GUIDEBOOK FOR
RECONSTRUCTION OF EARTHQUAKE RESISTANT HOUSES

Supporting Compliance with the National Building Code, Nepal

For House owners

June, 2016

Foundation: Stone masonry in cement mortar 1:4

Wall: Stone masonry in cement mortar 1:4

Lintel Band: RCC: Concrete 1:1.5:3
Reinforcement mainbar 12mm*4, Foot 6mm@150mm

Sill Band: RCC: Concrete 1:1.5:3
Reinforcement mainbar 12mm*2, Foot 6mm@150mm

Plinth Band: RCC: Concrete 1:1.5:3
Reinforcement mainbar 12mm*4, Foot 6mm@150mm

Roof Band: RCC: Concrete 1:1.5:3
Reinforcement mainbar 12mm*4, Foot 6mm@150mm
GUIDEBOOK FOR RECONSTRUCTION OF EARTHQUAKE RESISTANT HOUSES

Supporting Compliance with the National Building Code, Nepal

Japan International Co-operation Agency
# Part 1. Housing reconstruction

1.1 Housing reconstruction  
1.2 Design catalogue  
1.3 Earthquake  
1.4 Effects of earthquake on buildings  
1.5 Earthquake resistant design  
1.6 Advantage of cement mortar

# Part 2. The earthquake resistant house

2.1 Design of house  
2.2 Construction  
  2.2.1 Preparation of Construction  
  2.2.2 Proper Construction process

# Appendix: Models of house Design

- Stone Masonry in Cement mortar 1-storey  
- Brick Masonry in Cement mortar 1-storey  
- Stone Masonry in Cement mortar 1-storey (option)  
- Brick Masonry in Cement mortar 1-storey (option)  
- Stone Masonry in Cement mortar 2-storey  
- Brick Masonry in Cement mortar 2-storey
1.1 Housing reconstruction

The April 25\textsuperscript{th} 2015 and May 12\textsuperscript{th} 2015 earthquakes in Nepal caused widespread damage to housing in the affected districts, as well as loss of life of almost 9,000 people. The Government of Nepal figures indicate that 602,257 houses were fully damaged, and 285,099 houses were partially damaged.

The large-scale destruction of housing resulted primarily from the seismic vulnerability of un-reinforced masonry houses that predominate throughout the country. Most houses (85.9\% of all housing construction) are low strength masonry stone or brick masonry with mud mortar, without seismic-resilient features.

Figures show the number of houses damaged in 31 districts.
The Government of Nepal Post Disaster Needs Assessment (PDNA) set out principles for housing and human settlements recovery and reconstruction as follows:

1. Encourage the participation of communities by empowering them to take control of reconstruction of their houses and ensuring facilitation of Owner Driven Reconstruction.
2. A comprehensive view of housing reconstruction should include holistic habitat development, with basic services and community infrastructure. The principle of build back better (BBB) should translate into a concept of safer settlements.
3. Reconstruction should be seen as a vehicle to build long-term community resilience by reducing vulnerabilities and strengthening community capacities to mitigate future disasters through improved construction practices for the majority of the building stock in the country.
4. Strengthen the local economy through reconstruction and processes that work to the benefit of the poor and marginalised sections who are mostly in the informal sector. Reconstruction should provide an opportunity for the poor to upgrade their living conditions.
5. Ensure sustainable and environment-friendly reconstruction processes, taking note of climate change, natural resource management and scientific risk assessments.
6. Ensure that rehabilitation is equitable and inclusive.
Design catalogue for reconstruction of earthquake resistant houses has been produced by the Department of Urban Development and Building Construction (DUDBC) to support rural households in the reconstruction of their houses. The objective of this document is to provide rural households with clear guidance regarding earthquake resistant construction techniques and to support them to have house designs in compliance with the National Building Code of Nepal.

Designs included in the Design Catalogue for Reconstruction of Rural Housing can be selected and used as is, the prototype designs, or can be adapted based on the parameters as defined in the National Building Code of Nepal, the flexible designs. Once a design has been selected this can be used by the household as part of the building permit application process.
List of Model Houses in design catalogue Vol.1

<table>
<thead>
<tr>
<th>Structural Type</th>
<th>No. of Floor</th>
<th>Model No.</th>
<th>Designed by</th>
<th>Page</th>
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<tbody>
<tr>
<td>Stone masonry in cement mortar, P5-SMC</td>
<td>1</td>
<td>SMC-1.1</td>
<td>JICA</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>SMC-1.2</td>
<td>JICA</td>
<td>15</td>
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<td>2</td>
<td>SMC-2.1</td>
<td>JICA</td>
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<td>DUDBC</td>
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<td>SMC-2.3</td>
<td>DUDBC</td>
<td>33</td>
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</tr>
<tr>
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<td>2+ATTIC</td>
<td>SMC-2.5</td>
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<td>2+TERRACE</td>
<td>SMC-2.6</td>
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<tr>
<td></td>
<td>Technical details</td>
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<td>67</td>
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<tr>
<td></td>
<td>Flexible design</td>
<td></td>
<td></td>
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</table>

| Brick masonry in cement mortar P71-BMC | 1 | BMC-1.1 | JICA | 75 |
|                                       | 1 | BMC-1.2 | JICA | 81 |
|                                       | 2 | BMC-2.1 | JICA | 87 |
|                                       | 2 | BMC-2.2 | DUDBC | 93 |
|                                       | 2+ATTIC | BMC-2.3 | DUDBC | 99 |
|                                       | 2+TERRACE | BMC-2.4 | DUDBC | 105 |
|                                       | Technical details |  |  | 117 |
|                                       | Flexible design |  |  | 126 |

| Stone masonry in mud mortar, P129-SMM | 1 | SMM-1.1 | DUDBC | 135 |
|                                        | Technical details |  |  | 141 |
|                                        | Flexible design |  |  | 143 |

| Brick masonry in mud mortar, P147-BMM | 1 | BMM-1.1 | DUDBC | 153 |
|                                       | Technical details |  |  | 159 |
|                                       | Flexible design |  |  | 161 |

Minimum Requirements for building construction with Stone Masonry in Mud Mortar for Residential Building

<table>
<thead>
<tr>
<th>No.</th>
<th>Category</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Site selection</td>
<td>It shall be done in a manner that it is not against natural hazards. A building shall not be constructed if any of the following conditions exist.</td>
</tr>
<tr>
<td></td>
<td>Geological stability</td>
<td>Not more than 2 degrees of slope</td>
</tr>
<tr>
<td></td>
<td>Hazard susceptible area</td>
<td>Not more than 15% of the area</td>
</tr>
<tr>
<td></td>
<td>Seismic susceptible area</td>
<td>Not more than 15% of the area</td>
</tr>
<tr>
<td></td>
<td>Rock fall area</td>
<td>Not more than 15% of the area</td>
</tr>
<tr>
<td></td>
<td>Till area</td>
<td>Not more than 15% of the area</td>
</tr>
<tr>
<td>2</td>
<td>Site size</td>
<td>Not more than 1,500 sqm</td>
</tr>
<tr>
<td></td>
<td>Size of room</td>
<td>Not more than 15 sqm</td>
</tr>
<tr>
<td></td>
<td>Height of wall</td>
<td>Not more than 3.0m</td>
</tr>
<tr>
<td></td>
<td>Proportion</td>
<td>Simple and regular shape as square and rectangular</td>
</tr>
<tr>
<td></td>
<td>Stone</td>
<td>Axial use of rounded, sub-rounded, easily breakable soft stone and broken stones in the natural shape. Rock stones shall be dressed. Size of stone shall not be smaller than 50cm in thickness and 100cm in length or breadth.</td>
</tr>
<tr>
<td></td>
<td>Mortar</td>
<td>Free from organic material, piddles, hard materials.</td>
</tr>
<tr>
<td></td>
<td>Cement mortar</td>
<td>cement and mortar shall not be less than 0.5 of the cement and 6 parts sand by volume for masonry.</td>
</tr>
<tr>
<td></td>
<td>Concrete</td>
<td>It shall not be less than M15 grade concrete, or mix ratio 1:2:4, (1 part cement, 2 parts sand and 4 parts aggregate by volume)</td>
</tr>
<tr>
<td></td>
<td>Rebar</td>
<td>High strength deformed bar with fy = 592 MPa, 50KN/Mpa</td>
</tr>
</tbody>
</table>

GROUND FLOOR PLAN

FLOOR AREA: 39.69sqm
1.3 Earthquakes

An earthquake is a sudden and violent motion of the earth caused by plate tectonics which lasts for a short time, and within a very limited region. Most earthquakes last for less than a minute. The larger earthquakes are followed by a series of after shocks which also may be dangerous.

Nepal is located in a seismic area From time to time earthquake occur which affect inadequately constructed houses, causing major damage and in many case partial or total collapse.

As the Indian subcontinent pushes against Eurasia, pressure is released in the form of earthquakes. The constant crashing of the two plates forms the Himalayan mountain range.
1.4 Effects of Earthquake on Buildings

Typical failure pattern of masonry structure

During an earthquake, a building is shaking in all possible directions. The shaking loosens the joints of different components of building that leads to subsequent damage or collapse.

➢ **Separation of walls**
Separation of walls at corners and T-Junctions takes place due to poor connection between the walls.

➢ **Delamination of wall**
Delamination of wall is vertical separation of internal stone and external stone through middle of wall thickness, this occurs due to mainly to the absence of bonding elements and weak mortar filling in stone masonry wall.

➢ **Gable wall collapse**
In case of gable wall the triangular of wall has no restraint. Hence, when the force is in perpendicular direction it shakes excessively. Under such pull and push a crack develops. In heavy shaking it can also collapse.
Earthquake-resistant design

Earthquake-resistant structures are designed to withstand earthquakes. While no structure can be entirely immune to damage from earthquakes.

To construct earthquake resistant building no. of factors such as site selection, shape of house, foundation, Plinth, walls, opening, vertical reinforcement, horizontal Band, roof, materials should be considered. The details of the seismic elements at different level of the buildings are clearly shown in the figure below.

**Technology for Earthquake Resistant Building Construction**

**(Stone in Cement Mortar)**

- **Roof band:** Rcc:Concrete 1:1.5:3
  - Reinforcement mainbar 12mm *4,
  - Stirrups 6mm@150mm
- **Wall:** Stone masonry in cement mortar 1:4
- **Lintel Band Rcc:** Concrete 1:1.5:3
  - Reinforcement mainbar 12mm *4,
  - Stirrups 6mm@150mm
- **Stitch Band Rcc:** Concrete 1:1.5:3
  - Reinforcement mainbar 8mm *2,
  - Stirrups 6mm@150mm
- **Sill Band Rcc:** Concrete 1:1.5:3
  - Reinforcement mainbar 12mm *4,
  - Stirrups 6mm@150mm
- **Plinth Band Rcc:** Concrete 1:1.5:3
  - Reinforcement mainbar 12mm *4,
  - Stirrups 6mm@150mm
- **Foundation Stone masonry in cement mortar 1:4**

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**Eg.: Technology for Earthquake Resistant Building Construction**

**(Charikot, Dorakha)**
Seismic horizontal band
A continuous band, also called ‘ring beam’ is a RC band at different levels in all walls of the building for tying walls together to enhance box action. It improves horizontal bending resistance thereby preventing out-of-plane collapse of walls. It also helps to prevent shrinkage, temperature and settlement cracks.

Effectiveness Seismic Band

- **without band**
- **with band**

Earthquake happen!!!

Seismic Horizontal wooden band
1.6 Advantage of cement mortar

Mortar is a paste prepared by adding required quantity of water to a mixture of binding material like cement and fine aggregate like sand.

Cement mortar helps to carry the weight placed on the wall and seal the joints where it has a high degree of impermeability and is more prone to shrinkage than others mortar.

Advantages of cement mortar over other mortars:
- It gives strength to masonry.
- It is an excellent binding material.
- It is easily workable.
- It offers good resistance to moisture
- It possess good plasticity.
- It hardens early and starts gaining strength in around 10 hours.
Part 2: The earthquake resistant house

2.1 Design of house
2.2 Construction
   2.2.1 Preparation of Construction
   2.2.2 Appropriate Construction process
Earthquake resistant house

2.1 Design of house

a. Site selection

Adequate locations: Safe place to build houses are those located far from areas where natural Hazards may occur.

✔ **Do not select near steep slope**
Building built on sites with a narrow hill ridge, separated high hills, steep slopes or complicated terrain are susceptible to damage than a building built on sites with plain topography. so such sites should be avoided as far as possible. However, buildings can be constructed in such areas after the provision of proper precaution by retaining walls and its periphery must be improved by terracing and constructing breast.

✔ **Do not select landside prone area**
Landslides usually completely wash out buildings lying in its course. Rock fall damages buildings partially or completely. so its better not to select the sites on landslide prone area.

✔ **Do not select near river bank**
Since river banks are susceptible to frequent flooding and to liquefaction. Buildings should be far enough from the flooding zone of river and construction in such areas should be undertaken only after carrying out necessary protection works to avoid flash flood and earthquake damage.
✓ **Do not select filled or soft ground**
In a back filled area, the bearing capacity of foundation sub soil is low and settlement of foundation may occur. Also, foundation may be exposed due to easy scouring of backfilled soil. If a building is to be constructed on a filled ground, the foundation should be deep enough so as to rest on firm soil and not on filled up soil.

✓ **Do not select Rock fall Area**
✓ **Do not select Geological fault or Ruptured Area**
✓ **Do not select Liquefaction susceptible Area**
Earthquake resistant house

b. Shape of house

To make earthquake resistant house successfully, design must have a good shape and an adequate distribution of walls.

- **Symmetry**

The building, as a whole or its individual blocks, shall be planned symmetrical as far as possible.

- **Regularity**

Simple rectangular shapes behave better in an earthquake than shapes with projections. Torsional effects of ground motion are pronounced in long narrow rectangular blocks. The length of a block shall not be greater than three times its width of the building.

If longer lengths are required two separate blocks with sufficient separation between should be provided.

According to National Building Code, Nepal, the minimum requirement that should be considered are as follows:

- **Number of storey:**
  - It shouldn’t be more than 2 storey + attic incase of the stone and brick masonry with cement mortar
  - Incase of stone/brick masonry in mud mortar with wooden band the total number of storey should be limited to one storey whereas if R.C band is used instead of wooden band then one plus attic floor can be constructed.
Earthquake resistant house

2.1 Design of house

b. Shape of House

- Span of wall
  The clear span of the wall shouldn’t be more than 12 times thickness of the wall and not more than 4.5 m.

- Size of Room
  Each room should not exceed 13.5 sq. m.

- Height of wall
  Floor height shall not be more than 3.0m. Incase of attic floor, maximum height from floor level to ridge level shall be 1.8 m and maximum height from floor level to eave level shall be 1.0m.

- The building should not be too long or too tall
C. Opening of wall

Openings are the voids in walls to make them weak. So, their sizes and locations are to be carefully decided while construction. Some of the rules for size and location of openings in masonry buildings are shown in the next page. Following are the guidelines on the size and position of opening:

- **The total length of openings**
  It should not be more than 50% of the total length of the walls in case the building is of single storey. But it should not be more than 42% at ground floor when the building is 2 storied.

- **Distance of opening from the end of a wall**
  It should be more than \( \frac{1}{4} \) of the height of the opening but not less than 0.6 m.

- **The horizontal distance between two openings**
  It should not be less than half of the height of the shorter opening, but not less than 0.6 m.

- **The vertical distance between two openings**
  If there are two openings in the height of a wall, then vertical distance between the two openings should not be less than 600 mm or 50% of the width of the smaller opening.]

- **When the openings do not comply with requirements above points,**
  they should either be boxed around in reinforced concrete or reinforcing bars provided at the jambs through the masonry as shown in figure below

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Any opening in the wall reduces load bearing capacity against the earthquake. The size of opening and location should be well considered and comply with the followings:

- \( L = b_1 + b_2 + b_3 + b_4 + b_5 \leq 4.5 \) m
- \( b_1 + b_2 \leq 0.5L \) for 1-storrey
- \( b_1 + b_2 \leq 0.42L \) for 2-storrey
- \( b_4 \leq 0.5h_2 \), but no less than 600 mm
- \( b_5 \leq 0.25h_1 \), but no less than 600 mm
- \( b_3 \geq 0.25h_2 \), but not less than 600 mm
Large sizes and inappropriate locations of opening are another cause of severe damage of masonry buildings.

Openings are the voids in walls to make them weak. So, their sizes and locations are to be carefully decided while construction. Some of rules for size and location of openings in masonry buildings are shown in next page. Following are the guidelines on the size and position of opening:

- **The total length of openings**
  It shouldn’t exceed 30% of the length of the wall between consecutive cross-walls in single storey mud masonry whereas in case of cement masonry construction, it shouldn’t exceed 50% in single storey construction and 42% in two storey construction.

- **Distance of opening from the end of a wall**
  Openings are to be located away from inside corners by a clear distance equal to at least ¼ of the height of the opening, but not less than 0.6m.

- **The horizontal distance between two openings**
  It should not be less than half of the height of the shorter opening, but not less than 0.6 m.

- **The vertical distance between two openings**
  If there are two openings in the height of a wall, then vertical distance between the two openings should not be less than 600 mm or 50% of the width of the smaller opening.

- When the openings do not comply with requirements above points, they should either be boxed around in reinforced concrete or reinforcing bars provided at the jambs through the masonry as shown in figure below.
2.1 Design of house

Brick/Stone masonry with mud mortar:

Note:
- चौ 1 + चौ 2 <0.3 लम्बाई 1 एक तल्लाको लागि, 0.25 लम्बाई 1 एक तल्ला र बुईगलको लागि
- चौ 6 + चौ 7 <0.3 लम्बाई 2 एक तल्लाको लागि, 0.25 लम्बाई 2 एक तल्ला र बुईगलको लागि
- चौ 4 >=0.5 चौ 2 तर 600 मि.मि. भन्दा कम
- चौ 5 >=0.25 चौ 1 तर 450 मि.मि. भन्दा कम

Brick/Stone masonry with cement mortar:

Note:
- चौ 1 + चौ 2 + चौ 3 <=0.5 लम्बाई 1 एक तल्लाको लागि, 0.42 लम्बाई 1 दुई तल्लाको लागि
- चौ 6 + चौ 7 <=0.5 लम्बाई 2 एक तल्लाको लागि, 0.42 लम्बाई 2 दुई तल्लाको लागि
- चौ 4 >=0.5 चौ 2 तर 600 मि.मि. भन्दा कम
- चौ 5 >=0.25 चौ 2 तर 600 मि.मि. भन्दा कम
- चौ 4 >=0.25 चौ 1 तर 600 मि.मि. भन्दा कम
- चौ 5 >=0.25 चौ 1 र 600 मि.मि. मध्यको अधिकतम
✓ **Laying masonry**
Masonry should not be laid staggered or straggled in order to avoid continuous vertical joints. At corners or wall junctions, through vertical joints should be avoided by properly laying the masonry. It should be interlocked.

✓ **Mortar Mixture**
Mortar joints should not be more than 20mm and less than 10mm in thickness. The ratio recommend 1:6(Cement: Sand).

✓ **Through-stone**
Through-stone of a length equal to the full wall thickness should be used in every 600 mm lift at not more than 1.2 m apart horizontally.

✓ **Key Technical Points**
- The pressure acting on stones should be vertical.
- Dressed stones are preferable than natural round shaped stones.
- Broken or small stones should not be used.
- Through stone should be laid in every 600mm lift and not more than 1.2m apart horizontally.
- Wet stone should be used to avoid sucking moisture from mortar.
- Stone should be cleaned no to loss bonding strength with mortar.
- Mortar should be packed and chipped in properly without void space
- Mortar joint should not be in one continuous vertical line.
- The plumb bob should be used to check verticality.

✓ **Thickness of wall**

<table>
<thead>
<tr>
<th>MASONRY TYPE</th>
<th>MASONRY TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>One</td>
</tr>
<tr>
<td>Stone</td>
<td>350-450</td>
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<tr>
<td>Brick</td>
<td>230</td>
</tr>
</tbody>
</table>
2.1 Design of house

Related Minimum requirement
No’4,No’7 and No’8

e.Seismic horizontal band:

A continuous band, also called ‘ring beam’ is a RC band at different levels in all walls of the building for tying walls together to enhance box action. It improves horizontal bending resistance thereby preventing out-of-plane collapse of walls. It also helps to prevent shrinkage, temperature and settlement cracks.

Stone in cement Mortar with R.C. band

Stone in mud Mortar with wooden band
- **Plinth band**
  This band is provided where soil is soft or uneven in their properties. It may also serve as a damp-proof course.

- **Sill band**
  This band is provided just below the window openings through all walls at the bottom. It becomes critical if the floor height is high.

- **Lintel band**
  A lintel band shall be provided through all walls at the top level of opening, thus the top-level of all the openings shall be made equal as far as practicable. It must be provided in all stories of the building as per table.

- **Roof band**
  This band shall be provided at the eave-level of trussed roofs and also just below the joists on all such floors which consist of joists and covering elements (flexible floors), so as to integrate them properly at their ends and fix them into the walls.

### रिबारको नाम (मुख्य डण्डी)

<table>
<thead>
<tr>
<th>नाम</th>
<th>प्रमाणित सिमेंट व्यान्डको त्यूनतम मोटाई</th>
<th>फलाम्र इण्डीको त्यूनतम संख्या</th>
<th>फलाम्र इण्डीको त्यूनतम व्यास (मिमी)</th>
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<tbody>
<tr>
<td>कर्न मुख्य (२५ मिमी)</td>
<td>२५ मिमी</td>
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<td>२२ मिमी</td>
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<td>फन्झ प्लेक (३५ मिमी)</td>
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<td>२</td>
<td>२२ मिमी</td>
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<td>२२ मिमी</td>
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<td>सवाप प्लेक (बढ्छको माध्यम)</td>
<td>३५ मिमी</td>
<td>२</td>
<td>२२ मिमी</td>
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### नोट:
1. यदि खुला भागको छोडाई ९०० मिमी भन्ना त्यही भागमा १५० मिमी मोटाईको लिन्टेल व्यान्डको प्रयोग गरुनुपर्ने।
2. यदि भागमा सुदूरको छोडाई र खुला भाग मध्यको उचाई १००० मिमी र ९०० मिमी छ माने वस्तुको त्यूनतम मोटाई ५५ मिमी को हुन्छ।

<table>
<thead>
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<th>तलालको संख्या</th>
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<tr>
<td>१ तल्ले</td>
<td>१२ मिमी</td>
</tr>
<tr>
<td>२ तल्ले</td>
<td>१६ मिमी</td>
</tr>
</tbody>
</table>
Earthquake resistant house

2.2 Construction

2.2.2 Preparation of Construction

Materials used in building construction is also one of the factor affecting the quality of building. So quality of construction materials used in construction has to be ensured for assuring the final quality of construction. The required quality of materials should be decided beforehand the construction is started; generally it is decided during planning and designing phase. Depending upon the construction type, structural element and location of site the quality of materials required should be differs. The very commonly used construction materials are shown below in pictures.

- **Boulder stone (River round stone)** should not be used. Need treatment of shape.
**CEMENT**
- Portland Cement
- not hardened
- dry
- not mixed with other materials
- uniform color

**BRICKS**
- completely burnt
- flat, not warping
- does not break easily
- uniform size
- corners not damaged
- standard size: 230 x 110 x 55 mm

**MUD MORTAR**
- Free from organic materials
- Neither too sandy nor too clayey
- Sand content not more than 40% by volume

**TIMBER**
- dry and straight
- no cracks and notch
- treated against termite
- hard wood shall be used for main structural elements

<table>
<thead>
<tr>
<th>Hard Wood</th>
<th>Soft Wood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Babul, Black Siris, Dhaman, Indian Rose Wood (Shisam), Jamun, Mesua, Oak, Sain, Sal, Sandan, Stiso, Teak, Khair</td>
<td>Chir, Deodar, Jack, Mango, Salla, Simal, Utlis (Red), Uttis (White)</td>
</tr>
</tbody>
</table>

**R.C. BARS**
- Fe415: High Strength Deformed Bar
- uniform size
- conform with standard bars
- not rusted
- straight
- diameter in accordance with drawing

**CORRUGATED GALVANISED IRON (CGI) SHEET**
- standard 26 gauge size
- thickness 0.55 mm

---

**Quality Check!**

**Stone**  
BAD!  
GOOD!

**Brick**
2.2 Construction

2.2.2 Appropriate Construction Process:

a. Mixture of concrete

Cement concrete is a mixture of cement, sand, and stone aggregates in a specified proportion. Mixing may be done by mixer machine or by hand. Preferable is mixing by machine as it gives uniform quality and homogeneous concrete mix. Procedure for mixing concrete manually has been explained in the following diagrams.
2.2 Construction

2.2.2 Appropriate Construction Process:

a. Mixture of concrete

Related Minimum requirement No’10

M20 ग्रेड कंक्रिट
न्यूनतम वर्मिजीब्यक्ति: 20N/mm² (20MPa)
न्यूमिनल मिश्रण अनुपात: 1 : 1.4 : 3 (सिमेंट : बालुचा : गिझी)
पानी र सिमेंटको अनुपात: ध्वाधकतम 0.6
2.2 Construction

2.2.2 Appropriate Construction Process:

a. Mixture of Mortar

Cement Mortar is a paste prepared by adding required quantity of water to a mixture of binding material like cement and fine aggregate like sand. For the preparation of good mortar there should be quality cement, sand and water with appropriate proportions. Procedure to mix the mortar has been explained in the following diagrams.
Mixture of Mortar

Mud mortar
The soil for preparation of mud mortar should be free from organic materials. It shall also be free from pebbles and other hard materials which could upset the mortar thickness. The sand content in the mud shall not be more than 30% in order to achieve a proper cohesiveness. Dry mud shall be thoroughly kneaded with water in order to prepare the dense paste.

Field Test
a. Dry strength test
Five or Six small balls of soil of approximately 2 cm in diameter are made. Once they are dry (after 48 hours), each ball is crushed between the forefinger and the thumb. If they are strong enough that none of them breaks, the soil has enough clay to be used in the adobe construction, provided that some control over the mortar micro-fissures caused by the drying process is exercised, as shown in figure below. If some of the balls break, the soil is not considered to be adequate, because it does not have enough clay and should be discarded.
2.2 Construction

2.2.2 Appropriate Construction Process:

c. Foundation

Foundation is a bottom-most part of the building which transfers the weight of the building to the ground. It plays a vital role in overall stability of the structure. Foundation for a particular structure depends on type of structure and foundation sub soil. The foundation trench should be of uniform width and its bed should be on the same level throughout the flat area.

- **Backfilled by Excavated Soil**
- **Natural Ground**
- **Mortar / Compacted Soil (100 mm)**
- **Brick (55 mm)**
- **Filled Soil**
- **Excavation Line**
- **Plinth Band**
- **450 mm (Recommended) min 300 mm**
- **Excavation Line**
- **Stone / Brick Masonry**
- **Lean Concrete**
- **Brick/Gravel Bedding**

The base width of foundation is varied depending on:

- Wall Material: Stone or Brick
- No. of Story: 1-Storey or 2-Storey
- Bearing Strength of Ground: Soft, Medium or Hard
Foundation for masonry Building

- For load bearing wall construction, strip footing of masonry, plain concrete or RC is commonly used.
- RC strip footing is most effective for seismic and settlement consideration in soft as well as firm soils.
- Masonry footings are most frequently used.

The depth of footing in the soil should go below the zone of deep freezing in cold regions and below the level of shrinkage crack in clay soil. It is the most common strip foundation, which can be constructed in cement or mud mortar. This type of footing is generally made of steps, the width at the bottom being more and the width at the top of the footing is equal to the width of the wall above. The footing wall may be of brick or stone depending upon the availability of it and the mortar also mud or the cement.

The minimum size of foundation for masonry footing in different types of foundation sub soil and different no. of stories should be as shown below in table.

<table>
<thead>
<tr>
<th>Types of Masonry</th>
<th>Storey</th>
<th>Soft</th>
<th>Medium</th>
<th>Hard</th>
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<tbody>
<tr>
<td>Brick</td>
<td>2-Storey</td>
<td>900</td>
<td>650</td>
<td>450</td>
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<tr>
<td></td>
<td>1-Storey</td>
<td>650</td>
<td>550</td>
<td>450</td>
</tr>
<tr>
<td>Stone</td>
<td>2-Storey</td>
<td>-</td>
<td>800</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>1-Storey</td>
<td>800</td>
<td>600</td>
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</tbody>
</table>
2.2 Construction

c. Foundation Detail for Mud Mortar

Foundation Detail for Mud Mortar

2.2.2 Proper Construction Process:
Foundation Detail for Mud Mortar

ए = सतहको चौडाई— गारोको चौडाई/६
माटोको प्रकार अनुरुप गारोबाट निर्मित जगको लागि चाहिए न्यूनतम सतहको चौडाई (मि.मि)

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</table>

ईंटाको गारोमा माटो मसला

हुंड़को गारोमा माटो मसला
2.2 Construction

2.2.2 Proper Construction Process:

d. Construction Sequence

1. Layout plan

The first important step in construction of a foundation is the layout. It is an essential procedure before the start of work. Clean the ground from all organic or any odd elements. Then tighten the ropes using trestles made by wood poles nailed to a transversal stick and embed it to the ground, as shown in the figure. Trestles are placed at external part of build. Check the angle of 90°(at the corners making triangle of 3-4-5 length sides) as shown here. Use chalk or gypsum powder to mark.

2. Excavation

It is important that foundation to be leveled below the ground level, on natural soil at a depth not less than 1.0 m. If thickness of the shallow landfill is greater than 1.0 m the trench should be over excavated until it reach the natural soil and refilled with simple concrete.
3. Laying Brick Bedding

The excavated area is then filled by a layer of brick.

4. Placing lean concrete

The layer of brick is covered by lean concrete

5. Construction of Foundation with installation of vertical Rebar

Reinforcement bars are placed and fixed into the foundation
6. Construction of plinth band

After the reinforcement a layer of concrete is placed over lean concrete.

7. Construction of Masonry wall and RC bands

Masonry wall is constructed above plinth band and openings are made and RC bands are placed over, middle and under masonry wall.

8. Construction of Corner and transverse bands

After the completion of the opening, the construction of the masonry wall is stopped to construct the corner and transverse band.
A continuous lintel band is constructed through walls at the top level of opening.

9. Construction of lintel band:

After completion of lintel band, masonry wall is constructed and above that roof band is constructed and above that timber truss is made.

11. Installation of roof

After the construction of wall, roof is placed over it.
Treatment of shape

Mixing mortar

Though Stone

Laying properly

Bar bending

Fook 135 degree

Seismic band

Seismic band
Part-3 Standard Design
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भूक्रम्प प्रतिरोधी नमुना आवास डिजाइन (एक तल्ले)
गारे भवन, दुङ्गा सिमेंटको जोडाइ

नमुना नं: एस एम सि 9.२

नमुना नं. एस एम सि 9.२
डिजाइन गर्न: जाईका

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नेपाल सरकार
सहरी बिकास मन्त्रालय
सहरी बिकास तथा भवन निर्माण विभाग
बबारमनु, काठमाडौं भोट नं. ४-२६२२६६/ ४-२६२२६६
www.dustbc.gov.np
Email:www.dustbchousing@gmail.com

स्केल: None
भूकम प्रतिरोधी नमुना आवास डिजाइन (एक तल्ले)
गारे भवन, ईटा सिमेंटको जोडाइ

कुल क्षेत्रफल – ३१.७५ वर्ग.मि

चित्र: भूकम प्रतिरोधी वनोटहर राखिएका घरको सचिव दृष्टि

अगाडि कोहोडा
ग्रामीण कोहोडा

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नेपाल सरकार
सहरी विकास प्रभाग
सहरी विकास गर्न भएको निर्देशन विभाग
बन्दोल, काठमाडौं फोन नं.: ५-२७२८८ / ५-२७२८६

Email: www.durdibhousening@gmail.com

नमुना नं. वि एम सि १.२

डिजाइन गरेका: जाइका

स्केल: None


### भूमिप्रतिरोधी नमुना आवास डिजाइन (दुई तलले)

### गारे भवन, दुई नमुना सिमेंटको जोडाइ

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#### नमुना नं. एस एम सि २१

#### डिजाइन गर्ने जाइका

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### स्क्रीन: None
भुक्तम प्रतिरोधी नमुना आवास डिजाइन (दुई क्लेथ) (कार्त्तिकी भवन, इटा सिमेंटको जोडाइ)

नमुना नं: वि.एम सि. २.९

कार्त्तिकी भवन

### उपकक्ष
- ब्राउन पात्र
- ज्याडी पक्की
- सातो ब्राउन
- रेडियो ब्राउन
- ज्याडी पात्र
- ज्याडी पात्र
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- ज्याडी पात्र
- ज्याडी पात्र

### लक्षण
- रेडियो ब्राउन
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- ज्याडी पात्र

### विशिष्टता: भुक्तम प्रतिरोधी बनेटिंग स्किमिंग पात्रको समग्र इमार

### जलाभिकृति
| सिपाल | ज्याडी | ईटा | सिमेंटको | बालुका | एसिग्रेट | काठ | केसटा पात्र | ड्युई
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नेपाल सरकार
महानिक निर्माण
सहरी निर्माण समिति
टेलिफोन: ५-२५२२२५/५-२५२२३५
Email: www.durabc.gov.np

नमुना नं: वि.एम सि. २.९
डिजाइन गरेको: जाईका

स्कैक: None