World Housing Encyclopedia Report

Country: Malawi

Housing Type: Rammed earth house with pitched roof (Nyumba yo dinda OR Nyumba ya mdindo)

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1 General Information

1.1 Country

Malawi

FIGURE 1: Typical "nyumba yo dinda" house

1.3 Housing Type

Rammed earth house with pitched roof (Nyumba yo dinda OR Nyumba ya mdindo)

1.4 Summary

This type of construction is used for residential purposes only. The building technique consists of in situ ramming of moist soil in a carefully aligned/placed mould. The mould dimensions are between (250 mm - 300 mm) wide X (400 mm - 450 mm) long X (200 - 300) mm height. The plan of the house is rectangular. The roof is either grass thatch or iron sheets supported on timber poles. This type is found in all three regions of Malawi. The strength of the wall is low and depends on the compacting effort applied. The expected seismic performance is poor. There are no vertical or horizontal reinforcements.

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	X
< 100 years	
< 200 years	
> 200 years	

Is this construction still being practiced?	Yes	No
	X	

1.6 Region(s) Where Used

The house type is found in all three regions of Malawi. This house type represents about 35% of total housing stock in Malawi.

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	

2 Architectural Features

2.1 Openings
Generally three openings are provided, i.e. one door and two windows. The door is in front and so are the windows. The door is about 1.7 m high X 0.6 m wide. The windows are 0.3 m wide X 0.6 m high. The window and door areas are about 5% of the overall wall surface area.

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 2 meters

2.3 Building Configuration
Rectangular shape.

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)	

2.5 Means of Escape
None.

2.6 Modification of Buildings
Re-roofing and wall smearing i.e. smearing with specially prepared mud mortar.

3 Socio-Economic Issues

3.1 Patterns of Occupancy

Generally one family occupies one housing unit.

3.2 Number of Housing Units in a Building

1 units in each building.

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	X
5 to 10		X
10-20		
> 20		
Other		

3.4 Number of Bathrooms or Latrines per Housing Unit

Number of Bathrooms: 1
Number of Latrines: 1

Additional Comments: Bathrooms and toilets are externally provided by a small shelter and a pit latrine.

3.5 Economic Level of Inhabitants

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

Additional Comments: 50% very poor and 50% poor. It is difficult to estimate the ratio of house price/annual income.

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)	X
Owned by group or pool	
Long-term lease	
Other	

4 Structural Features

4.1 Lateral Load-Resisting System

The wall is made by use of a mould which is placed where the wall will be located. Moist soil is placed in it and rammed using a tamping wooden piece in at least three layers. The process is repeated until the proper height is reached. The wall height is about 2.5 m with a thickness of between 0.20 m and 0.30.

4.2 Gravity Load-Bearing Structure

The roof is directly supported by the rammed earth wall which in turn rests directly on the ground.

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	
		6	Rammed earth/Pise construction	X
	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		

4.4 Type of Foundation

Type	Description	
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	X
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	Rammed earth with plaster/smear finishing	X	

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

4.6 Typical Plan Dimensions

Length: 6 - 6 meters
Width: 6 - 6 meters
Additional Comments: This is only indicative size because the size varies depending on the requirements of the owner.

4.7 Typical Number of Stories

1

4.8 Typical Story Height

2.1 meters

Additional Comments: The length to width ratio is never less than 2.

4.9 Typical Span
4 meters

4.10 Typical Wall Density
About 30%.

4.11 General Applicability of Answers to Questions in Section 4
This is traditional building type.

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	Very poor lateral resistance; lintels provided are very weak; soil structure is brittle and prone to crumbling.	Built in situ	
Frame (columns, beams)			
Roof and floors	No ties between roof and wall; weak joining of roof members; and floor is made up of rammed earth.	Wide bearing area at roof support	

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

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)
1989	Salima	6	MMI VIII
1967	Thambani in Mwanza	5.4	
1966	Mwanza	5.3	
1957	Champira	5	MMI IIIV

Additional Comments: In 1973 another earthquake hit Livingstonia with magnitude of 5.1 on the Richter scale. The 1989 Salima earthquake was the worst in Malawi. 9 persons lost their lives whilst over 50,000 people were left homeless. Geologists forecast more intense earthquakes in Malawi. Rammed earth buildings were the worst affected.

7 Building Materials and Construction Process

7.1 Description of Building Materials

Structural Element	Building Material	Characteristic Strength	Mix Proportions/ Dimensions	Comments
Walls	Rammed earth	N/A		
Frame	Timber			

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

Yes

7.3 Construction Process

The house is built by a special master builder who learns the job as an assistant. He learns the job as he helps with bringing the soil (as assistant). A pit is dug and water is poured in it overnight. The soil is only expected to be moist i.e. the soil must not retain the water. The tools used are a hoe, two buckets, a mould, a tamping wooden piece, and a scraper for removing soil from the mould.
FOUNDATION: There is no foundation. The lines of the walls are marked on levelled ground, pegs are placed where necessary.
WALL CONSTRUCTION: The wall is made of rammed earth. A site of the soil pit is identified with trials to make sure that the soil does not have a lot of clay content. Soil is dug and water poured in it to soak it over night. The moisture of the soil is critical so that remixing is done from time to time. The soil is then moved to the mould which is already placed in the proper place on the construction site. The soil is rammed in layers in the mould. It is necessary to ensure that a proper compacting effort has been achieved before removing the mould.
ROOFING: The roof is made up of grass thatch placed on timber poles made into a grid/mesh to retain the grass. The poles are supported on a timber pole beam which is itself supported on two king posts which are supported by timber pole beams spanning across the longitudinal walls. The two beams are placed at 1/4 points from the ends. Once the grass thatch has been placed, small sized timber poles are split and placed above grass and tied to poles below grass so that grass does not move out of place. This is done at 1/3 points all round.
OPENINGS: The openings are few. Timber lintels are provided although not strong.

7.4 Design/Construction Expertise

Generally good level of expertise based on this practice.

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 role so far.

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

7.9 Building Maintenance

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

7.10 Process for Building Code Enforcement

N/A

7.11 Typical Problems Associated with this Type of Construction

Major problem is if roof leaks because soil crumbles.

8 Construction Economics

8.1 Unit Construction Cost (estimate)
Difficult to estimate because of communal nature of working.

8.2 Labor Requirements (estimate)
The builder, assistant, and others for drawing water from borehole, etc.

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)	Weak lintels	Reinforcing with wood lintels
	No ties between roof and wall	Inserting of ties
	Weak joining of roof members	Wood transverse connections

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

No.

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

Repair following earthquake damage.

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

Yes.

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

The owner - no architects or engineers are involved.

10.6 What has been the performance of retrofitted buildings of this type in subsequent earthquakes?

N/A

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13 Figures

FIGURE 1: Typical "nyumba yo dinda" house

FIGURE 2: Typical Building

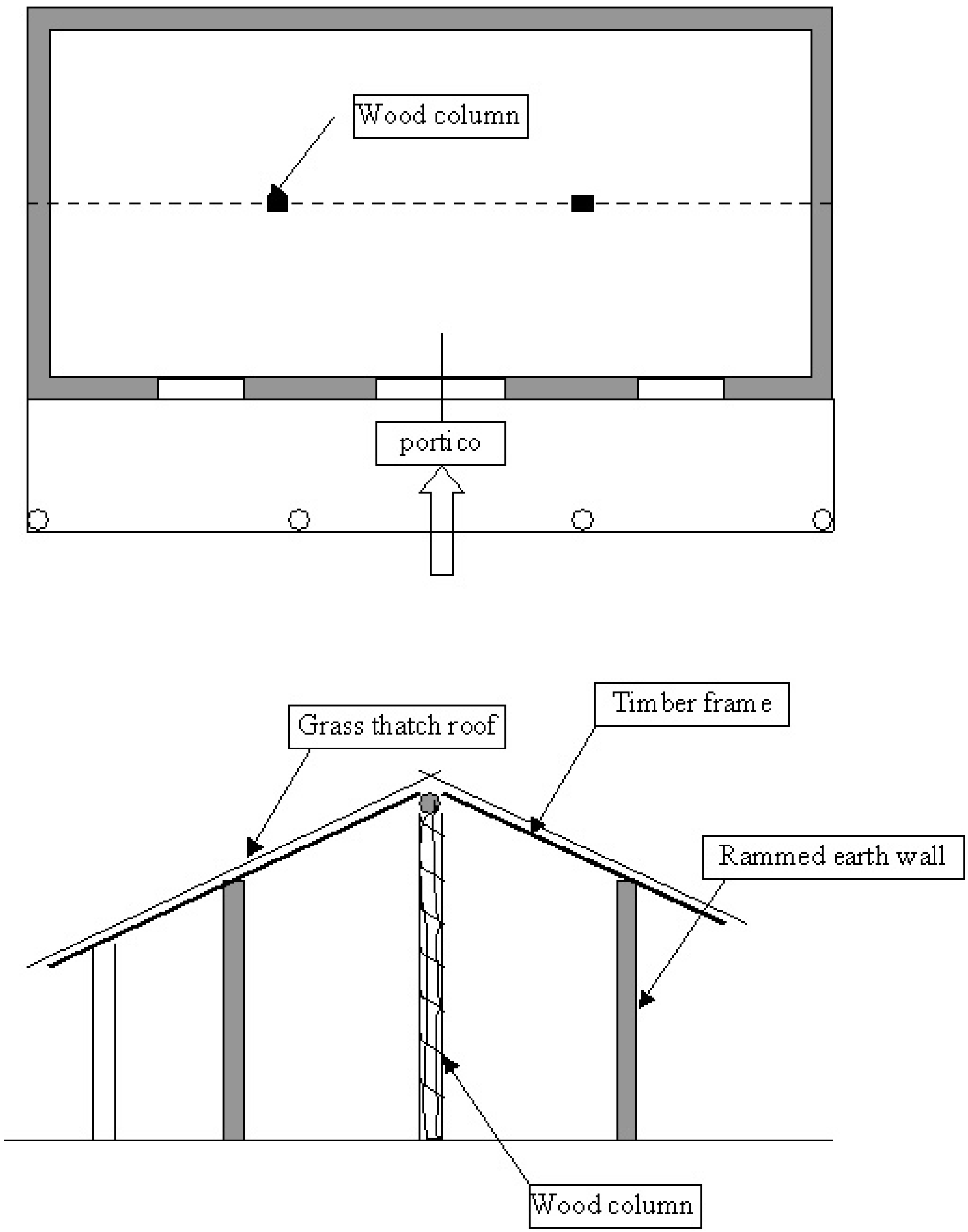

FIGURE 3: Plan and transverse section of a Typical Building

FIGURE 4: Critical Structural Detail

FIGURE 5: An Illustration of Key Seismic Features and/or Deficiencies