مجلة جامعة تشرين للدراسات و البحوث العلمية _ سلسلة العلوم الهندسية المجلد (28) العدد (1) 2006
Tishreen University Journal for Studies and Scientific Research- Engineering Science Series Vol. (28) No (1) 2006

The Syrian Contribution in the "EERI/IAEE Encyclopedia of Housing Construction in Seismically Prone Areas of the World"

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(Accepted 15/2/2006)

□ ABSTRACT □

This Work presents our contribution at the project entitled: An Encyclopedia of Housing Construction Types in Seismically Prone Areas of the World, supported by Earthquake Engineering Research Institute (EERI) in USA and International Association of Earthquake Engineering (IAEE) in Canada. The aim of this project is to develop a global categorization of characteristic housing and construction types in these areas, analogous to existing seismic categorizations of U.S constructions. The categorization for each housing type is presented in a standardized comparative form. The emphasis will be on identifying the structural elements of each housing type; how/if the construction type currently provides seismic resistance; and possible strengthening schemes for housing types that don't adequately provide seismic resistance. The contribution will be aimed at local public and private organizations and individuals concerned with understanding and improving the seismic resistance of a region's housing stock.

The housing type chosen is found in the main cities of Syria. The floor system is characterized by 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. This type of building is a multiple housing unit.

The following outlines summarize the intended scope of this paper:

1- General Information 2- Architectural Features
3- Socio-Economic Issues 4- Structural Features
5- Evaluation of Seismic Performance and Seismic Vulnerability
6- Earthquake Damage Patterns
7- Building Materials and Construction Process
8- Construction Economics 9- Insurance
10- Seismic Strengthening Technologies
11- Conclusions
12- References

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مساهمة سوريا في إعداد الموسوعة العالمية للأبنية السكنية الواقعة في مناطق معرضة للأخطار الزلزالية
برعاية و تنظيم المعهد الأمريكي لأبحاث الهندسة الزلزالية و الجمعية العالمية للهندسة الزلزالية في كندا

الدكتور بسام حويجة*

(قبل للنشر في 2006/2/15)

□ الملخّص □

يعرض هذا العمل مساهمة سوريا في المشروع المنظم من قبل المعهد الأمريكي لأبحاث الهندسة الزلزالية (EERI) و الجمعية العالمية للهندسة الزلزالية في كندا (IAEE) . يهدف هذا المشروع إلى إعداد الموسوعة العالمية للأبنية السكنية الواقعة في مناطق زلزالية مختلفة من العالم، و يسمح بإجراء تصنيف شامل لأنظمة البناء السكني في هذه المناطق و أيضاً تحديد خواصها، بطريقة مشابهة للتصنيف المعتمد للمنشآت الواقعة في مناطق زلزالية في أمريكا.

في الواقع، إن هذا العمل يتوجه إلى قطاعات مختلفة من المجتمع مثل المكاتب الهندسية الخاصة والمؤسسات والأفراد المعنيين في فهم سلوك الأبنية السكنية القائمة إزاء الأفعال الزلزالية و تحديد درجة قابليتها للتضرر، والعمل على حمايتها و تخفيف المخاطر عنها بتقويتها و تدعيمها لمقاومة الزلازل.

اخترنا أنموذجاً لبناء سكني شائع الاستخدام في سوريا، موجود في الضواحي السكنية الخاصة بالعاملين في الجيش، حيث يتألف الهيكل الحامل من بلاطات مصمتة و جوائز و أعمدة مصممة لمقاومة الأفعال الشاقولية فقط.

و اعتمدنا في الدراسة المحاور التالية التي حددت منهجية العمل:

1- معلومات عامة عن النموذج المعتمد
2- العناصر والخواص المعمارية
3- القضايا الاجتماعية و الاقتصادية
4- العناصر الإنشائية
5- التقييم الزلزالي
6- أنماط التضررات الزلزالية
7- مواد البناء و عمليات الإنشاء
8- اقتصاد الإنشاء
9- التأمين
10- تقنيات التدعيم الزلزالي
11- استنتاجات
12- المراجع

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1 - General Information:

1.1 ***Country:*** Syria

1.2 ***Form ID Number:*** 2, our second contribution in the Encyclopedia (two housing types chosen), the first one represents the buildings in Syria which have a dual system (Frame with concrete shear walls), and the second:

1.3 ***Housing Type****:* Moment resisting frame designed for gravity loads only

1.4 ***Summary:*** These buildings are found in the main cities of Syria. The floor system is characterized by 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. This type of building is a multiple housing unit.

1.5 ***Typical Age for Buildings of This Construction Type***

What is a typical building age for this construction type?	Select all that apply **(X)**
<25 years	
26-50 years	X
51-75 years	
76-100 years	
101-200 years	
>200 years	

1.6 ***Period of Practice***

Modern construction followed in the last 50 years.

1.7 ***Region(s) Where Used***

This type of construction exists in main cities of Syria: Damascus, Aleppo, Latakia, Homs, Hama, Deir-ez Zor , Idleb , AL-Haskeh , Al-Raka , Al-Sweida , Dara , Tartus , Jableh , Qunitera ….

1.8 ***Urban vs. Rural Construction***

Where is this construction type commonly found?	Select one**(X)**
In urban areas	X
In rural areas	
Both in rural and urban areas	

1.9 General Weather Patterns [1, 3]:

1.9.1 Max. Average /Mini. Average temperature in different regions in Syria26.7 C° / 9.0 C° (Damascus); 24C° /12.3 C° (Homs), 27.2 C° /13.5 C° (Palmyra); 26 C° / 12.9 C° (Hama); 24 C° /16.3 C° (Latakia); 25 C°/12 C° (Aleppo); 28.4 C° /14.3 C° (Deir-ez Zor); 26.6 C° /13.7C° (Al-Kamishly).

1.9.2 Maximum average rainfall (precipitation) per year (mm) , 1998: Damascus 81; Homs 345.4; Palmyra 102.5, Hama 315; Latakia 709.1; Aleppo 275.2 Deir-ez zor 109.9; Al-Kamishly 333.

1.9.3 Average humidity

Average humidity (%), 1998: Damascus 55; Homs 71; Palmyra 53; Hama 60; Latakia 85; Aleppo 60; Deir-ez zor 48; Al-Kamishly 45.

2 - Architectural Features

2.1 Openings

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

2.2 Siting

It is found on both flat terrain and sloped terrain.

2.3 Building Configuration

Rectangular.

2.4 Building Function

What is the main function for buildings of this construction type?	Select one **(X)**
Single family house	
Multiple housing units	X
Mixed use (commercial ground floor, residential above)	
Other (explain below)	

3 - Socio-Economic Issues [1,3]

3.1 Density of Population in the Region:

Density of population in Syria (per sq.km.): 74 (1995 census); 86 (1999 census).

Density of population in the Region (per sq.km.), (1994 census): Damascus city = 13754; Damascus rural area = 93; Aleppo = 160; Homs = 28; Hama = 124; Latakia = 324; Deir-ez Zor = 21; Idleb = 148; AL-Haskeh = 44; Al-Raka = 28; Al-Sweida = 48; Dara = 161; Tartus = 308 & Qunitera = 26 per sq. km.

3.2 Density of Housing:

Additional comments: 3500-6000 houses/km2 in the main cities.

Additional comments:

In 1994, 43% of the total population lived in only two biggest centers (Damascus & Aleppo). The actual percent of illegal dwelling is as follows: Damascus city 27%; Damascus rural area 8% ; Aleppo city 25%. These types of building are widely spaced.

3.3 Patterns of Occupancy:

One family typically occupies one house.

3.4 Number of Housing Units in a Building: 6-12

3.5 Average Number of Inhabitants in a Building

How many inhabitants reside in a typical building of this construction type?	During the day (i.e. during business hours)	In the evening/night
	Select all that apply **(X)**	Select all that apply **(X)**
< 5		
5 to 10		
10-20	X	
> 20		X
Other (provide numbers)		

3.6 Number of Bathrooms or Latrines per Housing Unit (if shared by more than one unit, number per Building—please indicate which):

One Bathroom.

3.7 Economic Level of Inhabitants (see below) [3]

Economic Status (see Note 1)	Select all that apply (X)	House Price/Annual Income
Very poor		
Poor	X	$ 10000-$15000/$1000-$2500
Middle Class	X	$ 15000-$20000/$2500-$5000
Rich		

Notes:

1. Below are the general guidelines related to the economic status of the inhabitants:

Very Poor = lowest 10% of the population

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

3.8 Typical Sources of Financing

What is a typical source of financing for buildings of this type?	**Select all that apply (X)**
Owner financed	X
Personal savings	X
Informal network: friends and relatives	
Small lending institutions/microfinance institutions	
Commercial banks/mortgages	X
Investment pools	
Combination (explain)	
Government-owned housing	X
Other (explain below)	

3.9 Ownership

Type of Ownership	Select all that apply **(X)**
Rent	X
Own outright	X
Own with debt (mortgage or other)	X
Units owned individually (condominium)	
Owned by group or pool	
Long-term lease	X
Other	X

Additional comments:
Other: Ownership by heritage.

4 - Structural Features (Fig.1-5)

4.1 Lateral Load-Resisting System:

We can assume that the frames (Columns + Beams) provide a partial strength and stiffness to control lateral displacements due to moderate earthquakes (Fig. 1& 2).

4.2 Gravity Load-Bearing Structure:

Frames (columns, beams) carry gravity loading (Fig. 3, 4 & 5).

4.3 Type of Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	Select the most appropriate type **(X)**
Masonry	Stone Masonry Walls	1	Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)	
		2	Massive stone masonry (in lime/cement mortar)	
	Earthen/Mud/ Adobe/Rammed Earthen Walls	3	Mud walls	
		4	Mud walls with horizontal wood elements	
		5	Adobe block walls	
		6	Rammed earth/Pise construction	
	Clay brick/block masonry walls	7	Unreinforced brick masonry in mud mortar	
		8	Unreinforced brick masonry in mud mortar with vertical posts	
		9	Unreinforced brick masonry in cement mortar with reinforced concrete floor/roof slabs	
	Clay/concrete	10	Confined brick/block masonry with concrete posts/tie columns and beams	
	Concrete block masonry	11	Unreinforced in lime/cement mortar (various floor/roof systems)	
		12	Reinforced, in cement mortar (various floor/roof systems)	

Structural concrete	Moment resisting frame	13	Designed for gravity loads only (predating seismic codes i.e. no seismic features)	X
		14	Designed with seismic features (various ages)	
		15	Frame with unreinforced masonry infill walls	
		16	Flat slab structure	
		17	Precast frame structure	
		18	Frame with concrete shear walls-dual system	
	Shear wall structure	19	walls cast in-situ	
		20	precast wall panel structure	

Steel	Moment-resisting frame	21	with brick masonry partitions	
		22	with cast in-situ concrete walls	
		23	with lightweight partitions	
	Braced frame	24		
Wooden structures	Load-bearing timber frame	25	thatch	
		26	post and beam frame	
		27	Walls with bamboo/reed mesh and post (Wattle and Daub)	
		28	frame with (stone/brick) masonry infill	
		29	frame with plywood/gypsum board sheathing	
		30	frame with stud walls	

4.4 Type of Foundation

Type	Description	Select the most appropriate type **(X)**
Shallow foundation	Wall or column embedded in soil, without footing	
	Rubble stone, fieldstone isolated footing	
	Rubble stone, fieldstone strip footing	
	Reinforced concrete isolated footing	X
	Reinforced concrete strip footing	
	Mat foundation	
	No foundation	
Deep foundation	Reinforced concrete bearing piles	
	Reinforced concrete skin friction piles	
	Steel bearing piles	
	Wood piles	
	Steel skin friction piles	
	Cast in place concrete piers	
	Caissons	
Other		

4.5 Type of Floor/Roof System

Material	Description of floor/roof system	Floor	Roof
Masonry	Vaulted		
	Composite masonry and concrete joist		
Structural concrete	Cast in place solid slabs	X	X
	Cast in place one way joist slabs	X	X
	Cast in place waffle slabs		
	Cast in place flat slabs		
	Precast joist system		
	Precast planks		
	Precast beams with concrete topping		
	Postensioned slabs		
Steel	Composite steel deck with concrete slab		
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 that support slate, metal, asbestos-cement or plastic corrugated sheets or tiles		
Other			

4.6 Typical Plan Dimensions: (Length/Width, in meters): *See Fig. (2&3):*
2-20/12-16

4.7 Typical Number of Stories:
Typically form 3-5 stories
Typical Story Height: 2.85 m to 3.10 m

4.8 Typical Span*: See Fig. (3):*
3.0 to 5.5 m

4.9 Typical Wall Density:
Total wall area/plan area (for each floor) 10% to 15%

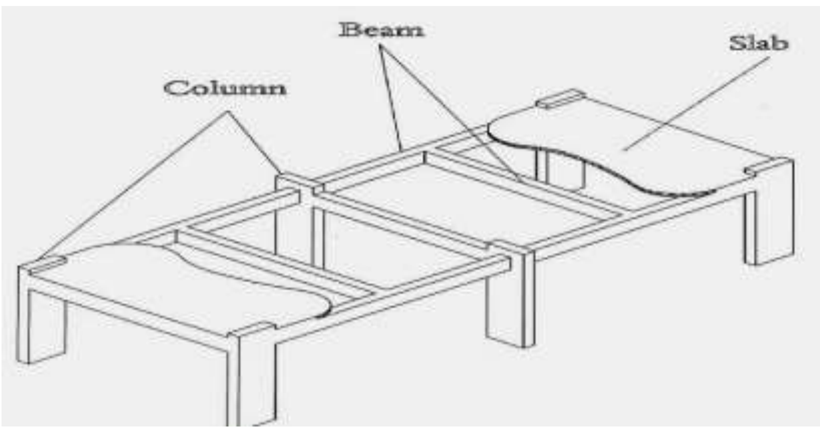
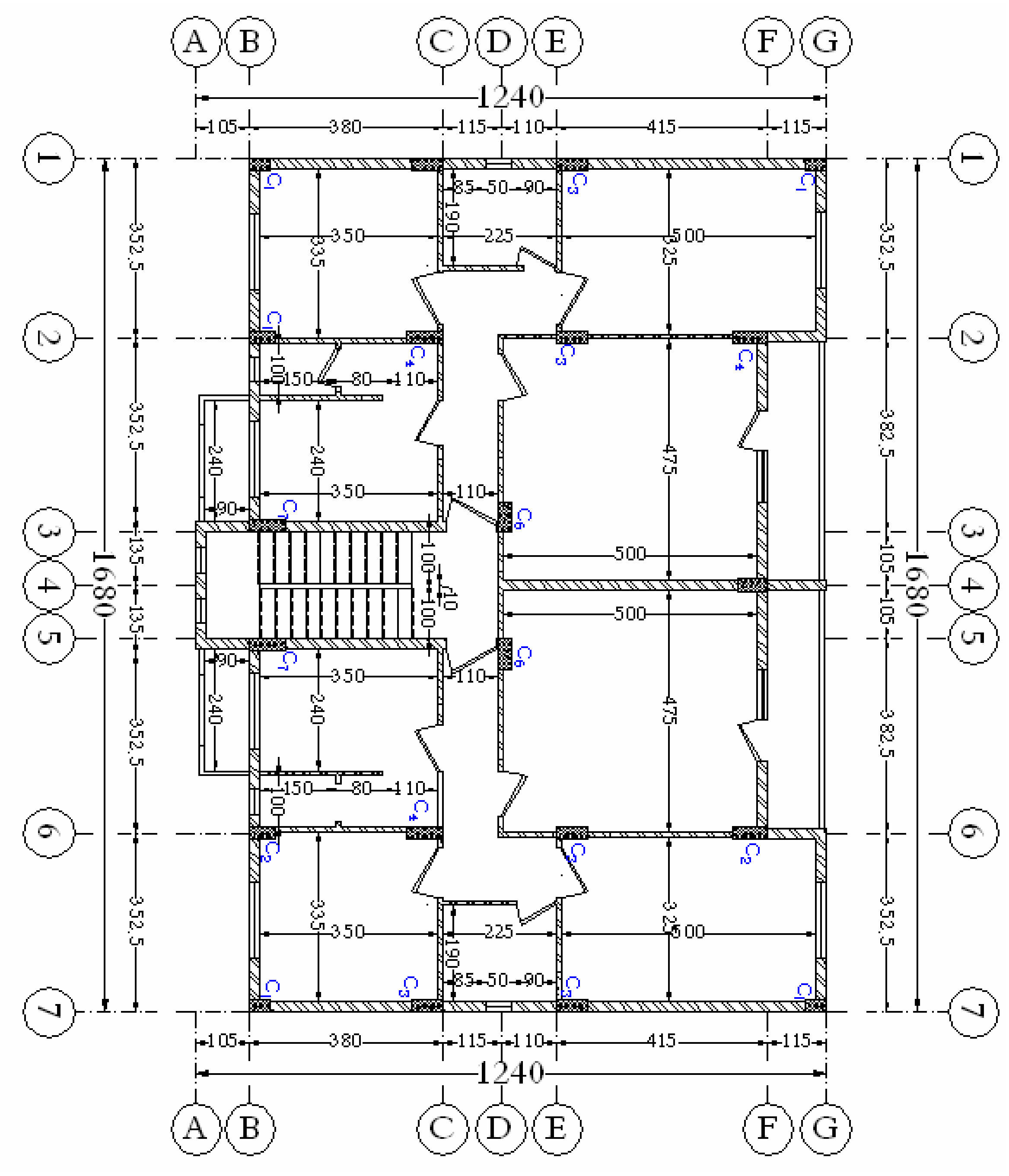


FIGURE 1: Perspective Drawing Showing Key Load-Bearing Elements



<u>FIGURE</u> 2: **Architectural Plan of a Typical Building**

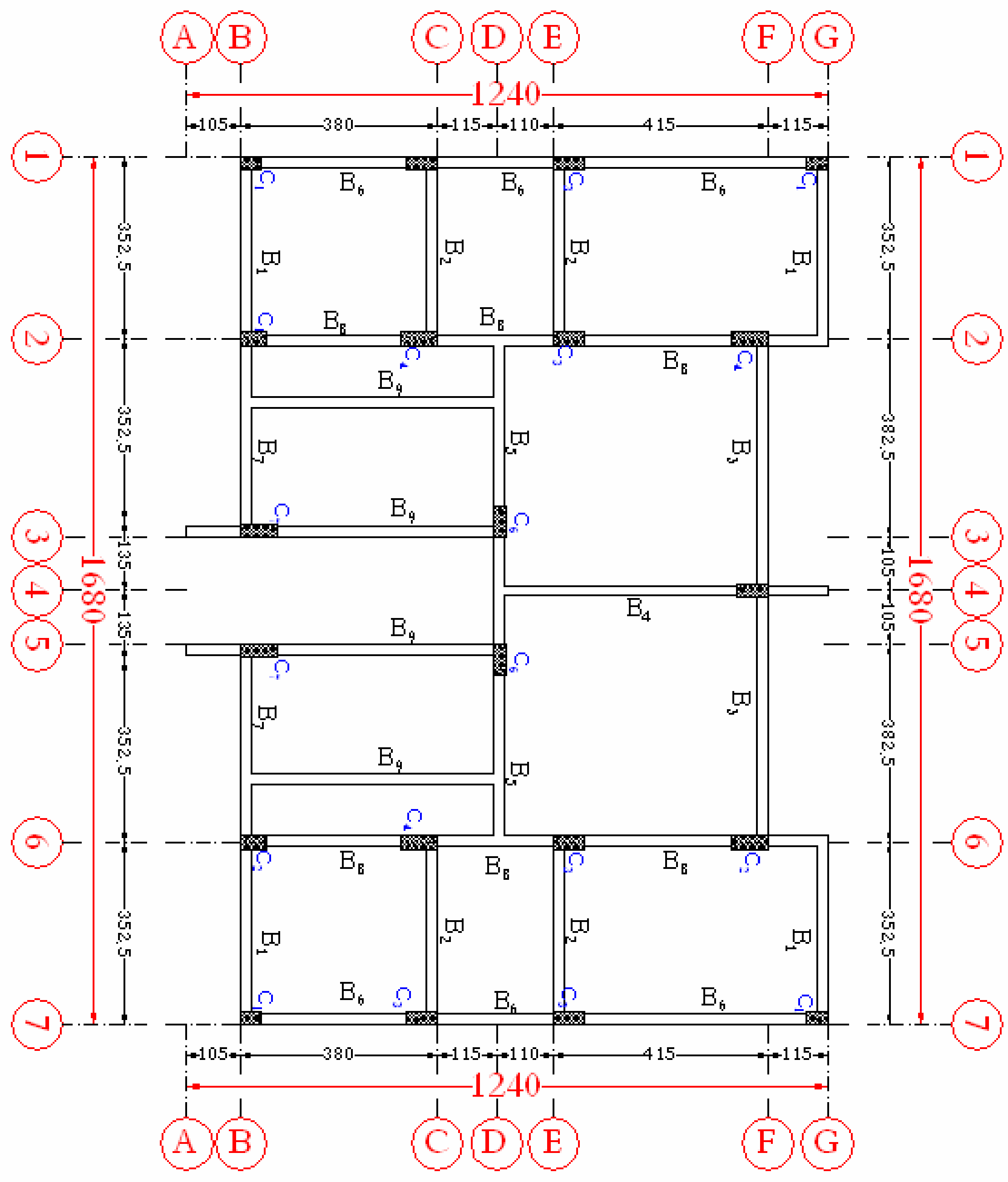


FIGURE 3: **Structural Plan of a Typical Building**

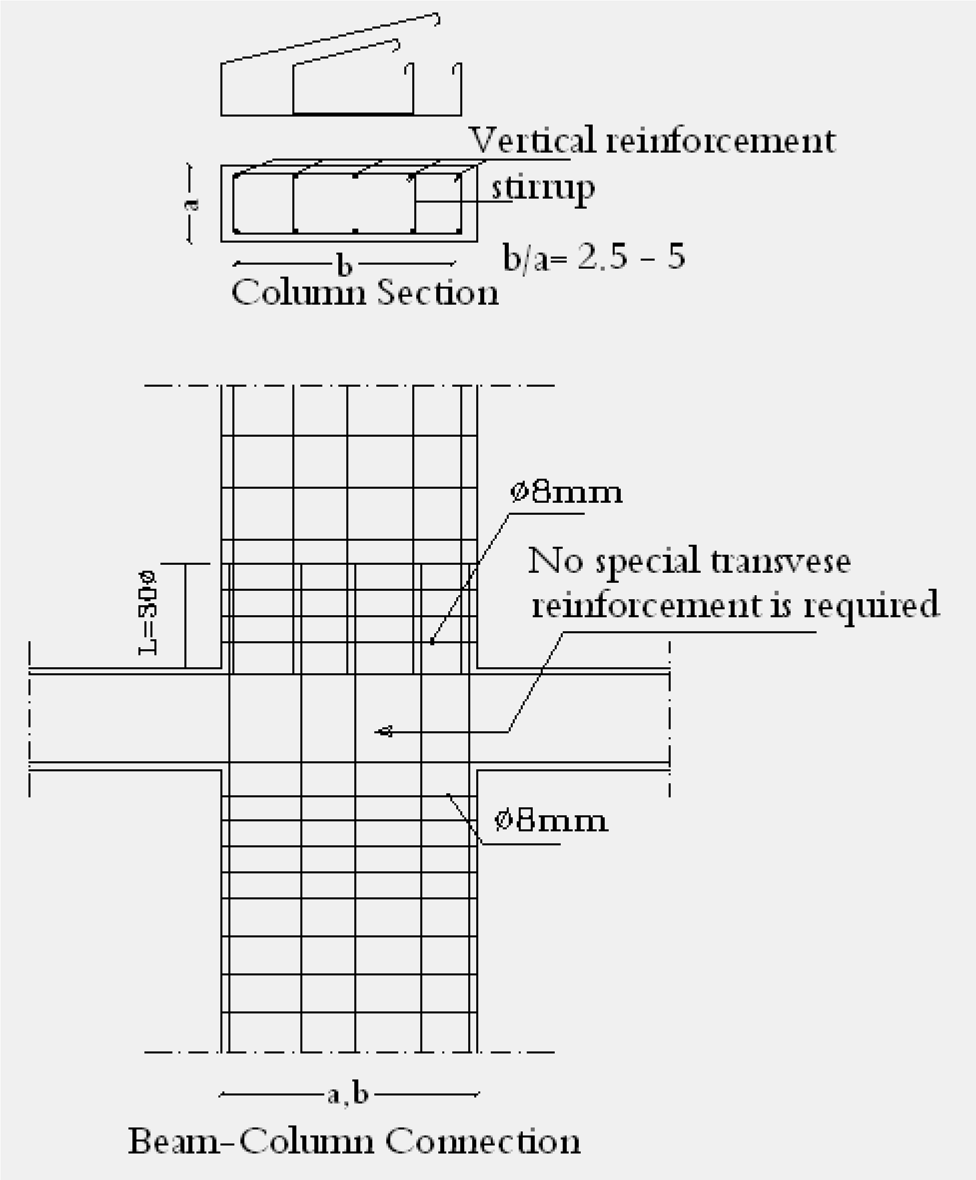


FIGURE 4: **Critical Structural Details (Beam-Column Connection)**

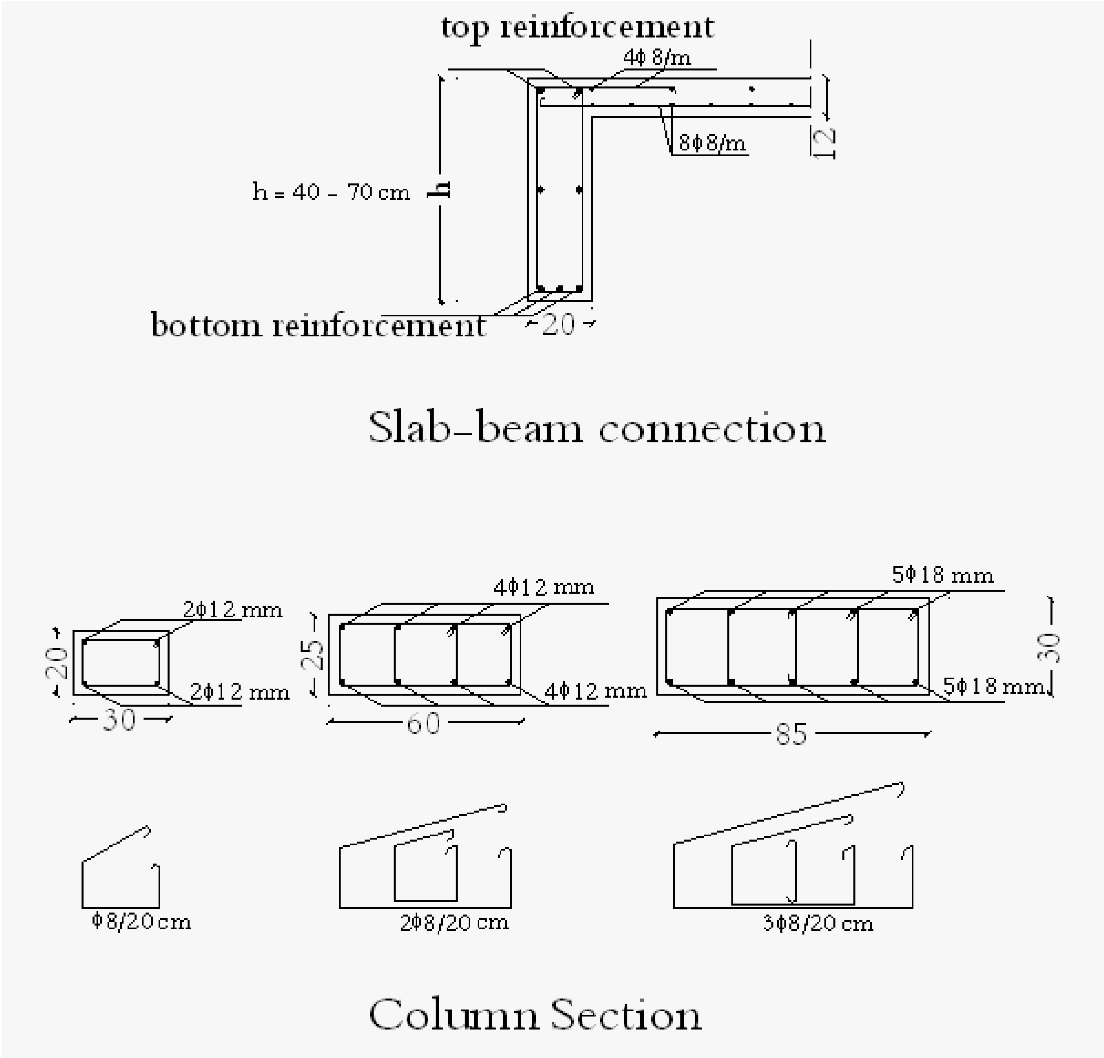


FIGURE 5: **Critical Structural Details (Column Cross-Sections & Slab-Beam Connection)**

5 - Evaluation of Seismic Performance and Seismic Vulnerability

5.1 Structural and Architectural Features: Seismic Resistance

Structural/ Architectural Feature	Statement[1]	Select one **(X)**		
		True	False	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.		X	
Building Configuration	The building is regular with regards to both the plan and the elevation.	X		
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.	X		
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.	X		
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.	X		
Wall and frame structures-redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	X		
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);			X
Foundation-wall connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	X		
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps			X

[1] The main reference publication used in developing the statements used in this table is FEMA310 "Handbook for the Seismic Evaluation of Buildings-A Prestandard", Federal Emergency Management Agency, Washington, D.C., 1998.

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

5.2 Seismic Deficiencies [4, 5]:

Structural Element (modify this column as appropriate)	Seismic Deficiency Describe in a few words
Foundations	Reinforced concrete isolated footing without compression/tension ties
Frame (columns, beams)	Weak connections between secondary and primary beams. No special transverse reinforcement at the critical region (joints).
Other	Poor quality of workmanship and materials. Development length not sufficient (≤ 30ϕ) in compression and tension regions.

5.3 Seismic Vulnerability Rating [6]:

Use symbols listed in the Notes below the table

	High Vulnerability = Very Poor Seismic Performance **A**	**B**	**Medium Vulnerability** **C**	**D**	**E**	**Low Vulnerability = Excellent Seismic Performance** **F**
Seismic Vulnerability Class	|-	-	•	-|		

Notes:
• = Expected seismic vulnerability class
|- =Probable vulnerability range –lower bound
-| =Probable vulnerability range-upper bound

6 - Earthquake Damage Patterns [2]

Year	Earthquake Epicenter (nearest city, state, for ex: Izmit, Turkey, or Killari, Maharashtra)	Richter magnitude (M)	Maximum Intensity : (Modified Mercalli Intensity : MMI)	Number of buildings of this type that completely or partially collapsed **(X)**		
				FEW	SOME	MOST
1719	Aleppo	5.5	VII	X	-	-
1759	Damascus	7.6	X	-	-	X
1759	Damascus/ Lattakia	7.5	X	-	-	X
1796	Lattakia	6.0	VIII	-	X	-
1822	Aleppo/Al-jaziereh	7.0	IX-X	-	-	X
1822	Harem/ Aleppo	6.0	VIII	-	X	-

FEW= very few buildings (less than 25%)
SOME= 25 to 50% of buildings
MOST= over 50% of buildings
Additional comments:
- Data about earthquakes taken from reference [2] (Ambraseys, 1983)
Starting from 18 th. Century up to date.
- Estimation of values: Magnitude M (Richter Scale) and Maximum Intensity (Modified Mercalli Intensity: MMI) was made by us depending on our finding and experience.
- Most of the buildings destroyed were of adobe and stone masonry particularly in urban regions.

7 - Building Materials and Construction Process

7.1 Description of Building Materials

Structural element	Building material(s)	Characteristic strength, see Note 1 (MPa)	Mix Proportion/ Dimensions, see Note 2	Comments
Foundations Frame Roof and floors	Concrete	1-3/18-25/1-2	1:2:4	
	Steel	360-420		Deformed bars

Notes:

1. Tension / compression / shear strength (e.g. concrete compression strength, steel yield strength, masonry compressive / shear strength).

2. Explain mix of different material used in the construction e.g. masonry mortar mix (1:6 cement / sand mortar or 1:3 lime / sand mortar); concrete mix 1:2:4 (cement: sand: aggregate); dimensions of masonry units e.g. brick size 228 mm (9 in) x 114mm (4.5 in)x 76mm (3 in).

7.2 Does the builder typically live in this construction type, or is it more typically built by developers or for speculation?

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

7.3 Construction Process

The owner of the land will hire an architectural office and structural engineer to design the building.

7.4 Design/Construction Expertise

The structural engineer will have 5 years of studies (BS – 5 years University degree) and more 5-10 years of experience. The construction engineer may have 5 years of studies and less experience than the structural engineer. The designer may visit the construction site, at request.

7.5 Is this Construction Type Addressed by Codes/Standards?

Yes. Starting from 1997, the seismic design for buildings is mandatory as a low: 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.

7.6 Role of Engineers and Architects:

Yes, they have a role in the design and inspection during the construction phase (see 7.3 and 7.4).

7.7 Building Permits and Development Control Rules

	Select one **(X)**	
	Yes	No
Are building permits required?	X	
Is this typically informal construction?		X
Is this construction typically authorized as per development control rules?	X	

7.8 Phasing of Construction

	Select one **(X)**	
	Yes	No
Is it likely that construction of this type takes place over time? (incrementally)		X
Are the buildings originally designed for its final constructed size?	X	

7.9 Building Maintenance

Who typically maintains buildings of this type?	Select all that apply **(X)**
Builder	
Owner (s)	X
Renter (s)	X
No one	
Other (explain)	

7.10 Process for Building Code Enforcement:

The building design must follow the Syrian code 2004 [5]. In case of damage arbitration process may take place at the court of justice.

7.11 Typical Problems Associated with this Type of Construction:

The main problems are associated with the construction
Process: Mixing, conveying and construction joints.

8 - Construction Economics

8.1 Explain unit construction cost:

A unit construction may cost 60-300 $/ m2

8.2 Explain labor requirements

One floor per month.

9 - Insurance

9.1 Insurance Issues

	Select one**(X)**	
	Yes	No
Is earthquake insurance for this construction type typically available?		X
Are premium discounts or higher coverages available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features?		X

9.2 If earthquake insurance is available, what does this insurance typically cover/cost?

N/A

10 - Seismic Strengthening Technologies

Seismic strengthening is not mostly applied in Syria.

11 - Conclusions

This paper is intended to introduce the Encyclopedia of Housing Construction Types in Seismically Prone Areas of the World, supported by Earthquake Engineering Research Institute (EERI) in USA and International Association of Earthquake Engineering (IAEE) in Canada. It demonstrates the level of detail and thoroughness of the second Syrian contribution: two housing types represent the buildings in Syria, the first one has frame with concrete shear walls - dual system, and the second one considers buildings which have moment resisting frame system designed for gravity loads only.

In this work, we have presented the scope of this Encyclopedia, and described our housing type (moment resisting frame system), including over 50 different questions that address architectural and structural features, several illustrations (photo, drawings, and sketches), socio-economic characteristic, seismic features, performance in past earthquakes, codes and constructions practices, known seismic strengthening techniques used in our country. This contribution is now producing guidelines on reducing the seismic vulnerability of construction, and it has acted as the catalyst for a wide community of architects, engineers, builders and housing officials around Syria who are striving to reduce earthquake risk.

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