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
Typical Single-Story Residential Construction Practices in Trinidad and Tobago

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Report#	156
Last Updated	
Country	Trinidad and Tobago
Author(s)	Richard P. Clarke, Rakesh Ramnath,
Reviewers	Ofelia Moroni, Andrew W. Charleson,

Important

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General Information

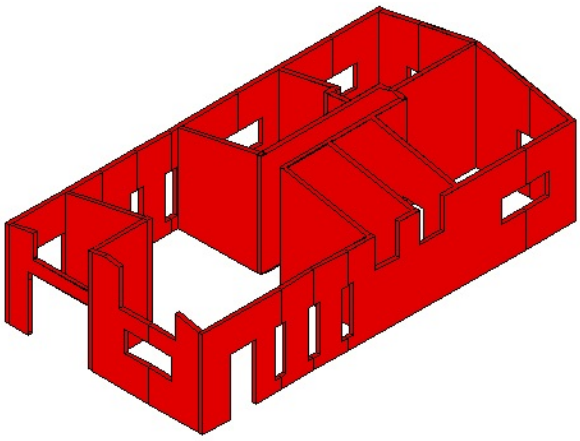
Building Type:	Typical Single-Story Residential Construction Practices in Trinidad and Tobago
Country:	Trinidad and Tobago
Author(s):	Richard P. Clarke Rakesh Ramnath
Last Updated:	
Regions Where Found:	This type of housing construction is commonly found in rural, sub-urban and urban areas.This form of construction is to be found in about 70% of all of the residential construction (i.e. isolated houses, apartment buildings, condominiums, townhouses).
Summary:	Typical single-story residential construction in Trinidad and Tobago comprises 100 mm thickunreinforced clay tile or concrete block masonry (URM) load-bearing walls supporting the roof. The roofing is a 20 to 30 degree gable or hipped shape and is of approximately 0.2 to 0.5 kN/m2 in weight. It comprises galvanized steel sheets supported by timber laths or coldformed steel Z-purlins, in turn supported by timber or structural steel rafters. The rafters are nailed or bolted to the top of the walls, without blocking between the rafters. The flexible roof cannot act as a diaphragm. The soil class ranges from IBC classes B to E. Given the significant seismic hazard for Trinidad and Tobago, (i.e. rock PGA in the range of 0.2g to 0.6g for 10% exceedance probability in 50 years), this form of residential construction is quite vulnerable.
Length of time practiced:	25-60 years
Still Practiced:	Yes
In practice as of:	
Building Occupancy:	Single dwelling
Typical number of stories:	1
Terrain-Flat:	Typically
Terrain-Sloped:	Typically
Comments:	This type of construction has become prevalent because it is the least costly.The main function of this building typology is sin

Features

Plan Shape	Rectangular, solid
Additional comments on plan shape	A typical residential structure is rectangular and 8.6 m wide x 11.0 m long, in plan. The floor height is typically 2.4 m.The walls on the perimeter of the roof support the roof, though sometimes an interior wall can be used as well. Thesame type of URM wall

	is used for the internal partitions and are connected to other walls by 'toothing'.
Typical plan length (meters)	7-14
Typical plan width (meters)	6-10
Typical story height (meters)	2.4
Type of Structural System	Masonry: Unreinforced Masonry Walls: Brick masonry in lime/cement mortar
Additional comments on structural system	Gravity Load-Resisting SystemThe vertical load-resisting system is un-reinforced masonry walls. The load-bearing walls are under combined axialload and out-of-plane bending. Since they are supported at the base on a simple mortar bed, and given the simpleconnection to the roof rafters at the top, the walls are 'pinned' at their base and at the top of the walls.Lateral Load-Resisting SystemThe lateral load-resisting system is un-reinforced masonry walls. Under lateral load the walls cannot be considered asflanged in -plan since the vertical connections between walls at their corners are inadequate for structural integrity.Given the low roof weight and wall weight, and their squat aspect ratio, the walls will act as shear walls resisting inplanesliding loads at the base joint and out-of-plane toppling loads. There is a RC beam at the top of the walls thatact as a "ring beam" enabling a degree of interaction among orthogonal walls.
Gravity load-bearing & lateral load-resisting systems	It is not "brick" that is used, but rather either clay tiles, which have horizontal cells, or concrete hollow blocks, whichhave vertical cells.
Typical wall densities in direction 1	3-4%
Typical wall densities in direction 2	3-4%
Additional comments on typical wall densities	The typical structural walldensity is up to 3 %. There is limited scope for variation since the amount of structural wall area is determined by theroof support requirements.Wall proportions are up to 25% for unreinforced masonry wall.
Wall Openings	
Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	The most common type of modification is to add along one or both sides of the house for additional bedrooms,expansion of the kitchen or living room, or for a carport.
Type of Foundation	Shallow Foundation: Reinforced concrete strip

Type of Foundation	footing
Additional comments on foundation	It consists of cast in-place reinforced concrete piers. Wall footings are used when the soil is firm. They are typically0.6m wide and 0.3m deep with 3 No. 12mm high tensile steel longitudinal rebars, and 10mm mild steel transverserebar at 250mm center-to-center spacing. Cast-in-place piers are used when the soil is soft. The tie-beams are typically0.3m wide and 0.4m deep with 3 No. 12mm high tensile steel longitudinal rebars top and bottom, and 10mm mildsteel transverse rebar at 200mm center-to-center spacing. The piles are typically spaced 3.0m apart along wall lines andare 300mm in diameter and 4.0m deep with 4 No. 16mm high tensile steel longitudinal rebar, and 10mm mild steeltransverse rebar at 200mm center-to-center spacing. For both types of foundation, the concrete typically has a 28-daycompressive strength of 21 MPa (3000 psi). The regions between the tie beams are comprised of slab-on-gradeconcrete construction as described previously for the case of shallow foundations.
Type of Floor System	Other floor system
Additional comments on floor system	The floor is a 100mm thick slab-on-grade and the reinforcement is steel fabric of 142 mm2/m.
Type of Roof System	Roof system, other
Additional comments on roof system	The roofing iscomprised of galvanized steel sheets supported by timber laths or cold-formed steel Z-purlins, in turn supported bytimber or structural steel beams or rafters.
Additional comments section 2	On sloping land it is common practice to cut or fill and use retaining walls When separated from adjacentbuildings, the typical distance from a neighboring building is 5.0 meters.



Example layout of a single-story URM house in Trinidad and Tobago

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	100 mm thickclay tile (ASTMC34) orconcrete hollowvertical cellblock (ASTMC129)	Characteristic Strength: The 100 mm thick clay tile 28-day compressivestrength is typically 2.5 MPa (individual unit). The100 mm concrete block 28-day compressivestrength is typically 3.0 MPa (individual unit).MIx Proportions: The clay tile units are 100mm thick by 300 mm longby 200 mm high. Theconcrete block units are 100mm thick by 400 mm longby 200 mm high. All mortarmixes are typically of 1 partcement to 3 parts sand. Limeis typically not used.Comments: Sometimes at wall intersections, when the concrete blocks are used, rebar is placed vertically in the cells andgrouted with a wet mix. This isineffective since the dimensions of thecell are too small relative to the rebarfor adequate compaction (i.e. 10mmand 25mm respectively), and the groutw /c is too high.
Foundations	Reinforcedconcrete	Characteristic Strength: The foundation concrete typically has a 28-daycompressive strength of about 21 MPa (3000 psi).Longitudinal rebar is typically deformed and ofyield strength of 410 MPa. Transverse rebar istypically smooth and of yield strength of 250 MPa.Mix Proportions: Concrete mixes forfoundation elements aretypically 1 part cement to 3parts fine to 3 parts coarseaggregate. The w /c is notmeasured during constructionbut probably varies from0.60 to 0.70.

Floors		Mix Proportions: The floor is a 100mm thickconcrete slab-on-gradereinforced with steel fabric142 mm2/m. The concretetypically has a 28-daycompressive strength ofabout 21 MPa (3000 psi).
Roof	The roofingsystem isconsidered a'deck' systemsince a truss isnot typicallyused. It is asystem ofsheeting,secondary andmain beams.	Characteristic Strength: The sheeting is typically corrugated or patternedgalvanized steel sheet of 26 g thickness. It issupported on treated timber beams (100mm w ideby 50mm deep), or 100mm cold-formed steel Zsectionpurlins. In the former case, the timberbeams span 1.2m, and the Z-purlins span 3.0m.The main beams or ? rafters? are typically 200 mmdeep if of timber, but of 100mm deep mild steel Isectionif of steel beams.
Other		

Design Process

Who is involved with the design process?	Other
Roles of those involved in the design process	Certified architects or engineers have no role with respect to typical residentialsingle-story construction in Trinidad and Tobago.
Expertise of those involved in the design process	

Construction Process

Who typically builds this construction type?	Other
Roles of those involved in the building process	The design is 'deemed-to-satisfy' based on custom, and the construction is by uncertified apprentices of certifiedbuilders, but under their supervision. Certified architects or engineers have no role with respect to typical residentialsingle-story construction in Trinidad and Tobago.The builder typically lives in this type of construction.
Expertise of those involved in building process	
	The typical construction process is: 1. Prepare the site. 2. Install the foundation. 3. Install the floor slab.

Construction process and phasing	4. Build theexternal walls on the floor slab. 5. Install the roof. 6. Build the internal partition walls. 7. Install the electrical andplumbing items. 8. Plaster all walls. 9. Paint the walls. The construction of this type of housing takes place in a singlephase. Typically, the building is originally designed for its final constructed size.
Construction issues	

Building Codes and Standards

Is this construction type address by codes/standards?	No
Applicable codes or standards	
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?	Yes
Additional comments on building permits and development control rules	

Building Maintenance and Condition

Typical problems associated with this type of construction	
Who typically maintains buildings of this type?	Owner(s)Renter(s)
Additional comments on maintenance and building condition	

Construction Economics

Unit construction cost	Typical construction cost is TT$4,800/m2 including contractor markup and excluding the cost of the land (1US$=TT$6.36). The current labor to material cost is about 75%.
Labor requirements	

Additional comments section 3	

Photo of URM clay tile house

Photo of concrete block house

Formwork for RC ring beam

Rebar cage for RC ring beam

Timber roof beam to wall plate connection

Stem wall of foundation for load-bearing walls

Socio-Economic Issues

Patterns of occupancy	Each building typically has 1 housing unit(s). A typical household comprises of the "extended" family in which case, inaddition to the parents and children, there are also grandparents, aunts, uncles, some of their children, and friends. Inmany instances there is only one parent. The retirees or unemployed usually come and go. The former assist with obtaining supplies, and the latter seek workor odd jobs.
Number of inhabitants in a typical building of this construction type during the day	<5
Number of inhabitants in a typical building of this construction type during the evening/night	5-10
Additional comments on number of inhabitants	It is common for visitors to periodically live in the house, and maystay at a number of houses over time. This is due to their inability to afford rent.
Economic level of inhabitants	Very low-income class (very poor)Low-income class (poor)Middle-income class
Additional comments on economic level of inhabitants	The type of residential structure described herein is used by all income levels since it has become a standard ofhousing construction.
Typical Source of Financing	Owner financedPersonal savingsSmall lending institutions/microfinance institutionsCommercial banks/mortgagesGovernment-owned housing
Additional comments on financing	
Type of Ownership	RentOwn with debt (mortgage or other)
Additional comments on ownership	
Is earthquake insurance for this construction type typically available?	Yes
What does earthquake insurance typically cover/cost	Though stated as available, the coverage is usuallylumped with other natural disaster coverage so is nominal and typically insufficient.
Are premium discounts or higher coverages available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features?	No
Additional comments on premium discounts	Strengthening is not officially recognized.

Additional comments section 4	

Earthquakes

Past Earthquakes in the country which affected buildings of this type

Year	Earthquake Epicenter
1766	
1825	
1910	
1954	
1968	
1982	
1983	
1988	
1996	
1997	

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	The durations for the earthquakes were short (<6 sec). Damage was mainly as repairable horizontal or diagonalcracking to piers. In south Tobago in the 1997 event there was considerable liquefaction failure. There were about 3events of magnitude > 5.5 from 1997 to the present of (MMI) V to VI. Data is available from the Seismic ResearchCenter of The University of the West Indies.
Additional comments on earthquake damage patterns	

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	TRUE

	seismic force effects from any horizontal direction that serves to transfer inertial forces from the building to the foundation.	
Building Configuration-Vertical	The building is regular with regards to the elevation. (Specify in 5.4.1)	TRUE
Building Configuration-Horizontal	The building is regular with regards to the plan. (Specify in 5.4.2)	TRUE
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.	TRUE
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.	TRUE
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);	TRUE
Foundation-Wall Connection	Vertical load-bearing elements (columns, walls) are attached to the foundations;	FALSE

	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.	FALSE
Wall Openings		FALSE
Quality of Building Materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	N/A
Quality of Workmanship	Quality of workmanship (based on visual inspection of a few typical buildings) is considered to be good (per local construction standards).	N/A
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber).	TRUE

Building Irregularities

Additional comments on structural and architectural features for seismic resistance	The quality of the materials and workmanship relative to standards' requirements are not measurable since no standards existfor this type of housing construction.
Vertical irregularities typically found in this construction type	No irregularities
Horizontal irregularities typically found in this construction type	No irregularities
Seismic deficiency in walls	Load-bearing Walls - Unreinforced, slender, low bearing stress.
Earthquake-resilient features in walls	
Seismic deficiency in frames	
Earthquake-resilient features in frame	

Seismic deficiency in roof and floors	Roof - No chord continuity.
Earthquake resilient features in roof and floors	
Seismic deficiency in foundation	
Earthquake-resilient features in foundation	Foundation - Capacity to demand probably high.

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	o				

Retrofit Information

Description of Seismic Strengthening Provisions

Structural Deficiency	**Seismic Strengthening**
Walls have insufficient ductility and strength in both the in-plane and out-of-planedirections	None used.
Walls have insufficient ductility and strength in both the in-plane and out-of-planedirections	None used.

Additional comments on seismic strengthening provisions	None exists as a code, but the University of the West Indies developed recommendations based on wall testing andthe use of ferrocement overlays. This is available over the internet
Has seismic strengthening described in the above table been performed?	The strengthening procedure described has not been utilized.
Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	
Was the construction inspected in the same manner as new construction?	

Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?	
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	
Additional comments section 6	

References

The Hysteretic Behaviour of Ferrocement-Retrofitted Clay Tile WallsRichard P. Clarke and Anil K. SharmaAmerican Concrete Institute Structures Journal 2004 Vol 101 No. 3 pp 387-394

Authors

Name	Title	Affiliation	Location	Email
Richard P. Clarke	Lecturer	Civil & Environmental Engineering, The University of the West Indies	St. Augustine Campus, St. Augustine , TRINIDAD AND TOBAGO	Richard.Clarke@sta.uwi.edu
Rakesh Ramnath	Civil Engineering, University of the west indies	St. Augustine, Trinidad, WestIndies, Port Of Spain , TRINIDAD AND TOBAGO	rax-ramnath@hotmail.com	

Reviewers

Name	Title	Affiliation	Location	Email
Ofelia Moroni	Civil Engineer/Assistant Professor	University of Chile	Santiago , CHILE	mmoroni@cec.uchile.cl
Andrew W. Charleson	Associate Professor	School of Architecture, Victoria University of Wellington	Wellington 6001, NEW ZEALAND	andrew.charleson@vuw.ac.nz