CHAPTER 9

EVALUATION OF URBAN VULNERABILITY

Chapter 9. Evaluation of Urban Vulnerability

9-1 Seismic Evaluation of Existing Buildings

CGS and JST discussed and selected the target buildings for a seismic evaluation and retrofitting of existing buildings, which included three strategic and two typical buildings. CGS and JST performed the site and building inspections of all strategic buildings, and collected the existing detailed data of all target buildings as shown in Table 9-1.

Table 9-1 Collected Detailed Data for Seismic Evaluation of Buildings

Building Name	Constructed Year/ Design Code	Main Structure Type	Number of Stories	Data Collected
CMPC/ Mustapha Hospital	1990/ RPA81 ver 83 (designed in 1988)	Reinforced Concrete with Moment Frame	3F/B1F	Architectural drawings Structural drawings
Senator Office SENATE	Before 1912, for Extension 1912 to 1915/ N.A.	Stone Masonry	4F/B1F	Architectural drawings Structural drawings (w/ Detail of Floor System)
Presidential Palace	1830s and 1915/ N.A.	Stone Masonry	3F/B1F and 2F/B1F	Architectural drawings Photos of Repair Work Detail of Floor System
An Apartment House	2000/ RPA88 (designed in 1999)	Reinforced Concrete with Moment Frame	5F	Architectural drawings Structural drawings Structural calculation sheets Report of Concrete core sampling test
A School Building	RPA88	Reinforced Concrete with Moment Frame and Shear Wall	2F	Structural sketches

These collected data will be used for the seismic evaluation and the retrofitting designs in collaborative work with CGS and JST. Since an apartment house and a school building are now occupied by many people, the seismic evaluation for these two buildings will be performed based on the collected data only, and the building inspections may be arranged at the retrofitting design stage. Each level of the seismic evaluation work of existing buildings has basically many difficulties with owners live in them, many people making use of them, owner's financial and/or emotional problems etc.

9-1-1 Masonry Buildings

CGS and JST held on site and building surveys in cooperation with the owner's architect or engineer, and got some of the latest drawings and information that explain the historical circumstances. Since the two selected strategic masonry buildings are very old, some characteristics of the construction methods of the bearing walls are unknown, especially the strength of the joint material. CGS and JST discussed and agreed on an evaluation method and policy and judging criteria in the seismic evaluation stage, provided some plans and recommendations for the retrofit design stage for the Presidential PALACE building (here in after Le PALAIS) and the Senators' Office SENATE building (here in after Le SENAT) as follows;

(1) General Matter of Seismic Evaluation for Le PALAIS and Le SENAT

1) Evaluation Method and Policy

Evaluating the shear force, judging criteria and structural analysis followed the "Algerian Seismic Code RPA 99/Version 2003: Regulations for Earthquake-Resistant Algeria" (Regles Parasismiques Algeriennes). The seismic evaluation method adopted is basically the "FEMA (Federal Emergency Management Agency) -178 and 310/ June 1992: NEHRP Handbook for the Seismic Evaluation of Existing Buildings".

The unknown structural components due to lack of full drawings are assumed by the engineer. Since there are plentiful retaining walls in the basement floor structural system, it is not necessary to make a seismic evaluation.

The calculation for the weight of a building is to determine the dead load of the roof and floor(s), and the walls between the upper floor and the bottom of the bearing wall on the subject floor for a masonry structure. The live load on each floor for seismic evaluation is 20 % of 2.5 kN/m^2 (0.5 kN/m^2), but the live load on the roof is neglected in the seismic evaluation. The weight of walls will be calculated at each line due to conditions such as wall height, opening ratio, and conditions for floors and roof of average unit weights.

2) The judging criteria

The final judgment of the seismic evaluation will be based on the agreement between CGS and the JICA Study Team that the Safety Factor must be at least "1.15" and the assumed average shearing strength of the bearing wall unit must be "0.056 Mpa (0.056 N/mm^2)". The average resistance in compression of the bearing wall unit is 1.50 Mpa (1.50 N/mm^2). The total shear force of the masonry bearing wall is to be calculated based on the Algerian Seismic Code RPA 99/Version 2003.

(2) Le PALAIS

1) Overview of property

- Building Name: "PALAIS DU PEUPLE"/ "Presidential PALACE"/ "Le PALAIS"
- Property Location: Rue Franklin ROOSVELT, Algiers
- Building Criteria: Governmental Facility; VIP Guest House
- Construction Type: Stone Masonry with structural steel arch reinforcement only
- Main Material: Stone; Density 27 kN/m^3, Bearing Wall Unit weight 22 kN/m^3
- Foundation/Bearing Soils: Spread Foundation / Design Soil Capacity; Unknown
- Number of Stories: "Old Palace"; 2-story building with 1-level basement floor, "New Palace"; 3-story building with 1-level basement floor and 1-story mezzanine floor
- Building Area: "Old P.": 349.89 m^2 "New P." 957.66 m^2
- Total Floor Area: "Old P.": 703.64 m^2, "New P.": 2,895.92 m^2, G. Total: 3,599.56 m^2
- Structural Height: "Old P.": 9.82 m, "New P.": 17.73 m
- Story Height: B1; 3.61 m, 1st Fl; 4.95 ~ 5.98m, 2nd Fl; 4.48 ~ approx. 10.30 m

- Year of Completion: "Old Palace"; Before 1830s, "New Palace"; 1915
- Topography: Flat in Building Area, and basically moderate slope down to south east side

2) Evaluation Basis and Hypothesis with Site and Building Survey, and Drawing Check in Detail are as follows; (The site and building survey conducted by Mr. Med Lamine KHIAR: Directeur du Palais du Peuple and Ms. BRAHIMI; Architect).

(A) The old Palace was constructed of stone masonry with lime/sand joints sometime before the 1830s. The floor system was constructed of wood. Later, it was partially changed to an RC floor with joist beams.

(B) The new Palace was added onto the south-east side of the old Palace and partially connected at the south-west end only with stone masonry with lime/sand joints in 1915. The floor system was constructed of wooden. Later, it was changed to RC floor with joist beams. The roof of the main hall was supported by steel truss beams and covered with corrugated asbestos sheets.

(C) Basically, neither building had used cement mortar joints in the stone masonry walls before 1915. The cement mortar joint has since been provided in the bearing walls, but it was provided in repair work only by a balance filling method.

(D) Le PALAIS has rigid diaphragm floors and roofs, except for a steel truss roof in the main hall, and simple supported steel joists in another part of the New Palace. Each frame of those non-rigid roof system parts has been evaluated independently.

(E) The arches in the main hall in the New Palace were made of a steel arch truss and supported by marble columns, and covered with solid brick at the initial construction phase.

(F) Some small cracks in the floor of the New Palace were caused by the 2003 Boumerdes Earthquake, but these are not detrimental to the seismic capacity. Other cracks in the exterior walls of the New Palace are under repair by a Chinese constructor.

(G) Le PALAIS photographs are shown below;

Photo 9-1 Entrance of Old and New Palace Building

Photo 9-2 New Palace: Back Side View

Photo 9-3 Old Palace: Court Space in the Room

Photo 9-4 New Palace: Main Hall on 2nd Floor

Photo 9-5 Old Palace: Entrance Corridor on 2nd Floor

Photo 9-6 New Palace: Asbestos Roof for Main Hall

3) Unit weight of each element

According to Le PALAIS's information, CGS and JST confirmed the unit weigh of each part as shown following and in Figure 9-1.

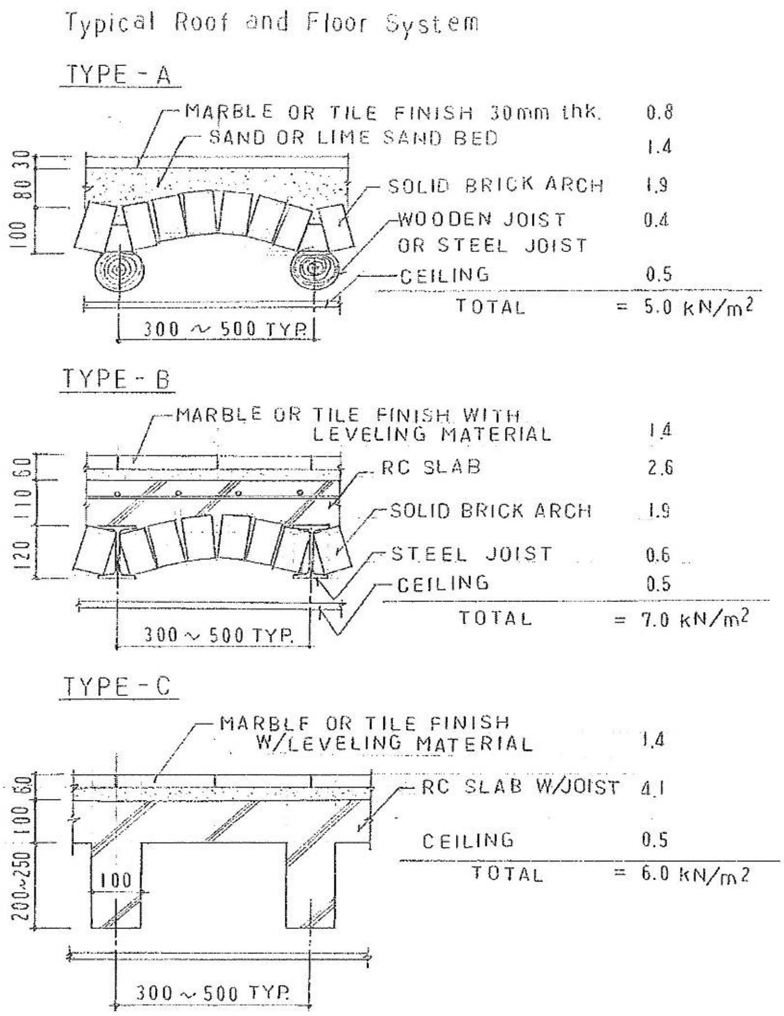


Figure 9-1 Unit Weights of Typical Roof and Floor System

(A) A stone masonry bearing wall with plaster or mortar finish: 26 kN/m^3

(B) A hollow brick (half brick thk.) partition wall with plaster finish: 2.0 kN/m^2

(C) A marble finished floor with RC slab and joist system (Type C): 6.0 kN/m^2

(D) A tile finished floor with RC slab and joist system (Type C): 5.0 kN/m^2

(E) A marble finished floor with RC slab on steel joist system (Type B): 7.0 kN/m^2

(F) A tile finished floor with RC slab on steel joist system (Type B): 6.0 kN/m^2

(G) A marble finished floor with brick arch and steel joist system (Type A): 5.0 kN/m^2

(H) A tile finished floor with brick arch and steel joist system (Type A): 4.0 kN/m^2

(I) A flat roof with RC slab and joist system (Type C): 6.0 kN/m^2

(J) A flat roof with RC slab on brick arch and steel joist system (Type B): 7.0 kN/m^2

(K) A flat roof with brick arch and steel joist system (Type A): 5.0 kN/m^2

(L) A corrugated asbestos cement roof with steel trusses: 1.0 kN/m^2

(M) A brick dome with plaster and mortar finishing: 6.0 kN/m^2 (in plan area)

(N) A glass roof with steel trusses: 1.0 kN/m^2 (in plan area)

4) Total Load of the Old Palace and the New Palace

The calculated total load of the Old Palace and the New Palace is shown in Table 9-2.

Table 9-2 Total Load of the Old Palace and the New Palace

Place	Story	Floor Area (m^2)	Floor Load (kN)	Wall Weight (kN)	Load Sum (kN)	Total Load (kN)
Old Palace	2nd Fl.	429.3	3,026	9,623	12,649	12,649
	1st Fl.	349.9	1,968	12,071	14,039	26,688
Entrance Block of New Palace	2nd Fl.	330.9	1,694	8,412	10,106	10,106
	1st Fl.	316.8	1,742	7,665	9,407	19,513
Main Hall Block of New Palace	3rd Fl.	630.1	2,300	9,492	11,792	11,792
	2nd Fl.	784.5	7,056	19,880	26,936	38,728
	1st Fl.	848.8	6,281	19,723	26,004	64,732
Combine of New Palace	3rd Fl.	630.1	2,300	9,492	11,792	11,792
	2nd Fl.	1,115.4	8,750	28,292	37,042	48,834
	1st Fl.	1,165.6	8,023	27,388	35,411	84,245
Combined New Palace & Old Palace	3rd Fl.	630.1	2,300	9,492	11,792	11,792
	2nd Fl.	1,544.7	11,776	37,915	49,691	61,483
	1st Fl.	1,515.5	9,991	39,459	49,450	110,933

5) Wall Sectional Area of the Old Palace and the New Palace

A calculated wall sectional area of the Old Palace and the New Palace is shown in Table 9-3.

Table 9-3 Wall Sectional Area of the Old Palace and the New Palace

Place	Direction	3rd Floor (m^2)	2nd Floor (m^2)	1st Floor (m^2)
Old Palace	X	---	42.84	62.60
	Y	---	34.49	56.96
Entrance Block of New Palace	X	---	18.29	23.94
	Y	---	27.15	37.61
Main Hall Block of New Palace	X	42.11	51.93	66.51
	Y	42.59	53.01	68.51
Combined Entrance and Main Hall Block of New Palace	X	42.11	70.22	90.46
	Y	42.59	80.16	106.12
Combined Old Palace and New Palace	X	42.11	113.06	153.05
	Y	42.59	114.65	163.08

6) Shear Force for Evaluation based on RPA 99/Version 2003

The shear force for evaluation is calculated based on the following formula.

V = A D Q W/ R = 0.4 x 1.9 x 1.0 W/2.5 = 0.304 W

Where;

A = 0.4; Coefficient of Ground Acceleration

$\eta = \sqrt{\frac{7}{\xi + 2}} = 0.76$ with $\xi = 10$ %)

D = 2.5η = 1.9

Q = 1.0 ; Quality Factor

R = 2.5 ; Ductility Factor

W = m g; Building weight

The average shear stress of a bearing wall is calculated by the following formula;

τ = 0.304 x Σ W / Σ Wa

Where;

Σ W : Total Load (kN)Σ Wa : Total wall sectional area (mm^2)

7) The Seismic Evaluation for Le PALAIS

The seismic evaluation is judged based on the following formula, and the judgment of the seismic evaluation is shown in Table 9-4.

$\tau_0 \geq F\ \tau \rightarrow \tau_0/F\ \tau \geq 1.0$ ---The building is a “Safe Structure”

$\tau_0 < F\ \tau \rightarrow \tau_0/F\ \tau < 1.0$ ---The building is an “Unsafe Structure”

Where;

$\tau 0$ = 0.056 MPa (N/mm^2) : Assumed shearing strength of the bearing wall unit

F = 1.15 : Safety factor

Table 9-4 The Seismic Evaluation for Le PALAIS

Place		Numerical Value					Judgment
		τ_0	X-direction		Y-direction		
			$F\tau$	$\tau_0/F\tau$	$F\tau$	$\tau_0/F\tau$	
Old Palace	2nd Fl.	0.056	< 0.104	0.54	< 0.128	0.44	Unsafe Structure
	1st Fl.	0.056	< 0.149	0.38	< 0.164	0.34	Unsafe Structure
New Palace Entrance Block	2nd Fl.	0.056	< 0.193	0.29	< 0.130	0.43	Unsafe Structure
	1st Fl.	0.056	< o.285	0.20	< 0.181	0.31	Unsafe Structure
New Palace Main Hall Block	3rd Fl.	0.056	< 0.098	0.57	< 0.097	0.58	Unsafe Structure
	2nd Fl.	0.056	< 0.261	0.21	< 0.255	0.22	Unsafe Structure
	1st Fl.	0.056	< 0.340	0.16	< 0.330	0.17	Unsafe Structure
Combined Entrance and Main Hall Block of New Palace	3rd Fl.	0.056	< 0.098	0.57	< 0.097	0.58	Unsafe Structure
	2nd Fl.	0.056	< 0.243	0.23	< 0.213	0.26	Unsafe Structure
	1st Fl.	0.056	< 0.326	0.17	< 0.277	0.20	Unsafe Structure
Combined Old Palace and New Palace	3rd Fl.	0.056	< 0.098	0.57	< 0.097	0.58	Unsafe Structure
	2nd Fl.	0.056	< 0.190	0.29	< 0.187	0.30	Unsafe Structure
	1st Fl.	0.056	< 0.253	0.22	< 0.238	0.24	Unsafe Structure

Conclusion of this seismic evaluation:
The Presidential PALACE building is judged to be an "Unsafe Structure".
Therefore, Le PALAIS will require retrofitting design and work.
Refer to the Recommendations for the Retrofit Plan (Refer to Chapter 10-3-2 (2).

Since the above seismic evaluation was performed based on "the assumed shear strength of the bearing wall unit of 0.056 Mpa (N/mm^2)", it should be confirmed that this is the actual shear strength of the joint material in the existing bearing wall unit before final a decision is made. In general, the shear strength of a masonry wall unit is limited by the joint material. This information can be obtained through core sampling or the other effective methods.
In case of employing the core sampling method, the recommended number of samplings are as follows;
For the Old Palace: 5-samples on the 1st and 2nd floors; total 10-samples
For the Entrance Block of the New Palace: 3-samples on the 1st and 2nd floors; 6-samples
For the Main Hall Block of the New Palace: 5-samples on the 1st and 2nd floors, 3-samples on the 3rd floor; 15-samples
Total 29-samples

(3) Le SENAT

1) Overview of property

- Building Name: "Senator Office SENATE"/ "Le SENAT"
- Property Location: Boulevard ZIROUT Youcef, Algiers
- Building Criteria: Governmental Facility; the Congress
- Construction Type: Portions are Stone Masonry using round/cut stone
- Main Material: Stone; Density 27 kN/m^3, Bearing Wall Unit weight 22 kN/m^3
- Foundation/Bearing Soils: Spread Foundation (continuous)/ Design Soil Capacity; Unknown
- Number of Stories: 5-story building with 1-level basement floor
- Building Area: 2,171 m^2
- Total Floor Area: 8,683 m^2
- Structural Height: 21.95 m

- Story Height: B1; N.A., 1st Fl; 4.20 & 7.60m, M2 Fl; 3.40 m, 2nd Fl; 5.65 m & 9.70 m, 3rd Fl; 4.05 m, 4th Fl; 4.65 m
- Year of Completion: B1 ~ 2nd Fl: Before 1912, Extension: 3rd & 4th Fl: 1912 ~ 1915
- Topography: Flat in Building Area, but footing level may be sloped down to the east side

2) Evaluation Basis and Hypothesis with Site and Building Survey, and Drawing Check in Detail are as follows; (The site and building survey conducted by Mr. Kheiredine BOUKHERISSA; Architect and Mr. Omar BENAOUDA; Engineer).

(A) The initial 2-story building with 1-basement floor was constructed of stone masonry before 1912 as a "Post Office building". Later, three more floors were added between 1912 and 1915, and after 1915 it was changed to "the House of Parliament; SENATE".

(B) The wall material is basically round stone with mortar or lime/sand joints, plaster or plaster board finish. The steel posts and steel beams were provided partly as simple support structures without seismic resistance. The roof for the assembly hall was made of steel trusses with glass finish, and the pre-cast plaster ceiling of the assembly hall is supported by wooden trusses.

(C) The roof and floor system was constructed of tuff-bed on a brick arch system with steel joists. The tuff-bed for roof and floors were changed to mortar bed as shown in Figure 9-3.

(D) The glass roof with steel trusses covers the courtyard at the center of the building, and is supported on the 3rd floor level.

(E) There is no structural damage to the bearing walls, but some cracks were observed in some partition walls and in the floor slab due to permanent condition and the 2003 Boumerdes Earthquake.

(F) Since there are many retaining walls in the basement floor structural system, it is not necessary to do a seismic evaluation.

(G) The building has rigid diaphragm floors with a mortar bed and roofs with steel bracing.

(H) Le SENAT photographs are shown below;

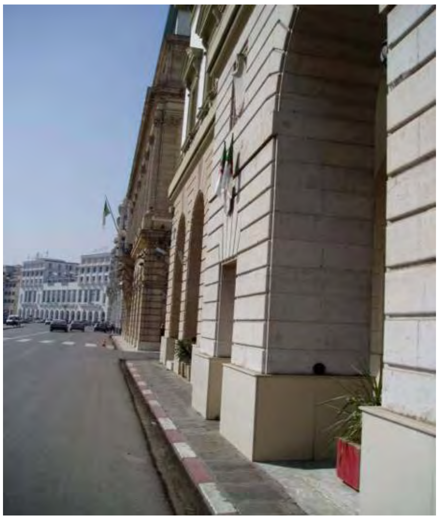


Photo 9-7 Front View and Front Road

Photo 9-8 Back (West) Side Façade

Photo 9-9 Top Light and Ceiling at Assembly Hall

Photo 9-10 Lounge on 2nd Floor and Wall Painting

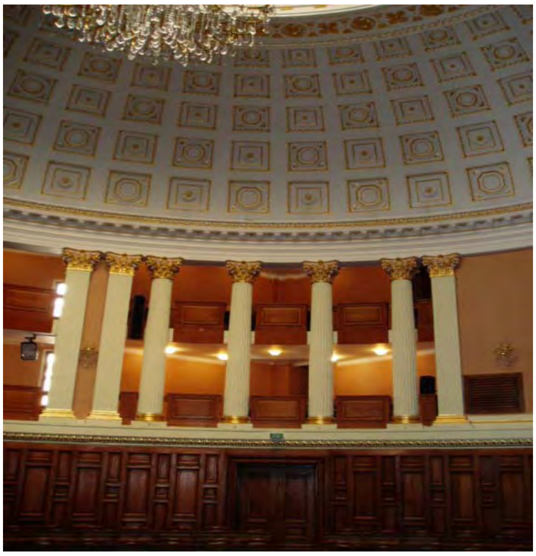


Photo 9-11 Gallery Space in Assembly Hall

Photo 9-12 Center Court with Wall Painting

3) Unit weight of each element

According to the information from the site and building surveys, CGS and JST confirmed the unit weights of each part as follows and as in Figure 9-2 and Figure 9-3.

(A) A stone masonry bearing wall with plaster or mortar finish: 22 kN/m^3

(B) A marble or tile finished floor with steel joist system (Type D): 5.0 kN/m^2

(C) The wooden floor and carpet finish of the Assembly Hall with (Type E): 6.0 kN/m^2

(D) The marble or terrazzo finished steps and floor at the Stair case with an RC slab (Type F): 8.0 kN/m^2

(E) A roof with water proofing (Type A): 6.0 kN/m^2

(F) The glass roof over the Assembly Hall with pre-cast plaster ceiling (Type B): 2.0 kN/m^2

(G) A glass roof with steel trusses (Type C): 1.0 kN/m^2 (in flat area)

(H) The R.C. slab roof of the Gallery with water proofing (Type G): 5.0 kN/m^2

(I) The R.C. floor of the Gallery with external ceiling (Type H): 5.0 kN/m^2

(J) The live load for seismic design of the floor: 20 % of 2.5 kN/m^2 = 0.5 kN/m^2, however, live loads on the roof were neglected for the seismic design

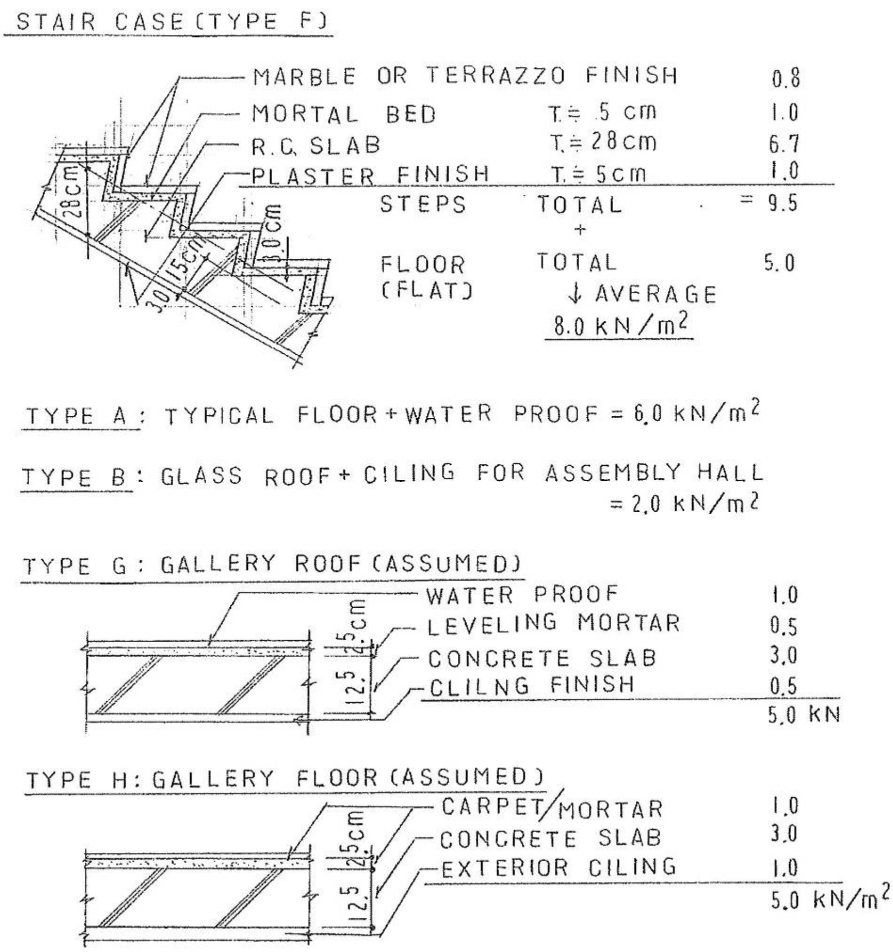


Figure 9-2 Typical Unit Weight of Each Element (1/2)

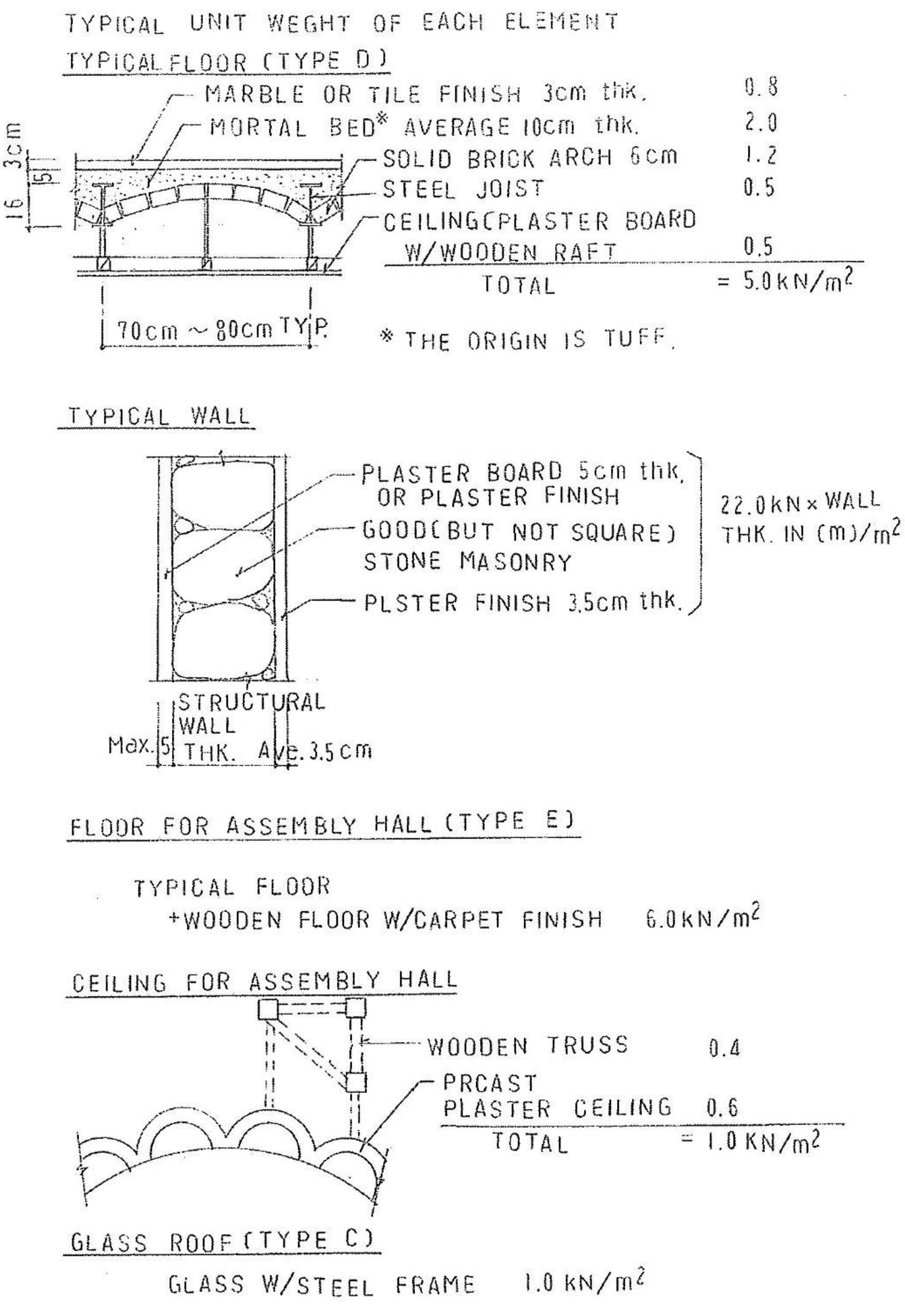


Figure 9-3 Typical Unit Weight of Each Element (2/2)

4) Total Load of Le SENAT

A calculated total load of Le SENAT is shown in Table 9-5.

Table 9-5 Total Load of Le SENAT

Story	Floor Area (m^2)	Floor Load (kN)	Wall Weight (kN)	Load Sum (kN)	Total Load (kN)
4th Floor	1,447	9,556	22,211	31,767	31,767
3rd Floor	1,589	9,384	21,205	30,589	62,356
2nd Floor	1,501	8,658	32,258	40,916	103,272
Mezzanine Fl.	2,029	11,660	25,859	37,519	140,791
1st Floor	1,165	6,741	29,923	36,664	177,455

5) Wall Sectional Area of Le SENAT

The calculated wall sectional area of Le SENAT is shown in Table 9-6.

Table 9-6 Wall Sectional Area of Le SENAT

Direction	4th Floor (m^2)	3rd Floor (m^2)	2nd Floor (m^2)	Mezzanine Fl (m^2)	1st Floor (m^2)
X	119.80	147.83	159.48	179.22	187.03
Y	91.82	119.76	130.91	191.85	203.31

6) Shear Force for Evaluation based on RPA 99/Version 2003

The shear force for evaluation is calculated based on the following formula.

$V = A\ D\ Q\ W/ R = 0.4 \times 1.9 \times 1.0\ W/2.5 = 0.304\ W$

Where;

A = 0.4; Coefficient of Ground Acceleration

$\eta = \sqrt{\frac{7}{\xi + 2}} = 0.76$ with $\xi = 10$ %),

$D = 2.5\eta = 1.9$ Q = 1.0 ; Quality Factor

R = 2.5; Ductility Factor W = m g; Building weight

The average shear stress of a bearing wall is calculated by the following formula;

$\tau = 0.304 \times \Sigma W / \Sigma Wa$

Where;

ΣW : Total Load (kN) ΣWa : Total wall sectional area (mm^2)

7) The Seismic Evaluation for Le SENAT

The seismic evaluation was judged based on the following formula, and the result of the seismic evaluation is shown in Table 9-7.

$\tau_0 \geq F\ \tau \rightarrow \tau_0/F\ \tau \geq 1.0$ ---The building is a "Safe Structure"

$\tau_0 < F\ \tau \rightarrow \tau_0/F\ \tau < 1.0$ ---The building is an "Unsafe Structure"

Where;

$\tau 0 = 0.056$ MPa (N/mm^2) : Shearing strength of the bearing wall unit

F = 1.15 : Safety factor

Table 9-7 The Seismic Evaluation for Le SENAT

Place	Numerical Value					Judgment
	τ_0	X-direction		Y-direction		
		$F\tau$	$\tau_0/F\tau$	$F\tau$	$\tau_0/F\tau$	
4th Floor	0.056	< 0.093	0.60	< 0.121	0.46	Unsafe Structure
3rd Floor	0.056	< 0.147	0.38	< 0.182	0.31	Unsafe Structure
2nd Floor	0.056	< 0.226	0.25	< 0.276	0.20	Unsafe Structure
Mezzanine Floor	0.056	< 0.275	0.20	< 0.256	0.22	Unsafe Structure
1st Floor	0.056	< 0.332	0.17	< 0.305	0.18	Unsafe Structure
Conclusion of this seismic evaluation: Le SENAT building is judged as an "Unsafe Structure". Therefore, Le SENAT building will require retrofitting design and work. Refer to the Recommendations for the Retrofit Plan.						
Since the above seismic evaluation was performed based on "the assumed shear strength of the bearing wall unit of 0.056 Mpa (N/mm^2)", the actual shear strength of the joint material in the existing bearing wall unit should be confirmed before a final decision is made. In general, the shear strength of a masonry wall unit is limited by the joint material. This information can be obtained through core sampling or other effective methods. In case of employing the core sampling method, the recommended number of samplings are as follows; For of the whole building: 5 samples on the 1st to 2nd floors (3-levels), and 3 samples on each of the 3rd and 4th floors ; Total 21-samples						

9-1-2 RC Buildings

More than half of all existing buildings in the study area of Wilaya Algiers are reinforced concrete moment frame buildings as indicated in Table 6-2 "Ratio of Structural Type in each Commune" in Chapter 6. In this section, the vulnerability of existing RC frame buildings is evaluated through seismic evaluation for three typical buildings, an apartment house, a school building, and a hospital.

(1) A Methodology of Seismic Evaluation for Reinforced Concrete Buildings

Seismic evaluation of existing Reinforced Concrete buildings was performed based on;

Standard for Seismic Evaluation of Existing Reinforced Concrete Buildings, 2001 (English version, 1st edition), The Japan Building Disaster Prevention Association, Tokyo, Japan.

There are three levels of seismic screening procedures in this method. The first level seismic screening is simple and the result is on the safe side. It estimates the seismic capacity low for moment frame structures and it was not applied in this case. The second level screening is performed based on column collapse mode, which assumes that floor beams are more resistant than columns. This assumption will be reasonable from the observation of earthquake damage as shown in Appendix 2 "Earthquake Damage". The third level screening is performed including beam collapse mode, but calculation volume increases very much compared with that of the second level.

As a result, the second level seismic screening procedure was applied. A list of corrigenda for the above standard (English version) is shown for information in Appendix 3.

Indices and key formulas of second level screening are indicated for information as follows;

Seismic Index of Structure,

$$Is = EoS_DT \quad \text{......(1)}$$

Eo : Basic Seismic Index of Structure

S_D : Irregularity Index

T : Time Index

Eo of ductility-dominant Structure,

$$Eo = n+1/n+i\sqrt{(C1F1)^2+(C2F2)^2+(C3F3)^2} \quad \text{......(4)}$$

Eo of strength-dominant Structure,

$$Eo = n+1/n+i\ (C_1+\Sigma\alpha_j C_j)F_1 \quad \text{......(5)}$$

C : Strength Index,

F : Ductility Index, Ductility Index is estimated mainly depending on the margin of members against shear failure.

n+1/n+i : Storey-shear modification factor

α : Effective strength factor

$$C = Qu / \Sigma W \quad \text{......(12)}$$

Qu : Ultimate lateral load-carrying capacity of the vertical members in the storey concerned

ΣW : Total weight supported by the storey concerned

Seismic Judgment

$$Is \geqq Iso \quad \text{......(37)}$$

Iso : Seismic Demand Index of Structure

$$Iso=EsZGU \quad \text{......(38)}$$

Es : Basic Seismic Demand Index of Structure

Z : Zone Index (1.0, typical case)

G : Ground Index (1.0, typical case)

U : Usage Index (1.0, 1.25, 1.5)

Regarding the Basic Seismic Demand Index of Structure, Es, a range of 0.50 to 0.60 is recommended considering seismic intensity in the study area, and a minimum value 0.50 was used in the seismic evaluation of vulnerability.

Another equation of judgment is as follows;

$$C_{TU}S_D \geqq (0.2 \sim 0.3)ZGU \quad \ldots\ldots (39)$$

C_{TU}: Cumulative strength index at the ultimate deformation of the structure

(0.2~0.3) is the recommended range for the above equation, and 0.2 was used in the judgment. Refer to Section 3-2 of Chapter 10 "Recommendations for Earthquake Impact Reduction" for more information.

There are some similarities between the Japanese Code for Seismic Evaluation and RPA99 ver.2003 as follows;

- **C(= Q/W) ・ F ・ (SD ・ T) ≥ (Es ・ Z ・ G ・ U)**

  Z=1.0, G=1.0, Typical, Japanese Standard

- **(V/W) ・ R ・ 1/Q ≥ (A ・ D)** RPA99 ver. 2003

  A : Zone acceleration coefficient
  D: Dynamic amplification factor

(2) Seismic Evaluation of Existing RC Buildings

An outline of the three RC buildings used for seismic evaluation is shown in Table 9-1 Collected Detailed Data for Seismic Evaluation of Buildings. Seismic evaluation was performed with respect to the following three buildings;

- A Five Storey Apartment House, designed based on RPA 88
- A Two Storey Elementary School, designed based on RPA88
- Pierre and Marie Curie Center Chemo-Therapy Building, Mustapha Hospital, designed based on RPA83. This hospital building has been nominated as a strategically important building. A general view is shown in Photo 9-13.

The above buildings are all reinforced concrete moment frame structures.

In addition, seismic evaluation of a five storey non-engineered apartment house was done for the evaluation of vulnerability of buildings subject to variations of concrete strength and is shown in Appendix 1;


Photo 9-13 General View of Mustapha Hospital

1) A Five Storey Apartment House

(A) General

This building is a typical five storey apartment house of reinforced concrete moment frame and was designed based on seismic design code RPA88.

(B) Building

Outline of this building is as follows;

a) Storey height; 1st storey to 5th storey, all 2.9 m.

b) Column span; X direction 5.1m, Y direction from grid A to grid D, 3.6 m, 3.0 m, 4.8 m.

c) The narrow gap between adjacent buildings was evaluated by the irregularity index.

Typical floor plan and typical framing plan of design drawings are shown in Figure 9-5. Structural frame is shown in Figure 9-6.

(C) Material

Materials used are as follows;

Main re-bar σy = 420 N/mm^2 (400 x 1.05), Hoop σy = 240 N/mm^2 (230 x 1.05)

Concrete 27.5 N/mm^2 (Result of 4 core sampling tests during the construction was shown, design strength was 25 N/mm^2)

(D) Columns

Column sections are as follows;

1st and 2nd storey at Grid C & D only; width x depth; 35 cm x 35 cm, Main bars; 16 mm x 4 (corners), ϕ14 mm x 4 (intermediate), Hoop; ϕ8 mm @100 mm, Diagonal ø 8 mm @100 mm

Others; width x depth, 30 cm x 30 cm, reinforcements are the same as above.

(E) Loads

Unit weight for the estimation of building weight is as follows;

Unit weights are 10 kN/m^2 for the Roof, 12k N/m^2 for a typical floor, and 6 kN/m^2 for the balcony

(F) Judgment on Seismic Safety

Seismic Demand Index Iso = 0.50 (usage index of 1.0), and $C_TS_D \geq 0.20$ was applied.

(G) Result of Seismic Evaluation

A summary of the results are shown in Table 9-8, and Figure 9-4. This building was judged as 'Not Safe' as shown below.

a) Is of the 1st storey and 3rd storey were lower than the seismic demand index, Iso, 0.50.

Is of the 1st storey was 80% of the seismic demand index. Ductility Index of the 1st storey was low at 2.25 because of the high axial force ratio of columns.

b) C_TS_D of the 1st, 2nd, 3rd and 4th stories was lower than the required value of 0.20.

c) Is and C_TS_D of only the 5th storey were higher than the required value.

Table 9-8 Seismic Index of Structure, Is (X, Y direction)

Storey	ΣW (kN)	C	F	n+1/n+i	Eo	Is	C_TS_D
5	2,090	0.57	3.2	0.545	1.10	1.02	0.32
4	4,557	0.30	3.2	0.667	0.65	0.60	0.19
3	7,024	0.22	3.0	0.75	0.50	0.47	0.16
2	9,491	0.22	3.0	0.857	0.57	0.53	0.18
1	11,958	0.19	2.25	1.0	0.43	0.40	0.18

S_D; 0.95(lack of gap at expansion joint)
T; 0.975 was used

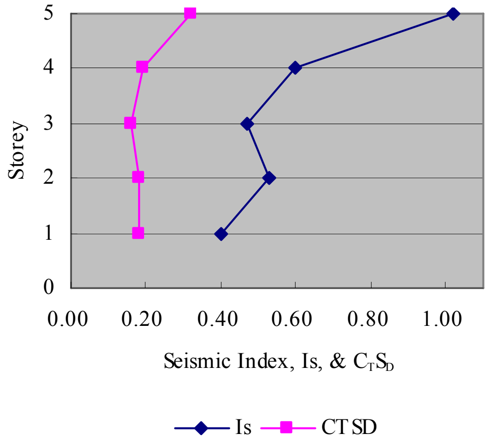


Figure 9-4 Result of Seismic Evaluation

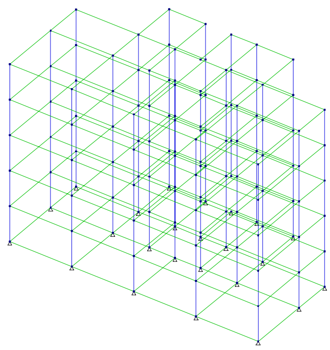
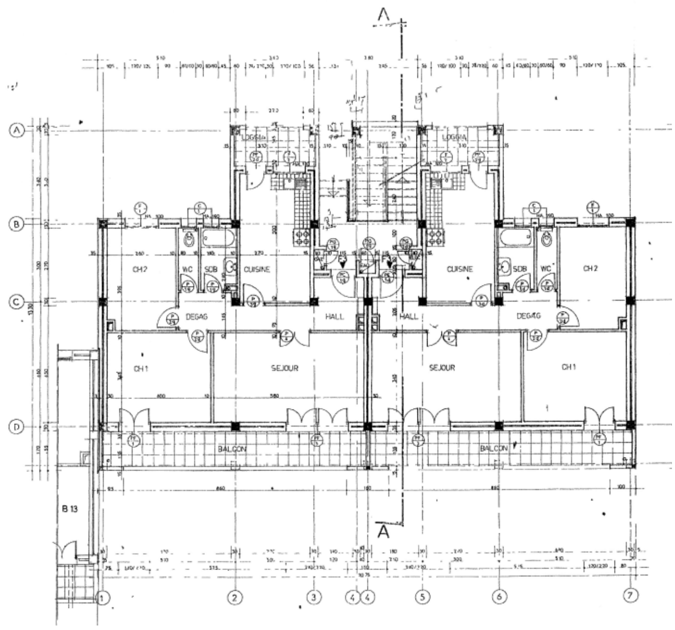
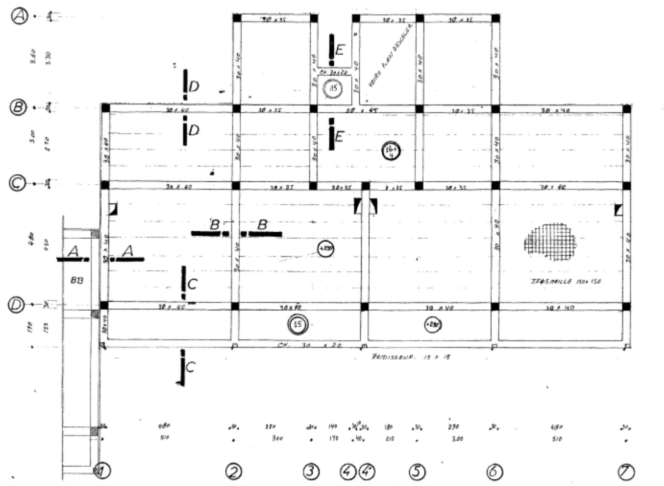


Figure 9-6 Structural frame



a) Typical Floor Plan



b) Typical Framing Plan

Figure 9-5 Design Drawings

2) A Two Storey School, Designed based on RPA88

(A) General

This is a typical two storey reinforced concrete building with moment frame structure, and seismic design was done by RPA88.

(B) Building

Outline of this building is as follows;

a) 6 spans of 4.5 m length in X direction.
b) 2 spans of 2.0 m and 7.0 m in Y direction
c) Storey height 3.5 m for the first and second stories.
d) Columns of X direction of grid A were evaluated as short columns because of solid brick standing walls.

The structural framing plan and elevation are shown in Figure 9-7.

(C) Column Members and Material

Column members and material used are as follows;

Grids A & B, width x depth, 600 mm (Y direction) x 300 mm (X direction)
Main-rebar, ø16 mm x 10 no (3 no for Y direction, 4 no for X direction)
Grid C, 300 mm x 300 mm, main bars, ø16 mm x 8 no
Hoop, ø 8 mm @100 mm at top and bottom, @150 mm at centre
Diagonal hoop, ditto
Main re-bar; ø 16 mm 400 Mpa (400 N/mm^2, yield stress)
Hoops; ø 8mm 240 Mpa (240 N/mm^2, yield stress)

Note: Min. interval of hoops is 150mm in Algiers, zone II, according to RPA 81(83) and 88.
But according to CGS intervals of 100mm were used generally at top and bottom.
Concrete f c28 = 20 Mpa (200 kg/cm^2, 28 days strength)

(D) Unit Weight and Floor Area

Unit weight for the estimation of building weight is as follows;

Weight of each floor for dead load plus live load; 1.3 tf/m^2 (13 kN/m^2) for roof and second floor. Axial force of column by vertical loads is used for the column strength and variation of axial force by seismic load was ignored because of low height. Conversion of unit of 1kgf=10 N was used for simplicity instead of 1 kgf=9.8 N.

Floor area second floor
27 m x 9 m = 243 m^2, first floor 27 m x 9 m = 243 m^2

(E) Irregularity Index and Time Index

Irregularity index for the X direction was estimated considering the eccentricity of the frames.

Eccentricity L of X direction;

E = 4.5m (assumed distance between centre of gravity and centre of stiffness)
B = 9.0m, D = 27.0m
$L = E / \sqrt{(B^2+D^2)} = 4.5 / \sqrt{(92 + 272)} = 0.158 > 0.15$
$S_D = 0.8$ was applied for X direction
Time Index, T = 0.95 was used.

(F) Judgment on Seismic Safety

Seismic Demand Index Iso = 0.50 (usage index of 1.0), and $C_T S_D \geq 0.20$ was applied.

(G) Results of Seismic Evaluation

A summary of the results is shown in Table 9-9. Columns at grid A were evaluated as extremely brittle columns in the X direction and the irregularity by eccentricity reduced the seismic capacity. The first and second stories of this school building were judged as 'Not Safe' in the X direction, and were judged as 'Safe' in the Y direction.

Table 9-9 Summary of Seismic Evaluation

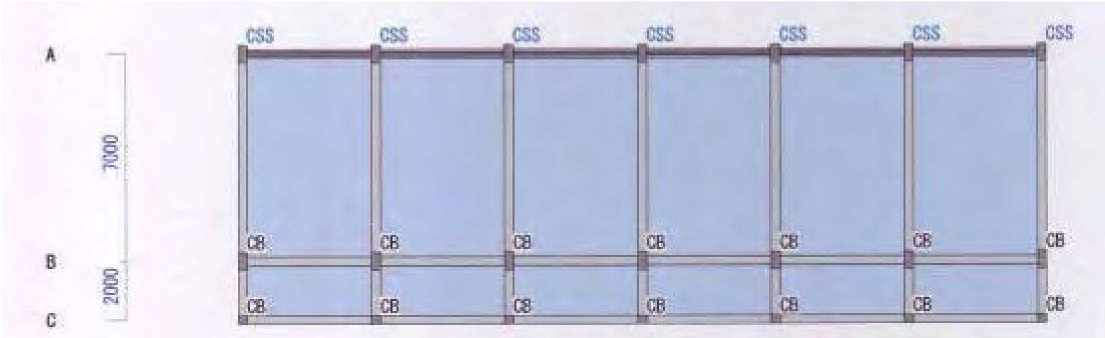
Summary of Seismic Evaluation

Building Name:		Constructed Year:	1990 (RPA88)	Date:	2006/6/17
Screening Lev	2	Usage:	School	Engineer:	

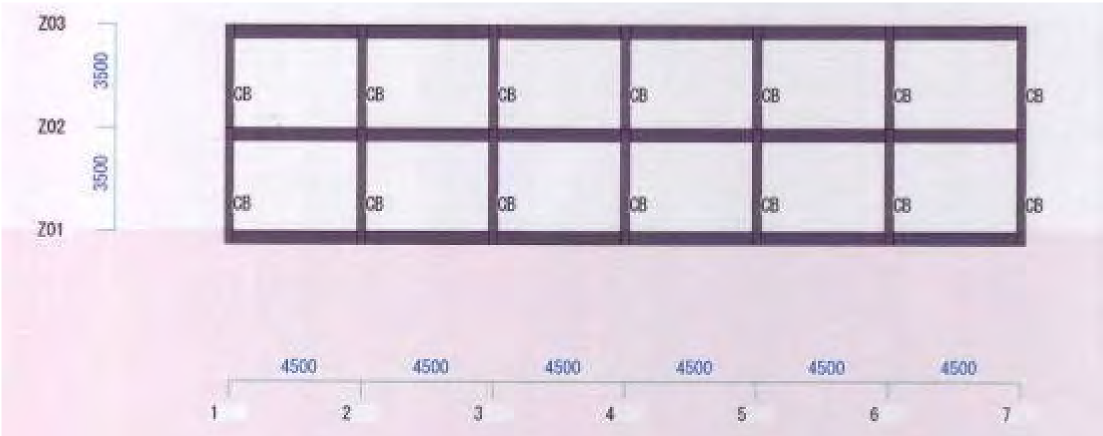
Directi	Storey	C_T	F	Failure Mo	Eo	S_D	T	Is	$C_{TU}S_D$	Judgment
X	2	0.495	0.80	Ext.Brittle	0.474	0.80	0.95	0.36	0.37	NG
		0.253	3.20	Flexural						
	1	0.346	0.80	Ex.Brittle	0.338	0.80	0.95	0.26	0.27	NG
		0.152	3.20	Flexural						
Y	2	0.467	3.20	Flexural	1.491	1.00	0.95	1.42	0.47	OK
	1	0.391	3.20	Flexural	1.251	1.00	0.95	1.19	0.39	OK

$C_T = Cx(n+1)/(n+i)$ C_{TU} at ultimate of F1 index

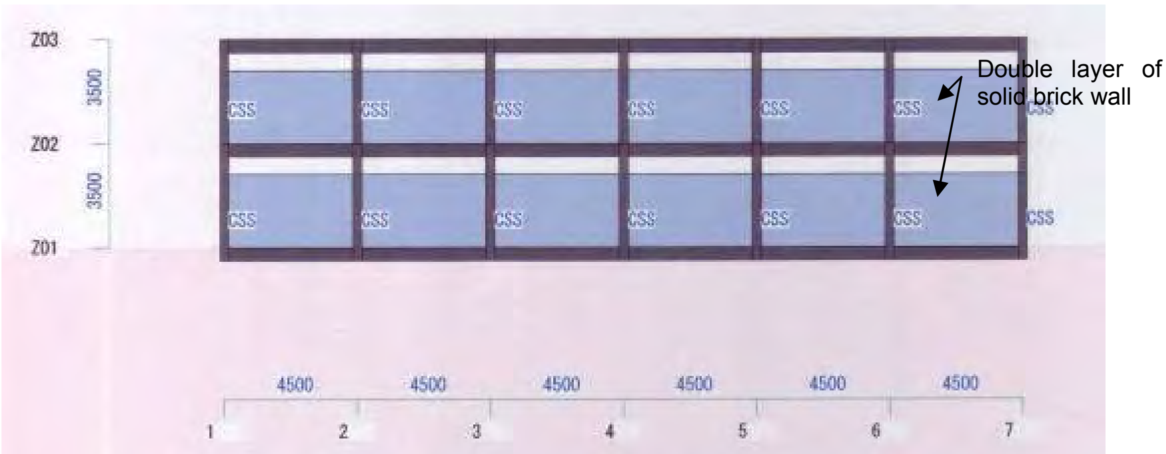
It is noted that the Ductility Index, F, is reduced from 3.2 to 2.6 in case of hoop intervals @ 150 mm, and therefore, the Seismic Index of the Structure, Is, is also be reduced accordingly.



a) Framing Plan of 2nd Floor and Roof Floor



b) Framing Elevation of Grid B and Grid C



c) Framing Elevation of Grid A

Figure 9-7 Structural Framing Plan and Elevation

3) Pierre and Marie Curie Center Chemo-Therapy Building, Mustapha Hospital

(A) General

This hospital is a reinforced concrete moment frame structure, and was designed based on seismic design code RPA83.

This hospital building has been nominated as a strategic important building.

(B) Building

Outline of this building is as follows;

a) This hospital building is divided into 4 blocks, with 4 cm gaps at the joints
b) Typical 1 block separated by expansion joints was evaluated
c) Stories: 3 storey above ground and 1 storey basement
d) Type of Structure: Reinforced Concrete Moment Frame
e) X-direction 5 spans @6.0 m, Y-direction 4 spans @5.1 m
f) Storey height, 1st storey 4.5 m, 2nd storey 3.0 m, 3rd storey 3.0 m

Floor plan and framing plan are shown in Figure 9-8.

(C) Material

Materials used are as follows;

Re-bars; Main 400 kN/mm^2, Hoop 235 kN/mm^2, Concrete 27 N/mm^2 (Design Strength)

(D) Columns

Column section of 1st storey to 3rd storey is as follows;

Width x Depth; 50 cm x 50 cm, Main bars; 25 mm x 4 (corners), ϕ20 mm x 4 (intermediate)

Hoops; ϕ10 mm @100 mm, Diagonal ϕ10 mm @100 mm

(E) Loading Condition

Unit weight for the estimation of building weight is as follows;

Unit weights; Roof, 11 kN/m^2, 3rd and 2nd Floor, 14 kN/m^2 based on an estimation of loads for typical areas.

(F) Judgment on Seismic Safety

Seismic Demand Index Iso = 0.50 x 1.5=0.75, and $C_TS_D \geq 0.20 \times 1.5=0.30$ was applied (usage index, 1.5 was used).

(G) Results of Seismic Evaluation

A summary of the results is shown in Table 9-10. The 1st storey of this building was judged as ‘Not Safe’ as a strategically important hospital building.

a) Is of 1st storey was slightly lower than Iso, and C_TS_D was lower than the required value. This showed that the horizontal strength at the 1st storey is inadequate.

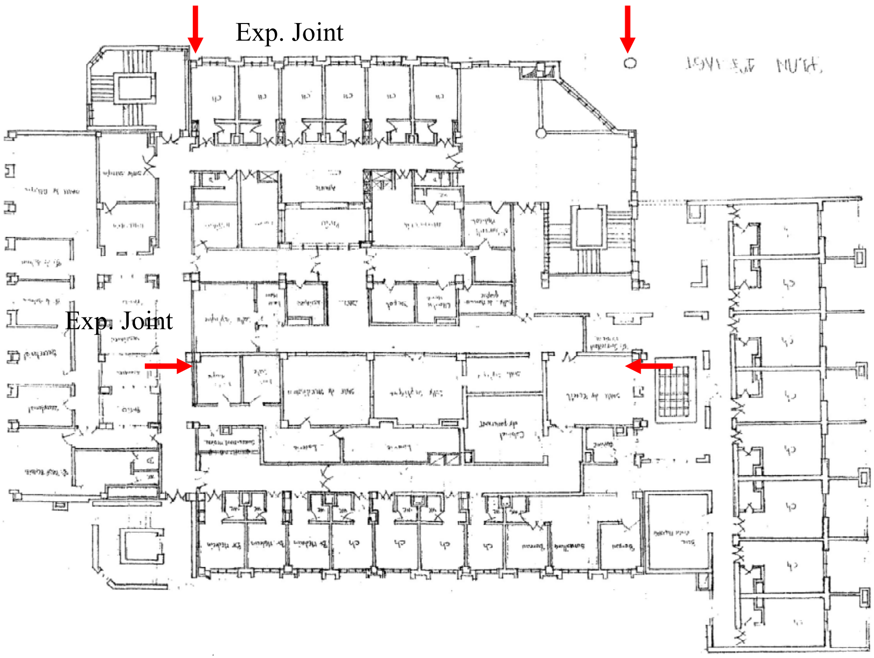
b) Is and C_TS_D at the 2nd storey and 3rd storey were higher than the required value.

c) This building has a one storey basement, which increased the seismic capacity, but the stiffness/mass ratio at the 1st storey reduced the seismic capacity, as shown by the irregularity index.

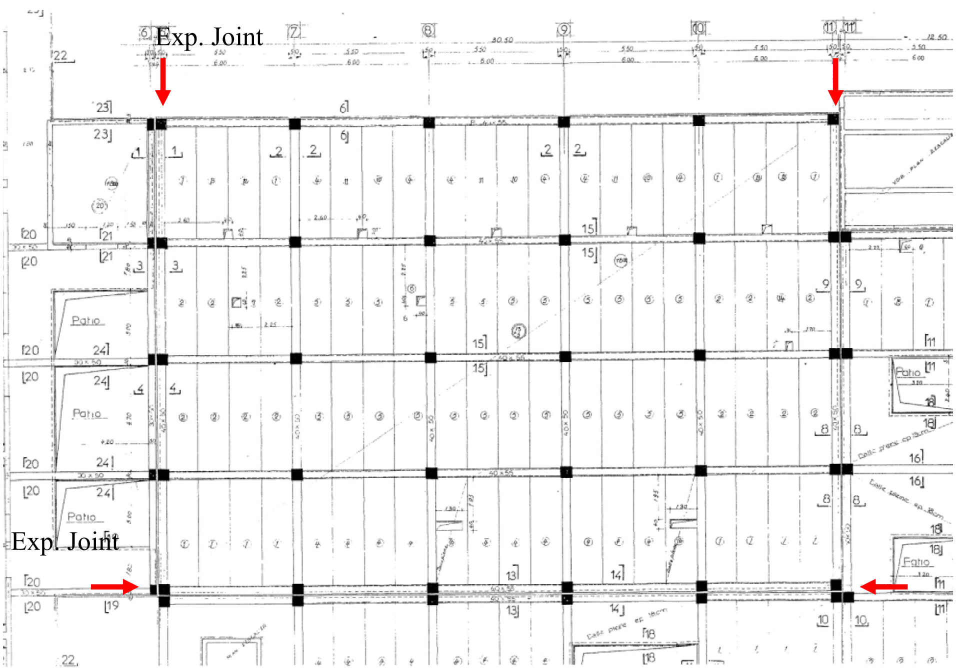
Table 9-10 Seismic Index of Structure, Is, and C_TS_D (2nd Level)

Y direction									X direction	
Storey	C	F	n+1/n+i	Eo	S_D	T	Is	C_TS_D	Is	C_TS_D
3	0.76	3.2	0.67	1.61	1.11	0.95	1.72	0.84	1.74	0.85
2	0.42	3.2	0.80	1.07	1.11	0.95	1.13	0.46	1.15	0.47
1	0.24	3.2	1.00	0.76	1.00	0.95	0.72	0.24	0.72	0.24

S_D 1.11 (3rd and 2nd storey), 1.0 (1st storey), T: Time Index (0.95 is used)
S_D: Irregularity Index (Expansion Joint, x 0.95, Storey Height Uniformity, x 0.975, Underground Storey, x 1.20, Stiffness/mass Ratio, x 1.0 (3rd & 2nd Storey), 0.9 (1st Storey)),



a) 2nd Floor or Plan



b) 2nd Floor Framing Plan

Figure 9-8 Design Drawings

Appendix 1 Seismic Evaluation of a Non-engineered Five Storey Apartment House

A) General

A seismic evaluation was done to assess the vulnerability of a hypothetical five storey apartment house, which was typical of those that suffered severe damage or had collapsed in the recent earthquakes. The apartment house was supposed to have been constructed around 1970 and was a non-engineered building.

The effect of low strength concrete on the seismic index of the structure was assessed. Concrete strengths with an average of 16 N/mm^2 were reported by CGS as a result of their core sampling of collapsed houses.

A reinforced concrete frame structure with 4 span x 2 span x 5 storey building was selected, which seems to be typical of apartment houses. Second class seismic screening was applied for the first storey (column collapse mode was supposed).

Member sizes and reinforcements were estimated based on reports from a CGS engineer and a project manager engaged in rebuilding apartment houses in Boumerdes.

A typical framing plan and structural frame are shown in Figure 9-A2 and Figure 9-A3 respectively.

B) Unit weight, Materials, and Column Section

a) Supposed unit weight of buildings

Roof; 10 kN/m^2, Typical Floor, 13 kN/m^2, Balcony, 6.5 kN/m^2

b) Materials

Re-bars
main re-bar 400 N/mm^2
hoop 235 N/mm^2
Concrete standard strength 25 N/mm^2

c) Supposed Column Section

Width x depth 30 cm x 30 cm
Main bars: 8-D16
Hoop 8 mm@150 mm
Beams 35 cm x 40 cm (40 cm is used to calculate clear length of column)

d) Additional Axial Forces during Earthquake

Additional axial forces for columns during earthquake were estimated by elastic analysis using seismic loads with a base shear coefficient C = 0.15.

C) Results of the Seismic Evaluation

The seismic index of the structure at the 1st storey with different concrete strengths is shown in Figure 9-A1.

a) The seismic index of the structure, Is, with standard concrete strength was 0.25 or more.

b) The seismic index of the structure, Is, with low strength concrete was 0.15 or below.

This was caused mainly by the low ductility index subject to the high axial force ratio of the columns.

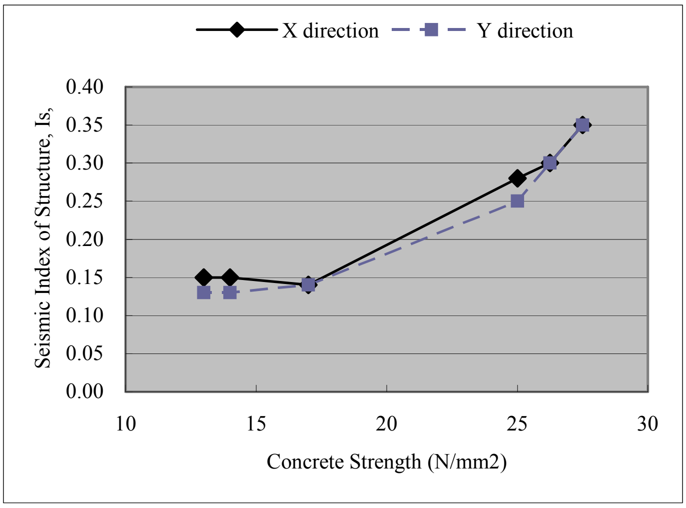


Figure 9-A1 Seismic Index of structure, Is, and Concrete Strength

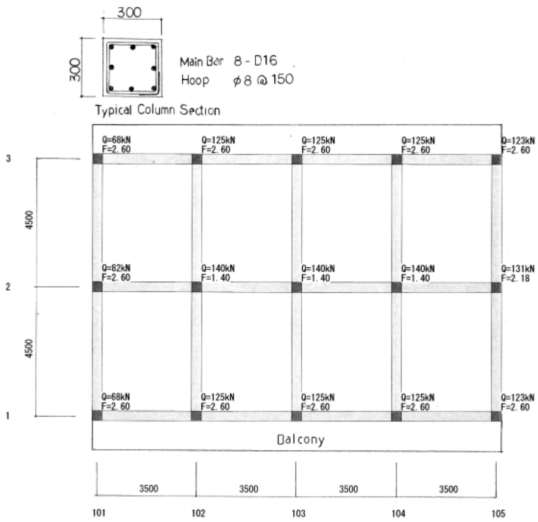


Figure 9-A2 Typical Framing Plan

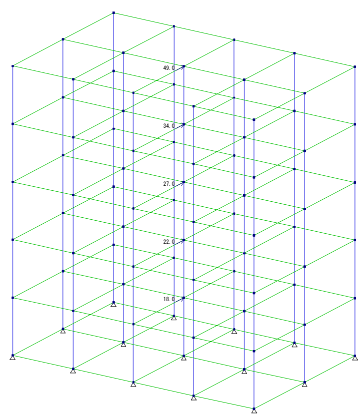


Figure 9-A3 Structural Frame

Appendix 2 Earthquake Damage

a) Heavy Non-structural Damage at 1st storey

b) Destruction by Column Collapse

c) Destruction by Column Collapse

d) Destruction by Column Collapse

source: CGS

Figure 9-A4 Apartment Houses Damaged by 2003 Boumerdes Earthquake

a) Shear Failure of Short Column

b) Flexural/Shear Failure of Column

source: CGS

Figure 9-A5 Damage to a School by 1994 Mascara Earthquake

Appendix 3 Correction of Errors for Standard of Seismic Evaluation (English Version)

Following is a list of correction of errors for the Standard of Seismic Evaluation (English version) that were observed during the study through comparison with the Japanese version (this cannot be assumed to be complete);

Table 9-A1 A List of Corrigenda for the Standard of Seismic Evaluation (English Version)

Page	Section	Original	Correction
1-11	(a) Ductility-dominant basic index of structure	The index F of the first group shall be taken as **larger than** 1.0 …	The index F of the first group shall be taken as **larger than or equal to** 1.0 …
1-20	(d) flexural column	(i) Incase **Rmn** < Ry (ii) Incase **Rmn** ≥ Ry	(i) Incase **Rmu** < Ry (ii) Incase **Rmu** ≥ Ry
1-46	(3) Upper limit of the drift angle of flexural columns	$n' = (\eta-\eta_L)(\eta_H-\eta_L)$	$n' = (\eta-\eta_L)/(\eta_H-\eta_L)$
2-25	(b) Shear strength of column	Qsu = ϕ (……)	Qsu = (……)
3-27	Table 1.1.A-13	Current F of Y2 frame at 4 storey, **3.14**	Current F of Y2 frame at 4 storey, **3.17** (3.17 is indicated in Table 1.1.A-10)
3-29	Table 1.1.A-17	One low at 1 storey is missing	1.86, 0.185, --, --, --, --, 0.34

9-2 Urban Vulnerability to Earthquake Disaster

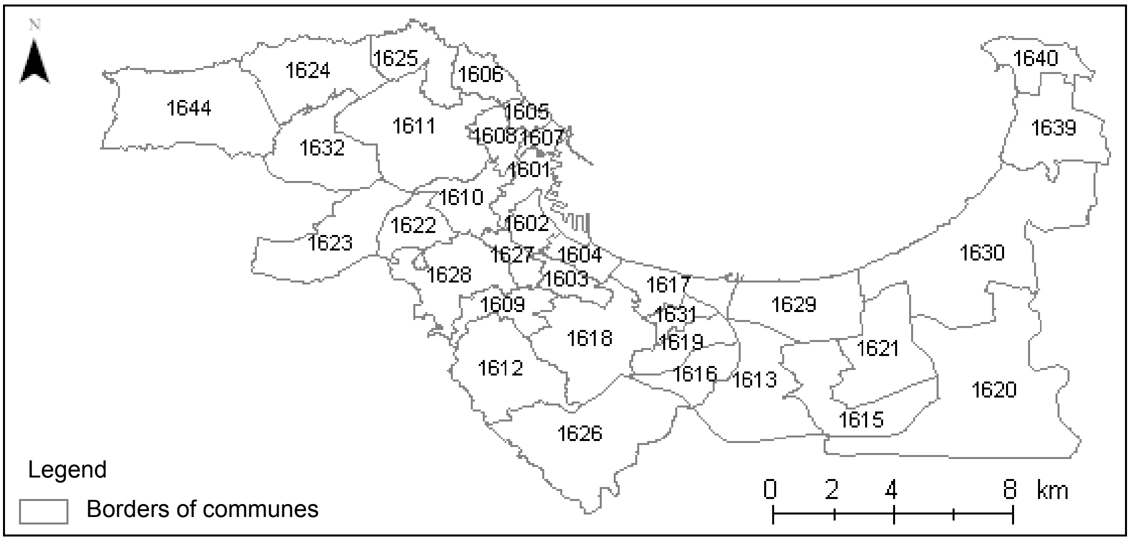
9-2-1 Urban Vulnerability to Earthquake Disaster

The vulnerability of urban areas to earthquake disasters in the 34 communes included within the Study Area was assessed by analyzing GIS data prepared by the JICA Study Team.

The following criteria were used to allocate vulnerability classes:

- Population density
- Building age
- Economic value
- Ground surface motion potential
- Slope failure risk
- Ease of evacuation/rescue in an emergency

This assessment is a static one because no "Scenario Earthquakes" have been taken into consideration. Figure 9-9 shows the 34 communes within the Study Area.



1601: ALGER CENTRE, 1602: SIDI M'HAMMED, 1603: EL MADANIA, 1604: HAMMA EL ANNASSER, 1605: BAB EL OUED, 1606: BALOGHINE, 1607: CASBAH: 1608: OUED KORICHE, 1609: BIR MOURAD RAIS, 1610: EL BIAR, 1611: BOUZAREAH, 1612: BIRKHADEM, 1613: EL HARRACH, 1615: OUED SMAR, 1616: BOUROUBA, 1617: HUSSEIN DEY, 1618: KOUBA, 1619: BACH DJERAH, 1620: DAR EL BEIDA, 1621: BAB EZZOUAR, 1622: BEN AKNOUN, 1623: DELY BRAHIM, 1624: HAMMAMET, 1625: RAIS HAMIDOU, 1626: DJASR KACENTIANA, 1627: EL MOURADIA, 1628: HYDRA, 1629: MOHAMMADIA, 1630: BORDJ EL KIFFAN, 1631: EL MAGHARIA, 1632: BENI MESSOUS, 1639: BORDJ EL BAHRI, 1640: EL MARSA

Source: INCT and JICA Study Team

Figure 9-9 Communes within the Study Area

9-2-2 Urban Vulnerability within the Study Area

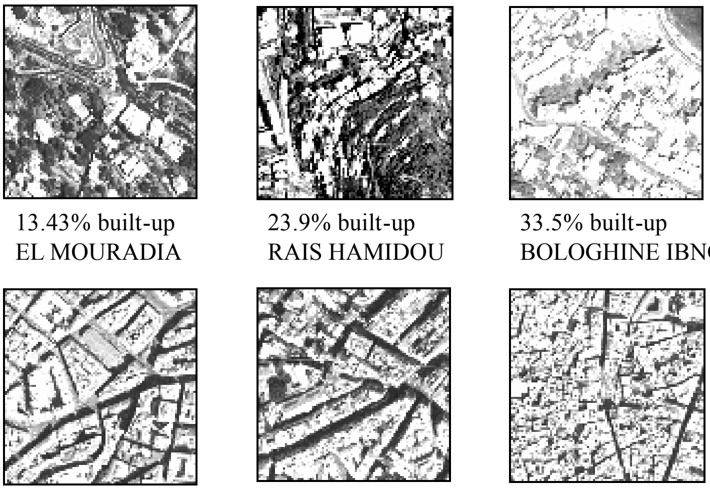
No global standard for evaluating the vulnerability of urban areas to earthquakes exists. Therefore, assessment of the vulnerability of urban areas to earthquake disasters in a given region is often done by considering various specific local conditions. It is noted that previous JICA studies have evaluated urban area vulnerability to earthquakes in some cities in the world. However, the various assessment methodologies that were used in those studies were not always consistent. Even in this JICA Study, the assessment method for determining urban vulnerability to earthquakes is different to the previous JICA studies. The main reason for this lack of consistency in methodologies is that the quality and quantity of available data have always been different in each city that was studied.

9-2-3 Identification of "Urban" Areas within the Study Area

The following two (2) GIS data layers were used to determine the extent of urbanized areas:

- Polygons representing the plan view shape of buildings (building "foot-prints"); and
- Polygons representing grid-cells for seismic micro-zoning.

These two layers were co-registered in GIS and this allowed calculation of the percentage of the area of each seismic micro-zoning cell that was occupied by buildings. The results of this calculation were compared with the aerial photograph of the study area. Based on this comparison, it was determined that where built-up areas covered 10% or more of the micro-zoning cell, these cells could generally be classed as built-up areas (urbanized areas) within the Study Area. Figure 9-10 shows examples of various built-up area densities that can be seen in the aerial photograph.



13.43% built-up
EL MOURADIA

23.9% built-up
RAIS HAMIDOU

33.5% built-up
BOLOGHINE IBNOU ZIRI

45.3% built-up
BAB EL OUED

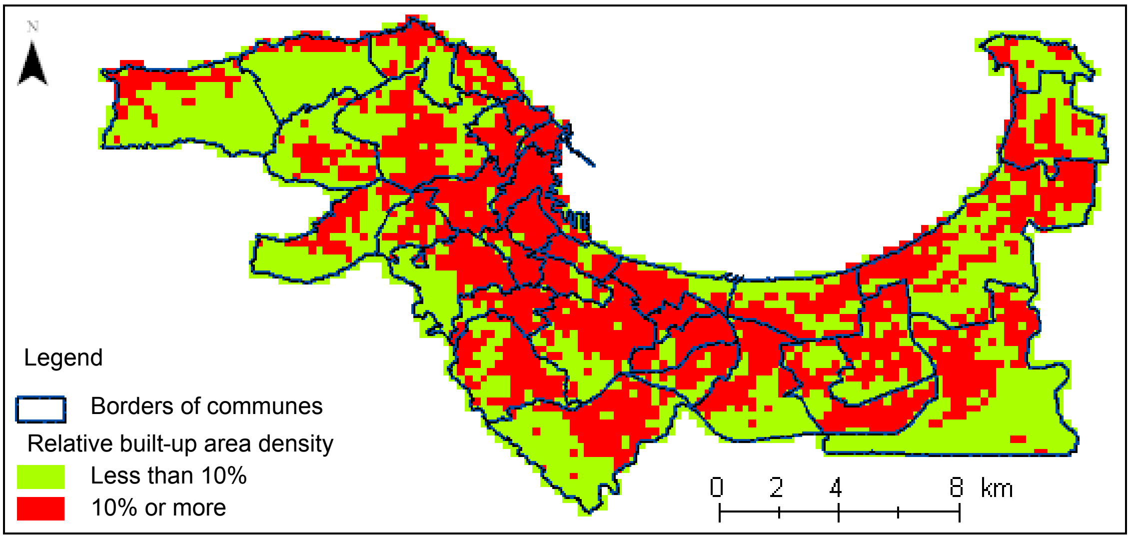
57.9% built-up
ALGER CENTRE

77.5% built-up
CASBAH

Source: INCT

Figure 9-10 Aerial Photo Image Samples of Built-up Areas

Figure 9-11 shows the relative density of built up areas within the Study Area.

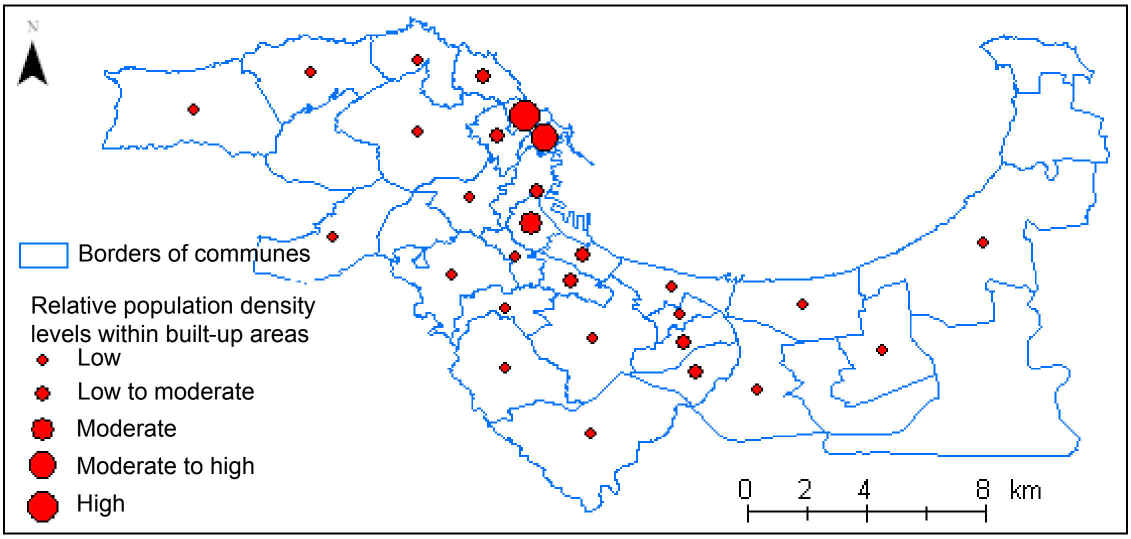


Source: JICA Study Team

Figure 9-11 Relative Density of Built-up Areas within the Study Area

9-2-4 Population Density

Relative population density is an important factor concerning the loss of people's lives in a major earthquake disaster. The total area of urbanized cells (having built-up densities of 10% or more) for each commune was calculated using GIS and the relative population density was calculated using the following simplified formula: [Relative population density] = [Population[1]] / [Area (ha) of Urbanization]. The relative population density level was classified into the five (5) categories as shown in Figure 9-12. Table 9-11 shows the relative population density within each commune.



Source: JICA Study Team

Figure 9-12 Relative Population Density within Built-up Areas

1 The annual statistics of the Wilaya of Algier 2003

Table 9-11 Relative Population Density

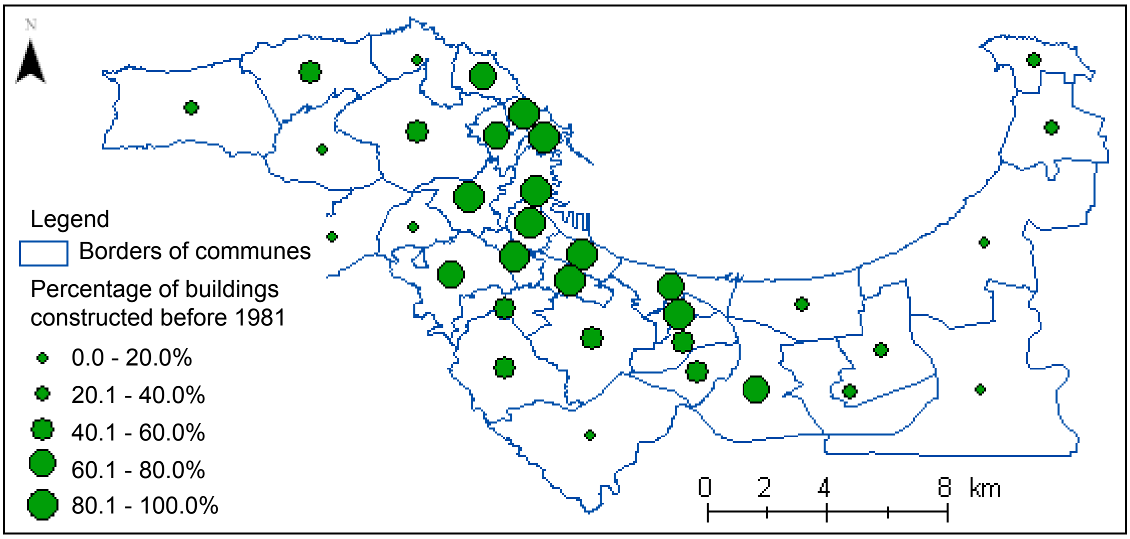
Code	Commune	Relative population density (Persons/ha)	Evaluation
1605	BAB EL OUED	76315	5: High
1607	CASBAH	55692	4: Moderate to high
1602	SIDI M'HAMED	46785	3: Moderate
1604	HAMMA EL ANNASSER	38032	3: Moderate
1616	BOUROUBA	33800	3: Moderate
1603	EL MADANIA	33600	3: Moderate
1608	OUED KORICHE	32850	2: Low to moderate
1601	ALGER CENTRE	30786	2: Low to moderate
1619	BACH DJARAH	30424	2: Low to moderate
1606	BOLOGHINE IBNOU ZIRI	25731	2: Low to moderate
1631	EL MAGHARIA	21137	2: Low to moderate
1621	BEB EZZOUAR	19251	2: Low to moderate
1627	EL MOURADIA	17522	1: Low
1617	HUSSEIN DEY	17268	1: Low
1618	KOUBA	17156	1: Low
1644	AIN BENIAN	16649	1: Low
1609	BIR MOURAD RAIS	16452	1: Low
1610	EL BIAR	15046	1: Low
1624	EL HAMMAMET	14747	1: Low
1626	DJASR KASANTINA	13977	1: Low
1625	RAIS HAMIDOU	12014	1: Low
1611	BOUZAREAH	11828	1: Low
1628	HYDRA	11452	1: Low
1612	BIRKHADEM	11239	1: Low
1630	BORDJ EL KIFFAN	10628	1: Low
1613	EL HARAACH	10423	1: Low
1623	DELY BRAHIM	10121	1: Low
1629	MOUHAMMADIA	9719	1: Low
1622	BEN AKNOUN	9041	1: Low
1639	BORDJ EL BAHRI	8911	1: Low
1640	EL MARSA	7949	1: Low
1632	BENI MESSOUS	7478	1: Low
1620	DAR EL BEIDA	6649	1: Low
1615	OUED SMAR	4195	1: Low

Source: JICA Study Team

9-2-5 Building Age

Relatively old buildings are considered to be more fragile and less resistant to strong seismic shocks than relatively new buildings that have been constructed under the newer building codes. These newer building codes are considered to provide more seismic-resistance. The results of the building inventory survey carried out by the JICA Study Team were used as the data set for the analysis of building age.

The ratio of aged buildings (constructed before 1981) to modern buildings (constructed during or after 1981) was determined for each commune by using GIS. These data were classified into the following five (5) categories as shown in Figure 9-13 and Table 9-12.



Source: JICA Study Team

Figure 9-13 Percentage of Buildings Constructed before 1981 in Each Commune

Table 9-12 Percentage of Buildings Constructed before 1981

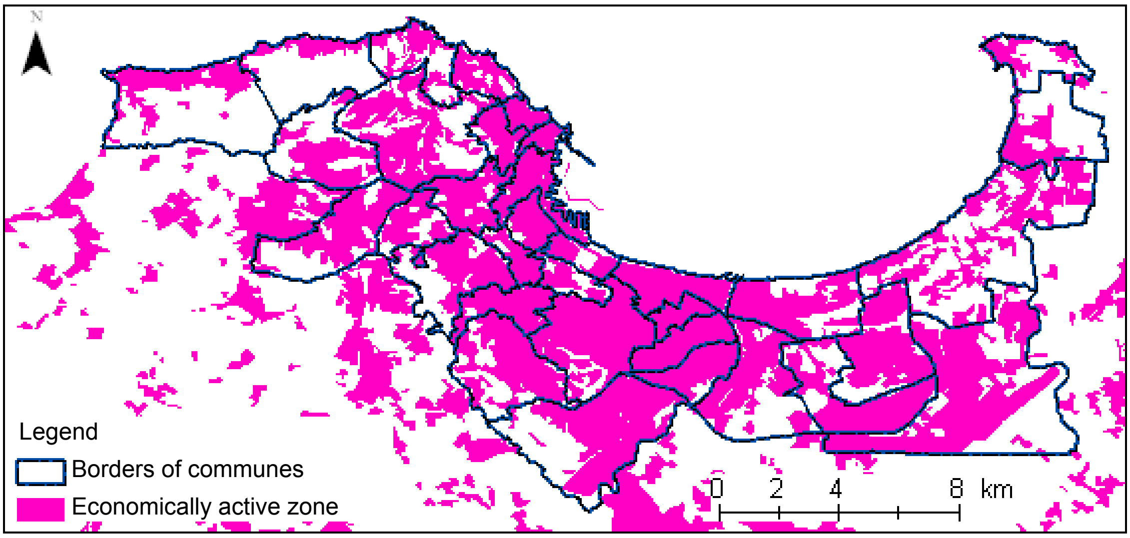
Code	Commune	Percentage of buildings constructed before 1981	Evaluation
1604	HAMMA EL ANNASSER	80.1-100%	5: High
1602	SIDI M'HAMED	80.1-100%	5: High
1605	BAB EL OUED	80.1-100%	5: High
1601	ALGER CENTRE	80.1-100%	5: High
1607	CASBAH	80.1-100%	5: High
1603	EL MADANIA	80.1-100%	5: High
1610	EL BIAR	80.1-100%	5: High
1631	EL MAGHARIA	80.1-100%	5: High
1627	EL MOURADIA	80.1-100%	5: High
1617	HUSSEIN DEY	60.1-80.0%	4: Moderate to high
1613	EL HARAACH	60.1-80.0%	4: Moderate to high
1606	BOLOGHINE IBNOU ZIRI	60.1-80.0%	4: Moderate to high
1608	OUED KORICHE	60.1-80.0%	4: Moderate to high
1628	HYDRA	60.1-80.0%	4: Moderate to high
1612	BIRKHADEM	40.1-60.0%	3: Moderate
1619	BACH DJARAH	40.1-60.0%	3: Moderate
1618	KOUBA	40.1-60.0%	3: Moderate
1616	BOUROUBA	40.1-60.0%	3: Moderate
1609	BIR MOURAD RAIS	40.1-60.0%	3: Moderate
1611	BOUZAREAH	40.1-60.0%	3: Moderate

Code	Commune	Percentage of buildings constructed before 1981	Evaluation
1624	EL HAMMAMET	40.1-60.0%	3: Moderate
1640	EL MARSA	20.1-40.0%	2: Low to moderate
1644	AIN BENIAN	20.1-40.0%	2: Low to moderate
1615	OUED SMAR	20.1-40.0%	2: Low to moderate
1639	BORDJ EL BAHRI	20.1-40.0%	2: Low to moderate
1629	MOUHAMMADIA	20.1-40.0%	2: Low to moderate
1621	BEB EZZOUAR	20.1-40.0%	2: Low to moderate
1626	DJASR KASANTINA	0-20%	1: Low
1630	BORDJ EL KIFFAN	0-20%	1: Low
1620	DAR EL BEIDA	0-20%	1: Low
1623	DELY　BRAHIM	0-20%	1: Low
1625	RAIS HAMIDOU	0-20%	1: Low
1632	BENI MESSOUS	0-20%	1: Low
1622	BEN AKNOUN	0-20%	1: Low

Source: JICA Study Team

9-2-6　Economic Value

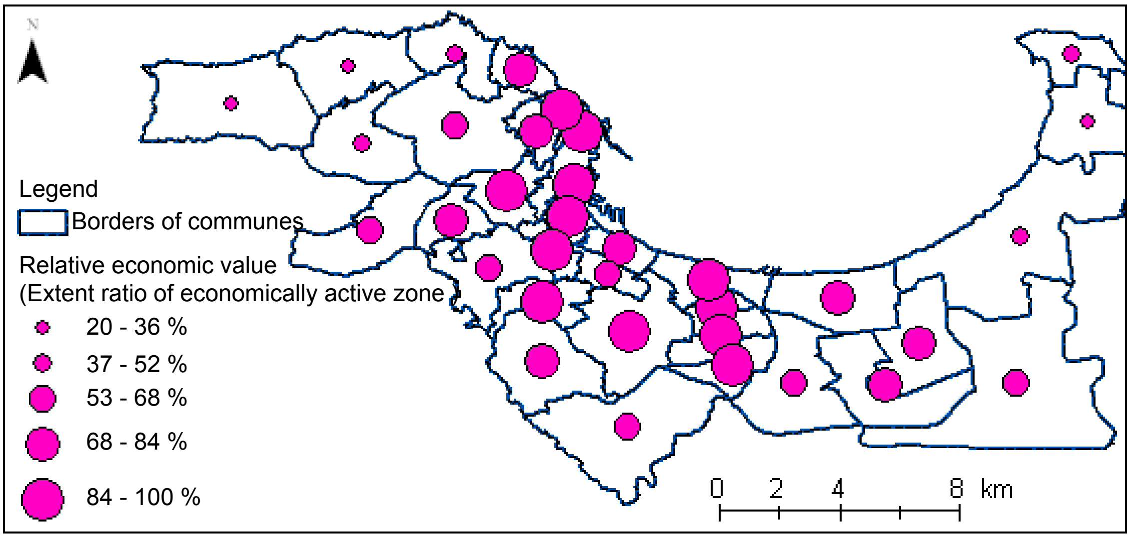
The extent of the major economically active zone within each commune was determined by using GIS to measure the area of urbanization within each seismic micro-zoning cell. This included urban areas, industrial areas and large infrastructure such as airports. These three (3) land cover/use classes were selected from the land cover/use maps that were prepared for 2000/2001. Figure 9-14 shows the distribution of the urban areas, industrial areas and large infrastructure areas within the Study Area.



Source: JICA Study Team

Figure 9-14　Economically Active Zone in the Study Area

The relative economic value of each commune was calculated using the following simplified formula: [Relative economic value] = [Area of the economically active zone] / [Commune Area]. The relative economic value was classified into the five (5) categories as shown in Figure 9-15. Table 9-13 below shows the relative extent (area) ratio of the economically active zones within each commune.



Source: JICA Study Team

Figure 9-15 Relative Extent Ratio of the Economically Active Zones within Each Commune

Table 9-13 Percentage of the Economically Active Zone Area within Each Commune

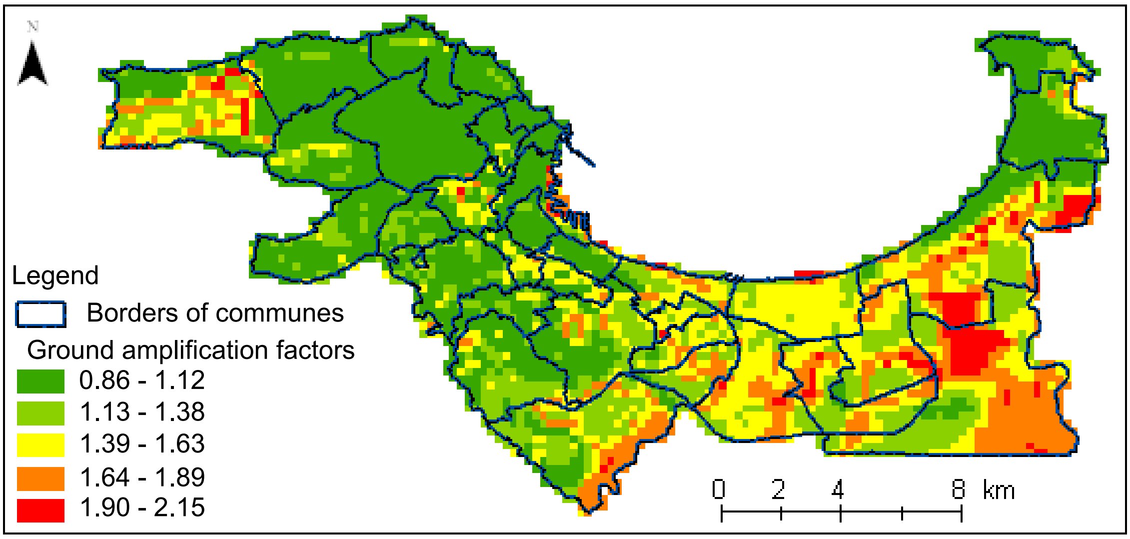
Code	Commune	Percentage of the economically active zone area	Economic value
1631	EL MAGHARIA	100	5: High
1619	BACH DJARAH	100	5: High
1607	CASBAH	99	5: High
1609	BIR MOURAD RAIS	95	5: High
1602	SIDI M'HAMED	93	5: High
1601	ALGER CENTRE	93	5: High
1617	HUSSEIN DEY	91	5: High
1616	BOUROUBA	91	5: High
1605	BAB EL OUED	91	5: High
1618	KOUBA	90	5: High
1610	EL BIAR	87	5: High
1627	EL MOURADIA	85	5: High
1608	OUED KORICHE	84	4: Moderate to high
1621	BEB EZZOUAR	76	4: Moderate to high
1615	OUED SMAR	74	4: Moderate to high
1604	HAMMA EL ANNASSER	73	4: Moderate to high
1606	BOLOGHINE IBNOU ZIRI	71	4: Moderate to high
1629	MOUHAMMADIA	70	4: Moderate to high
1622	BEN AKNOUN	69	4: Moderate to high

Code	Commune	Percentage of the economically active zone area	Economic value
1612	BIRKHADEM	69	4: Moderate to high
1626	DJASR KASANTINA	66	3: Moderate
1623	DELY BRAHIM	64	3: Moderate
1603	EL MADANIA	64	3: Moderate
1611	BOUZAREAH	63	3: Moderate
1620	DAR EL BEIDA	62	3: Moderate
1613	EL HARAACH	62	3: Moderate
1628	HYDRA	59	3: Moderate
1632	BENI MESSOUS	51	2: Low to moderate
1625	RAIS HAMIDOU	47	2: Low to moderate
1630	BORDJ EL KIFFAN	46	2: Low to moderate
1640	EL MARSA	43	2: Low to moderate
1639	BORDJ EL BAHRI	35	1: Low
1644	AIN BENIAN	31	1: Low
1624	EL HAMMAMET	20	1: Low

Source: JICA Study Team

9-2-7 Ground Surface Motion Potential

Ground amplification factors indicate the amount of ground motion (shaking) that can be expected to result from seismic shocks. Higher values indicate that a greater amount of ground motion can be expected and therefore more extensive damage could occur to buildings and infrastructure. Values for ground amplification factors were determined by using the results of geological investigations and geologic modelling that were done by the JICA Study Team. The ground amplification factors determined for the 34 communes were grouped into five classes as shown in Figure 9-16.



Source: JICA Study Team

Figure 9-16 Distribution of the Ground Amplification Factors within the Study Area

Table 9-14 below shows the average ground amplification factor in the built-up areas within each commune.

DAR EL BEIDA, EL HARAACH, BEB EZZOUAR, BOUROUBA and OUED SMAR have relatively high ground amplification factors. MOUHAMMADIA, DJASR KASANTINA and other communes follow those five (5) communes. Communes having relatively high ground amplification factors are located in the Plain of Mitidja. Communes that are located in the Sahel Hills area have relatively low ground amplification factors.

Table 9-14 Average Ground Amplification Factor in Built-up Areas within Each Commune

Code	Commune	Ground Amplification factor	Rating
1620	DAR EL BEIDA	1.6055	5: High
1613	EL HARAACH	1.5403	5: High
1621	BEB EZZOUAR	1.5328	5: High
1616	BOUROUBA	1.5024	5: High
1615	OUED SMAR	1.4621	5: High
1629	MOUHAMMADIA	1.4600	4: Moderate to high
1626	DJASR KASANTINA	1.4287	4: Moderate to high
1630	BORDJ EL KIFFAN	1.4002	4: Moderate to high
1619	BACH DJARAH	1.3837	4: Moderate to high
1631	EL MAGHARIA	1.3546	4: Moderate to high
1617	HUSSEIN DEY	1.3342	4: Moderate to high
1603	EL MADANIA	1.2860	3: Moderate
1618	KOUBA	1.2425	3: Moderate
1627	EL MOURADIA	1.2261	3: Moderate
1644	AIN BENIAN	1.2094	3: Moderate
1601	ALGER CENTRE	1.2075	3: Moderate
1610	EL BIAR	1.1953	3: Moderate
1612	BIRKHADEM	1.1501	2: Low to Moderate
1623	DELY BRAHIM	1.1086	2: Low to Moderate
1622	BEN AKNOUN	1.0947	2: Low to Moderate
1632	BENI MESSOUS	1.0943	2: Low to Moderate
1604	HAMMA EL ANNASSER	1.0838	2: Low to Moderate
1639	BORDJ EL BAHRI	1.0772	2: Low to Moderate
1609	BIR MOURAD RAIS	1.0709	2: Low to Moderate
1628	HYDRA	1.0706	2: Low to Moderate
1602	SIDI M'HAMED	1.0541	2: Low to Moderate
1608	OUED KORICHE	0.9993	1: Low
1640	EL MARSA	0.9686	1: Low
1625	RAIS HAMIDOU	0.9432	1: Low
1606	BOLOGHINE IBNOU ZIRI	0.9039	1: Low
1611	BOUZAREAH	0.8964	1: Low
1607	CASBAH	0.8953	1: Low
1624	EL HAMMAMET	0.8850	1: Low
1605	BAB EL OUED	0.8838	1: Low

Source: JICA Study Team