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SEISMIC MICROZONING BASED ON EARTHQUAKE RECORDS AMPLIFICATION

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SUMMARY

A model to determine the Seismic Microzoning of Viña del Mar city based on the seismic behavior of the soils is presented. The analysis was performed for the flat areas of Viña del Mar, the seismic response was obtained by applying Quad-4 computer program, and the subsoil properties were obtained from laboratory tests results and geological reports.

The seismic response is expressed in terms of intensity parameters, such as Maximum Acceleration, Arias Intensity, Destructiveness Potential Factor and Spectral Ratio. Isoseismal amplification maps for the most important parameters are also presented; the results are compared to the existing Viña del Mar Microzoning Map performed after the 1985 Chilean earthquake based on the observed damage.

INTRODUCTION

The soil of the flat areas of Viña del Mar city is a result of sedimentary deposits of Marga-Marga river basin. As a consequence, the ground motions recorded on these areas are normally more severe than the earthquake ground motion recorded on the hills of the city where the bedrock is near the ground surface. It is believed that the damage of 1985 Chilean earthquake recorded at these flat areas is a result of local amplification of the ground motion. In this paper the zones identification were obtained from the ground motion acceleration response by the evaluation of the amplification of well known intensity indices.

The amplification analysis requires having an estimation of the Poisson Module, the Shear Module and the Internal Damping of the soil. It is a known feature that the Shear Module of the soil decreases as long as the seismic deformation increases, on the other hand the internal damping increases when the seismic deformation increases. The aforementioned changes of the soil properties are more important for soils having smaller plasticity ratio than for soil having larger plasticity ratios, so the larger is the plasticity ratio the longest is the elastic deformation range.

This paper presents a Microzoning Map for Viña del Mar based on amplification analyses performed by applying one and bi-dimensional models [1, 2]

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AMPLIFICATION ANALYSIS APPROACH

Soil Properties Determination

The properties of the soil as well as the bedrock depth were obtained from the information of reports as a complement to the site geophysical measurements and Standard Penetration Tests records (SPT) [3, 4].

Fig. 1 shows a map with the distribution of standard penetration tests, seismic refraction tests and it also includes the location of the accelerometer in Viña del Mar. SPT tests reaches a 30 m depth and the seismic refraction tests provide information up to 15 m depth. The bedrock topography was determined by Verdugo [5], he used a gravimetric method, the study estimate the deepest zone around 175 m. A geological report prepared later by Thorson [6], establishes that the maximum soil depth should be less than 100 m.

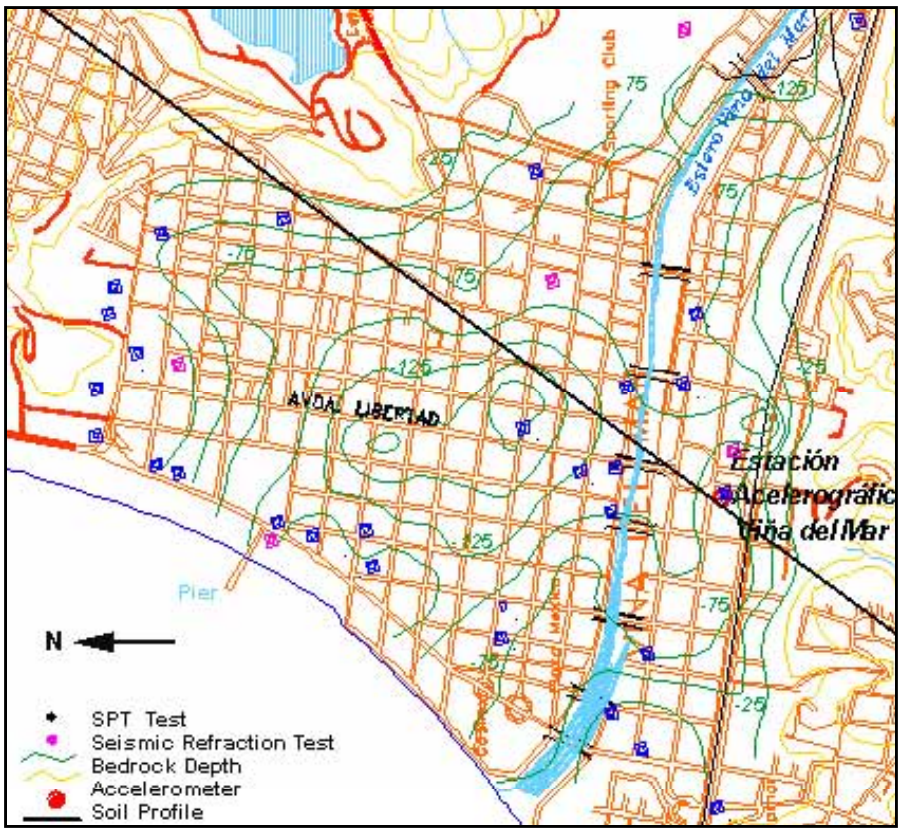

Fig. 1– Basic Data for the Analysis

In order to define the soil properties up to the bedrock, it was necessary to integrate all the existing information and to estimate the soil properties for the deepest layers; the approach is explained in detail by Perez [7].

Ground motion records from the March 3 1985 Chilean Earthquake were used; one of the records was obtained on alluvium in Viña del Mar and the other one on hard rock in Valparaiso. The characterization

of the calculated records was done in terms of Maximum Acceleration (A_{max}), Predominant Frequency (PF), Arias Intensity (AI), Destructiveness Potential Factor (DPF) and Spectral Ratio(SR). Table 1 shows some parameters of the aforementioned ground motion records, Fig 2 shows the acceleration response spectra with a 5% damping for the horizontal components.

Table 1 – Ground Motion Properties

Record	Dur. (s)	Comp.	A_{max} (g)	Predominant Frequency 1/(s)	DPF (10^{-4}g s^3)	AI (m/s)
Viña del	112	n70w	0.22	3.01	54.03	3.00
Mar		s20w	0.35	2.36	113.49	5.50
		u-d	0.16	6.18	5.97	1.22
USM	79	n70e	0.18	4.81	5.79	1.13
		s20e	0.16	6.67	3.26	0.72
		u-d	0.12	8.05	1.17	0.39

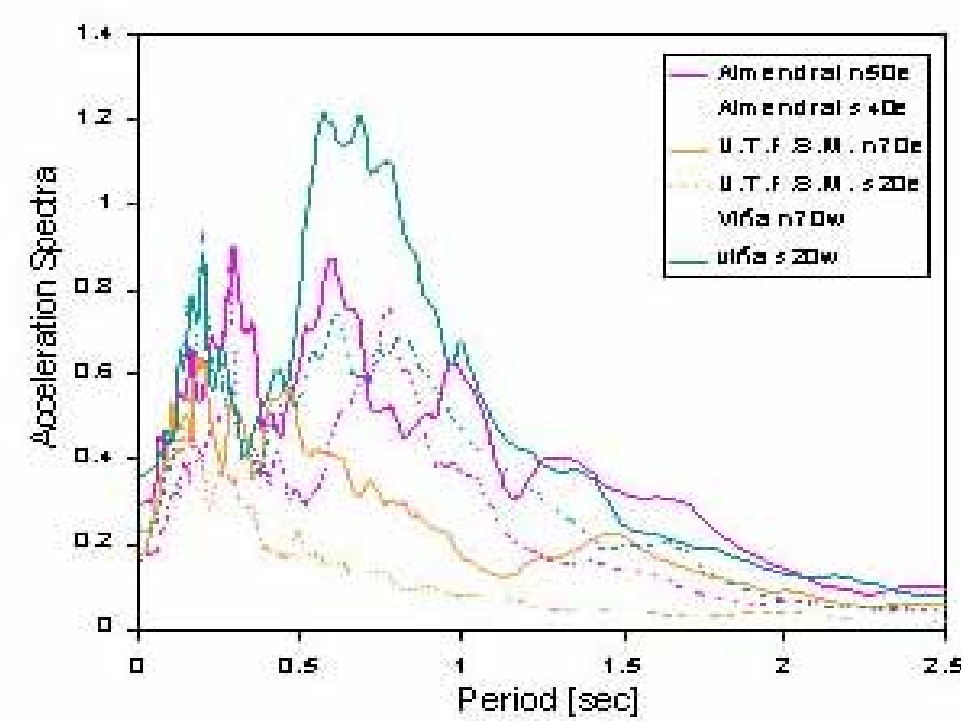

Fig. 2 – Response Spectra

The records obtained on rock, exhibit smaller acceleration peaks, higher frequency contents and the duration is smaller than the duration of the record obtained on the soil deposit. The peak of the acceleration spectrum for the soil deposit is larger than the peak for the base rock and it is placed on the intermediate periods. The peaks of the acceleration spectrum shift to the smaller periods for the record on rock, as a consequence the damage indices for the soft soil deposits are larger than the indices for the rock.

Model Validation
In order to validate the model there were performed several analyses, a calibration of every variable was done and the results were compared by using equivalent models.

There were selected several sections, some sections were chosen parallel to the sea cost, the direction is perpendicular to a geological existent fault known as Marga-Marga. Fig. 1 shows a typical section, it includes the accelerometer placed downtown Viña del Mar, whose record was used as a reference for the calibration of the model. The finite element mesh is shown on Fig. 3; the figure also shows some characteristics places and nodal points. The analysis was performed with the USM record, obtained on rock.

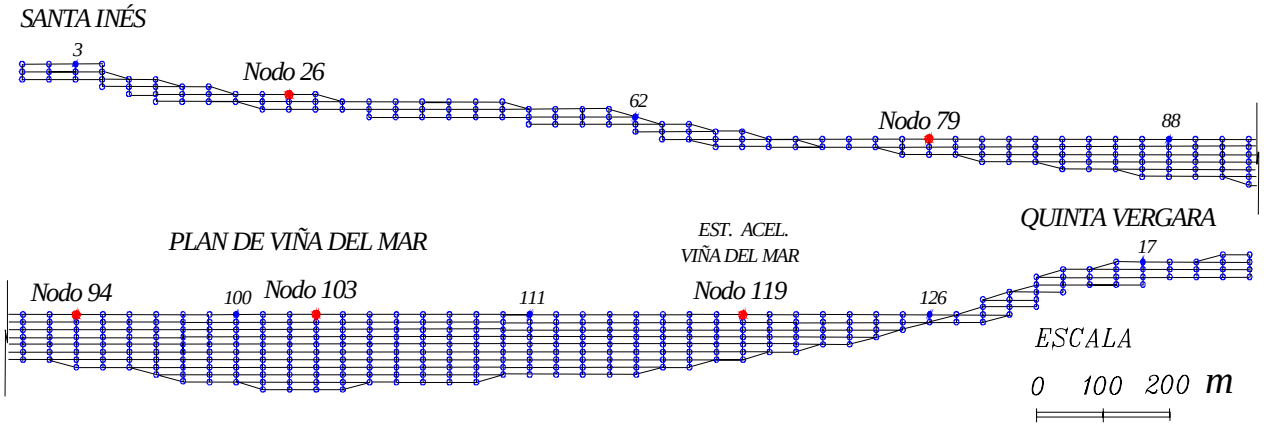

Fig. 3 – Finite Element Mesh

The ground motion was applied simultaneously to all the nodes at the base and the response was obtained on all the nodes placed at the ground level. The acceleration existing record, placed on node 119 was used to calibrate the model parameters, such as the soil properties deeper than 20m or the depth of the base rock. The best fitting of the calculated accelerations to the registered ones was obtained with a maximum soil thickness of 100m; this figure agrees very well respect to the thickness proposed by Thorson [6], a more detailed explanation can be found in Perez [7].

Determination of Intensities
The bi-dimensional model was applied at the seven sections shown on Fig. 4; they define 72 nodes on the ground surface. The acceleration was calculated for the 72 nodes, those calculated acceleration records were the data base to obtain the different ground motion indices.

Isoseismal lines for every parameter were drawn, so the Microzoning Maps in terms of Maximum Acceleration, Arias Intensity, Destructiveness Potential Factor and Spectral Ratio Response were obtained. Two spectral ratios indices were calculated: the Mean Spectral Ratio (REM) calculated in the interval from 0.1 sec up to 1.0 sec and the Spectral Ratio (RS) for a 0.7 sec period, which is an average period of buildings placed in that area.

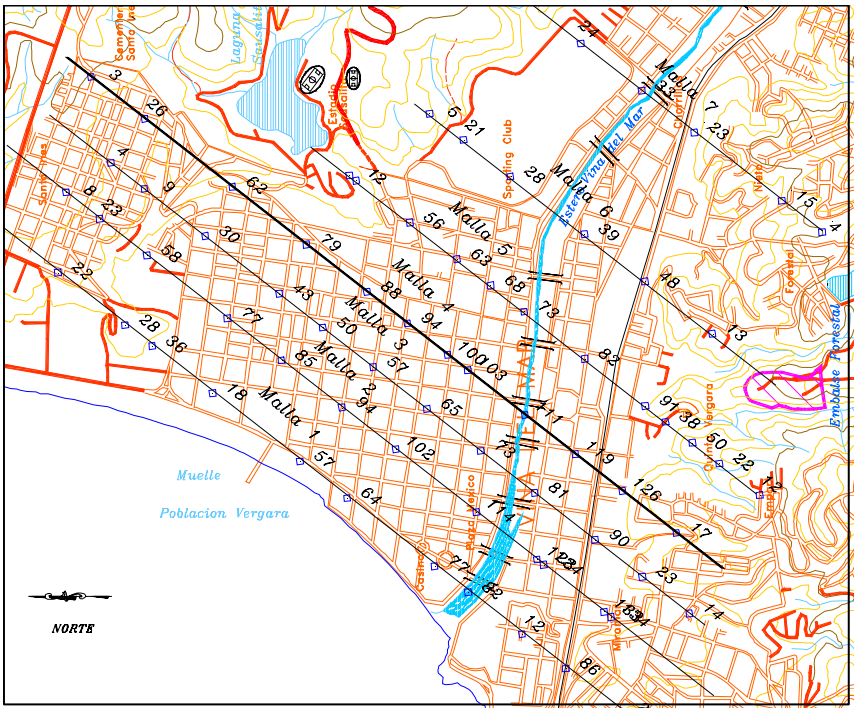

Fig. 4 – Sections on Viña del Mar

RESULTS

Seismic Response

Table 2 is a summary of some calculated parameters belonging to nodes 79, 103 and 119; the location is shown on Fig. 3.

Table 2 - Parameters Obtained from Analysis

ZONE	Node	Soil Thickness (m)	A_{max} (g)	PF (1/s)	DP (10^{-4}g s^3)	AI (m/s)	REM	T_n (s)
VIÑA	79	20	0.29	2.70	85.31	3.17	1.67	1.07
	119	60	0.29	1.70	274.50	3.71	2.31	
	103	100	0.21	1.22	350.75	2.29	1.73	

T_n: Soil Period reached during the ground motion

Fig. 5 shows the acceleration response spectra calculated for the ground nodes and the spectral ratios of those nodes respect to the base of the soil profile.

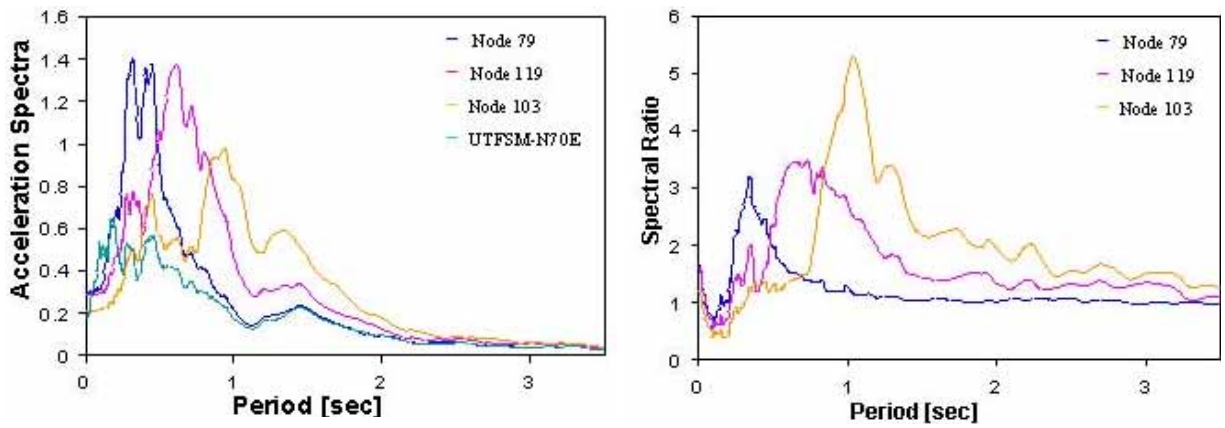

Fig. 5 - Response Spectra and Spectral Ratio

The results show that the peak of the acceleration response spectrum changes as long as we move toward the center of the valley, in a symmetrical distribution respect to the deepest point. The acceleration peak at the center is not close to the predominant period of the soil; however, it comes closer it as long as we move toward the higher areas, where higher acceleration levels occur. For this reason the acceleration at the center of the alluvium is smaller than the acceleration on the border of the deposit.

The places near to the hills exhibit higher accelerations; however the amplification levels are not important. The largest amplification figures are obtained at the center of the basin for the main period of the soil, however due to these periods are not close to the predominant period of the ground motion record the accelerations are rather small. The amplification observed is consistent to the damage recorded at the city after the 1985 Chilean earthquake and to the fact that the fundamental period of damaged tall buildings were close to the predominant period of the soil deposit.

Isoseismals and Microzoning: The isoseismals distribution for the different parameters is presented in figures 6 to 8. Fig. 6 shows the distribution of the Arias Intensity, Fig. 7 shows the Destructiveness Potential Factor and Fig. 8 shows the Mean Spectral Ratio calculated within a time interval from 0.01 sec up to 1.25 sec, which includes most of the existing buildings at the time of this study.

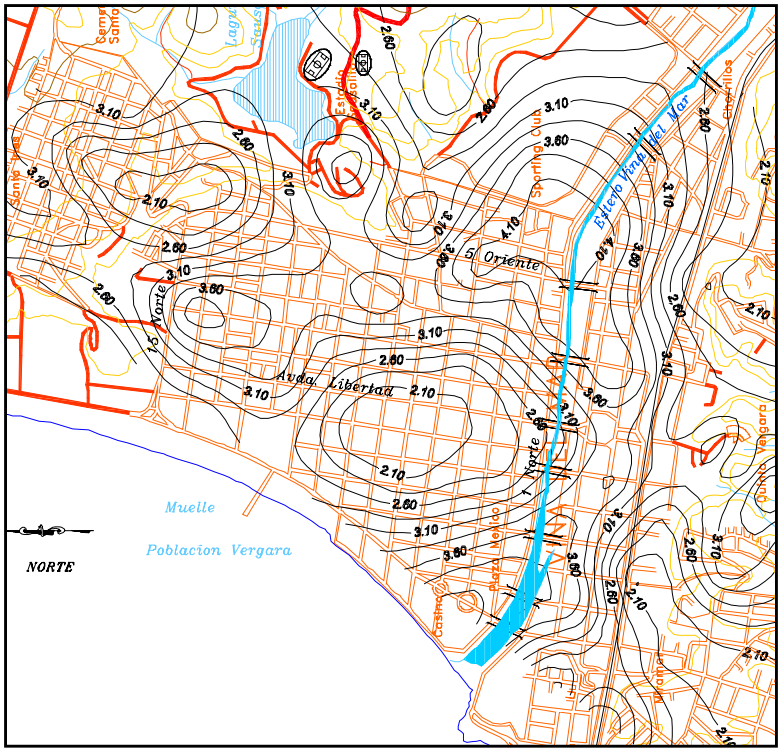

Fig. 6 – Arias Intensity

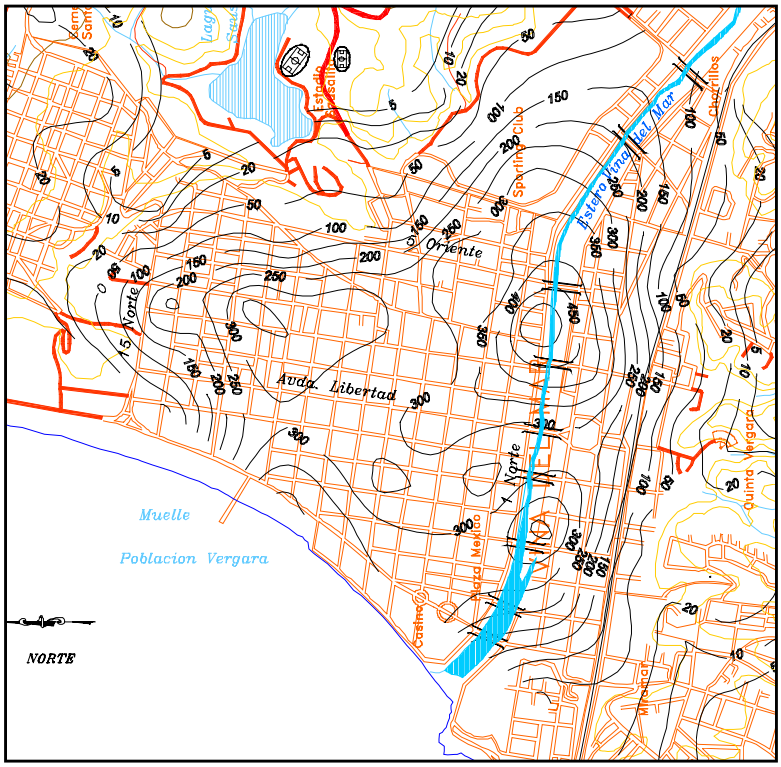

Fig. 7 – Destructiveness Potential Damage

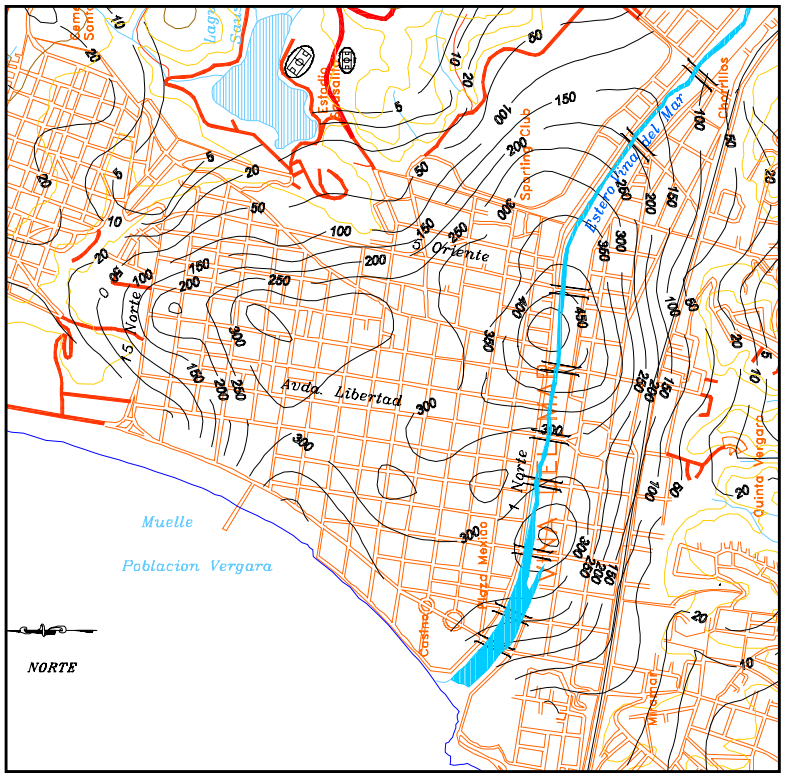

Fig. 8 – Mean Spectral Ratio

The aforementioned results were compared with the existing Microzoning Map for Viña del Mar proposed by Perez [8] after the 1985 Chilean Earthquake. The comparison shows that the Destructiveness Potential Damage and the Mean Spectral Ratio are the indices that fit better to the zones determined from the earthquake damage. Most of the damage was concentrated on the flat areas and it became smaller for the points on the higher zones.

Fig. 9 presents a Microzoning Map based on the isoseismal lines from Fig. 8 that is the Mean Spectral Ratio, which is the index of best fitting to the damage measurements.

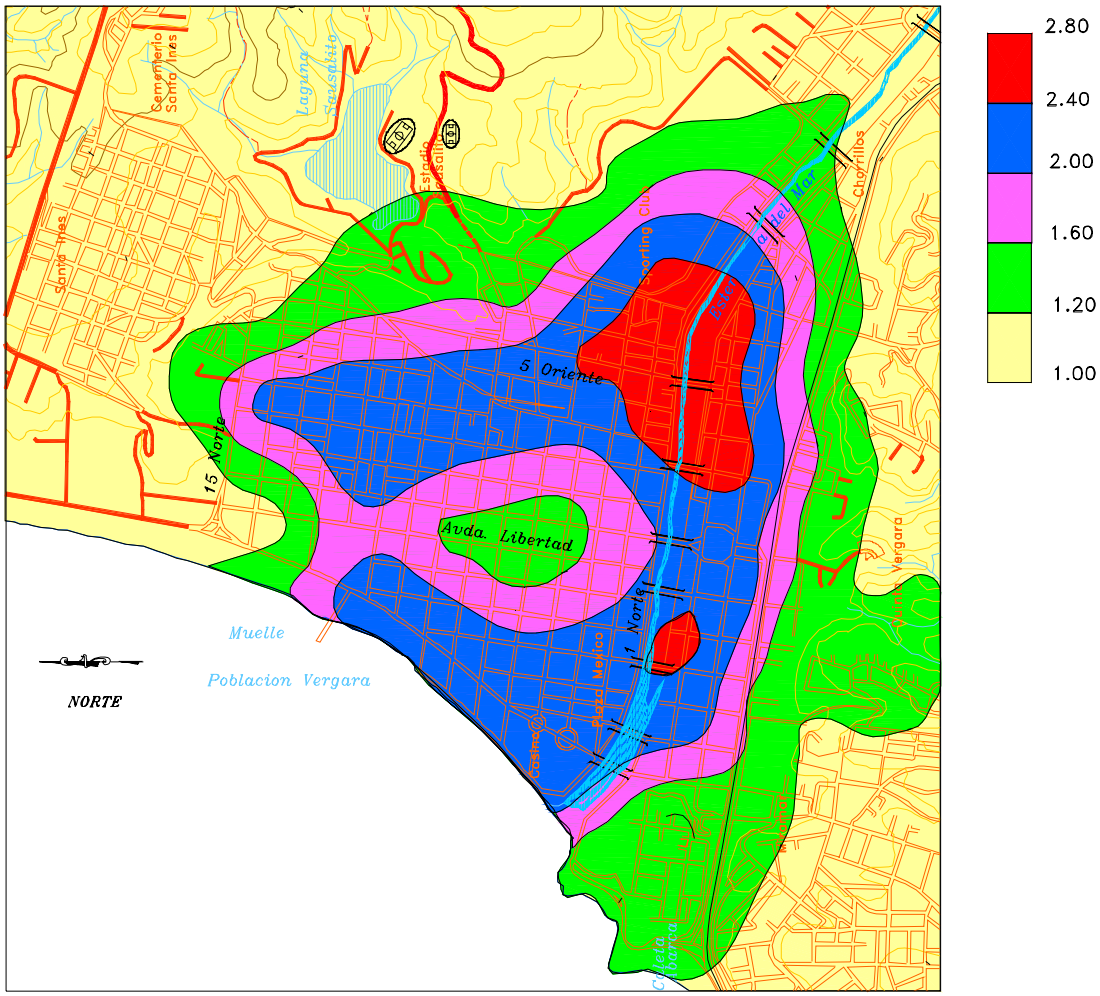

Fig. 9- Seismic Microzoning for Viña del Mar

Analysis under another ground motion Records

In order to estimate the effects of other kind of earthquakes on the same soil-site, the model was used to analyze the effects of Mexico 1985, Loma Prieta 1989 and Kobe 1995 ground motion records. In all those cases there were considered a simultaneous action of the vertical and horizontal components on the base nodes. Table 3 shows the properties of the records and Fig. 10 shows the response spectra.

Table 3 - Properties of the Records

EARTHQUAKE	STATION	COMP.	Amax (g)	PF (1/s)	AI (g s)	DPD (10^{-4}g s^3)
Kobe, 1995	JMA	NS	0.83	2.03	8.39	182.34
Loma Prieta, 1989	LPGC	EW	0.57	2.28	7.92	343.91
México, 1985	CALE	EW	0.14	4.22	0.64	4.38
Chile, 1985	UTFSM	N70E	0.18	4.81	1.13	5.79

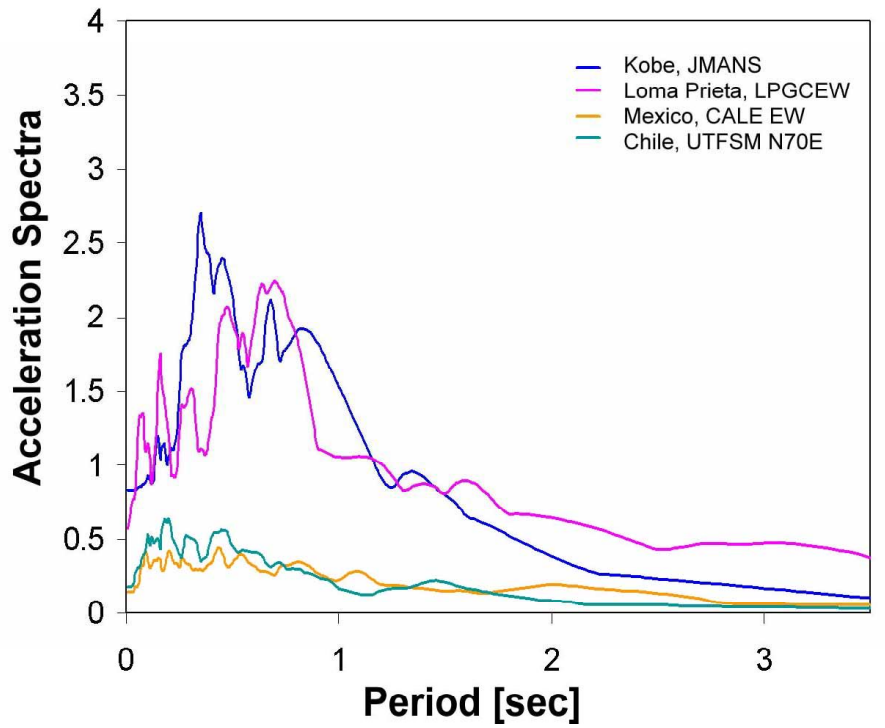

Fig. 10 – Acceleration Response Spectra

Table 4 shows a summary of the indices calculated from the response at the center of the soil deposit, which is the deepest place.

Table 4 - Indices for the deepest node (103)

Earthquake	Station	Comp.	A_{max} (g)	PF (1/s)	AI (g s)	DPD (10^{-4}g s^3)	REM	T_n
Kobe, 1995	**JMA**	**NS**	**0.56**	**0.80**	**5.77**	**3376.23**	**0.59**	**1.82**
Loma Prieta, 1989	**LPGC**	**EW**	**0.59**	**0.56**	**6.66**	**6156.59**	**0.51**	**2.08**
México, 1985	**CALE**	**EW**	**0.24**	**0.96**	**2.64**	**653.55**	**1.75**	**1.13**
Chile, 1985	**UTFSM**	**N70E**	**0.21**	**1.22**	**2.29**	**350.75**	**1.73**	**1.07**

Fig. 11 shows the response spectra for all the analysis, on the same figure it is shown the amplification of the Mean Spectral Ratio. Mexico and Chile exhibit large amplification in terms of the Mean Spectral Ratio, the peaks are concentrated in the neighborhood of 1.1 sec.

In the case of Kobe and Loma Prieta there is a wide interval of periods involved but the amplification is smaller.

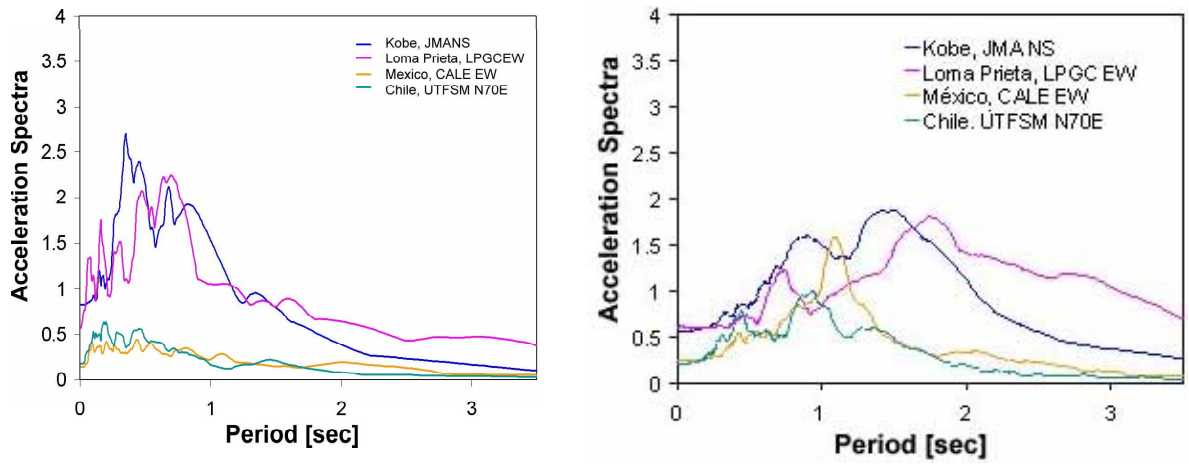

Fig. 11 – Response Spectra and Spectral Ratio

It can be seen that Kobe and Loma Prieta records exhibit a large predominant period and vibration level than the Chilean records, they produce large acceleration levels. It seems that the vibration level increases as long as the earthquake severity increases; as a consequence the soil behavior is non linear behavior. The Mean Spectral Ratio for Kobe and Loma Prieta records present the largest values on the large periods, however the peaks are not extremely large. The largest amplification values occur under the Mexico and Chilean ground motions and they take place in the middle period zone, in that sense Mexico record is closer to the Chilean earthquake than the other ground motions record.

CONCLUDING REMARKS

Microzoning Maps can be obtained from seismic amplification studies; the case of Viña del Mar as well as a similar analysis for Valparaiso city demonstrate that is possible such approach when part of the information is available.

The damage indices by themselves are not enough to determine the damage in a given place; the most important limitation seems to be that they don't consider the characteristic of the structures.

Destructive earthquakes take the soil deposits into the non linear behavior zone, this is important for the seismic response and the damage indices, this feature is even more remarkable in the case of ground motion records presenting high acceleration levels where the seismic amplification is rather small and they take place on large periods.

The bi-dimensional model has some limits and it is not appropriate where the topography presents important changes. It seems better its use on rather stables sedimentary soils. Liquefaction or active faults are not included in the model.

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