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SEISMIC RESPONSE ANALYSIS IN A PREFABRICATED 17-STORY RESIDENTIAL BUILDING

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ABSTRACT

Two Earthquakes occurred in the Center-North region of Venezuela, with epicenters in Tácata and Los Teques, nearly the city of Caracas. The magnitudes in the Richter scale were Mb = 4.9 and 4.8 respectively, causing peak ground accelerations of 12 gals. The event durations were 21 and 18 seconds.

A prefabricated building of seventeen floors situated in the metropolitan zone of Caracas, was affected by the earthquakes, recording its dynamic response with ground motion accelerographs located at the basement, ninth floor and seventeenth floor. The distances from the building to the epicenter were 37 Km corresponding to the Tácata earthquake and 28 Km for the Teques one.

This paper presents an analysis of the responses and the identification of the dymanics properties of this building, calculated from the acceleration records, using digital processing techniques as windows and spectral smoothing.

The frequency values for the first two modes were:

- Tácata Earthquake	$\omega_1 = 2.0$	$\omega_2 = 6.9$
-Los Teques Earthquake	$\omega_1 = 1.9$	$\omega_2 = 7.1$

KEYWORDS

Dynamics response, digital processing technical, accelerographic record, prefabricated building, Fourier analysis, spectral smoothing, dynamic properties, building instrumentation, transference function.

INTRODUCTION

The determination of the dynamic properties of structures through experimental measures, is a very interesting activity, which offers information about parameters that rule the dynamic response of the system in front of any kind of stress. This information, proceeding from the analysis of the structural response, allows between other things to correct or to readjust the analytic models, which don't appropriately reflect the reality, to analyze the structures damages, to detect not evident pathologies. Everything in order to increase the structural reliability. (Genatios, 1991).

In this paper a methodology to determinate the dynamic properties of a building is applied starting from its structural response recorded during an earthquake.

This situation inhibit to control the excitation conditions, however, it offers the advantage that the excitation corresponds with the properties of real event that fits to the local conditions corresponding to the setting of the building.

It is important for the case to know, all the information about to the earthquake as, the excitation, the building as a system to be evaluated and the site (kind of soil and foundation) as a complement to interpretate the information obtained from records processing.

The main purpose of this work is to determine the dynamic properties of the building. Such as vibration natural frequencies ωi, and critical damping fractions ξi , associated to the first vibration modes.

GENERAL CONSIDERATIONS

The excitation and site of instrumentation

During August of 1986, the Center-North region of Venezuela was shaked by two important earthquakes. In August 18 a telluric movement occurred which epicenter was located in Tácata, Miranda State (N 10.16, W 67.09) with a magnitude of 4.9 in the Richter scale. One week later, August 25, there was another earthquake, which epicenter was located in Los Teques, the Capital City of Miranda State, (N 10.29, W 67.09) with a magnitude of 4.8 in the same scale. Because of the location of the epicenters it is possible that these events are associated to the Tàcata and La Victoria faults (Fig 1).

According to the seismological 1986 reports, it was assigned an intensity of VI in the Mercali scale to both earthquakes, the Tàcata earthquake (18-08-86), and the Los Teques earthquake (25-08-86). Both of them were registered by four of the accelerograph stations that compose the National Accelerograph Network which is coordinated and maintained by the Fundación Venezolana de Investigaciones Sismológicas (FUNVISIS).

One of the four stations that registered both earthquakes, constitutes the multiple instrumentation of a building that is located at Conjunto Residencial Las Danielas, in Las Minas de Baruta sector, Miranda State (coordinates: N 10.43, W 66.87); the distances from the epicenters of the Tácata and Los Teques earthquakes to the instrumentated building are approximately 36.7 Kms and 29.0 Kms, respectively.

The building and its instrumentation

The instrumentated building is a part of the constructions played during the 70's, by the company Viviendas Venezolanas, S.A. Specifically the Conjunto Residencial Las Danielas was built in 1979.

Between the main characteristics of the building, highlights the fact of being a seventeen story prefabricated system, dedicated to multi - familiar housing with four apartments by floor.

Its structuration is based on a system of prefabricated walls, which are assembled in site shaping a regular plan with four resistant lines in each direction.

The facade walls, the bracing walls and the floor slabs were poured with horizontal forms, with the difference that the slabs are prestressed.

The instrumentation scheme employed consists of three accelerographs model SMA-1 fabricated by Kinemetrics, placed practically in the center of each floor, they are located on 0, 9 and 17 floors respectively (Fig. 2 and Fig. 3).

The three units SMA-1, are interconnected with a common release at ground floor, which activates when the component of the vertical acceleration is over 0.01 g, and a common release located at the nine floor, which activates when the component of the horizontal acceleration is over 0.01 g. When any of the releases (horizontal or vertical) activate, the three units start simultaneously the recording process.

Each unit allows to get a triaxial photographic record that corresponds, one of them to the vertical acceleration component and the others two to the orthogonal components of horizontal acceleration, which had been oriented in the same direction of the main resistant lines defined by the structural walls of the building, that will be called from now on, as longitudinal and transverse components respectively.

DESCRIPTION OF THE EXCITATION AND RESPONSE RECORDS.

For this building 18 records were obtained from accelerograph components, corresponding to the vertical, longitudinal and transverse components of the ground floor, 9th floor and 17th floor for the Tácata and Los Teques earthquakes.

These records, that at the beginning were available in 70mm film, it subjected to a processing, following the procedure proposed by the California Technological Institute (CALTECH), (6). The accelerographics records of the Tácata earthquake (duration 21 sec) and the Los Teques earthquake (duration 18 sec) it digitized with a time increase $\Delta t = 0.02$ sec.

RECORDS PROCESSING

In order to obtain the higher quantity and quality of results better than the ones that are traditionally obtained by the direct interpretation of the records, they were transformed to the frequency domain through the use of the Fourier thecniques. The processing scheme used depends on the wanted result:

* To determine the frequencies of the vibration modes:

  - To correct the records according to the CALTECH algorithm.
  - To apply a window filter type to each record (Hanning window)
  - Determination of Fourier spectra (FFT).
  - To apply the spectral smoothing algorithm.
  - Determination of the transference functions records at 9 and 17 floors against the ground floor records.

* To determine damping:

  - To correct the record in accordance with the CALTECH algorithm (8).
  - Determination of the Fourier spectrum.
  - To apply the bandwidth criteria.

Window filter type.

The Figures 4 and 5, illustrate the application of the Hanning filter for the 17 floor record.

The Figures 6 and 7, compare the FFT for the 17 floors records corresponding to the Tácata earthquake with and without application of the Hanning window.

Fourier spectrum

The application of the Fourier transformed is justified because it can demonstrate that in those systems that own a little damping the maximum value of the transformed modulus occurs when for a frequency equal to the natural frequency of the system, and that the critical damping fraction may be calculated through the criterion of bandwidth associated to the said frequency . In this way, this thecnique gets a high practical utility to the determination of dynamic properties, specially for systems which present natural frequencies enoughly separated.

In practice to obtain the Fourier transform The FFT algorithm is used.

Spectral smoothing

In order to make easier the interpretation of the Fourier spectrum, it is advisable to implement a smoothing algorithm based on the criterion that the quotient between standard deviation and the medium value of the spectral density function is approximately equal to the unit. This criterion leads to a satisfactory approximation in most practical cases of calculus, of the original spectrum by a smoothing spectrum.

The algorithm associated to the said criterion, consists in to determine a smoothing spectral value as the average of the adjacent spectral values to each value. In the general case, if 2L+ 1 adjacent values are averaged, the following result is obtained:

$$\overline{S}(\omega_k) = \frac{1}{(2L+1)} \sum_{l=-L}^{L} S(\omega_{k+l}) \qquad (1)$$

The Figures 8 and 9, present the effect of the spectral smoothing with L=10 for the case of the 17 floor Fourier spectrum corresponding to the longitudinal component of the Tàcata earthquake.

Transfer function

The transfer functions were calculated from the Fourier transforms of the 17 floor records taking as reference the response at the ground floor of the building.

The Figures 10 and 11, show a detail of ground floor FFT and the transfer function of 17 floor/ Ground floor, for the longitudinal component of Tàcata earthquake.

RESULTS

From the analysis of the transfer functions graphics it is possible to determine the natural frequencies of the Fourier transforms without the application of window filters nor smoothing the fractions of damping relative to critical are determinated.

The following tables summarize these results:

Table 1. Los Teques earthquake: Frecuency and critical damping

	Longitudinal component				Transverse component			
	Natural Frequency		Critical Damping		Natural Frequency		Critical Damping	
Level	Mode 1	Mode 2	Mode 1	Mode 2	Mode 1	Mode 2	Mode 1	Mode 2
9F	2.02	7.09	0.037	0.023	1.89	6.35	0.034	0.014
17F	2.02	6.96	0.040	0.019	2.02	6.35	0.034	0.016
Ave	2.02	7.02	0.039	0.021	1.96	6.35	0.034	0.015

Table 2. Tácata earthquake: Frecuency and critical damping

	Longitudinal component				Transverse component			
	Natural Frequency		Critical Damping		Natural Frequency		Critical Damping	
Level	Mode 1	Mode 2	Mode 1	Mode 2	Mode 1	Mode 2	Mode 1	Mode 2
9F	2.02	7.08	0.034	0.013	1.98	7.02	0.036	0.016
17F	1.92	7.08	0.034	0.019	1.97	7.02	0.034	0.012
Ave	1.97	7.08	0.034	0.016	1.98	7.02	0.035	0.014

CONCLUSIONS

1. The recommendations relative to the appropriate points for the measurement are verified.

2. It was impossible to obtain the vibration mode forms due to the limited number of measurement points.

3. The possibility to derive information of interest by the direct interpretation of the records is verified; fundamentally relative to the first vibration mode.

4. The use of Fourier thecniques, permits to get a higher quantity and quality of the information, since from the Fourier spectra , the natural frequencies vibration of the first modes can be identified and calculate their corresponding fractions of critical damping through the criterion of the bandwidth.

5. The thecniques of spectral smoothing act as a low pass filter, allowing to simplify the spectra outline, making easier their interpretation.

6. The application of window type filters, allows to emphasize the frequencies of interest, however for the close frequencies the modal interference increase as consequence of the overflow effect that at the same time disturbs the spectral values.

7. It is convenient to determine the fractions of critical damping through the criterion of bandwidth, which spectrum haven't been object of the application of window type filters and/or smoothing algorithms, since these add an overflow effect, leading to a wrong calculus.

8. It is convenient to determine the natural frequencies vibration since of the transfer functions, because of this way the contribution of the structural system in the response is increased, reducing the appearance of other source of information that disturbs the interpretation of the results.

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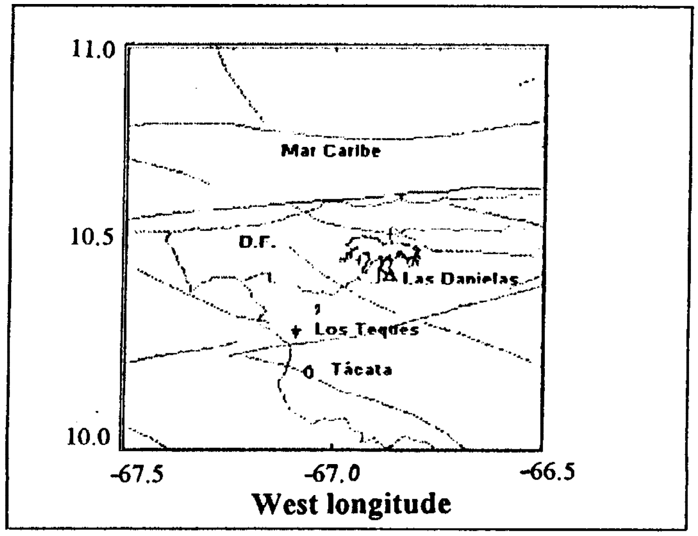

Fig. 1 Faults on the study region

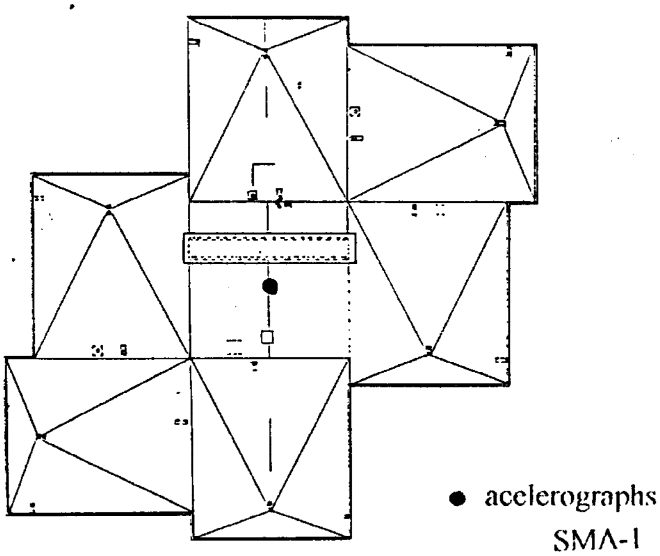

Fig. 2 Building plan

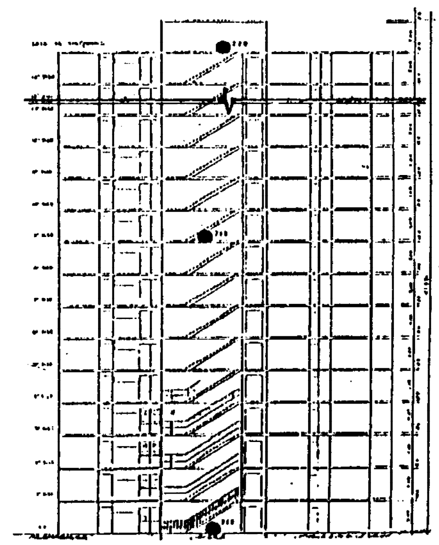

Fig. 3 Sectional elevation of the building

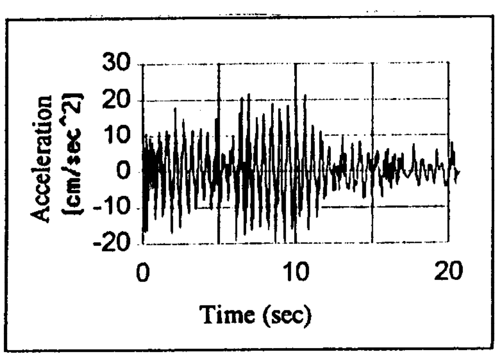

Fig. 4 Corrected accelerogram

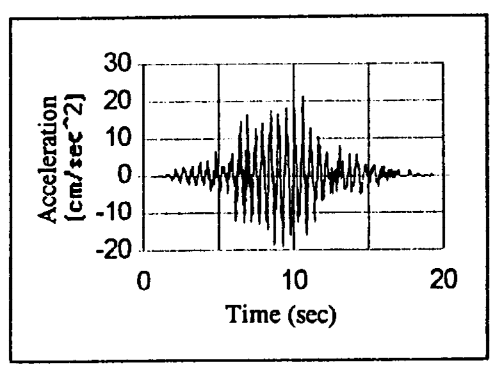

Fig. 5 Hanning filter application

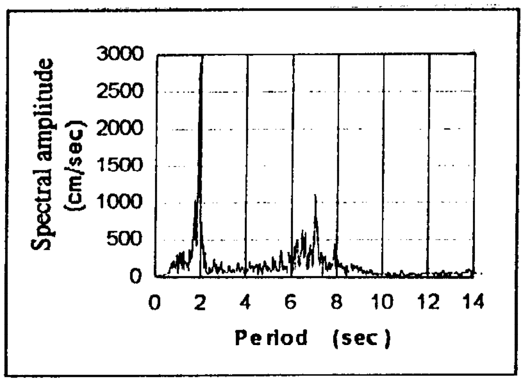

Fig. 6 FFT without window

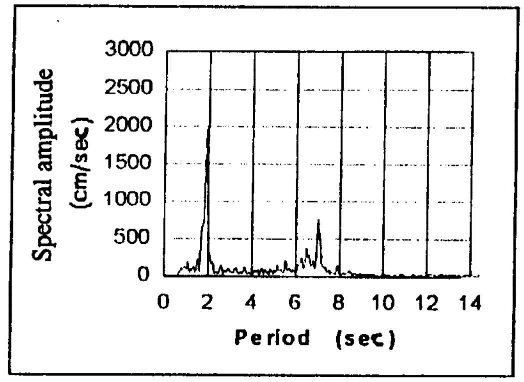

Fig. 7 FFT with window

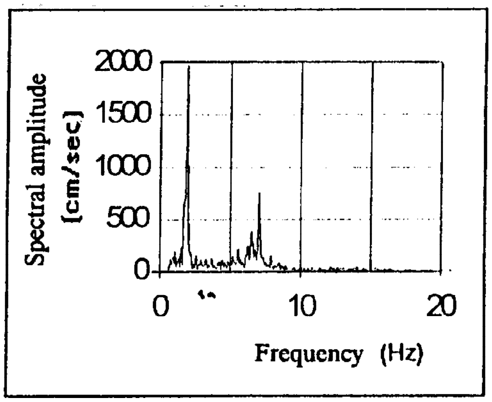

Fig. 8 17th f FFT without smoothing

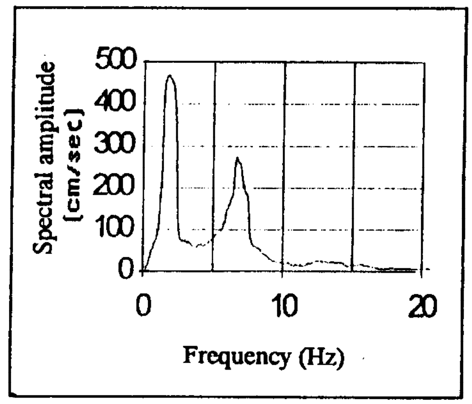

Fig. 9 17th f FFT with smoothing

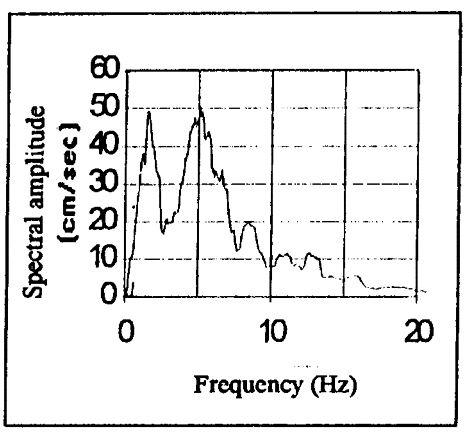

Fig. 10 GF FFT smoothing

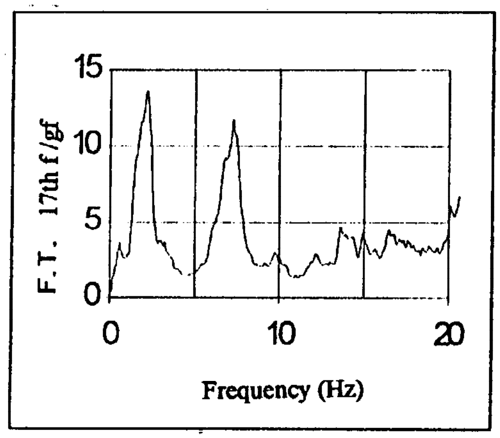

Fig. 11 Transfer function