# AMBIENT VIBRATION TESTS USED TO EVALUATE SEISMIC PROPERTIES OF A MEXICAN CONCRETE DAM

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**ABSTRACT :**

New ways of constructing structures are found every day, but also ways in which they are analyzed or modeled, to obtain an ideal behavior or nearer to the reality in case of an external excitement produced either by natural, or accidental phenomena, being earthquakes one of the most important to take into account. For the study of the behavior of a massive structure, like a dam, there have been adopted ambient vibration tests as a good method of study; It is a trustworthy, economical, suitable method that provides good information on seismic response. It is also an efficient method to review or adjust the mathematical model of the structure. This work reports the preliminary results of the study of Ensenada's dam: "Emilio López Zamora", located, at Northwest of Mexico, It is in a high risk earthquake zone, so a seismic response study is needed. For this purpose, ambient vibration as source of excitement and several arrays of sensors have been used and processing and interpretation of data used to obtain results about structure and soil.

**KEYWORDS:** ambient vibration, seismic study, accelerometers, concrete dam

## 1. LOPEZ ZAMORA DAM DESCRIPTION

The Emilio López Zamora (ELZ) Dam is located in the city of Ensenada, Baja California, to the northwest part of Mexico and about 300 km south of Los Angeles, California (Figure 1), inside the urban area of Ensenada city (Figure 2).

This dam was constructed in the 70's, primarily for flood control, with a maximum capacity of 8.85 millions of $m^3$. Made out of concrete, the dam has a gravity section, 260 m length, it has a maximum height of 34 m, crest width of 4 m, extended to 8.50 m, to form a roadway for moderate circulation; the upstream slope is vertical from the crest, down to the 10.65 m elevation and from there it continues down to the ground with 0.10:1 slope; downstream, it is vertical from the crest down to the 21.67 m elevation, where it changes to 0.75:1 down to the foundation. It has an inspection and drainage gallery, of horseshoe section, 2.00 m wide in the base, interior height of 3.00 m and 0.40 m thick walls of reinforced concrete; the gallery has entrance from both ends at the stations 0+038.50 and 0+233.50 m of the dam; the left wing entry, with threshold to the elevation 18.0 m with 0.02 slope at three levels, 15.68, 12.60 and 7.46 with earring up to the maximum threshold lower than the elevation 6.34 m; it has a small (0.30 m x 0.20 m) collecting channel (Comisión Nacional del Agua, 1999).


Figure 1 Dam Site (http://earth.google.es/)

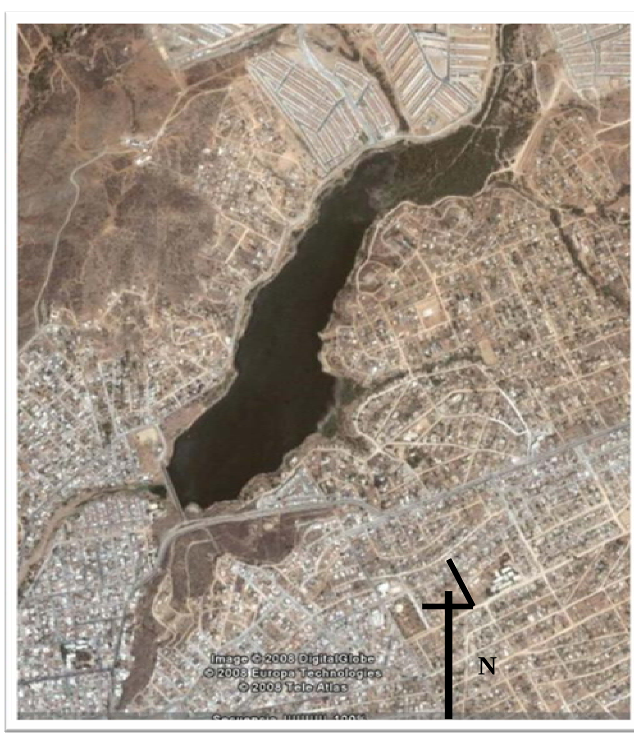


Figure 2 Emilio López Zamora Dam and housing units surroundings (http://earth.google.es/)

## 2. EXPERIMENTAL SET-UP

### 2.1. Measurement equipment

Two EpiSensor FBA ES-T accelerometers (figure 3) that use piezoelectric elements to detect the three orthogonal components of the vibrations of the dam were used. Their specifications are shown in the table 1.

Table 1. Triaxial EpiSensor FBA ES-T accelerometer specifications (http://www.kinemetrics.com/product_Content.asp?newsid=111)

| | |
|---|---|
| Bandwidth | DC-200 Hz |
| Cross-axis sensitivity: | < 1% (including misalignment) |
| Full-scale range: | User selectable at ± 0.25g |
| Outputs: | User selectable at: ± 2.5V single-ended; ± 10V single-ended;± 5 V differential;± 20 V differential |


Figure 3 Episensor FBA ES-T accelerometer

To record dam vibrations, a Kinemetrics SSR-1 six channel recorder (figure 4) was used. Its specifications are listed at Table 2, below. A laptop is used to set the recording parameters: the computer is plugged to the recorder and using a communication protocol, the parameters to start the record are defined. When a wave is registered by the accelerometer, it enters the recorder, there, the number of channels, sample velocity, gain, and filter type are selected, according to the way the sign should be registered.

Table 2. Kinemetrics SSR-1 recorder specifications

| | |
|---|---|
| Storage type | Solid state memory |
| Available channels | 6 |
| Analogic-digital converter | 16 bits |
| Filters type | 6 poles Butterworth and Bessel |
| Filter’s crop frequency | 5, 15 ó 50 Hz |
| Gain | 1, 10, 100 ó 1000 |
| Sample frequency | 50, 100 o 200 samples/s |

Figure 4 Kinematrics SSR-1 six channel recorder

## 3. PROCEDURE

### *3.1. Excitation source*

Ambient Vibration, consisting in low energy waves and periods between 0.1 and 10 s, are the excitation source used to measure the structure's response. Microtremors are mainly generated by human activity, industrial machinery performance and vehicular traffic. Also, contains wind-produced vibrations induced into the soil by trees, buildings or by their impact on the relief. This source is not associated to earthquakes and some researchers regard that microtremors (natural noise) is formed by superficial waves generated at ocean-continent interaction zones, by planet's fundamental vibration modes, by atmospheric pressure changes and by internal volcanic activity, as well as by artificial sources previously quoted (Espinoza, 1999). As an advantage, this excitation source is non-destructive –does not cause damage to the structure– because of its acceleration is of the order $10^{-3}$ cm/s$^2$.

### *3.2. Sensor's arrays*

The sensors were placed on the crest. One of them was fixed at the center, while the other alternated its position to the ends of the crest and in between positions (see figure 5). They all were positioned with the *x* axis in the direction of the crest axis, the *y* axis facing downstream, and *z* axis in the vertical direction.

### *3.3. Data recording and processing*

Collected time series range was 25 minutes and sample frequency was 25 Hz, for all cases. Registered microtremors waves (Figure 6) were processed at the frequencies domain (Figure 7). To obtain transfer functions using as input, the sign measured at free field and as output the signal at the bridge's deck. Will be realized in a next step.


Figure 5 Location of measuring points. (http://earth.google.es/)

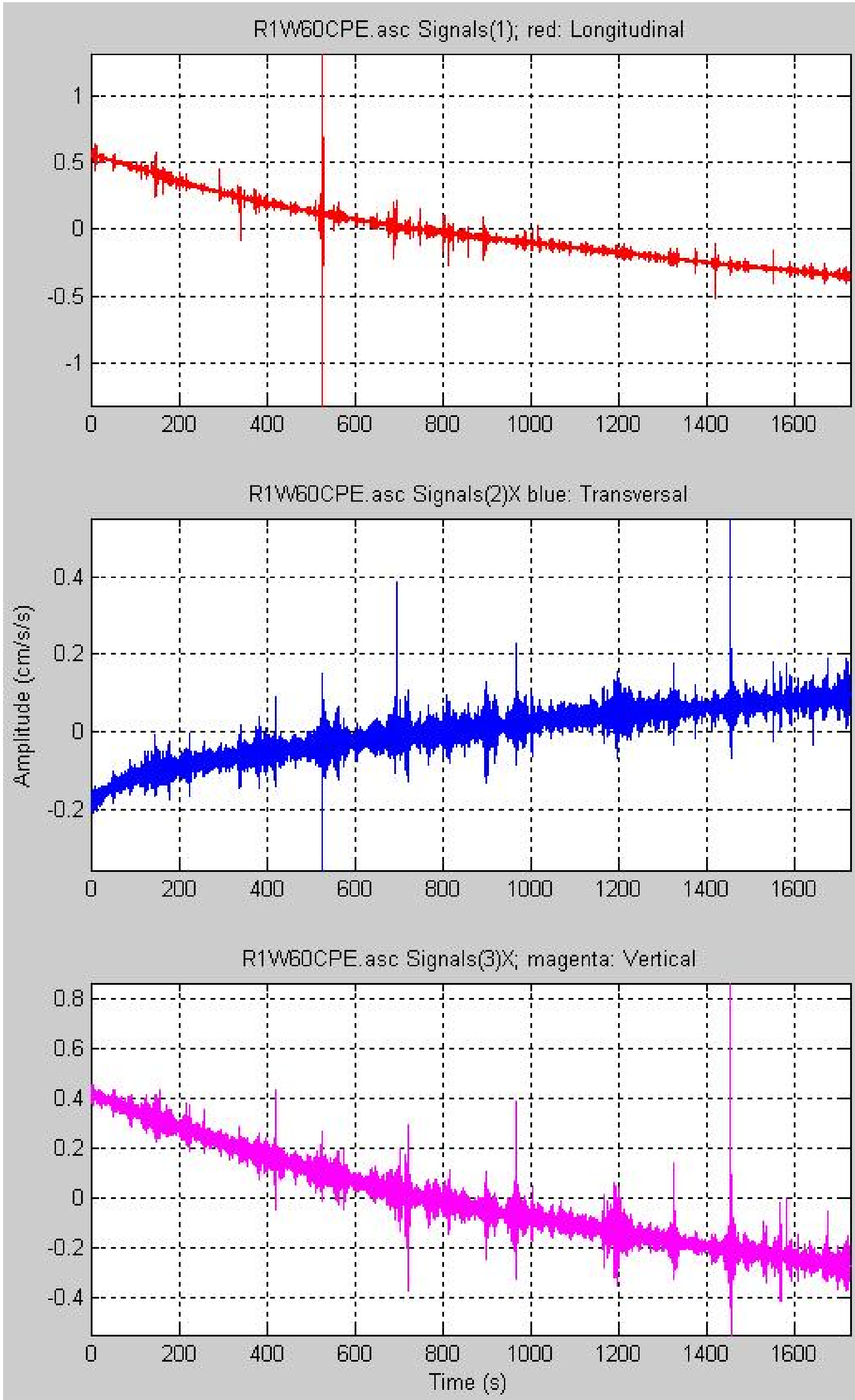


Figure 6 Graphs of time signals registered at dam center showing the three components.

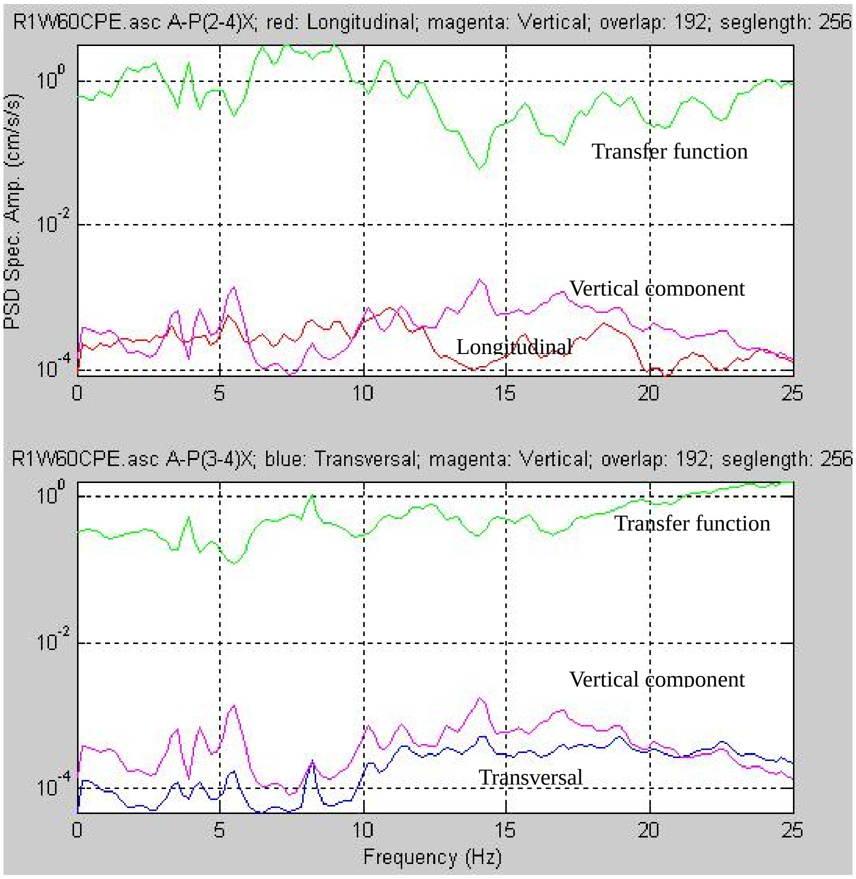


Figure 7 Fourier transform of signals at dam center. In both graphs, the upper line represents the Transfer Function obtained dividing the horizontal component by the vertical one.

## 6. RESULTS

Preliminary results show fundamental frequencies of 2 Hz (0.5 s) in longitudinal direction and 4 Hz (0.25 s) in transversal direction, showing more flexibility in this component. In the next stage of this investigation, we are going to measure in free field to obtain better data.

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