World Housing Encyclopedia

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

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

HOUSING REPORT
Moment resisting frame designed for gravity loads only

Report #	60
Report Date	05-06-2002
Country	SYRIAN ARAB REPUBLIC
Housing Type	RC Moment Frame Building
Housing Sub-Type	RC Moment Frame Building : Designed for gravity loads only, with URM infills
Author(s)	Adel Awad, Hwaija Bassam, Isreb Talal
Reviewer(s)	Ravi Sinha

Summary

These buildings are found in the main cities of Syria and represent modern construction practice followed in the last 50 years. The floor system is a two-way reinforced concrete slab, which spans between orthogonal sets of beams that transfer the load to the columns. The

frames are designed to carry gravity loads only.

1. General Information

Buildings of this construction type can be found in the main cities of Syria like Damascus, Aleppo, Latakia, Homs, Hama, Deir-ez zor, Idleb, Al-Haskeh, Al-Raka, Al-Sweida, Dara, Tartus, Jableh, Qunitera etc. This type of housing construction is commonly found in urban areas. This construction type has been in practice for less than 50 years.

Currently, this type of construction is being built. It is the modern construction followed in the last 50 years.

Figure 1: Typical Building

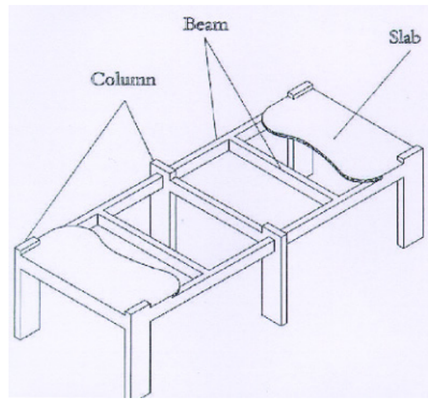

Figure 2: Key Load-Bearing Elements

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They do not share common walls with adjacent buildings. When separated from adjacent buildings, the typical distance from a neighboring building is several meters.

2.2 Building Configuration

Rectangular. Area of openings /walls surface area = 20% for inner walls and 40% for outer walls.

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. Usually the building hasn't additional exits besides the main. exit.

2.4 Modification to Building

There aren't a lot of modifications in these buildings yet.

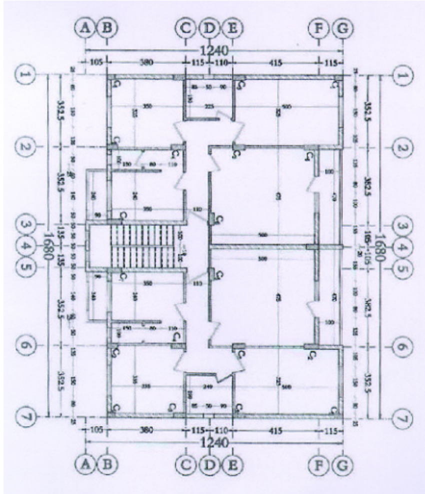

Figure 3A: Plan of a Typical Building

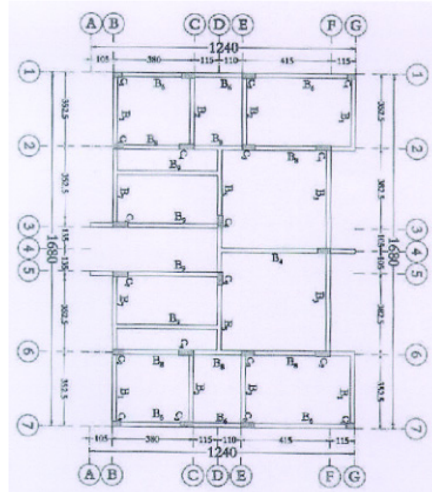

Figure 3B: Plan of a Typical Building

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	☐

Structural concrete		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)	☐

3.2 Gravity Load-Resisting System

The vertical load-resisting system is others (described below). Frames (columns, beams) carry gravity loading.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is others (described below). We can assume that the frames (columns + beams) provide a partial strength and stiffness to control lateral displacements due to moderate earthquakes.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 20 and 20 meters, and widths between 16 and 16 meters. The building has 3 to 5 storey(s). The typical span of the roofing/flooring system is 3.0-5.5 meters. Typical Plan Dimensions: Length varies from 12 to 20 meters, width varies from 12 to 16 meters. Typical Story Height: Story height ranges from 2.85 to 3.1 meters. The typical storey height in such buildings is 3 meters. The typical structural wall density is up to 20 %. Total wall area/plan area (for each floor) 10% to 15%.

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	☑	☑

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	☐

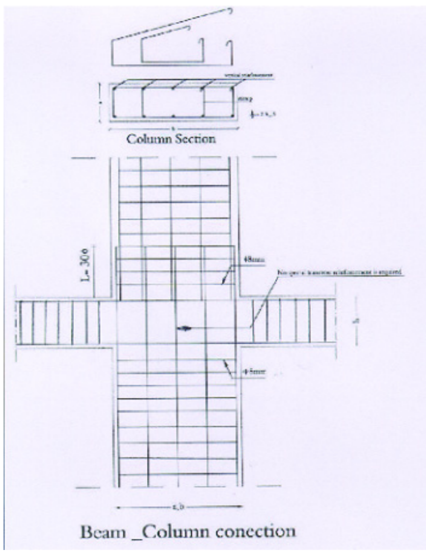

Figure 4A: Critical Structural Details

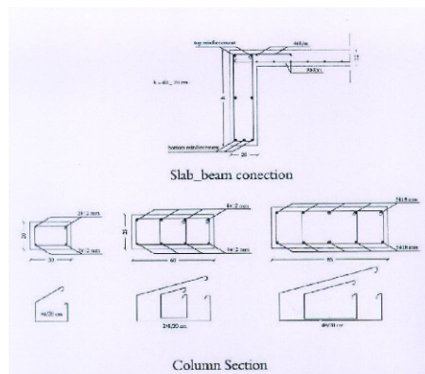

Figure 4B: Critical Structural Details

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 10-20 housing unit(s). 12 units in each building. There are from 6 to 12 units in each building. The number of inhabitants in a building during the day or business hours is 11-20. The number of inhabitants during the evening and night is more than 20.

4.2 Patterns of Occupancy

One family typically occupies one apartment.

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)	☐

GNP per capita, in 1997, was $1120 ; GDP per capita, in 1996, was $1288. Economic Level: For Poor Class the

Houisng Price Unit is 10000 and the Annual Income is 2500. For Middle Class the Housing Price Unit is 15000 and the Annual Income is 6000.

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 1 bathroom(s) without toilet(s), no toilet(s) only and 1 bathroom(s) including toilet(s).

1 to 2 bathrooms. .

4.4 Ownership

The type of ownership or occupancy is renting, outright ownership , ownership with debt (mortgage or other) , long-term lease and others.

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)	☑

Ownership by heritage is also found.

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
Infill walls			
Frame (columns, beams)	Weak connections between the secondary and primary beams. No special transverse reinforcement at the critical region joints).		
Roof and floors			
Foundations	Reinforced concrete isolated footing without compression/tension ties		

Poor quality of workmanship and materials. Development length not sufficient in compression and tension regions.

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
1719	Aleppo	5.5	(MMI) VII
1759	Damascus/Lattakia	7.5	(MMI) X
1759	Damascus	7.6	(MMI) X
1796	Lattakia	6	(MMI) VIII
1822	Harem/Aleppo	6	(MMI) VIII
1822	Aleppo/Al-jaziereh	7	(MMI) IX-X

Data about the earthquakes, starting from 18th century up to date, were taken from Ambraseys (1983). However, we have developed the estimate of the magnitude (M) and the maximum MMI intensity based on our findings and experience. Most of the buildings destroyed in the past earthquakes were of adobe and stone masonry, particularly in the urban areas.

6. Construction

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls				

Foundation	Concrete		1:2:4	
Frames (beams & columns)	Steel	360-420 MPa		Deformed bars
Roof and floor(s)	Steel	360-420 MPa		Deformed bars

6.2 Builder

It is built by developers and sold to the people who live in this construction type.

6.3 Construction Process, Problems and Phasing

The owner of the land will hire an architect and a structural engineer to design the building. They will use modern equipment. 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

A structural engineer will have 5 years of education and more 5-10 years of experience. A construction engineer may have 5 years of education and less experience than the structural engineer. The designer may visit the construction site at request. Yes, They have a role in the design, constriction and inspection during the construction phase (see 7.3 and 7.4).

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. Starting from 1997, the seismic design for buildings is mandatory as a law: Syrian code for earthquake resistant building (1995). Prior to 1997, seismic design was not applicable but the normal Syrian building code was used from 1972. Title of the code or standard: Starting from 1997, the seismic design for buildings is mandatory as a law: Syrian code for earthquake resistant building (1995).

The building design must follow the 1995 Syrian code. In case of damage arbitration process may take place at the court of justice.

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 Owner(s) and Tenant(s).

6.8 Construction Economics

A unit construction may cost 100-200 USD/m² (USD =50 Syrian pound (SP), on market rate).

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. Not applicable.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Seismic strengthening has generally not been performed in Syria.

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?

No.

8.3 Construction and Performance of Seismic Strengthening

Reference(s)

1. Statistical Abstract 1999
   Central Bureau of Statistics,Damascus 1999

2. Earthquake Damage in the Arabic Region
   Ambraseys,N.N.
   Assessment And Mitigation, UNESCO Publication, pp. 11-15 1993

3. Urban Development Report 1999
   United Nations Development Program (UNDP)
   Oxford University Press, NY 1999

4. Seismic Design of Reinforced Concrete and Masonry Buildings
   Paulay,T. and Priestley,M.J.N.
   John Wiley and Sons 1992

5. Syrian Code for Earthquake Resistant Design and Construction of Buildings
   Syrian Engineers Order, Damascus 1995

6. European Macroseismic Scale 1998 (EMS 98)
   Gr
   European Seismological Commission (ESC), Luxembourg 1998

Author(s)

1. Adel Awad
   Civil Engineer/Professor, University of Tishreen
   P.O. Box 1385, Latakia , SYRIAN ARAB REPUBLIC
   Email:tuniv-lat@net.sy FAX: 963-41-418504

2. Hwaija Bassam
   Civil Engineer/Associate Professor, University of Tishreen
   P.O. Box 1385, Latakia , SYRIA

Email:tuniv-lat@net.sy FAX: (963-41) 418504

3. Isreb Talal
   Civil Engineer, University of Tishreen, Latakia , SYRIA
   Email:tuniv-lat@net.sy

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