World Housing Encyclopedia

A Resource on Construction in Earthquake Regions

an initiative of
Earthquake Engineering Research Institue (EERI) and
International Association for Earthquake Engineering (IAEE)

HOUSING REPORT

Timber stilt homes

Report#	165
Last Updated	
Country	Belize
Author(s)	Laura Redmond, Reginald DesRoches ,
Reviewers	Sugeng Wijanto ,

Important

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participant’s organizations.

General Information

Building Type:	Timber stilt homes
Country:	Belize
Author(s):	Laura Redmond Reginald DesRoches
Last Updated:	
Regions Where Found:	Buildings of this construction type can be found in the suburbs surrounding Belize City and Belmopan, as well as rural communities throughout the country. This type of housing construction is commonly found in both rural and sub-urban areas.
Summary:	This type of home is a wood frame building built on stilts. The first story is left open to prevent flooding in hurricanes. This construction practice may make these structures vulnerable to seismic events as the building is effectively a large mass placed on top of a very flexible soft story. Additional vulnerabilities may come from settlement effects of the stilts, which are attached to concrete footings, as the soil conditions are variable and generally no formal geotechnical surveys are done in Belize.
Length of time practiced:	76-100 years
Still Practiced:	Yes
In practice as of:	
Building Occupancy:	Single dwelling
Typical number of stories:	2
Terrain-Flat:	Typically
Terrain-Sloped:	Off
Comments:	The main function of this building typology is single-family house. Extended family will live in the house as well if the famil

Features

Plan Shape	Rectangular, solid

Additional comments on plan shape	Buildings are regular in plan, but have an open first story, which could produce a soft-story mechanism.
Typical plan length (meters)	5-10
Typical plan width (meters)	5-10
Typical story height (meters)	41702
Type of Structural System	Wooden Structure: Load-bearing Timber Frame: Post and beam frame (no special connections)
Additional comments on structural system	Lateral load-resisting system: The lateral load-resisting system is timber frame. The lateral load-resisting system is not formally designed. As built, the siding and the plywood walls take the pressure loading from wind, but these structures have been shown to perform poorly in hurricanes. Gravity load-bearing system: The vertical load-resisting system is timber frame. Loads are transferred to the frame through a plywood floor.
Gravity load-bearing & lateral load-resisting systems	
Typical wall densities in direction 1	0-1%
Typical wall densities in direction 2	0-1%
Additional comments on typical wall densities	The typical structural wall density is up to 1 %.
Wall Openings	There are typically one to two windows on each face of the house with a single front door.
Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	There are no typical structural modifications to the original building plan.
Type of Foundation	Other Foundation
Additional comments on foundation	Typically, the buildings have shallow concrete footings that are made of plain concrete and a timber post is attached with a bracket.
Type of Floor System	Composite cast-in-place reinforced concrete and masonry floor system
Additional comments on floor system	Timber: Wood plank, plywood or manufactured wood panels on joists supported by beams or walls; The typical flooring system is plywood panels nailed into wood joists.
Type of Roof System	Roof system, other

Additional comments on roof system	Timber: Wood planks or beams that support slate, metal, asbestos-cement or plastic corrugated sheets or tiles; The corrugated metal sheeting used for roofing is rarely tied down appropriately for hurricanes and there has been severe damage to the roofs in the past.
Additional comments section 2	Typical separation distance between buildings: 10 meters

Typical wooden stilt home with a shed added underneath

Close up of wood stilts

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	The walls are made of plywood or press board with wood siding. The frames and columns are timber posts and beams.	Building data is unknown and in poor families the materials may be reclaimed.
Foundations	The foundations are timber posts attached to un-reinforced concrete footings.	
Floors	The floor is a plywood sheeting nailed into timber joists attached to the beams.	
Roof	The roof is constructed of	

	corrugated metal sheeting placed on timber trusses, often without tie downs.	
Other		

Design Process

Who is involved with the design process?	Other
Roles of those involved in the design process	Most residential homes are not "designed" and are drawn up by technicians with high school or technical college degrees who have experience in construction. Details are generally determined based on experience and similarly sized projects. In formally constructed residences, the house is designed and plans are drawn by either a technician, an architect or an engineer and sent to the Central Building Authority (CBA) for approval.
Expertise of those involved in the design process	

Construction Process

Who typically builds this construction type?	OwnerContractor
Roles of those involved in the building process	In formally constructed residences the house is built by a contractor who is hired by the homeowner. Informal construction is typically built by the owner or the community.
Expertise of those involved in building process	Construction workers and contractors typically have no formal training. Engineers and architects are typically not involved in the construction process of this type of housing.
Construction process and phasing	Once they have a building permit, construction is conducted in a single phase by either the engineering company, or a contractor the owner has hired to build the house. However, most of the timber homes in the area are informally constructed. The construction of this type of housing takes place in a single phase. Typically, the building is originally not designed for its final constructed size.
Construction issues	

Building Codes and Standards

Is this construction type address by codes/standards?	Yes
	Currently the CBA recommends using the IBC design code,

Applicable codes or standards	but the Caribbean Uniform Building Code (CUBiC), the British Standards, and the former UBC are also commonly used. The year the first code/standard addressing this type of construction issued was 1986. The first building code in place was the CUBiC. The most recent code/standard addressing this construction type issued was 2008. The Central Building Authority now recommends the use of the IBC. The Central Building Authority is a new governing body established in 2008. It is comprised of a 12 person board and 4 inspectors. Their primary purpose is to make recommendations to the local building authorities within each city. It is up to the local authorities to enforce their recommendations.
Process for building code enforcement	

Building Permits and Development Control Rules

Are building permits required?	Yes
Is this typically informal construction?	Yes
Is this construction typically authorized as per development control rules?	No
Additional comments on building permits and development control rules	In order to get a permit to build, the CBA recommendations specify that a building 1-2 stories tall and less than 1,000 sq. ft. can be constructed by a technician or contractor; buildings that are 1,000-3,000 sq. ft. must have the stamp of either an architect or an engineer, and buildings greater than 3,000 sq. ft. must have the stamp of both an engineer and an architect. However, there is no requirement for calculations to be submitted, just the final drawings with the appropriate stamps needed for approval. Inspections are conducted before occupancy starts and in case of a change of use. CBA also recommends routine inspection of commercial structures every four years. Buildings of this type are rarely reported to the Central Building Authority, and are usually built informally.

Building Maintenance and Condition

Typical problems associated with this type of construction	
Who typically maintains buildings of this type?	BuilderOwner(s)
Additional comments on maintenance and building	The CBA recommends routine inspection of commercial structures every four years, but the local district authorities can choose rather or not to enforce this

condition	requirement. Residential construction is maintained by the owner.

Construction Economics

Unit construction cost	
Labor requirements	Construction typically takes less than five months.
Additional comments section 3	

Wooden stilt houses may be poorly maintained, but still occupied

Stilt houses fell off their timber posts during the 2009 earthquake

Construction of a timber stilt home

Socio-Economic Issues

Patterns of occupancy	In the rural communities occupancy does not vary much, with only the men gone throughout the day as most make their living by farming their own land. In suburban areas the entire family may be gone for the day, at jobs or school in the city.
Number of inhabitants in a typical building of this construction type during the day	5-10
Number of inhabitants in a typical building of this construction type during the evening/night	5-10
Additional comments on number of inhabitants	The number of people in the house typically depends on the income of the family. If they are poor, which tends to be the majority rural community, the extended family will also occupy the house.
Economic level of inhabitants	Very low-income class (very poor)Low-income class (poor)
Additional comments on economic level of inhabitants	House Price/Annual Income (Ratio): 4:1 The higher-income families live in the suburbs and do not share the home with extended family members. Lower-income families live in rural areas and will share the home with extended family members.
Typical Source of Financing	Personal savingsCommercial banks/mortgages
Additional comments on financing	
Type of Ownership	Own with debt (mortgage or other)Units owned individually (condominium)
Additional comments on ownership	
Is earthquake insurance for this construction type typically available?	Yes
What does earthquake insurance typically cover/cost	In Belize, insurance is now available against floods, hurricanes and earthquakes.
Are premium discounts or higher coverages available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features?	Yes
Additional comments on premium discounts	

Additional comments section 4	

Earthquakes

Past Earthquakes in the country which affected buildings of this type

Year	Earthquake Epicenter
1976	(15.32# N, 89.10# W)
1977	(16.70# N, 86.61# W)
1980	(15.89# N, 88.52# W)
1997	(16.16# N, 87.92# W)
1999	(15.78# N, 88.33# W)
2009	(16.73# N ,86.22# W)

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	The past earthquakes listed here are only those over magnitude 6.0. The effects of the earthquakes are often less intense in Belize because the earthquake epicenters have been fairly shallow and far off the coast in the Caribbean Sea.
Additional comments on earthquake damage patterns	Overall damage patterns observed in past earthquakes for this type of construction included - (footing foundation): Houses sunk several feet into the ground (wood post stilts): Houses have fallen off their timber post stilts during a past earthquake (roof): No earthquake damage observed, but many roofs have been taken off during hurricanes.

Structural and Architectural Features for Seismic Resistance

The main reference publication used in developing the statements used in this table is FEMA 310 “Handbook for the Seismic Evaluation of Buildings-A Pre-standard”, Federal Emergency Management Agency, Washington, D.C., 1998.

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.

Structural/Architectural

Feature	Statement	Seismic Resistance
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.	FALSE
Building Configuration-Vertical	The building is regular with regards to the elevation. (Specify in 5.4.1)	FALSE
Building Configuration-Horizontal	The building is regular with regards to the plan. (Specify in 5.4.2)	FALSE
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.	FALSE
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.	FALSE
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.	FALSE
Wall and Frame Structures-Redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	TRUE
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);	N/A

Foundation-Wall Connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	TRUE
Wall-Roof Connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps.	FALSE
Wall Openings		TRUE
Quality of Building Materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	TRUE
Quality of Workmanship	Quality of workmanship (based on visual inspection of a few typical buildings) is considered to be good (per local construction standards).	FALSE
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber).	FALSE

Building Irregularities

Additional comments on structural and architectural features for seismic resistance	1) Lateral Load Path: The lateral load system is designed for wind loads but does not have seismic connections. The buildings are not designed for earthquake forces. 2) Building Configuration: The houses are regular in plan but not in elevation (soft story). 3) Roof Construction: Roofs are not designed for earthquakes and about 50% have adequate tie-downs for hurricanes. 4) Quality of Workmanship: Often inexperienced laborers build their own homes, and no special connections are used.
Vertical irregularities typically found in this construction type	No irregularities
Horizontal irregularities typically found in this construction type	Soft/weak story

Seismic deficiency in walls	
Earthquake-resilient features in walls	
Seismic deficiency in frames	(wood frame system) : They are not designed for earthquake forces, and no special connections are used. Soft story mechanisms are likely because the bottom level is often left open.
Earthquake-resilient features in frame	
Seismic deficiency in roof and floors	Most roofs are not designed for earthquakes and do not have out-of-plane bracing. Additionally, only about 50% of roofs have adequate tie-downs.
Earthquake resilient features in roof and floors	
Seismic deficiency in foundation	(Footing Foundation): Soils are variable and no testing is conducted. Houses often have visible settlement. Footing has no reinforcement.
Earthquake-resilient features in foundation	

Seismic Vulnerability Rating

For information about how seismic vulnerability ratings were selected see the Seismic Vulnerability Guidelines

	High vulnerability		Medium vulnerability		Low vulnerability	
	A	B	C	D	E	F
Seismic vulnerability class	o	-|				

Retrofit Information

Description of Seismic Strengthening Provisions

Structural Deficiency	Seismic Strengthening
Soft story on open first level	Additions of shear walls and columns at first story
Lack of continuity and lateral stability of roof	Applying roof ties to timber and corrugated metal roofing
Poor connection between the timber posts and the second story	Special connection detailing for timber should be used

Large settlements in soft soils	(New Construction):Conduct soil testing to determine locations of soft clay and the depth needed to drill to bedrock

Additional comments on seismic strengthening provisions	
Has seismic strengthening described in the above table been performed?	Retrofit practices have been started by a few companies in Belize, who have rebar scanners and insert reinforcement where it is not found to strengthen the structure. Some retrofit with respect to hurricanes has also been started using roof ties for timber roofs and corrugated metal roofing. Limited retrofit has begun using FRP wraps on commercial structures.
Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	This work has been done on undamaged buildings
Was the construction inspected in the same manner as new construction?	The construction retrofits were inspected in the same manner as new construction.
Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?	An engineer or contractor performed the construction of the seismic retrofit measure.
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	There is no documented case of performance of these retrofits in subsequent seismic events.
Additional comments section 6	

References

Personal communication (interview) Carlton N. Young Youngs Engineering Consultancy Limited. 828 Coney Drive, PO Box 2665 Belize City, Belize

Personal communication (interview) Dwayne A.W. Thurton Anthony Thurton and Associates Limited. P.O. Box 777 1 # Mls Western Highway Belize City, Belize

Personal communication (interview) C. Phillip Waight Central Building Authority. 23 Cor. Baymen Ave & 5th St. P.O. Box 2589 Belize City, Belize

Earthquake in Belize, Monkey River Hardest Hit, Images of the Damage Belize News Post http://belizenewspost.com/2009/06/02/belize-news/earthquake-in-belize-monkey-river-hardest-hit-images-of-the-damage/

Authors

Name	Title	Affiliation	Location	Email
Laura Redmond		Civil Engineering, Georgia Institute of Technology	Mason Building, 790 Atlantic Drive, Atlanta GA 30332, USA	laura.mae.redmond@gmail.com
Reginald DesRoches	Civil Engineering, Georgia Institute of Technology	Mason Building, 790 Atlantic Drive, Atlanta GA 30332, USA		

Reviewers

Name	Title	Affiliation	Location	Email
Sugeng Wijanto	Senior Lecturer	Civil Engineering Dept., Trisakti University	Jakarta Barat 11440, INDONESIA	s.wijanto1@xtra.co.nz