World Housing Encyclopedia

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

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HOUSING REPORT
Unburnt brick wall building with pitched roof (nyumba ya zidina)

Report #	46
Report Date	05-06-2002
Country	MALAWI
Housing Type	Adobe / Earthen House
Housing Sub-Type	Adobe / Earthen House : Adobe block walls
Author(s)	Mauro Sassu, Ignasio Ngoma
Reviewer(s)	Manuel A. Lopez M.

Summary

This type of building is found both in urban and rural areas throughout Malawi. It is a construction type that is gaining popularity at the moment; it is estimated that it constitutes 45% of the country's housing stock. The thatched roof is supported by unburnt mud brick

walls built in mud mortar. The walls are built on a stone platform raised above ground as a protection against floods. These buildings are built without any horizontal and vertical reinforcement. As a result, the strength of the building is very low and it is considered to be very vulnerable to earthquake effects. In the 1989 Salima earthquake (magnitude 6), 9 people died and over 50,000 people were left homeless. Many buildings of this type suffered extensive damage or collapsed.

1. General Information

Buildings of this construction type can be found in all three regions of Malawi and in neighboring countries i.e. Zambia and Tanzania. The percentage of this type of housing is estimated at over 45 %. This type of housing construction is commonly found in both rural and urban areas. This construction type has been in practice for less than 100 years.

Currently, this type of construction is being built. .

Figure 2: Key load-bearing elements

Figure 1: 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 2-3 meters.

2.2 Building Configuration

Rectangular. The number of openings is more than one i.e. could be two doors and two to three windows depending on the size of the building. 8% estimated as overall window and door areas as a fraction of the overall surface area.

2.3 Functional Planning

The main function of this building typology is single-family house. This type of housing is also used for commercial rental housing--many people having multiple rooms, but it is not built as high-rise buildings. In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. None unless it is two door openings type building. Windows are generally too small.

2.4 Modification to Building

Some extensions have been made. In some cases the roofing material has been changed.

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	☐
	Moment-resisting frame	29	With brick masonry partitions	☐
		30	With cast in-situ concrete walls	☐
		31	With lightweight partitions	☐

Steel	Braced frame	32	Concentric connections in all panels	☐
		33	Eccentric connections in a few panels	☐
	Structural wall	34	Bolted plate	☐
		35	Welded plate	☐
Timber	Load-bearing timber frame	36	Thatch	☐
		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)	☐

3.2 Gravity Load-Resisting System

The vertical load-resisting system is timber frame load-bearing wall system. The roof loads are supported on the timber members which are supported on walls. Generally gable walls are used both internally as room partitions and at the extreme ends of the building.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is timber frame load-bearing wall system. The wall takes the load from the roof and wall elements. The walls are placed on a raised platform as a way of keeping above ground/surface water levels during the rainy season. This platform may be considered as a foundation because it projects outside the wall thickness and is generally constructed of stone. However, the connection between the wall and the raised platform is not structural, so there is no transfer of lateral forces at this point. The connection between the roof and the wall does not provide lateral transfer of forces.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 6 and 6 meters, and widths between 4 and 4 meters. The building is 1 storey high. The typical span of the roofing/flooring system is 3 meters. Typical Plan Dimensions: Dimensions can vary. Typical Span: Span varies from 2 to 3 meters. The typical storey height in such buildings is 2.4 meters. The typical structural wall density is up to 20 %. About 20 %.

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	☐	☐
	Solid slabs (cast-in-place)	☐	☐

Structural concrete	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	☑	☑

The floor is made up of rammed earth with mud smear finish. Sometimes iron sheets are used.

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	☐

Stone raised wall is built to support wall and for rainwater dearance.

Figure 3A: Critical structural details

Figure 3B: Critical structural details

Figure 4: An illustration of key seismic features and/or deficiencies

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. Housing units can be many if made for commercial purposes. In this case the house is built as a block. 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 less than 5. or 5-10.

4.2 Patterns of Occupancy

Generally single family occupies one house.

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)	☐

Very poor: no rate, no salary (subsistence farmers). Poor: less than 30 US$ salary.

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 1 bathroom(s) without toilet(s), 1 toilet(s) only and 1 bathroom(s) including toilet(s).

Bathrooms and toilets are externally provided and are not joined to the housing unit. .

4.4 Ownership

The type of ownership or occupancy is renting and 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.	☑	☐	☐
	The roof diaphragm is considered to be rigid and it is expected that the roof structure will maintain its			

Roof construction	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: Less than 25 (concrete walls); Less than 30 (reinforced masonry walls); 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.	☐	☑	☐
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps	☐	☑	☐
Wall openings	The total width of door and window openings in a wall is: For brick masonry construction in cement mortar : less than ½ of the distance between the adjacent cross walls; For adobe masonry, stone masonry and brick masonry in mud mortar: less than 1/3 of the distance between the adjacent cross walls; 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 lateral resistance, weak timber lintels.	Gable construction.	
Frame (columns, beams)			
Roof and floors	Roofing timber embedded in wall.	Light roof system.	

The construction practice is not based on engineering expertise. The tying of the wall girder to the roofing structure contributes somehow to the seismic resistance.

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is *A: HIGH VULNERABILITY (i.e., very poor seismic performance)*, the lower bound (i.e., the worst possible) is A: HIGH VULNERABILITY (i.e., very poor seismic performance), and the upper bound (i.e., the best possible) is *A: HIGH VULNERABILITY (i.e., very poor 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
1957	Champira	5	MMI VIII
1966	Mwanza	5.3	
1967	Thambani in Mwanza	5.4	
1989	Salima	6	MMI VIII

In 1973 another earthquake hit Livingstonia measuring 5.1 on the Richter scale. The 1989 Salima earthquake was the worst in Malawi. It is reported that 9 people died and over 50,000 people were left homeless. These types of buildings suffered a lot of damage, including collapse. Geologists forecast more intense earthquakes could occur in Malawi.

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Unburnt soil block.	N/A	Mud mortar	Soil blocks laid in mud mortar.
Foundation	(no foundation, but wall is rested/placed on a raised platform of stones).	N/A		Stone rubble construction in mud mortar.
Frames (beams & columns)	Timber.	N/A		
Roof and floor(s)	Timber: timber Floor: 1. rammed earth 2. cement screed			Floor: cement screed is laid on rammed earth

6.2 Builder

The builder lives in this type of construction.

6.3 Construction Process, Problems and Phasing

The house is constructed by builders. General knowledge is used during construction. FOUNDATION: The ground is leveled. Stone wall 0.4 m wide is built along the wall perimeter from ground level in mud mortar to a height of 0.4 m. WALL CONSTRUCTION: The dry day/mud blocks form the masonry units with mud mortar as the joining medium. The procedure is like any masonry wall construction. The mortar thickness is 10 mm - 15 mm. At the roofing level of the wall, a wall plate is introduced which is generally of timber poles. ROOFING: Grass thatch or iron sheets supported by timber purlins (generally poles) which run over the gable walls. Truss construction is also used. The construction of this type of housing takes place in a single phase. Typically, the building is originally designed for its final constructed size.

6.4 Design and Construction Expertise

Generally the builders are not trained at any school but learn on the job although some may have been trained at trade school. The level of skill is reasonably good. These buildings are not covered by design standards which makes it very difficult to talk of expertise. No engineers or architects are involved in the design/construction of this housing type. The practice is looked down upon hence less attractive to the professionals.

6.5 Building Codes and Standards

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

6.6 Building Permits and Development Control Rules

This type of construction is a non-engineered, and not authorized as per development control rules.

Malawi does not have National Building Regulations. Building Regulations are generally applicable in cities. Moves are underway to enact National Building Regulations. 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

There are no established/fixed ways of building so that it is difficult to arrive at the unit construction cost. As in 8.1, labor requirements vary considerably from one-man operation to group work.

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. N/A.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Strengthening of Existing Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used

Low level of connection between base of wall and foundation	Truss-wall connection at ground-wall contact

Strengthening of New Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Weak connections between roof and walls	Rebuilding of roof
Weak level of shear strength of mortar	Rebuilding of damaged wall

The practice is generally to build a new building when one shows weaknesses. The only lesson taken into account is that of strengthening weak areas in new construction. These are at truss-wall connection at ground-wall contact.

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?

N/A.

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

N/A.

8.3 Construction and Performance of Seismic Strengthening

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

N/A.

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

Mainly the owner.

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

N/A.

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Author(s)

1. Mauro Sassu
   Associate Professor, Dept. of Structural Engineering, University of Pisa
   Via Diotisalvi 2, Pisa 56126, ITALY
   Email:m.sassu@ing.unipi.it FAX: 39 050 554597

2. Ignasio Ngoma
   Senior Lecturer, University of Malawi
   The Polytechnic P/B 303, Blantyre 3, MALAWI
   Email:ingoma@poly.sdnp.org.mw FAX: 265-670578

Reviewer(s)

1. Manuel A. Lopez M.
   Engineer
   Escuela de Ingenier, Universidad de El Salvador
   San Salvador , EL SALVADOR
   Email:manuel.lopez@unipv.it FAX: 503-225-2506