Aga Khan Planning and Building Services, Pakistan
Building and Construction Improvement Programme – BACIP

FIELD VISIT
HABITAT RISK MANAGEMENT PROGRAMME (HRMP)

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Non-cement masoned traditional houses and some public schools constructed with cut-face stones fall apart by themselves due to numerous small earthquakes and erosion.
Seismically retrofitting these walls with external reinforcement (columns, tie beams or stitches) is a useless exercise; reconstructing is the only recommended option.

1. INTRODUCTION

Habitat Risk Management Programme (HRMP)

During the field assessment of BACIP (Building and Construction Improvement Programme), the mission was invited to have a look at the Habitat Risk Management Programme (HRMP). The HRMP activity is financed by the ALCAN fund[1] and operating in the Ghizer Valley of the Northern Areas of Pakistan.

The HRMP project includes (among other activities) a one-year identification and formulation phase, a few months of actual retrofitting of buildings and another two years of awareness raising. The retrofitting of 20 houses, 4 schools and 1 clinic (public building) was currently ongoing, to be completed in two weeks' time (before end November 2008). The deadline is related to the increasingly colder night temperatures, which curtails the use of cement mortar because it will not harden properly.

The HRMP activity follows the principles developed by the existing FOCUS programme and has similarities to the UNDP and CAMP programmes. The FOCUS programme is an international programme on hazard and disaster mitigation operating in close collaboration with the AKDN in several countries and other expert organisations worldwide. However, in the documentation provided by HRMP staff and during verbal explanations, no reference was made to this programme, nor was it clear whether the HRMP has had communication with the FOCUS programme in Pakistan.

Although not part of the BACIP mission, a site visit of five house constructions (Numbers 1-5) and one school retrofitting was undertaken. The findings during this short site visit were rather worrisome to this mission. For this reason, this report is being submitting. It is hoped that some timely programme adjustments will be made to avoid misleading information from being disseminated.

Based on time restrictions, the mission does not elaborate on the programme as a whole nor goes into detail on the content of the documentation provided.

Although the mission is submitting herewith some rather critical notes about the technicalities of the seismic retrofitting implementation, it is doing so with the hope that the HRMP project and AKPBSP will benefit from these observations and redirect some elements towards increased benefit for the population.

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[1] The BACIP programme, in combination with the Water and Sanitation Extension Programme (WASEP), received the 2005 ALCAN Award for sustainable projects.

2. CONSTRUCTION PROJECT SITE VISITS

House 1 – This retrofitted house covered the main traditional room only, having four massive support columns under the wooden traditional roof construction.

The activity included: waterproofing and ring beaming of the entire foundation; partial stone wall reconstruction, stitching of cracks and cement pointing; applying vertical corner reinforcements; constructing an upper reinforced concrete ring beam; and redoing the roof cover.

The traditional house design with its heavy wooden columns has a relatively high earthquake resistance, especially in relation to its support structure. Although most roofs are overweight, the strong columns and timber roof construction will generally hold up during an earthquake, while the walls around it may collapse due to their loosely masoned structure.

The traditional Pamiri house with its four or seven columns is seldom subject to total collapse during an earthquake. What happens is that the walls gradually fall apart during the lifetime of the building and need to be reconstructed every 20 to 30 years depending on the quality of the (re)construction.

Retrofitting of a traditional room with its wooden support columns, therefore, should consist of:

- Making the roof construction lighter, applying thermal insulation and waterproofing.
- Totally reconstructing the outside walls in cement mortar, using less stone materials, but with internal wall reinforcement; and applying thermal insulation on the inside.

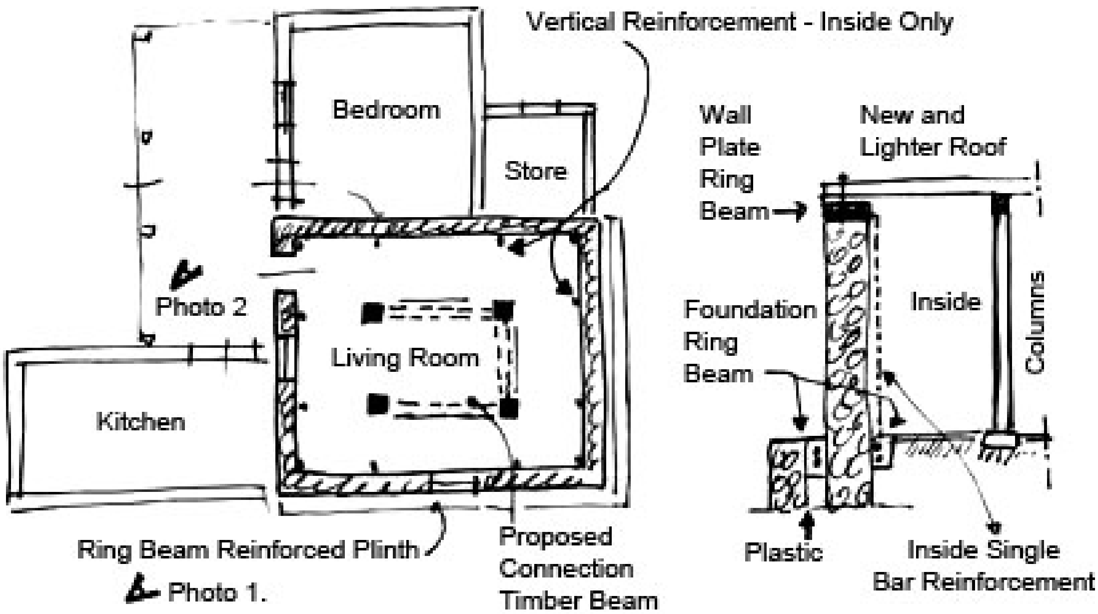

Left: Outside wall of the main room with foundation ring beam and wall stitches.
Right: House owner in front of bedroom – the lintels are not linked nor connected to the main room wall plate ring beam (right of bedroom door).

The main living/guest room, once retrofitted with the new reinforced concrete wall plate ring beam construction and lighter roof construction, will better withstand earthquakes. However, while the heavy inside and outside plinth reinforcement (and waterproofing) may prevent the wall from cracking due to vertical settlement of the building (wet underground), new cracks can easily develop right next to the newly made stitches because of the loose internal stone masonry of the walls.

The stitching looks impressive, but it is more a psychological improvement as it contributes little to the overall strength of the room. In the event of an earthquake, it will be the upper wall plate ring beam keeping the walls together, not the stitches. It needs to be assessed if it is worth the money, especially as the building is a ground-floor-only construction.

HRMP planned to make a connecting beam under the four wooden main columns of the living room, creating an open U-shaped linkage. It is the opinion of the mission that making this incomplete connection under the four columns is unnecessary. Furthermore, disturbing the columns might even weaken the structure. The one-sided (only internal) vertical corner reinforcements provide a little strengthening (see Chapter 3, page 12).

Neither the lintels over the door and window of the bedroom (see photo page 2, right), nor the lintels of the kitchen, were connected to the ring beam of the main room. This was based on the idea that the programme would only improve the main living/guest room. The mission was of the opinion that it would have made more sense to avoid disturbing the massive old columns and instead connect the interrupted lintels to the ring beam (for less cost). Only the living room (or the visitor's part of the house) was dealt with, while the occupants obviously would spend most of their time in the bedroom (12 hrs/day), the kitchen (6 hrs/day) and outside.



Left: Floor plan of the house consisting of the central (traditional) living room with adjoining kitchen and bedroom. During the winter period, the living room is seldom used (only for visitors). The position of the photos (page 2) is indicated in the sketch.
Right: House section showing the lower foundation ring beam reinforcement and waterproofing.

While the project document might define reinforcement of only one part of the house as demonstration, it is highly unlikely that the house owner is going to retrofit the rest of the house. In terms of escape chances during an earthquake, it makes more sense to reinforce the bedroom where one sleeps, rather than the living room where one is awake and which is not in daily use or used only for the occasional visitor.

According to the site engineer, the retrofitted main room would not support a second storey, although land for construction is extremely scarce in the village and valley. The house owner admitted to the problem of land scarcity, but would eventually build a new cement block house in his garden.

The overall cost of the retrofitting – very heavy foundation ring beam construction, wall reinforcement with columns and stitching, wall plate ring beam and total roof recovering – is said to amount to about 20% of the value of the building, counting (valuating) all the materials, such as the dressed stone and entire timber column and roof construction. However, it is estimated that the cost of total reconstruction would be equal to retrofitting in both time and expense, plus with stone materials left over due to a lighter wall construction. In addition, a new wall construction with internal BACIP galvanised wire reinforcement (GWR) would support a second storey, thus saving valuable land.

Opinion of the Mission

- Retrofitting traditional houses having strong wooden support columns should consist of lightening, insulating and waterproofing the roof construction; and reconstructing the walls using less material, but with internal wall reinforcement and cement mortar, and applying thermal insulation.

- Retrofitting should include the **entire house** and not only one room. In addition, a seismically retrofitted room should be adequately strong enough to allow the possibility for a future lightweight upper storey. The design of lightweight constructions would be a challenge for BACIP.

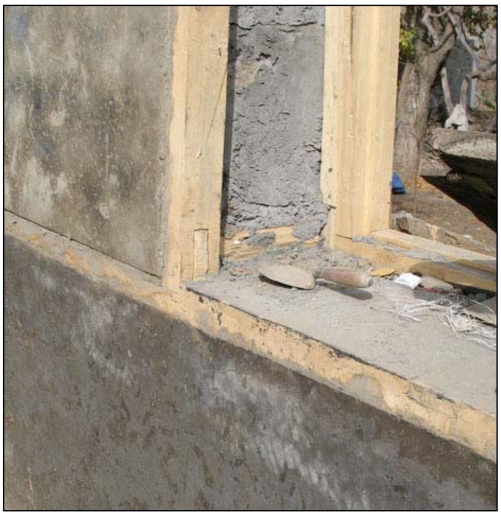
- Local stitching of cracked walls consisting of masoned stone and rubble does not add much to the strength of the wall as a whole, making it a costly exercise that should not be repeated. It is better to frame the entire wall sections as shear walls.

Traditional Pamiri houses have low vulnerability for earthquakes,
but when retrofitting, the roof should be made lighter
and thermal insulation applied, including a roof hatch window.

House 2 – This house was being entirely rebuilt, not retrofitted.

Totally rebuilding this house was based on the very dilapidated condition of the old house. The owner is a retired military man who is physically disabled (advanced rheumatism) and is therefore unable to undertake maintenance himself.

A few vertical reinforcement bars have been placed inside the wall corners and horizontal wooden beams (from the demolished house) were used as tie beams in a 16" masoned stone wall. In the upper part of the wall, a horizontal steel bar reinforcement was used around the corners (picture below, left), but no BACIP-GWR was used in the wall construction. It is unclear why this concrete upper corner and wall reinforcement is not continued throughout the wall, as the additional cost would be minimal. The created continuity in the reinforcement would substantially strengthen the long wall against lateral earthquake forces. The inside wall was plastered with a straw plaster mix with volumes of: 1 cement / 2.5 chopped straw / 10 clay soil, providing a one-inch thick insulating plaster (see photo below, right); a similar plaster was used on the floor.



Left: House 2 – the floor is at the level of the first timber line; entrance door is at the rear.
Right: Insulating plaster layer at the window opening.

The roof will have the same traditional design as in the former house. As with House 1, this new house will be unable to support a second storey of similar construction, according to the site engineer.

Because the retired house owner is unable to walk, he keeps the entrance door open in order to communicate with the outside world; this obviously being a thermal problem during the winter. The newly constructed house will have an insulating floor plaster and an additional layer of PE foam, making it suitable for the floor-bound occupant. Unfortunately, the architect had not considered making the window at sitting level to allow the invalid person to look outside. In addition, access to the house was via a 3-ft. high platform.

Opinion of the Mission

- Timber should not be used for structural wall reinforcement in new houses, especially not when it is supposed to serve as a demonstration house. There is very little binding between timber and stone construction, insufficient timber cross ties are generally applied, the overlapping connections in the corners are weak due to their short length, and the cost of the timber is prohibitively high for people who do not have access to a free timber supply.

- Reconstruction of dilapidated traditional houses is a better option than retrofitting. It is important, however, to take the physical needs of the house owner into consideration in reconstruction, especially if one is physically handicapped or cannot walk.

House 3 – This house was being 90% rebuilt; thus, not a retrofitting activity.

The engineers had maintained the old existing foundation, as well as the 2-ft. high cut stone and rubble masonry plinth on top of it. The foundation was retrofitted with double reinforcement bars. The 2-ft. high plinth was pointed, but still weak in comparison with the addition. On top of this weak plinth, a new very strong cemented stone wall was **entirely rebuilt.** The upper wall had a combination of BACIP-GWR with steel bars inside the wall corners, as well as a fully reinforced concrete wall plate tie beam. The house only missed the roof. The walls, being of strong cement mortar masonry, will substantially increase heat transmission and firewood consumption for the occupants. Wall insulation was not included in the programme.

It was told that the use of BACIP L-shaped cement corner blocks were **not** considered because: "the cement blocks were weaker than the stones; being an incompatible material, it doesn't go together."

The question now arises: why then use masoned cement mortar joints, or in the former house, timber tie beams? Apparently the function of the BACIP L-shaped cement blocks to create the space for the corner reinforcements and allow easy and straight corners was not understood by the implementing architect and engineers, nor the structural relation between cement mortar and granite stone.

The joint is the dividing line between the old foundation and the new stronger masoned upper wall section. The foundation was additionally cement pointed[2].

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Observation

The mission did not agree with the concept of building an excessively strong cement mortar masoned stone wall on top of an old non-reinforced rubble-soil pointed stone plinth; this is building on a weak foundation.

Opinion of the Mission

- Retrofitting should look at the house as a whole and include thermal insulation, especially when the new construction uses a high concentration of cement and will have a substantially higher heat transmission. At least the reconstruction could have considered placing wooden pegs in the wall for future application of wall insulation.

- Double reinforcement (BACIP-GWR throughout the wall <u>and</u> RCC ring beams) is excessive for a ground-floor-only house. As an example for masons, this is an unnecessary expensive practice.

[2] Photo by Architect Ghulam Saeed, assistant to the mission.

Primary School – The next site visited was a Primary School being retrofitted.

Retrofitting schools is an important activity, considering the devastating effect of the Kashmir earthquake where especially government buildings and schools collapsed, causing thousands of deaths.

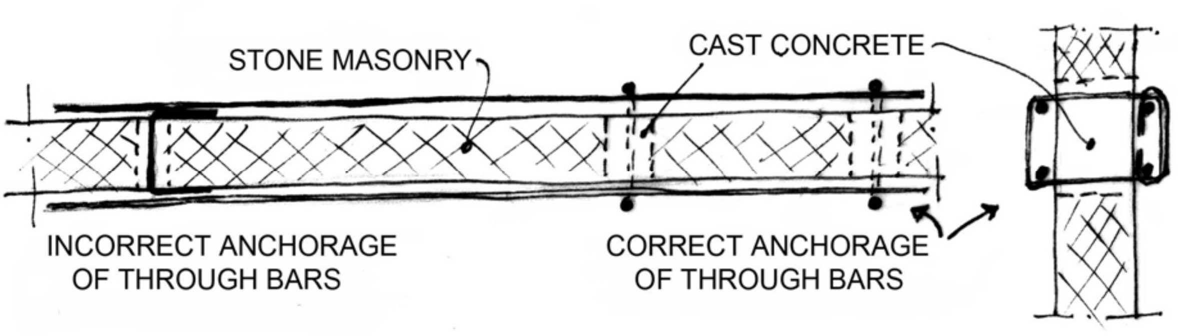
The school retrofitting was executed along the principles developed more than twenty years ago in India, Nepal and other countries. Although some minor errors could be detected, in general terms, the retrofitting will be a structural improvement. It is planned that the school doors will be opening to the outside.

The classroom doors still opening to the inside, obstructing a free escape route in the event of an earthquake.

In retrofitting the school, internal wall reinforcement bands and columns have been connected through the existing wall to external bands and columns at multiple locations. This creates wide structural beams around the perimeter walls and corners; giving great lateral strength and function as tie beams. Although care was taken with the making of the stirrups of these lintel beams, the connections between inside and outside beams were **insufficient in number and without double bar links.** In many cases, only single bars were used for through connections.

As could be observed from the reinforcement details of one of the exterior columns, the lintel strip reinforcement is going inside the vertical reinforcement while these should be fitted around the vertical reinforcements. In addition, in the opinion of the mission, the number of through-the-wall anchoring is insufficient and the single bar with hook inadequate.

The connection between the inside ring beam and outside ring beam is based on only one single bar passing through the wall instead of going back again, making a full loop. The number of through connections between the inner and outer ring beam is rather low. The vertical bars are from the window framing, placed correctly[3].



Seismic retrofitting should be accompanied by thermal retrofitting.
It would be a waste of resources if after seismic retrofitting the schoolchildren are still sitting outside in the winter and summer because the building is, respectively, too cold or too hot.

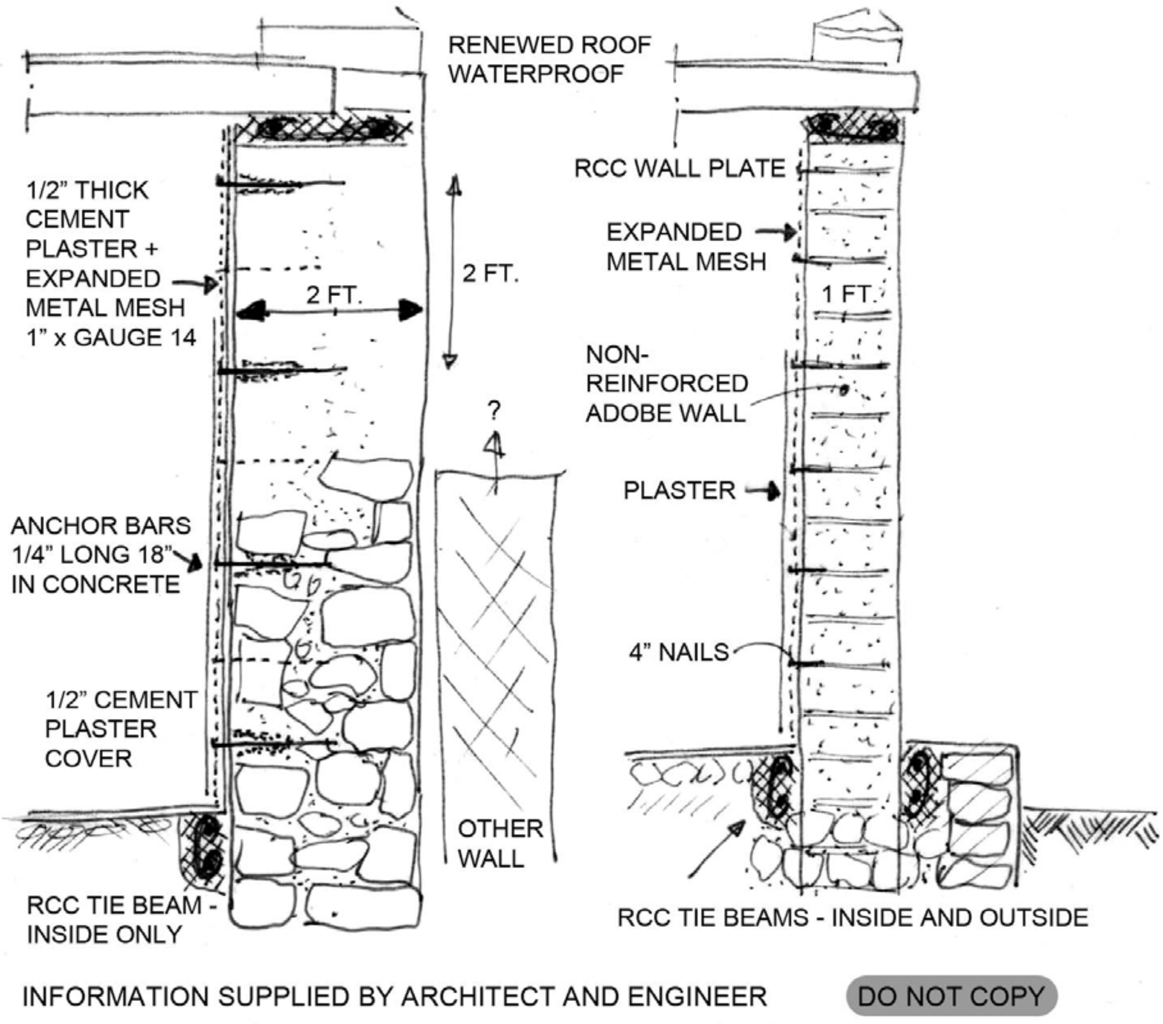
[3] Photo by Architect Ghulam Saeed

House 4 – This was again a retrofitting of the main room.

In this case, the existing massive 2-ft. thick stone and rubble masonry wall of the house, located against the wall of the neighbour, was strengthened only on the inside with an expanded metal mesh. The expanded metal mesh was fixed with 12-18" anchoring pins cemented into the wall and plastered. Anchoring this plastered expanded metal (one inch) to a floor and roof tie beam would supposedly avoid inward collapse of the 2-ft. thick rubble stone masonry wall during an earthquake.

Opinion of the Mission

- Such a construction is not only costly, but strengthening only one face of a weak stone wall does not really add to the strength of the wall to withstand earthquakes, especially not when it is a supporting wall. In the case of a 2-ft. thick rubble stone masonry wall, the **best thing is to totally reconstruct the 20-ton wall** and reconstruct it in a lighter way. The two sketches of House 4 and House 5 (below) are the technical details according to the architect.



Left: This sketch illustrates the technique used to anchor the 2-ft. heavy stone and rubble wall of House 4 where a 1" expanded metal mesh and plaster is placed on one side only. The cemented anchors will only grab onto some of the outer face stones. Because the rubble stone masonry walls are internally loose, it does nothing for the other face.

Right: Sketch of House 5. The anchoring in the adobe wall is even worse. Those anchors hold onto nearly nothing in the adobe or clay bricks.

House 5 – This was a retrofitting of an adobe house, also nearing completion.

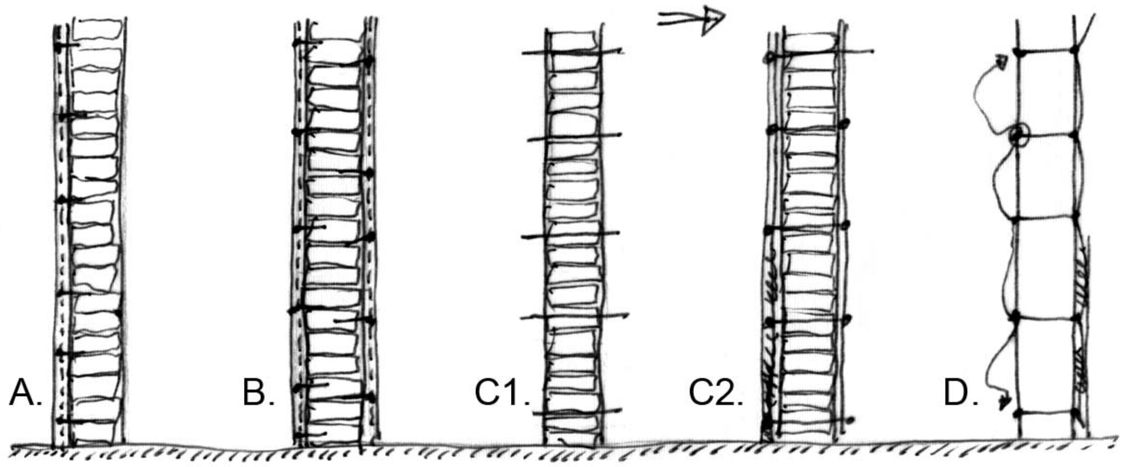
Here a massive foundation reinforcement inside and outside was realised and the roof lightened. A single bar between the foundation and roof will be applied in the four inside corners of the main room and plastered. These bars won't hold up anything if the wall fails. The detailing of this corner solution is surprising because in the school design there were through connections in the corners, creating double and anchored columns; why then not in a weaker adobe house?

View of the massive foundation ring beam of the small one-floor-only adobe house

The proposal for strengthening the inside wall of the house was even more surprising than House 4 because the expanded metal mesh was supposed to be "nailed" into the adobe (see sketch page 9, right). To the opinion of the mission, the money would have been better spent on a thermal wall construction because the current "wall reinforcement" will fold like a sheet of cardboard when the adobe wall fails during an earthquake.

The BACIP-GWR has been especially designed for traditional stone and adobe walls that are not masoned with strong cement mortar. The rolls of wire mesh are available in the region.

Adobe walls should be entirely reconstructed with the GWR instead of applying external "reinforcement".



Sketch A refers to the adobe House 5, one-sided "anchoring". This will easily be pulled out of the clay adobe blocks if the wall bulges to the right.

Sketch B is an "anchoring" on both sides. This will strengthen the wall slightly as a shear wall, but with alternating lateral forces, the anchored plasterwork will immediately peal off from the inside where the wall bulges outside, and vice versa.

Sketches C1 and C2 indicate an improved solution: many 2 mm GI wires are poked through the wall; on each face an expanded metal mesh is fixed to the protruding ends of the wires and the expanded metal mesh plastered. This will reinforce the wall both laterally and as a shear wall.

Sketch D is the option where the wall is newly masoned with horizontal BACIP-GWR, being ½" to 1" wider than the adobe wall. A series of vertical 2 mm GI wire is connected to all horizontal GWRs. This way a GI wire network is created on each face of the adobe wall. Both sides are plastered, causing an intimate contact between the GWR side reinforcement and the wall. This reinforcement provides lateral and shear reinforcement.

The house owner has now been requested to supply timber for a wooden wall plate tie beam, **a cost he possibly cannot afford**. Because this had not yet been realised, the assisting project staff was advised to compare the cost of the wooden wall plate tie beam with the cost of a double BACIP-GWR. Quick calculation indicates that a wooden tie beam would cost Rs. 100/ft. and the GWR only Rs. 26/ft., about one quarter of the wooden solution.

Considering the massive inside and outside foundation ring beam reinforcement; the unnecessary non-seismic wall with expanded metal mesh; the unnecessary and non-functional inside corner bar reinforcement; and the obligation to make a wooden wall plate tie beam instead of using the low-cost GWR reinforcement, makes this adobe house an example of how retrofitting should **not** be undertaken.

Opinion of the Mission

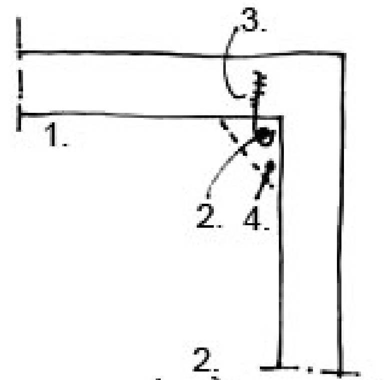
- Based on the excessive work and cost of the foundation ring beam for a ground-floor-only adobe house, as well as the nonsense internal wall reinforcement, **the mission advices to review the technicalities of this kind of retrofitting.**

3. OBSERVATIONS

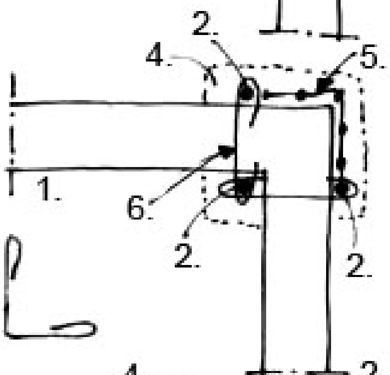
Different Standards

The HRMP exercise appears to work with different standards for houses and schools, presenting house owners with reinforcement designs and costs having little structural value.

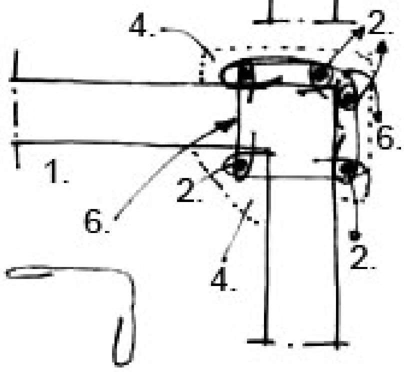
Although the inside-outside linkage of double vertical reinforcement bars has been practiced in the school building retrofitting, the houses visited only had single reinforcement bars in the inside corners. The question arises, why were these single inside reinforcement bars of the houses not linked to outside reinforcement bars, following the well-known design of the school retrofitting. The single inside bar won't hold up anything during an earthquake, but for which the house owner needs to incur substantial expenses.



The top sketch shows the position of the vertical reinforcement in Houses 1, 4 and 5.
The single bar (2) is supposedly anchored between the foundation ring beam and wall plate ring beam, and possibly nailed (3) to the wall (1).
The inside corner bar is then plastered (4).
This solution does not provide sufficient anchorage of the bar, with the effect that the bar will pop loose from the wall during an earthquake.



The second sketch shows a suitable minimum design.
The inside bar (2) is linked to the outside bars (2) in two directions (6). L-shaped bars can be used.
The two vertical outside bars are linked around the corner with a strong wire mesh (5), and the reinforcements are covered with strong cement mortar plaster (4).
For vertical wall reinforcement, columns need to be formed by linking the inside and outside bars.



The third sketch shows the solution as planned for the school retrofitting with double inside and outside vertical bars.
Compared with sketch two, additional bars are placed in the outside corner (2) and all linked to each other (6). L-shaped stirrups can be used.
The reinforcements are covered with strong cement mortar plaster, indicated by the dotted lines (4).

While all the house owners were supposed to make a substantial contribution in finances (building materials and/or unskilled labour), such a condition was not applied for the retrofitting of the government school. Instead, the school board only promised to retrofit a smaller school building "later".

Documentation
The 2009 and 2010 continuation of the HRMP suggests that extensive awareness raising will be the main activity. Although the school building and all houses were nearing completion in the next two weeks, apparently **no video record** or systematically planned photographs were taken to provide professional work documentation for future education and dissemination of the technology, planning of a poster exhibition or the like. Bringing people to a finished product does not adequately explain to them how the retrofitting was done as the reinforcement work is hidden.

Supervision of Mason Work
Although the house and school retrofitting exercise was partly done to educate local masons on the structural technology of reinforcement, there was inadequate supervision in overseeing that the steel reinforcement was correctly applied in all its aspects. This would suggest to the masons that these details are not important. It has been shown worldwide in the failure of structures that the difference between damage and collapse are often in the proper execution (or not) of the reinforcement details.

Training and Awareness
The HRMP is providing on-the-job training for 6 masons/carpenters in 12 villages (total 72) on the technologies described above and suggests that autonomous replication will take place.

This mission considers a number of the applied “retrofitting” technologies inappropriate for the types of house constructions visited. The total reconstruction of House 2 is the best solution, although the HRMP reconstruction team did not consider the use of BACIP-GWR as wall reinforcement.

Although the two years 2009 and 2010 are supposed to be dissemination years of the programme, it was unclear how the currently applied building practice would be included. It is felt that the current mix of good and wrong retrofitting designs, coupled with the costly and unnecessary non-retrofitting practices demonstrated, **is not a proper basis for training, nor for replication.**

Although the HRMP documentation provided indicated that most victims of past earthquakes perished in the collapse of poor building constructions, the planned awareness and training programme did not consider a major role of BACIP in either construction training or the use of the BACIP galvanised wire reinforcement (GWR). Precise control of the steel bar reinforcement of the school retrofitting was not done, providing a deficient training example.

4. COMMENTS

About the house retrofitting and full reconstruction of the houses, a lot can be said, but in short:

- **General:** Retrofitting of ground-floor-only traditional semi-dressed stone and rubble houses or adobe houses will most likely not be replicated by the villagers because they will not want to incur the expenses. Villagers would most probably rather build a new house. In doing so, they can use the same building materials for stone foundations and timber roofing, but with thinner walls and earthquake reinforcement. In this context, the demonstration is wasted.

- The notion that retrofitting with a cost of 20% of the total building cost would be preferable is incorrect. If the whole house would be rebuilt, it would also cost about 20% because the value of the materials is estimated rather high (by HRMP). Time wise, it makes no difference between rebuilding and retrofitting.

- Not retrofitting to allow a **second storey** is a **lost opportunity,** considering the scarcity of land and high population growth. Reconstructing a house would provide the opportunity to plan a future second storey, being a special advantage considering the land scarcity. The cost of land needs to be considered in the overall picture.

- A very essential point of earthquake retrofitting is to make the **whole construction lighter**. Only the roofs of the five houses were made lighter. Fixing up very heavy stone and rubble walls (or adobe walls) with only one-sided expanded metal mesh is a waste of resources and involves a technology a village mason should not replicate.

- In the event the house owner does not have large quantities of timber available for wall or wall plate reinforcement, the BACIP-GWR is only **1/4 of the cost** and easier to apply.

- Strengthening ground-floor-only houses by mainly making a very heavy and strong foundation tie beam does not add much to the safety of the house if the upper house is not integrally reinforced. In the case of the adobe house, it is **a waste of resources.**

- The retrofitting of the houses took only one ("living") room into consideration and not the house as a whole. In one case, not connecting the retrofitted room to the rest of the house leaves the occupants in danger as the family spends more time in the other rooms than the retrofitted room.

- If the retrofitting was supposed to provide a training example to 72 craftsmen, they have partly been mislead. In the case of the school retrofitting, non-precise workmanship in the reinforcement bar placement was observed; **not a good training example**.

- Retrofitting a house for 90%, but leaving a weak section above the old foundation is not a good idea. Additionally strengthening that foundation does not make sense.

- Retrofitting of traditional houses should **primarily** consist of lightening the roofs, including thermal insulation and waterproofing, and **secondarily** of reconstructing the outside walls with cement mortar and reinforcement, and adding thermal insulation.

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