

# World Housing Encyclopedia

*A Resource on Construction in Earthquake Regions*



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

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## HOUSING REPORT

### Stone masonry apartment building

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<b>Report#</b>	75
<b>Last Updated</b>	
<b>Country</b>	Algeria
<b>Author(s)</b>	Mohammed Farsi, Farah Lazzali, Yamina Ait-Mziane,
<b>Reviewers</b>	Marjana Lutman ,

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### Important

This encyclopedia contains information contributed by various earthquake engineering professionals around the world. All opinions, findings, conclusions & recommendations expressed herein are those of the various participants, and do not necessarily reflect the views of the Earthquake Engineering Research Institute, the International Association for Earthquake Engineering, the Engineering Information Foundation, John

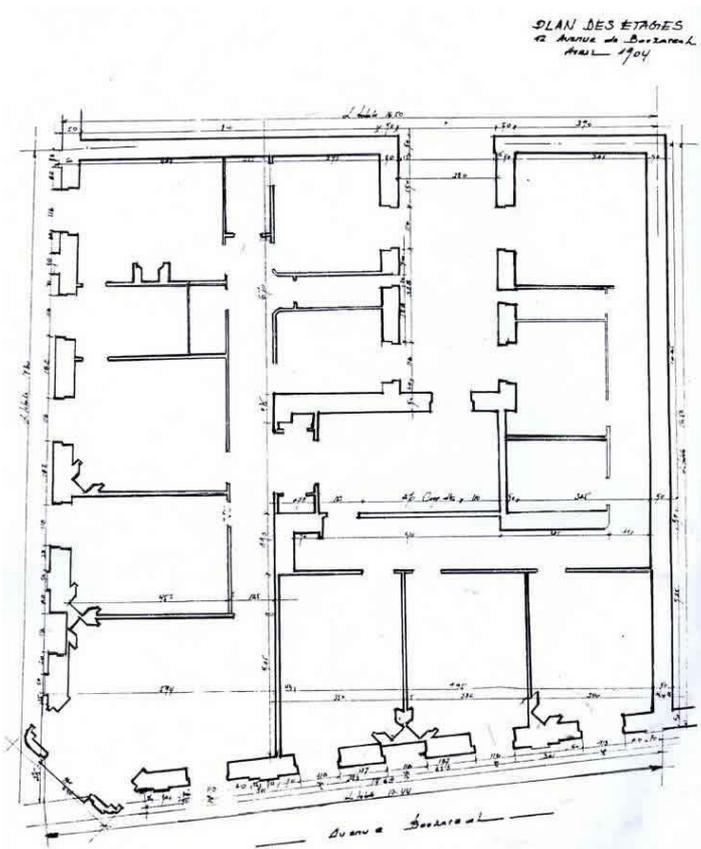
## **General Information**

<b>Building Type:</b>	Stone masonry apartment building
<b>Country:</b>	Algeria
<b>Author(s):</b>	Mohammed Farsi Farah Lazzali Yamina Ait-Mziane
<b>Last Updated:</b>	
<b>Regions Where Found:</b>	These stone masonry buildings exist throughout northern Algeria. In particular, the multi-story buildings exist mainly in the major cities e.g. Algiers, Oran, Constantine, Annaba, etc. This construction type may constitute 40 to 50% of the urban housing stock.
<b>Summary:</b>	Stone masonry building is typical multi-family residential construction found in most Algerian urban centres, and it constitutes 40 to 50% of the total urban housing stock. This construction, mostly built before 1950s by French contractors, is no longer practiced. Buildings of this type are typically 4 to 6 stories high. The slabs are wooden structures or shallow arches supported by steel beams (jack arch system). Stone masonry walls, usually 400 to 600 mm thick, have adequate gravity load-bearing capacity, however their lateral load resistance is very low. As a result, these buildings are considered to be highly vulnerable to seismic effects.
<b>Length of time practiced:</b>	101-200 years
<b>Still Practiced:</b>	No
<b>In practice as of:</b>	1950
<b>Building Occupancy:</b>	Mixed residential/commercial
<b>Typical number of stories:</b>	5
<b>Terrain-Flat:</b>	Typically
<b>Terrain-Sloped:</b>	Typically
<b>Comments:</b>	This construction was practiced prior to 1950 by French contractors. It is the same construction type found in countries around

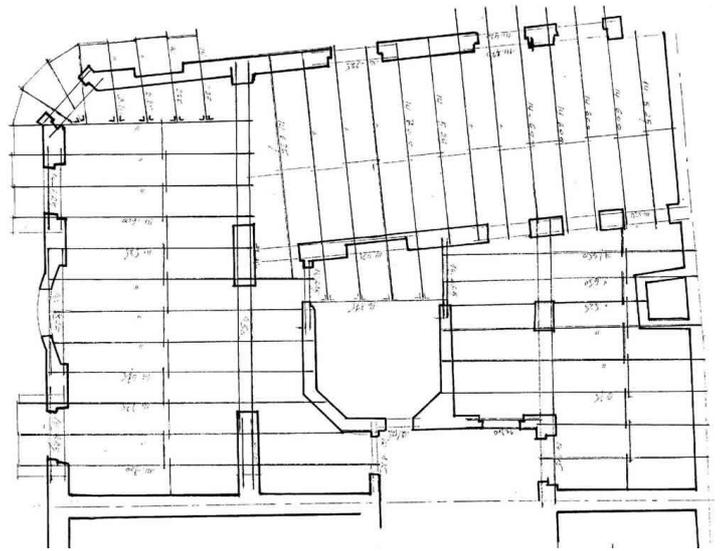
## Features

<b>Plan Shape</b>	Square, solidSquare, with an opening in planRectangular, solidRectangular, with an opening in planL-shapeTriangular, with an opening in planE-shapeU- or C-shapeIrregular plan shape
<b>Additional comments on plan shape</b>	The building plan for this housing type can be of different forms: rectangular, L-shaped, U-shaped, etc. (see photos 1 and 2)
<b>Typical plan length (meters)</b>	25
<b>Typical plan width (meters)</b>	15
<b>Typical story height (meters)</b>	3.5
<b>Type of Structural System</b>	Masonry: Stone Masonry Walls: Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)Masonry: Stone Masonry Walls: Massive stone masonry (in lime/cement mortar)
<b>Additional comments on structural system</b>	Lateral load-resisting system: The lateral load-resisting system consists of the stone masonry walls built in longitudinal and cross directions. Wall thickness varies from 400 to 600 mm. Low-strength mortar (either cement/sand or mud mortar) has been used. According to the Algerian Seismic Code (RPA99), this construction is permitted only if confined with reinforced concrete ties in vertical and horizontal direction, and with RC slabs used as floor and roof structures. The maximum building height allowed by the Code depends on the seismic zone (17 m, 14 m and 11 m, for seismic zones I, II and III, respectively).Gravity load-bearing system: Stone masonry walls are the principal elements of the gravity load-bearing structure.
<b>Gravity load-bearing &amp; lateral load-resisting systems</b>	The predominant structural system is composed of load bearing external stone masonry walls and wooden floors slabs. Thick external walls are distributed in both directions, however interior non-structural walls are thin and used to partitioning the space. In some cases, varied structural units (adobe, brick and stone) and systems are used resulting in variable wall strength and stiffness. Photos 03 & 04
<b>Typical wall densities in</b>	

<b>Typical wall densities in direction 1</b>	5-10%
<b>Typical wall densities in direction 2</b>	5-10%
<b>Additional comments on typical wall densities</b>	The ratio of total wall area/plan area (for each floor) in each principal direction is between 5% and 6%.
<b>Wall Openings</b>	The number, size and position of openings for a typical floor in a building are shown on the typical plan (Figure 3). The total window and door area is about 25% of the overall wall surface area. Openings are categorized according to their construction period and method; in some of them wooden lintels are used and in others the top of the opening is closed with a small vault.
<b>Is it typical for buildings of this type to have common walls with adjacent buildings?</b>	No
<b>Modifications of buildings</b>	Modifications are often undertaken by the residents without any professional assistance provided by engineers. They include demolition of interior walls, opening commercial areas, and vertical extensions.
<b>Type of Foundation</b>	Shallow Foundation: Wall or column embedded in soil, without footing Shallow Foundation: Rubble stone, fieldstone strip footing
<b>Additional comments on foundation</b>	
<b>Type of Floor System</b>	Other floor system
<b>Additional comments on floor system</b>	Floor: vaulted masonry (bricks) supported by steel beams Floor and roof structures are not considered as rigid diaphragms.
<b>Type of Roof System</b>	Roof system, other
<b>Additional comments on roof system</b>	Timber: wood planks or beams that support clay tiles Floor and roof structures are not considered as rigid diaphragms. Photo 03
<b>Additional comments section 2</b>	Typical separation distance between buildings: 4-6 meters



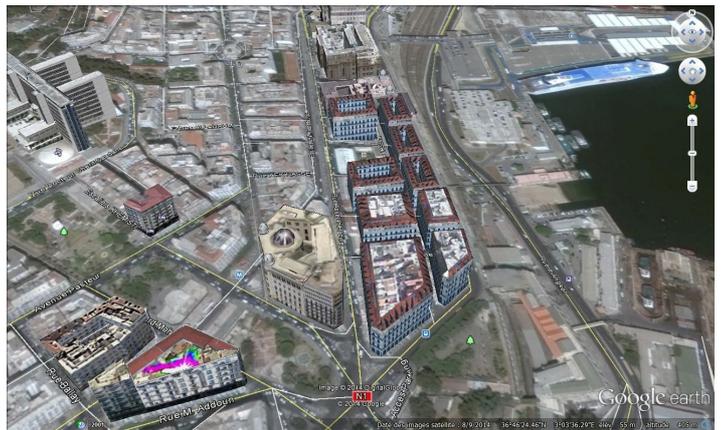
**Typical Building Plan**



**Typical Roof Plan**



**Plan shape of Stone masonry apartment buildings**



**Plan shape of Stone masonry apartment buildings**

## **Building Materials and Construction Process**

### **Description of Building Materials**

<b>Structural Element</b>	<b>Building Material (s)</b>	<b>Comment (s)</b>
Wall/Frame	Wall: Field stone in cement or mud mortar	Massive stones used at the corners and around the openings
Foundations	Field stone in cement or	

mud mortar

Floors	Vaulted bricks and wooden frames	
Roof	Vaulted bricks and wooden frames	
Other		

## Design Process

<b>Who is involved with the design process?</b>	Architect
<b>Roles of those involved in the design process</b>	Only architects had a role in the design/construction of this housing type
<b>Expertise of those involved in the design process</b>	The level of expertise of all parties involved in the design and construction process was at the worldwide level of the 20th Century.

## Construction Process

<b>Who typically builds this construction type?</b>	Other
<b>Roles of those involved in the building process</b>	Owners and contractors were involved in the construction of this type. This construction was practiced prior to 1950 by French contractors.
<b>Expertise of those involved in building process</b>	The level of expertise of all parties involved in the design and construction process was at the worldwide level of the 20th Century.
<b>Construction process and phasing</b>	The stone blocks were laid by hand and the basic construction equipment was used. This building type was typically constructed incrementally and so was not always designed for its final constructed size.
<b>Construction issues</b>	

## Building Codes and Standards

<b>Is this construction type address by codes/standards?</b>	No
<b>Applicable codes or standards</b>	
<b>Process for building code enforcement</b>	Not applicable - building codes are not applicable to this construction practice. This construction type was

<b>enforcement</b>	used before the advent of seismic codes
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## Building Permits and Development Control Rules

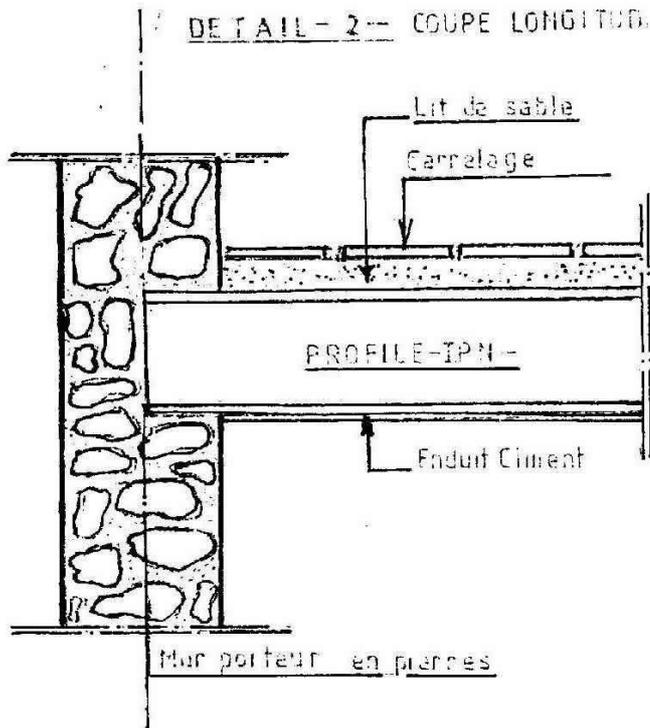
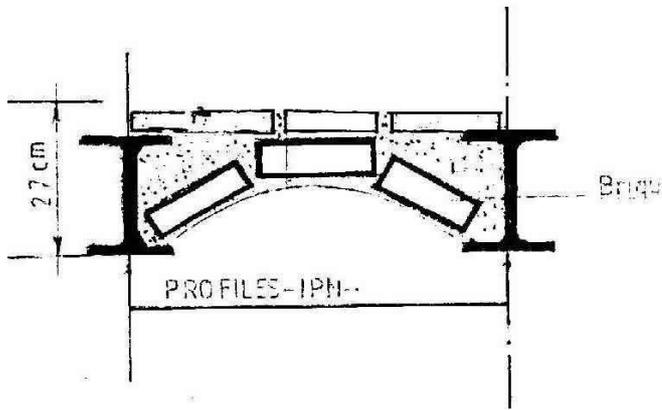
<b>Are building permits required?</b>	No
<b>Is this typically informal construction?</b>	Yes
<b>Is this construction typically authorized as per development control rules?</b>	No
<b>Additional comments on building permits and development control rules</b>	This type of construction is permitted in seismic areas if resisting elements are added as extra strength reinforced concrete ties in vertical and horizontal directions.

## Building Maintenance and Condition

<b>Typical problems associated with this type of construction</b>	
<b>Who typically maintains buildings of this type?</b>	Other
<b>Additional comments on maintenance and building condition</b>	Problems with maintenance - most of this construction is in a lamentable state.

## Construction Economics

<b>Unit construction cost</b>	10 000-15 000 Algerian Dinars /m.sq. (150-200 \$US/m.sq.)
<b>Labor requirements</b>	Information not available.
<b>Additional comments section 3</b>	



***Critical Structural Details: Wall-Roof Connection and Vaulted Brick Floor Structure***

**Socio-Economic Issues**

<p><b>Patterns of occupancy</b></p>	<p>In Algeria there is a serious housing crisis. On an average, there are two families occupying the same housing unit: the parents and a son's or daughter's family.</p>
<p><b>Number of inhabitants in a typical building of this construction type during the day</b></p>	<p>10-20</p>
<p><b>Number of inhabitants in</b></p>	

<b>a typical building of this construction type during the evening/night</b>	>20
<b>Additional comments on number of inhabitants</b>	In most cases the women in the families are not working and stay at home during the day.
<b>Economic level of inhabitants</b>	Low-income class (poor)
<b>Additional comments on economic level of inhabitants</b>	Economic Level: For the Poor Class the ratio of Housing Price Unit to their Annual Income is 10:1.
<b>Typical Source of Financing</b>	Owner financed Personal savings Government-owned housing
<b>Additional comments on financing</b>	
<b>Type of Ownership</b>	Rent Own outright
<b>Additional comments on ownership</b>	
<b>Is earthquake insurance for this construction type typically available?</b>	Yes
<b>What does earthquake insurance typically cover/cost</b>	Earthquake insurance for all construction types is available since 2004 This insurance, known as CATNAT, was set up following the Boumerdes earthquake by the group of insurance companies. The insurance premium is assessed, for the moment, only on the seismic zone, the surface and the height of the construction. Since the beginning of 2013, a working group was set up to reflect on the parameters to be taken into account for the evaluation of the premium
<b>Are premium discounts or higher coverages available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features?</b>	No
<b>Additional comments on premium discounts</b>	
<b>Additional comments section 4</b>	

# Earthquakes

## Past Earthquakes in the country which affected buildings of this type

Year	Earthquake Epicenter
1980	El-Asnam
1989	Tipaza
1994	Mascara
1999	Ain-Tmouchent
2003	Boumerdes

## Past Earthquakes

<b>Damage patterns observed in past earthquakes for this construction type</b>	Damage patterns vary from diagonal "X"-cracks to total wall collapse, and partial to total collapse of the roofs/slabs. The following damage patterns were also observed:- Horizontal cracks between walls and floors, - Vertical cracks at walls intersections, - Out of plane collapse of external walls, - Diagonal cracks in wall piers, - Partial or complete disintegration of walls, - Partial or complete collapse of the building
<b>Additional comments on earthquake damage patterns</b>	Earthquake Total Number of Apartment Buildings (all types) Damage level (MSK scale) 1 2 3 4 5 1980 El-Asnam 4844439 1304 1351 863 8871989 Tipaza 4511 1480 1102 223 426 12801994 Mascara 1874 470 302 351 212 5391999 Ain-Tmouchent 3398 1062 606 684 528 518

## 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  $\frac{1}{2}$  of the distance between the adjacent cross walls; For adobe masonry, stone masonry and brick masonry in mud mortar: less than  $\frac{1}{3}$  of the distance between the adjacent cross walls; For precast concrete wall structures: less than  $\frac{3}{4}$  of the length of a perimeter wall.

Structural/Architectural Feature	Statement	Seismic Resistance

Lateral load path	The structure contains a complete load path for seismic force effects from any horizontal direction that serves to transfer inertial forces from the building to the foundation.	TRUE
Building Configuration-Vertical	The building is regular with regards to the elevation. (Specify in 5.4.1)	FALSE
Building Configuration-Horizontal	The building is regular with regards to the plan. (Specify in 5.4.2)	FALSE
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.	FALSE
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	TRUE

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

## Building Irregularities

<b>Additional comments on structural and architectural features for seismic resistance</b>	In some cases, the use of these buildings changed.
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<b>Vertical irregularities typically found in this construction type</b>	Other
<b>Horizontal irregularities typically found in this construction type</b>	Other
<b>Seismic deficiency in walls</b>	- Poor mortar strength;- Walls not tied together;- varied structural units (adobe, brick and stone) and systems
<b>Earthquake-resilient features in walls</b>	
<b>Seismic deficiency in frames</b>	
<b>Earthquake-resilient features in frame</b>	
<b>Seismic deficiency in roof and floors</b>	-Not monolithic;-Not rigid in-plane;
<b>Earthquake resilient features in roof and floors</b>	
<b>Seismic deficiency in foundation</b>	
<b>Earthquake-resilient features in foundation</b>	

## Seismic Vulnerability Rating

For information about how seismic vulnerability ratings were selected see the [Seismic Vulnerability Guidelines](#)

	<b>High vulnerability</b>		<b>Medium vulnerability</b>		<b>Low vulnerability</b>	
	A	B	C	D	E	F
Seismic vulnerability class	0					



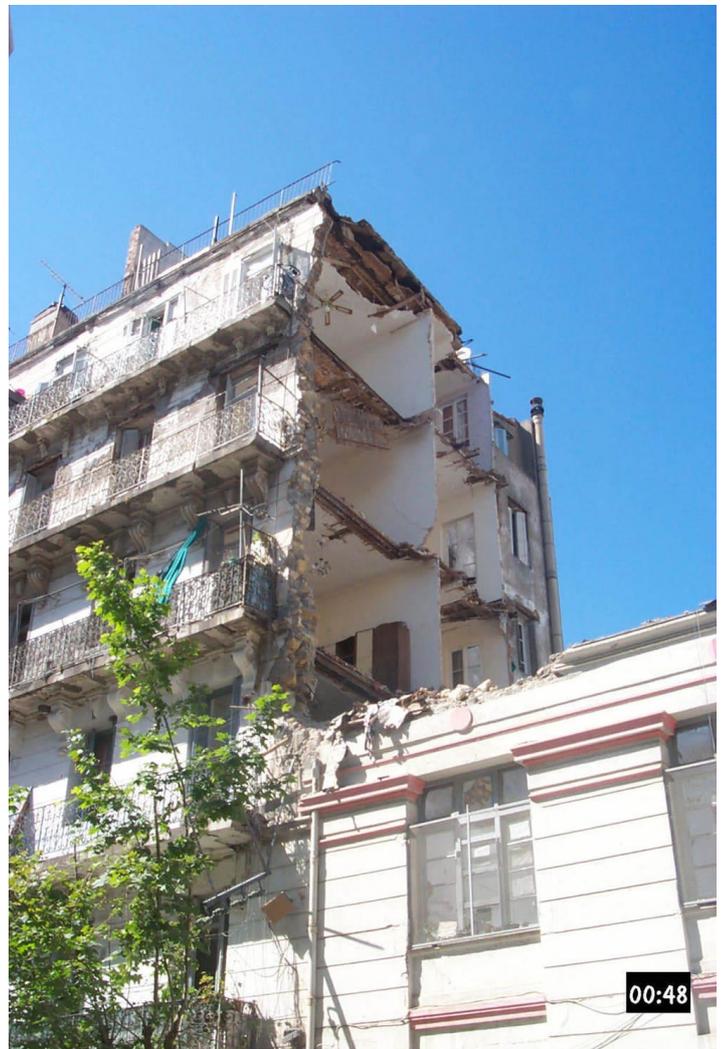
**Typical Earthquake Damage:  
Partial Roof Collapse (1999 Ain-  
Temouchent Earthquake)**



**Typical Earthquake Damage:  
Collapsed Roof of a Masonry  
Building (1989 Tipaza Earthquake)**



**Typical Earthquake Damage:  
Cracking in the Wall Corners**



**Damage to a stone masonry  
building in Algiers in the May 21,  
2003 earthquake**



***Totally collapsed stone masonry building in Dellys (Boumerdes) in the May 21, 2003 earthquake***



***Collapse of the vaulted brick and steel floor system in the May 21, 2003 earthquake (El Harrach district, Algiers)***



***Collapse of a rubble stone masonry wall made of river stones and mud mortar in the May 21, 2003 earthquake (Sidi Daoud, Boumerdes)***



***Damaged wooden framed roof of stone masonry apartment buildings by the May 21st, 2003 Boumerdes earthquake.***



***Rubble stone (field stone) masonry with earth mortar constituting the apartment building walls in many***

*cases.*

## **Retrofit Information**

### **Description of Seismic Strengthening Provisions**

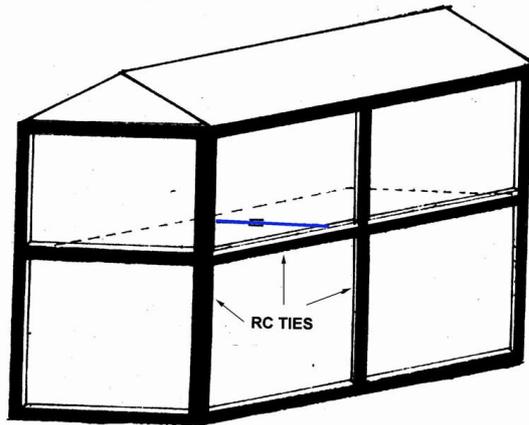
<b>Structural Deficiency</b>	<b>Seismic Strengthening</b>
Cracks in the stone masonry walls	- Cracks less than 0.3 mm width; by injection using fluid cement mortar- Large cracks: injection and adding stitching dog or steel bars; rebuilt using bricks or stones to bridge the crack zone in case of vertical crack; using metallic plate in case
Lack of integrity	Addition of horizontal and vertical RC ties at exterior and steel ties in the interior, see Figure 7A

<b>Additional comments on seismic strengthening provisions</b>	
<b>Has seismic strengthening described in the above table been performed?</b>	These strengthening techniques were used to repair and strengthen the damaged buildings after the Algerian earthquakes reported in this contribution. A guide for using these seismic strengthening techniques is available in Algeria ("Mthodes de Rparation et de Renforcement des Ouvrages" was edited by CGS in 1992).
<b>Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?</b>	Vulnerability studies for strategic buildings were done in 1996 at Algiers City, and some buildings of this type were strengthened as a result of the study.
<b>Was the construction inspected in the same manner as new construction?</b>	No.
<b>Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?</b>	A contractor performed the construction and engineers were involved.

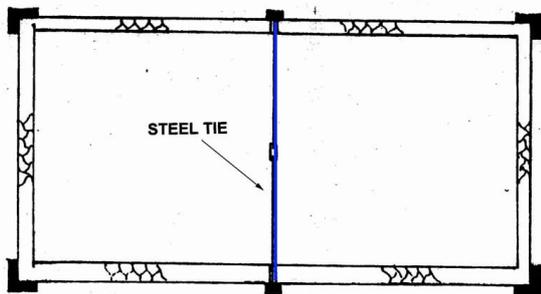
**What has been the performance of retrofitted buildings of this type in subsequent earthquakes?**

Good.

**Additional comments section 6**



ELEVATION



PLAN

***Seismic Strengthening Techniques: Provision of Horizontal and Vertical RC Ties at the Exterior and Horizontal Steel Ties at the Interior***



***Seismic Strengthening Techniques: An Example of a Strengthened Building with Vertical and Horizontal RC Ties at the First Floor Level***



***Seismic Strengthening  
Techniques: Construction of RC Ties***



***Young victims of 21 May  
2003 earthquake in Al Bordj Menail  
city- there is a hope in spite of the  
tragedy that affected population  
and caused severe human and  
economic losses; the earthquake  
killed more than 2,200 people,  
injured more***



***Retrofitted building following 1980 El Asnam earthquake. Addition of horizontal and vertical RC ties at exterior and steel ties in the interior.***

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