely available in Pakistan. Hydraulic lime on the other hand does not exist. In some places locally made hydrated lime can be found, but of very irregular quality.

Rebars are rippled except for the 6mm bars used for stirrups. The quality of the steel is inconsistent. Some steel seems to have been produced from scrap metal and is excessively brittle (stirrups would brake at a 90° angle!).

Spacers as small concrete blocks provided with a fixing wire were unknown. Workers use pebbles or pieces of tiles to keep a proper distance between formwork and armature. The armature however tends to slip off such makeshift blocks while concrete is poured in. The fabrication of proper spacers, and their correct placement, was therefore part of our training programme (fig. 14).



Proper aggregates in general are available, but their grading and mixture is often wrong.

Concrete is mixed by hand or with a mixer, depending on the quantity needed and accessibility of the site. Usual proportion is (theoretically) 1:2:4 (cement : sand : aggregates), plus excessive water! However, this proportion might change depending on many factors (availability, habit of the contractor, etc).

Mortar is exclusively a cement-sand mix (usually 1:3 or 1:4) which is spread over the whole length of a course and smoothed before the next course of bricks is laid. In order to compensate for the irregularity of the burned bricks, mortar beds are higher than the ideal 15mm and can measure up to 25mm (1”). Bricks are never pressed on the mortar beds with the back of the trowel. The frogs therefore cannot assume their full function.

Vibrators are unknown to private builders and small scale contractors. In our trainings we insisted that sticks be used to stir the concrete of columns, rather than adding water in excess as it usually is done.

Formwork for concrete is mostly made of old irregular wooden boards. To ensure that the formwork for a concrete slab is water tight, a worker fills all the gaps between boards with mud before concrete is poured on top. In vertical formworks this is not possible, and water leaks from between the planks.

Power cuts are a serious problem on building sites: they do not only stop the concrete mixer but also the pump necessary to get the water out of a well. In that case concrete works may be interrupted for several hours, with less than ideal results if the workers were in the midst of pouring a concrete slab.

DESIGN PROCESS

The technical details (e.g. wall thickness, reinforcements, etc.) are based on calculations which took into account a peak ground acceleration of 0.35 g and a two storey building with two concrete floor/roof slabs. The codes used for the calculations were

- the Eurocode 8 (Design of structures for earthquake resistance),
- the Swiss Norms 260 (Basis of structural design), 261 (Influence on structures), 262 (Concrete structures) and 266 (Masonry),
- Iranian Code of Practice for Seismic Resistant Design of Buildings No. 2800 (2nd edition 1999)

However, without further calculations we reduced the thickness of the shear walls from a width of 1.5 bricks to only 1 brick (i.e. from about 30cm/1ft to 20cm/8”). 1.5 brick wide walls were just ‘unsellable’.

We encountered major difficulties with engineers educated in a RC frame philosophy. They had great difficulties understanding the mechanics and advantages of Confined Masonry. For these engineers, walls were disturbances to the RC frames rather than elements with a major role. To remain on the safe side, they stubbornly went on calculating RC frames. This of course is also due to the fact that no codes were available for confined masonry. Engineers have to base their calculations on something, so they had to use the ‘RC codes’.

A good example are the school buildings for which there were Ministry of Education guidelines, all based on the RC frame technique (many such schools had collapsed during the quake: the fault though was never put on the designs or engineers, but on the workers who had done a bad job!).

Though we had an excellent local engineer who was convinced of the advantages of CM, he had to elaborate a difficult compromise, designing a CM structure which would satisfy RC frame requirements. This of course brought additional costs and complications with the result that these designs could not be used to demonstrate that CM is a viable (i.e. a rational and economic) technology. In addition, the workers involved could not understand the logic of construction, as both CM and RC frame systems were mixed together. We lost a great opportunity to promote CM through its use in public buildings. In fact, our trainees criticized us saying: “why are you teaching us one thing but in your schools you use another and certainly safer technology?”

DESIGN DETAILS

Basics:

As first step in the design process of a house we insisted on the importance of selecting a safe site and on some universally valid seismic engineering rules, such as the proportions and forms of houses. Basic rules specific to confined masonry, introduced as a second step, covered the following issues:

Foundations:

Good engineering would require specific foundations depending on the local soil resistance. However it is not obvious how soil resistance can be tested accurately by workers or self-builders. Simple tests should therefore be used which lead to a maximum of three results: soft, medium or hard soil. Accordingly, foundations will have to be of three types to respond to the three possible situations. We limited our foundations widths to two possibilities, 2ft (60cm) for hard to medium soil, and 2 ½ ft (75cm) for medium to soft soil.

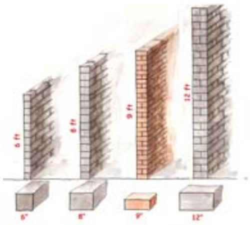
We didn't recommend any steel reinforcements in the foundations, but considered the 9"/22.5cm plinth band as an 'extension' of the foundation which would maintain the horizontal distance between tie-columns as well as compensate for any unforeseen deformation of the foundations.

Walls:

Maximum wall length: Instead of defining general rules about the number and distribution of perpendicular walls acting as shear walls, we decided to use a definition easier to understand for lay people: we defined a maximum wall length of 15 ft (4.5m) before it would meet a perpendicular wall. We are convinced that with a similar definition we cover the requirements of 95-99% of all housing projects.

Shear walls: The shear wall concept is more difficult to explain. In fact, it's not the shear walls themselves which are difficult to grasp, but the idea of distributing these walls in a regular way to avoid rotation. While in the manual we limited the explanation to a simple 'two full outer wall panels in each direction', we went more into detail in our PowerPoint lessons.

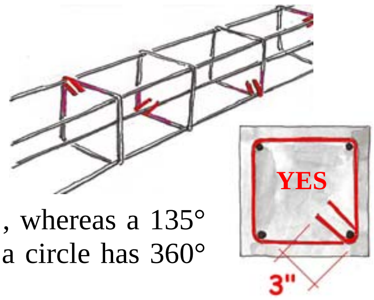
Wall proportion: We recommended a wall proportion of 1:12. This means: the maximum height of a wall is 12 times its thickness. Wall height and width are therefore linked. With a 9" (22.5cm) brick a room can only be 9 ft high (270cm). While scientific literature gives 1:12 as one of several possible proportions, we chose it because it fits so perfectly the imperial system: for every inch of wall thickness one foot of room height!



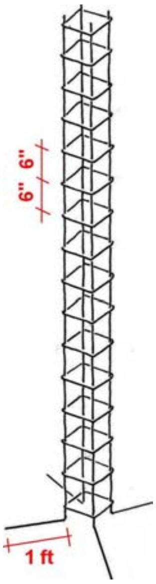
Wall masonry: Given the low level of technical knowhow of the average worker, the training included some basics on masonry such as: watering of bricks before use, alternating of vertical joints, mortar beds of 15mm (5/8"), daily maximum wall height of 120cm (4ft), curing and/or protecting fresh walls against evaporation, etc. Much care was given to the teaching of correct toothing at the end of each wall masonry panel. Toothing (fig. 9) is linked to the type of bond used. We recommended the use of the Flemish rather than the English bond: the number of vertical joints in the Flemish bond is constant whereas the English bond forces workers to compensate for missing joints in every other layer, causing excessive joint width (see fig. 18). In order to achieve a maximum strength of the walls, we also insisted that no slits were made into the walls to place pipes. Small pipes like electrical conducts can easily be hidden in the plaster, while bigger water and sewage pie have to remain apparent (fig. 15).

Tie-columns, tie-beams and seismic bands:

Armature: We tried to keep the rules as simple and consistent as possible. The first, 'universal' rule was that all stirrup ends had to be bent at 135°. To keep language and concepts simple, we called this a 45° angle, rather than a 135° one (a '45° angle' is a concept most people are familiar with, as another way of saying 'half a right angle', whereas a 135° angle requires calculation and the knowledge that a circle has 360° and half a circle 180°).

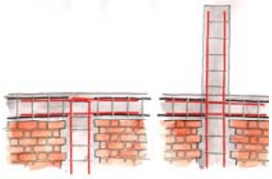


Vertical ties (tie-columns): The second important simplification was the placement of all stirrups of the tie columns at a regular distance of 6"/15cm, whereas literature suggests that the initial and final stirrups should be at shorter intervals (4-5"/10-12cm) than the ones in the centre (8"/20cm). The creation of a simple rule for training purposes was one, but not the main reason for this change.



Our horizontal seismic bands, placed at sill and lintel level, do not only subdivide the wall panel in smaller elements, but do also ensure the parallelism of the tie-columns on either side of the panel. Together with the toothing of the masonry the homogeneity of the masonry-cum-tie-columns is ensured and any stress should be distributed evenly. Hence our recommendation for an even distribution of stirrups.

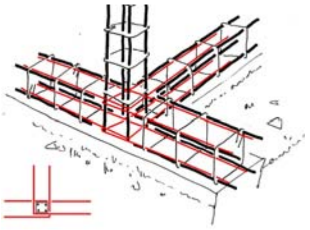
A particular issue of concern is how tie columns reinforcements are connected with the bond beam. Instead of bending the ends of the tie-beam reinforcements into the bond beam reinforcements, people often want to let the vertical irons come out of the roof slab to allow for future vertical extensions. In that case, such rebars sticking out of the roof slab must be cast in lean concrete to protect them against rusting. Lean concrete can then easily be removed when works go on. However, this adding of lean concrete to protect the rebars proved to be a difficult concept, even among our best trainers/engineers (fig. 16).



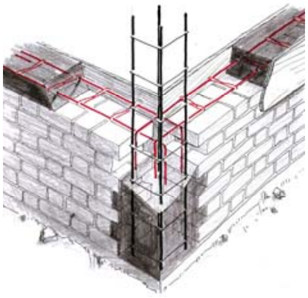
We also recommended that the pouring of concrete for the tie-columns should be done in steps, that is, whenever the level of a seismic band is reached. The advantage of such progressive filling lies in the fact that the formwork is relatively short and can not only be cleaned more easily, but the concrete can be stirred properly, an important factor in the absence of vibrators (fig. 4, 5+6).

Tie beams are made in much the same way as tie-columns, with the difference that the bond beam on the top of the walls has a bigger distance between stirrups (8”/20cm instead of 6”/15cm)

Corner connections: Instead of a cumbersome and imprecise bending of the long rebars, we opted for straight lengthwise bars and special bent elements for the corners. Experience however has shown that our solutions with special, additional rebars in the corners created more problems than they resolved. The corners got crowded with steel and the pouring of concrete became difficult (fig. 13). The usual system of bending the long bars is probably still the best.



Horizontal Bands: Horizontal reinforced concrete bands are placed at sill and lintel level. These bands do a) ensure a better anchoring against out-of-plane acceleration, and b) reduce the panel size which has to work under compression under in-plane strains, thus reducing the risk of buckling, and c) keep the vertical ties at a constant distance from each other, thus ensuring a permanent confinement of the brick wall. The bands do as well have a role of ‘crack stoppers’, blocking diagonal cracks before they stretch over the whole wall panel, thus ensuring an increased wall homogeneity during an earthquake (fig. 7+8).



There was also a psychological aspect to the use of horizontal bands: they would be a visual reminder that we’re not building an RC frame, but a confined masonry house. This is an important aspect not only for the workers, but also for the engineers to start to perceive confined masonry as something completely different from RC frames (fig. 1, 2, 3).

Stitches: Where windows were higher than 3 feet, additional intermediate stitches (as they are used in the reinforced masonry Indian style) were suggested. However, as we were not sure about the usefulness and additional cost of these stitches we have left them out of the manual and mentioned them only during our PowerPoint training sessions.

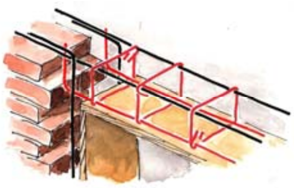
Openings:

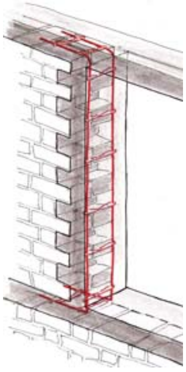
Size of openings: We defined a maximum width for any opening as half the length of the respective wall panel. The maximum vertical size, except for doors, was 4 ft (120cm) which is also the maximum distance between two horizontal bands.

Confinement of Openings:

All openings are confined with vertical bands. Contrary to the main vertical ties (with 4 bars of Ø12mm / ½”), the confinements of openings have only 2 bars of Ø10mm (3/8”) (fig. 10, 11+12).

All lintels had to have a minimum height o 6” (15cm). The 3” high seismic bands therefore had to be increased where they spanned windows.





CONSTRUCTION PROCESS AND CHALLENGES

Confined Masonry certainly presents a simplification as compared to the RC frame technology. But this might not be enough to ensure a quality construction. Proper workmanship is a basic ingredient to quality that is not always available. In countries with no or only a limited number of professional training institutions work quality is generally low.

Basic construction training is therefore a necessity in many countries. Basic instructions on how to make mortar and cement, and how to lay bricks, must be part of any training package on Confined Masonry (fig. 17+18). This information should either be included in guidelines intended for workers, or a separate manual/training module should be developed (will certainly already exist).

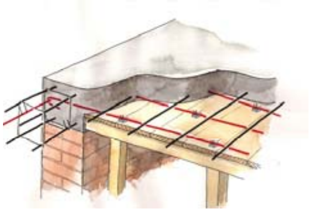
Simplification: All details in Confined Masonry must be standardised and brought to a very simple and straightforward level. In the end, CM technology must become as obvious as brick laying. Any special details, so frequent with RC frames, must be eliminated. Because that is what workers are doing all the time, also with RC frames: they simplify and take shortcuts. Such ‘planned shortcuts’ must be part of the standard from the beginning. Only if we achieve this, will CM become a very safe standard.

Refinements and additional cost-saving tricks can be developed by engineers on a case by case basis. CM must be relatively cheap, that is the cheapest solution for a given level of safety, not the cheapest solution at all. People don’0t always want the cheapest thing. Otherwise they wouldn’t even bother about RC frames.

VULNERABILITIES, PROBLEMS

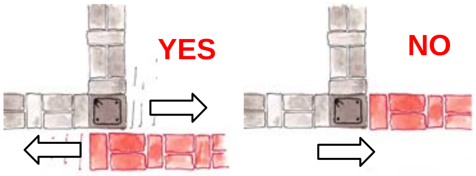
Vertical extensions: roofs and slabs:

House owners usually want a concrete slab on their houses to allow for a future vertical extension. We included in our training and manual some basic and safe rules how this could be done (based on LaRed recommendations, see footnote 5). However, official reconstruction policy wanted people to build only one storey houses with light roofs covered in CGI sheets. With much regret we had to eliminate these instructions from the manual. We think this fear of the consulting engineers of allowing concrete roof slabs is not only unrealistic (people will do the roof slabs later, without any guidance), but also annihilates the whole issue of shear walls: if shear walls cannot take up the load of other walls thanks to a horizontal diaphragm, they are pretty much useless.

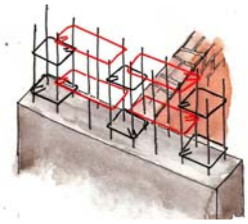


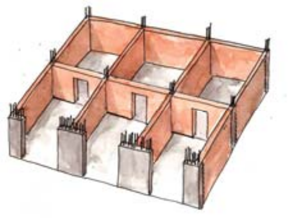
Horizontal extensions:

Given the usual adding of rooms to an existing house, we wanted to tackle the issue of horizontal extensions. Vertical seismic joints of 1/100th of the height of the building (or at least 5cm/2”) are not realistic. Such joints must be perfectly empty and this cannot be ensured without a very tight control by a qualified engineer and very good detailing. We opted for a most shocking concept, that of a ***crush zone*** as a building element which will be destroyed by a quake. This narrow room placed between the original building and the extension will have to be a place where people stay only for short periods of time. It may be a storage room or a toilet, thus reducing the risk that anybody will be in there during an earthquake. All elements of the crush zone have to be built *against* the existing and new building, not *in-between.*



The shop window problem:





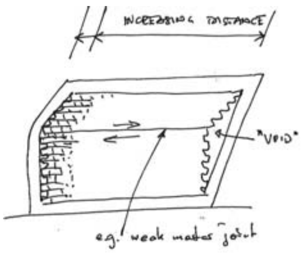
In urban areas house owners often want to use the ground floor for shops. Such ‘shop buildings’ with a big open front present a serious risk under earthquake conditions because they don’t offer any lateral resistance (in the form of a shear wall) at the ground floor. With the principles of confined masonry this problem of a missing front wall cannot be overcome. We therefore suggested very simple concrete frames for the front part of such buildings, with massively over-dimensioned columns to compensate for hazardous detailing and execution.

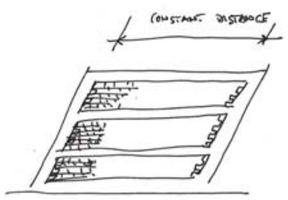
RESEARCH NEEDS

Wall proportions: There are two types of proportions to verify: a) the length-height ratio of the wall panel and b) the thickness-diagonal (of panel) ratio. Clear limits of possible loads must be defined depending on the proportions used. I’m particularly concerned with thin walls (1/2 brick wide) as they are done in tropical countries. While they most probably work well with a light roof, what will happen if people one day decide to put a concrete slab and a second floor on top? Also, the whole issue of shear walls doesn’t work without a rigid horizontal diaphragm (a slab). In that case, what shall be the minimum proportions for ANY wall (as each one has to resist horizontal loads in itself)? What about safety factors?

Usefulness of seismic bands at sill and lintel level: We feel that seismic bands are not only a good way of making a wall more resistant against out-of-plane failure, but also do improve its in-plane resistance (or resilience). In this (in-plane) sense the bands have a double role: a) to keep the tie-columns at a constant distance (and thus tight against the wall ends), and b) to create, through subdivision, smaller panels with a better height-thickness ratio which could be useful to increase resistance against buckling. This might be particularly important when construction is done with inconsistent material or work quality.

A last added advantage might be that cracks cannot develop over the whole surface of the wall at once, increasing the chances that the wall material remains in place (ensuring that the confined masonry principle is working for as long as possible).





Additional question: could horizontal bands reduce some of the risks related to thin-wall constructions?

Distribution of stirrups in tie-columns: as explained in the previous chapter, we suspect that tie-columns don't need a closer spacing of stirrups in the bottom and top zones because, with a proper connection with the brick wall through toothing and seismic bands, it becomes difficult to predict where and whether such additional reinforcements are needed. Tests up to now seem all to have been done through a 'RC frame with infill' approach, rather than with a 'masonry wall with a string around' concept in mind.

COST VS RC FRAMES

We don't have figures. But I would expect that Confined Masonry is slightly more expensive than the *usual*, under-dimensioned and badly executed RC frame which collapses regularly during earthquakes. If however we compare Confined Masonry with *properly done* RC frames (including anchoring of infill walls), then construction costs of Confined Masonry most probably are lower, even if horizontal bands are used as in our case. What is more important though is the higher level of safety achieved by a lowly qualified workforce, through the use of Confined Masonry, as compared to RC frames built by the same workers.

ADVANTAGES RELATIVE TO ALTERNATIVES

Simplicity and safety: Confined Masonry, for an equal or lower cost than RC frames, offers more safety because of the simplicity of its execution which even lowly qualified workers can achieve.

The CM system is 'hyper-static' by nature (our designs must guarantee that) and will not fail if one of its parts fails. With RC frames this aim is much more difficult/costly to achieve.

The CM system is based on what workers know to do best: masonry. It's the walls that provide the earthquake resistance, not tricky steel and concrete articulation as in RC frames which workers don't understand and which have to be checked in detail by the designing engineers (which by definition don't check non-engineered buildings).

DISADVANTAGES OR CONCERNS

Cost comparison: On of the difficulties of demonstrating that Confined Masonry doesn't cost more, or even costs less, than RC frames, is that the average customer and contractor will not understand that we compare Confined Masonry with *proper* RC frames. They only know the cost of *usual*, that is *improper* RC frames which collapse but which are a lot cheaper. To the average customer therefore Confined Masonry seems more expensive than the badly done RC frames they know.

POINT OF LEVERAGE FOR IMPROVED CONFINED MASONRY DESIGN

Training at BSc level: Cost comparison as a major argument for the use of Confined Masonry must go through people who can understand that comparison, that is, who know what a proper RC frame would cost. These are the engineers. It is therefore important that CM is taught early on in the engineering schools so that BSc engineers (the future field technicians and/or contractors) will understand the advantage of CM.

Government standards and seismic codes: Without introducing Confined Masonry in the collection of official standards for government buildings there is little hope that it will become widely used. To get that far however, CM must be first of all included in the national seismic code. And for that, CM must be well known to the engineers who are developing this code. The question therefore is how to reach these engineers.

ILLUSTRATIONS

Fig. 1: Finished demonstration houses

Fig. 2: Seismic reinforcements put in evidence through colour and mortar

Fig. 3: Seismic bands at sill and lintel level

Fig. 4: Raising wall from sill to lintel band before pouring of the tie-columns

Fig. 5: To ensure proper filling of the tie-column it would have been better to fill the lower part of the tie-column together with the sill band

Fig. 6: Pouring concrete bit by bit

Fig. 7: Seismic band at lintel level

Fig. 8: Seismic band at lintel level

Fig. 9: Proper toothing

Fig. 10: Vertical reinforcements around openings

Fig. 11: Vertical band around openings

Fig. 12: Vertical bands around openings

Fig. 13: Crowded corner reinforcement shouldn't have happened according to the drawings

Fig. 14: Pebbles as spacers will not stay in place

Fig. 15: No slits to be made in the masonry. Pipes can be hidden in the plaster, or left apparent

Fig. 16: Rebars on roof should be cast in lean concrete for protection

Fig. 17: Teaching the basics of masonry

Fig 18 top: Teaching the Flemish bond; bottom: English bond