World Housing Encyclopedia

an Encyclopedia of Housing Construction in
Seismically Active Areas of the World

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# HOUSING REPORT
# Traditional rural house in Kutch region of India (bhonga)

| | |
|---|---|
| Report # | 72 |
| Report Date | 05-06-2002 |
| Country | INDIA |
| Housing Type | Adobe / Earthen House |
| Housing Sub-Type | Adobe / Earthen House : Adobe block walls |
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## Summary

The Bhonga is a traditional construction type in the Kutch district of the Gujarat state in India, which has a very high earthquake risk. A Bhonga consists of a single cylindrically shaped room. The Bhonga has a conical roof supported by cylindrical walls. Bhonga

construction has existed for several hundred years. This type of house is quite durable and appropriate for prevalent desert conditions. Due to its robustness against natural hazards as well as its pleasant aesthetics, this housing is also known as "Architecture without Architects." It performed very well in the recent M7.6 Bhuj earthquake in 2001. Very few Bhongas experienced significant damage in the epicentral region, and the damage that did occur can be mainly attributed to poor quality of the construction materials or improper maintenance of the structure. It has also been observed that the failure of Bhongas in the last earthquake caused very few injuries to the occupants due to the type of collapse.

# 1. General Information

Buildings of this construction type can be found in Kutch district of Gujarat state in India. This type of housing construction is commonly found in rural areas.

There is no evidence of Bhongas constructed in urban areas. However, since the Bhongas rarely survive for over 50 years, Bhongas constructed in urban areas do not exist any more due to the prevalence of modern construction materials in urban areas during the last 50 years.

This construction type has been in practice for more than 200 years.

Currently, this type of construction is being built. Bhongas older than 50 years have been found in Kutch district of Gujarat state in India.

Figure 1: Typical Building

Figure 1A: Typical Building

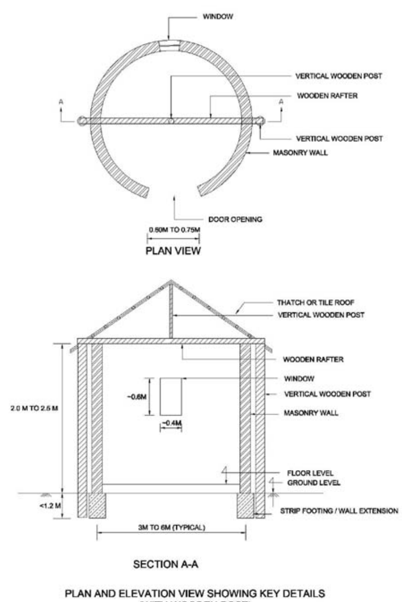


Figure 2: Plan of a typical building

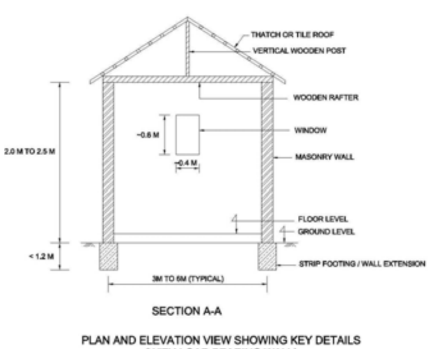

Figure 1F: Typical Building

# 2. Architectural Aspects

## 2.1 Siting

These buildings are typically found in flat terrain. They do not share common walls with adjacent buildings. When separated from adjacent buildings, the typical distance from a neighboring building is 3.0 meters.

## 2.2 Building Configuration

Bhonga is circular in plan, with cylindrically shaped walls and topped with conical roof. The inner diameter of the Bhonga is typically between 3m to 6m. A Bhonga generally has only three openings one door and two small windows.

## 2.3 Functional Planning

The main function of this building typology is single-family house. In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. Main door of the Bhonga is the only means of escape.

## 2.4 Modification to Building

Recent Bhongas constructions have used wide variety of construction materials. These indude the stone or burnt brick masonry either in mud mortar or in cement mortar. Traditional roof consists of light-weight conical roof, while some recent constructions have used heavy manglore tiles on roofs. Some recent constructions have used circular strip footing below the wall, while traditional construction simply extended the walls below ground level.

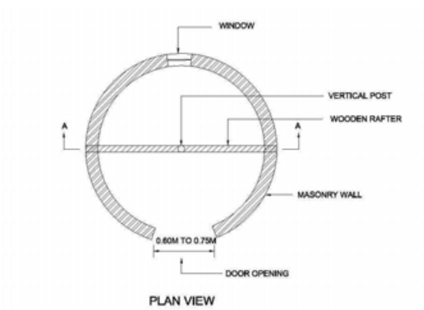

Figure 1D: Typical Building


Figure 4: Critical Structural Details


Figure 5A: A Photograph Illustrating Typical Earthquake Damage (2001 Bhuj Earthquake)


Figure 6A: A Photograph Illustrating Typical Earthquake Damage (2001 Bhuj earthquake)

# 3. Structural Details

## 3.1 Structural System

| Material | Type of Load-Bearing Structure | # | Subtypes | Most appropriate type |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Masonry | Stone Masonry Walls | 1 | Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof) | ☐ |
| | | 2 | Dressed stone masonry (in lime/cement mortar) | ☐ |
| | Adobe/ Earthen Walls | 3 | Mud walls | ☐ |
| | | 4 | Mud walls with horizontal wood elements | ☐ |
| | | 5 | Adobe block walls | ☑ |
| | | 6 | Rammed earth/Pise construction | ☐ |
| | Unreinforced masonry walls | 7 | Brick masonry in mud/lime mortar | ☐ |
| | | 8 | Brick masonry in mud/lime mortar with vertical posts | ☐ |
| | | 9 | Brick masonry in lime/cement mortar | ☐ |
| | | 10 | Concrete block masonry in cement mortar | ☐ |
| | Confined masonry | 11 | Clay brick/tile masonry, with wooden posts and beams | ☐ |
| | | 12 | Clay brick masonry, with concrete posts/tie columns and beams | ☐ |
| | | 13 | Concrete blocks, tie columns and beams | ☐ |
| | Reinforced masonry | 14 | Stone masonry in cement mortar | ☐ |
| | | 15 | Clay brick masonry in cement mortar | ☐ |
| | | 16 | Concrete block masonry in cement mortar | ☐ |
| Structural concrete | Moment resisting frame | 17 | Flat slab structure | ☐ |
| | | 18 | Designed for gravity loads only, with URM infill walls | ☐ |
| | | 19 | Designed for seismic effects, with URM infill walls | ☐ |
| | | 20 | Designed for seismic effects, with structural infill walls | ☐ |
| | | 21 | Dual system – Frame with shear wall | ☐ |
| | Structural wall | 22 | Moment frame with in-situ shear walls | ☐ |
| | | 23 | Moment frame with precast shear walls | ☐ |
| | Precast concrete | 24 | Moment frame | ☐ |
| | | 25 | Prestressed moment frame with shear walls | ☐ |
| | | 26 | Large panel precast walls | ☐ |
| | | 27 | Shear wall structure with walls cast-in-situ | ☐ |
| | | 28 | Shear wall structure with precast wall panel structure | ☐ |
| Steel | Moment-resisting frame | 29 | With brick masonry partitions | ☐ |
| | | 30 | With cast in-situ concrete walls | ☐ |
| | | 31 | With lightweight partitions | ☐ |
| | Braced frame | 32 | Concentric connections in all panels | ☐ |
| | | 33 | Eccentric connections in a few panels | ☐ |
| | Structural wall | 34 | Bolted plate | ☐ |
| | | 35 | Welded plate | ☐ |
| | | 36 | Thatch | ☐ |

| | | | | |
|---|---|---|---|---|
| Timber | Load-bearing timber frame | 37 | Walls with bamboo/reed mesh and post (Wattle and Daub) | ☐ |
| | | 38 | Masonry with horizontal beams/planks at intermediate levels | ☐ |
| | | 39 | Post and beam frame (no special connections) | ☐ |
| | | 40 | Wood frame (with special connections) | ☐ |
| | | 41 | Stud-wall frame with plywood/gypsum board sheathing | ☐ |
| | | 42 | Wooden panel walls | ☐ |
| Other | Seismic protection systems | 43 | Building protected with base-isolation systems | ☐ |
| | | 44 | Building protected with seismic dampers | ☐ |
| | Hybrid systems | 45 | other (described below) | ☐ |

Many old Bhongas (constructed over 40-50 years) consist of adobe block walls with mud or lime mortar whereas the walls of recently constructed Bhongas consists of cut stone or clay bricks in mud or lime mortar.

## 3.2 Gravity Load-Resisting System

The vertical load-resisting system is others (described below). The conical roof of a Bhonga is supported at its crest by a vertical central wooden post, which rests on a wooden joist. The base of the roof and the wooden joist are generally directly supported on Bhonga walls. Sometimes, the roof load on wooden joist is transferred to diametrically placed timber posts (vertical members) adjacent to the cylindrical wall. This reduces the roof-load on the walls. The Bhonga wall is usually extended below ground up to the required foundation depth, and separate foundation is not traditionally constructed. In newer constructions, proper strip footing is also used.

## 3.3 Lateral Load-Resisting System

The lateral load-resisting system is others (described below). Due to circular shape of wall in plan, inertial forces developed in wall are resisted through shell action providing excellent resistance to lateral forces. In addition, the thick walls required for thermal insulation have high in-plane stiffness which provides excellent performance under lateral loads The roofing materials are generally very light weight, and develops low inertia forces. Since the roof is constructed from extremely ductile materials such as bamboo and straw, the performance of.these roofs is usually very robust. Even in situations where the roof collapses, its low weight ensures that the extent of injuries to occupants is very low. In several Bhongas, the roof joist is not directly supported on the cylindrical walls, but is supported by two wooden vertical posts outside the Bhonga, which further improves seismic resistance of the inertia force generated in the roof. In some instances, reinforcing bands at lintel level and collar level have been used to provide additional strength. These bands are constructed from bamboo or from RCC. These increase the lateral load-carrying strength greatly and increase the seismic resistance of the Bhongas.

## 3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 0 and 0 meters, and widths between 0 and 0 meters. The building is 1 storey high. The typical span of the roofing/flooring system is 6 meters. Typical Plan Dimensions: Inner diameter generally varies between 3.0 m to 6.0 m. Typical Span: Cylindrical wall having an inner diameter of 3 to 6. The typical storey height in such buildings is 2.5 meters. The typical structural wall density is more than 20 %. 25% (totally) since the plan is circular in shape.

## 3.5 Floor and Roof System

| Material | Description of floor/roof system | Most appropriate floor | Most appropriate roof |
|---|---|---|---|
| Masonry | Vaulted | ☐ | ☐ |
| | Composite system of concrete joists and | ☐ | ☐ |

| | | | |
|---|---|---|---|
| | masonry panels | | |
| Structural concrete | Solid slabs (cast-in-place) | ☐ | ☐ |
| | Waffle slabs (cast-in-place) | ☐ | ☐ |
| | Flat slabs (cast-in-place) | ☐ | ☐ |
| | Precast joist system | ☐ | ☐ |
| | Hollow core slab (precast) | ☐ | ☐ |
| | Solid slabs (precast) | ☐ | ☐ |
| | Beams and planks (precast) with concrete topping (cast-in-situ) | ☐ | ☐ |
| | Slabs (post-tensioned) | ☐ | ☐ |
| Steel | Composite steel deck with concrete slab (cast-in-situ) | ☐ | ☐ |
| Timber | Rammed earth with ballast and concrete or plaster finishing | ☐ | ☐ |
| | Wood planks or beams with ballast and concrete or plaster finishing | ☐ | ☐ |
| | Thatched roof supported on wood purlins | ☐ | ☑ |
| | Wood shingle roof | ☐ | ☐ |
| | Wood planks or beams that support clay tiles | ☐ | ☐ |
| | Wood planks or beams supporting natural stones slates | ☐ | ☐ |
| | Wood planks or beams that support slate, metal, asbestos-cement or plastic corrugated sheets or tiles | ☐ | ☐ |
| | Wood plank, plywood or manufactured wood panels on joists supported by beams or walls | ☐ | ☐ |
| Other | Described below | ☑ | ☑ |

Random rubble with mud finishing. Roof is considered to be a flexible diaphragm.

## 3.6 Foundation

| Type | Description | Most appropriate type |
|---|---|---|
| Shallow foundation | Wall or column embedded in soil, without footing | ☑ |
| | Rubble stone, fieldstone isolated footing | ☐ |
| | Rubble stone, fieldstone strip footing | ☐ |
| | Reinforced-concrete isolated footing | ☐ |
| | Reinforced-concrete strip footing | ☐ |
| | Mat foundation | ☐ |
| | No foundation | ☐ |
| Deep foundation | Reinforced-concrete bearing piles | ☐ |
| | Reinforced-concrete skin friction piles | ☐ |
| | Steel bearing piles | ☐ |
| | Steel skin friction piles | ☐ |
| | Wood piles | ☐ |
| | Cast-in-place concrete piers | ☐ |
| | Caissons | ☐ |
| Other | Described below | ☐ |

# 4. Socio-Economic Aspects

## 4.1 Number of Housing Units and Inhabitants

Each building typically has 1 housing unit(s). 1 units in each building. Each Bhonga is a single room housing unit. Depending on the economic condition of the owner, a housing unit may consist of several Bhongas. The number of inhabitants in a building during the day or business hours is less than 5. The number of inhabitants during the evening and night is 5-10.

## 4.2 Patterns of Occupancy

A Bhonga is occupied by a single family. Sometimes, a single family housing unit may consist of several Bhongas. The variation depends on the size and economic condition of the family.

## 4.3 Economic Level of Inhabitants

| Income class | Most appropriate type |
|---|---|
| a) very low-income class (very poor) | ☑ |
| b) low-income class (poor) | ☑ |
| c) middle-income class | ☐ |
| d) high-income class (rich) | ☐ |

| Ratio of housing unit price to annual income | Most appropriate type |
|---|---|
| 5:1 or worse | ☐ |
| 4:1 | ☐ |
| 3:1 | ☐ |
| 1:1 or better | ☑ |

| What is a typical source of financing for buildings of this type? | Most appropriate type |
|---|---|
| Owner financed | ☑ |
| Personal savings | ☐ |
| Informal network: friends and relatives | ☑ |
| Small lending institutions / micro-finance institutions | ☐ |
| Commercial banks/mortgages | ☐ |
| Employers | ☐ |
| Investment pools | ☐ |
| Government-owned housing | ☐ |
| Combination (explain below) | ☐ |
| other (explain below) | ☐ |

In each housing unit, there are no bathroom(s) without toilet(s), no toilet(s) only and no bathroom(s) including toilet(s).

Bathroom and latrines are constructed in a separate structure. .

### 4.4 Ownership

The type of ownership or occupancy is outright ownership.

| Type of ownership or occupancy? | Most appropriate type |
|---|---|
| Renting | ☐ |
| outright ownership | ☑ |
| Ownership with debt (mortgage or other) | ☐ |
| Individual ownership | ☐ |
| Ownership by a group or pool of persons | ☐ |
| Long-term lease | ☐ |
| other (explain below) | ☐ |

## 5. Seismic Vulnerability

### 5.1 Structural and Architectural Features

| Structural/ Architectural Feature | Statement | Most appropriate type | | |
|---|---|---|---|---|
| | | Yes | No | N/A |
| Lateral load path | The structure contains a complete load path for seismic force effects from any horizontal direction that serves to transfer inertial forces from the building to the foundation. | ☑ | ☐ | ☐ |
| Building Configuration | The building is regular with regards to both the plan and the elevation. | ☑ | ☐ | ☐ |
| Roof construction | The roof diaphragm is considered to be rigid and it is expected that the roof structure will maintain its integrity, i.e. shape and form, during an earthquake of intensity expected in this area. | ☐ | ☑ | ☐ |
| Floor construction | The floor diaphragm(s) are considered to be rigid and it is expected that the floor structure(s) will maintain its integrity during an earthquake of intensity expected in this area. | ☐ | ☑ | ☐ |
| Foundation performance | There is no evidence of excessive foundation movement (e.g. settlement) that would affect the integrity or performance of the structure in an earthquake. | ☑ | ☐ | ☐ |
| Wall and frame structures-redundancy | The number of lines of walls or frames in each principal direction is greater than or equal to 2. | ☐ | ☐ | ☑ |
| Wall proportions | Height-to-thickness ratio of the shear walls at each floor level is:<br><br>Less than 25 (concrete walls);<br><br>Less than 30 (reinforced masonry walls);<br><br>Less than 13 (unreinforced masonry walls); | ☑ | ☐ | ☐ |
| Foundation-wall connection | Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation. | ☑ | ☐ | ☐ |
| | Exterior walls are anchored for out-of-plane seismic | | | |

| | | | | |
|---|---|---|---|---|
| Wall-roof connections | effects at each diaphragm level with metal anchors or straps | ☐ | ☑ | ☐ |
| Wall openings | The total width of door and window openings in a wall is:<br><br>For brick masonry construction in cement mortar : less than ½ of the distance between the adjacent cross walls;<br><br>For adobe masonry, stone masonry and brick masonry in mud mortar: less than 1/3 of the distance between the adjacent cross walls;<br><br>For precast concrete wall structures: less than 3/4 of the length of a perimeter wall. | ☑ | ☐ | ☐ |
| Quality of building materials | Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate). | ☐ | ☑ | ☐ |
| Quality of workmanship | Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards). | ☐ | ☑ | ☐ |
| Maintenance | Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber) | ☐ | ☐ | ☑ |
| Additional Comments | | | | |

## 5.2 Seismic Features

| Structural Element | Seismic Deficiency | Earthquake Resilient Features | Earthquake Damage Patterns |
|---|---|---|---|
| Wall | Poor quality of construction materials (especially the use of adobe blocks and mud mortar | Excellent resistance to lateral loads due to the shell action of cylindrical walls. | Minor damage for walls constructed with cement mortar and significant damage for walls constructed with mud mortar were observed after Bhuj earthquake. |
| Frame (Columns, beams) | Not Applicable | | |
| Roof and floors | Roofs are simply supported on the walls. Sometimes, vertical posts are used to support the wooden joists, but the connection is not proper. | Roofs have good resistance due to their light weight and use of highly ductile materials. | Only minor damage to the roofs were observed during the Bhuj earthquake, even for Bhongas whose walls had totally collapsed. The roof was able to maintain its structural integrity due to its light weight and weak connection between the roof and the wall. |
| Other | | | |

Bhonga is a very unique example of shear-wall building.

## 5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is D: MEDIUM-LOW VULNERABILITY (i.e., good seismic performance), the lower bound (i.e., the worst possible) is C: MEDIUM VULNERABILITY (i.e., moderate seismic performance), and the upper bound (i.e., the best possible) is E: LOW VULNERABILITY (i.e., very good seismic performance).

| Vulnerability | high | medium-high | medium | medium-low | low | very low |
|---|---|---|---|---|---|---|
| | very poor | poor | moderate | good | very good | excellent |
| Vulnerability Class | A | B | C | D | E | F |
| | ☐ | ☐ | ☑ | ☐ | ☑ | ☐ |

## 5.4 History of Past Earthquakes

| Date | Epicenter, region | Magnitude | Max. Intensity |
|---|---|---|---|
| 0 | Bulandshahar (Uttar Pradesh) | 6.7 | VIII (MSK) |
| 2001 | Bhuj (Gujarat) | 7.6 | X (MSK) |


Figure 1B: Typical Building


Figure 1E: Typical Building


Figure 6B: A Photograph Illustrating Typical Damage (2001 Bhuj earthquake)

# 6. Construction

## 6.1 Building Materials

| Structural element | Building material | Characteristic strength | Mix proportions/dimensions | Comments |
|---|---|---|---|---|
| Walls | Stone masonry in mud mortar (most common for new construction), Adobe walls (old construction), burnt bricks with mud or lime mortar | | | Stone masonry in mud mortar (most common for new construction), Adobe walls (old construction), Burnt bricks with mud or lime mortar |
| Foundation | Same as wall | | | Usually the walls are extended to a depth of 1.0 m into the ground as foundation |
| Frames (beams & columns) | | | | |
| Roof and floor(s) | Bamboo, straw and thatch roof | | | Very light weight and ductile |

## 6.2 Builder

In almost all situations, the owner lives in this construction.

## 6.3 Construction Process, Problems and Phasing

These constructions are carried out by local village masons. The locally available soft stone can easily be cut or chiselled into rectangular blocks, which are used for wall masonry. The local soil is used for mud mortar and to make adobe blocks. Locally available timber and bamboo are used for roof. The entire construction process, which is carried out by the mason with very few unskilled laborers, can be completed within 30 days. The construction of this type of housing takes place in a single phase. Typically, the building is originally designed for its final constructed size. Bhongas are never "designed" in the modern context. However, Bhonga architecture is a very unique aspect of traditional desert architecture of Kutch region in which the size, location and orientation of the Bhonga are planned for very good structural and functional results.

### 6.4 Design and Construction Expertise

The construction process uses traditional expertise and understanding of performance of local building materials. No engineers and architects are involved in the design or construction since this is a traditional housing form which has been in use for several hundred years.

### 6.5 Building Codes and Standards

This construction type is not addressed by the codes/standards of the country.

Not applicable since rural constructions do not require building code compliance.

### 6.6 Building Permits and Development Control Rules

This type of construction is a non-engineered, and not authorized as per development control rules. Building permits are not required to build this housing type.

### 6.7 Building Maintenance

Typically, the building of this housing type is maintained by Builder.

### 6.8 Construction Economics

Rs 160 per sq m (US $4 per sq m) per house in the case of a conventional Bhonga constructed using sun-dried brick, mud and thatch roof. Rs. 1075 per sq m (US $23 per sq m) per house in the case of a Bhonga constructed using a single layer thick burnt brick wall in cement mortar, and with timber conical roof. Only unskilled or semi-skilled labor is required for its construction.

## 7. Insurance

Earthquake insurance for this construction type is typically unavailable. For seismically strengthened existing buildings or new buildings incorporating seismically resilient features, an insurance premium discount or more complete coverage is unavailable.

## 8. Strengthening

### 8.1 Description of Seismic Strengthening Provisions

Strengthening of Existing Construction :

| Seismic Deficiency | Description of Seismic Strengthening provisions used |
|---|---|
| Low resistance to lateral loads | Providing seismic bandage between lintel and roof levels on both outside and inside of the wall. |
| Weak roof support system | Providing additional joists to transfer roof load to the cylindrical walls. |
| | |

| | |
|---|---|
| Weak roof support system | Providing new vertical post adjacent to walls (on the outside) to support the roof joist. |

Strengthening of New Construction :

| Seismic Deficiency | Description of Seismic Strengthening provisions used |
|---|---|
| Low resistance to lateral loads | Using cement mortar and stone or burnt brick masonry for walls. |
| Low resistance to lateral loads | Constructing seismic bands at lintel and roof levels to enhance wall stiffness to lateral loads and to also improve shear resistance near corner of openings |
| Weak roof support system | Providing vertical post adjacent to walls (on the outside) to support roof joinsts |
| Weak roof support system | Providing several joists to transfer roof load to the cylindrical walls or vertical posts. |

## 8.2 Seismic Strengthening Adopted

Has seismic strengthening described in the above table been performed in design and construction practice, and if so, to what extent?

No, seismic strengthening of Bhongas has not been carried out.

Was the work done as a mitigation effort on an undamaged building, or as repair following an earthquake?

Not applicable.

## 8.3 Construction and Performance of Seismic Strengthening

Was the construction inspected in the same manner as the new construction?

No formal structural inspection is done for either new or rehabilitated constructions.

Who performed the construction seismic retrofit measures: a contractor, or owner/user? Was an architect or engineer involved?

In these rural constructions, technically trained personnel are seldom available. Most constructions are carried out by skilled or semi-skilled persons only.

What was the performance of retrofitted buildings of this type in subsequent earthquakes?

No data is available. However, new constructions with earthquake-resistant features performed very well compared to Bhongas without any earthquake-resistant features. The performance of these Bhongas was comparable to that of RCC frame structures in the epicentral region.

Figure 7: Illustration of Seismic Strengthening Techniques

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