SEISMIC HAZARD ASSESSMENT FOR THREE STATES OF THE MEXICAN PACIFIC COAST (OAXACA, GUERRERO AND MICHOACAN)

H. Juárez-García[1], A.G. Jerónimo-García[2], E. Inca-Cabrera[3] and A. Gómez-Bernal[4]

[1] *Professor, Universidad Autónoma Metropolitana - Azcapotzalco, Mexico City, MEXICO, hjg@correo.azc.uam.mx*
[2] *Graduate student, Posgrado en Ingeniería Estructural – Universidad Autónoma Metropolitana - Azcapotzalco, Mexico City, MEXICO, angrijega@hotmail.com*
[3] *Graduate student, Posgrado en Ingeniería Estructural – Universidad Autónoma Metropolitana - Azcapotzalco, Mexico City, MEXICO, e.inca.cabrera@gmail.com*
[4] *Professor, Universidad Autónoma Metropolitana - Azcapotzalco, Mexico City, MEXICO, agb@correo.azc.uam.mx*

Abstract

Mexico is located in a high seismic activity region, where moderate to large earthquakes have happened in the past that have caused casualties and structural damage. Over the last decades, seismological and earthquake engineering research has been increased in México. Capital cities were the first sites where authorities and researchers developed seismic hazard studies. In this paper we considered the seismic hazard assessment for medium to small cities in three states of the Mexican pacific coast. We also present a method for producing new seismic design parameters (i.e. Uniform Hazard Spectra), using the Sheppard method, [14 and 7]; the method helped developing new seismic design parameters for every city affected by the Mexican Pacific zone, [8], and in this particular case produce new seismic parameters along the three states: Michoacán, Guerrero and Oaxaca.

Keywords: Seismic; Hazard; Mexico; Pacific; Coast

1. Introduction

In this paper we will explain the methodology by detailing the UHS developed for the so-called Ometepec Segment in Guerrero State, and then this methodology was used to developed more than 250 UHS for three states along the Mexican pacific coast.

1. The methodology will be explained using the segment known as Ometepec, in the Guerrero State
(a) Seismic hazard, quantitative estimation of ground shaking hazards at Ometepec segment
(b) UHS interpolation: with the calculated UHS for given coordinates, an interpolation was conducted in order to obtain new seismic parameters. The interpolation of UHS was done using the IDW, the Sheppard method, [14]. The interpolation surface is a weighted measurement between 2 known points, and the weight given to each point. The weight decreases as the interpolation distance increases.
2. Seismic parameters for Michoacán, Guerrero and Oaxaca
(a) Seismic sources (faults and areas)
(b) Attenuation relationships
(c) Database with uniform hazard spectra (UHS) parameters

2. Ometepec segment

In this paper we collected seismic historical information for Guerrero and part of Oaxaca states. We selected 64 seismic events (aftershocks were not considered), we also defined an area between longitudes 97° W and 103° W and latitudes 16° N and 18.5° N; and earthquakes with magnitudes larger than 6.5, the selected area included the municipality of Ometepec, Guerrero (Latitude: 16° 41' 7.57" N; Longitude: 98° 24' 19.14" W).

2.1 Seismic potential for Ometepec

The Ometepec segment should be considered between Río Copala, southwest of Guerrero, and Río Verde, southeast of Guerrero; this constitutes approximately 130 km length for the rupture area, according to [13]. This segment behaves differently than those which produce the great seismic events in Mexico. The difference is that it ruptures with events of about 7.0 to 7.5 magnitudes, with a recurrence interval which averages about 14 years. Reported depths of the events on the Ometepec segment range from 10 to 70 km and focal mechanisms are both normal and thrust, [10].

Seismic activity in southern Mexico, mostly results from subduction zone events along the Mexican Trench, where the Cocos Plate is being consumed under the southernmost parts of the North American Plate. The Ometepec segment lies down in this subduction zone. The mechanism of energy accumulation and release has been associated with large cycles of inter-slab events (Ms $\leq$ 7), [6].

There have been a few shallow earthquake events in the 20th century: 1890 (M=7.2), 1937 (Ms=7.5), 1950 (M=6.8), the doublets with a reverse fault of 1948 (Ms=6.7), 1982 (M=7.0) and 2012, (M=7.4). It is considered that the same subduction segment ruptured during the 1937, 1950, 1982 and 2012 earthquakes, because the epicentres and aftershocks are almost overlapped at the same location, [8 and 10].

In this paper we considered two types of seismic sources capable of producing earthquakes at Ometepec: Faults and Areas. Seismic sources are modeled in a seismic hazard assessment with their geometric and recurrence characteristics.

2.1.1 Seismic sources: Faults

We have considered 3 areas where earthquakes might occur, with radii, Figure 1: 200 (pink circle), 320 (yellow circle) and 500 km (red circle), these areas were selected according to the faults described by [12]. We have also selected and characterized faults by their geometry and by the size of earthquake events that they produce. Figure 1 (Left) shows all the seismic sources (Faults) and the areas described by the radii selected; Ometepec is at the center of those circles (red dot). The fault segments described by [12] that affect the Ometepec subduction segment are: Oaxaca Este (OX-E), Oaxaca Central (OX-CI and OX-CII), Oaxaca Oeste (OX-O), Ometepec (OX-M), Acapulco - San Marcos (AC-SM), Guerrero Central (GC), Petatlán (PE) and Michoacán (MI).

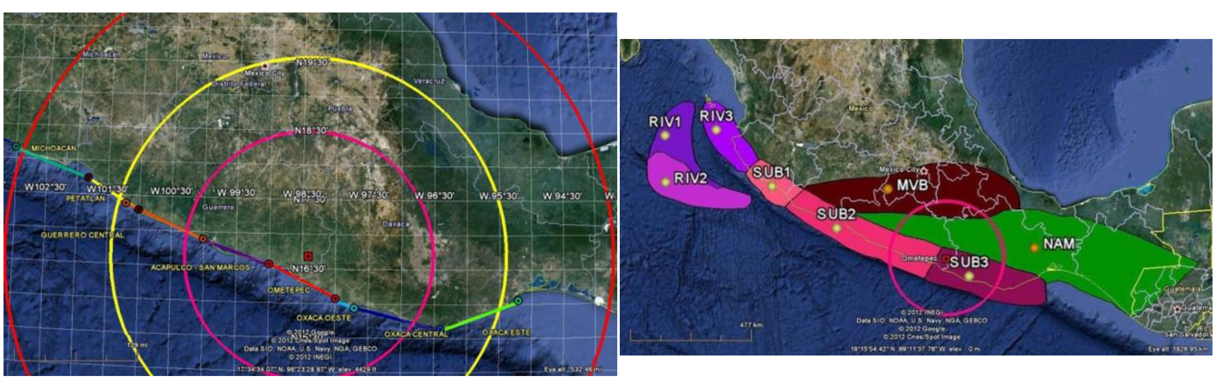

Fig. 1 - Seismic sources for Ometepec: Left, Fault types; Right, Area types.

2.1.2 Seismic sources: Areas

The tectonic settings published by [17] were considered in this paper; the authors defined 19 areas capable of producing earthquakes. The Ometepec segment is being affected by areas SUB2, IN1 and NAM, and it is also less influenced by areas SUB3 and IN2. These seismic areas were also described by [13]. These areas are defined by the type of earthquakes that they produce; Figure 1 (Right) and Figure 2 show the location of the Ometepec municipality (red square) and the seismic sources (areas) by which it is being activated.

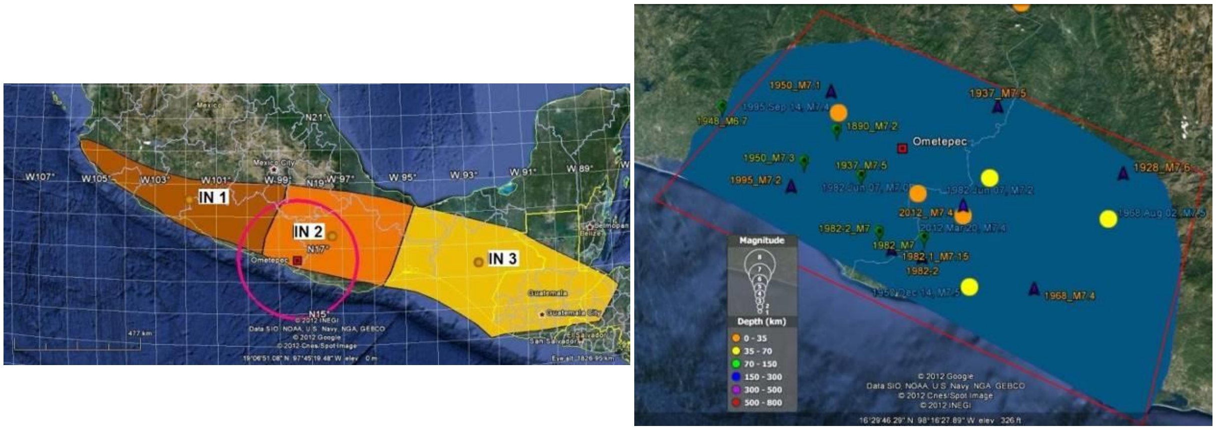

Fig. 2 - Left: Seismic areas affecting Ometepec. Right: Epicenters of earthquakes that have affected Ometepec (M>6.5). Purpure arrows: [13] characterization; green balloons: [6] characterization; and orange circles: epicentres reported by the USGS.

Núñez-Cornú in 1996 [13] defined that the Ometepec municipality is located in Zone 8, this zone also affects Ometepec, Pinotepa Nacional and Jamiltepec, the last 2 cities are located along the Oaxaca coast. In 1787 it is believed that the most violent earthquake took place at the Ometepec segment, the rupture area was estimated as 130 x 80 km. The recurrence interval proposed by [13] averages about 14 years, [6, 10 and 15], with characteristic magnitudes M > 7, [6 and 13]. Figure 2 (Right) shows the Ometepec segment as described by [13].

2.2 Attenuation relationships

We used four Peak Ground Acceleration (PGA) attenuation relationships in this paper, two of them were developed with a global scope, and two of them were developed for the Mexican subduction zone. The attenuation relationships are: [16] - (Y97) and [1] – (AB03) which considered inter-plate and intra-plate seismic sources; [4] – (GA05), that considered intra-plate seismic areas; and [5] – (GOea12), for intra-plate and inter-plate seismic sources.

2.3 Uniform hazard spectra (UHS)

The seismic hazard assessment was performed using the [3 and 11] methodology. 12 models were developed, that were also considered as interpolation points for the Sheppard methodology - Inverse Distance Weight method (IDW), [14]. These models along with the IDW were used to obtain UHS for the Ometepec segment. Firm soil was considered in all of the calculations, with a shear velocity of Vs = 760 m/s, and local site effects were neglected. The first step, was the definition of three areas (described by three circles), in order to estimate the influence of all the seismic sources along the Mexican subduction zone, Figure 1 (Left). Table 1 shows the three models, the radii, and the seismic sources selected.

Table 1 - Parameters used for the seismic hazard in Ometepec, Guerrero

	Red circle	Yellow circle	Pink circle
Model	OM-500 km	OM-320 km	OM- 200 km
Radii	500 km	320 km	200 km
Fault sources	OX-E, AX-CI, OX-CII, OX-O, OM, AC-SM, GC, PE, MI, SUB2, SUB3	OX-E, AX-CI, OX-CII, OX-O, OM, AC-SM, GC	AX-CI, OX-CII, OX-O, OM, AC-SM,
Area sources	IN1A, IN2A, IN1B, IN2B, IN1C, IN1C, NAM	SUB2, SUB3, IN1A, IN2A, IN1B, IN2B, NAM	SUB2, SUB3, IN1A, IN2A, NAM

For the yellow circle (r = 320 km), PGA values were estimated and are shown in Table 2. PGA values for Y97 are 100 % larger than the ones observed for AB03. PGA values obtained for GOea12 show similar values to the ones observed in AB03 for return periods less than 100 years. Figure 3 shows all the UHS for two attenuation relationships, with return periods of 2475, 975, 475, 100, 45 and 20 years for the three circles: 500 km (blue dots), 320 km (black line) and 200 km (red line).

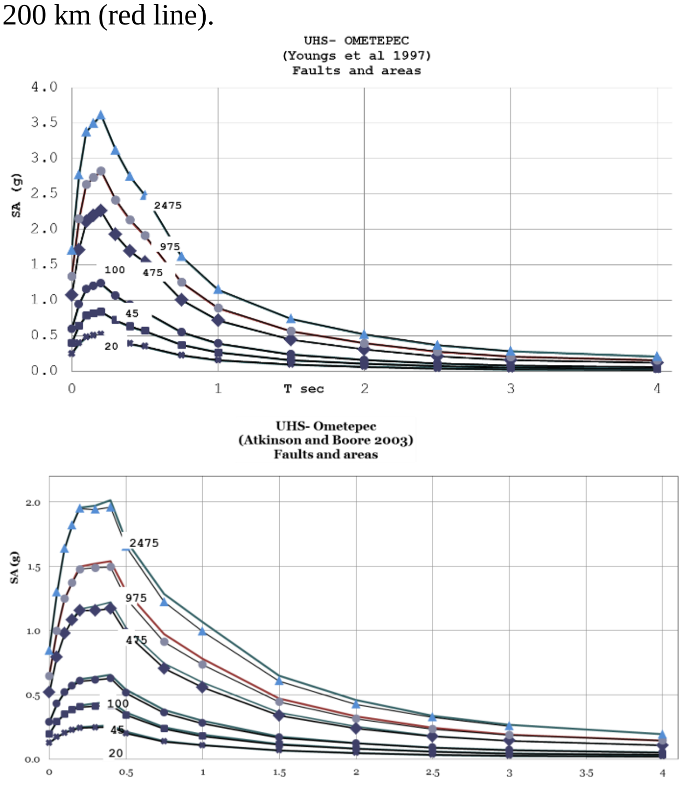

Fig. 3 - UHS for Ometepec.

Table 2 - PGA values using 4 attenuation relationships for Ometepec, Guerrero.

PGA (g)	T=20 yrs	T=45 yrs	T=100 yrs	T=475 yrs	T=975 yrs	T=2475 yrs
[15]	0.25	0.41	0.60	1.08	1.34	1.71
[1]	0.13	0.20	0.29	0.52	0.65	0.84
[4]	0.06	0.10	0.15	0.32	0.41	0.53
[5]	0.16	0.28	0.31	0.33	0.34	0.36

2.3.1 UHS interpolation

An interpolation was performed with the calculated UHS for given coordinates, in order to obtain new seismic parameters. The interpolation of UHS was done using the IDW, the Sheppard method, [14]. The interpolation surface is a weighted measurement between 2 known points, and the weight given to each point. The weight decreases as the interpolation distance, d^p, increases. In this paper p values ranged from 2 to 9.

We used 3 interpolation distances, in order to define the best distance to consider in the interpolation. Interpolation distances: within 15 km (4 interpolation points); 30 km (5 interpolation points) and 70 km (4 interpolation points). The center of all the distances was Ometepec, so that we could use the calculated UHS values for Ometepec and the interpolated UHS values as well. We used the yellow circle (320 km of faults and areas for Ometepec), and attenuation relationships Y97 and AB03. Figure 4 shows for model 1 (15 km) and Y97 the interpolation distances, and the selected points and Ometepec at the center. Top left figure shows the interpolated UHS from 0 to 0.40 sec, with different interpolation p values, top right figure shows the interpolated UHS from 0 to 4 seconds, with different interpolation p values.

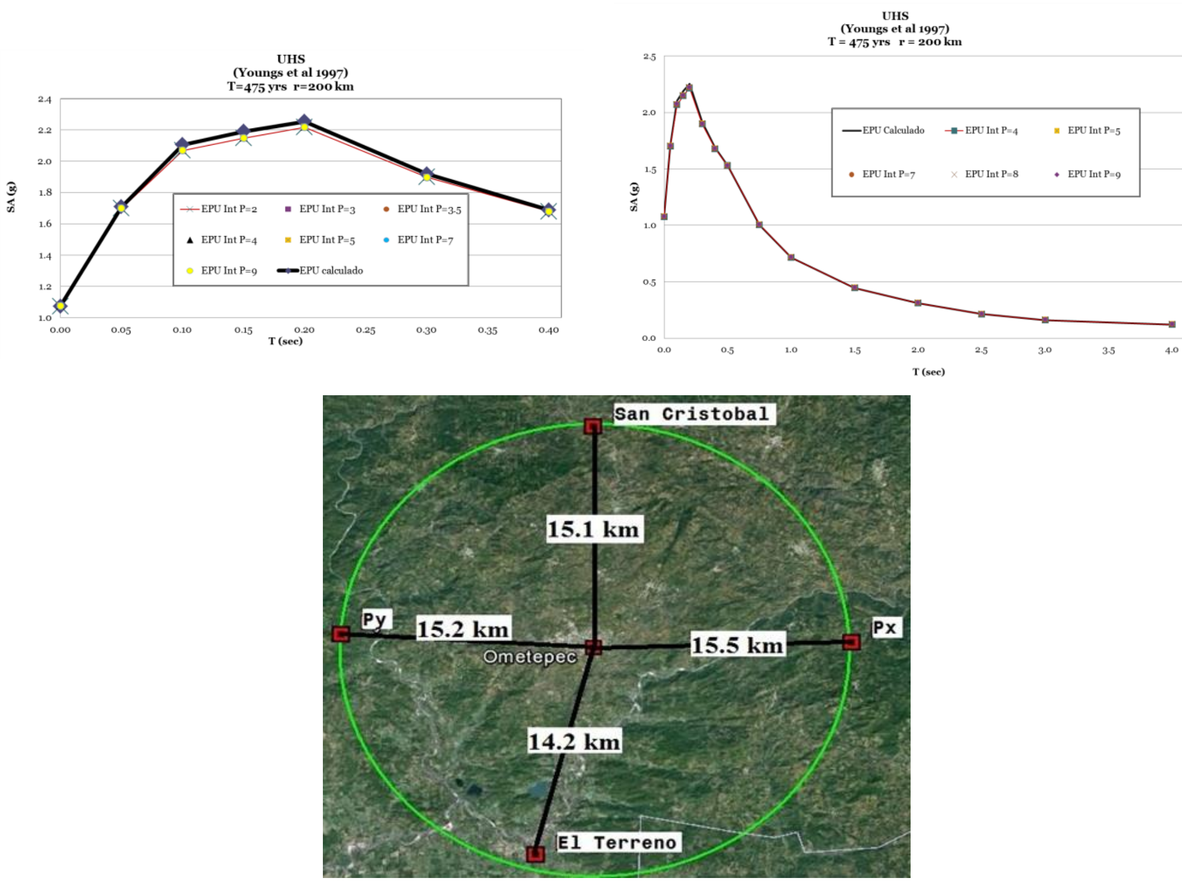

Fig. 4 - Interpolated UHS, model 1 (15 km) and Y97.

For model 1 (within 15 km), and using Y97, the errors were about 3.9 % for p = 9, and 4.13 % for p = 2. Using AB03 the best value was p = 2 with 5 % error for periods 0.3 s and 1.5 s. For model 2 (within 30 km), using Y97 for p values between 2 and 9, the calculated errors were less than 3 %; using AB03, and p values ranging from 5 to 9, the calculated errors were about 1 %. If we increased the interpolation distance, the interpolated UHS would be non-conservative; hence, we decided to use interpolation distances less than 30 km and five or more interpolation points to calculate new UHS.

2.4 UHS values for Ometepec, Guerrero

Table 3 shows the values for UHS for several sites selected at the Ometepec segment in Guerrero, we only show the values associated with the attenuation relationship by [1]. Figure 5 shows calculated UHS for Ometepec, with a return period T = 475 years, and using [16] in comparison with design spectra of the region. This would be the Uniform Hazard Spectra proposed for Ometepec, Guerrero. The ones with return period T = 20 years, T = 45 years and T = 100 years, would be the ones for three levels of seismic performance for buildings in the region. The other 2 UHS for T = 475 years and T = 950 years should be considered for special infrastructure facilities.

Table 3 - UHS for different cities in Guerrero and interpolated values for Ometepec, T = 475 yrs

Period (sec)	0	0.05	0.1	0.15	0.2	0.3	0.4	0.5	0.75	1	2	3	4
OM (r=320km)	0.515	0.792	0.973	1.080	1.155	1.155	1.171	0.977	0.704	0.558	0.237	0.142	0.105
AZ	0.503	0.770	0.946	1.043	1.120	1.115	1.126	0.940	0.676	0.536	0.229	0.137	0.102
JU	0.477	0.731	0.901	0.994	1.066	1.071	1.085	0.908	0.651	0.517	0.221	0.134	0.100
SJC	0.546	0.844	1.050	1.157	1.244	1.257	1.284	1.057	0.758	0.600	0.252	0.148	0.111
XO	0.544	0.840	1.036	1.146	1.224	1.223	1.236	1.032	0.743	0.590	0.249	0.149	0.110
CUA	0.474	0.733	0.904	1.006	1.077	1.095	1.122	0.935	0.669	0.532	0.226	0.136	0.102
Int D<30km	0.510	0.784	0.968	1.070	1.147	1.151	1.169	0.974	0.699	0.555	0.236	0.141	0.105

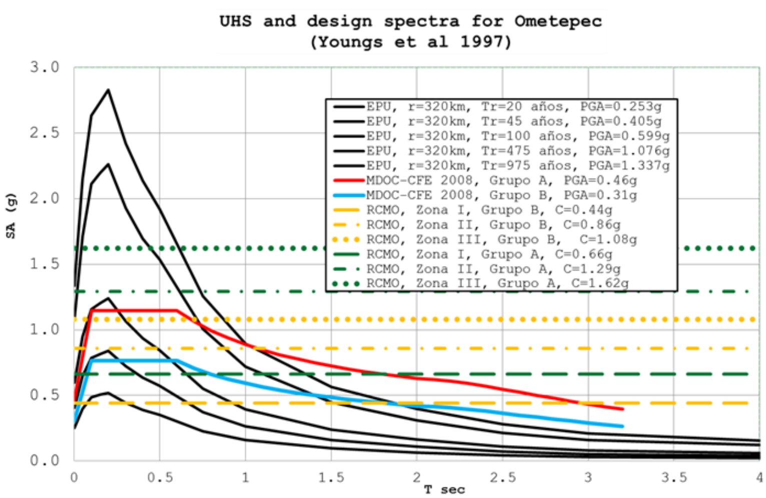

Fig. 5 - UHS for Ometepec in comparison with design spectra

3. Seismic parameters for Michoacán, Guerrero and Oaxaca

We conducted seismic hazard assessment for these three states of the Mexican pacific coast, all the methodology and details from the process presented herein can be found in [9]. Figure 6 shows more than 200 locations where

UHS were calculated for Michoacán, Guerrero and Oaxaca. We used a 30 km mesh to establish all the sites within these three states.

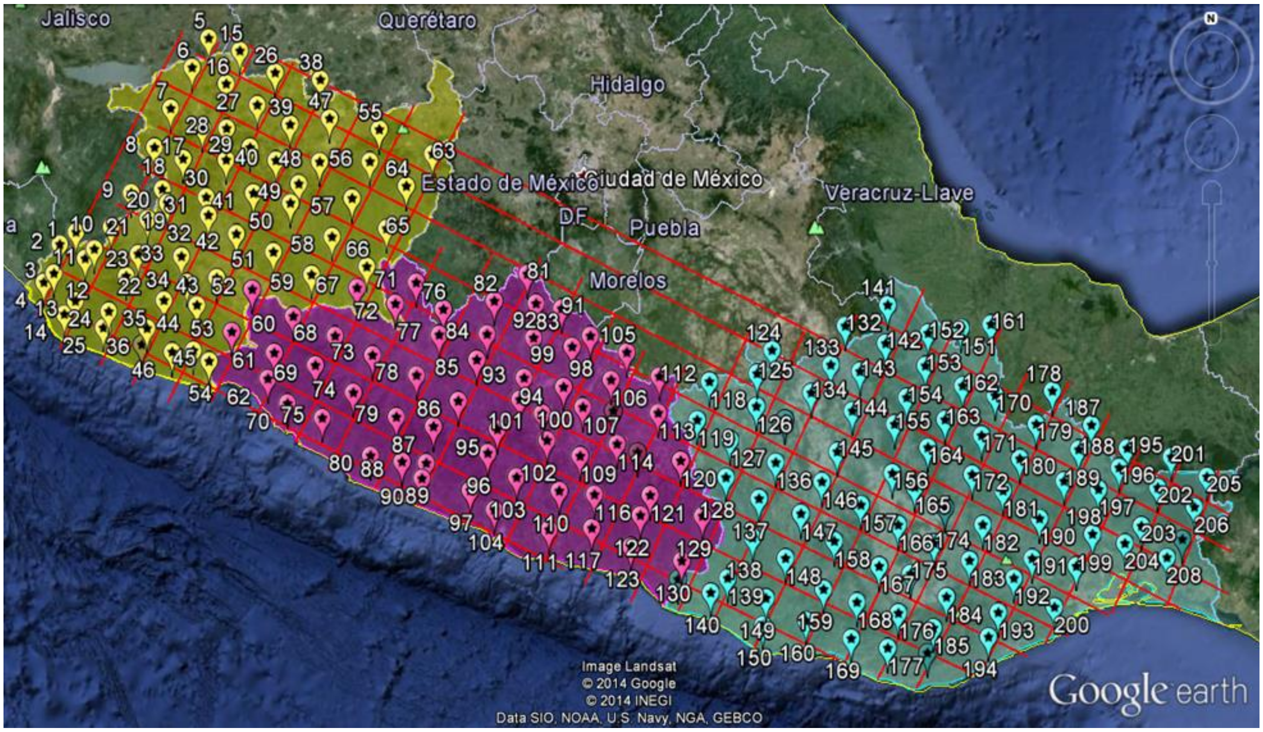

Fig. 6 – sites where UHS were calculated for Michoacán (yellow), Guerrero (fuchsia) and Oaxaca (aqua)

3.1 Seismic sources

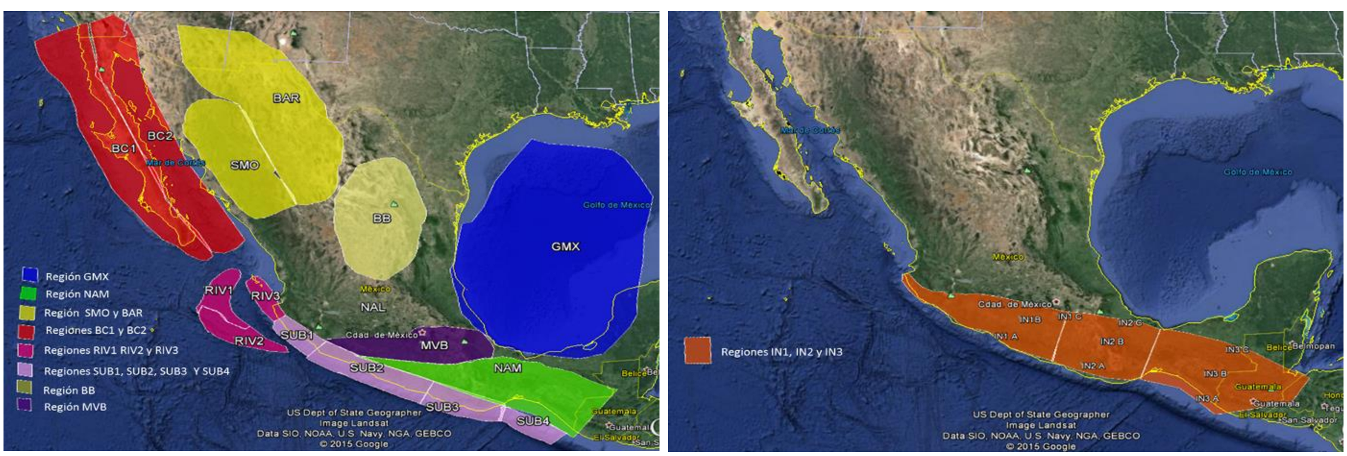

Fig. 7 – Seismic sources for shallow (left) and deep earthquakes (right) for México - Areas

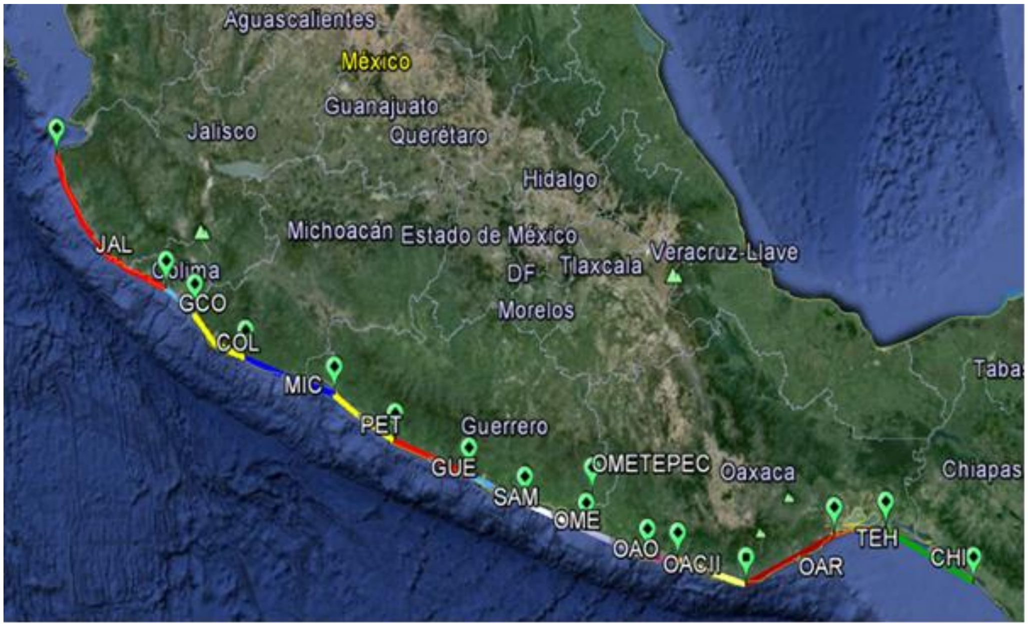

Fig. 8 – Faults considered for México

Figures 7 and 8 show the seismic sources considered in this paper, these sources are described in detail in [12 and 17].

3.2 Recurrence and attenuation relationships

Table 4 – Characteristics of the recurrence relationships for faults considered in this paper

FAULT	Code	Type	Fault	Recurrence	Σ/avg	Mw		
						min	max	avg
JALISCO	JAL	interplate-subduction	Normal	0.0364	0.3245	7.6	8.2	7.9
COLIMA GAP	GCO	interplate-subduction	Normal	0.0325	0.3245	8.3	8.9	8.6
COLIMA I	COL	interplate-subduction	Normal	0.0072	0.3245	7.2	7.8	7.5
MICHOACÁN	MIC	interplate-subduction	Normal	0.0135	0.3245	7.2	7.8	7.5
PETATLÁN	PET	interplate-subduction	Normal	0.0290	0.3245	7.2	7.8	7.5
GUERRERO CENTRAL	GUE	interplate-subduction	Normal	0.0268	0.3245	7.23	7.83	7.53
SAN MARCOS	SAM	interplate-subduction	Normal	0.0177	0.3245	7.2	7.8	7.5
OMETEPEC	OME	interplate-subduction	Normal/ Inverse	0.0575	0.4160	7	7.9	7.45
OAXACA OCCIDENTAL	OAO	interplate-subduction	Normal	0.0294	0.3245	7.4	7.7	7.55
OAXACA CENTRAL II	OACII	interplate-subduction	Normal	0.0380	0.9000	7.4	7.9	7.65
OAXACA CENTRAL I	OAC	interplate-subduction	Normal	0.0190	0.3245	7.2	7.9	7.55
OAXACA ORIENTAL	OAR	interplate-subduction	Normal	0.0393	0.1300	7.2	7.35	7.28
GAP DE TEHUANTEPEC	TEH	interplate-subduction	Normal	0.0426	0.3245	8.35	8.95	8.65
CHIAPAS	CHI	interplate-subduction	Normal	0.0382	0.3245	7.2	7.8	7.5

Table 5 - Characteristics of the recurrence relationships for areas considered in this paper

Code	Type	Depth	Recurrence	β	Mw min	Mw max	Observations
NAL	intraplate	H < 15 km	-	-	-	4.5	
BB	intraplate	H < 15 km	0.0167	2.41	5	5.4	
GMX	intraplate	H < 20 km	0.0343	2.39	5	6.6	
MVB	intraplate	H < 40 km	0.118	2.48	5	7.2	Normal and inverse
NAM	intraplate	H < 20 km	0.3645	3.16	5	7.4	Normal
RIV 2	interplate	H < 15 km	1.3608	2.39	5	7.2	Strike-slip
3	interplate -subduction	H < 20 km	0.0504	2.66	5	7.2	
SUB 1	interplate-subduction	H< 40 km	1.218	2.42	5	7.2	Inverse
2			1.148	2.21	5	7.2	
3			1.152	2.55	5	7.2	
4			1.492	2.76	5	7.2	
IN1 A	intraplate- subduction	40 km < H < 120 km	1.379	2.41	5	7.9	Normal
B			0.5599	2.41	5	7.9	
C			0.1659	2.41	5	5.9	
IN2 A	intraplate- transition of the Cocos plate	40 km < H < 260 km	0.3694	2.02	5	7.9	Normal
B			0.404	2.02	5	7.9	
C			0.3809	2.02	5	7.9	
IN3 A	intraplate- subduction transition	40 km < H < 300 km	1.1033	2.59	5	7.9	Normal
B			1.8914	2.59	5	7.9	
C			2.2592	2.59	5	7.9	

Table 6 – Attenuation relationships

Author	Code	State	Type	Observations	
Atkinson - Boore (2003)	**AB-2003**	Guerrero	subduction, inter and intraplate	Shallow and medium depth	Mw > 5 con H < 100 km, Mw > 7 con H < 300 km
Clemente et al. (2012)	**CL-2012**	Guerrero	Subduction interplate	---	Mw < 6.6, H < 30km
García et al. (2005)	**GA-2005**	Guerrero, Michoacán, Oaxaca	inslab (intraplate)	Intermediate depth for normal fault	5.2 < Mw < 7.4; 35 < H < 138 km
García et al. (2006)	**GA-2006**	Guerrero, Michoacán, Oaxaca	interplate-subduction and inverse fault	---	5 < Mw < 8, 8 < H < 29 km
Gómez et al. (2005)	**GO-2005**	Guerrero, Michoacán, Oaxaca	subduction	Normal faults are neglected	Mw > 4.5, H < 80 km
Gómez et al. (2012)	**GO-2012**	Guerrero, Michoacán, Oaxaca	Inter and intraplate and shallow cortical events	---	Mw > 6
Youngs et al. (1997)	**YO-1997**	Guerrero, Michoacán, Oaxaca	subduction, inter and intraplate	---	---

Table 4 and 5 show the characteristics of the recurrence relationships used in this paper, after [12 and 17]; table 6 shows the characteristics and observations for the attenuation relationships used for the three states in the Mexican pacific zone.

3.3 Seismic parameter database for Michoacán, Guerrero and Oaxaca

Table 7 – Sample characteristics for Michoacán

Code	Site	State	Seismic sources			Attenuation
			AREAS shallow	AREAS Deep	FAULTS	
AG-MI01	Cuchilla	MICHOACÁN	NAL,RIV2, RIV3, SUB1, SUB2, MVB, NAM	IN1-A, IN1-B, IN1-C	JAL, GCO, COL, MIC, PET	GA-2005, GA-2006, GO-2005, GO-2012, YO-1997
AG-MI02	Las Morenas	MICHOACÁN	NAL,RIV2, RIV3, SUB1, SUB2, MVB, NAM	IN1-A, IN1-B, IN1-C	JAL, GCO, COL, MIC, PET	GA-2005, GA-2006, GO-2005, GO-2012, YO-1997
AG-MI03	Aquila	MICHOACÁN	NAL,RIV2, RIV3, SUB1, SUB2, MVB, NAM	IN1-A, IN1-B, IN1-C	JAL, GCO, COL, MIC, PET	GA-2005, GA-2006, GO-2005, GO-2012, YO-1997
AG-MI04	Placita Morelos	MICHOACÁN	NAL,RIV2, RIV3, SUB1, SUB2, MVB, NAM	IN1-A, IN1-B, IN1-C	JAL, GCO, COL, MIC, PET	GA-2005, GA-2006, GO-2005, GO-2012, YO-1997
AG-MI05	Monteleon	MICHOACÁN	NAL,RIV3, BB, SUB1, SUB2, MVB, NAM	IN1-A, IN1-B, IN1-C	JAL, GCO, COL, MIC, PET	GA-2005, GA-2006, GO-2005, GO-2012, YO-1997
AG-MI06	La Sauceda	MICHOACÁN	NAL, RIV2, RIV3, BB, SUB1, SUB2, MVB, NAM	IN1-A, IN1-B, IN1-C	JAL, GCO, COL, MIC, PET	GA-2005, GA-2006, GO-2005, GO-2012, YO-1997
AG-MI07	Guáscuaro de Múgica	MICHOACÁN	NAL,RIV2, RIV3, BB, SUB1, SUB2, MVB, NAM	IN1-A, IN1-B, IN1-C	JAL, GCO, COL, MIC, PET	GA-2005, GA-2006, GO-2005, GO-2012, YO-1997
AG-MI08	La Taberna	MICHOACÁN	NAL, BB, RIV2, RIV3, SUB1, SUB2, MVB, NAM	IN1-A, IN1-B, IN1-C	JAL, GCO, COL, MIC, PET	GA-2005, GA-2006, GO-2005, GO-2012, YO-1997
AG-MI09	Tepalcatepec	MICHOACÁN	NAL,RIV2, RIV3, SUB1, SUB2, MVB, NAM	IN1-A, IN1-B, IN1-C	JAL, GCO, COL, MIC, PET, GUE	GA-2005, GA-2006, GO-2005, GO-2012, YO-1997
AG-MI10	El Resumidero	MICHOACÁN	NAL,RIV2, RIV3, SUB1, SUB2, MVB, NAM	IN1-A, IN1-B, IN1-C	JAL, GCO, COL, MIC, PET, GUE	GA-2005, GA-2006, GO-2005, GO-2012, YO-1997
AG-MI11	Coalcamán de Vázquez Pallares	MICHOACÁN	NAL,RIV2, RIV3, SUB1, SUB2, MVB, NAM	IN1-A, IN1-B, IN1-C	JAL, GCO, COL, MIC, PET, GUE	GA-2005, GA-2006, GO-2005, GO-2012, YO-1997
AG-MI12	Las Joyas	MICHOACÁN	NAL,RIV2, RIV3, SUB1, SUB2, MVB, NAM	IN1-A, IN1-B, IN1-C	JAL, GCO, COL, MIC, PET,GUE	GA-2005, GA-2006, GO-2005, GO-2012, YO-1997
AG-MI13	El Coire	MICHOACÁN	NAL,RIV2, RIV3, SUB1, SUB2, MVB, NAM	IN1-A, IN1-B, IN1-C	JAL, GCO, COL, MIC, PET,GUE	GA-2005, GA-2006, GO-2005, GO-2012, YO-1997
AG-MI14	Colola	MICHOACÁN	NAL,RIV2, RIV3, SUB1, SUB2, MVB, NAM	IN1-A, IN1-B, IN1-C	JAL, GCO, COL, MIC, PET,GUE	GA-2005, GA-2006, GO-2005, GO-2012, YO-1997
AG-MI15	El Palmito	MICHOACÁN	NAL, BB, SUB1, SUB2, MVB, NAM	IN1-A, IN1-B, IN1-C	JAL, GCO, COL, MIC, PET	GA-2005, GA-2006, GO-2005, GO-2012, YO-1997
AG-MI16	Tlazazalca	MICHOACÁN	NAL, BB, SUB1, SUB2, MVB, NAM	IN1-A, IN1-B, IN1-C	JAL,GCO, COL, MIC,PET	GA-2005, GA-2006, GO-2005, GO-2012, YO-1997
AG-MI17	Charapan	MICHOACÁN	NAL, BB, SUB1, SUB2, MVB, NAM	IN1-A, IN1-B, IN1-C	JAL, GCO, COL,MIC,PET, GUE	GA-2005, GA-2006, GO-2005, GO-2012, YO-1997
AG-MI18	Apo	MICHOACÁN	NAL, RIV2, RIV3, SUB1, SUB2, MVB, NAM	IN1-A, IN1-B, IN1-C	JAL, GCO, COL, MIC,PET, GUE	GA-2005, GA-2006, GO-2005, GO-2012, YO-1997

Table 7 shows a sample of the database for 18 points within Michoacán state, some other parameters are not shown in this paper but details can be found on [9]. Table 8 shows a sample for site AG-MI01 within Michoacán, for a T = 20 years and 5 attenuation relationships.

Table 8 – Sample database for Sa

CLAVE	Att. Rel.	UHS T= 20 years									
		0	**0.05**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.75**	**1**	**1.5**
AG-MI01	GA-2005	0.0975	0.1722	0.2376	0.1367	0.0702	0.0471	0.0389	0.0261	0.0164	0.0084
	GO-2005	0.2993	0.2993	0.2993	0.2993	0.2993	0.2993	0.2993	0.2993	0.2993	0.2993
	GO-2012	0.1725	0.1725	0.1725	0.1725	0.1725	0.1725	0.1725	0.1725	0.1725	0.1725
	YO-1997	0.2154	0.4063	0.4952	0.5346	0.4612	0.4058	0.3691	0.2419	0.1690	0.1043
	GA-2006	0.2273	0.3907	0.4955	0.4774	0.4380	0.3778	0.3337	0.2665	0.1925	0.1245

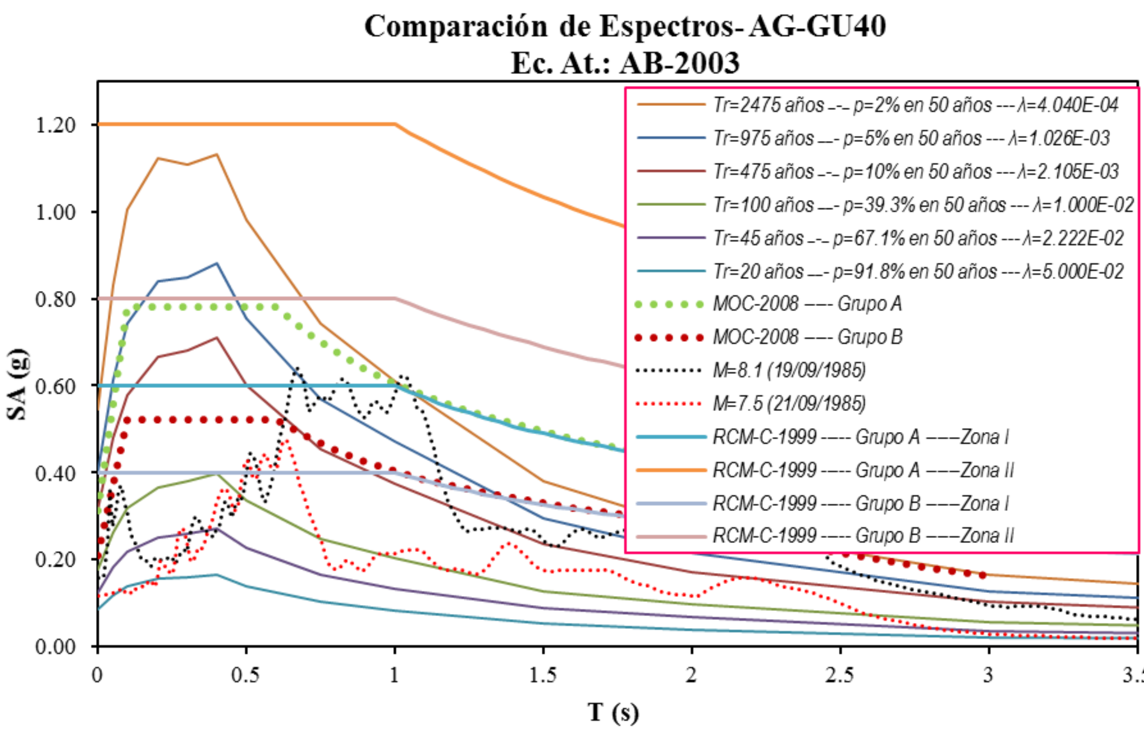

Fig. 9 – Comparison with calculated UHS for [1] attenuation relationship, design spectra obtained in PRODISIS, design spectra obtained with RCM-C-1999, and response spectra for 19th and 21st September 1985 earthquakes

Figure 9 shows the results for site AG-GU40 for Chilpancingo, Guerrero, we only show a comparison within UHS calculated using AB-2003 attenuation relationship, two seismic codes and two response spectra. We observed that these results can be considered as an accurate UHS for Chilpancingo, Guerrero.

4. Conclusions

208 sites were studied for Michoacán, Guerrero and Oaxaca, all the UHS obtained were compared with actual seismic codes. The database can be used to obtain new seismic parameters. All the sites were obtained for firm soil; all the seismic sources shall be updated so that the DB can be reliable.

5. References

[1] Atkinson, G. M. and Boore, D. M. (2003). Empirical ground-motion relations for subduction-zone earthquakes and their application to Cascadia and other regions, *Bulletin of the Seismological Society of America*, Vol. 93, No. 4, pp 1703-1729.

[2] CFE, (2008). Manual de Diseño de Obras Civiles de la Comisión Federal de Electricidad. Diseño por Sismo, *Instituto de Investigaciones Eléctricas de la CFE*.

[3] Cornell, C. A., (1968). Engineering seismic risk analysis. *Bulletin of the Seismological Society of America*, vol. 58(5), pp 1583–1606.

[4] García, D., Singh, S.K., Herráiz, M., Ordaz, M. and Pacheco, J.F. (2005). Inslab earthquakes of Central Mexico: peak ground-motion parameters and response spectra, *Bull. Seism. Soc. Am.*, 95, 2272-2282.

[5] Gómez-Bernal, A., Lecea, M.A. and Juárez-García, H. (2012). Empirical attenuation relationship for Arias Intensity in Mexico and their relation with the damage potential, *XV WCEE*, Lisboa, Portugal, 2012.

[6] González-Ruíz, J.R. and McNally, K.C. (1988). Stress Accumulation and Release since 1882 in Ometepec, Guerrero, Mexico: Implications for Failure Mechanisms and Risk Assessments of a Seismic Gap, *Journal of Gerophysical Research*, Vol 93, no B6, pp. 6297-6317.

[7] Halchuk, S. and Adams, J. (2008). Fourth generation seismic hazard maps of Canada: Maps and grid values to be used with the 2005 National Building Code of Canada, *Geological Survey of Canada Open File 5813*; p. 32

[8] Inca-Cabrera, E. (2013). Estudio de peligro sísmico para la ciudad de Ometepec y otras ciudades aledañas al estado de Guerrero. Master thesis. Posgrado en Ingeniería Estructural, División de Ciencias Básicas e Ingeniería, Universidad Autónoma Metropolitana – Azcapotzalco.

[9] Jerónimo-García, A. G. (2016). Parámetros de diseño sísmico para algunos estados del Pacífico Mexicano (Michoacán, Guerrero y Oaxaca). Master thesis. Posgrado en Ingeniería Estructural, División de Ciencias Básicas e Ingeniería, Universidad Autónoma Metropolitana – Azcapotzalco, (in process, in spanish)

[10] Juárez-García, H., Gómez-Bernal, A., Rangel Núñez, J.L., Tena Colunga, A., Pelcastre Pérez, E and Roldán Islas, J.N. (2012). Learning From Earthquakes. The March 20, 2012, Ometepec, Mexico, Earthquake. Earthquake Engineering Research Institue, *EERI Special Earthquake Report* - May 2012. http://www.eeri.org/wp-content/uploads/Ometepec-2012-eq-report.pdf

[11] McGuire, R. K. (2004), Seismic Hazard and Risk Analysis, Earthquake Engineering Research Institute, Oakland.

[12] Nishenko, S.P. and S.K. Singh (1987). Conditional probabilities for the recurrence of large and great interpolate earthquakes along the Mexican subduction zone, *Bull. of the Seismological Society of America*, Vol. 77, pp. 2094-2114.

[13] Nuñez- Cornú, F. J. (1996). A double seismic front and earthquake cycles along the coast of Oaxaca, Mexico, *Seismological Research Letters*, Vol. 67, n6 pp. 33-39.

[14] Sheppard, D. (1968). A two-dimensional interpolation function for irregularly-spaced data, *ACM National Conference*, pp. 517-24.

[15] Sordo, E., Gómez-Bernal, A., Juárez-García, H., Gama, A., Guinto, E.R., Whitney, R. A., Vera, R., Mendoza, E. and Alonso, G. (1995). The September 14, 1995 Ometepec, Mexico, earthquake, learning from earthquakes, *EERI special earthquake report*, Diciembre.

[16] Youngs, R.R., Chiou, S.J., Silva, W.J. and Humphrey, J.R. (1997). Strong ground motion attenuation relationships for subduction zone earthquakes. *Seismological Research Letters*, vol. 68 (1), pp 58-73.

[17] Zúñiga, R., Suárez G., Ordaz M. y García-Acosta V. (1997), Peligro Sísmico en Latinoamérica y el Caribe, *Capítulo 2: México. Reporte Final, IPGH*.