13th World Conference on Earthquake Engineering
Vancouver, B.C., Canada
August 1-6, 2004
Paper No. 3115

SEISMIC RISK ASSESSMENT OF CURRENT BUILDINGS OF ALGIERS CITY

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SUMMARY

Algiers, capital of Algeria, because of bigger concentrations of economic infrastructures and population, requires a particular attention to protect it, to an acceptable level, against the negative consequences of seismic event, a phenomenon that threatens it to the highest degree, and that can hit at any time.
The authorities of the city aware of this risk and in order to have the necessary elements that let them to know and estimate the potential losses in advance, with an acceptable error, and to take the necessary countermeasures, initiated a seismic vulnerability and risk assessment of Algiers city. The main goal being to put in evidence the zones or districts that are more exposed to the seismic risk, and so, to be able to localize the places of intervention and the appropriate means before the event occurrence, and reduce its negative impact on population and socio-economic assets.
The results of this seismic vulnerability and risk study obtained using the RADIUS method and the European Macroseismic Scale (EMS 92), assuming an earthquake of magnitude 6.5 generated by the Bouzaréah Fault at 10H00 in the morning, are synthesized in tables and maps where are represented the losses and damages (in terms of buildings and human lives) in the city limited to 26 districts. These will allow the concerned authorities to take arrangements to put the necessary tools in place (emergency plan, politics of prevention, etc.) to reduce these potential losses and

INTRODUCTION

The seismic risk significantly increased these last decades, on account as a result of rapidly developing cities, in the earthquakes area[1]s, and in particular in the developing countries (increase in populations and strong urbanization), and that the demand for housing often was such that construction is made in

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detriment of quality. It is necessary for any policy of rational city planning to evaluate this risk and to know it.

In Algeria, the last earthquakes of Chlef (1980), Constantine (1985), Oued Djer (1988), Tipaza (1989), Mascara (1994), Ain-Benian (1996), Ain Temouchent (1999), Beni Ourtilane (2000), and very recently Boumerdés (2003) show that the seismic activity is significantly high. This activity concerns essentially the North of the country where the largest cities are located (Algiers, Oran, Constantine, Annaba, etc.) for which the seismic risk goes growing with the development of economic activity and the growth of the population.

The city of Algiers, because of greater concentration of economic infrastructures and population, requires a detailed attention to protect it, on an acceptable level, against this natural phenomenon, which threatens it, and which can strike at any time. The evaluation of the risk which threatens this city becomes a need and a priority particularly because Algiers is the political, administrative, economic and social capital of the country.

Within the framework of the policy of reduction of the seismic risk in Wilaya (department) and more particularly of the town of Algiers, one of the privileged ways consists in installing tools for analysis and undertaking studies and actions for an effective prevention of the effects of this natural phenomenon which is the earthquake. Among them there is **the study of vulnerability and seismic risk evaluation.**

The present study will be limited to the evaluation of the losses or damage to the buildings in 26 districts of the town (figure n°1).

Figure n°1**:** Study area of Algiers city

METHODOLOGY

Two methodologies were used to estimate the losses and damage:

a) RADIUS (Risk Assessment Tools for Diagnosis of Urban Areas Against Seismic Disaster) which was developed within the framework of the international decade of the United Nations for the prevention against natural disasters (IDNDR : International Decade for Natural Disaster Reduction, 1990-1999) and which uses the vulnerability functions represented on figure n°2.

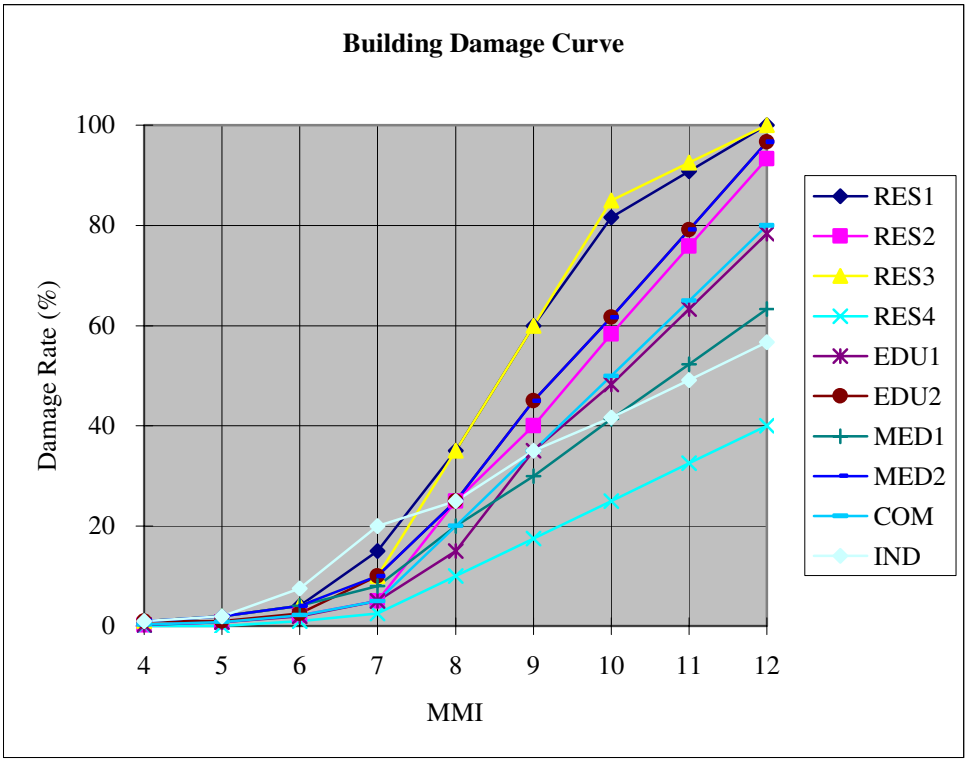

Figure n°2 : RADIUS vulnerability Curves

RES1	Informal construction: mainly slums, row housing etc. made from unfired bricks, mud mortar, loosely tied walls and roofs
RES2	URM-RC composite construction: substandard construction, not complying with the local building code provisions. Height up to 3 stories. URM = Unreinforced Masonry, RC = Reinforced Concrete
RES3	URM-RC composite construction: old, deteriorated construction, not complying with the latest building code provisions. Height 4 - 6 stories
RES4	Engineered RC construction: newly constructed multi-story buildings, for residential and commercial purposes
EDU1	School buildings, up to 2 stories: generally, the percentage of this type of building should be very low
EDU2	School buildings, greater than 2 stories: office buildings should also be included in this class; generally, the percentage of this type of buildings should be very low
MED1	Low to medium rise hospitals: generally, the percentage of this type of building should be very low
MED2	High rise hospitals: generally, the percentage of this type of building should be very low.
COM	Shopping Centers
IND	Industrial facilities: both low and high risk

b) The second methodology used is a direct method which is the European Macroseismic Scale (EMS 92). This methodology defines 6 different categories of buildings (6 classes of vulnerability) from A to F.

ALGIERS EARTHQUAKE HAZARD

The Algiers region has experienced in the recent and past history several earthquakes from moderate to strong ones. The catalogue of the historical seismicity (CRAAG, 1994), mentions particularly the major seismic events of February 3rd, 1365, and January 2nd, 1716 (20 000 dead). The last one was followed by a tsunami which affected the low parts of the city. Recently, the Zemmouri earthquake (May 21st, 2003, $M_S = 6.8$) caused serious losses.
Recent studies undertaken in the area of Algiers (Meghraoui, 1988; C.G.S., 1993; Boudiaf, 1996; SWAN, 1995) have shown a certain number of potentially seismic faults (Figure 3).

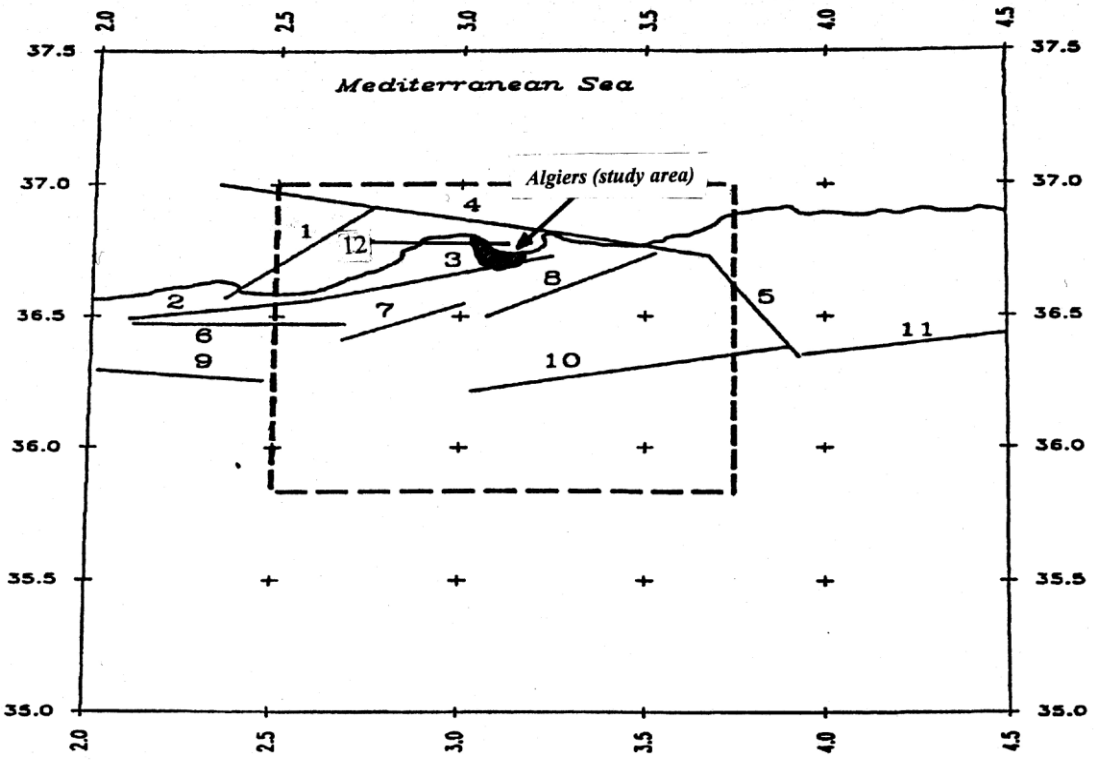

Figure n°3: Map of potentially seismic faults in Algiers region

1-Chenoua –Tipaza, 2-Menaceur, 3-Sahel, 4-Thenia, 5-Isser- Bouira, 6-Sud Mitidja, 7-Blida , 8-Khemis El Khechna, 9-Miliana, 10-El omaria-Bouira, 11-Bouira-Bedjaia, 12- Bouzaréah

DESCRIPTION OF THE EXISTING BUILDINGS (TEBBAL, 1985)

Algiers knew a semicircular extension around the historical centre "Casbah", since the 17th and 18th centuries. The old residences of the Casbah are built in poor masonry, slightly tied horizontally by wooden beams.

Around this urban nuclei, old colonial constructions were built (photo n°1) dating from 19th century and the beginning of the 20th century. They are buildings of several stories (up to 12) generally not horizontally and vertically tied (Bab El Oued; Hamma, Sidi M'hamed).

A third belt of individual constructions or buildings of medium low (three stories) is located on the hills surrounding the centre of the city. These structures are generally in reinforced concrete or in tied masonry, but not designed according to the code.

The most recent constructions are buildings from five to nine storeys calculated according to the seismic code. The quality of construction is however neither always satisfactory, nor uniform. 22 000 of these residences (photo n°2.), were built in the suburbs of the city (Kouba, Bab Ezzouar, Bir Mourad Rais....).

It is important to note that the majority of the administrative buildings are old buildings dating from the colonial period. These constructions, of which some have up to eight stories, are not calculated according to a seismic code. These structures are in reinforced concrete or heavy masonry with flexible low stories which permit large entries. This compromises the capacity of these buildings to support significant earthquake forces.

The majority of the hospitals (Mustapha, Parnet....) are old and obviously non resistant to earthquakes.

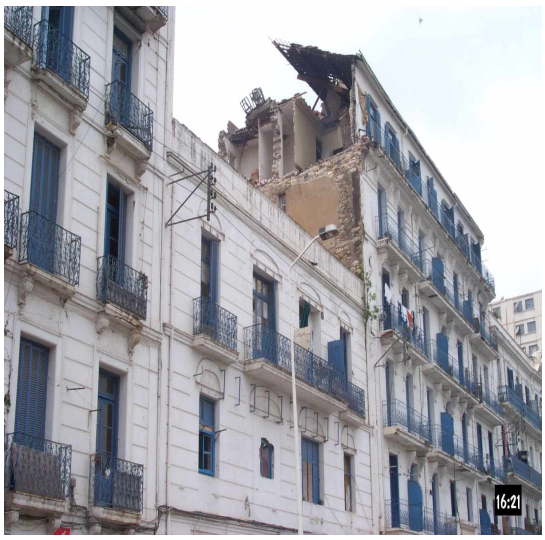

Photo n°1 : Old masonry building

Photo n°2:New RC building at Bab-Ezzouar district

GENERAL CENSUS OF THE POPULATION AND THE HABITAT OF 1998 (RGPH 98)

The analysis of the population and building data is based on the results of the General Census of the Population and the Habitat (RGPH-98) carried out by the National office of Statistics (ONS) in 1998.

It comes out from this census that for the 26 principal districts studied:

- The population is estimated at 1 498 043 inhabitants
- The surfaces area is about 12 301 ha
- The building stock is about 260 684 units.

The main needs for this study were:

- The number of Population and its geographical distribution
- The different categories of buildings

Table 1. Density of apartments and population

District	Dwellings / ha	HAB/ ha	District	Dwellings / ha	HAB/ ha
ALGER CENTRE	105	485	OUED SMAR	4	27
SIDI M'HAMED	181	449	BOUROUBA	30	213
EL MADANIA	36	226	HUSSEIN DEY	16	102
HAMMA ANASSER	64	370	KOUBA	19	108
BAB EL OUED	120	747	BADJARAH	35	220
BOLOGHINE	35	215	BAB EZZOUAR	26	115
CASBAH	92	478	BEN AKNOUN	18	96
OUED KORICH	31	184	RAIS HAMIDOU	7	43
BIR-MOURAD-RAIS	36	187	DJASR-KASENTINA	20	111
EL BIAR	25	139	EL MOURADIA	28	159
BOUZAREAH	6	35	HYDRA	13	67
BIRKHADEM	12	69	MOHAMMADIA	12	63
EL HARRACH	12	74	EL MAGHARIA	62	388

In order to know the percentage of each construction type in the same district (necessary for the RADIUS method) and to make a classification (10 classes) compatible with the vulnerability curves of the figure n°2, a field inventory was carried out in the twenty six districts concerned by the study.

LOSSES ESTIMATION

Radius Method

Input data parameters are Magnitude, Epicentre, Depth and Occurrence Time. The analysis made consider the following data: magnitude 6.5 generated by the fault of Bouzaréah at 12 km of depth, and occuring at 10H 00 of the morning during a day of week. The epicentral distance is taken equal to 5 km and the attenuation laws are the ones of Joyner and Boore
This supposes that the majority of the inhabitants are in working places, the children are in schools, the hospitals operate normally, etc. The analysis which combines these seismic data, the nature of the ground, the constructive type and the density of population led to the results which are given on figure 4:
The RADIUS methodology uses the algorithm of Coburn (Coburn et al. 1992) in order to estimate casualties. These results are given in table 2.

This scenario gives an average damage of 20% for all the studied area. This is equivalent to losses of approximately 62 515 dwellings. In term of surface, the losses would be more than 3 750 000 m2 of floors, which represents **financial losses** of more than **700 000 000 USD,** with regard to the casualties, we will have more than **3000 dead people** and more than **40 000 injured.**

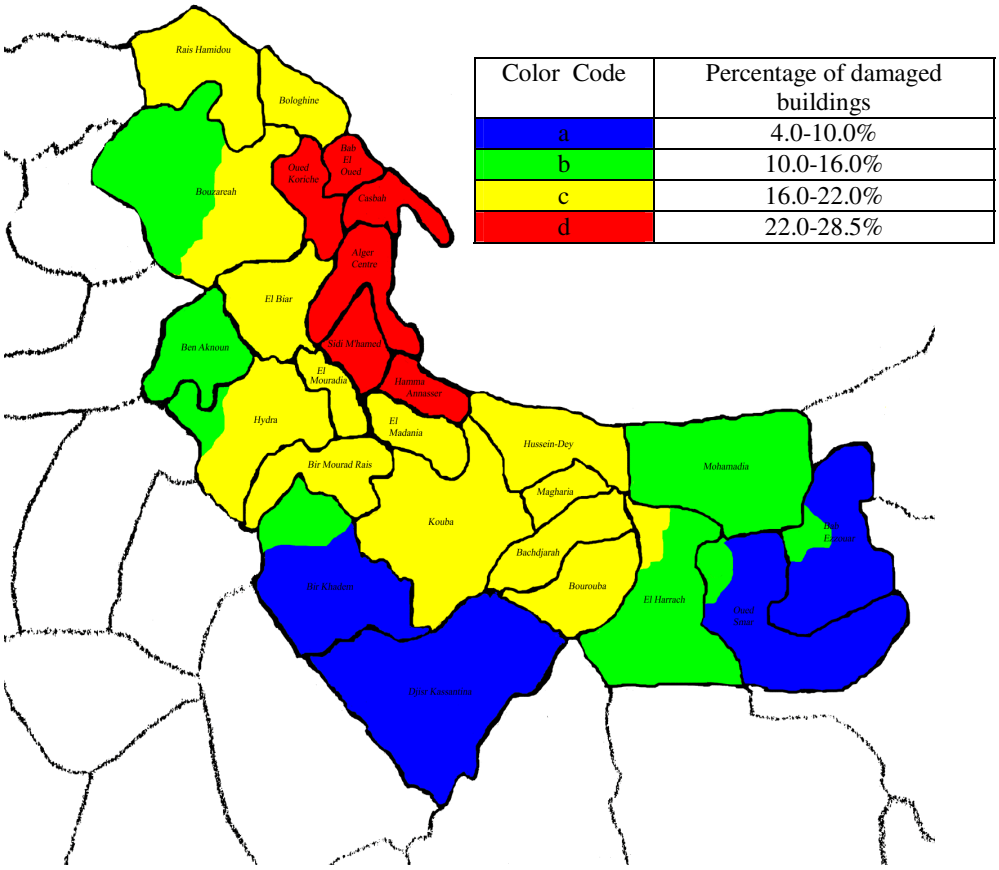

Figure 4: Damage buildings distribution according to the RADIUS method

Table 2: Number of dead people and injured by district

N°	District	Dead	Injured	N°	District	Dead	Injured
1	RAIS HAMIDOU	45	534	14	BACHDJARAH	133	1807
2	BOLOGHINE I- ZIRI	87	964	15	EL-MAGHARIA	59	682
3	BAB EL-OUED	81	1048	16	KOUBA	181	2332
4	CASBAH	102	1316	17	EL-MADANIA	64	733
5	ALGER CENTRE	202	2820	18	EL-MOURADIA	51	554
6	SIDI M'HAMED	200	2449	19	EL-BIAR	130	1496
7	HAMMA ANNASSERS	100	1250	20	OUED KORICHE	91	933
8	HUSSEIN DEY	109	1267	21	BOUZAREAH	211	2715
9	MOHAMMADIA	110	1556	22	BEN AKNOUN	119	1414
10	BAB EZZOUAR	95	1889	23	HYDRA	103	1364
11	OUED SMAR	55	835	24	BIR MOURAD RAIS	126	1644
12	EL-HARRACH	135	1898	25	BIRKHADEM	206	3028
13	BOUROUBA	151	1962	26	DJ-KASENTINA	133	2428
TOTAL						**3081**	**40917**

EMS-92 Scale

Two seismic intensities VIII and IX were considered to apply the vulnerability functions of European scale EMS-92.
An average value of damage was given for the considered area.

Summary of the results

With the exit of this first study on evaluation of the seismic risk for Algiers, it arises the following results:
By application of the RADIUS method:

- Financial losses: 700 000 000 USD
- human losses : 3081 dead and 40 917 injuries

By application of the EMS Scale:

- Financial losses: 826 300 000 USD for intensity VIII of EMS-92
- Financial losses: 1 558 000 000 USD for intensity IX of EMS-92
- human losses : not given

CONCLUSION

The study, with its limits (only 26 districts studied, lifelines not considered) gives us precious information about the vulnerability of the city and its weak points. The knowledge of what will happen if an earthquake occurs is necessary for earthquake-prone cities since this information can help to set priorities in using the limited resources of the city and the country.

For us, it will be urgent to take strong decisions in order to protect the town against a seismic event, this is for an effective seismic disaster mitigation.

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