World Housing Encyclopedia

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

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Earthquake Engineering Research Institute (EERI) and
International Association for Earthquake Engineering (IAEE)

HOUSING REPORT
Reinforced concrete frame building with timber roof

Report #	44
Report Date	05-06-2002
Country	MALAYSIA
Housing Type	RC Moment Frame Building
Housing Sub-Type	RC Moment Frame Building : Designed for gravity loads only, with URM infills
Author(s)	Azlan B. Adnan, Tuan N. Tuan Chik, Bahiah Baharudin
Reviewer(s)	Ravi Sinha

Summary

This housing type is commonly used for family housing and it is found in urban areas of Malaysia. Columns and beams are of reinforced concrete to provide structural strength. The roof consists of timber trusses. These houses are designed according to the British Code BS

8110 without seismic design considerations.

1. General Information

Buildings of this construction type can be found in almost all parts of Malaysia. This type of housing construction is commonly found in both rural and urban areas.

About 30-40% are located in semi-urban areas.

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

Currently, this type of construction is being built. .

Figure 1: Typical Building

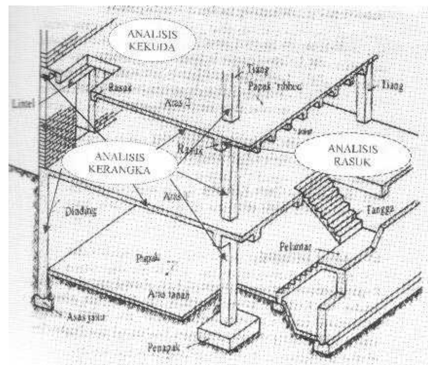

Figure 2: Key Load-Bearing Elements

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They do not share common walls with adjacent buildings. The typical separation distance between buildings can be more than 10 meters as a rule When separated from adjacent buildings, the typical distance from a neighboring building is 10 meters.

2.2 Building Configuration

The typical shape of a building plan for this housing type is rectangular shape. A typical house has approximately several windows, with average size of 2.4 m².

2.3 Functional Planning

The main function of this building typology is multi-family housing. In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases.

2.4 Modification to Building

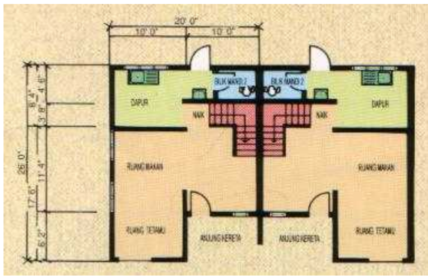

Figure 3A: Plan of a Typical Building

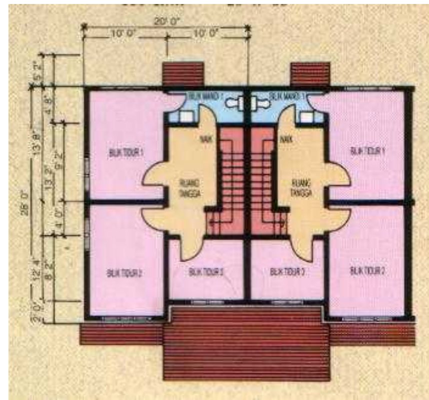

Figure 3B: Plan of Typical Building

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	☐
	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 concrete	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)	☐

3.2 Gravity Load-Resisting System

The vertical load-resisting system is reinforced concrete structural walls (with frame). The roofs are designed to transmit gravity loads to the slabs, beams, and columns. The walls are from the non-load bearing wall system. All external walls and partition walls are 9-inch brick walls. Internal partitions are timber framing.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is reinforced concrete moment resisting frame. Columns and walls give stiffness to the structure, which controls the lateral drift. The common size of columns is 600 mm X 600 mm and for walls are 150 mm thickness.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 6 and 6 meters, and widths between 20 and 20 meters. The building is 2 storey high. The typical span of the roofing/flooring system is 6 meters. Typical Story Height: Story height is 3-4 meters. The typical storey height in such buildings is 4 meters. The typical structural wall density is up to 5 %. 2% (1% -5%).

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	☑	☑

Floor/roof are considered to behave as rigid 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	☐
	Reinforced-concrete bearing piles	☐

Deep foundation	Reinforced-concrete skin friction piles	☐
	Steel bearing piles	☐
	Steel skin friction piles	☐
	Wood piles	☐
	Cast-in-place concrete piers	☐
	Caissons	☐
Other	Described below	☐

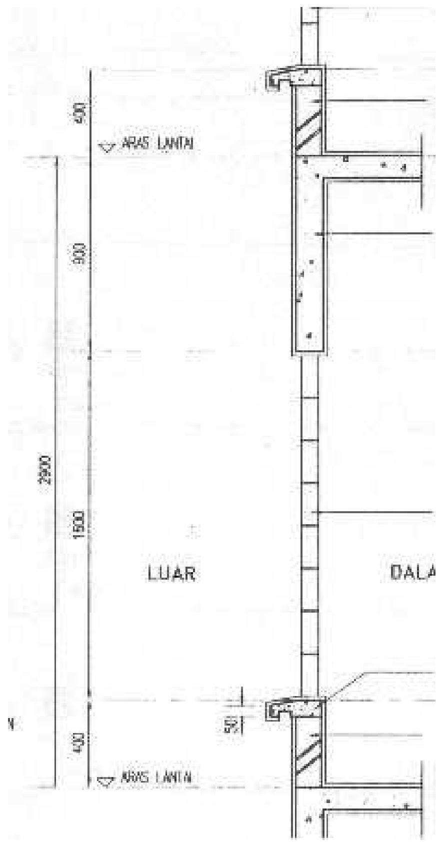

Figure 4: Critical Structural Details (e.g. wall section, foundations, roof-wall connections, etc.)

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 5-10 housing unit(s). 10 units in each building. There are more than 10 units in one building usually. These housing unites are usually clustered. 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 5-10.

4.2 Patterns of Occupancy

One family occupies a single apartment or housing unit.

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)	☑

The house price indicated is just for one tenement. Economic Level: For Poor Class the Housing Price Unit is 6250 and the Annual Income is 2100. For Middle Class the Housing Price Unit is 25000 and the Annual Income is 4500 For Rich Class the Housing Price Unit is 30000 and the Annual Income is 4600.

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)	☑

Government loan. In each housing unit, there are 2 bathroom(s) without toilet(s), 2 toilet(s) only and 2 bathroom(s) including toilet(s).

4.4 Ownership

The type of ownership or occupancy is renting, outright ownership , ownership with debt (mortgage or other) and individual 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.	☑	☐	☐
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
Wall	Wall is not designed to sustain the seismic forces.		
Frame (columns, beams)	Seems sufficient due to the design method.		
Roof and floors	Have adequate rigidity		
Other	The structure does not have ability to withstand large drifts		

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 C: MEDIUM VULNERABILITY (i.e., moderate seismic performance), and the upper bound (i.e., the best possible) is *E: LOW VULNERABILITY (i.e., very 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
1991	Labuan, Sabah	5.8	
1996	Penang	6	

Figure 5A: A Photograph Illustrating Typical Earthquake Damage in the

Labuan, Sabah (M5.8) of 26 May 1991

Figure 5B: Typical Earthquake Damage (Penang (M6.0) earthquake of 10 October 1996

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Concrete	24 kN/m³ -30kN/m³ Grade 25-30.	1:2:4 (cement: fine aggregate: course aggregate).	
Foundation	Concrete	24 kN/m³ -30kN/m³ Grade 25-30.	1:2:4 (cement: fine aggregate: course aggregate).	
Frames (beams & columns)	Concrete	24 kN/m³ -30kN/m³ Grade 25-30.	1:2:4 (cement: fine aggregate: course aggregate).	
Roof and floor(s)	Concrete	24 kN/m³ -30kN/m³ Grade 25-30.	1:2:4 (cement: fine aggregate: course aggregate).	

6.2 Builder

It is more typically built by developers or for speculation.

6.3 Construction Process, Problems and Phasing

Developers normally build structures of this type. Process start with the foundation of the building, then columns and brick walls are built, finally beams and roofs are made at the time to get a monolithic structure. The tools typically used in this type of construction, are hammers, nails, construction wire, etc. and the equipment used include concrete vibrator, concrete mixer and others. To start the construction of the building one needs to get a construction license. Municipal authorities are in charge to give this license to the builder companies. Each housing project must have four kinds of technical drawings: structural drawings, architectural drawings, water installation drawings and electric installation drawings. Municipal authorities need to approve this technical information in order to get construction license. The construction of this type of housing takes place incrementally over time. Typically, the building is originally not designed for its final constructed size. Buildings are originally designed for a specific number of stories. However is commonly found that owners decide to build additional stories some years later of the end of the original construction.

6.4 Design and Construction Expertise

Engineers and architects have experience in design and construction process. This is one of the most typical constructions in Malaysia, so there are good capable professionals with experience on this kind of building. Engineers are in charge of the structural design and the construction process. Architects are in charge of the architectural design.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. BS 8110 (British Standard). The year the first code/standard addressing this type of construction issued was 1980's. The BS 8110 code also includes national building codes, specifications for materials and seismic standards. Title of the code or standard: BS 8110 (British Standard). Year the first code/standard addressing this type of construction issued: 1980's National building code, material codes and seismic codes/standards: The BS 8110 code also includes national building codes, specifications for materials and seismic standards.

Municipal authorities just approve the design of the building. Typically, the owner hires a particular supervisor for construction of the building.

6.6 Building Permits and Development Control Rules

This type of construction is an engineered, and authorized as per development control rules. Building permits are required to build this housing type.

6.7 Building Maintenance

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

6.8 Construction Economics

Unit construction cost is approximately 13.3 US$/m². This type of building needs about 12 months or more to complete the construction. However, the time required does not depend on the architectural characteristics of the building.

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
Roof	Timber
Columns	Shear steel reinforcement

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?

Yes.

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?

A contractor performed the construction and also an engineer was involved.

Reference(s)

1. BS 8110 - British Standard
2. Structural Terrace Plan and Brochures of Residential Area

Author(s)

1. Azlan B. Adnan
   Senior Lecturer, Civil Enginering Department, University of Technology Malaysia
   UTM Skudai, Johor 81310, MALAYSIA
   Email:azelan@fka.utm.my FAX: 607-556 6157

2. Tuan N. Tuan Chik
   Master Student, UTM, Johor 81310, MALAYSIA
   Email:tntc77@hotmail.com FAX: -

3. Bahiah Baharudin
   Student, Civil Enginering Department, University of Technology Malaysia, Johor 81310, MALAYSIA
   Email:adik_lea@yahoo.com

Reviewer(s)

1. Ravi Sinha
   Professor
   Civil Engineering Department, Indian Institute of Technology Bombay
   Mumbai 400 076, INDIA
   Email:rsinha@civil.iitb.ac.in FAX: (91-22) 2572-3480, 2576-7302