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Nonlinear Deterministic Study of Seismic Microzoning of a City in North of Algeria

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Abstract

This paper presents also an overview of seismic microzonation studies of the city of Mohammadia-Algiers, which are important for a detailed ground movement modeling of urban cities. According to the seismic history of the city, one extraordinary earthquake event has been taken into consideration is Boumerdes earthquake (Algeria, May 21, 2003, magnitude Mw=6.5), that caused a huge damage. Thereby, the variability prediction of the seismic ground movement in a given built-up area, it is considered as an effective tool for planning appropriate urban development and understanding both seismic risk and damage pattern, caused by a strong movement event. We note that the shaking level is mainly described in terms of both maximum ground acceleration and visualized amplification by using response spectra. The study is carried out in two steps: - a detailed mapping of the geology and geotechnical properties of the area - numerical modeling of expected ground motions during earthquakes. A qualitative microzonation of the Mohammadia-Algiers city is presented, and it is discussed by comparing it to the historically reported damage of the 2003 Boumerdes earthquake. Finally, this study deals with the seismic microzonation map development, based on a SIG geological model.

Keywords: Seismic Microzonation; Site Effects; Shear Wave Velocity; Ground Response Analysis.

1. Introduction

The town of Mohammadia city is located in the heart of Algiers, about 10 km to the east. It is bounded, on the west, by Oued El Harrach, on the north, by the sea, on the south, by the national road (NR.5) and, on the east, by the municipalities of Bordj El Kiffan and Bab Ezzouar. It is located according to the following geodetic coordinates 36° 44' 00" North 3° 08' 00" East (Figure 1). This zone is known by its great seismic activity due to the approximation of the Eurasia and Africa tectonic plates. Algeria's north has witnessed several destructive earthquakes whose the majority has been registered. To illustrate, the Setif earthquake (419) which is the first historically known list, postponed by Miniati (1995) [1], then Algiers in 1365 and 1716, Oran in 1790, and Gouraya in 1891. In the recent period, we can list the cheleff / (The city of Orleans) earthquakes on September 09th, 1954, El Asnam on October 10th, 1980, M = 7.3 [2 -4], Constantine on October 27th,1985, M = 6 [5], Tipaza on October 10th, 1986, M = 6.1 [6] Mascara on August 17th, 1994 [7], Ain Temouchent on December 22nd, 1999 [8], Beni-Ouartilane on November 10th, 2000, M = 5.7 [9] and Boumerdes on May 21st, 2003, M = 6.8 [10-12].

The crust quake is the reason for the majority of damages, which are generated by an earthquake. Therefore, they can represent the direct repercussions of soil vibrations coming directly from the focus. However, lands movements can be

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created at the same time and cause other types of material damage. One of the most important destructive factors is related to the tremor duration, which depends on the soil constitution. According to the underground topography of the site and the soils nature, seismic tremors, as well as the caused damages, can be either diminished or amplified.

For identifying the areas with a high seismic risk and guarding against the damage that may occur, we try through this method to estimate the lands movement's parameters or the macroseismic intensities during an earthquake triggering. The seismic movement arrival, in a fixed site, is estimated through the seismic hazard; it may suffer from variations in terms of value [13]. That is to say, even if the movement from the seismic source is attenuated in some places during the perturbation spreading, the morphological and topographical characteristics induce amplification [14-18]. Moreover, the movement interaction with the geotechnical and hydrogeological conditions which are really related to a fixed site can create some induced phenomena such as the liquefaction phenomenon, landslide, etc.

Studying seismic hazard for a good design and efficient structures implantation, an accurate assessment of earthquake-resistant amplification is required. The tremor level is mainly described in terms of maximum ground acceleration and amplification [19] and preparing microzonation maps will assure, in a way, an effective solution for urban planning in terms of seismic risks [20, 21]. On the other hand, the cities microzonation will allow the characterization of a potential seismic vulnerability as well as the risk, which must be taken into account, when to design new structures or modernize those which have already existed. Rational approaches for seismic microzonation have been proposed in a very large number of journal and conference papers [22-28].

Seismic microzonation is required in urban areas or the ones which are close to them, which belong to the high seismic risk area; it is mainly based on identifying the seismic activity sources [29]. In the region when to study microzonation of Mohammadia city, 1D dynamic analyzes were carried out through the field data which contain geological, geophysical and geotechnical surveys for predicting. The analysis of the movement response is applied on sub-basically movements, in order to prepare the design spectra response and, finally, determine the ground responses that include the dynamic insistence and the seismic zoning map [30, 31]. Local site effects play, as well, an important role in the resistant earthquake design and should be separately treated as concerns each case [32]. The site factors can affect the earthquake waves in two ways: Topographic effects that are resulted by changing the nature waves (such as the amplitude and the satisfied frequency of ground movement) as well as the effect of the soil layers number and type on the bedrock [33]. Moreover, urbanization is a factor that foresees the construction of the megastructure. The main reason, for human and material damages, is when the desired importance is not taken into account by preparing adequately for a possible consideration of the seismic hazard.

The seismic zoning map presents a large scale view that allows an interpretation of the site behavior during an earthquake because of the local variations in the soil type and geology. Earthquakes are unavoidable but it is possible to minimize their consequences if the areas, which are the most sensitive to soil movements and suffer from a maximum action, are identified. Seismic Microzonation will be a response to the need for cushioning measures against seismic risks, as it gives a real response in terms of soil movement with a higher resolution [34-35].

In this study, the microzonation analysis of the seismic risk, according to the effect of Mohammadia city, in the province of Algiers, is explained.

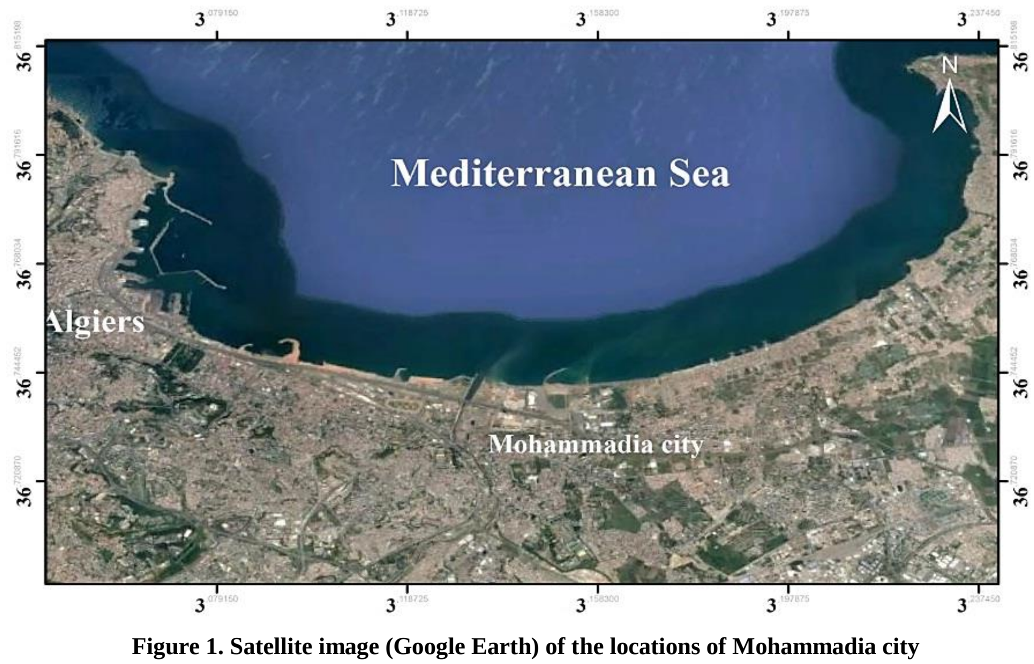

Figure 1. Satellite image (Google Earth) of the locations of Mohammadia city

2. Microzonation Methodology

The site effects are considered as an important challenge in the seismic prevention. In this context, it is obviously not possible to anticipate an earthquake, but it seems admissible to predict where and how the seismic signal should be amplified [36]. Therefore, the microzonation goal is to delimit, on maps, the zones with a homogeneous hazard. For each zone, we must identify the fundamental sites frequency and recognize the spectral site's response (their transfer function). Therefore, the soils recognition and their response allow the identification of typical behaviors and the adaptation of the structures design spectra, which are imposed by the seismic regulations, in order to take into account the site effects [37-38]. In fact, regulations can only give a lump and simplified values that rarely reflect the soils physical reality. The challenge is to understand the phenomena as well as to develop reliable methods for refining the regulation, either in a national context or in the local one (Within the framework of the risk prevention plan).

On the whole, it is important to estimate the response of soil layers, under the seismic excitations, as well the variation of soil earthquake movement characteristics in the soil surface. The general methodology, to proceed to the seismic microzonation of Mohammadia city, has been subdivided into four major elements:

1. The assessment of soil movements' parameters through historical seismicity and earthquake movements' data that include the position of potential sources, magnitude, mechanism, distances to the epicenter.
2. The site characterization by using geological, geomorphologic, geophysical and geotechnical data.
3. The assessment of local site effects, including amplification, predominant frequency, the risk of liquefaction, landslides, tsunami, etc.
4. The preparation of seismic microzonation maps.

The method, which is used to assess the 1-D seismic response of the site, is a simple computer-based analysis according to the seismic response of soil profiles. The seismic response determination of soil profiles, with a seismic stress, is related to the assessment of the seismic movement characteristics (displacement, speed, acceleration, stress) in the vicinity of the free surface, see (Figure 2).

3. Geology and Geomorphology of the Study Area

The geological context of Algiers is very complex, as there is a sudden passage from the ancient metamorphic soils of the primary age to the tertiary-age of sedimentary soils. They have included three major elements (The crystalliferous shelf, the tertiary and the quaternary), (See Figure 3).

Ancient soils are highly tectonized; they consist of crystalliferous rocks which are mainly composed of gneiss, schist, mica schist and marbles. The crystalliferous shelf is composed of the metamorphic rocks of the Algiers massif which flocks from Baïnem to the Agha, as well as three points, which are isolated by the Neogene from the west in Ain-Benian, Sidi Fredj and from the East near Tamentfoust. As it is referred, according to certain authors, to the primary stage, it doesn't present any element allowing the situation of these facies sedimentation in this era. However, the metamorphism age is very controversial. It is anticambrian for someones, Hercynian and even alpine for others.

According to several studies [39-40], it is observed, in the tertiary one, a stratigraphic gap coming from the Eocene and the Oligocene. The Tertiary is so represented by the Mio-Pliocene post-sedimentary forming, which cover the metamorphic facies and the metamorphic shelf; the latter is represented by coastal sandstones, on a conglomerate base.

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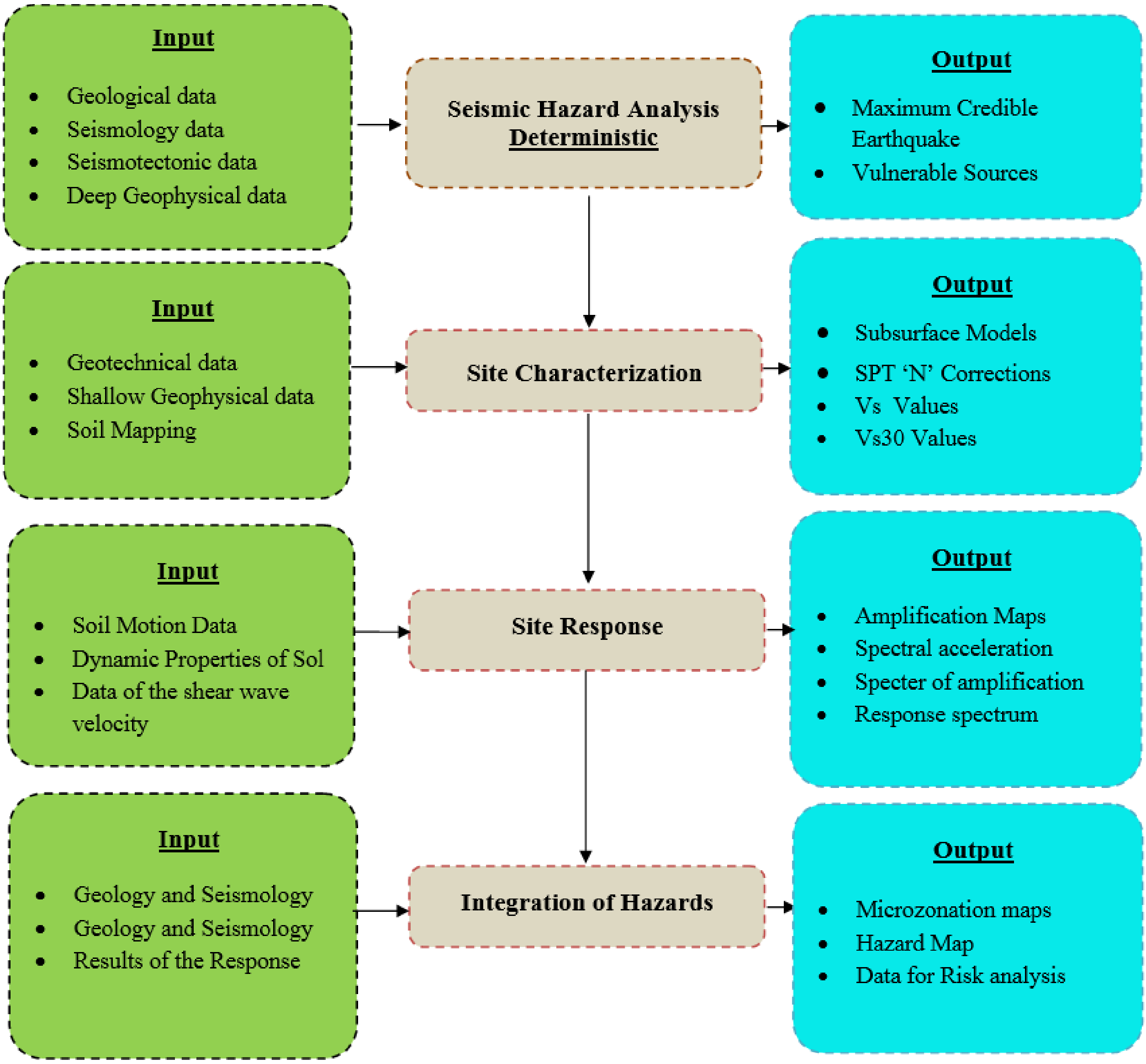

Figure 2. Methodology for studying the Seismic microzonation of Mohammadia city

According to several studies [39, 40], it is observed, in the tertiary one, a stratigraphic gap coming from the Eocene and the Oligocene. The Tertiary is so represented by the Mio-Pliocene post-sedimentary forming, which cover the metamorphic facies and the metamorphic shelf; the latter is represented by coastal sandstones, on a base conglomerate bed, with a thickness of about 0.5 to 6 m. This bed consists of detrital elements, resulting from the Algiers massif erosion.

The Pliocene is composed of two layers which are: the Pliocene onset Pleistocene when the sea occupied the whole zone. This sedimentation through receives all the clay deposits, which would later compose the blue marls, with an average thickness of 200 m. This forming stands, in discordance, on the sandstones and Miocene marls.

In the plain of El Hamma, the Pleistocene is covered by a recent deposit. It forms the substratum of the Mitidja subsurface basin. On the surface, the marls show weathering and are observed on the outcrops of Algiers heights. In-depth, the marls are compact and compose sometimes conchoidal fractures. The passage from the Pleistocene to the Astienis is marked by the position of a glauconite green level which is clayey-sandy, with a thickness of 0.1m to 5 m, containing numerous grains of greenish glauconite and macro-fossils such as Terebratula, Ampula. The Astien, molassic facies with a thickness of 100 m to 150 m, is characterized by the following lithological:

- Marl-sandy facies;
- Calcareous-sandstone facies;
- Sandstone and sandy facies.

In Algiers, the Quaternary is composed of sandstone soils which are formed by sand, alluvium, scree, silt, and muddy clay. Its thickness can reach 30 m where we essentially distinguish the lower Pleistocene.

It consists of a detrital continental deposit, composed of red sands, forming the terraces that can reach up to 5 m thick. We also find marls and pebbles, in the Mitidja filling, which outcrop the southern Sahel piedmont. In Mitidja, it results from the erosion of the Tellian Atlas and the accumulation of products, which are generated during this erosion. The upper Pleistocene is spreading out the Algiers coast, in the Sahel in the form of terraces (See Figure 3).

The geological map 1/50000 of Algiers shows that the studied site of Mohammadia is located on an old alleviation flap, belonging to the stony clay series of the Mitidja. On the quaternary deposit, we find the recent series including sands which are, in a way, more or less clayish and, on the other hand, less rubified [40].

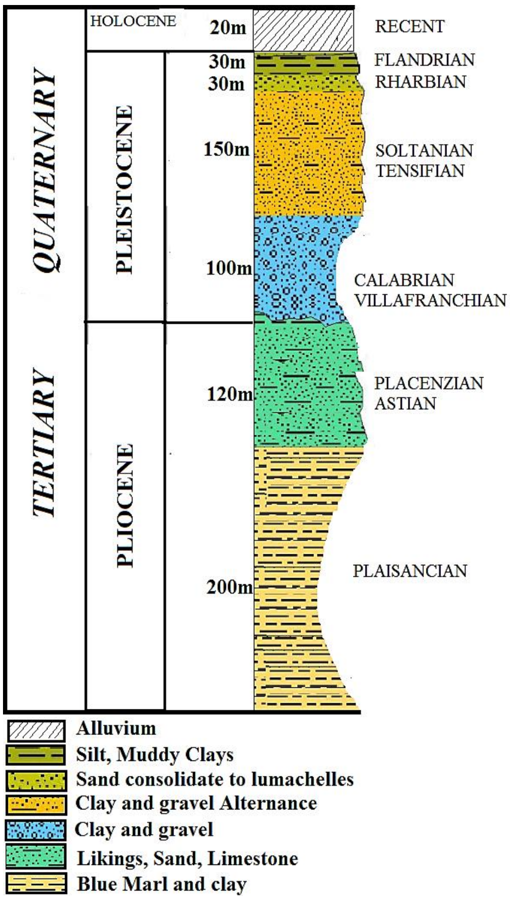

Figure 3. A synthetic stratigraphic log showing more or less loose quaternary formations. These beds of variable thicknesses laying on solid formations with hard Pliocene, being able to represent the seismic bedrock

4.1. Regional Hydrogeology

The Algiers region is characterized by several aquifers, which are the metamorphic complex aquifer, known by the presence of water in the metamorphic shelf, is located in the cracks, and fractures that are accumulated in the weathering zones. " It appeared in the form of resurgences (sources) or aquifers " The tertiary aquifer is the most important aquifer area in Algiers, whose the wall is composed of the Piacenzian blue marls, through an aquifer of Algiers' drippy tableland, this aquifer is free, its water has been exploited for providing Algiers with drinking water. The Quaternary aquifer consists of Quaternary dunes sandstone. It forms aquifers in several towns of this zone:

- The littoral strip between Bordj El Kifane and the right bank of the Oued El Harrach;
- The eastern littoral plain, between the 1st of May city and the left bank of the Oued El Harrach;
- The littoral zone stretching between Ain Benian and Staouali heights;

In all these areas, the Pleistocene blue marls constitute the aquifer's wall.

5. Characteristics of Algiers Seismicity

Algeria is situated on the Africa plate, which is in a perpetual collision with the Eurasia one. The collision of these two plates is proceeded with a speed of 5mm per year approximately; it gives to side of the border of the plate, a mountain range, folds and faults, which are mostly orientated to NE-SW, NNW-SSE and shortening direction in the Tellian Atlas [41-45]. In our study zone, is that we mainly find out five (05) faults: Sahel fault, Chenoua fault, Blida fault, Zemmouri fault, and Thenia fault.

The Algiers seismicity is located on the northern fringe of the country; it is composed of morpho-structural fields (Tellian Atlas). The frequency and magnitude of the seismicity are important in the Tellian Atlas. However, it will diminish if we go to the south (Figure 4).

The seismicity of the northern of Algiers is characterized by superficial earthquakes; it is located on the first 20 kilometers. This seismicity is generally characterized by a weak to moderate seism. However, strong earthquakes occurred in the Tellian Atlas. We can list the major earthquake of El Asnam on October 10th, 1980 (Ms = 7.3) and the strong one of Boumerdes-Zemmouri on May 21st, 2003 (Mw = 6.8) whose the result of dead persons was estimated at 2286: 3323 wounded ones, 100 lost ones, 175.000 disaster victims and 18.000 destroyed homes. These results have shown to which extent the consequences of such events can be catastrophic on the socio-economic context. The active structures are generally composed of inverse and/or sliding faults (Figure 3). The faults, that generate these earthquakes, are mainly oriented to NE-SW [2, 4, 8, 10, 46].

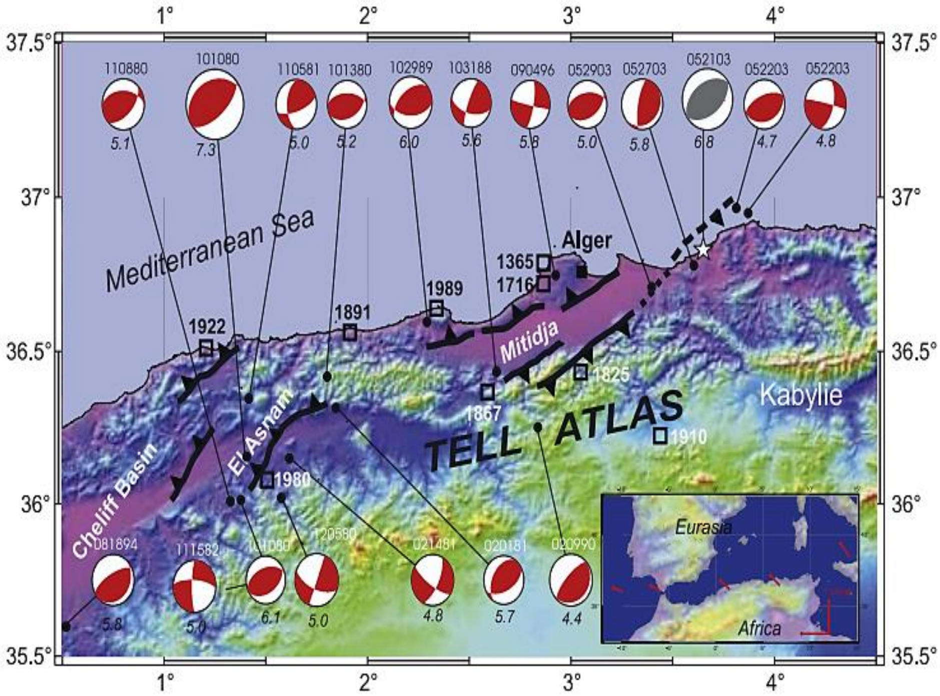

Figure 4. Seismotectonic map of the Tell Atlas of north-central Algeria (Meghraoui, 1988); Historical seismic events indicated in squares are from (Rothe, 1950); The Zemmouri earthquake focal mechanism is in grey

6. Geotechnical Properties of Soils in the Region

The dynamic properties of the region soils were evaluated through the soil data that can be determined by dynamic or seismic tests, which are carried out either in the laboratory or in the soil [48]. Despite the fact that dynamic soil tests are extremely useful for the site characterization, these ones, whose the cost is not as high as one of the static penetration tests (SPT), are commonly used in the surveys field. Through the results of static penetration tests, the soils dynamic properties can comfortably be calculated according to empirical equations, which improve the calculation of dynamic resistance parameters of the ones of static resistance.

The standard penetration test (SPT) may be the most known and used in the world [49]. In addition to the large database of these tests and the financial obtained advantages; it is plausible to understand the soils dynamic properties through these tests. The parameters, that can be empirically deduced, are listed, such as the shear wave speed, shear modulus, and soil amplification. Several tests of the SPT type (52 tests of cored surveys), with a depth of 30m, were executed at the studied site of " Mohammadia " (Figure 5).

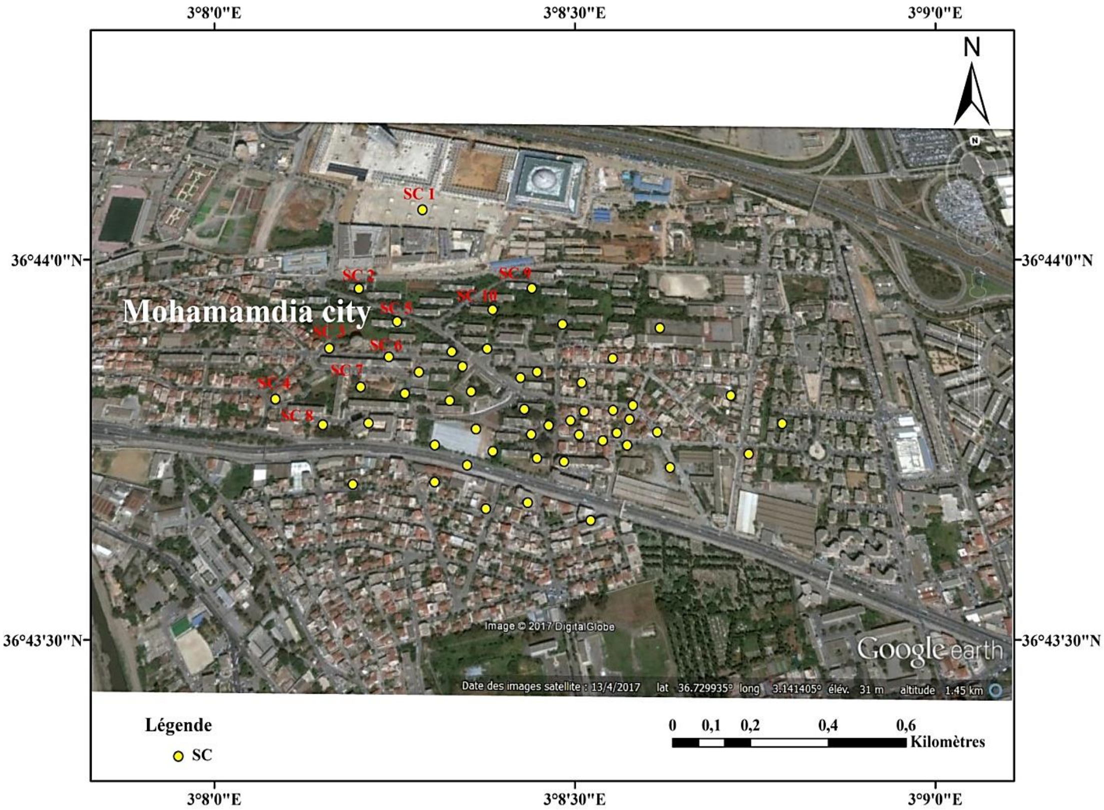

Figure 5. Tests of the SPT executed at the studied site of Mohammadia

The SPT tests were systematically effectuated on the various facies, traversed by the cored surveys which are carried out in "Mohammadia" site. The results show the following lithological succession: A superficial covering that mainly consists of silts, sand, some consolidated passages and heterogeneous embankments per places, a layer of clay and / or marl which is localized in the surveys, a fine alluvium alternation which is essentially composed of Sand and silt with a few gravels, enrobed with a clay matrix, with roughly alluvium, in which we observe stones, pebbles, some of the blocks, as well as silt and gravels. These results reveal certain homogeneity of the site according to the compactness point of view.

In fact, the SPT tests values, registered over the first 30 meters, comply with the send level. The obtained raw values N1, N2 and N3 of the SPT test, of which only N2 and N3 will be taken into account, as the value N1 corresponds to the soil reworked part which is designed to elimination. We will, therefore, take into account the N2 and N3, as concerns the value of N. The main characteristics of the test are:

- The sheep weight must reach 63 Kg.
- The fall height is 76 cm.

6.1. Determination of the Shear Wave Velocity (V_s)

The V_S measurements are possible in very stiff and gravelly soils. These parameters are obtained through the in situ direct measure, according to laboratory measures or empirical links with other usual geotechnical parameters, such as the SPT shocks number, a number of empirical links between G_{max} and several parameters of the existing in-situ tests. However, they still need to be improved by collecting other data. The usefulness of such correlations is often limited by preliminary G_{max} assessment. Therefore, the soil class assessment can be calculated through the average shear-wave velocity [50, 51].

Therefore, the soil class assessment can be acquired by using average shear wave velocities. The formula can be used to make a link between SPT counts and shear wave velocity, were calculated using (Equation 1) [52];

$$V_s = 68.96\, N^{0.51} \tag{1}$$

Where N is the uncorrected SPT blow count and V_s is the shear wave velocity (m/s).

6.2. Mapping of V_{s30} Values

The weighted average value of shear wave velocity V_s, in the upper 30 m of ground is denoted as V_{s30} and used worldwide e.g. [53-56], for characterizing a site in terms of the expected characteristics of earthquake shaking, despite the criticism which is given by several investigators. The classification of soils, for characterizing a seismic site and mainly classifying soils, is based on the average shear-wave velocity in the first 30 m of subsoil [57 -58]. This parameter is classically called V_{s30}, which is calculated according to the following expression

$$V_S^{30} = \frac{30}{\sum_{i=1,N} d_i / v_i} \quad (2)$$

Where d_i the thickness of the i^{th} soil layer in meters; v_i shear wave velocity for the i^{th} *layer* in $m.s^{-1}$ and N is the number of layers in the top 30 m soil strata which will be considered in evaluating Vs_{30} values.

A classification system of the site based on V_{s30} values was proposed by national program of research on earthquake risk (NEHRP) also classification of International Building Code (IBC), [62]. So to understand the velocity distribution shear waves average around the region of Mohammadia, average velocity was calculated using the Equation 2 for the location of each drilling. However, the average Vs_{30} was calculated to a depth of 30 m.

The Figure 6 represents the Vs_{30} map of the "Mohammadia" city was identified. The majority of the study area has a velocity range of 360 to 658 ($m.s^{-1}$). The range of V_{s30} values, specified for each site class, is different in the three methods NEHRP 2003**,** Eurocode 8 and RPA 2003**.** The urban city of "Mohammadia" is classified in the category class C for the NEHRP method (2003), Class B for Eurocode 8 and finally class S2 for RPA2003. The site will be considered as a solid one, consisting of sands deposits, very dense gravel and/or strengthened clay from 10 m deep.

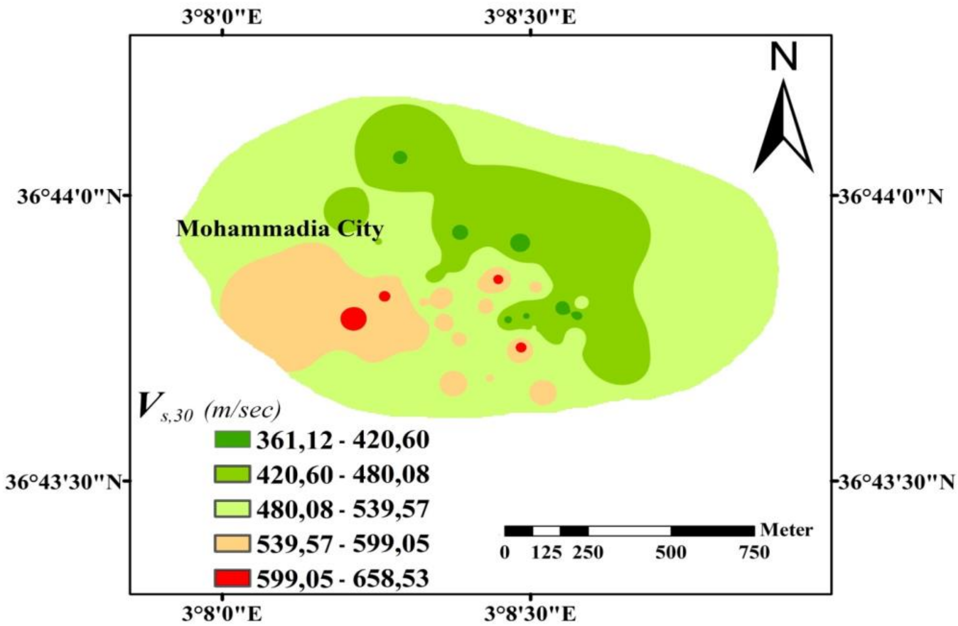

Figure 6. Spatial variation of V_{s30} in the Mohammadia area

7. The Input Earthquake and the Site Response Analyses

In order to obtain the site seismic response results, geotechnical cored test in the town of "Mohammadia" were realized. Some parameters such as the physical soil characteristic, soil type, thickness, and unit weights are obtained. The analyses are conducted by the one-dimensional linear equivalent method.

The linear approach is the simplest approach to evaluate the ground response. It relies on the principle of superposition. This approach is only suitable for analysis of linear systems. However, the nonlinear behavior of the soil can be approximated by iterative procedure with equivalent linear soil properties. In the equivalent linear analysis, it is required to first estimate the level of shaking in each layer assuming some constant initial values of shear modulus and damping. Later in successive iterations, the shear modulus and damping of the soils that corresponds to the estimated levels of shaking (shear strains) are used in the analysis [65]. Thus, the method considers the nonlinear stress-strain response of the soils indirectly. It is worth remembering that even though it considers equivalent shear modulus and damping where these values are constant throughout the shaking (analysis) in any iteration. A widely used computer program, SHAKE [66] and DYNEQ [67] implemented this equivalent linear approach.

According to the thicknesses and properties of soil layers and by using the seismic response calculation software, designed to soil profiles which are horizontally stratified, i.e. SHAKE91, we calculate for the soil column. This soil profile is modeled, according to the SHAKE91 program, as a multi-degree system of unidirectional freedom. This software is able to calculate the free-field seismic response in terms of acceleration from the excitation that is applied in the rocky substratum, the amplification function between the rocky substratum and the free surface of the ground, the vibration frequency for this amplification, the response spectrum in pseudo acceleration, relative pseudo speed and relative displacement [22]. By taking the following assumptions into consideration:

The soil column is defined as an insulated soil profile that is known by horizontal layers, surmounting an elastic half-space. Each soil layer is known by its thickness h_i, its density ρ_i, its damping coefficient ξ_i and by the shear wave's velocity V_{si} or its shear modulus G_i.The profile seismic response is generated by the vertical propagation of shearing waves. The excitation wave is introduced as an accelerogram.

The nonlinear behavior (variation of the shearing module and the damping coefficient) is taken into account through an iterative diagram by supposing an equivalent linear behavior [68].

A transfer function is used as a technique for 1D ground response analysis. The seismic signal at the bedrock (input) motion is in the frequency domain obtained by using Fourier transform. Each term in the Fourier series is subsequently multiplied by the Transfer function. The surface (output) motion is then expressed in the time domain using the inverse Fourier transform. The surface ground response is only considered as the input signal product, through the transfer function. Therefore, we obtain a frequency function taking into account the soil movement in the free surface; this is the Fourier transform (FT) of the output signal. We collect, through the inverse Fourier transform (IFT), the temporal ground movement at the surface.

In the Mohammadia microzonation case study, 7 scaled acceleration time histories of earthquake of May 21st, 2003 in "Boumerdes" probable magnitude range (Mw = 6.8) were used as input motion for site response analyses by Shake 91 and the average of the acceleration response spectra on the ground surface were determined to obtain the necessary parameters for microzonation. Selected time histories scaled with acceleration values at engineering bedrock level are listed in (As shown in Table 1) and (Figure 7).

Table 1. List of earthquake acceleration records used for site response analysis

Earthquake	Station	Magnitude	PGA (g)	Time (s)
Boumerdès 21/05/2003	Dar Biada	6.8	0.3169	7.28
Boumerdès 21/05/2003	Ain Defla	6.8	0.0296	5.86
Boumerdès 21/05/2003	Blida	6.8	0.0468	15.78
Boumerdès 21/05/2003	Hussein Dey	6.8	0.2716	6.88
Boumerdès 21/05/2003	Tizi Ouzou	6.8	0.1924	6.24
Boumerdès 21/05/2003	Kaddara (1)	6.8	0.2556	7.48
Boumerdès21/05/2003	Kaddara (2)	6.8	0.316	7.86

8. Results and Discussion

In the final results, the microzonation map of the 52 boreholes located in Mohammadia city has been done, taking into account the ground shaking. The peak ground surface acceleration is obtained as a result of seismic ground analysis has been obtained using SHAKE91.

8.1. Site Response Analysis

The Dynamic site response analyses are employed on various cells to question the soil behavior under seismic action. The microzonation maps prepared indicate a medium variation of the amplification factor, the period of the soil column, and the peak spectral acceleration.

Results of site response at the surface made by 1-D linear equivalent codes in correspondence to the conventional bedrock of 52 boreholes have been collected for creating some ground shaking maps for the urban area of Mohammadia city using a geographical information system tool (GIS). The rock motion obtained from ground motion model is assigned at the bedrock level as input in SHAKE91and evaluated peak acceleration values and acceleration time histories at the top of each sub layer.

The acceleration time history at the surface is obtained as well as the response spectrum acceleration as shown in (Figure 8). The PGA at the surface of the selected site in Mohammadia city is amplified due to the effect of the soil profile to be equal to (0.3169 g, 0.0296 g, 0.0468 g, 0.2716 g, 0.1924 g, 0.2556 g, 0.316 g) and the maximum spectral acceleration is varying from 0.51g to 0.96g. This amplification is influenced by both the effect of the input signal and soil profile. The seismic signal placed on the substratum crosses the different layers, and by the mechanism of reflexion/refraction, this signal arrives at the surface after having undergone transformations due to the nature of the ground. Then, the soil profile affects the seismic signal and modifies its characteristics.

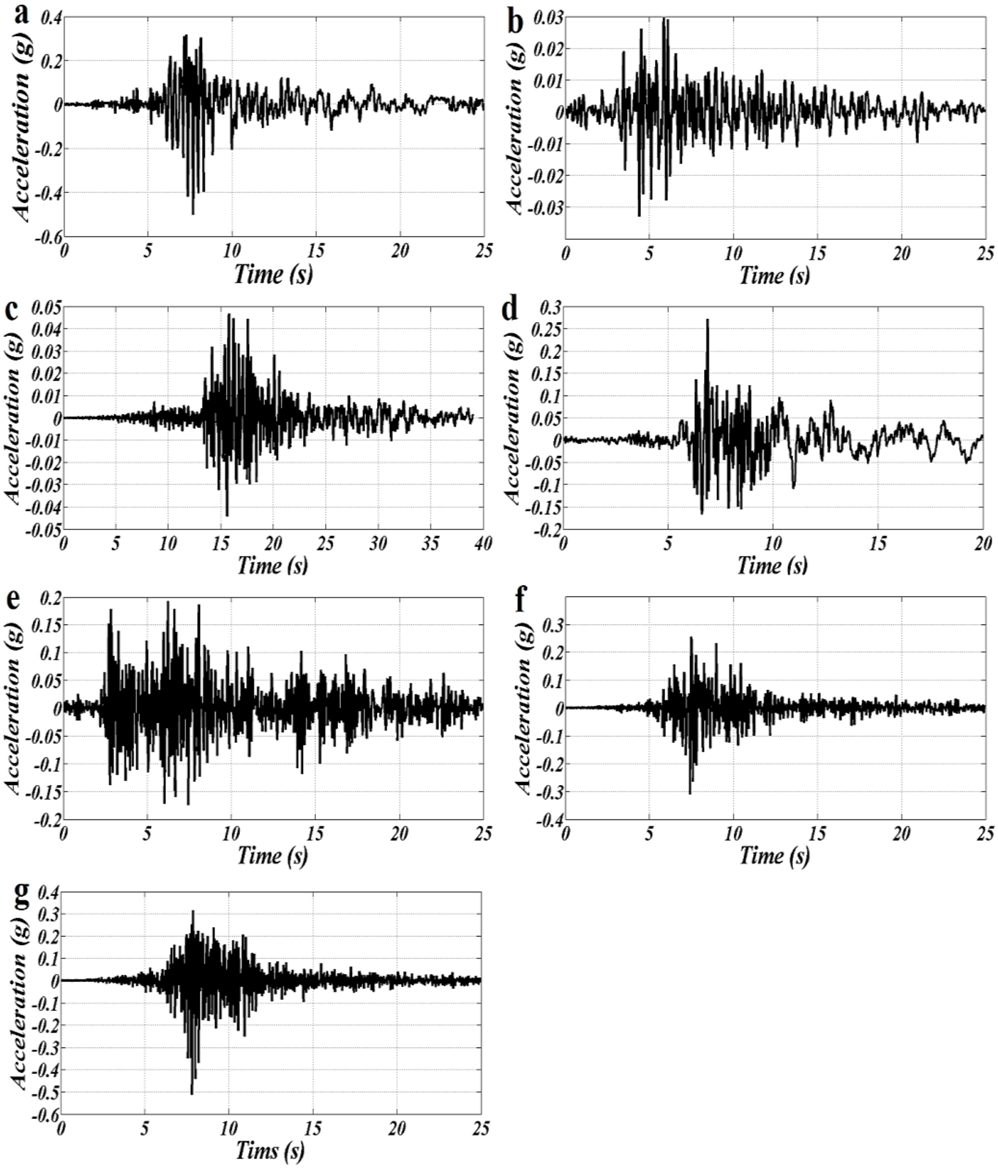

Figure 7. Acceleration time histories used as input in the site response analysis of earthquake of May 21st, 2003 in "Boumerdes" (a) Dar Biada Station, (b) Ain Defla Station, (c) Blida Station, (d) Hussein Dey Station, (e) Tizi Ouzou Station, (f) Kaddara (1) Station, (g) Kaddara (2) Station

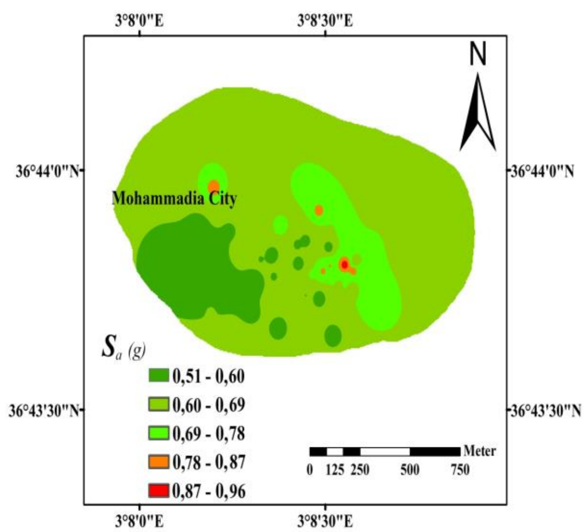

Figure 8. Contour maps with respect to average spectral accelerations Sa (g) calculated by site response analyses in the city of Mohammadia

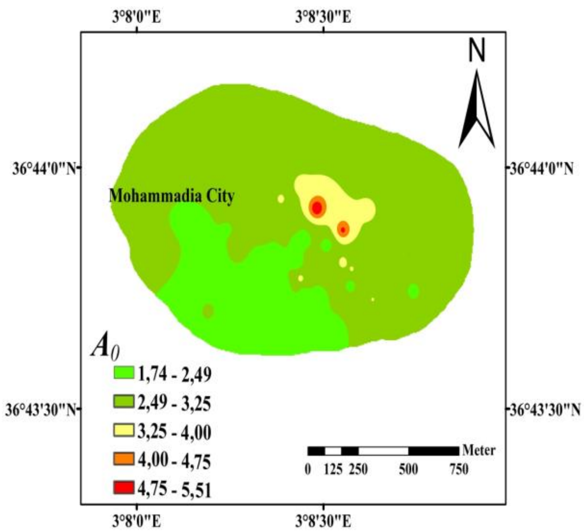

Figure 9. Contour map of computed average amplification in the city of Mohammadia

8.2. Amplification Factor Map

The term "Amplification Factor" is hence used here to refer to the ratio of the peak horizontal acceleration at the ground surface to the peak horizontal acceleration at the bedrock. The distribution of average amplification values is also prepared to be considered in the final seismic microzonation map in order to account for site response effects in the study area of Mohammadia city. The classification ranges and the average amplification factor map are presented in (Figure 9). With the average amplification factors varying from 1.74 to 5.51, it can be observed that the average amplification factor for most of the northern part of the study area is in the range of 2.49 - 3.25. This can be considered as significant zone of amplification. The region is moderately amplifying.

9. Conclusion

Seismic microzonation is a technique that takes into account the effects of site (geology, topography, landslide, etc.) on the local seismic hazard around the city of Mohammadia in order to mitigate the risk of the earthquake. In first, we have used the Vs30 estimated values to build a map for his spatial variation on the Mohammadia city that will permit us to propose a classification of the site based in accordance with the NEHRP classification. The nonlinear behavior of soil is modeled by an equivalent linear model which is implemented in SHAKE91. The site amplification is evaluated by assuming the soil column as a dynamic system of multi-degrees freedom in which the input signal is placed at the bedrock and a free field signal will be estimated. From these two signals the site amplification can easily evaluated and used to build the microzonation map. The resulting microzonation maps of seismic site class and spectral ground surface acceleration will be useful to structural engineers to design structures that are relatively resistant to earthquakes using the map information., The lithological site effects observed in the Mohammadia city are very particular and deserve further analysis by carrying out 1D simulation and better characterization of the mechanical properties of soils (in Geotechnical terms in particular). This would make it possible, in particular, to refine the damage scenarios taking in to account, like, the resonant frequencies of the soils observed in the zone and the amplification effects of the seismic movement. The results of the proposed analysis can be considered as an indispensable technical tool that characterizes the seismicity of the city of Mohammadia.

10. References

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