16th World Conference on Earthquake, 16WCEE 2017

Santiago Chile, January 9th to 13th 2017

Paper N° 4876

Registration Code: S-M1464630308

STUDY OF DYNAMIC BEHAVIOR FOR SOIL IN UNIVERSITY CITY PUEBLA, PUE. MEXICO

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Abstract

As information necessary for the seismic design of structures in University City (UC) of the Autonomous University of Puebla (BUAP), a study in its first stage was to determine the dynamic characteristics of soil. Thus contributing more to safer designs of all buildings in UC. At this stage only the ambient vibration recorded with sensors broadband speed CMG Guralp 40T connected to K2 Kinematrics equipment, processed using the technique of spectral ratios H/V. In this second stage, again it uses the technique of spectral ratios H/V, but this time acelerometric data processing records from a seismic station for period's dominant soil, also new ambient noise register with Guralp equipment installed in a temporary network arrangements. The network consists of 16 triaxial accelerometers Guralp broadband 6TD CMG-time synchronized recorded ambient vibration simultaneously, and then the information processed by SPAC method to determine the shear wave velocity. As result of analysis of data obtained in two stages and supported by testing direct geotechnical exploration, a correlation with which the dynamic properties of soils verified in order to perform mappings that can used to estimate spectra obtained site, same that will used for the construction of future buildings with more efficient seismic designs.

1. Introduction

Mexico is subject to constant and dangerous influence of large earthquakes, this because their costs are in the Circum-Pacific belt, where most of the seismic activity originates in the world. The subduction of the Cocos Plate beneath the North American plate is the main seismogenic source in the country. Historically, earthquakes have plagued the country. As an example we have the Michoacán earthquake in September 1985, which caused the loss of over 20,000 lives (National Seismological Service, 2011); or the Colima earthquake in October 1995 caused considerable damage in about 17,000 structures, as well as killing at least 50 people (Juárez, 1995).

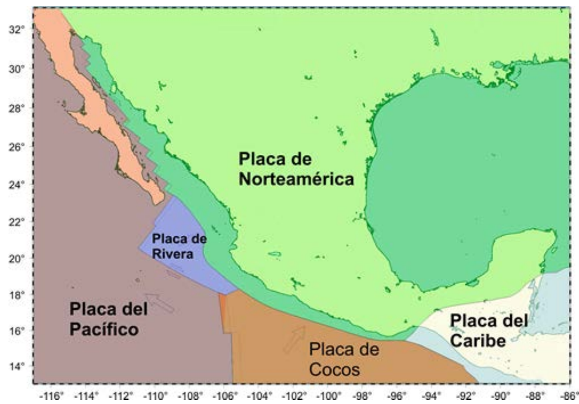

Fig. 1. Tectonic plates in the region of Mexico (Figure taken from: National Seismological Service)

In this context, the state of Puebla is located in a region of medium activity and relatively close to one of greater activity, specifically, the subduction zone of southeastern Mexico, its proximity to the Pacific coast and the regional geological setting, make significant both subduction earthquakes and intraplate perceive intensities.

The growth observed in recent years with tall buildings in the city of conurbation, is necessary to update the existing construction regulations. It expected that major structural projects have specific studies that guarantee a significant level of security. However, existing buildings would require a review considering the new information obtained about the earthquake in Puebla.

In University City (UC), in recent years it has seen an increase in its infrastructure. Currently UC is the area with the highest concentration of property, there 82 buildings of which 30 built from the foundation of UC and at least 15 have less than 5 years of built. This shows a great variety in construction periods and therefore in the techniques employed.

For all the above, this work has as main purpose to provide information that contributes to safer designs simian. The information shown here will contribute to the new structural designs of their buildings and as a starting point for reviewing existing ones.

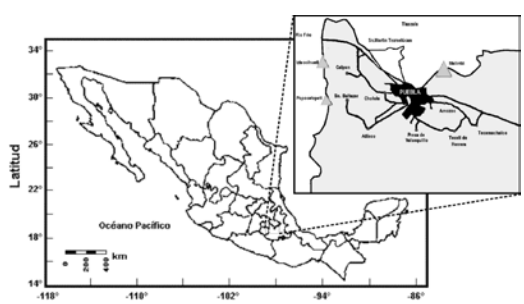

Fig. 2. Location of the state of Puebla (taken from Martinez, 2011)

2. Background

For UC no work done for the purposes of seismic design (design spectra), there are some specific buildings such as the recent stadium "Lobos BUAP" 2011. Due to the size and concentration of people from the building, made necessary a specific study to its seismic design so that their safety guaranteed. Unfortunately, as mentioned studies are not available and therefore we could not include them in this work.

This paper is the second part of a larger study to determine seismic risk in UC. As mentioned above, no information is available so it is necessary to start from gathering basic information.

The first stage involved the characterization of soil type, observing their dynamic behavior. To do this environmental noise, which subsequently processed by the technique of spectral ratios H/V (Nakamura, 1989) was recorded; a campaign of environmental noise measurements using the technique of spectral ratios H/V, within the area of UC was performed. The obtained data were processed to obtain the transfer functions and if the dominant periods to obtain soil at different points.

With respect to geotechnics, according to studies and geological zoning proposal by Auvinet (1976) City University is located in the tuff, whose geotechnical characteristics are generally good with the exception of areas of low compactness and expansive materials. Azomoza (1998) subsequently defined its location in the area of expansive clays, whose description corresponds largely to the formation of tuffaceous soil partially and fully covered by a high plasticity clay, product-lacustrine deposits alluvium palustres. This plastic clay sometimes been explored recent alluvial deposits or under tuffaceous, with thickness no greater than 1.50 to 2 m and occasionally in specific areas, up to 4 m.

It also has soil mechanics studies recently conducted the CU, which for this stage provide information that contributes to a comparison of the results by obtaining empirically dynamic properties.

The information in the first stage and the results of this work will aim to create a spectrum of room for all University City, to provide more optimal parameters structural design to earthquakes.

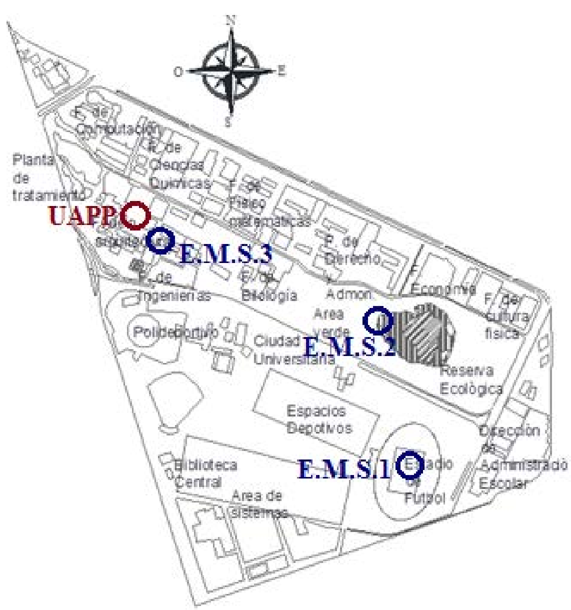

Fig. 3. Location map of the three soil mechanics studies and seismic station in University City, Puebla.

3. Methodology

For this study, used information obtained from the seismological station Autonomous University of Puebla (UAPP) located in Ciudad Universitaria, within the faculty of engineering for soil fundamental periods. Seismic data station shown in table one

Table 1. Facts station accelerograph Autonomous University of Puebla.

STATION ACCELEROGRAPH (UAPP)						
			COORDENADAS			
NAME	CODE	LOCATION	LAT. N	LONG. W	ALTITUDE (msnm)	SOIL TYPE
AUTONOMOUS UNIVERSITY OF PUEBLA	UAPP	BUAP. CITY UNIVERSITY (CU) NEXT TO SPORTS WITHIN THE FACULTY OF ENGINEERING. ACCESS BY AV. SAN CLAUDIO AND RIO PAPAGAYO. SOUTHEAST AREA, PUEBLA	19.002	98.202	2176	SILTY SAND.

From this station accelerograms of 17 earthquakes (Table 2) recorded from 1998 to 2004, these seismic records signals with Degtra software (Ordaz and Montoya, 2007) are processed; in order to obtain the spectral ratio H/V they are used

Table 2. Seismic events recorded with accelerograph UAPP station (II-UNAM) at the Autonomous University of Puebla.

DATA EARTHQUAKES							
				MAGNITUDE	COORDINATE		
No.	CODE	DATE OF EARTHQUAKE (GMT)	EPICENTER TIME (GMT)	M	LAT. N	LONG. W	FOCAL DEPTH (km)
1	UAPP9510.211	Oct. 21, 1995	02:38:59 a. m.	6.50	16.92	93.62	98
2	UAPP9510.301	Oct. 30, 1995	02:47:56 p. m.	5.30	16.35	98.51	27
3	UAPP9602.251	Feb. 25, 1996	03:08:17 a. m.	6.70	16.13	98.27	8
4	UAPP9602.252	Feb. 25, 1996	02:27:29 p. m.	5.20	15.79	98.28	5
5	UAPP9602.253	Feb. 25, 1996	03:02:31 p. m.	4.50	16.08	97.68	33
6	UAPP9603.271	Mar. 27, 1996	12:34:48 p. m.	5.40	16.24	98.25	10
7	UAPP9607.151	Jul. 15, 1996	09:23:39 p. m.	6.50	17.48	101.14	16
8	UAPP9701.211	Jan. 21, 1997	09:19:58 p. m.	5.60	16.24	98.29	5
9	UAPP9704.031	Apr. 03, 1997	09:22:32 p. m.	4.70	17.98	98.38	49
10	UAPP9705.221	May. 22, 1997	07:50:55 a. m.	5.90	18.43	101.79	61
11	UAPP9707.191	Jul. 19, 1997	02:22:08 p. m.	6.30	16.00	98.23	9
12	UAPP9712.161	Dec. 16, 1997	11:48:32 a. m.	5.90	15.86	99.16	10
13	UAPP9802.031	Feb. 03, 1998	03:02:01 a. m.	6.40	15.39	96.37	33
14	UAPP9806.071	Jun. 07, 1998	11:20:16 p. m.	6.20	15.82	94.07	16
15	UAPP9906.151	Jun. 15, 1999	08:42:07 p. m.	7.00	18.18	97.51	69
16	UAPP9909.301	Sep. 30, 1999	04:31:15 p. m.	7.60	15.95	97.03	16
17	UAPP0401.011	Jan. 01, 2004	11:31:50 p. m.	6.30	17.39	101.37	10

The hypocenter data taken from the National Seismological Service of Mexico.

Considering factors such as distance from the epicenter, intensity of the earthquake and possible interference due to adjacent structures to the seismic station, for processing signals only records that clearly show the pre-event and post-event earthquake taken into account, discarding the lack of good resolution. Because of this, of the 17 records obtained by the station, only records UAPP9510.211, UAPP9607.151, UAPP9909.301 and UAPP0401.011 show an adequate signal for reliable spectra.

3.1 Shear wave velocities

Obtaining the wave velocity it performed by environmental vibration with a spatial arrangement of 15 sensors installed Guralp CMG 6TD arrangements of a temporary network using the SPAC method, to have a simultaneous accelerometric arrangement. The instrumental arrangement arranged in a triangular fashion, distributed so that the space lattice forms a grid in which to obtain sub arrays of different sizes, in Figure 4 the arrangement of the spatial distribution of the sensors are shown within the area CU

Fig. 4. Distribution of accelerometers in University City.

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The instrumental arrangement is defined according to the geometry described above, in Figure 5 the spatial arrangement is shown in which the formed grid, which in turn within it to form small triangular arrangements enrolled in triangles larger are observed. In addition to the triangular arrangements, you can observe a hexagonal arrangement of the center of the grid.

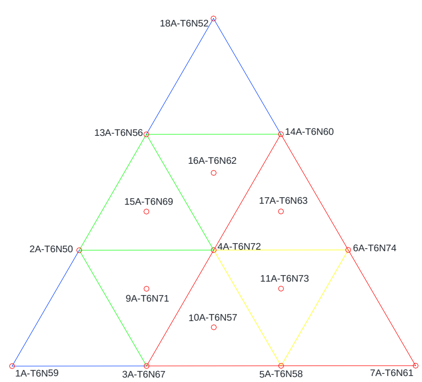

Fig. 5. Instrumental arrangement of sensors 16 arranged in a triangular fashion.

The lengths of the triangular arrangements are approximately 40 m per side for small triangles, 80 m per side for medium and 120 m per side for the larger triangle.

Subsequently the correlation coefficients and phase velocity from the Bessel function of first kind and zero order (dispersion curves), to finally obtain shear wave velocities.

4. Signal processing

Already selected records using the software Degtra (Ordaz and Montoya, 2007), the H/V spectral ratios are calculated.

For this four windows located in the intense part of the earthquake (the second time series depends on the quality of the signal) in each vertical component (V) and vertical N-S (N00E), E-O (N90E) extracted. It seeks to avoid, where possible, riots, so that time series remain statistically stationary within each window

A spectral ratio of each horizontal component separately in each of the windows obtained, and then geometric averaging performed to obtain a characteristic spectrum in each of the components. The two spectra obtained from each log accelerometric represent the effect site in each direction.

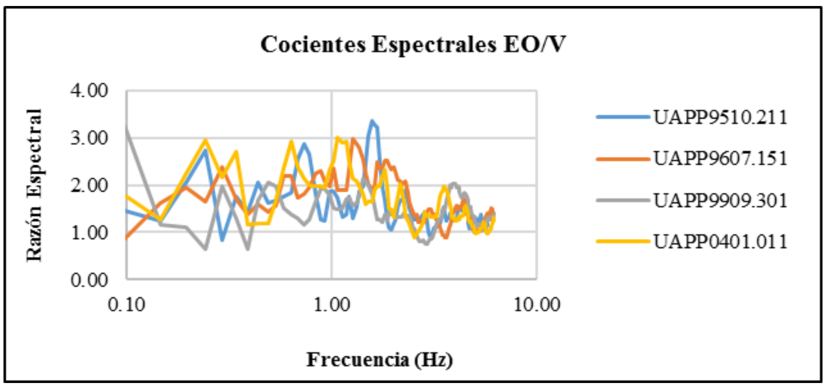

Fig. 6. NS/V spectral ratios for four earthquakes in the UAPP station

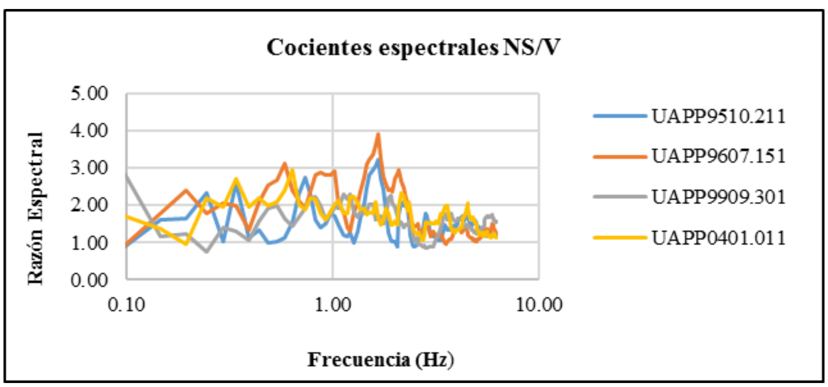

Fig. 7. EO/V spectral ratios for four earthquakes in the UAPP station

Subsequently the maximum frequency of each earthquake in each direction (Table 3) identify and obtain the inverse of the dominant frequency, natural soil period (To) is obtained in the given interval of time in each direction.

Table 3. Period's accelerometers records obtained from the seismic station in CU UAPP

N-S		
Earthquake	**Frequency (Hz)**	**Ts (seg)**
1	1.76	0.57
7	1.76	0.57
16	1.29	0.78
17	1.22	0.81

E-O		
Earthquake	**Frequency (Hz)**	**Ts (seg)**
1	1.65	0.61
7	1.34	0.75
16	1.55	0.65
17	1.12	0.89

In Figures 6 and 7 the characteristic spectral ratios four earthquakes accelerograms obtained by the seismic station, because the remaining 13 did not present a noticeably uniform relationship observed. Therefore, only the four registers seen in Figures 5 and 6 analyzed.

Finally, to observe the common maximum dominant frequency corresponding to the average of the ratios of the four earthquakes (Fig. 8 and 9) plotted. The frequency in this case turns out to be average 1.66 Hz in the direction N-S and 1.61 Hz in the E-O direction. Therefore, dominant period in each direction is 0.60 and 0.62 seconds respectively.

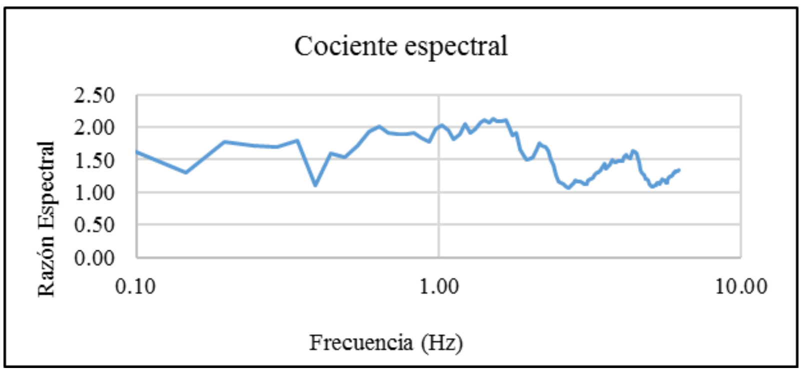

Fig. 8. NS/V spectral ratio representative for four earthquakes in the seismic station UAPP

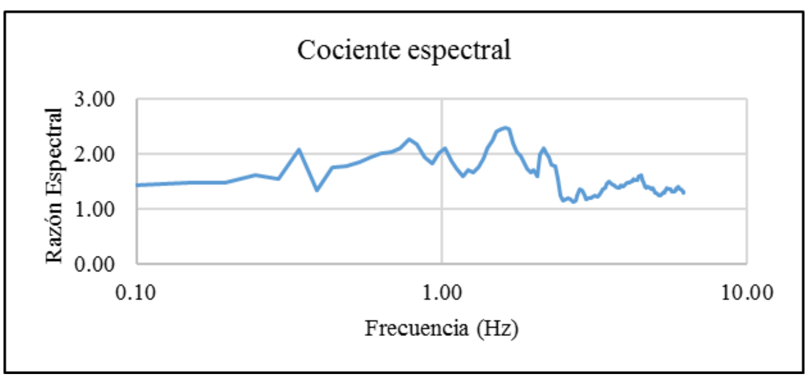

Fig. 9. EO/V spectral ratio representative for four earthquakes in the seismic station UAPP

To obtain shear wave velocities, as triangles larger give low frequencies and long wavelength, for geotechnical purposes only hexagonal array is analyzed as with triangles smaller high frequencies give short wavelength, can obtain the wave velocity of the surface layers. In addition, when choosing this arrangement the point of attribution is supposed to center the entire grid assuming a model stratified.

Readout time ambient noise was approximately 20 hours, the analysis of data performed with software Geopsy in windows 30 minutes with 500 samples to construct the dispersion curve (Fig. 10)

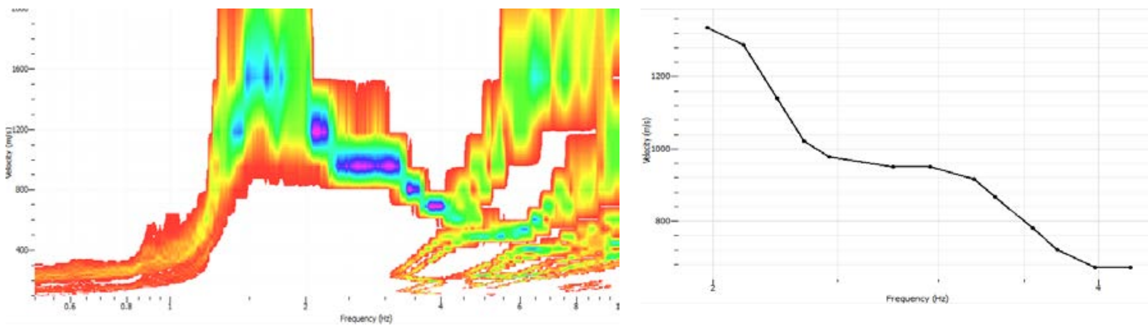

Fig. 10. Dispersion curve obtained from the hexagonal arrangement.

Subsequently supported by studies of soil mechanics four layers are assumed, 3 defined and semi space, with which shear wave velocities which is shown in Figure 11. The shear wave velocities model obtained constructed shown in Table 4.

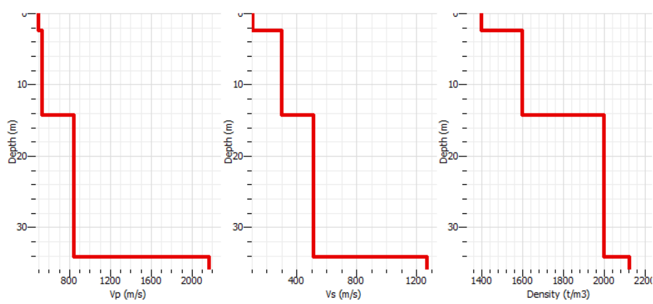

Fig. 11. Shear wave velocities with four layers assumptions.

Table 4. Model shear wave velocities (SPAC 1D model)

Thickness H (m)	**Density ρ (Tn/m3)**	**Vp (m/s)**	**Vs (m/s)**
3	1.4	490.76	105.92
15	1.6	526.28	294.27
30	1.9	846.03	506.92
Semi space	2.1	2160.43	1272.46

5. Correlation with geotechnical information

By soil mechanics, studies can determine the dominant period of the soil, using the one-dimensional theory of wave propagation in viscoelastic media cutting laminates.

In the area of interest are three studies of soil mechanics, stratigraphy composed of topsoil and organic matter of 60 cm thick surface defined, and to a depth of 15 m is a formation of soft soils, constituted by an intercalation of sandy clays, silts and loamy sand.

The estimate of the dominant periods of the soil can be determined by an expression that relates the thickness of the layers with its dominant period of vibration and the speed of propagation of shear waves using geotechnical properties (Newmark and Rosenbleuth, 1976) which defined by:

$$T_n = 4\sum_{i}^{i} \frac{D_i}{(V_S)i} \quad (1)$$

Where:

D = Stratum thickness i

Vs = Speed shear waves in the stratum i

The shear wave velocity expressed by:

$$V_S = \sqrt{\frac{G'}{\rho}} \quad (2)$$

Where:

G'= Shear modulus

P = Volumetric weight of the material

The shear modulus G '. It is empirically determined using the equation "Hardin and Black", for granular materials and > 0.6 and normally consolidated clay of low activity using the expression:

$$G' = \frac{3230(2.97 - e)^2}{1 + e}\sqrt{S_0} \quad (3)$$

Where:

So = Principal stress $kpa = (S_1 + S_2 + S_3)/3$

S1 = $p * g * z$

S2 = S3 = K0 S1

g= Acceleration of gravity = 9.81 m/s2

K0 = $1 - sen\ \phi$

ϕ = Internal friction angle

e = Void ratio

z = Depth stratum

ρ = Volumetric Weight

Finally, the values of the geotechnical properties of soil mechanics studies arrived at the following results:

GEOTECHNICAL PROPERTIES - STADIUM AREA CITY UNIVERSITY (E.M.S.1)						
DESCRIPTIONN	**STRATUM**	**z (m)**	**VOID RATIO (e)**	**INTERNAL FRICTION ANGLE (φ)**	**VOLUMETRIC WEIGHT ρ (Tn/m3)**	**ρ*g (Tn/m3)**
Topsoil	1	0.00 - 0.60	1.50	0	1.17	11.4777
Loamy Sand	2	0.60 - 10.0	0.89	30	1.17	11.4777
GEOTECHNICAL PROPERTIES - AREA CONCHA ACOUSTICS (E.M.S.2)						
Topsoil	1	0.00 - 0.60	1.50	0	1.75	17.1675
Sandy Loam	2	0.60 - 12.0	0.80	37	1.75	17.1675
GEOTECHNICAL PROPERTIES - NEW BUILDING IN AREA SCHOOL OF ENGINEERING (S.I.M.S.3)						
Topsoil	1	0.00 - 0.60	1.50	0	1.60	15.72543
Silty Clay with Sand	2	0.60 - 15.0	0.90	26	1.60	15.72543

UNIVERSITY CITY STADIUM AREA									
Stratum	**Ko**	**S1 (Tn/m3)**	**S2=S3 (Tn/m3)**	**S0 (Tn/m3)**	**e'**	**G' (Tn/m2)**	**Vs (m/s)**	**z (m)**	**T (seg)**
1	1.00	6.887	6.887	6.887	3230	7326.56	79.133	0.60	0.030
2	0.50	114.777	57.389	86.083	3230	68907.62	242.684	10.00	0.165
								To =	**0.195**
AREA CONCHA ACOUSTICS									
1	1	10.301	10.301	10.301	3230	8960.38	71.556	0.60	0.034
2	0.40	206.010	82.030	144.020	3230	101405.37	240.720	12.00	0.199
								To =	**0.233**
NEW BUILDING IN AREA SCHOOL OF ENGINEERING									
1	1	9.435	9.435	9.435	3230	8575.79	73.143	0.60	0.033
2	0.56	235.881	132.478	184.180	3230	98857.68	248.335	15.00	0.242
								To =	**0.274**
								Tn (seg) =	**0.70**

Obviously the layers shown in each study soil mechanics cannot explain the observed periods, since for the velocity model shown in the study areas is about 200 m/s, the thickness of the second layer should be about 30 m depth. Unfortunately, there is not more geotechnical information layers underlying the second layer, because exploration in each study only done at a depth-programmed project.

6. Conclusions

Analysis of seismic records by the technique of spectral ratios H / V allows for an acceptable identification of the dominant periods, the dominant peak based interpreted in the ellipticity of Rayleigh waves around the fundamental frequency of the soil in which must be a contrast in materials impedances. The difference in the values obtained by H/V and those obtained with the geotechnical correlation varies very little. The information on despite having openings 40 in accordance SPAC can be seen that the speeds range from 100 m/s and 500 m/s in the surface layers, which shows that the sediments in these layers are quite competent and they correspond to the type of material described in studies of soil mechanics

Considering not have a lot of geotechnical information and unfortunately could not be used all the records because the signal quality thereof, the information obtained is valuable for describing the type of soil and the information they shed on his dynamic behavior as they represent a characteristic of the movement to be considered to understand the seismic hazard and the level of risk you have in the area.

The results will be supplemented at a later stage, where is obtained a 3D model with more information of the surface layers to observe in detail the information of the dynamic behavior of soils CU and determine the vulnerability of typical structures in the presence earthquakes. The set of information will future design spectra to estimate in-situ and mapping of seismic risk.

7. Acknowledgements

Universidad Popular Autónoma del Estado de Puebla (Hugo Ferrer) funded this study. UNAM Institute of Engineering (Leonardo Alcantara and Jorge Aguirre González) provided seismic data. The Directorate of Educational Infrastructure Autonomous University of Puebla (BUAP) provided Geotechnical information. Provided Guralp accelerograph equipment for this research II UNAM (Jorge Aguirre Gonzales)

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