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Seismically Active Areas of the World

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HOUSING REPORT
Vivienda de Minifalda (Wooden houses with heavy bases)

Report #	148
Report Date	24-02-2008
Country	NICARAGUA
Housing Type	Timber Building
Housing Sub-Type	Adobe / Earthen House : Mud walls
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Summary

The term 'minifalda', translated 'miniskirt' refers to the building's walls which consist of

masonry or concrete in the lower part, while the upper part is made of a light wood construction (also 'madera y concreto'). According to a recent population census carried out in 2005 (INEC, 2006), the total percentage of minifalda houses in Nicaragua was around 7% (8% in urban and 5.6% in rural areas). In the year 1998, minifalda represented 9.8% of the total houses in Nicaragua (12.8% in urban and 6.1% in rural areas; according to OPAS, 2001). Comparing the two numbers, it shows that the rate of this construction type on the total building stock in Nicaragua has reduced considerably. The combination of a more stable and consolidated base made of concrete or masonry and a light and flexible upper part of the walls made of wood frame construction, provides these houses with some advantages. However, the heavy roofs, which consist mostly of tiles, increase the vulnerability of the buildings especially during earthquake action.

1. General Information

Buildings of this construction type can be found in all parts of the country, but a concentration of this construction technique can be seen in the municipalities of Managua and Masaya (both >10%) as well as in the municipalities of Rivas and Río San Juan (9.3% and 7.9% respectively). Figure 2 illustrates the percentages of minifalda houses in the 15 municipalities (departamentos) and the 2 autonomous communities (comunidades autónomas) of Nicaragua based on the population census of 2005 (INEC, 2006). This type of housing construction is commonly found in both rural and urban areas.

The percentage of minifaldas in urban areas is slightly larger than in rural areas, e.g., according to OPAS (2001) in 1998: 12.8% in urban and 6.1% in rural areas and according to INEC (2006) in 2005: 8% in urban and 5.6% in rural areas. However, these numbers show large variations between the different municipalities.

This construction type has been in practice for less than 50 years.

Currently, this type of construction is not being built. The Minifalda construction type was introduced as an alternative for an earthquake-resistant house after the 1972 Managua earthquake. Its forerunner was a building type, which had foundation walls several centimeters above the ground surface. Because of the high price of lumber, this construction type is not built very often today. A similar technique uses plasterboard walls (plycem) instead of lumber.

Figure 1: Typical minifalda houses in Masaya, Nicaragua. [Click to enlarge figures]

Figure 2: Percentages of minifalda houses in the 17 different municipalities of Nicaragua after the population census in 2005 (INEC, 2006). [Click to enlarge figures]

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat, sloped and hilly terrain. They share common walls with adjacent buildings. Minifalda houses often are built side-by-side without any gaps between them. Especially in Managua, minifalda houses often are built continuously

2.2 Building Configuration

The typical building shape is rectangular in plan. However, houses located at non-rectangular street corners are often irregular or asymmetric in plan. Figures 3 and 4 illustrate the typical plans of residential minifalda buildings in rural areas of Guatemala. Even though single structural details may differ between Guatemala and Nicaragua, the plans are generally representative for Nicaraguan conditions. A common plan dimension for minifalda houses in Nicaragua is 6m x 6m ('modulo basico' = 36 m²; Figure 5). Minifalda houses have few windows, often with very small dimensions (40*40cm; See Figures 1, 8, and 9). The windows are always located in the wooden (upper) part of the walls. The window sill is often formed by the upper edge of the concrete base. Even when the building is used for small retail trade or handicraft business, larger openings for showcases or sales counters do not exist. Compared to the size of the windows, the doors appear to be oversized. At the positions of the doors there are cut-outs in the concrete wall bases, such that the bottom quarter to half of the door frame consists of concrete, while its upper part is framed with wood.

2.3 Functional Planning

The main function of this building typology is single-family house. Minifalda houses often accommodate small shops (retail trade) or handicraft businesses, in addition to their common use as single family dwellings. In a typical building of this type, there are no elevators and no fire-protected exit staircases. Typically, each house has between 2 and 4 doors, which provide means of escape.

2.4 Modification to Building

One common modification is to change the roof material. During renovation, wooden walls are sometimes replaced by plasterboard walls (plycem).

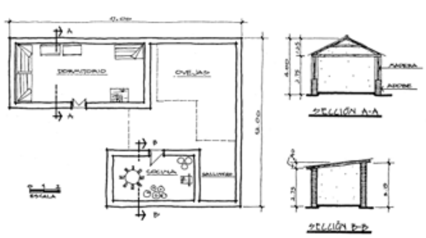

Figure 3: Plan shape and cross-sections of a residential home consisting of a minifalda and an adobe part (location: Zunil, Guatemala; from Marroquin and G

Figure 4: Plan and elevations of a typical minifalda building (location: San Raymundo, Guatemala; from Marroquin and G

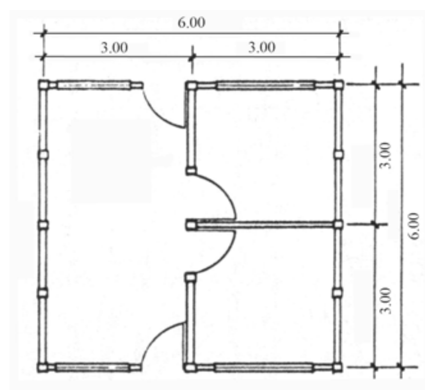

Figure 5: Typical plan of a minifalda building in Nicaragua with a living area of 36 m2 (

3. Structural Details

3.1 Structural System

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

Masonry	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)	☐

The structural system is a mix of a wooden frame standing on walls made of clay bricks, adobe masonry or concrete blocks.

3.2 Gravity Load-Resisting System

The vertical load-resisting system is timber frame load-bearing wall system. The gravity loads on the building mostly result from the roof material itself (i.e. heavy clay tiles, corrugated iron, asbestos sheets). They are transferred from the roof by wooden beams or purlins to the walls (Figure 7). The gravity loads are then transferred from the walls to the foundation.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is timber frame load-bearing wall system. Walls comprise the lateral load-resisting system in the building. The walls are made of masonry (clay bricks, concrete blocks or adobe) in the lower portion and a light wooden construction in the upper portion. Together the two parts of the wall (the lower massive part and the upper wood frame) are able to resist the lateral loads. However, the important feature in this respect is how both parts are connected, e.g., how the vertical frame elements (wooden posts) are tied to the masonry walls. In some cases, the posts are embedded between lengths of masonry at the base of the wall (Figure 6). The gabled or mono-pitched roof normally consists of a very light construction which cannot be considered a diaphragm and therefore may not support any lateral loading.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 3.5 and 6 meters, and widths between 3.5 and 6 meters. The building is 1 storey high. The typical span of the roofing/flooring system is 3.5-5.0 meters. The common plan size is 6m x 6m ('modulo basico'; Figure 5). The typical storey height in such buildings is 2.2-3.5 meters. The typical structural wall density is up to 10 %. Detailed measurements for typical wall density are not available.

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	☑	☑

The floor is directly built on the ground. The roof is not considered to act as a rigid 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	☐

Figure 6: Detailing of the transition zone between the masonry base and

Figure 7: Roof made of asbestos sheets supported by wooden beams

upper wooden part of the wall. [Click to enlarge figures] which loosely rest on the wooden walls. [Click to enlarge figures]

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 1 housing unit(s). and typically one family occupies the house. The number of inhabitants in a building during the day or business hours is less than 5. According to the recent population census conducted in 2005, 46.2% of all conventional houses in Nicaragua are occupied by less than 5 people, 46.3% by 5 to 9, and 7.5% by 10 or more persons (INEC, 2006). The number of inhabitants during the evening and night is 5-10.

4.2 Patterns of Occupancy

No details are available on this.

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)	☐

A typical house of this type costs US $3,770, while a typical annual income for a poor family is US $730.

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).

According to a population census in 1998 (OPAS, 2001) around 80% of the minifalda houses in Nicaragua had a direct connection to the potable water supply system, 12% an indirect and 8% no connection. .

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)	☐

Most houses are owned by the residents; some are rented out.

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: 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
Walls (generally)	- Use of different construction materials over wall height leads to stiffness and mass differences.		
Wall bases (masonry)	- Brittle and heavy with possibly insufficient resistance to out-of-plan forces		
Wooden wall frames	- Inadequate anchorage of wooden posts to the masonry base of the wall - Lack of preservative treatment of timbers leading to deterioration due to vermin or insects	- Flexibility, elasticity - Light-weight construction	- Anchorage / embedment failure of wooden posts
Roof	- No diaphragm action - No strong connection to the walls - Heavy dead loads in the case of heavy clay tiles - Material deterioration of wooden trusses due to climate effects	- Low dead loads in the case of corrugated iron or asbestos sheeting	- Total and partial collapse of roof construction

The minifalda construction type is not covered by the vulnerability table of the European Macroseismic Scale EMS-1998 (Grünthal (ed.), 1998). However, it is largely comparable with a timber wood frame construction. Timber structures are generally classified into vulnerability class D with a probable range between C and E, and in some exceptional cases B. However, since minifalda buildings basically consist of a mixed wall construction with different materials involved, their seismic behavior may not be as good as pure timber structures and may be classified as a higher vulnerability class. The different stiffness of the lower masonry and the upper wooden construction may lead to more damage. This two-part construction technique does provide some advantages which mainly consist of protecting the wood from ascending earth-moisture and splash water.

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is C: MEDIUM VULNERABILITY (i.e., moderate seismic performance), the lower bound (i.e., the worst possible) is B: MEDIUM-HIGH VULNERABILITY (i.e., poor 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
1972	Managua	6.2	VIII-IX
1985	Lago de Nicaragua, Rivas		
1992	Pacific ocean		
2000	Laguna de Apoyo	5.4	V-VI (MMI)
2005	Isla de Ometepe	5.6	

Compared to other dwelling types minifalda construction has behaved well during past earthquakes in Nicaragua, even though a considerable number of destructive earthquakes occurred (See table listing those events after 1972). After the 1972 Managua earthquake, minifalda houses became very popular. Some international aid organizations (e.g. German Red Cross, Guatemalan Red Cross, Asociación Christiana de Desarrollo) suggested the use of this construction technique for rebuilding residential and school buildings in Guatemala after the 1976 earthquake (Marroquin and Gándara, 1976).

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	For the wall base, masonry (adobe, clay bricks, or concrete blocks) is used. For the upper section of walls, wood is used.	No information is available on material strengths, mix of materials, etc. However, material properties of the base walls will not differ from those used for conventional adobe, clay brick or concrete block buildings in Nicaragua or entire Central America (See e.g., EERI-WHE contribution #144 by Lang et al. on adobe buildings in Guatemala).		
Foundation	For the foundations, mud, field stones, or concrete is used.	No information is available on material strengths, or mix of materials.		
Frames (beams & columns)				
Roof and floor(s)	For the roofs, wooden planks with clay tiles or corrugated sheets are used. Floors are made of earthen materials or cast plaster floor (screed).			

6.2 Builder

The builder generally occupies the house and is the house owner.

6.3 Construction Process, Problems and Phasing

Structural engineers or architects are generally not involved in the design or erection process of this building type. As it is described earlier, the bases of these buildings do not differ from conventional adobe, clay brick or concrete block buildings (compare e.g., to EERI-WHE contribution #144 by Lang et al. on adobe buildings in Guatemala). Consequently the first steps of the construction process will be comparable with those for these building types. After the base walls are completed, i.e. the walls are brought up to approximately 1/3 to ½ of the story height, the vertical elements (wooden posts) of the wood frame are connected to or embedded into the wall bases (see Figure 6). As soon as the wood frames are completed with the horizontal elements (beams) and diagonal struts, the external wooden panels are connected to the frame. The wooden panels always are oriented in vertical direction (see Figures 1, 8, and 9). Later or in parallel to the mounting of wall panels, the timber beams and purlins of the roof construction are connected to the wall frame. Tiling is done afterwards with the roofing material as e.g., clay tiles, asbestos-cement or corrugated metal sheets. The construction process is finished by furnishing the wall bases with plaster and bringing a colorful paint the wooden walls. 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

No design or construction expertise can be found. Expertise may only be gained by word-of-mouth. Some international aid organizations suggested the use of this construction technique for rebuilding residential and school buildings in Guatemala after the 1976 earthquake (Marroquin and Gándara, 1976). However, guidelines for its design and construction have not yet been developed.

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) and Tenant(s).

6.8 Construction Economics

A typical building of this type costs US $38/sqm. It typically takes 1-2 months to construct one housing unit.

Figure 8: Typical minifalda houses in Managua, Nicaragua. [Click to enlarge figures]

Figure 9: Typical minifalda houses in Masaya, Nicaragua. [Click to enlarge figures]

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. Earthquake insurance is only available for those buildings addressed in the code and which are constructed according to the code. For those buildings not meeting the requirements of the code, the insurance policies are higher. And since the owner or occupants of minifalda buildings are poor and unable to afford these higher rates, essentially none of these buildings are insured.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

There are no reports of minifalda houses in Central America having been damaged in past earthquakes. Consequently, strengthening or retrofitting measures are not known.

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?

Not applicable.

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?

Not applicable.

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

Not applicable.

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

Not applicable.

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