RECONSTRUCTING RURAL STONE HOUSES IN NEPAL AFTER THE 2015 EARTHQUAKES

REPORT FOR Catherine Forbes in response to her questions on how to rebuild houses in the Gorkha District, which was near the epicenter of the April 25 2015 earthquake.

By Randolph Langenbach, May 16, 2015
www.conservationtech.com & www.traditional-is-modern.net

Based upon my review of the pictures of the areas Catherine Forbes has asked me about, and having read her list of "Issues," the following report presents my initial thoughts on the situation. From the photos of the construction, it seems that the collapses were wide spread, and sometimes entire villages were leveled.

Destroyed rubble stone houses. (web)

The construction generally is of a mixture of rubble stone and partially dressed stones. Some of what looks like a river rock rubble (meaning rounded from erosion by water flow) has been used in the gables. While the roofs originally may have been covered with stone – probably thin shale or slates, now most of the roofs are of corrugated metal sheets.

The most pressing question now presented, after the devastation left by the earthquake and the homelessness of a large part of the population, is what to do to 'build back better," while still honoring and respecting the skills of the local population to rebuild their houses themselves - preferably out of the locally available materials as close to the traditional way as possible, while still making them more resilient. In fact, most likely the owners do not want to rebuild exactly what was now proven to be so lethally vulnerable. Thus, helping them to fix this problem is really of necessity – simply to get them resettled indoors.

Destroyed house in Gorkha District. (web)

The Problem: In Catherine's May 15 list of "Issues" (see below) she makes clear what some of the basic requirements are – namely, that people must be able to build their own houses out of the local stone, mud, and timber – with the stone and timber most likely coming from the ruins of their pre-earthquake home. Moreover, she states that the timber is not available in long lengths – and presumably the available pieces are needed for the roof and attic floor, or 2nd floor if there will be a two story house.

Collapsed house showing horizontally bedded rubble stone construction in Gorkha District. (web)

I can see that the school shown being constructed in photos by Prem K. Khatry that Catherine sent is being done with a degree of masonry expertise, and that the walls consist of flat stones that are roughly dressed (the term "dressed" (in stone masonry 'dressed' means tooled and shaped so that the stone can be properly bedded in horizontal layers or 'courses'). The mortar appears to be clay without added lime

(and thankfully, no Portland cement). The walls appear to have rubble cores between the inside and outside wythes (vertical layer or 'leaf' one stone thick). Since the stones are variable in length and width, it is not clear whether there are specific bond courses or not. The roof appears to be open rafters without an attic floor, with galvanized steel sheets.

A Proposed Solution: Looking at Catherine's list of "Issues," two comments caught my attention:

1) Fencing wire is available in long coils– make their own wire mesh for fencing.
2) Rock was placed in wire cages for footings – Gabion type wall to allow water to drain through – not traditional construction.

This leads me to propose a solution that may be remarkably, even deceptively, simple, inexpensive, and not requiring sophisticated engineering or construction training. I will only describe it briefly here – so as to open the conversation before further elaboration and development of graphics to show how it would be done.

This solution is both consistent with the observations and proposals described in my Sunday, May 10, 2015 email, in which I describe the efficacy of timber bands (ring beams). My proposal here, however, recognizes the lack of availability of material for properly crafted timber ring beams. Instead, I believe we could achieve the same effect by doing the following:

Photos by Prem K. Khatry of school construction in Gorkha district.

At designated points in the vertical height of the wall, a single course of stone will be entirely wrapped in galvanized wire – such as the same as Catherine describes is used for wire fences (it must be galvanized, of course). Stainless steel would be even better, but practicality demands that the wire be galvanized.

If durable wire is not easily obtained, an alternative material that may even last longer and be equally effective (but which may require more NGO work to set up a distribution network) is polypropylene geogrids – the kind of product used for earth stabilization in road building, etc. More on this later, but I have now seen that it has been used for the banding of stone buildings in China as reported in the EERI World Housing Encyclopedia tutorial on Stone Masonry construction.

The basic objective is to turn these individual stone courses into the bands (ring beams) as I have described on May 10th as made of timber. These bands would be overlapped in the corners and extend around the building, and be placed in any stone masonry interior crosswalls as well. In effect, to try to visualize what I mean, imagine each of these ring beams of wire-enclosed stone as being long thin gabion baskets, which run continuously without a break around the entire dwelling, only terminating where they overlap at the corners (to overlap, the band on

Photos from web of gabion basket retaining wall (above). The photo below shows how inconspicuous the wires can be if the basketing is of only a single layer of stone.

one intersecting wall would be set one course below the band on the other wall.)

Within each floor of the dwelling, there would be a band at the base above the foundation, but below the floor level of the ground floor. About one meter up from that would be a band at the window sill level. This band is the only one that will not be continuous, as it must be interrupted by the doorways. Above that, is a band just above the window lintels, and then at the level of the first floor (2nd floor to us in North America) or at the roof level for one story houses, there is a band just below the roof structure or below the joists which hold the floor. If the house is two stories, then an additional band is to be located just above the joists, so that the joists are sandwiched between bands.

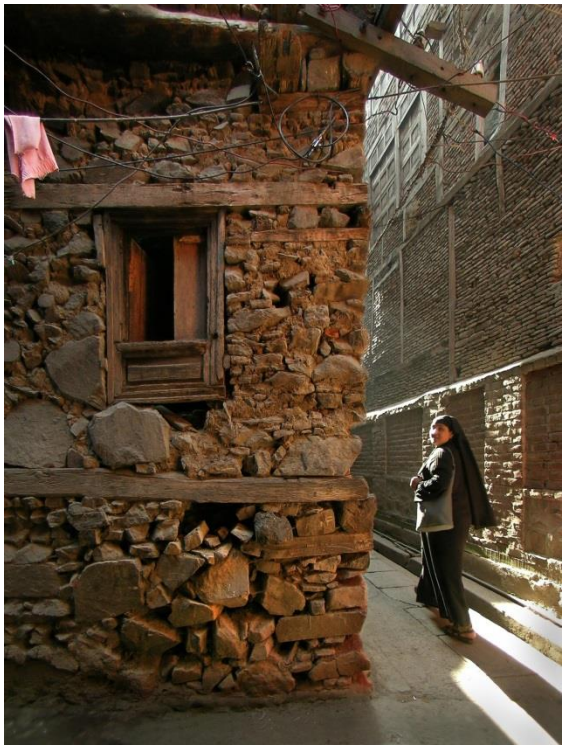
The Construction Sequence: One may think that the proposed system will be complicated to build and require extensive training, but in my mind it should be quite simple. The only material that is added to the construction is the wire described by Caroline as used for wire mesh fencing. The only tools that should be needed are a pair of plyers, and a pair of wire snips.

The process would go as follows: (1) At the level of a band, one would simply unroll the fencing wire along the partially completed stone wall, overlapping it if the role runs out and pieces must be joined together. (2) Bend it down on either side of the wall to get it out of the way to carry on the masonry work on the wall. (3) Add one more course (single layer) of stone masonry following the same craftsmanship and mortar as one has done already, (4) Bend the wire up and over this new layer of masonry, with the wire from one side overlapping the wire fencing from the other so that that one layer is inside a tube of wire tightly drawn together. Short pieces of wire can be used to tie the two sides together where they overlap with a simple twist, and to tie the gabion bands together at the corners where they overlap. (5) Then, carry on until the next band with the stone masonry work.

The advantages of this system: One may now ask why not instead use the wire and stucco jacketing as is proposed in the paper by Hima Shrestha, *et al.* below.

(http://www.iitk.ac.in/nicee/wcee/article/WCEE2012_2012.pdf)

1) There are a number of advantages of this proposed system. The jacketing is designed to improve existing buildings, while this is designed to be integrated into the construction of new ones.
2) Neither the costly materials for the stucco layer, nor the time and skill is needed to apply it.
3) If the 'gabion' bands are done with wire fencing that has a reasonably open pattern, the bands will be inconspicuous, and the overall appearance of the dwelling will be as before, but they will still be



Historic house in Sringar, Kashmir showing timber bands in rubble stone construction. (Photo by author)

A 19th century timber-laced rubble stone fort in Northern Pakistan near epicenter of 2005 earthquake that killed 89,000 people. It survived with very little damage despite having been abandoned and unmaintained for half a century! (Photo by author)

visible enough to demonstrate to the owners and their guests that the building is seismically safe. Also, if there is breakage or deterioration of the band, it will be visible, and can be addressed as a maintenance item.

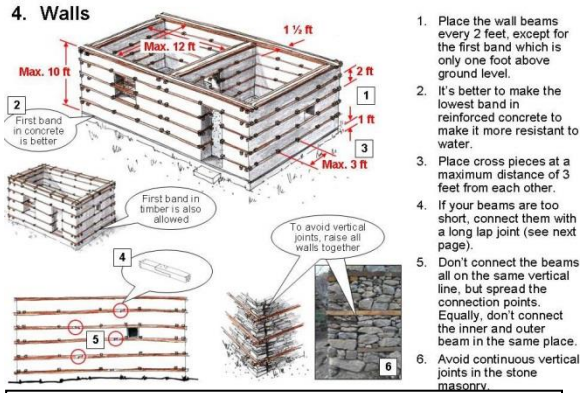
4) The stone masonry gabion bands are flexible, and of the same nature as the material into which they are place – such that there is material compatibility – something which cannot be said of reinforced concrete ring beams.

One point needs to be reiterated. If one thinks that because the stone gabion band is good, then a reinforced concrete band is better, I say NO, this is not true. In the 70's and 80's, reinforced concrete ring beams in stone buildings – particularly in Italy – were accepted practice – but subsequent earthquakes have repeatedly proven that this was a bad idea. Because of their rigidity, when an earthquake caused the stone wall above and below to vibrate and undulate, the rigid band separated from the stones and even sometimes walked out of the structure, carrying away everything that was above it.

The gabion bands may also out-perform the full wire jacketing of the building as is proposed for retrofitting because they are more flexible, and there is nothing to crack. And yet, they should be effective in holding the buildings together in the event of a large earthquake.

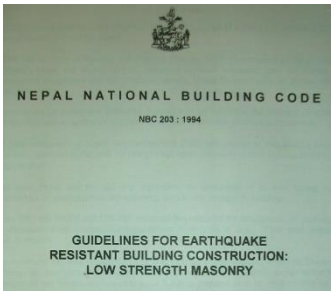
The gabion stone bands will remain with the wall as it undulates and vibrates, and if some stones below should come loose and fall, it serves to stop the progress of the cracks, and to bend and thus remain bearing upon the stonework of the remaining wall, which is essential to damp out the vibrations and keep the masonry under compression so as to resist the lateral forces.

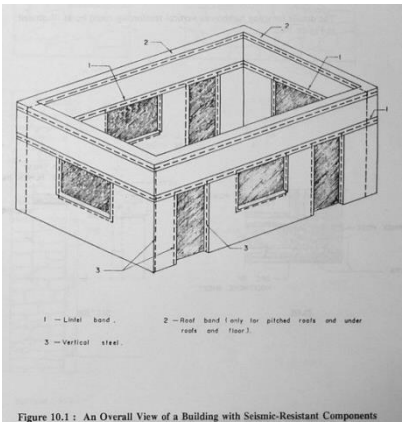
I hope this is enough information to begin to develop a way to make earthquake-safe houses using mainly traditional materials and handicrafts in the rural villages. I look forward to hearing the thoughts and contributions of others in reply.

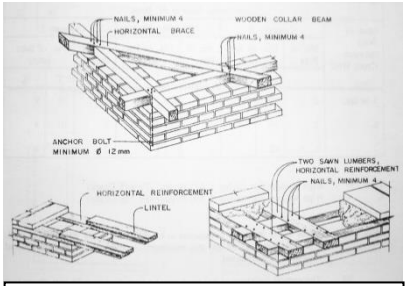


Page from manual for timber-laced construction produced for the Government of Pakistan after 2005 earthquake for when they approved this timber-laced construction for new buildings. The gabion bands proposed here are intended to work the same way. (Manual by Tom Schacher of SDC)

Example of new building being constructed with timber bands in Pakistan after the 2005 earthquake. The gabion bands proposed here would lay into the wall and overlap in a similar way. (Photo by Tom Schacher)







The Nepal National Building Codes 202+203+204 for Bearing-Wall Masonry, Low Strength Masonry and for Earthen Construction all feature bands either of timber, bamboo or steel for seismic resistance.

APPENDIX

GORKHA DISTRICT PRELIMINARY BRIEFING – ISSUES

Catherine Forbes, 15 May 2015

Building skills and materials

People build their own houses – not professional builders
Use the materials readily available – stone, mud, timber
Stone shaped and bedded with mud, sometimes dry stone
Timber is becoming a scarce resource
Deforestation is an issue in Nepal
Forestry committee in each village determines what timber can be used
Local timber is a hardwood, but not as hard as used in Australia (F17); not available in long straight lengths
Fencing wire is available in long coils– make their own wire mesh for fencing
Only building left standing in one village was the school for which I have sent photos of its construction
Rock was placed in wire cages for footings – Gambon type wall to allow water to drain through – not traditional construction

Geological and hydrological conditions

The rock is close to the surface and outcrops – very hard (possibly basalt?) – we need geological input
Lot of natural springs commonly located at rock outcrops
Building on very steep slopes – terraced in parts

Climatic Conditions

Monsoons June to September
High likelihood of landslides over monsoon period
Area not easily accessible during monsoons – 2 to 4 hour walk off road in dry season – up hill
Can't really build until after the monsoons – October

Social / cultural conditions – observations from an Australian perspective
People have no money to buy new materials or tools
Women do most of the building work (particularly laboring), but are not included in meetings to make decisions
I have been told that men talk, but don't usually get very involved in carrying out the work (this may be an overstatement to some extent, but was definitely common in the Solomon Islands).
Women are much more in tune with village needs, identifying who is most vulnerable, who controls what, etc

Historical Context

This area was where the Maoist uprising occurred and is therefore not supported politically.

Training
If training is to be done on a real building site, it would need to be for a communal building that everyone benefits from – cannot show favoritism or benefit to one family by working on a house.
Women must be involved in training – but may not be available when training is on as they are also responsible for collecting fuel and water, cooking, cleaning, child care, care of the sick and elderly, etc – therefore, training would need to be at a time and place they could attend.
People will walk up to 6 hours to attend training (experience with teacher training program)

Schools – Sambhav Nepal
One school building survived (the most recently completed) – all others and most houses collapsed or severely damaged
Sambhav Nepal is the only NGO operating in the Gorka District – locally based, supported financially by Rotary and clients of Ace the Himalaya trekking business – focus on education
Sambhav goal to rebuild main primary school and high school
Smaller schools will not be rebuilt at this stage – therefore, children in remote areas will not be going to school