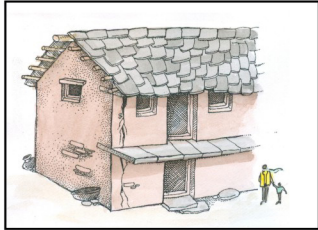
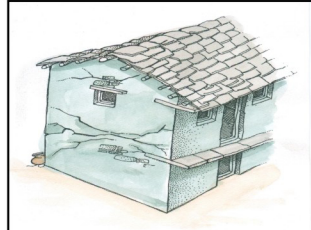


# Restoring Damaged Buildings in Nepal

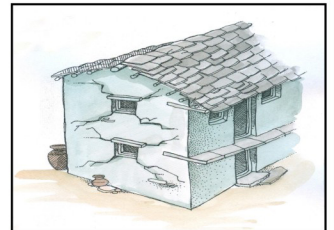
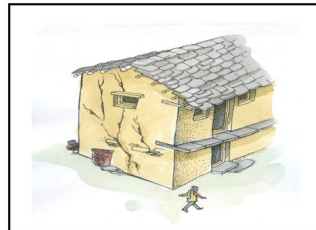
Earthquake shaking causes tension in masonry wall. Since masonry is weak in tension it gets damaged. This ranges from very fine cracks to wider and deeper cracks, partial collapse and finally, total collapse.



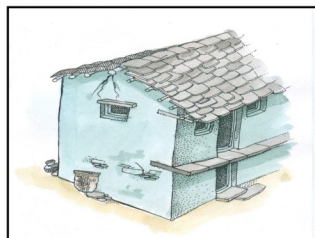
Vertical cracks at room corners and in middle of long or tall walls



Diagonal cracks in walls and from corners of opening



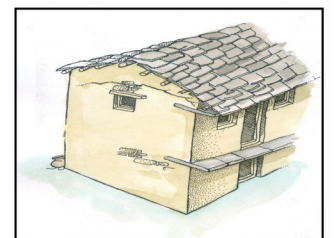
Horizontal crack at gable base



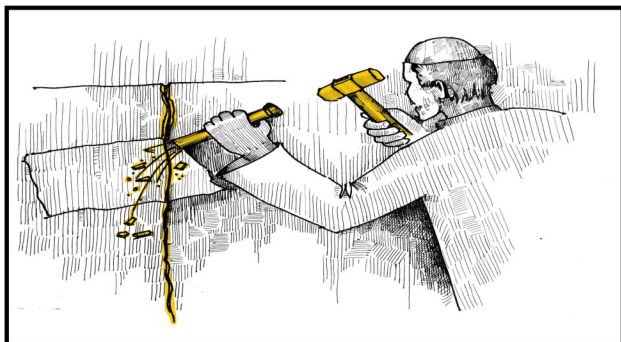
Cracks at floor and ridge beam support

## Severity of damage

- Grade G-1 : Thin Hairline crack in plaster
- Grade G-2 : Structural Crack up to 5mm (1/4") wide
- Grade G-3 : Structural crack 6mm to 10mm (1/4" to 1/2") wide

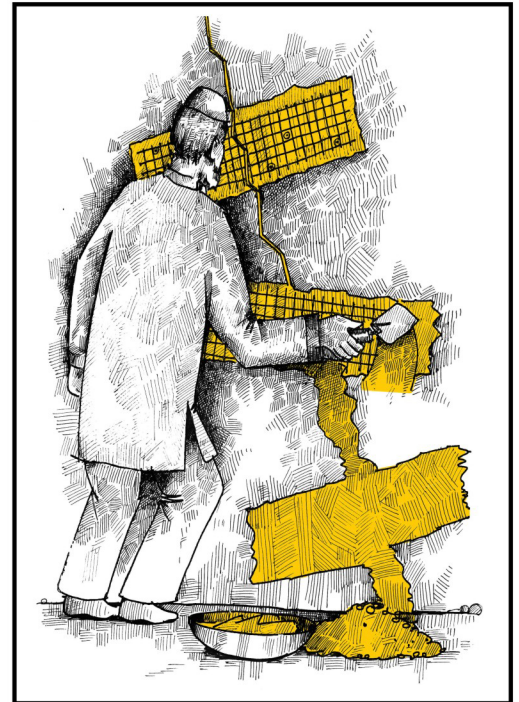
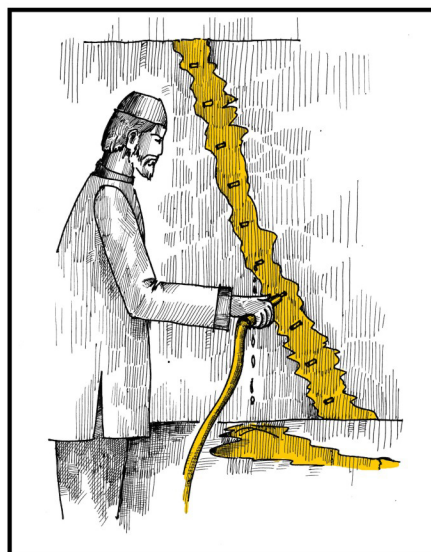


## Restoration Procedures for Different Grade Damage



Grade G-1: Sealing cracks (1) Make a 'V' notch along the crack, (2) seal it with mortar.

Grade G-2 & G-3 : Sealing & Grouting crack  
 (1) Make a 'V' notch along the crack & install nipples. (2) Seal crack with cement mortar. (3) Through nipples grout the crack with cement slurry.



Grade G-3 : Sealing and Splicing cracks (1) Make a 'V' notch along the crack and seal it with cement mortar. (2) Install galvanized iron welded wire mesh across the crack. (3) Apply cement plaster over mesh.

All restored structures should be retrofitted to reduce risk of future earthquake

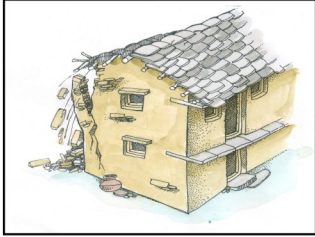


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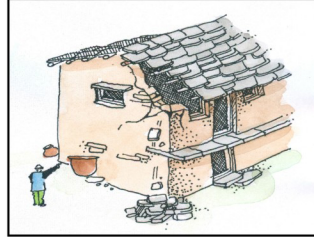
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# Restoring Damaged Buildings in Nepal

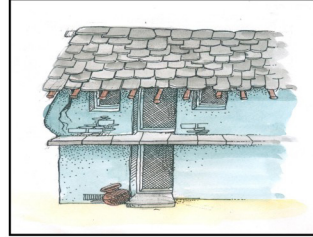
When shaking increases the crack widens and a part of the wall adjacent to crack goes out of plumb, and thicker walls of stone and bricks start bulging. Eventually part of the wall can delaminate or collapse if the shaking continues.



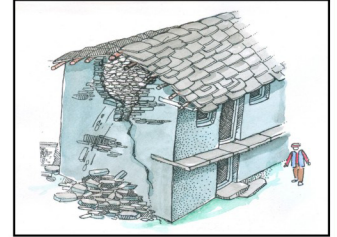
Walls out of plumb



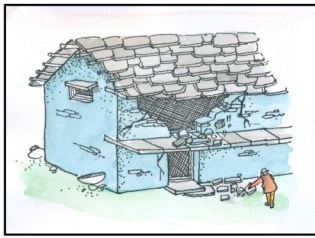
Collapse in corners



Bulging of Thick Walls



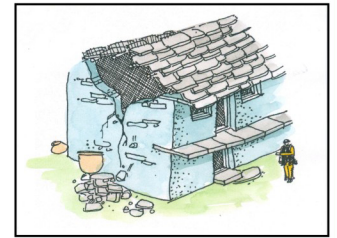
Delamination of portion of wall



Collapse at middle portion of long or tall walls

## Severity of damage

Grade G-4 : Cracks wider than 10mm ( $\frac{1}{2}$ " ), out of plumb wall, partially collapsed wall including gable wall, and bulged or delaminated wall.

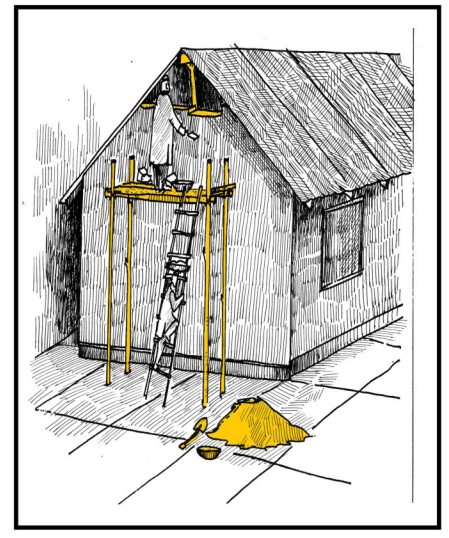
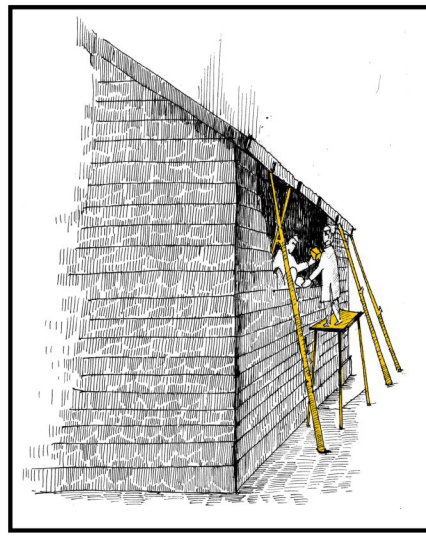
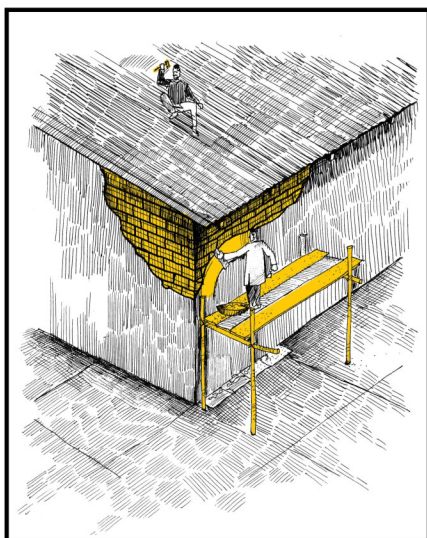


Collapse in Gable wall

## Restoration Procedures

### Grade G-4 : Reconstruction of Damaged Wall

1. Support the roof or the floor above the damaged portion of wall.
2. Remove that portion of wall in stepped manner.
3. Rebuild it using same as that used in existing construction or better mortar following all basic rules of good construction.

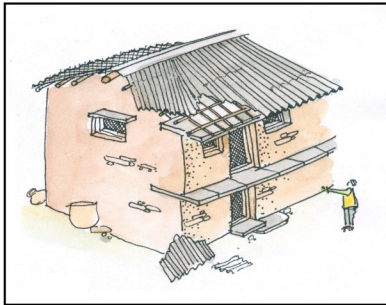


Severely damaged walls supporting an undamaged roof is dismantled by most. But such houses can be restored without dismantling the roof using method described above.

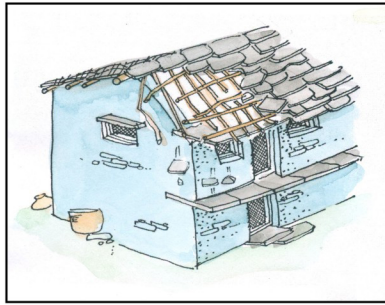
All restored structures should be retrofitted to reduce risk of future earthquake

# Restoring Damaged Buildings in Nepal

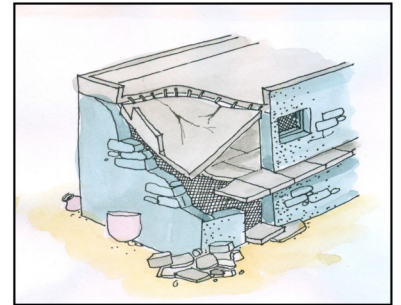
When earthquake shakes the structure, the movements cause damage in support walls. This leads to damage in roof.



**CGI Roof Damaged**  
This requires no special skills or knowhow.

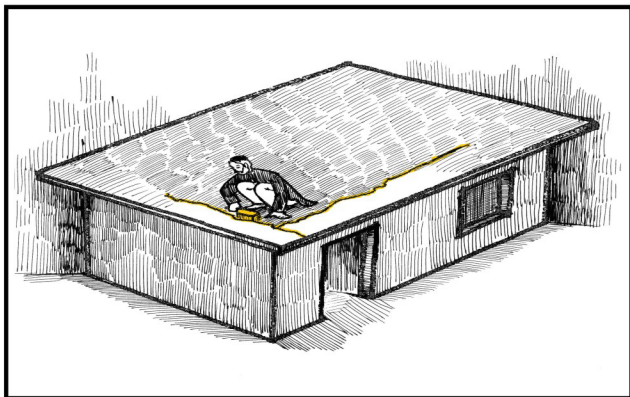


**Stone/slate Roof Damaged**  
This requires no special skills or knowhow.

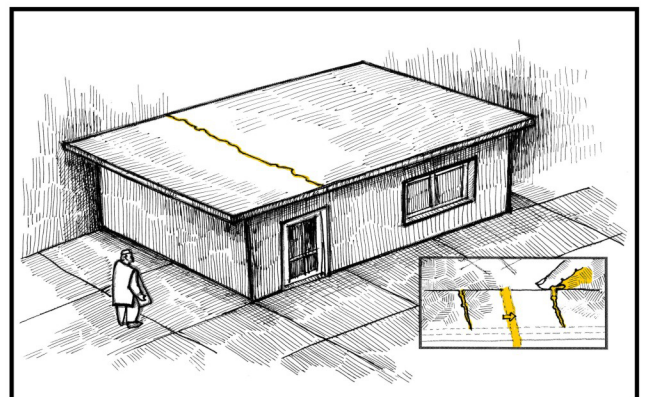


**Collapse of a part of RCC roof**

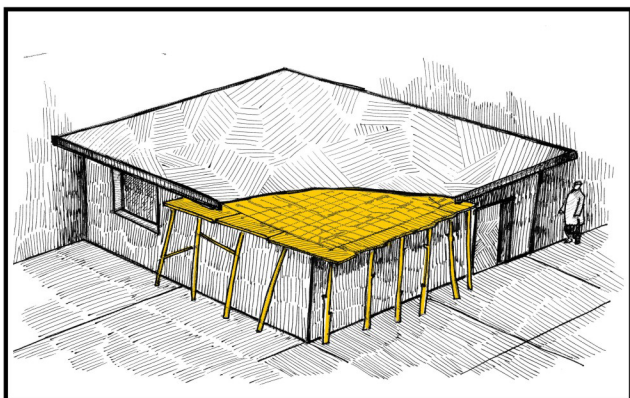
## Restoration of damaged roof



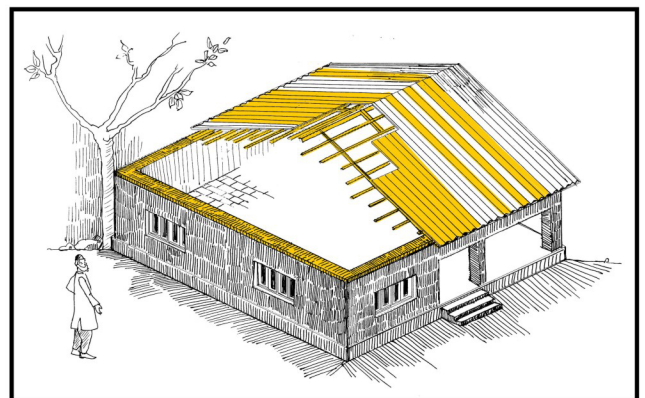
**Restoration of hairline crack in RCC roof :**  
(1) Fill crack with cement slurry. (2) Keep it wet for 15 days.



**Restoration of moderate crack in RCC roof :**  
(1) Widen the crack with chiesel. (2) Seal it with M-seal. (3) Remove excess sealant.



**Restoration of Partially Collapsed RCC Roof:**  
(1) Remove collapsed portion of slab including bars. (2) Expose bars near the collapse in undamaged portion of slab. (3) Attach new bars and cast the slab.



**Restoration of CGI Roof :**  
(1) Remove the damaged sheets and timber. (2) Install new timber elements or restore damaged ones by splicing. (3) Install new purlins or repair damaged one, replace CGI sheet.

**Retrofit the restored structure to reduce the risk of future earthquake**

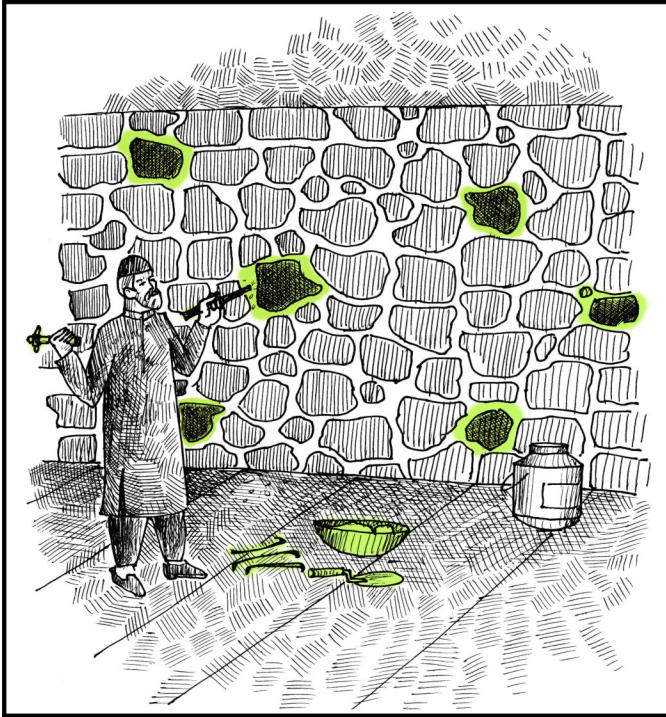


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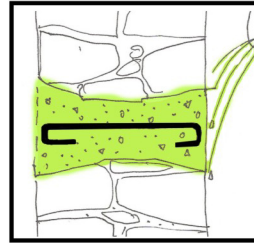
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# Retrofitting Damaged Buildings in Nepal

Earthquake shaking in most thick walls such as stone masonry initiates the wythes separation and eventually results in to collapse due to inadequate interlocking between stones, and absence of through stones. Such delamination can be prevented by installing **RC bond elements** in the existing walls.



## How to install reinforced concrete Bond-element in stone wall?:

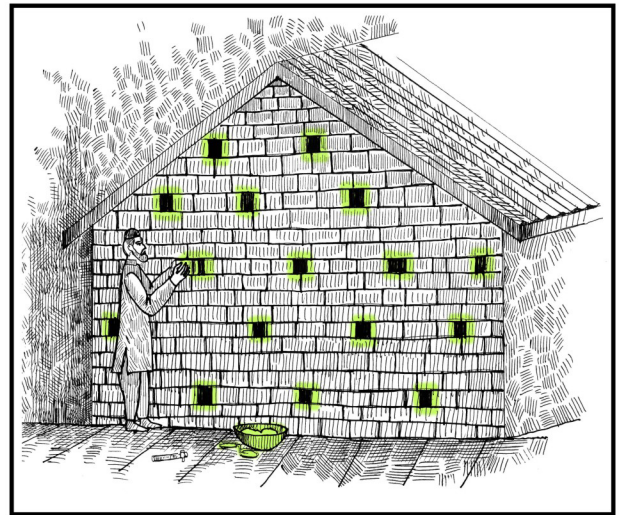
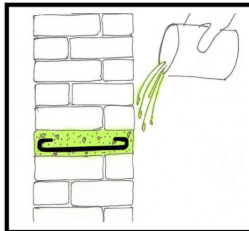


- (1) Make a dumbbell shaped through hole carefully. (2) Install 8mm TOR bar and encase it well in concrete while filling up hole fully with low shrink concrete. (3) Cure for at least a week. (4) Install one such element in every 0.7 sq.m. (7sq.ft.)

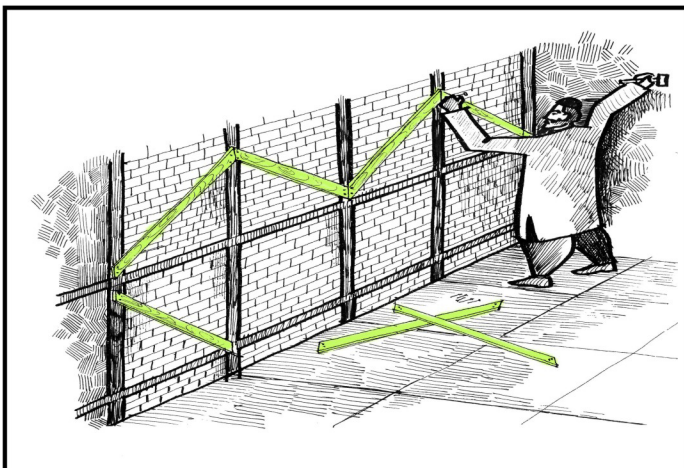
Note : Do not make more than 6 holes at a time in a single wall, and fill them up with concrete on the same day.

## How to install reinforced concrete Bond-element in thick brick walls?

- (1) Make 35mm dia. hole in case of cement mortar. In case of mud mortar simply remove a header and part of stretcher. (2) Place 8mm dia. MS bar in the hole and fill low shrink micro concrete of 1:1.5:3 proportions. (3) Cure for at least a week (4) Install one such element in every 0.7 sq. M.



Earthquake shaking causes cracking and dislodging of bricks in Dhajji Diwari. This can be prevented by installing diagonal bracing



## How to install diagonal bracings in Dhajji Diwari ?

- (1) Install diagonal timber planks on the face of wall panels bound by horizontal and vertical timber elements. (2) Use a minimum of two nails at each end with pre-drilled holes. (3) The connection between the vertical posts and the top and bottom elements may be improved with MS flat bars.

**All structures, damaged or not, should be retrofitted**

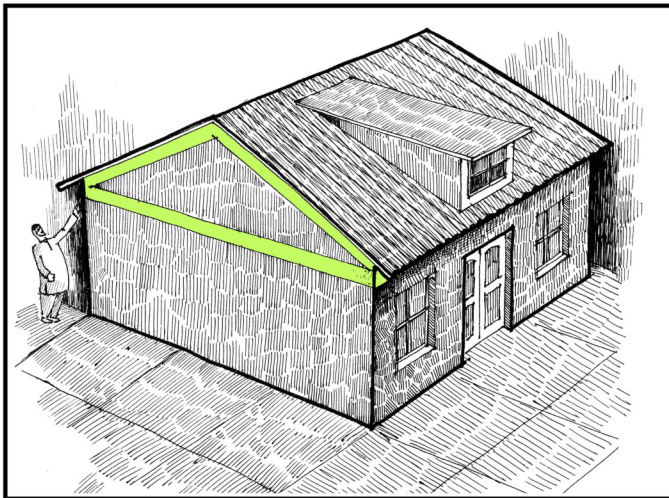


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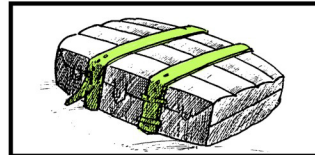
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# Retrofitting Damaged Buildings in Nepal

Earthquake shaking in load bearing masonry walls causes different types of cracks because walls are weak in tension. Such cracking can be prevented by Installing Seismic Belt.



## How does seismic belt work?

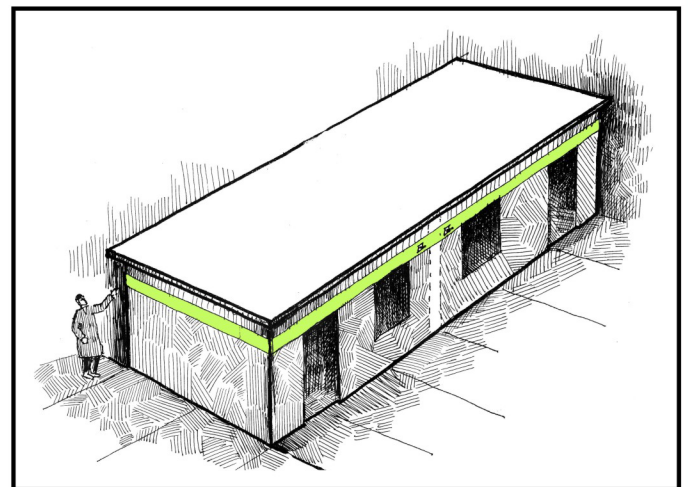


Like a string tied around a box the belt binds all walls together.

## Where should be installed?

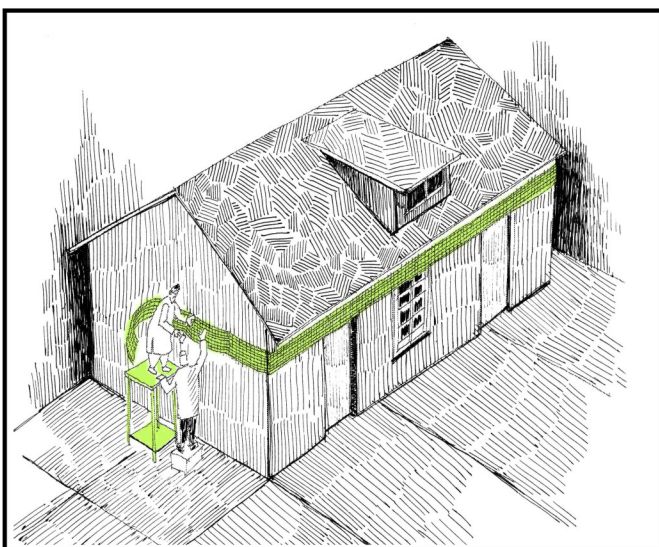
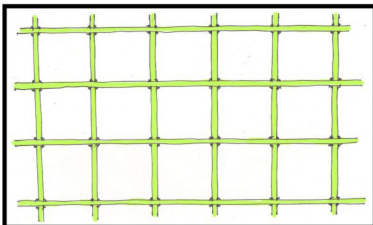
Un-interrupted seismic belts are to be provided on all walls (a) just below eave level of pitched roof, b) just above lintels of doors and windows, (c) just below wooden floor level (d) just below the sloping top edge of gable walls.

**It should be installed on both faces for walls longer than 5mm**



## How to make Seismic Belt ?

Belt consist of **galvanized welded wire mesh** either **6 wires of G13 250mm wide plus 3 - 6mm dia. MS bars** or **10 wires of G10 mesh 250mm wide** fully encased in cement plaster or micro-concrete.



## How to install Seismic Belt ?

In order to ensure satisfactory bond with wall (1)Remove plaster from the wall and rake all mortar joints well, (2) Clean surface with wire brush and splash water on it, (3) Use nails with washer to anchor the reinforcement, (4) In stone wall tie it to bent end of bar extending from RC bond element, (5) Cover it in two coats of cement plaster, (6) Ensure minimum 16mm (0.63") cover over the reinforcement, and (7) Cure plaster for 15 days.

**All structures, damaged or not, should be retrofitted**

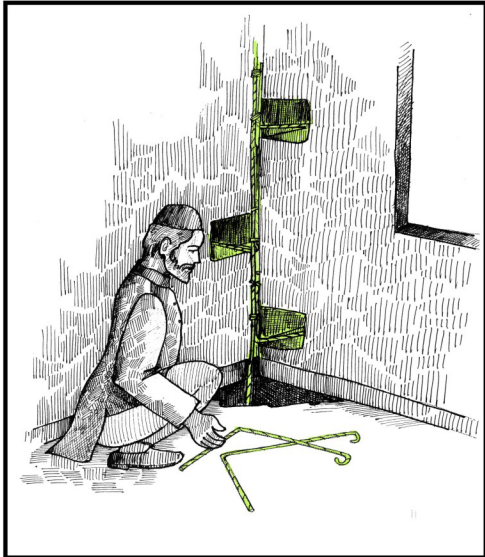


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# Retrofitting Damaged Buildings in Nepal

Earthquake shaking in most masonry walls results in to horizontal cracks as well as sliding of roof with respect to the lower story, due to inadequate bonding between walls, between storeys, and between walls and roof. This can be prevented by installing **Vertical Reinforcement** in existing structure.



## Options:

- \* Single reinforcing bar at each location
- \* Vertical Seismic Belt

## Where should it be installed?

- \* At all junctions of walls.
- \* At "T" junction on side only in case of single bar
- \* On the exterior face in case of mesh
- \* In all stories maintaining continuity between storeys with adequate overlap



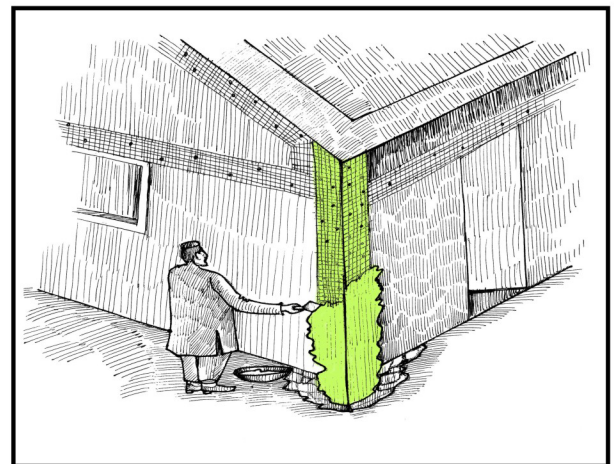
## How to install Vertical Bar in a corner?

(1) Adjacent to each corner remove the plaster and rake mortar joints, (2) Clean the surface with wire brush and splashed water, (3) Place bar in position 38mm (1.5") away from either wall, (4) Anchor it at base in concrete and to wall by tying it to bent end of bar extending from RC bond elements installed in corners, (5) Where the roof is of RC slab, connect the top end of vertical bar to slab reinforcement with adequate overlap, (6) Encase bar with a minimum of 15mm cover of micro concrete all around, (7) Cure all the concrete work for 15 days.

## How to install Vertical Seismic Belt?

In order to ensure satisfactory bond with wall-

(1) Remove plaster adjacent to corner and rake mortar joints, (2) Clean surface with wire brush and water, (3) Use nails with washer to anchor mesh, (4) Cover it in two coats of cement plaster, (5) Cure plaster for 15 days



All structures, damaged or not, should be retrofitted



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# Retrofitting Damaged Buildings in Nepal

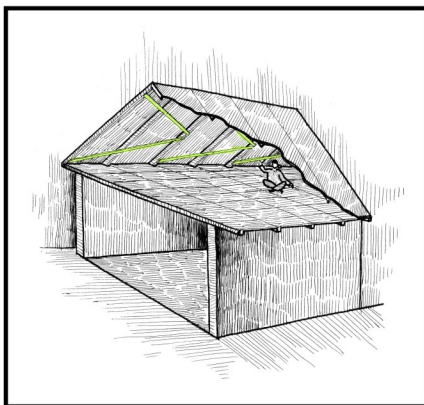
Earthquake shaking causes diagonal corner cracks at openings in walls. Such cracking can be prevented by **encasing opening** with **Seismic Belts**



## How to encase opening?

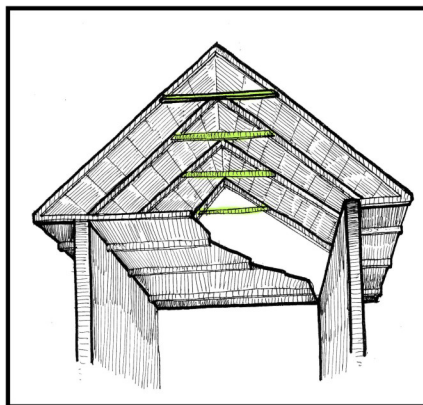
(1) Install 280mm wide Seismic Encasement Belt all around the opening reinforced with weld mesh and bars similar to lintel/eave level seismic belts, (2) Ensure overlap at corners and also with the lintel level belt.

Earthquake shaking can deform the CGI roof, which result into damage to roof and walls. Such damage can be prevented by installing Diagonal Bracings and Struts on underside of rafters.



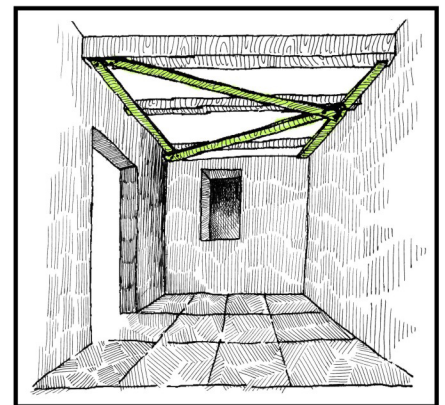
## How to install bracings & struts in roof?

Install pre-drilled timber planks for struts and bracings at underside of two successive rafters using minimum 2 bolts at each connection.



## How to improve roof trusses?

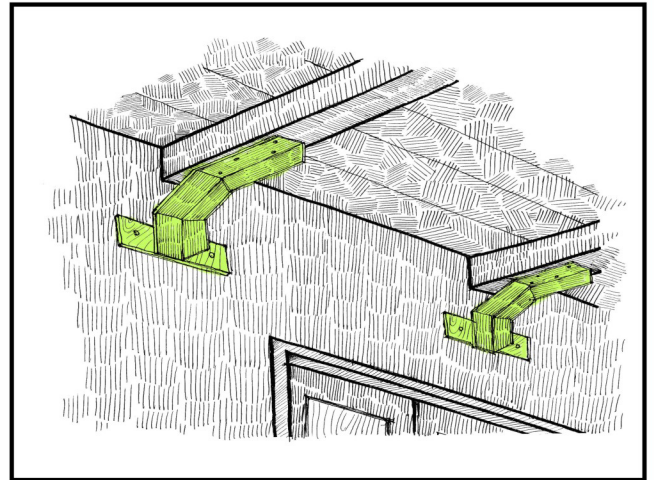
Install collar beam connecting two opposite rafters with pre-drilled wood plank and minimum two nails at each end.



## How to install floor diagonal bracings?

Install pre-drilled timber struts and diagonal braces on the underside of the floor beams using a minimum of two nails at each end.

Earthquake shaking causes damage to weak walls when roof and floor are not well connected to walls. This damage can be prevented by **anchoring roof & floor to walls**.



**Anchored roof works just like a tightly shut lid that strengthens the box.**

## How to anchor roof to wall?

Anchor roof/floor assembly to the walls with brackets made from MS steel angles. Install these on the wall using bolts and connect to the underside of wood beams with nails.

Earthquake shaking causes in-plane deformation in wooden floor leading to damage to floor and walls. This can be prevented by installing **diagonal bracings** under the floor.

**All structures, damaged or not, should be retrofitted**

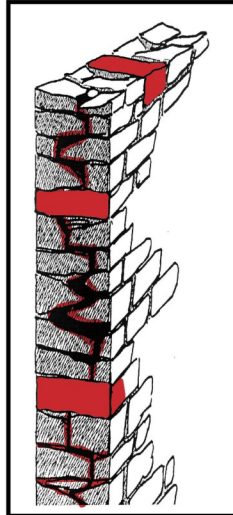
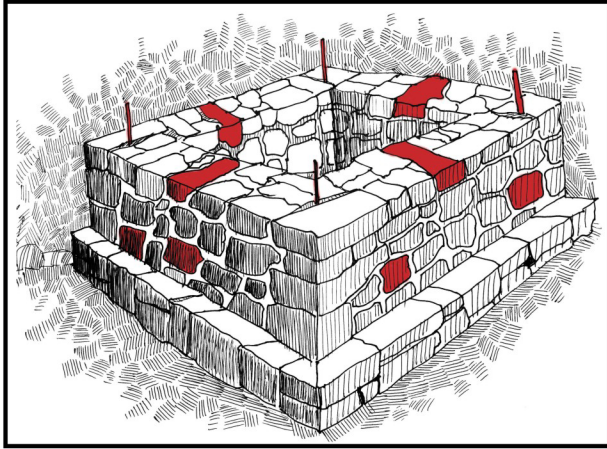


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# Building Earthquake Resistant Houses in Nepal

The house must resist earthquake force without collapsing. For this it is important how a construction material is used. (A) Ensure **good quality** and (b) use **earthquake resisting features**. It must be affordable and easy to execute. For this use maximum **locally available materials**.



**Good quality** means obey all rules of good construction practice.

A) In **brick, concrete block and stones masonry**:

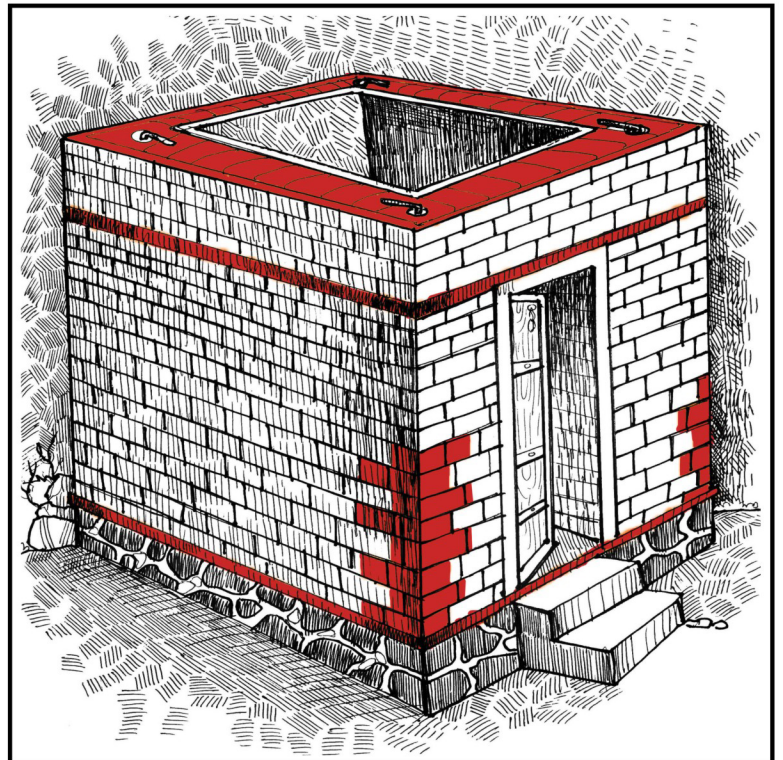
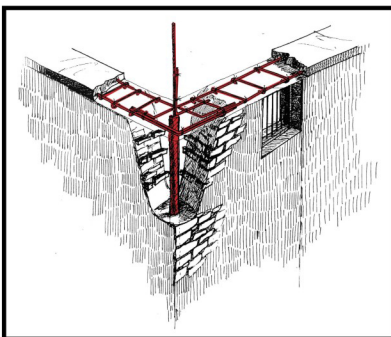
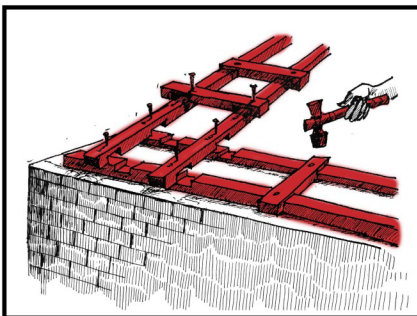
(1) Build all walls at the same time, (2) Cut all vertical joints, (3) Fill all vertical joints properly, (4) Thoroughly soak brick and concrete blocks just before using

(B) In **stone masonry**...

(1) Wall thickness to be 380mm (16") to 450mm (18") thick, (2) Do not use round stones and very small stones, (3) Use minimum one "through stone" in 0.7 sq.m (7sq.ft.) of wall, (4) Use long stones in the corners, (5) Do not place stone vertical on edge, (6) If the water for curing mortar is not available than build walls in mud mortar.

## Earthquake Resisting Features

(1) Install one vertical bar encased in concrete inside the masonry in all corners to prevent corner cracks. (2) Provide continuous RC band on all walls at plinth, lintel and roof/ floor level, to prevent vertical and diagonal cracks in walls, (3) Build gable wall of *Dhaji Divari* type OR use CGI sheet. (4) **If gable walls is made of masonry install RC band on sloping top of gable walls to prevent gable walls from collapsing.** (5) For wall longer than 5m. install buttresses at 3m spacing, (6) Cure all cement based construction for minimum of 15 days.



**Build Earthquake Resistant House**

**Because no one can predict when, where and how big earthquake will strike**



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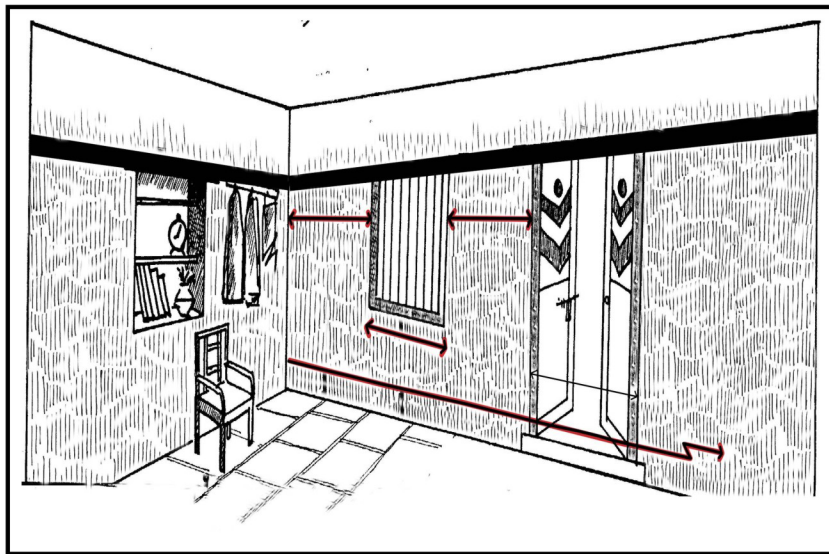
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# Building Earthquake Resistant Houses in Nepal

## Door & Window Openings

Earthquake shaking causes cracks at door and window opening corners since they weaken the walls. Such cracking can be prevented by **controlling the opening number, size and location, and encasing of openings.**



### Control of Openings:

#### A. Walls with cement mortar

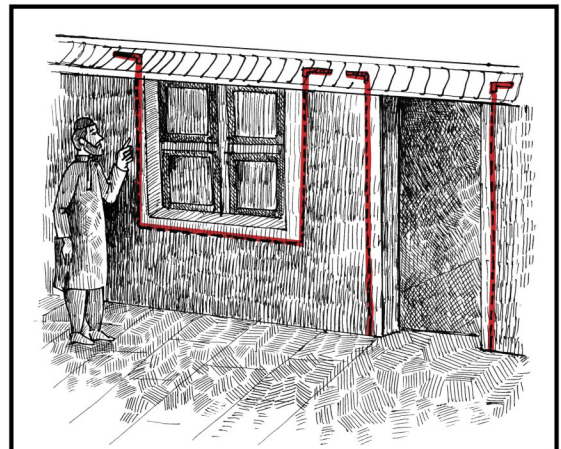
(1) Gap between opening and inside corner to be minimum 450mm (1'-6"), (2) Gap between opening to be minimum 600mm (2'-0"), (3) Total of all opening lengths to be no more than 50% of wall length for single story building and 42% for two story building.

#### B. Walls with mud mortar

(1) Gap between openings and inside corner to be minimum 600mm (2'-0"), (2) Gap between opening to be minimum 600mm (2'-0"), (3) Total of all opening lengths to be no more than 33% of wall length.

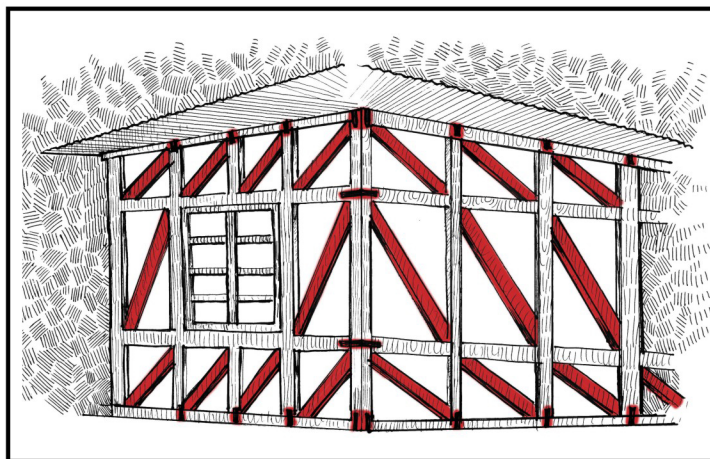
### Encasing of Opening:

(1) All openings must have vertical reinforcement next to jambs within the masonry, (2) When the openings are larger they must be boxed in reinforced concrete.



## Dhajji Diwari

Earthquake shaking in *Dhajji Diwari* causes breaking of plaster, weakening of timber joints and dislodging of bricks. Such damage can be prevented by **installation of bracings** and by **strengthening timber connections.**



### How to install bracings?

(1) At least one diagonal brace must be provided in every 1.6m x 1m area of wall, (2) All horizontal struts must be placed not more than 1m apart.

### How to make timber connections?

(1) All strong elements must be connected to each other using metal straps and wire nails.

**Build Earthquake Resistant House**  
Because no one can predict when, where and how big earthquake will strike



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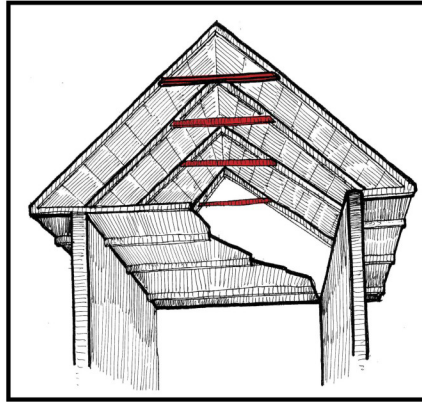
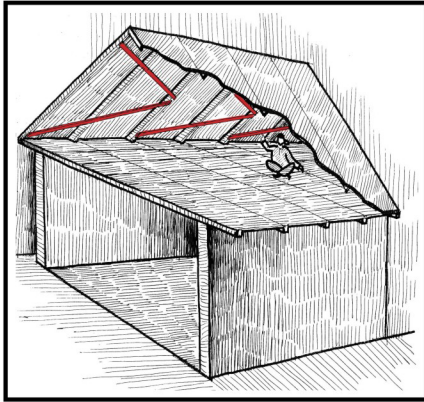
103, "Antariksh Building" Panjarapole Cross Roads, Vikram Sarabhai Marg, Ahmedabad - 380 015. Gujarat - (India)

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# Building Earthquake Resistant Houses in Nepal

## Roof:

Earthquake shaking can deform the CGI roof, which results into damage to roof and walls. Such damage can be prevented by (1) improving the roof by **installing bracing and strut system** in it, (2) by constructing **complete trusses instead of rafters**, and by (3) **anchoring roof deck** to walls..



### How to install bracings and struts?

- (1) Install diagonal bracings and struts of timber between two successive roof rafters on their underside starting from eave level to ridge without interruption.
- (2) Pre-drill the elements and use minimum two nails at each end

### How to construct truss?

- (1) Between the two opposite rafters install Collar Beam / Horizontal Tie. (2) Pre drill all elements and use a minimum of two nails at each end.

### How to anchor roof/floor deck to walls?

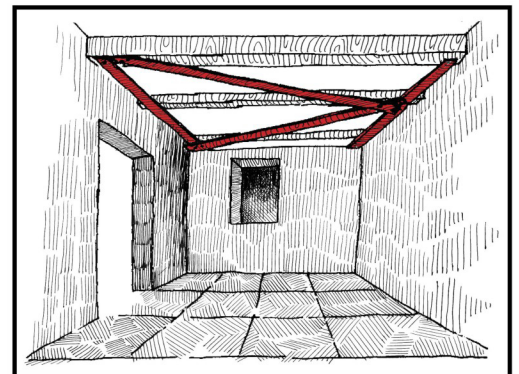
- (1) Anchor floor deck beams to the floor level band with the help of 2-13 gauge GI wires or 12mm diameter anchor bolts.

## Floor:

Earthquake shaking can deform wooden floor leading to damage to floor and walls. This can be prevented by installing **bracing and strut system** on underside of floor and by **anchoring**.

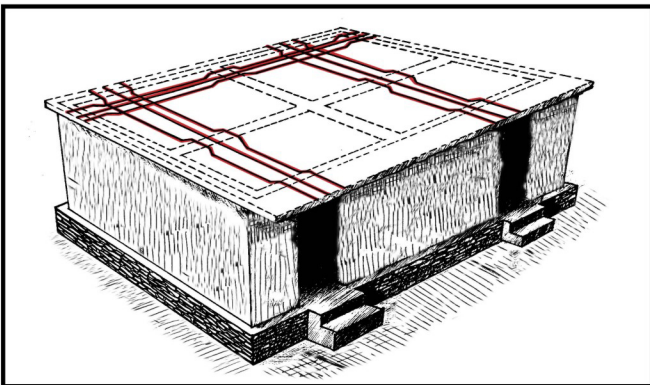
### How to install bracing and struts?

- (1) Install pre-drilled timber struts parallel to support walls. (2) Install braces diagonally ensuring continuity from one wall to other, (3) Pre drill timber and use minimum two nails at each end.



## RC Roof & Floor:

Earthquake shaking damages RC roof and floors. This can be prevented by better placement of reinforcement bars.



### How to build better RCC slab?

- (1) Provide reinforcement both ways in a slab, (2) Crank up alternate bars over the support walls, (3) Place reinforcing bars near the upper face of the slab when constructing chhajja and balconies projecting out, (4) Cure the slab for 15 days properly.

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