World Housing Encyclopedia Report

Country: India

Housing Type: Traditional rural house in Kutch region of India (bhonga)

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1 General Information

1.1 Country
India

1.3 Housing Type
Traditional rural house in Kutch region of India (bhonga)

Figure 1A: Typical Building

1.4 Summary
Bhonga is a traditional construction type of the Kutch district of Gujarat state in India, which has a very high seismic hazard. 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 type of housing is also known as "Architecture without Architects". This type of housing performed very well in the recent M 7.6 Bhuj earthquake of 2001. Very few Bhongas experienced significant damage in the epicentral region, and damage that did occur can be mainly attributed to poor quality of the construction materials or improper maintenance of the structure. It was also observed that the failure of Bhongas in the last earthquake caused very few injuries to the occupants due to the type of collapse.

1.5 Typical Period of Practice for Buildings of This Construction Type

How long has this construction been practiced	
< 25 years	
< 50 years	
< 75 years	
< 100 years	
< 200 years	
> 200 years	X

Is this construction still being practiced?	Yes	No
	X	

Additional Comments: Bhongas older than 50 years have been found in Kutch district of Gujarat state in India.

1.6 Region(s) Where Used
Kutch district of Gujarat state in India

1.7 Urban vs. Rural Construction

Where is this construction commonly found?	
In urban areas	
In rural areas	X
In suburban areas	
Both in rural and urban areas	

Additional Comments: 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.

Figure 1B: Typical Building

Figure 1C: Typical Building

Figure 1D: Typical Building

Figure 1E: Typical Building

Figure 1F: Typical Building

2 Architectural Features

2.1 Openings

A Bhonga generally has only three openings one door and two small windows.

2.2 Siting

	Yes	No
Is this type of construction typically found on flat terrain?	X	
Is this type of construction typically found on sloped terrain? (hilly areas)		X
Is it typical for buildings of this type to have common walls with adjacent buildings?		X

The typical separation distance between buildings is 3.0 meters

2.3 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.

2.4 Building Function

What is the main function for buildings of this type?	
Single family house	X
Multiple housing units	
Mixed use (commercial ground floor, residential above)	
Other (explain below)	

Additional Comments: Insert additional text if applicable

2.5 Means of Escape

Main door of the Bhonga is the only means of escape.

2.6 Modification of Buildings

Recent Bhongas constructions have used wide variety of construction materials. These include 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.

3 Socio-Economic Issues

3.1 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.

3.2 Number of Housing Units in a Building

1 units in each building.

Additional Comments: Each Bhonga is a single room housing unit. Depending on the economic condition of the owner, a housing unit may consist of several Bhongas.

3.3 Average Number of Inhabitants in a Building

How many inhabitants reside in a typical building of this construction type?	During the day / business hours	During the evening / night
< 5	X	
5 to 10		X
10-20		
> 20		
Other		

3.4 Number of Bathrooms or Latrines per Housing Unit

Number of Bathrooms: 0
Number of Latrines: 0

Additional Comments: Bathroom and laterines are constructed in a separate structure.

3.5 Economic Level of Inhabitants

Economic Status		House Price/Annual Income (Ratio)
Very poor	X	/
Poor	X	/
Middle Class		/
Rich		/

3.6 Typical Sources of Financing

What is the typical source of financing for buildings of this type?	
Owner Financed	X
Personal Savings	
Informal Network: friends and relatives	X
Small lending institutions/microfinance institutions	
Commercial banks / mortages	
Investment pools	
Combination (explain)	
Government-owned housing	
Other	

3.7 Ownership

Type of Ownership/Occupancy	
Rent	
Own outright	X
Own with Debt (mortgage or other)	
Units owned individually (condominium)	
Owned by group or pool	
Long-term lease	
Other	

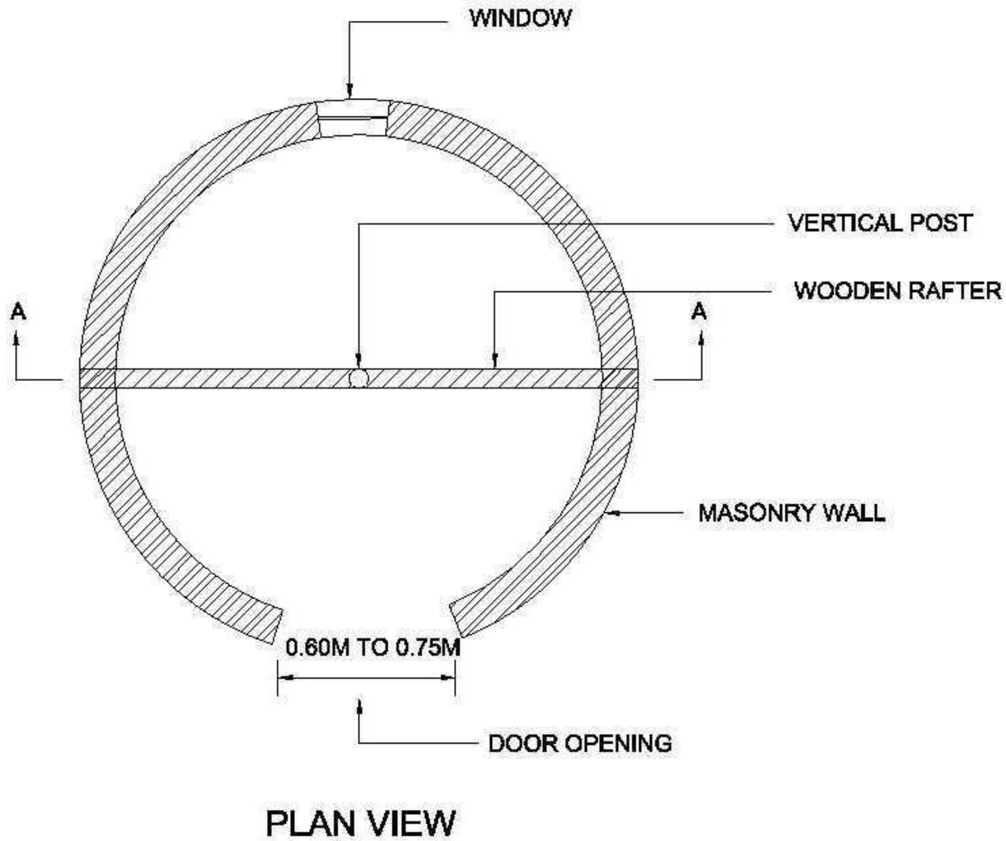


Figure 3: Plan of a Typical Building

4 Structural Features

4.1 Lateral Load-Resisting System

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 perfomance 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 inetia 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.

4.2 Gravity Load-Bearing Structure

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 upto the required fundation depth, and separate foundation is not traditionally constructed. In newer constructions, proper strip footing is also used.

4.3 Type of Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	
Masonry	Stone masonry walls	1	Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)	
		2	Massive stone masonry (in lime or cement mortar)	
	Earthen walls	3	Mud walls	
		4	Mud walls with horizontal wood elements	
		5	Adobe block or brick walls	X
		6	Rammed earth/Pise construction	
	Unreinforced brick masonry walls	7	Unreinforced brick masonry in mud or lime mortar	
		8	Unreinforced brick masonry in mud or lime mortar with vertical posts	
		9	Unreinforced brick masonry in cement or lime mortar (various floor/roof systems)	
	Confined masonry	10	Confined brick/block masonry with concrete posts/tie columns and beams	
	Concrete block masonry walls	11	Unreinforced in lime or cement mortar (various floor/roof systems)	
		12	Reinforced in cement mortar (various floor/roof systems)	
		13	Large concrete block walls with concrete floors and roofs	
Concrete	Moment resisting frame	14	Designed for gravity loads only (predating seismic codes i.e. no seismic features)	
		15	Designed with seismic features (various ages)	
		16	Frame with unreinforced masonry infill walls	
		17	Flat slab structure	
		18	Precast frame structure	
		19	Frame with concrete shear walls-dual system	
		20	Precast prestressed frame with shear walls	
	Shear wall structure	21	Walls cast in-situ	
		22	Precast wall panel structure	
Steel	Moment resisting frame	23	With brick masonry partitions	
		24	With cast in-situ concrete walls	
		25	With lightweight partitions	
	Braced frame	26	Concentric	
		27	Eccentric	
Timber	Load-bearing timber frame	28	Thatch	
		29	Post and beam frame	
		30	Walls with bamboo/reed mesh and post (wattle and daub)	
		31	Wooden frame (with or without infill)	
		32	Stud wall frame with plywood/gypsum board sheathing	
		33	Wooden panel or log construction	
Various	Seismic protection systems	34	Building protected with base isolation devices or seismic dampers	
	Other	35		

Additional Comments: 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.

4.4 Type of Foundation

Type	Description	
Shallow Foundation	Wall or column embedded in soil, without footing	X
	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	
	Wood piles	
	Steel skin friction piles	
	Cast in place concrete piers	
	Caissons	
Other		

4.5 Type of Floor/Roof System

Material	Description of floor/roof system	Floor	Roof
Masonry	Vaulted		
	Composite masonry and concrete joist		
Structural Concrete	Solid slabs (cast in place or precast)		
	Cast in place waffle slabs		
	Cast in place flat slabs		
	Precast joist system		
	Precast hollow core slabs		
	Precast beams with concrete topping		
	Post-tensioned slabs		
Steel	Composite steel deck with concrete slab		
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		X
	Wood single roof		
	Wood planks or beams that support clay tiles		
	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	Random rubble with mud finishing	X	

Additional Comments: Roof is considered to be a flexible diaphragm.

4.6 Typical Plan Dimensions

Additional Comments: Inner diameter generally varies between 3.0 m to 6.0 m.

4.7 Typical Number of Stories

1

4.8 Typical Story Height

2.5 meters

4.9 Typical Span

6 meters

Additional Comments: Cylindrical wall having an inner diameter of 3 to 6

4.10 Typical Wall Density
25% (totally) since the plan is circular in shape

4.11 General Applicability of Answers to Questions in Section 4
The answers are for a Bhonga with inner diameter of about 3.0 m. This is the lower-end of typical diameter of Bhonga. Bhongas with diameter of up to 6.0 m are also sometimes constructed.

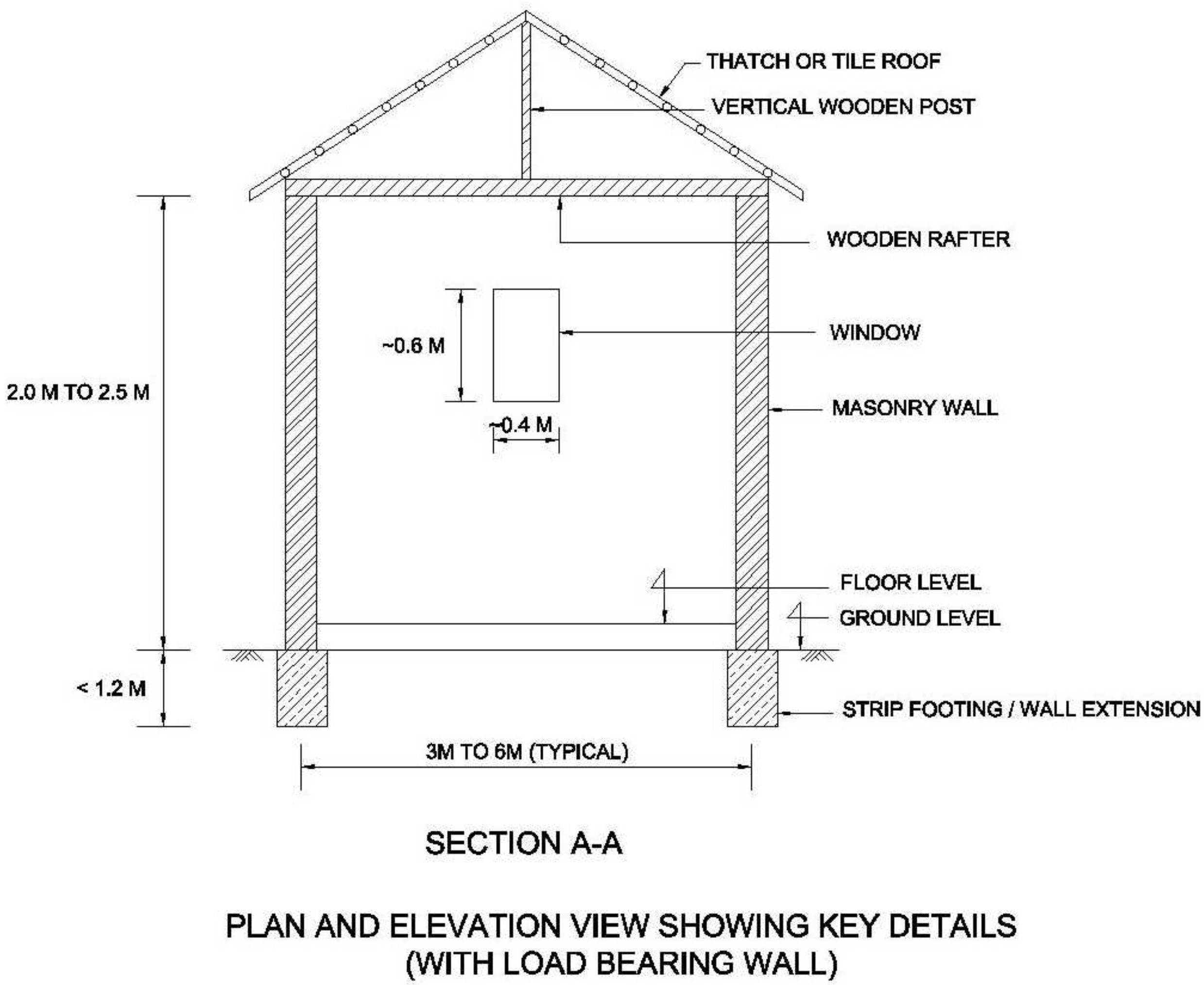


Figure 4: Critical Structural Details

5 Evaluation of Seismic Performance and Seismic Vulnerability

5.1 Structural and Architectural Features: Seismic Resistance

Structural/ Architectural Feature	Statement	True	False	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 form the building to the foundation.	X		
Building configuration	The building is regular with regards to both the plan and the elevation.	X		
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.		X	
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.		X	
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.	X		
Wall and frame structures-redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.			X
Wall proportions	Height-to-thickness ratio of the shear walls at each floor level is: 1) Less than 25 (concrete walls); 2)Less than 30 (reinforced masonry walls); 3) Less than 13 (unreinforced masonry walls).	X		
Foundation- wall connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	X		
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps.		X	
Wall openings	The total width of door and window openings in a wall is: 1) for brick masonry construction in cement mortar: less than 1/2 of the distance between the adjacent cross walls; 2) for adobe masonry, stone masonry and brick masonry in mud mortar: less than 1/3 of the distance between the adjacent cross walls; 3) for precast concrete wall structures: less than 3/4 of the length of a perimeter wall.	X		
Quality of building materials	Quality of building materials is considered to be adequate per requirements of national codes and standards (an estimate).		X	
Quality of workmanship	Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards).		X	
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber).			X
Other				

5.2 Seismic Features

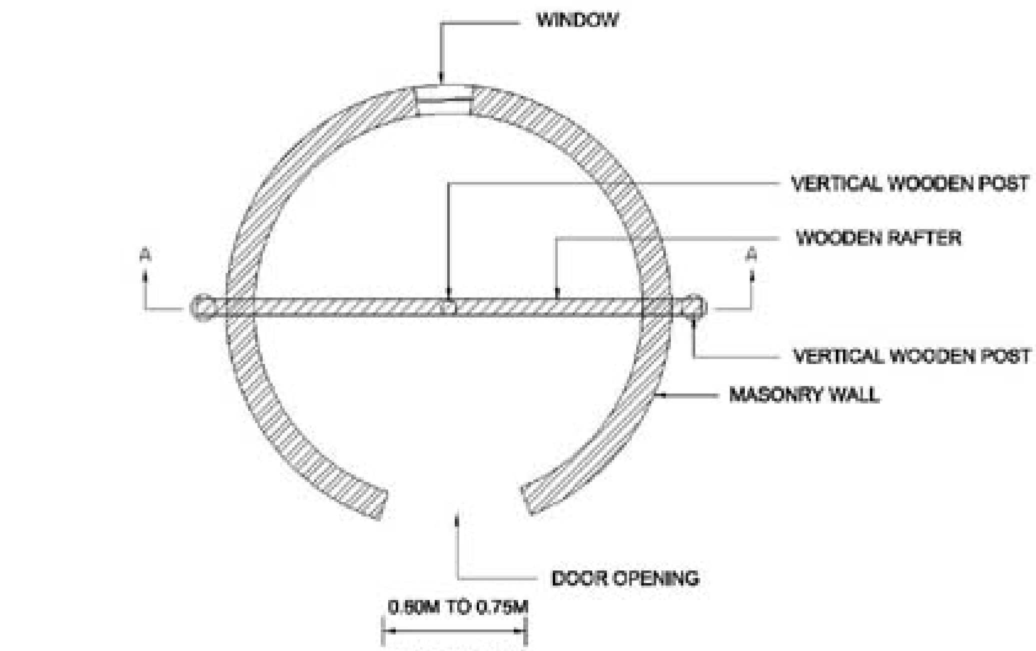
Structural Element	Seismic Deficiency	Earthquake-Resilient Features	Earthquake Damage Patterns
Wall	Poor quality of construction materials (especially the use of adobe blocks and mud mortar	Excellent resistance to lateral loads due to the shell action of cylindrical walls.	Minor damage for walls constructed 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			

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

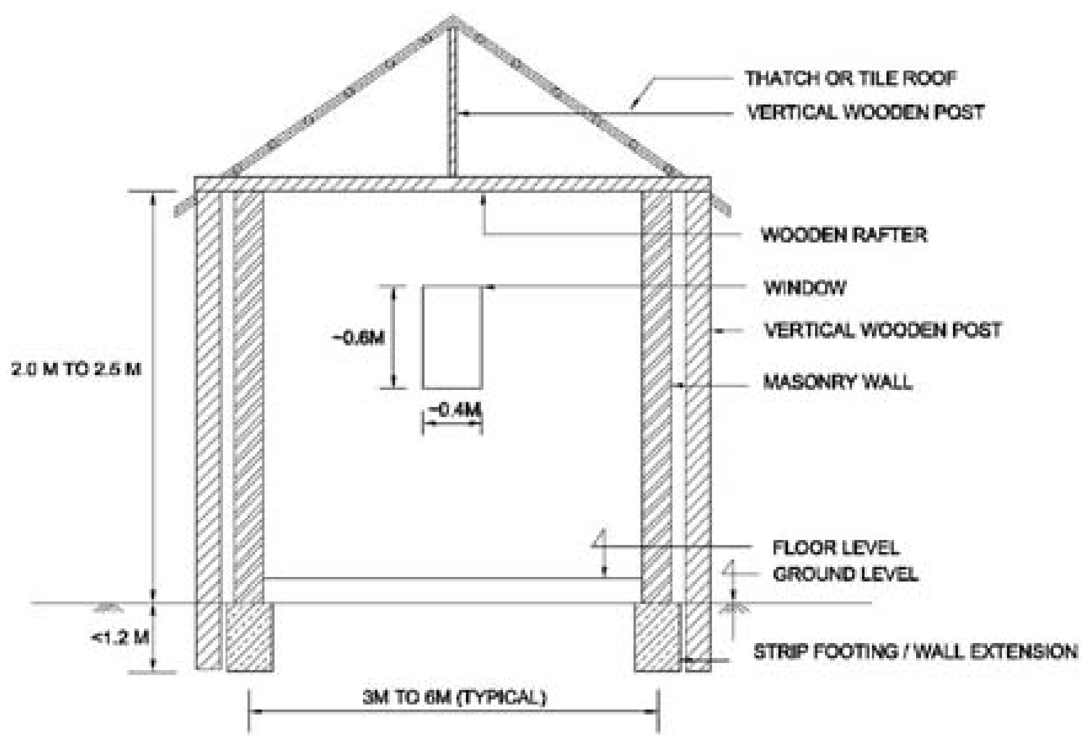
5.3 Seismic Vulnerability Rating

	Vulnerability					
	High (Very Poor Seismic Performance) A	B	Medium C	D	E	Low (Excellent Seismic Performace) F
Seismic Vulnerability Class			<	0	>	

0 - probable value
< - lower bound
> - upper bound



PLAN VIEW



SECTION A-A

PLAN AND ELEVATION VIEW SHOWING KEY DETAILS
(WITH WOODEN POST)

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

6 Earthquake Damage Patterns

6.1 Past Earthquakes Reported To Affect This Construction

Year	Earthquake Epicenter	Richter magnitude(M)	Maximum Intensity (Indicate Scale e.g. MMI, MSK)
0	Bulandshahar (Uttar Pradesh)	6.7	VIII (MSK)
2001	Bhuj (Gujarat)	7.6	X (MSK)

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

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

7 Building Materials and Construction Process

7.1 Description of Building Materials

Structural Element	Building Material	Characteristic Strength	Mix Proportions/ Dimensions	Comments
Walls	Stone masonry in mud mortar (most common for new constructions), Adobe walls (old constructions), Burnt bricks with mud or lime mortar	--	--	Stone masonry in mud mortar (most common for new constructions), Adobe walls (old constructions), Burnt bricks with mud or lime mortar
Foundations	Same as wall	--	--	Usually the walls are extended to a depth of 1.0 m into the ground as foundation
Frame	--	--	--	--
Roof and floors	Bamboo, straw and thatch roof	--	--	Very light weight and ductile
Other				
Other				

7.2 Does the builder typically live in this construction type, or is it more typically built by developers or for speculation?

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

7.3 Construction Process

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 labourers, can be completed within 30 days.

7.4 Design/Construction Expertise

The construction process uses traditional expertise and understanding of performance of local building materials.

7.5 Building Codes and Standards

	Yes	No
Is this construction type addressed by codes/standards?		X

7.6 Role of Engineers and Architects

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.

7.7 Building Permits and Development Control Rules

	Yes	No
Building permits are required		X
Informal construction	X	
Construction authorized per development control rules		X

7.8 Phasing of Construction

	Yes	No
Construction takes place over time (incrementally)		X
Building originally designed for its final constructed size	X	

Additional Comments: 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.

7.9 Building Maintenance

Who typically maintains buildings of this type?	
Builder	X
Owner(s)	
Renter(s)	
No one	
Other	

7.10 Process for Building Code Enforcement

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

7.11 Typical Problems Associated with this Type of Construction

These structures are not very durable due to the use of mud mortar. The use of light-weight roof also causes problems during cyclone season. Several instances of roof damage after cyclonic winds are reported every year. However, due to its light weight, the flying roof debris do not cause major secondary damage.

Figure 7: Illustration of Seismic Strengthening Techniques

8 Construction Economics

8.1 Unit Construction Cost (estimate)

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.

8.2 Labor Requirements (estimate)

Only unskilled or semi-skilled labour is required for its construction.

9 Insurance

9.1 Insurance Issues

	Yes	No
Earthquake insurance for this construction type is typically available		X
Insurance premium discounts or higher coverages are available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features	X	

9.2 If earthquake insurance is available, what does this insurance typically cover/cost?

10 Seismic Strengthening Technologies

10.1 Description of Seismic Strengthening Provisions

Type of intervention	Structural Deficiency	Description of seismic strengthening provision used
Retrofit (Strengthening)	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.
New Construction	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.

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

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

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

Not applicable.

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

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

10.5 Who performed the construction: 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.

10.6 What has been 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.

11 References

Sinha, R. et al., The Bhuj earthquake of January 26, 2001, Indian Institute of Technology, Bombay, April 2001 (available at http://www.civil.iitb.ac.in/BhujEarthquake/Cover_Page.htm).

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13 Figures

Figure 1A: Typical Building