

# STONE MASONRY IN CLAY MORTAR with GABION BANDS

# Submittal

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26 November, 2015

# GABION BANDS

Alternative to timber bands for masonry in mud mortar

A report submitted to the Nepal DUDBC by Randolph Langenbach, Conservationtech Consulting, [www.conservationtech.com](http://www.conservationtech.com)

This proposal is not for a single house type, but is rather a simple modification of what is already permitted in the Nepal National Building Code (NBC) in response to following criteria: First, the geography of Nepal makes access to industrially produced heavy construction materials such as concrete and steel prohibitively expensive and difficult or impossible to deliver to many of the rural mountainside sites in the country. Second, there is a profound need to provide a technology for the safe reconstruction of owner-built rubble stone houses that is not dependent on high quality timber in areas where timber has been depleted or is too costly for many families to afford. The system proposed here, which has been invented and named “**Gabion Bands**” by Randolph Langenbach of Conservationtech Consulting, is intended to be an alternative means to meet the provisions of the National Building Code, but with a substitution of wire mesh (or polypropylene geogrid mesh) instead of the timber or reinforced concrete that are shown in the NBC for bands (ring beams) in the masonry walls of code compliant buildings.

By unique circumstance, this concept was refined and demonstrated in the construction of a house in the hillside village of Mankhu, in Dhading District. This opportunity to demonstrate the system arose when the proposal came to the attention of Liesl Clark of Skydoor Films, who was making a science documentary film for the USA Public WGBH-TV program “NOVA.” The Gabion Band concept, and this very first house incorporating it in rural Nepal, is illustrated in this submittal.

The advantages of this system are potentially profound. Since it does not require the use of any Portland cement, sand or rebar in the construction, but rather, only requires the use of a much lighter galvanized welded wire mesh (or polypropylene geo-mesh), the weight of the materials to be carried to the site as well as the cost are far less than for any construction which requires reinforced concrete. It is also lighter and more affordable than using timber for horizontal bands.

This Gabion Band proposal is built on a fundamental philosophical point that construction in the mountainous rural regions of Nepal must be based on the use of the local materials of recycled stone and timber with newly dug local clay mud from the site itself, with nothing added that cannot be hand carried to the site or loaded onto a pack animal. A cement concrete ring beam cannot be said to conform to this criteria in any respect.

A longer explanation of the Gabion Bands and the background history can be found at:

[www.traditional-is-modern.net/nepal.html](http://www.traditional-is-modern.net/nepal.html).

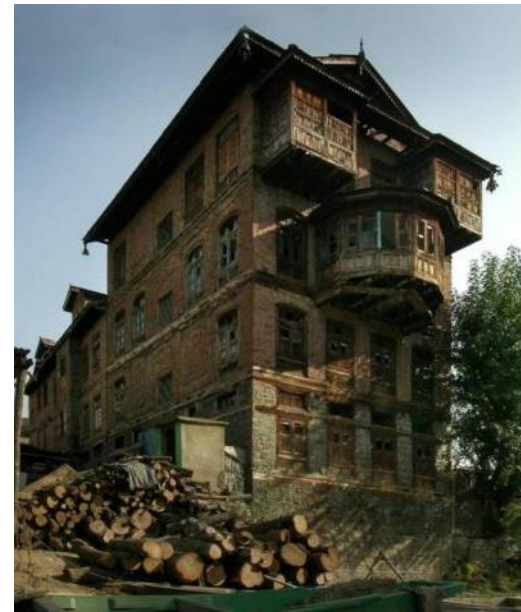
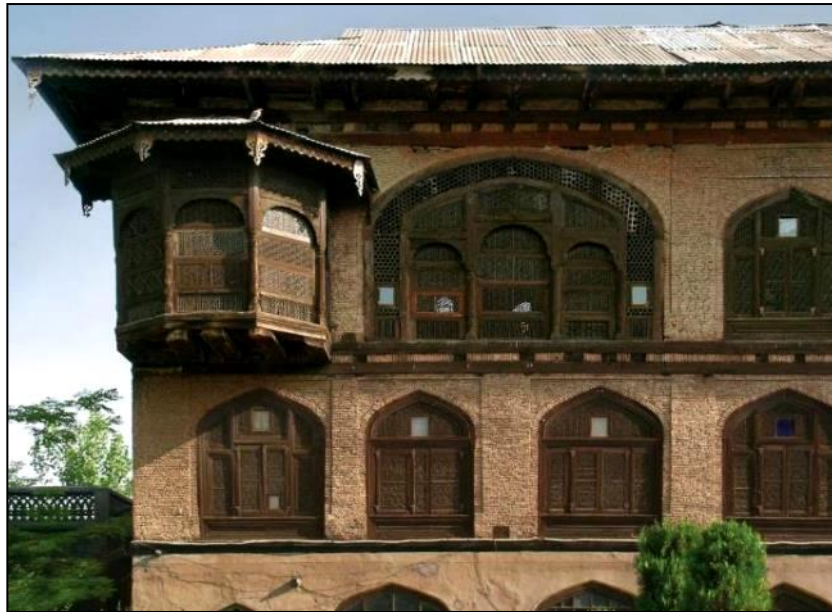


Above shows a roll of wire mesh for Gabion Bands being carried. Only about 2.5 rolls were needed for the house shown in this report. This can be compared with carrying of cement, sand and rebar for concrete, as is shown below. (Photos by Randolph Langenbach)



Nepal Housing Reconstruction Programme	TYPE OF HOUSE:	GABION BAND submitted proposal	SCALE:	None	DATE:	26/11/2015	3
	DRAWING TITLE:	Ramesh Hardwares in Kathmandu	DESIGNED BY:	Randolph Langenbach (USA)			

RUBBLE STONE MASONRY IN MUD MORTAR with “GABION BANDS” [submittal by Conservatiotech Consulting]



This idea for the use of galvanized welded wire mesh was conceived of in response to the April 25th Gorkha, Nepal Earthquake. It is based on over 30 years of research on the history and effectiveness of the use of timber lacing in bearing-wall masonry construction in Kashmir, Turkey, and other parts of the world. These systems have repeatedly proven to be effective in reducing the risk of collapse in both historical and recent earthquakes.

The kind of timber bands in Kashmir illustrated here are already recognized in the Nepal National Building Codes.

The photos on the left and center are of Srinagar, Kashmir, India showing historic buildings reinforced with horizontal timbers. The one in the center is over four stories in height. It has no vertical reinforcing, but has survived a number of earthquakes, as has the one on the left, which is known to have been constructed in the 1820s.

The photo on the right shows a nineteenth century fort in Northern Pakistan that survived the 2005 Kashmir earthquake with little damage. That earthquake killed over 80,000 people - almost ten times the losses in 2015 in Nepal. Most of the casualties in Pakistan in 2005 were in concrete buildings. (Photos by Randolph Langenbach)

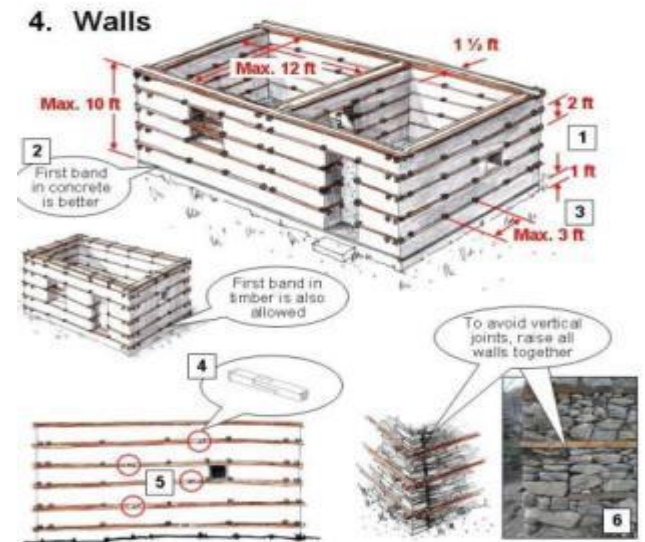
Nepal Housing Reconstruction Programme	TYPE OF HOUSE:	GABION BAND submitted proposal	SCALE:	None	DATE:	26/11/2015	4
	DRAWING TITLE:	Pakistan and Indian Kashmir	DESIGNED BY:	Randolph Langenbach (USA)			

RUBBLE STONE MASONRY IN MUD MORTAR with "GABION BANDS" [submittal by Conservatiotech Consulting]



The timber lacing seen in the buildings on the previous page is laid in the wall and tied through the walls like that visible in the photo on the upper left. The middle photo shows a full-size model of this system, used for the training of masons conducted under the auspices of the Government of Pakistan after their approval of this system, known as *bhatar*. On the right is new *bhatar* construction in Pakistan. After approval of this system (and of *dhajji*), there are close to a quarter of a million new houses constructed using these technologies.

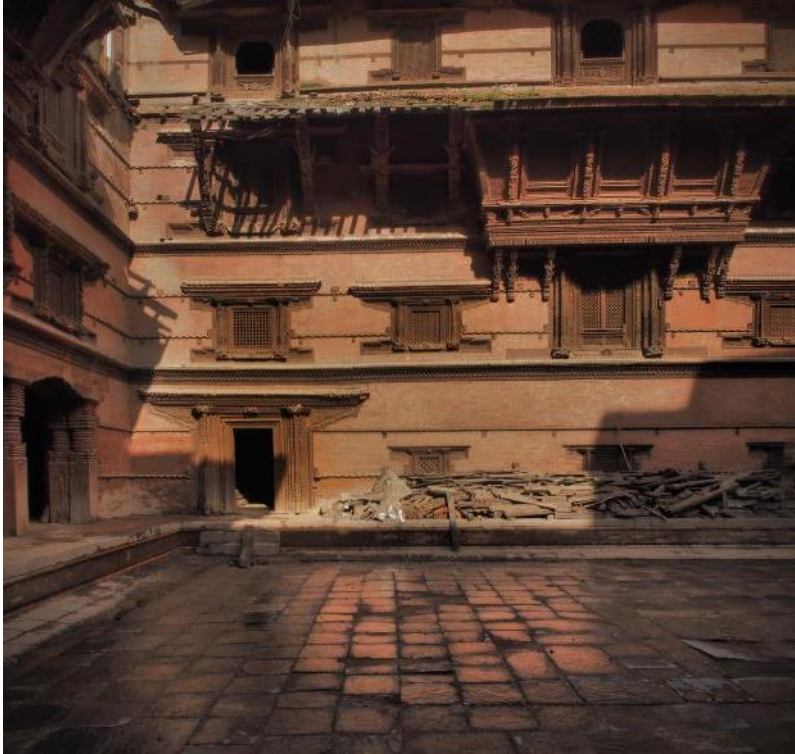
**Right:** From manual for timber-laced construction produced for the Government of Pakistan after 2005 earthquake when they approved this timber-laced construction for new buildings. The gabion bands proposed here are intended to work the same way. (Manual and photos in center and right by Tom Schacher of SDC). Left photo by Randolph Langenbach)



Nepal Housing  
Reconstruction Programme

TYPE OF HOUSE: GABION BAND submitted proposal  
DRAWING TITLE: Pakistan and Indian Kashmir

SCALE: None  
DATE: 26/11/2015  
DESIGNED BY: Randolph Langenbach (USA)



### KATHMANDU

Although less common than in Kashmir, the use of timber bands has been found to exist in the older of Kathmandu's heritage structures. The 2015 earthquakes have proven their effectiveness.

Except for the losses of the very tops of some of the towers, the much older sections of the Hanuman Dhoka Palace with the bands survived in good condition. As can be seen in the photo on the lower left, the earthquake caused the plaster to break off revealing the band underneath. This proves that the wall experienced stress and deformation and thus, the bands prevented what would have been significantly more damage or collapses.



On the left, the 18<sup>th</sup> century section of the Hanuman Dhoka Palace has horizontal timber bands, visible on the exterior and behind plaster on the interior. Those wings with these bands survived the recent earthquake in much better condition than did the much newer 20<sup>th</sup> century wing seen above that did not have timber reinforcements. (Photos by Randolph Langenbach)



**DEMONSTRATION HOUSE PROJECT, Sunar Farm, Mankhu, Dhading District**

**BUILDERS:** 2 masons and 6 family members worked on the project. Guidance and oversight was provided by Randolph Langenbach, assisted by native Nepalese, Lakpa Sherpa and Dipendra Gautam, recent graduates in the fields of environmental science and Civil Engineering.

**TIME:** The one room house shell was completed in 4 days to the level shown. The roof structure was still to be finished, and the roof shown was put on for temporary protection.

**COST:** The added cost for the galvanized welded wire mesh for the Gabion Bands (purchased in Kathmandu) was only about 15,000 NPR (Approximately \$150 USD). Purchase of hand tools to cut and shape the wire mesh came to about 3,00 NPR (\$30). The stone and the clay for the walls was available at the site from the collapsed house. No Portland Cement concrete was used. The GCI roofing sheets were purchased in the village at the base of the mountain. (Photos by Randolph Langenbach)



Nepal Housing Reconstruction Programme	TYPE OF HOUSE:	GABION BAND submitted proposal	SCALE:	None	DATE:	23/11/2015	7
	DRAWING TITLE:	Gabion Band demonstration project		DESIGNED BY:	Randolph Langenbach (USA)		

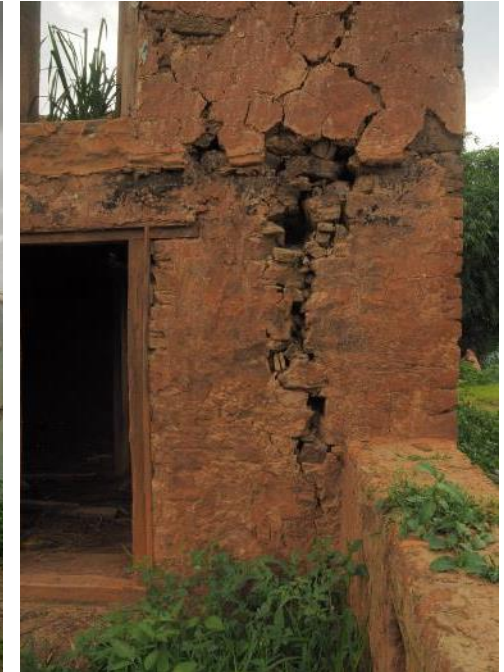
# STONE MASONRY IN CLAY MORTAR with GABION BANDS

Technical Details

**Masonry Bond:** The damage in many of the high mountain villages was nearly total, while in lower areas and further from the most intense vibrations, partially damaged houses reveal the most common reasons for the vulnerability of the stone structures. When rubble stone is used with mud mortar for masonry walls, to obtain smooth surfaces, the undressed stones must be laid parallel to the inside and outside walls. Rarely are stones even available that can serve as “through-stones” as specified in NBC-202 for a bonded “random rubble masonry” wall.

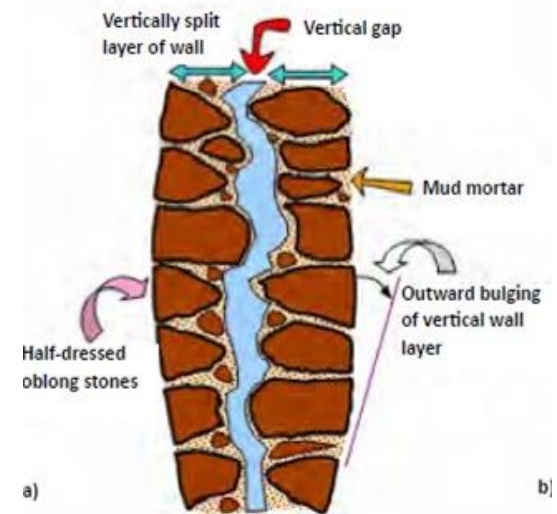
Thus most often rural stone construction lacks bond stones to hold the two leafs together, leaving nothing to prevent the wall from bursting as clay and rubble is shaken down between the inner and outer leafs.

Gabion Bands are designed to address this in a way that is most compatible with weak and uneven stone construction.



The above photos show the ruins of the main house at the Sunar Farm. This wall shows evidence that the collapse of the wall resulted from the separation of the inside and outside leafs and the spreading of the stones at the corners.

The image on the right is from **A Tutorial: Improving the Seismic Performance of Stone Masonry Buildings** by Jitendra Bothara & Svetlana Brzev, EERI World Housing Encyclopedia, 2011. (Jitendra Bothara is from Nepal.) (Photos by Randolph Langenbach)



Nepal Housing  
Reconstruction Programme

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SCALE: None

DATE: 26/11/2015

DRAWING TITLE: Rural rubble-stone masonry in Nepal

DESIGNED BY: Randolph Langenbach (USA)



**Strong Corners:** The onset of damage leading to collapse in earthquakes is often at the corners where the in-plane and out-of-plane motion coincide. The Gabion Band technology is particularly resistant to this kind of damage because, with very little training, masons understand the value of wrapping the wire mesh from each wall over one another to form a very strongly reinforced corner with each band.



**Left:** Photo of damaged masonry house in village next to Mankh showing characteristic example of separation of the walls in the corners – a frequent precursor to total collapse of the buildings. **Above:** View of the Gabion Band wrapping of a corner designed to avoid the kind of common failure shown on the left. (Photos by Randolph Langenbach)

Nepal Housing  
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SCALE: None

DATE: 26/11/2015

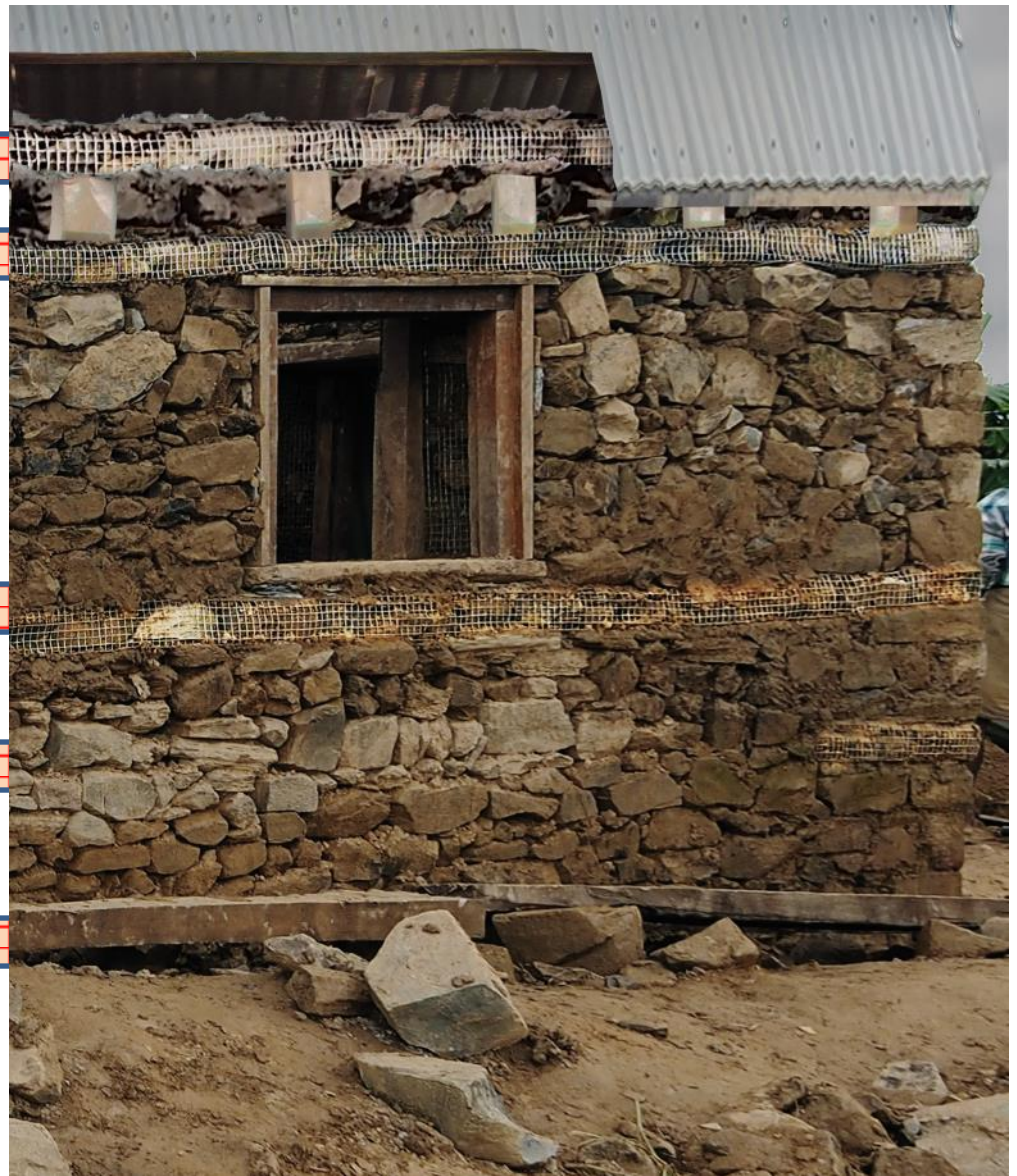
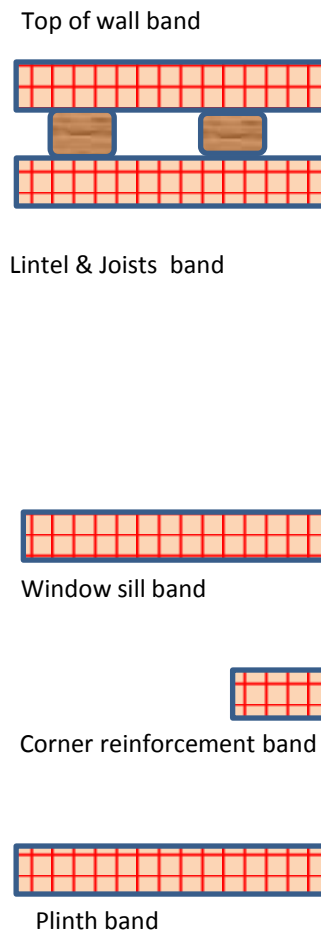
DRAWING TITLE: Rural rubble-stone masonry in Nepal

DESIGNED BY: Randolph Langenbach (USA)

**Gabion Bands layout:** The photo on the right shows the side of the constructed house with Photoshop used to show the parts not yet constructed, but which are important for the structure. The attic floor (or roof truss bottom cords) are shown penetrating the masonry wall and locked between two Gabion Bands for a diaphragm connection to secure the top of the wall. See NBC-201: 10.6.

The Gabion Bands are deliberately constructed by wrapping only a single course of masonry. This is done so that they maintain their constructed shape even when stressed by an earthquake.

In the region where this house was constructed it is customary to plaster the exteriors and interiors with a clay plaster. One may also choose to plaster just the bands, taking advantage of the mesh as a strong lath. (If Polypropylene geomesh is used for the bands, it must be plastered to protect it from the sun.)



**Half walls at Attic Level:** Not shown in the demonstration house, but which is structurally consistent with Gabion Bands, is the addition of short walls at the attic level-as shown in SMM-1.1 in DUDBC Catalogue. With an additional band at the top, this extra masonry increases the seismic resistance of the walls below by providing overburden weight above the attic floor diaphragm.



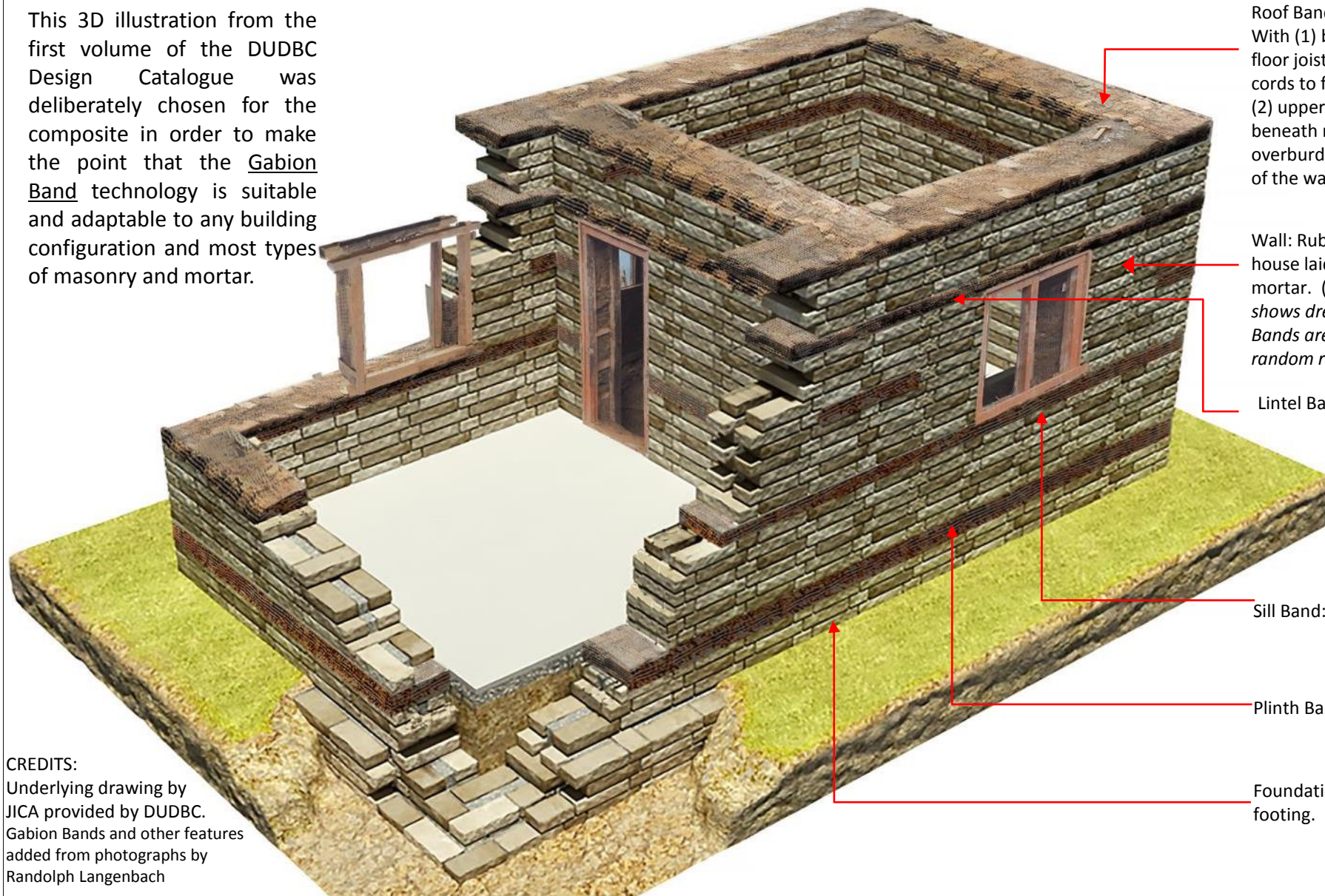
Above: Interior of attic of Nepal Family house in Mankhu showing the masonry walls extending up above the attic floor – which is also shown on the right in the DUDBC design for “Stone Masonry with Mud Mortar SMM-1.1. The Nepal Family house suffered very little damage in the earthquake.

**On the next page,** you will find a 3D image showing the location of Gabion Bands in a stone masonry house. This illustration used as its source an illustration from the DUDBC Design Catalogue.

Nepal Housing Reconstruction Programme	TYPE OF HOUSE:	GABION BAND submitted proposal	SCALE:	None	DATE:	26/11/2015	12
	DRAWING TITLE:		DESIGNED BY:	Randolph Langenbach (USA)			

# RUBBLE STONE MSONRY IN MUD MORTAR with "GABION BANDS" [submittal]

This 3D illustration from the first volume of the DUDBC Design Catalogue was deliberately chosen for the composite in order to make the point that the Gabion Band technology is suitable and adaptable to any building configuration and most types of masonry and mortar.



Roof Band: Double "Gabion Band" With (1) bottom band secured to attic floor joists or to roof truss bottom cords to form diaphragm connection & (2) upper band [not shown] laid beneath roof rafters to provide overburden weight and secure the top of the wall.

Wall: Rubble stone salvaged from prior house laid in locally obtained clay mud mortar. (NOTE: This DUDBC drawing shows dressed stone, but Gabion Bands are particularly well suited for random rubble in mud mortar.)

Lintel Band: "Gabion Band"

Sill Band: "Gabion Band"

Plinth Band: "Gabion Band"

Foundation: Stone masonry spread footing. (Cement mortar not required.)

CREDITS:  
Underlying drawing by JICA provided by DUDBC.  
Gabion Bands and other features added from photographs by Randolph Langenbach

## Technology for Earthquake Resistant Building Construction - Using "Gabion Bands" (Galvanized Welded Wire Mesh or Polypropylene Geogrids)

Nepal Housing Reconstruction Programme	TYPE OF HOUSE:	GABION BAND submitted proposal	SCALE:	None	DATE:	23/11/2015	Gabion Bands <sup>13</sup>
	DRAWING TITLE:	TECHNICAL DETAIL 1 (SEISMIC ELEMENTS)	DESIGNED BY:	Randolph Langenbach (USA)			

# STONE MASONRY IN CLAY MORTAR with GABION BANDS

Construction  
Sequence

**Construction Sequence:** The following drawings and photographs are designed to show the sequence of steps for the laying, folding and tying of the Gabion Bands. A short 6 minute video can also be watched which shows clips filmed during the construction of the demonstration house in Mankhu. That can be found at:

[www.traditional-is-modern.net/nepal.html](http://www.traditional-is-modern.net/nepal.html)

**Vertical Reinforcement:** No vertical reinforcement is shown in this proposal. The reasons for this are explained on pages 59-61 in Section 3.6.2 in **Don't Tear It Down, Preserving the Earthquake Resistant Vernacular Architecture of Kashmir** by Randolph Langenbach, Published in 2009 by UNESCO New Delhi. This explanation has been excerpted and placed for free public access on the web at the following URL:

[www.traditional-is-modern.net/vertical-reinforcement.pdf](http://www.traditional-is-modern.net/vertical-reinforcement.pdf)

Where this section cites the Indian Building Code, please note that the Nepal National Building Codes include the same requirements. This includes NBC-202 which recognizes random rubble masonry in mud mortar as legal construction. The reasons for this non-recognition of the vertical reinforcement are too long to include here, but are fully explained at the website link above.



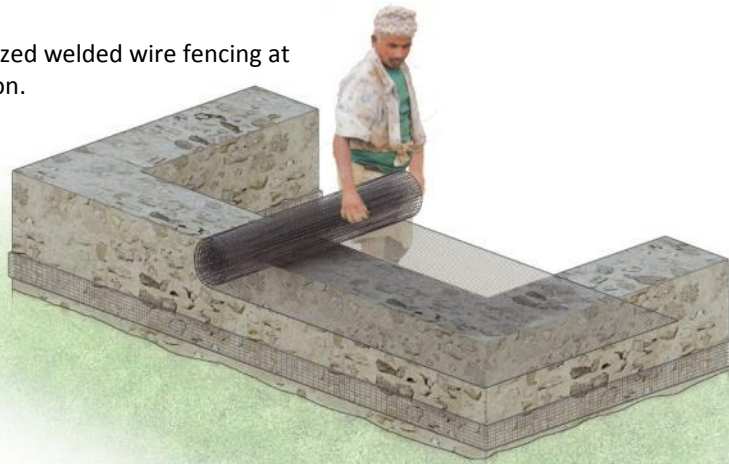
A view of the ruin in the site of the demonstration house on the Sunar Farm, in Mankhu. This was photographed the day before work was started at the site. The construction process to the point shown on page 7 was completed in four days.

Nepal Housing Reconstruction Programme	TYPE OF HOUSE:	GABION BAND submitted proposal	SCALE:	None	DATE:	26/11/2015	15
	DRAWING TITLE:		DESIGNED BY:	Randolph Langenbach (USA)			

# RUBBLE STONE MASONRY IN MUD MORTAR with "GABION BANDS" [submittal by Conservationtech Consulting]

1) Construct masonry wall with bond stones, and otherwise in usual manner with clay mortar.

2) Roll out galvanized welded wire fencing at designated location.



3) Trim the ends so that the sides and ends can be wrapped over the next single course of stone.

4) The wire bands overlap at the corners of the building.



Nepal Housing  
Reconstruction Programme

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SCALE: None

DATE: 23/11/2015

DRAWING TITLE: Gabion Band construction sequence

DESIGNED BY: Randolph Langenbach (USA)

# RUBBLE STONE MASONRY IN MUD MORTAR with "GABION BANDS" [submittal by Conservationtech Consulting]

5) Proceed to construct the next single course of stonework. It is important to build no more than a single course of stonework to be wrapped in the band.



6) Then wrap this stone course with the wire using galvanized wire to tie it tightly over the stone, such that the bands that intersect are overlapped and wire tied together.



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7) Then proceed to continue to build the masonry wall until the previously determined location of the next band.

8) Finish the bands with a protective layer of whitewashed clay plaster. If available, use lime to stabilize the clay plaster.



The computer drawings are by Ian Kaplan based on hand drawings by Randolph Langenbach. The figures of the workmen are from Langenbach's photos of the project in Mankhu showing the masons and Sunar family members who constructed the house.

Photos in this report by Randolph Langenbach are copyright © 2015

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DESIGNED BY: Randolph Langenbach (USA)