Caracas, Venezuela, Site Effect Determination with Microtremors

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Abstract — Caracas 1967 earthquake caused heavy damage to multi-story buildings. In 1995, 184 microtremor measurement points were performed over the city. The measurement grid was more or less dense and covered the main part of the alluvial basin as well as surrounding rock basement. For each point, the horizontal record spectrum was divided by the vertical one (H/V ratio). Subsequently, the strongest value (Ao) of this ratio in a given frequency band was kept, as well as the frequency (Fo) where it occurred. Spatial interpolations of Ao and Fo were performed among all points of Palos Grandes district. A map was plotted representing a single surface where Ao is relief and Fo is represented by grey gradation. An alluvion thickness (H) map can be compared with this result. Damaged buildings are located on the same map. Fo decreases until 0.6 Hz when alluvion thickness (H) increases. Fo values fit with frequencies previously predicted from computation and with 1967 earthquake observations. Moreover, interpolation surfaces show that amplification (Ao) of H/V on microtremor is quite low above rock but is high on the south part of the basin. The maximum occurs over the non-urbanized zone. However the other area, where Ao is higher than 5, roughly corresponds to the location of the four collapsed buildings. Furthermore, the estimated natural frequency of these buildings was around Fo. Graphics showing H, Fo and Ao evolution through the basin were composed. Links between all these values are noticeable. Fo is claimed to be very similar to the resonance frequency of soil. As for Ao, it could be a fairly relevant sign of damage seriousness. Microtremor technique is an economic tool and it allows measurement grid as dense as desired. H/V ratio processing followed by interpolation of maximum values provides precise and useful information about expected site effect.

Key words: Microtremor, H/V ratio, Nakamura’s technique, Caracas 1967 earthquake damage.

1. Introduction

Caracas is built on a typical alluvium basin. The 6.4 magnitude earthquake that occurred in 1967, July the 29th at 56 km on the north, caused the loss of over 200 lives and extensive damage in the town. The maximum ground acceleration was estimated of the order of 0.06 to 0.08 g in east Caracas. It was quite obvious that the

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importance of damage was linked to site effects. After the earthquake a very important work was undertaken by American soil specialists (BOLTON SEED et al., 1970; WESTON Inc., 1969; WHITMAN, 1969 and BOLTON SEED et al., 1972). A good correlation between the frequencies of damaged buildings themselves and the calculated frequencies of the sites was demonstrated. The Caracas 1967 earthquake was one of the first for which the importance of site effects was noticed. For this reason, we have tested at the same place with the collaboration of FUNVISIS, the method based on microtremor measurement, developed during recent years. This method called “H/V on microtremors” was applied in downtown Caracas in 1995. In this paper results around Los Palos Grandes district are discussed.

2. Damage due to 1967 Earthquake in Los Palos Grandes District

Caracas basin is about 17-km long, and 4.8-km wide. The topography of the fill is almost flat although it is surrounded by mountains. The Rio Guaire runs the length of this basin and an important tributary “La sierra da Avila” meets the Rio Guaire. These rivers deposited alluvium soils like sand, gravel and hard clay. Numerous studies (seismic refraction, geophysical bore-hole) were conducted after the 1967 earthquake (BOLTON SEED et al., 1970; WESTON Inc., 1969 and WHITMAN, 1969). These surveys allow good descriptions of Caracas geological conditions. The most important zone of alluvium is called “Los Palos Grandes.” Sediment fill can reach 300 meters in the center of this area. The shear-wave velocity is less than 500 m/s until 75 meters depth for Palos Grandes.

A map of alluvium thickness throughout the city was produced after the 1967 earthquake (BOLTON SEED et al., 1970). Figures 1 and 2 are partly extracted from it and show soft sediment thickness under the Palos Grandes district and the surrounding rock outcrop. The main interesting feature of the 1967 earthquake in Caracas was the geographical distribution of damage. Approximately 550 buildings between 10 and 25 stories were distributed at that time throughout the city and about 750 more in the 5 to 9 stories range (BOLTON SEED et al., 1970). Structural damage to high buildings (10 to 12 stories) was concentrated in Palos Grandes. Four of these buildings collapsed. While structural damage from 1 to 2 stories buildings was specially recognized in the northwestern part of Caracas, around the San Bernardino district, where alluvial deposit is less important. Structural damage to intermediate buildings (from 6 to 9 stories) was regularly spaced over the basin. It was also stated that while there were certainly differences among the degrees of earthquake resistance in various buildings, and while structural details were important in damage development for particular structures, design practice appeared to have been generally similar throughout the city. This damage distribution strongly suggests a link between sediment thickness and damaged building height. The more or less sophisticated computations that produce the first