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
Reinforced concrete frame with infill walls designed for gravity loading

Report #	48
Report Date	05-06-2002
Country	PALESTINIAN TERRITORIES
Housing Type	RC Moment Frame Building
Housing Sub-Type	RC Moment Frame Building : Designed for gravity loads only, with URM infills
Author(s)	Jalal N. Al Dabbeek, Abdel H. W. Al-Jawhari
Reviewer(s)	Polat Gulkan

Summary

This building type is usually found in most cities of West Bank and less often in the Gaza Strip. The structural system consists of solid slabs (either one-way or two-way) with beams and columns. The columns are usually of rectangular cross-section. The beams may be either

dropped (deep) or hidden. The infill walls in the external frames may consist of stone with plain concrete only, or stone with plain concrete and hollow block. Sometimes polystyrene of 2-cm thickness is added for isolation purposes. On the other hand, the internal infill walls consist only of concrete hollow blocks of 10 cm thickness but may be as thick as 15 or 20 cm. These walls are used and considered as partitions.

1. General Information

Buildings of this construction type can be found in the main cities of West Bank like East of Jerusalem, Nablus, Ramallah, Bethlehem and Jenin. It represents 30 to 40% of the housing stock in these cities. For Gaza Strip, it is applied on a small scale. This type of housing construction is commonly found in both rural and urban areas. This construction type has been in practice for less than 50 years.

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


Figure 1A: Typical Building


Figure 1B: Typical Building


Figure 1C: Typical Building

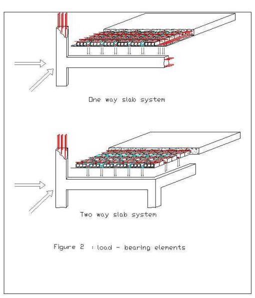

Figure 2: Key Load-Bearing Elements

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. The distance between adjacent buildings varies from 6 to 10 meters in the areas classified for housing purposes, and zero for commercial areas When separated from adjacent buildings, the typical distance from a neighboring building is 10 meters.

2.2 Building Configuration

Many of the buildings within this system are of rectangular shape. On the other hand, almost 50% of the buildings have irregular shape. This irregularity is variable and it is small in certain percentage of the buildings and high in the other. This is due to the shape and dimensions of the land parcels especially in the mountainous and hilly areas (see Figures 1A and 3A). The widows are usually centered within the wall, while the doors are located at the end. The height of the widows is usually 1.25 meters, and the width has a variable size depending on the architect's experience and personal judgment. Generally, the widows represent 20% of the wall area. The doors are 1.0 meter wide and 2.2 meters high as an average.

2.3 Functional Planning

The main function of this building typology is multi-family housing. There are a lot of mixed buildings too. In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. Generally, there is no additional doors besides the main entry, also there is no additional exit stairs besides the main ones.

2.4 Modification to Building

Investigations on this type of buildings showed the following: - Interior walls (partitions) are very often removed since they are changed and reallocated according to the owner's desire. - Extensions to buildings are applied in many cases using either short, medium or long time intervals. - Columns are rarely demolished. - Staircases are added whenever additional floors are needed. This happens in very few cases where staircases do not exist in single floor buildings.

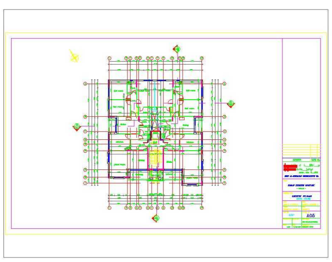

Figure 3A: Plan of a Typical Building

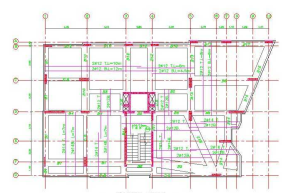

Figure 3B: Typical plan

3. Structural Details

3.1 Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
	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	☐
		7	Brick masonry in mud/lime mortar	☐
		8	Brick masonry in mud/lime	☐

Masonry	Unreinforced masonry walls		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	☐
Structural concrete	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 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)	☐

The internal frames are infilled with concrete hollow blocks while the external frames are infilled with stone and concrete or with stone and concrete with hollow block (See Figure 4A).

3.2 Gravity Load-Resisting System

The vertical load-resisting system is reinforced concrete moment resisting frame. The gravity load bearing system consists of beams, columns and slabs. It transfers the vertical loads to the foundations which may be either spread, mat or deep depending on the nature of the soil and the height of the building.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is reinforced concrete moment resisting frame. The lateral load resisting system consists of reinforced concrete beam-column frame resting on different types of foundations, either spread, mat or deep. In urban areas and especially in the last ten years, most of the buildings use the ground or basement floors as car park. The frames are bare in the lower floor while they are infilled with strong masonry walls in the upper floor. These masonry infills wall have very high stiffness and contribute a lot to the lateral load resisting system of the buildings. This variation in the stiffness creates a soft storey in the lower floor which is very weak and has very bad performance during earthquakes. It is also important to mention that due to the mountainous nature of the land, there is a need in many cases to have more than one basement (up to five sometimes) to reach the street level, thus creating additional soft stories. In addition to that and due to the irregularity in both vertical and horizontal configurations, torsional effect will appear when the building is subjected to horizontal loading (see Figure 1A and 3A).

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 15 and 15 meters, and widths between 12 and 12 meters. The building has 4 to 5 storey(s). The typical span of the roofing/flooring system is 5 meters. Typical Plan Dimensions: The dimensions of the building may increase depending on the size and shape of the land, the number of housing units and the variation in the slope. Usually length is 10-25 meters, width is 8-16 meters. Typical Story Height: The story height is governed by the number of stone layers. Since the normal height of each layer is 25 cm in addition to 1 cm between each layer. 12 or 13 layers are usually used and this makes the height of each story to be 3.1 and 3.35 meters respectively. Typical Span: Typical Span ranges from 3.5 to 6.0 meters. Sometimes, the span is increased especially when having car park in the basement floors. The typical storey height in such buildings is 3.1 meters. The typical structural wall density is none. 5% - 6% total wall area/plan area (for each floor), is the range between the ratios of the area of all the walls in each principal direction divided by the total area of the plan.

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	☑	☑

Single- or two-way ribbed slabs with hollow blocks. Please refer to Figure 2 for ribbed slabs.

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	☐

It consists of reinforced concrete end-bearing piles and reinforced concrete skin-friction piles.

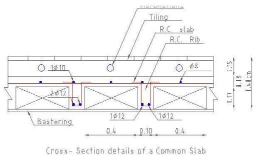

Figure 4A: Critical Structural Details-Concrete Slab

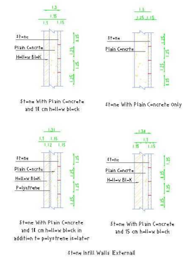

Figure 4B: Critical Structural Details-Walls

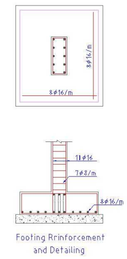

Figure 4C: Critical Structural Details-Foundations

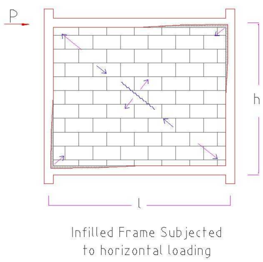

Figure 5A: Key Seismic Deficiencies-Infill Frame

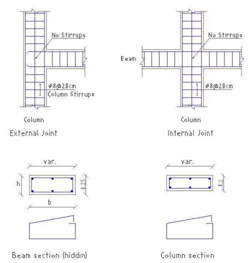

Figure 5B: Key Seismic Features-RC Frame Details

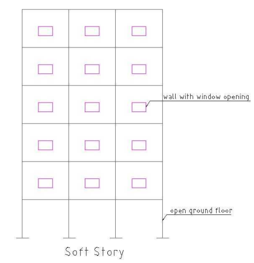

Figure 5C: Key Seismic Deficiencies-Soft Storey Effect

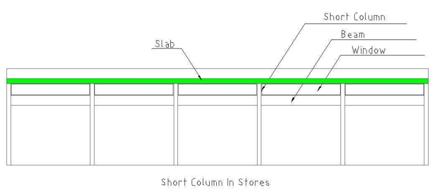

Figure 5D: Key Seismic Deficiencies-Short Columns

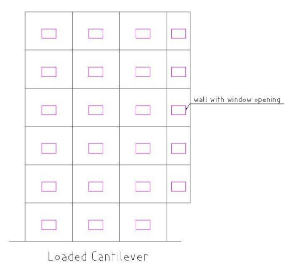

Figure 5E: Key Seismic Deficiencies-Loaded Cantilever

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. The number of housing units in the type considered in this study (as Figure 1A) varies between 8-14. In few cases, especially in Nablus and Ramallah cities, the number of the units may reach up to 30. The number of inhabitants in a building during the day or business hours is 5-10. The number of inhabitants during the evening and night is more than 20. The number of occupants during the night may go up to more than one hundred.

4.2 Patterns of Occupancy

One family generally occupies one housing unit. We can find in very few cases or even rarely more than one family in one 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)	☐

Economic Level: For Middle Class the Housing Unit Price is 60,000 and the Annual Income is 9,000.

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)	☐

The government-owned housing projects are still constructed on a limited range or scale. In each housing unit, there are 1 bathroom(s) without toilet(s), no toilet(s) only and 1 bathroom(s) including toilet(s).

Each housing unit have 1 -2 bathrooms. .

4.4 Ownership

The type of ownership or occupancy is renting, outright ownership , ownership with debt (mortgage or other) and ownership by a group or pool of persons.

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	For the building configuration, the answer represents less than 50% of the buildings (see item 2.3 for building configuration). The building materials are used depending on a big variety of codes from either adjacent countries like Jordan, Syria and Egypt or international codes like ACI, BS and DIN. The quality of workmanship is not good enough, on the other hand and in few cases especially for public projects, workmanship is of high level of quality. The seismic joints are not applied because the maximum size of joint is 2-3 cm for all heights and types of structural systems of the buildings.

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Wall	- The connection between the infill wall and the internal frame is poor and the bond between the hollow block pieces is also poor. - The bond between the decorative stone and the concrete infill wall of the external frame is weak (no mechanical bond). This causes the separation and falling down of the stone pieces when the building is subjected to shaking.		Damage caused by these kinds of deficiencies has been observed in similar construction in earthquakes in the surrounding region---Aqaba, Jordan; Egypt and Turkey.
Frame (columns, beams)	- Inadequate confinement (transverse reinforcement) in the vicinity of the beam-column joint and within the joint itself. - Inadequate transverse cross ties (stirrups) in the columns and beams as well. - Strong Column-Weak beam design concept is not considered. - Variation of stiffness in plan and elevation as well, which creates soft or weak stories in many cases. - Short column effect is predominant in many case and due to variety of reasons. - Heavily loaded cantilever beams.		
Roof and floors	- Inadequate transverse reinforcement of the ribbed slabs. (Open ties, excessive spacing). - Heavily loaded cantilever slabs.		
Foundations	- Short column effect appears in the column necks when using isolated footing.		

1. See Figure 5A for seismic deficiencies 2. According to EMS-98 and from post earthquake investigation results, it is expected that the performance of the reinforced concrete frame buildings with serious defects (such as soft stories, weak columns, lack of stiffening elements like masonry infill and shear walls) vulnerability class B or even A may be appropriate. Please consider this comment when looking at vulnerability table in item 5.3 next.

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
1927	Jerico		MMI, VIII
1995	Aqaba Gulf		MMI, VII - VIII

- The magnitude of the Aqaba Gulf earthquake ranged between 6.2-6.5. -The magnitude of the Jerico earthquake ranged between 6.2-6.3. # In the 1995 earthquake, the Epicenter was located about 100 kilometers south of Aqaba and Elat cities where MMI was VII. On the other hand, MMI near the zone of the Epicenter was VIII. - PGA for 1995 earthquake was 0.20 g.

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	- Hollow blocks (internal) - Concrete/Stone(external)	3.0 15-20/1.0-2.0	1:3:6 - 1:3:5	The stone used for decorative purposes in the external infill walls is neglected in the strength.
Foundation	Concrete	2-3/25-30/2-3	1:2:4	
Frames (beams & columns)	Concrete	2-3/25-30/2-3	1:2:4	
Roof and floor(s)	Concrete	2-3/25-30/2-3	1:2:4	

6.2 Builder

The builder lives in this type in many cases. Also, a developer may build the house for investment purposes and others buy or rent it.

6.3 Construction Process, Problems and Phasing

The construction process can be briefly described as follows: - The architect prepares the architectural drawings of the building. - The civil engineer makes the structural design. - Both the electrical and mechanical engineers prepare their drawings also. - All the drawings are signed by the engineers who must be authorized and submitted to the engineers Association for approval. The engineers Association gives the approval for design requirements and certifies the signature of the engineers only. The designer office is totally responsible for the design depending on its classification or pre-qualification which is usually given by the Association. Typically, the engineers and the design offices are authorized and pre-qualified by the Association. - The documents are then submitted to the Municipality for building license - A contractor then is awarded the project using different methods of procurement. - The work is usually done under the supervision of the engineer which is a requirement. - Generally, conventional building techniques are utilized and part of the work is done using conventional tools as well. Also in many cases and for big projects advanced building techniques, ready mixed concrete and precast units are used. 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 engineers should be authorized by the engineers Association to practice the work. A minimum three years of experience and practice is required. Also the engineering office should be officially registered and authorized. This is required from all engineers involved in the process. The engineers play the major role during the whole stages of the process. They make the design, prepare tender documents and supervise the construction. This is also a requirement needed for these projects. In very few cases and for small scale buildings there might not be the supervising engineer.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. As mentioned earlier, the engineers consider different varieties of codes of adjacent countries like Jordan, Syria, Egypt or other international codes like ACI, BS and DIN as well. There is not a national code for Palestine (West Bank and Gaza Strip) yet and we are in the process of preparing our national code of practice. Title of the code or standard: As mentioned earlier, the engineers consider different varieties of codes of adjacent countries like Jordan, Syria, Egypt or other international codes like ACI, BS and DIN as well. There is not a national code for Palestine (West Bank and Gaza Strip) yet and we are in the process of preparing our national code of practice.

There is no national code applied. Also the court of law applies the Egyptian and Jordanian laws.

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

200-300 $/m^2$ of built-up area (This does not include the land price which is generally high and also the taxes). For a housing unit of 60,000 $ cost, approximately 500 workdays or person-days are required to complete the construction. (Considering that 8 labors can finish the construction, both skeleton and finishing, within two months).

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

The retrofitting of structures is not governed by certain provisions. It is performed rarely by individual engineers for certain cases without applying unique principles and tools. In general, jacketing using reinforced concrete or steel is used for strengthening purposes.

8.2 Seismic Strengthening Adopted

8.3 Construction and Performance of Seismic Strengthening

Reference(s)

1. Building code requirements for structural concrete and commentary, ACI 318-95
   American Concrete Institute (ACI) 1995

2. Vulnerability and seismic performance of buildings in Palestine
   Al-Dabbeek,J.
   Expert Meeting on Earthquake Engineering and retrofit, UNESCO, Beirut 2000

3. 1999 and 2000 Bulletins and site investigation reports
   Earth Sciences and Seismic Engineering Center (ESSEC), An-Najah University, Palestine 2000

4. European Microseismic Scale (EMS)
   Luxembourg 1998

5. The Aqaba earthquake of November 22,1995
   Hussein Malkawi,A.I, Numayr,K.S., and King,S.A.
   Earthquake Spectra, 15 (3), 397-415 1999

6. Seismic Risk Assessment and Design of Building Structures
   Koridze,A.
   Omega Scientific, UK 1998

7. Detailing for Al-Masri building and Al-Jardaneh School
   Municipality of Nablus-Engineering Department, Nablus Palestine 1998-2001

8. Learning from earthquake-the Aqaba earthquake of November 22, 1995
   Osman,A. and Ghobarah,A.
   EERI Special Earthquake Report, May 1995

Author(s)

1. Jalal N. Al Dabbeek
   Civil Engineer/Associate Professor, Center of Earth Sciences & Seismic Engineering, An-Najah National University
   P.O. Box 707, Nablus West Bank , PALESTINIAN TERRITORIES
   Email:seiscen@najah.edu FAX: +972 9 2387982

2. Abdel H. W. Al-Jawhari
   Civil Engineer, Engineering Department, Municipality of Nablus
   P.O. Box 218, Nablus , PALESTINIAN TERRITORIES
   Email:awjawhari@nablus.org FAX: +972 9 2374690

Reviewer(s)

1. Polat Gulkan
   Professor
   Department of Civil Engineering, Middle East Technical University
   Ankara 6531, TURKEY
   Email:pgulkan@metu.edu.tr FAX: +90 312 210 1193