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THE INFLENCE OF SPECTRAL RESPONSES ON THE STRUCTURES HEIGHTS: CASE OF THE RHISS RIVER EARTHQUAKE IN MOROCCO (6.3MW) - SEISMOGENIC SOURCE 4 (RIF ORIENTAL - AL HOCEIMA - ALBORAN)

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ABSTRACT

Morocco is located in a risky geographical area: the ibero-maghrebi Mediterranean zone, which is situated on the “seismic belt”, known for its seismic instability and comprising high risk areas. Each year, hundreds of earthquakes of different magnitudes are recorded by seismic surveillance stations belong to the National Institute of Geophysics. The aim of this paper is to study the influence of Spectral Responses on the Structures as well as to make a comparison with the requirements of the Moroccan seismic construction regulations (RPS) 2000 revised in 2011 in the case of the Rhiss river earthquake saved in seismogenic source 4 (Rif Oriental - Al Hoceima - Alboran).

Keywords: ground motion, earthquake, spectral response, seismic analysis, structures heights.

1. INTRODUCTION

The random propagation of seismic waves in soil makes seismic action a transitory disturbance. Three principal factors rule motion in any given location: the source of seismic action, the path taken by seismic waves, and local geotechnical conditions [1].

A characteristic of seismic motion, released energy propagates in elastic wave form. These waves are formed near the epicenter and propagate towards the ground. Two types of elastic waves exist: compression and shear, each having its velocity [2].

The aim of this study is, on the one hand, to construct the spectral response of the ground motion for Rhiss earthquake [3], and, on the other hand, study structure stability via spectral method, with the objective of analyzing the influence of seismic characteristics on structures of different heights. In this regard, we have conducted a comparison between seismic analysis following Moroccan Seismic Regulation RPS 2000 (v. 2011), and spectral analysis for a structure of different heights in Al Hoceima, subject to an Earthquake of 6.3MW.

For that reason, in the first part, the construction of response spectra was done using Matlab code developed by M. AHATRI [4, 5, 6].

2. RESEARCH SIGNIFICANCE

Many seismic codes and regulations (RPS20111, UBC97, Eurocode 8, Indian Seismic Code etc.) use simplified methods, depending on the nature of the structure and its purpose, namely, the equivalent static method and the spectral modal analysis method. Despite the presence of these latters, real seismic data remains a key point in the building stability [7].

Indeed, the objective of this research is to compare the results obtained by the real data of the Rhiss seismic event recorded in (Rif Region - Al Hoceima - Alboran) with the requirements of the Moroccan Seismic Construction Rules (RPS) 2000 revised in 2011. It aims to see the influence of this spectral response on buildings of different heights (GF+4 to GF+10) in order to optimise in the seismic analysis.

3. RESPONSE SPECTRA BY THE DUHAMEL INTEGRATION METHOD

The response spectra of in acceleration, velocity and / or displacement allow involving the notion of frequency movement content. Its purpose is to characterize an earthquake based on the response of a simple structure [8]. By definition, an acceleration response spectrum is the curve giving the maximum acceleration of simple oscillators at a variable degree of freedom and natural frequency. Such an oscillator is characterized by a mass m, a stiffness k and a damper C [9].

The motion equation of forced oscillations after the earthquake application in the accelerogram ag(t) form will be the following [10]:

$$ma(t) + Cv(t) + kD(t) = -ma_g(t) \tag{1}$$

The differential equation resolution makes it possible to know the maximum acceleration undergone by the mass M.

Taking into account the damping definition ζ, the equation can be written in the form [11]:

$$a(t) + 2\omega v\zeta(t) + \omega^2 d(t) = -a_g(t) \tag{2}$$

$$T = 2\pi\sqrt{\frac{m}{k}} \tag{3}$$

$$f = \frac{1}{T} \tag{4}$$

$$\omega = \frac{2\pi}{T} = 2\pi f \tag{5}$$

K : The system stiffness
ω : The non-damped system pulsation (in radian / second);
T : Period (in seconds); the motion being periodic, the cycle duration is called the motion period;
f : Frequency (in hertz) ;

The solution is given by Duhamel's integral. The relative displacement is obtained [11]:

$$d(t) = \frac{-1}{\omega_D}\int_0^t a_g(\tau)e^{-\zeta\omega(1-\tau)}sin\omega_D(t-\tau)d\tau \quad (6)$$

$\omega_D = \omega\sqrt{1-\zeta^2}$: Pseudo-pulsation of the free oscillations damped;
τ: Integration variable.

It is noteworthy that the displacement value depends only on the pulsation ω, on the damping coefficient ζ and on the ground acceleration a_g.

Given The structures' very low damping value, we can assume that ω_D=ω, which corresponds to a very little damped oscillator. Thus, neglecting the secondary terms, the seismic motion components can be simplified. Relative displacement can be written as [11]:

$$d(t) = \frac{-1}{\omega}\int_0^t a_g(\tau)e^{-\zeta\omega(1-\tau)}sin\omega(t-\tau)d\tau \quad (7)$$

Relative velocity as [11]:

$$v(t) = -\int_0^t a_g(\tau)e^{-\zeta\omega(1-\tau)}cos\omega(t-\tau)d\tau \quad (8)$$

And pseudo-acceleration as [11]:

$$a(t) = +\omega\int_0^t a_g(\tau)e^{-\zeta\omega(1-\tau)}sin\omega(t-\tau)d\tau \quad (9)$$

The formulas below with the earthquake registration (accelerogram) allow to calculate systematically for all simple oscillators possible (i.e. for the whole periods range and possible damping) the maximum response values in the displacements terms [d(t)] max and draw the corresponding graphics, called responses spectra travel. Similarly, we can draw the maximum responses in the velocity terms [v(t)] max and the acceleration [a(t)]max.
The displacement response spectra [11] :

$$S_d = [d(t)]_{max} = \frac{S_v}{\omega} = D_{max} \quad (10)$$

The velocity response spectra [12]:

$$S_v = [v(t)]_{max} = \omega S_d \quad (11)$$

The acceleration response spectra [11]:

$$S_a = [a(t)]_{max} = -\omega^2 d(t) = \omega S_v = \omega^2 S_d \quad (12)$$

4. STRUCTURE ANALYSIS UNDER A SEISMIC ACTION (MOROCCAN SEISMIC CONSTRUCTION REGULATIONS (RPS) 2000 REVISED IN 2011)

Following the Seismic construction regulations (RPS) 2000 revised in 2011, the earthquake evaluation on a structure is carried out using the following parameters:

- The maximum soil acceleration Amax obtained from the seismic zoning (article 5.2.2 of the RPS2000) is : Amax (Z0) = 0.04 g; Amax (Z1) = 0.07 g; Amax (Z2) = 0.10g; Amax (Z3) = 0.14g; Amax (Z4) = 0.18g, with an occurrence probability of 10% in 50 years [13];
- The maximum soil velocity Vmax obtained from the seismic zoning (article 5.2.2 of the RPS2000) is: Vmax(Z0) = 0,05m/s; Vmax(Z1) = 0,07m/s; Vmax(Z2) = 0,10m/s; Vmax(Z3) = 0,13m/s; Vmax(Z4) = 0,17m/s, with an occurrence probability of 10% in 50 years [13];
- A response spectrum in terms of acceleration for the horizontal motion relative to a type of site normalized to the unit acceleration;
- A response spectrum of vertical motion (2/3 of the horizontal spectrum).

The elastic response spectrum or computational spectrum is defined in the RPS2000 revised in 2011 for a spectrum is defined in the RPS2000 revised in 2011 for a and metal frames with heavy external walls and partitions) by: A (T) = (Amax / g) D (T) [13] where g is the acceleration of gravity and D (T) the dynamic amplification factor (art.5.2.3.3 of the RPS2011 [14]). It represents the amplification of the accelerations in the structure compared to that of the ground.

Other parameters are involved in the elastic response spectrum to take account of the site effect (S, art.5.2.3.2 of the RPS2011 [13]), the importance coefficient (I, article 3.1.2 of the RPS2011 [13]) and the coefficient (I, article 312 of the RPS2011 [13]) and the RPS2011 [13]). The inelastic response spectrum is obtained by applying an acceleration reduction factor called the behaviour factor or ductility coefficient (K, Art.3.3.4 of the RPS2011 [13]) as A (T) = (Amax / g) D (T) / K [13].

5. CASE STUDY

5.1 Earthquake Data

A strong earthquake occurred on February 24th, 2004, which affected the coast of Al Hoceima. It had a moment magnitude of 6.3 on the Richter scale (value recorded by seismogenic source 4 (Rif Oriental - Al Hoceima - Alboran) of the OuedRhiss site [3].

5.2 Base Data of the Studied Structures

We have studied 4 structures of the same type but with different stories (Ground floor + 4 stories, Ground floor + 6 stories, Ground floor + 8 stories and Ground floor + 10 stories) via a seismic analysis following RPS

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2000 v.2011, as well as Spectral analysis by applying the response spectra of the Rhiss Earthquake.

We have conducted both analyses using the Robot Structural Analysis software, which uses finite element method [14].

6. RESULTS AND DISCUSSIONS

6.1 Acceleration

The acceleration response is acquired through seismic inputs of the Rhiss earthquake. Figure-1 represents the acceleration of the Rhiss earthquake as a function of temps.

Maximum acceleration is 0,367g at 2,996s while minimum acceleration is 0,2826g at 3,444s.

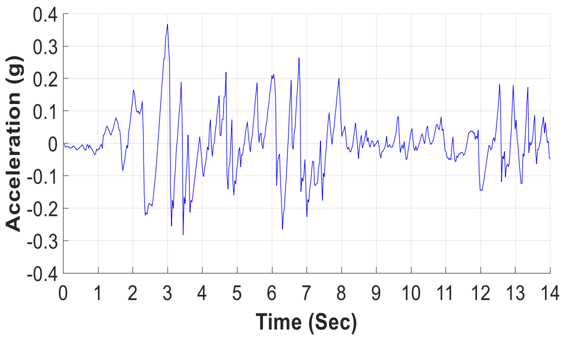

Figure-1. Evolution of acceleration according to time.

6.2 Response Spectra of the Rhiss Station

We used the Matlab routine developed by M. AHATRI [4,5,6] to obtain response spectra from the chronological recording of the Rhiss earthquake.

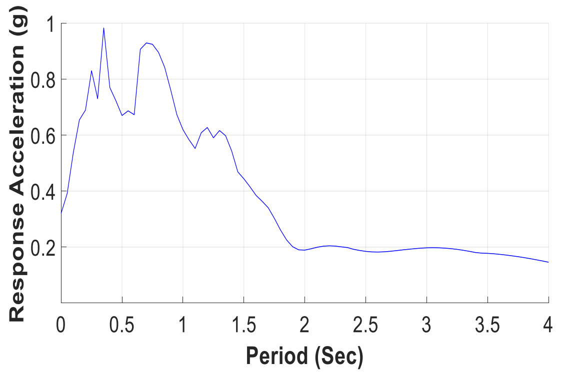

Figure-2. Acceleration Response Spectrum (Sa).

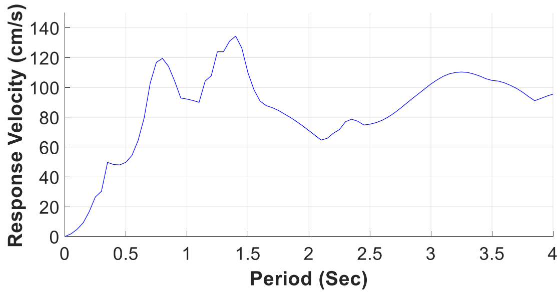

Figure-3. Velocity Response Spectrum (Sv).

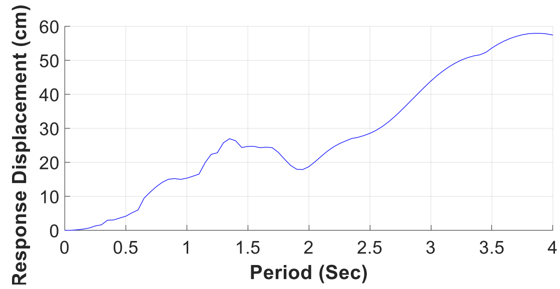

Figure-4. Displacement response spectrum (Sd).

Figures 2,3 and 4 show the response spectra at a damping of 5%.

The spectrum extracted directly from the accelerogram presents a series of irregular peaks.

The displacement spectra increase as a function of period. The tendency of velocity and acceleration spectra varies, with a decrease as a function of period.

In the engineering field, Infrastructure designers are more interested in structures with a response in the frequency range between 1 and 10Hz [4, 5, 6]. The elevated amplification factors of the soil movement at this frequency range have a paramount influence in seismic events [15].

Response spectra for differential movement can be acquired for any time interval as a function of derivative equations (equations: (10), (11) and (12)) [16].

6.3 Response Spectrum Influence on Structures of Different Story Heights Submitted to the Rhiss Earthquake

To analyse the influence of seismic characteristics on structures of different story heights, we have studied the structual stability using the spectral method [17, 18, 19]. We have conducted a comparison between spectral analysis for structure of different story heights in Alhoceima, submitted to the Rhiss earthquake, and the seismic analysis following the Moroccan seismic regulation RPS 2000 (v. 2011).

We have obtained the deflections, stresses, reactions and displacements of the structures with the help of the Robot Structural Analysis software.

The Tables (1-5) show that the displacements and solicitations of a structure grow with the number of stories following both analyses.

After comparing the results of both analyses, we note that the seismic analysis has a more security-based

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approach than spectral analysis. Thus, the coefficients as they appear in RPS 2000 v. 2011 must be revised to ease regulatory requirements.

Table-1. Deflection values following both types of analysis.

Structure	Analysis	Value	Uz[cm]
GF+4	Seismic (RPS 2011)	Max	0.4
		Min	-0.4
	Spectral (RHISS)	Max	0.1
		Min	-0.2
GF+6	Seismic (RPS 2011)	Max	0,6
		Min	-0,6
	Spectral (RHISS)	Max	0.1
		Min	-0.3
GF+8	Seismic (RPS 2011)	Max	0,9
		Min	-0,9
	Spectral (RHISS)	Max	0.2
		Min	-0.3
GF+10	Seismic (RPS 2011)	Max	1,1
		Min	-1,1
	Spectral (RHISS)	Max	0.3
		Min	-0.3

Table-2. Inter-story global displacements following both types of analysis.

Structure	Analysis	Value	Fx	Fy	Fz	Mx	My	Mz
GF+4	Seismic (RPS 2011)	Max	1768,22	29,8	110,83	15,53	44,48	36,08
		Min	-794,47	-26,3	-97,59	-15,33	-120,32	-33,66
	Spectral (RHISS)	Max	1768,22	20,04	110,83	15,53	38,53	36,08
		Min	-262,61	-21,29	-97,59	-15,33	-120,32	-32,12
GF+6	Seismic (RPS 2011)	Max	2257,14	33,57	124,92	16,43	65,28	47,24
		Min	-1001,8	-24,86	-110,35	-16,4	-156,56	-45,44
	Spectral (RHISS)	Max	2266,05	43,22	121,31	17,68	44,14	40,68
		Min	-417,35	-24,05	-106,7	-17,9	-144,47	-37,17
GF+8	Seismic (RPS 2011)	Max	2735,75	58,47	133,21	18,99	84,08	70,63
		Min	-1282,01	-43,89	-112,68	-19,22	-192,94	-67,66
	Spectral (RHISS)	Max	2738,67	51,74	136	18,74	49	45,16
		Min	-496,94	-26,74	-117,07	-19,31	-179,25	-45,91
GF+10	Seismic (RPS 2011)	Max	3238,75	69,08	148,25	23,38	94	90,43
		Min	-1419,38	-48,1	-121,48	-20,57	-229,16	-87,61
	Spectral (RHISS)	Max	3239,93	62,35	151,59	21,96	74,16	58,47
		Min	-594,12	-29,28	-125,87	-21,28	-214,81	-60,23

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Table-3. Stresses following both types of analysis (F[kN], M[kN.m]).

Structure	Analysis	Ux [cm]	Uy [cm]
GF+4	Seismic (RPS 2011)	0.7	0.6
	Spectral (RHISS)	0.1	0.1
GF+6	Seismic (RPS 2011)	1.0	1.0
	Spectral (RHISS)	0.2	0.3
GF+8	Seismic (RPS 2011)	1.4	1.6
	Spectral (RHISS)	0.4	0.4
GF+10	Seismic (RPS 2011)	1.9	1.9
	Spectral (RHISS)	0.5	0.6

Table-4. Global displacements following both types of analysis (U[cm], R[Rad]).

Structure	Analysis	Value	Ux	Uy	Uz	Rx	Ry	Rz
GF+4	Seismic (RPS 2011)	Max	3,5	3,5	0,7	0,003	0,003	0,001
		Min	-0,3	-3,4	-1,1	-0,003	-0,003	-0,001
	Spectral (RHISS)	Max	0,6	0,6	0,1	0,002	0,003	0
		Min	-0,3	-0,7	-1,1	-0,003	-0,003	0
GF+6	Seismic (RPS 2011)	Max	6,8	7,2	1,1	0,004	0,004	0,002
		Min	-0,8	-7,1	-1,7	-0,004	-0,004	-0,002
	Spectral (RHISS)	Max	1,4	1,6	0,2	0,003	0,004	0
		Min	-0,7	-1,7	-1,7	-0,004	-0,004	0
GF+8	Seismic (RPS 2011)	Max	12,9	14	1,6	0,006	0,006	0,003
		Min	-1,5	-14,1	-2,4	-0,006	-0,005	-0,003
	Spectral (RHISS)	Max	2,7	2,9	0,3	0,003	0,005	0,001
		Min	-1,3	-3,3	-2,4	-0,005	-0,005	-0,001
GF+10	Seismic (RPS 2011)	Max	19,4	21,3	2	0,007	0,007	0,005
		Min	-2,2	-21,5	-3,2	-0,007	-0,006	-0,005
	Spectral (RHISS)	Max	4,6	5	0,5	0,004	0,006	0,001
		Min	-2,1	-5,5	-3,2	-0,006	-0,005	-0,001

Table-5. Reactions following both types of analysis.

Structure	Analysis	Value	Fx	Fy	Fz	Mx	My	Mz
GF+4	Seismic (RPS 2011)	Max	488,55	526,12	3605,46	217,86	162,36	13,34
		Min	-152,42	-322,06	-2028,17	-128,31	-124,31	-11
	Spectral (RHISS)	Max	177,69	219,99	1768,22	100,22	68,83	4,56
		Min	-129,89	-142,52	-669,76	-59,37	-86,89	-5,59
GF+6	Seismic (RPS 2011)	Max	547,62	674,31	4552,54	277,7	207,73	14,75
		Min	-186,96	-416,49	-2551,22	-161,13	-152,99	-12,41
	Spectral (RHISS)	Max	239,13	313,8	2266,05	149,15	101,34	5,7
		Min	-170,22	-186,01	-1059,03	-78,74	-114,56	-7,47
GF+8	Seismic (RPS 2011)	Max	477,98	551,25	4576,54	219,99	178,41	20,25
		Min	-200,89	-335,46	-2470,61	-117,43	-141,23	-14,92
	Spectral (RHISS)	Max	310,97	376,48	2738,67	184,76	126,31	7,07
		Min	-218,73	-220,19	-1253,95	-102,3	-144,63	-9,62
GF+10	Seismic (RPS 2011)	Max	490,89	607,1	5225,39	250,17	204,85	21,22
		Min	-246,17	-377,94	-2729,8	-131,27	-163,56	-16,41
	Spectral (RHISS)	Max	367,15	443,38	3285,83	221,77	154,32	7,7
		Min	-268,92	-265,67	-1496,06	-126,96	-174,33	-11,79

7. CONCLUSIONS

To consider 5% damping for soil and structures, Robot structural analysis software has been developed. This software is based on the finite element method.

As our case study finds out, there is a difference between the two analyses. The first is Seismic construction ry introducing a response spectrum of a real case, the global as well as inter-story displacements, the deflections and the reaction difference shows that the results of the analysis meet the requirements of the seismic regulation. Despite the presence of seismic codes and regulations, using the spectral method remains a key point in the building stability, especially high buildings, in order to optimise in the seismic analysis.

Furthermore, this study shows the importance of studying and analyzing the response spectra recorded structure by accelerograms and the Seismic construction regulations to have a general idea of the structures behaviour in an earthquake loading. The important strategic structures, e.g. bridges, and long-term administrative buildings, e.g. hospitals, are the structures most expected to undergo these movements. This is the case of structures near the earthquake epicentre.

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