World Housing Encyclopedia

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

an initiative of
Earthquake Engineering Research Institute (EERI) and
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HOUSING REPORT
Rural mud wall building (nyumba yo mata OR ndiwula)

Report #	43
Report Date	05-06-2002
Country	MALAWI
Housing Type	Adobe / Earthen House
Housing Sub-Type	Adobe / Earthen House : Mud walls
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Summary

This housing construction type is used only for residential purposes. The building technique consists of timber poles as the core or base with a mud smear (plaster) applied on both sides. The plan is circular (only one floor) and the roof is formed by grass thatch supported on timber

poles and cross members. The circular shape of the plan and the light weight of the roof, combined with the wood skeleton or frame, ensure a good seismic response. The seismic vulnerability is increased by poor connections of the wood skeleton and by progressive damage to the natural components.

1. General Information

Buildings of this construction type can be found in the three regions of Malawi (Northern, Central and Southern region). This housing type represents about 5% of the entire housing stock. This type of housing construction is commonly found in rural areas. This construction type has been in practice for less than 200 years.

Currently, this type of construction is being built. .

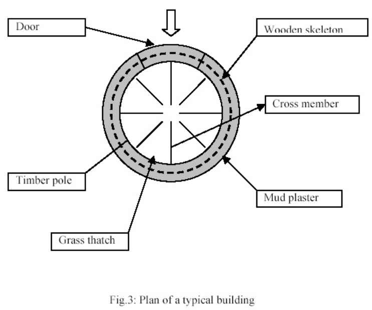

Figure 1: Typical "nyumba yo mata" Buildings


Figure 2: Key load-bearing elements


Figure 3: Plan of a 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 meters.

2.2 Building Configuration

Mainly circular shape. Windows are not provided in this type of circular housing and there is only one door with a typical size range of (1.50 - 1.70 m) height X (0.60 - 0.80 m) wide. The diameter of the round plan is estimated at about 3 - 4 m. In some cases an additional external ring of about 0.50 m is constructed to keep domestic animals and for extra storage space.

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. None.

2.4 Modification to Building

Periodic restoration of the roof (three-five years) and re-smearing with mud on internal and external surfaces.

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	☐
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)	☐

Wattle and daub may not fully cover/describe the structural timber elements where wooden poles are used instead of bamboo/reeds mesh.

3.2 Gravity Load-Resisting System

The vertical load-resisting system is others (described below). The roof and the mud smear vertical loads are directly supported by the wooden structure.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is timber frame. Timber poles form the inner skeleton of the building. Timber vertical elements, of about 5-7 cm diameter (butt end) with a spacing of approximately 1.5 cm, provide the circular transverse section of the structure; horizontal wooden elements (half part of an element with a diameter of 2-3 cm) connect the vertical ones by way of bark strings. The mud layers give transverse stiffness to the wooden skeleton, completing the connection.

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 4 meters. Typical Plan Dimensions: 3 - 4 m in diameter i.e. circular plan Typical Story Height: The height is generally less than two meters. Typical Span: The plan is mainly of circular shape with diameter 3-4 m. There is a principal beam bearing the main central post which supports all the purlin members carrying the thatched roof. The typical storey height in such buildings is 2 meters. The typical structural wall density is up to 20 %. 10 - 13%.

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)	☐	☐
	Waffle slabs (cast-in-place)	☐	☐
	Flat slabs (cast-in-place)	☐	☐

Structural concrete	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	☑	☑

Roof and floor are considered to be flexible diaphragms.

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	☐

The back-fill is tamped (compacted) after all vertical members are placed.

Figure 4: Critical structural details

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. 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 occupants.

4.2 Patterns of Occupancy

Generally a single family occupies a single dwelling.

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)	☐

These houses are communal built and haven't been priced. 50% (very poor - less than 50 US$/per year) - 50% (poor - less than 100 US$/per year). It is difficult to estimate. (From the web page -CIA-The world factbook- the GPD per capita is USD 900.00, 2000 est.) http://www.odci.gov/cia/publications/factbook/geos/mi.html#Econ.

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).

external single latrine and small shelter for bathing are used per housing unit. .

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.	☑	☐	☐
	Height-to-thickness ratio of the shear walls at each floor level is:			

Wall proportions	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	No structural bond between mud and timber core	Well tied vertical and horizontal members light structure.	None
Frame (columns, beams)	N/A	N/A	N/A
Roof and floors	Wall/roof connection weak. Floor is non- structural - it is made of rammed earth.	Roof with strong mesh structure.	None

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 D: MEDIUM-LOW VULNERABILITY (i.e., good seismic performance), and the upper bound (i.e., the best possible) is *D: MEDIUM-LOW VULNERABILITY (i.e., 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
1957	Champira	5	MMI IIIV
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 magnitude. The 1989 Salima earthquake was the worst in Malawi. It is reported that 9 people lost their lives and over 50,000 people were left homeless. Rural mud wall buildings performed reasonably well. Geologists forecast more intense earthquakes in Malawi.

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Timber/mud.	N/A	N/A	Not able to measure.
Foundation	N/A	-	-	Not able to measure.
Frames (beams & columns)	Timber.	N/A	N/A	Not able to measure.
Roof and floor(s)	Roof: Timber. Floor: Rammed earth	Roof: N/A Floor: N/A	Roof: N/A Floor: N/A	Roof: N/A Floor: -

6.2 Builder

Builder lives in this construction type. It is communally built.

6.3 Construction Process, Problems and Phasing

This type of construction is completed by a group/communally. Timber poles are cut to the same length 2.5 m, holes (0.3 m depth) to receive the poles dug in the ground, poles are placed in the holes but not firmly back filled, the horizontal members are tied to the poles, and the embedded poles are firmly fixed in the ground ensuring that the poles are vertical. The mud is now placed/smeared on both sides of the pole walls. The tools used are axe, hoe and buckets. As regards the roof, a central pole (0.2 - 0.3 m diameter) is placed at centre (embedded 0.3 m in the ground) to receive pitched/sloping members (0.06 - 0.07 m diameter) acting as rafters spanning to circular walls. These receive horizontal members 0.03 m diameter acting as purlins placed at 0.3 m centres top and bottom and tied by bark strings. The pitch is not less than 20 degrees. The grass depth is about 0.025 m forming a thatch. The grass is supported on the timber skeleton by three rows of timber placed at the eaves level, mid-way and top tied by bark strings. Poles 0.15 m diameter and spaced 0.6 m apart support eaves projections. These poles are placed about 0.7 m from the wall forming a verandah or khonde. The verandah/khonde is raised 0.15 m above ground level to protect wall from surface or rain water. 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

The level of expertise is good as it is a practice communally executed which ensures all the necessary skills and knowledge. No role at all.

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. Building permits are not required to build this housing type.

6.7 Building Maintenance

Typically, the building of this housing type is maintained by Owner(s).

6.8 Construction Economics

Not possible to estimate because of communal nature of construction. In general, 7 to 10 days (can take longer if done by single person) are required to complete the construction. This includes the cutting of timber poles, digging of holes, placing of poles in the holes, tieing the horizontal members (connecting the vertical poles with transverse thin wooden branches), smearing/application of mud on both sides of poles wall, roofing, and flooring.

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
Wall/roof connection is weak	Periodic rebuilding of the roof
Mud not properly connected with timber core	Periodic re-plastering of the surfaces
Floor is not structural	Possible relative settlements

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?

Yes.

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

The work prevents environmental damages, including damage from earthquakes.

8.3 Construction and Performance of Seismic Strengthening

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

Yes.

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

The owner.

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

N/A: the damaged buildings has been rebuilt.

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