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Land characterizing for seismic design in the urban zone of Veracruz-Boca del Río, México (ZCV)

Javier Lermo. Felicita Limaymanta (1), Francisco Williams Linera. Guadalupe Riquer Trujillo. Regino Leyva (2)

(1) Instituto de Ingeniería, Universidad Nacional Autónoma de México, Cd. Universitaria, Coyoacan, 04510, México, D. F., México. jles@pumas.iingen.unam.mx
(2) Instituto de Ingeniería, Facultad de Ingeniería Civil de la Universidad Veracruzana, Av. S.S. Juan Palo II, s/n, 94294, Boca del Río, Ver., México. franciscowilliamslinera@yahoo.com.mx

Abstract

This work intends a method for land characterization on seismic design purposes starting from the evaluation of the site effect using the spectral forms obtained from microtremors registrations, geologic, geotechnical and geophysical information. In this proposal the predominant period of the land is the main parameter and it is related with the depth of the land. Before presenting our proposal, we characterize the land using the national norms, as well as The International Building Code of USA IBC -2000. The obtained results with IBC are more detailed than the national norms, but complications exist to apply it, which we will mention in this work. When IBC-2000 was applied, were found two land types (C, D), with the national norms just a single type (type III), while when applying our proposal we found three types of lands (C, D and E).

Key-words: Microzoning, Microtremors, Site effect, Spectral Forms, land characterization.

Introduction

The land characterization with seismic design ends emerges from the necessity to take into account the site effects in the design of structures and to be part of the regulations and design manuals. The manual of the Comisión Federal de Electricidad design from 1993 (CFE) and the proposal of the Normas Técnicas Complementarias (NTC) from the construction regulation of Veracruz state of 1998, assist the site effects adopting a land classification (three types of lands) depending the dominant period and the cut wave speed on the ground. Other regulations as The International Building Code of USA, IBC-2000 and Eurocode 8 - 2004 classify the land in five types using the parameter VS30, defined as the cut wave speed in the first 30 m.

According to the seismic zoning letter of the República Mexicana, the ZCV is in an area of moderate seismic risk, but it must to take on consideration the devastating effects happened in the last earthquakes, as well as the economic and population growth which would be affected with similar events, if the site effect is not take into account.

With these antecedents, our objective is to propose a methodology for the land characterization related or in function of the site effect, which classifies land into a more detailed way than the current classifications, present in the norms, manuals and national regulations.

The site effect was evaluated with registrations of microtremors and earthquakes, with geologic, geotechnical and geophysical data. After this evaluation the land was characterized using the national norms and the IBC-200 in order to compare the results and to study the advantages and disadvantages of these classification systems.

The Methods

Geologic, geotechnical and geophysical information

The geologic and geotechnical information on ZCV (Zona Conurbada Veracruz) was taken from the works of Esquivel et al. (1976) and Paéz Andrade (2001). These works divide the city in five geologic formations: Sandstorm-conglomerate deposit T(ar-cg), Coral deposit (Qc), Beach deposit (Qp), Dunes deposit (Qd) and Alluvial deposit (Qal). Information of 24 geotechnical studies was also gathered, with a total of 40 exploration test drilling with altered sampling combined with standard penetration tests (SPT), in these tests drilling the resistance was evaluated the sharp resist by the number of hits in SPT, as well as the founded ground classification. This geologic and geotechnical information is shown in figure 1. With the founded tests drilling they proposed stratigraphic cuts whose location is shown in figure 1.

The cut waves speeds (SH) of the deposits were measured using seismic refraction, seven seismic prospecting were made. Environmental vibration was measured evenly in 187 points divide up in the whole ZCV (approximately a registration for square kilometer). The located of these measuring can observe in the Figure 2.

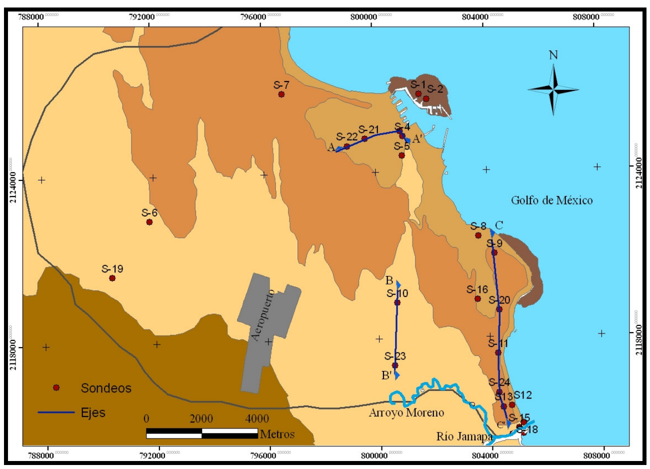
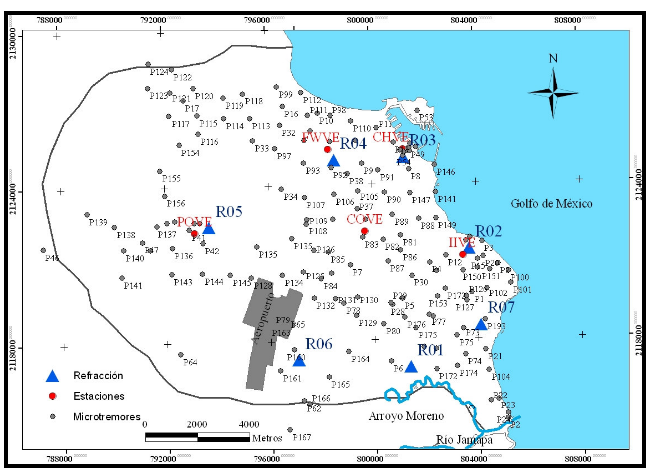


Figure 1.Geologic map. Geotechnical tests drilling and stratigraphic cuts location.



Figures 2. Location of microtremors points, seismic refraction and acelerographic stations location.

Calculation of the Function of Empiric Transfer (FTE)

The microtremors registrations were analyzed with the technique of Nakamura (HVNR) for to get FTE.

On the other hand, Williams et al. (2003) obtained spectral quotients of some areas of ZCV with records of local and regional earthquakes of to acelerographic net temporal (the temporary acelerographic net belongs of the city of Veracruz). The methods that they used to obtain these quotients were: the method standard (SSR) and that of Nakamura (HVSR) for some cases. In this work they took the results obtained by these investigators in order to know the real amplification of the lands. To obtain the theoretical transfer functions the method standard it was used how references station the POVE station. The distribution of the acelerographic net temporal is show up in the figure 2.

Obtaining of spectral families according to the spectral forms of FTE and microzoning.

FTE was grouped according to the geologic deposit to which belonged, but it was found that not all the measuring points had the same spectral form (the same dynamic behavior). That is because they were regrouped without keeping in mind the geologic classification and were found different spectral families. As a result of this grouping were obtained four areas, which show up in the Figure 3.

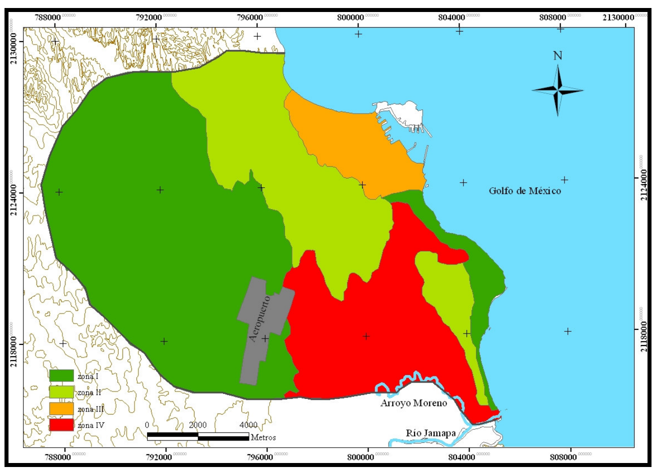


Figure 3. Dynamic Microzoning of the ZCV.

Calculate of the Functions of Transfer Theoretical (FTT) and of the stratigraphic models of each zone.

To calculate FTT was used the Haskell method (1962), which uses the propagation one-dimensional model of waves for a stratified half, to apply this method was considered the case of vertical incidence (γ =0) of waves S polarized horizontally (θ = 0, waves SH).

The encountered zones with the spectral families are related with the geological and geotechnical characteristics to determine a stratigraphic model representative and to calculate the theoretical function transfer (FTT). Next it is described, in descending form of the site effect, each one of the areas defined are in the Figure 4 and shows up the stratigraphic model of each area. FTT shows up together with the spectral families in the Figure 4.

Zone IV

This zone is in the lowest area of alluvial deposits and it is defined by the 10 meters over the sea level of direction east, it is important to point out that this area is inside the flood area in rainy seasons and of formed swamps, at some time, for the left margin of the Jamapa River. With the stratigraphic cut B-B and with other stratigraphic profiles located inside the area or in the limits, it was determined the average resistance from underground.

Table 1. Stratigraphic unidimensional Model of zone IV

Approximate depth (m)	Resistance average	Number of blows (N)
0.0 - 0.30	low	5<N<20
3.00 - 5.00	middle	10<N<30
5.00 - 11.00	low	5<N<20
1100 - 16.00	high	30<N<50

To determine the stratigraphic model was used the thicknesses definite since from the resistances shown in the Table 1. Also was also assumed critical damping of 4% for the layers of low and middle resistance, and 1% for the layer base. Also, the density was considered from the information of the tests drilling geotechnical. The wave speeds SH assigned for this area is an average of the values obtained in the refractions R01 and R02. (see Table 2).

Table 2. Stratigraphic unidimensional Model of zone IV

Nº	H (m)	ρ (t/m3)	β (m/s)	ξ (1)
1	3.0	1.4	144.92	0.04
2	2.0	1.6	357.14	0.04
3	6.0	1.4	147.05	0.04
4	5.0	1.6	380.00	0.04
5	6.0	1.5	200.00	0.04
Base	-	1.9	900.00	0.01

Where: ρ = density of the stratum, β = speed of court wave and. ζ= damping.

In the Figure 4 show up FTT like an encircling curve of FTEP that validates the values of the stratigraphic model. On the other hand, in this area exists FTT (line of orange color in the figure 4) obtained with the analysis of earthquakes (Riquer et to the one. 2003), registered in a acelerographic station temporal (IIVE) located in this area, this transfer function validated with FTT obtained with the stratigraphic model.

Zone III

This zone covers part of the beach deposits and dunes. With the stratigraphic cut A-A it were determinated the characteristics and average resistance of the underground shown in the Table 3.

Table 3. Stratigraphic unidimensional Model of zone III

Approximate depth (m)	Resistance average	Number of blows (N)
0.0 - 4.00	low at middle	5<N<30
4.00 - 7.00	alta	30<N<40
7.00 - 15.50	baja	5<N<10
15.5 - 21.0	alta	30<N<40

The wave speeds SH was obtained from the seismic profile of refraction R03 and R04, the values of damping and densities were assumed under the same conditions described in the zone IV. Therefore, we have the stratigraphic model of the Table 4.

Table 4. Stratigraphic unidimensional Model of zone III

Nº	H (m)	ρ (t/m3)	β (m/s)	ξ (1)
1	4.0	1.4	166.13	0.04
2	3.0	1.6	444.20	0.04
3	8.5	1.4	150.00	0.04
4	6.0	1.7	635.80	0.04
Base	-	1.9	900.00	0.01

In the figure 4 FTT is shown for each component with a thick line of red color. In that same figure is presented FTT using technical SSR (with a line orange) and HVSR with the earthquakes of the station CHVE (with a blue line).

Zone II

This zone covers the most of the deposit of dunes. The underground is formed basically by deposits of fine muddy sand whose resistance average shows up in the table 5.

Table 5. Stratigraphic unidimensional Model of zone II

Approximate depth (m)	Resistance average	Number of blows (N)
0.0 - 3.00	low	5<N<10
3.00 – 4.50	middle	10<N<30
4.50 – 8.0	low	5<N<10
8.0 - 11.0	high	30<N<50

For each of the layers were assumed speeds cut with base to the values found in the analysis of seismic refraction R02 and R04. The values of damping and density were taken under the same considerations of the previous zones. The stratigraphic model shows up in the table 6 and the FTT in the two horizontal components in the figure 4.

Table 6. Stratigraphic unidimensional Model of zone II

Nº	H (m)	ρ (t/m3)	β (m/s)	ξ (1)
1	3.0	1.4	162.3	0.04
2	1.5	1.5	250.0	0.04
3	4.5	1.4	150.0	0.04
4	3.0	1.7	580.0	0.04
Base	-	1.9	900.0	0.01

Zone I

This area covers the most part of the alluvial deposits, part of the beach deposits and dunes. In the table 7 the resistance average of the stratums is shown.

Table 7. Stratigraphic unidimensional Model of zone I

Approximate depth (m)	Resistance average	Number of blows (N)
0.00 - 3.00	baja	5<N<20
3.00 - 5.00	media	10<N<30
5.00 - 9.50	alta	40<N<60

The value of speed of court wave SH was assumed with the data of the seismic profiles R07 and R02, R05 and R06. The values of damping and density were taken under the previous same considerations. The stratigraphic pattern shows up in the table 8.

Table 8. Stratigraphic unidimensional Model of zone I

Nº	H (m)	ρ (t/m3)	β (m/s)	ξ (1)
1	3.00	1.4	195.00	0.04
2	2.00	1.5	355.00	0.04

3	4.50	1.7	150.00	0.04
Base	-	1.9	900.00	0.01

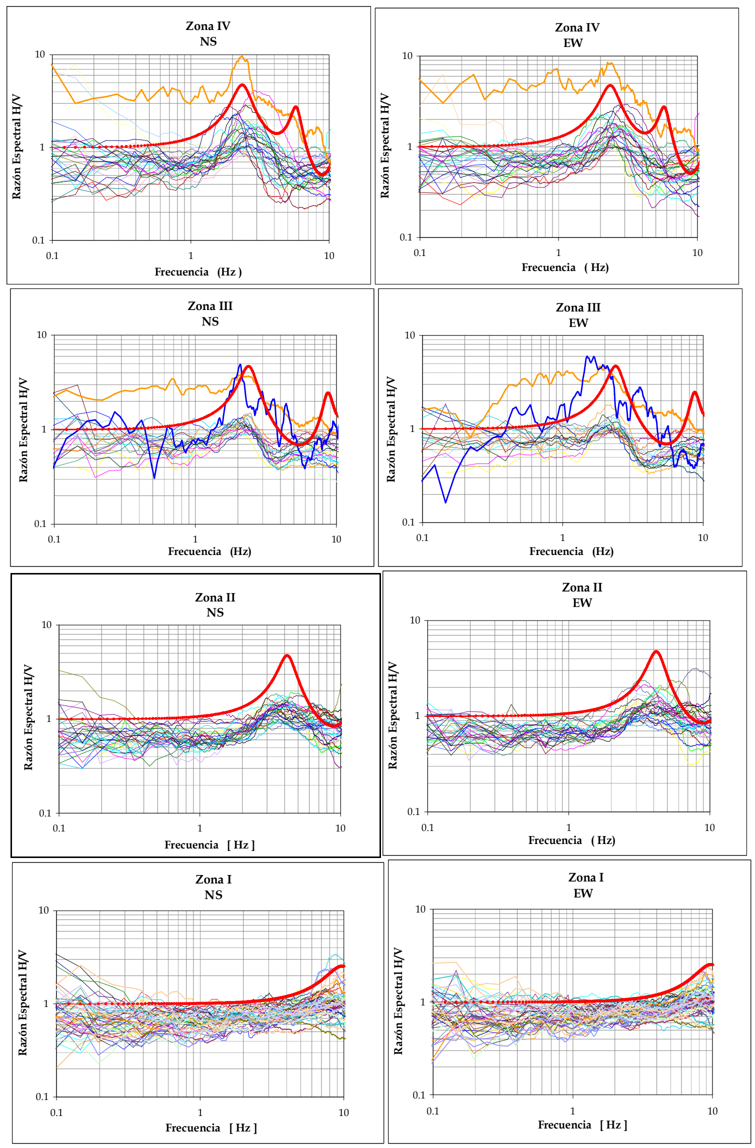


Figure 4. Spectral form found in ZCV. FTT, dotted Lines; FTEP, thick line, FTT like an encircling of FTEP.

Results and Discussion

To characterize the land of each zone it will be used the values of speed of wave from stratigraphic models court, as well as the systems of classification of IBC-2000 and of the national codes.

Characterization with IBC-2000

To classify the land with this system, first it should be calculated the speed of court wave until 30 m of depth. (Dobry R. et. al 2000).

The stratigraphic models of the zones didn't reach 30 m of depth, because was assumed that the last layer extends just until 30 m. The table 9 shown the values of VS30, as well as the classification obtained with this system.

Table 9. VS30 and classification of land using the IBC-2000

Zone	VS30 (m/s)	Type of ground	Description
I	614.766	C	Rock o hard ground
II	376.616	C	Rocks o hard ground
III	281.978	D	Sandy grounds
IV	251.841	D	Sandy grounds

Characterization using the Manual de Diseño de Obras Civiles de la CFE.

The zone ZCV belongs to the seismic zone B of the letter of seismic zonification of La República Mexicana of CFE-1993, the value of the speed of waves of characteristic court is 400 m/s and the dominant period characteristic 5.3 sec. The Table 10 shown up the speeds and periods effectives, as well as the classification of lands of this city.

Table10. Classification using the manual of CFE-1993

Zones	BS (m/s)	TS (s)	Type of ground
I	332.203	0.103	Type III
II	201.151	0.239	Type III
III	221.771	0.388	Type III
IV	199.576	0.441	Type III

Characterization with the proposal of the Normas Técnicas Complementarias (NTC) del Reglamento de Construcción proposed for the state of Veracruz, Mexico.

It is important to point out that this proposal considers enough 30 m of exploration to define the effective speed of propagation or the effective resistance of the land (Proposal of NTC of the state of Veracruz). When applying this norm the results obtained are shown up in the Table11.

Table 11. Classification of lands of ZCV according to the proposal of NTC for earthquakes of the state of Veracruz (bigger constructions at 5 ton/m^2).

Zone	Vs (m/s)	Type de ground	Description
I	332.203	II	Solid ground
II	201.151	II	Solid ground
III	221.771	II	Solid ground
IV	199.576	II	Solid ground

Comparison of the systems of characterization

We find some complications in applying the system of classification of IBC-2000, because is not possible calculate VS30 directly when the stratigraphic model is smaller to 30 m of depth. In spite of these difficulties it was found that the characterization of land obtained with this norm is more detailed, but it was obtained two land types in comparison with the characterizations obtained with the national regulations, like it is shown in the Table 12

Table12. Comparison of the classification systems used

Zones (Spectral Families)	Manual CFE	IBC y VS30	NTC Veracruz
I	III	C	II
II	III	C	II
III	III	D	II
IV	III	D	II

Discussion of Results

The smallest site effect is founded in the zone I, which is located in the other part of the Alluvial deposit, in the vicinity of the industrial area and of the airport where the resistance of the ground is bigger, and in the deposits of beach. Inside this zone is encountered one area whose dynamic response corresponds to the zone II, this would must to the intercalation of fine and granular materials of alluvial origin which have bigger site effect.

The site effect of the zone III are smaller to that of the zone IV, but it is of importance to be the dominant period in the range of 2.0 Hz to 3.0 Hz, also inside this zone there is material of low resistance at 4.0 m of depth, which would be the causing of the site effect. Is important to have present that the amplification of this area is moderate (4 times). The zone II is bigger than zone I, the site effect of this zone is moderate, however it should be kept in mind the two-dimensional effect due to the orientation of the dunes, since the amplification in component NS is smaller than in EW, this would be due to that the dunes is aligned in direction EW and therefore the topographical effect can exist, in this respect, Lermo et. al. 1993 mention that a good relationship exists among the dominate periods predict with models 2D and those obtained with the technique of Nakamura (HVNR). The use of models 1D to calculate FTT are justified for the good agreement that exists among the spectral families in the two horizontal components.

Due to the difficulties encounter when applying IBC and for the importance that has a characterization system detailed, we apply a new proposal of characterization which was obtained on base to studies of site effect in other cities of the República Mexicana (Thesis of Master, Felicita Marlene Limaymanta Mendoza). In this system of characterization the main parameter is the frequency or dominant period, the depth of the land and the effective speed, although this last factor can still have same values when the ranges of frequencies are different, it also assigns the land classes with uppercase letters of the A to F according to the ranges of frequency (of smaller frequency to more frequency), like it is shown in the Table 13.

Table 13.System of classification of lands proposed with ends of seismic design.

F (Hz)	Depth h (m)	Type of ground	Description
>10	-	A	Rock, VS>700 m/s
≤10	>6	B	Exposure rock, 500<Vs<700
≤8.0	<10	C	Rigid ground of superficial depth 350<Vs<500
≤5.0	>10	D	Rigid ground of intermediate depth 180<Vs<350
≤3.0	≥ 20	E	Soft or rigid very deep ground 180< Vs<250
≤1.5	≥ 30	F	Soft grounds Vs<,=180

If we apply this system of characterization of lands to ZCV we have the result of Table 14.

Table 14. Classification of lands proposal for ZCV

ZONE	F (Hz)	Depth h (m)	Type of groun d	Description
I	>8.0Hz	9.5	C	Rigid superficial ground. Vsd=332.203 m/s
II	3.50-4.50	12.0	D	Rigid ground of intermediate depth. Vsd=201.15 m/s
III	2.50-3.00	21.5	E	Soft ground. VSd= 221.77 m/s
IV	1.50- 2.50	22.0	E	Soft ground. Vsd= 250 m/s

When locating this result spacely we obtain the map that is shown in the Figure 5.

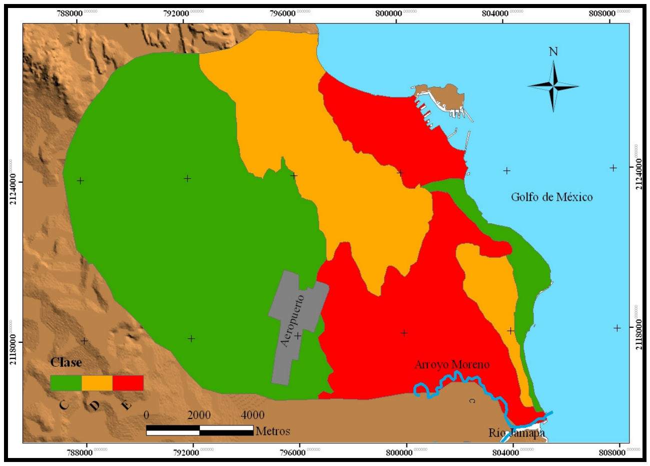


Figure 5. Classification of the lands of foundation of ZCV, with ends of seismic design.

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