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 with concrete shear walls - dual system

Report #	59
Report Date	05-06-2002
Country	SYRIAN ARAB REPUBLIC
Housing Type	RC Moment Frame Building
Housing Sub-Type	RC Moment Frame Building : Dual System - Frame with Shear Wall
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Summary

These buildings are characterized by a combination of shear walls and frames in both directions. The buildings are multiple housing units found in the main cities of Syria. The shear walls are often part of the elevator and service cores, whereas the frames are arranged in-

plane, in conjunction with the walls, to support the floor system. Stiffness and mass distribution are irregular and the majority of buildings may experience soft-story or torsional problems. As a result, these buildings are expected to have only moderate seismic resistance.

1. General Information

Buildings of this construction type can be found in the main cities of Syria like Damascus, Aleppo, Latakia, Homs, and Hama. This type of housing construction is commonly found in urban areas. This construction type has been in practice for less than 25 years.

Currently, this type of construction is being built. This is the modern construction followed in the last 30 years.


Figure 1: Typical Building

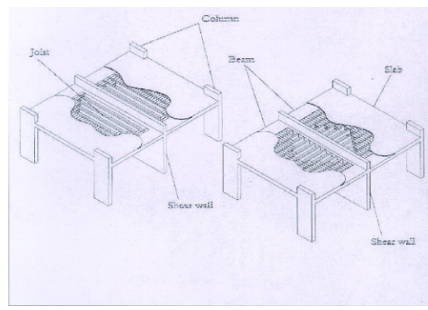

Figure 2: Key Load-Bearing Elements

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat, sloped and hilly terrain. They do not share common walls with adjacent buildings. It can be more than 10 meters as per rule When separated from adjacent buildings, the typical distance from a neighboring building is 10 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. In some cases buildings have additional exit star besides the main star.

2.4 Modification to Building

Buildings of this type haven't a lot of modifications yet.

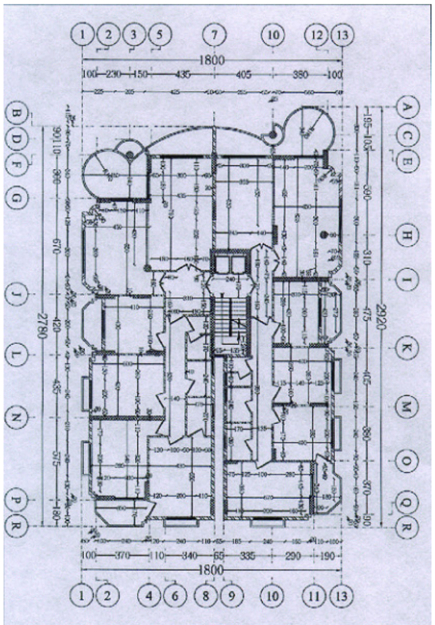

Figure 3A: Plan of a Typical Building

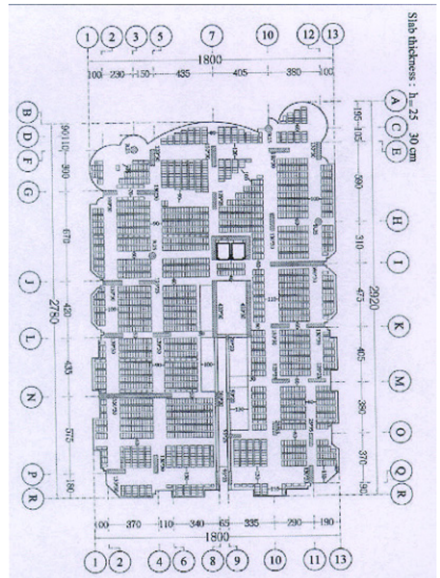

Figure 3B: Plan of a Typical Building

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	☐
		17	Flat slab structure	☐

Structural concrete	Moment resisting frame	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)	☐

3.2 Gravity Load-Resisting System

The vertical load-resisting system is others (described below). Shear walls and 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 shear walls provide adequate strength and stiffness to control lateral displacements.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 30 and 30 meters, and widths between 20 and 20 meters. The building has 6 to 15 storey(s). The typical span of the roofing/flooring system is 6 meters. Typical Plan Dimensions: Length varies from 12 to 30 meters, width varies from 12 to 20 meters. Typical Story Height: Range of story height is 2.8 - 3.1 meters. Typical Span: Usually typical span varies from 3.5 to 6 meters. The typical storey height in such buildings is 3.1 meters. The typical structural wall density is up to 3 %. The ratio between total wall area/plan area is 1 to 3% (for each floor).

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	☐

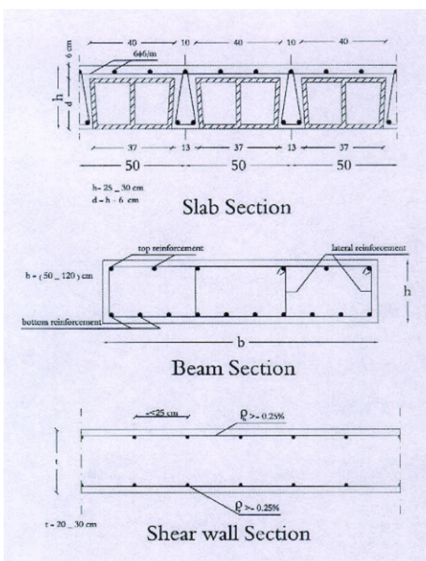

Figure 4A: Critical Structural Details (e.g. wall section, foundations, roof-wall connections, etc.)

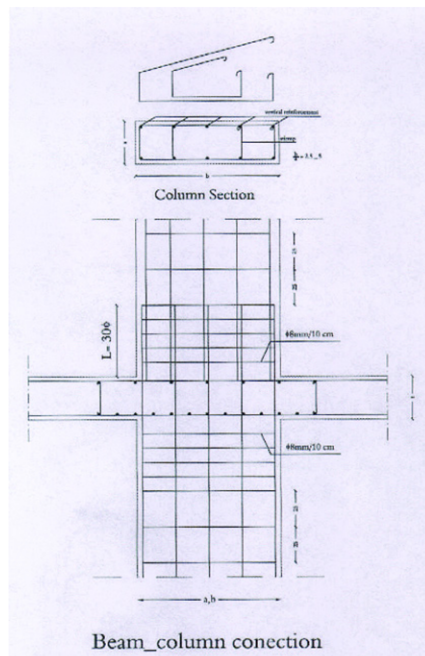

Figure 4B: Critical Structural Details

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 21-50 housing unit(s). 45 units in each building. There are 24 - 45 housing units in each building usually. The number of inhabitants in a building during the day or business hours is more than 20. The number of inhabitants during the evening and night is more than 20.

4.2 Patterns of Occupancy

One family typically occupies one house.

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)	☑

Notes: 1. Below are the general guidelines related to the economic status of the inhabitants: Very Poor = lowest 10% of the population (per GDP) Poor = lowest 30% of the population Middle Class = from the lowest 30% up to the top 20% of the population Rich = top 20% of the population. Additional comments: GNP per capita, in 1997, was $1120. GDP per capita, in 1996, was $1288. Economic Level: For Middle Class the Housing Unit Price is 25000 and the Annual Income is 6000. For Rich Class the Housing Unit Price is 40000 and the Annual Income is 15000.

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), 1 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)	☑

Other: Ownership by heritage.

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 (based on visual inspection of			

Quality of workmanship	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	No flexural tension reinforcement; and no confinement at the wall ends.		
Frame (columns, beams)	No special transverse reinforcement at the critical region (joints).		
Roof and floors	Weak connection between roof, floors and walls; and no lintel beams.		
Other	Poor quality of workmanship and materials; Development length not sufficient		

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
1759	Damascus	7.5	MMI) X
1796	Lattakia	6	(MMI) VIII
1822	Aleppo/Al-jaziereh	7	(MMI) IX-X
1827	Harem/ Aleppo	6	(MMI) VIII

Additional earthquakes: 1719, Aleppo, M5.5, MMI/VIII 1759, Damascus, M7.5, MMI/X Data about earthquakes taken from (Ambraseys, 1983), starting from 18th Century up to date. But estimation of values (Magnitude M and Maximum Intensity MMI) were made by us depending on our findings and experience. Most of the building destroyed were of adobe and stone masonry particularly in urban regions.

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Concrete	1-3/18-25/1-2	1:2:4	
Foundation	Concrete	1-3/18-25/1-2	1:2:4	
Frames (beams & columns)	Steel	360-420		Deformed bars
Roof and floor(s)	Steel	360-420		Deformed bars

6.2 Builder

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

6.3 Construction Process, Problems and Phasing

The owner of the land will hire an architectural office and 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

The structural engineer will have 5 years of studies and more than 5-10 years of experience. The construction engineer may have 5 years of studies and less experience than the structure engineer. There is compulsory inspection during the construction and good revision of the structural project. The designer may visit the construction site, at request. Yes, they have a role in the design, construction 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. Yes. 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 is used from 1972. The year the first code/standard addressing this type of construction issued was 1972. The most recent code/standard addressing this construction type issued was 1997. Title of the code or standard: Yes. 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 is used from 1972. Year the first code/standard addressing this type of construction issued: 1972 When was the most recent code/standard addressing this construction type issued? 1997.

The building design must follow the Syrian Code 1995. 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 170-300 USD/m² (USD =50 Syrian pound (SP), on market rate). One floor per month.

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

Seismic strengthening has not been done in Syria so far.

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

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