

# A SITE AMPLIFICATION STUDY USING OBSERVED RECORDS AT BMD, DHAKA FOR SEISMIC MICROZONATION

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## ABSTRACT

Dhaka city is currently seismically vulnerable both in natural and social condition, therefore seismic disaster management microzonation is indispensable. In this process, local site amplification plays an important role. For this purpose, due to shortage of soil data, a number of horizontal-to-vertical spectral ratio (H/V) for microtremor was already applied to estimate predominant period and amplification factor for geomorphological types, but without verification using real earthquake records. However, there are earthquake records obtained by the vertical array at the Bangladesh Meteorological Department (BMD), Dhaka.

In this study, in order to investigate an appropriate way to estimate site amplification due to subsurface soil for seismic microzonation of Dhaka, actual amplifications calculated using six actual small earthquake records are compared with the existing results of H/V for microtremor. This study provides the conclusions: (a) The predominant period estimated using H/V for microtremor is in a good agreement with those estimated using the real small earthquake records, (b) The amplification factor of PGV and the amplitude spectra show some differences between the real small earthquake records and the existing results of H/V for microtremor, (c) the predominant periods of the existing H/V for microtremor can be used for microzonation of Dhaka city, whereas the amplification factors estimated from them cannot be used directly, but more careful investigations are required. Finally we expect the results of this paper can be a clue for preparation of practical seismic microzonation for Dhaka city.

**Keywords:** PGV Amplification, H/V Spectral Ratio, Microtremors, Microzonation, Predominant Period

## 1. INTRODUCTION

According to a report published by the United Nations IDNDR-RADIUS Initiative, Dhaka and Tehran are the cities at the highest earthquake disaster risk (Cardona et al., 1999). Dhaka mega city is overstressed due to its extremely high population, pressure on housing, transportation and other necessities for day by day life. Due to seismo-tectonic surrounding by having boundaries between Indian Plate and Eurasia Plate to the north, and between Indian Plate and Burma Plate to the east, Dhaka city has been experienced many historical earthquakes. Especially the 1897 Shillon Earthquakes ( $M_s=8.1$ ) attacked Dhaka and provided severe damage (MMI 8). The existing study of seismic microzonation of Dhaka was composed of the probabilistic calculation of peak ground acceleration levels, and the estimation of predominant period of local amplification using H/V for microtremor and amplification factor of each geomorphological types (Kamal and Midorikawa, 2004;

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Kamal and Midorikawa, 2006). Though the applicability of H/V for microtremor has been said to have various questionable points (e. g., Satoh et al., 2001), it can reasonably be assumed that a major earthquake event in Dhaka region is capable of higher damage according to these results. But still the verification on site amplification characteristics by using actual earthquake records have not yet been realized, and necessary to certificate the accuracy. Fortunately, the Bangladesh Meteorological Department (BMD) has started seismic observation since August 2007, at Dhaka city especially with vertical array. This can provide a comparison between H/V for microtremor and actual earthquake motion amplification. This paper will also introduce an important clue for the practical seismic microzonation realization using existing data including H/V for microtremors, and more proper microtremor measurement.

## 2. Data

Six earthquakes were selected from one hundred three event files collected by the digital seismic network of BMD from August 31, 2007 to February 26. The existing microtremor data collected in Dhaka by Mr. M. Kamal were used also. Their observation points were near BMD and were employed by Kamal and Midorikawa (2004) and Kamal and Midorikawa (2006) for H/V analysis to estimate predominant period and amplification. They are labeled “MT” in the figures that appear hereafter.

## 3. ANALYSIS

### 3.1 Fourier Spectral Analysis

#### 3.1.1 Fourier Transformation:

Firstly, the recorded waveform format is SEED. Then, Fourier spectra of the selected segments of two horizontal and the vertical components are calculated using Fast Fourier Transform (FFT) algorithm using Seismic Analysis Code (SAC). Then, before calculation of spectral ratios such as transfer function and H/V spectral ratios, smoothing technique using logarithmic window (Kon’no and Ohmachi, 1998) with a bandwidth coefficient  $b=15$  is applied to reduce the distortion of peak amplitudes and to make it easy to show the peak of spectra.

#### 3.1.2 Calculation of spectral ratios:

In order to calculate ratios of horizontal-to-horizontal components (that is the transfer function of horizontal components) and horizontal-to vertical components (H/V), the two horizontal components that are of North-South and East-West must be combined to a horizontal component. In this study, the square root average ( $H=\sqrt{NS^2 + EW^2}$ ) and the geometric average ( $H=\sqrt{NS \times EW}$ ) are used, they do not provide big difference in results.

### 3.2 Fourier Spectral Ratio

For calculating site amplification and making comparison with existing microtremor results with earthquake motion records, the velocity waveform data sets are divided into six time windows (Figure 1). Due to varying duration of P-S interval and the main part of S-wave, Case F) is more recommendable than others for the discussion on S-wave, Case D) rather than Case C) for discussion on S-coda. Considering on its stability, Fourier spectra of Case A) can be used as those of microtremor.

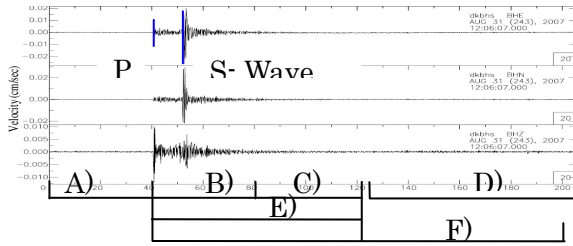


Figure 1. Division of velocity waveform of earthquake motion data. Case A) first 40sec before P-wave, Case B) 40.96 sec after P-wave, Case C) 40.96 sec after P-wave (2<sup>nd</sup> phase), Case D) last 81.92 sec, Case E) 81.92 sec after P-wave, and Case F) is 164 sec after P-wave.

### 3.3 Observed results of Spectral Ratios

#### 3.3.1 $H_s/H_b$ for earthquake:

Case F) shows clear three peaks at the periods 0.2, 0.4 and 1.1 second. The predominant one is given by the last one. The curve for microtremor (broken one) has peaks at almost same periods, but their amplitude at the peaks is smaller than those of earthquake records. Case B) and Case E) show similar shape to Case F). This suggests that the difference of Fourier spectra among Cases B), E) and F) is due to the source effect and cancelled out by calculating  $H_s/H_b$ . See Figure 2 (a).

#### 3.3.2 $H_s/V_s$ for earthquake and microtremor:

For Cases A), D), E) and F) a similarity to the curve for microtremor (broken one) is observed and for the latter two the more deviation of curves than the former two is observed.  $H_s/V_s$  is clearly different from  $H_s/H_b$  for all of Cases A), D), E) and F). For B) and Case C) the curves deviate much. See Figure 2 (b).

#### 3.3.3 $H_b/V_b$ for earthquake and microtremor:

For Cases A) and D), these are almost unity within factor of two in the period range shorter than 1sec, whereas in the longer period range these deviate more than the factor of two. For Case F), these can not fall in the factor of two around the unity. See Figure 2 (c).

#### 3.3.4 $V_s/V_b$ for earthquake and microtremor:

For all cases, this spectral ratio is not within factor of two around the unity in the period range shorter than 1 second, whereas in longer period range these for earthquakes (Case F)) show a good stability around the unity and these for noise (Case A)) show a slightly larger deviation but fall within the factor of two. See Figure 2 (d).

#### 3.3.5 $H_s/V_s$ for microtremor versus $H_s/H_b$ for earthquake

Above observation show that  $H_s/V_s$  for microtremor can not be an approximation of  $H_s/H_b$  for earthquake. Failure of the necessary conditions, i. e.,  $H_b/V_b$  and  $V_s/V_b$  might be unity, suggest it too.

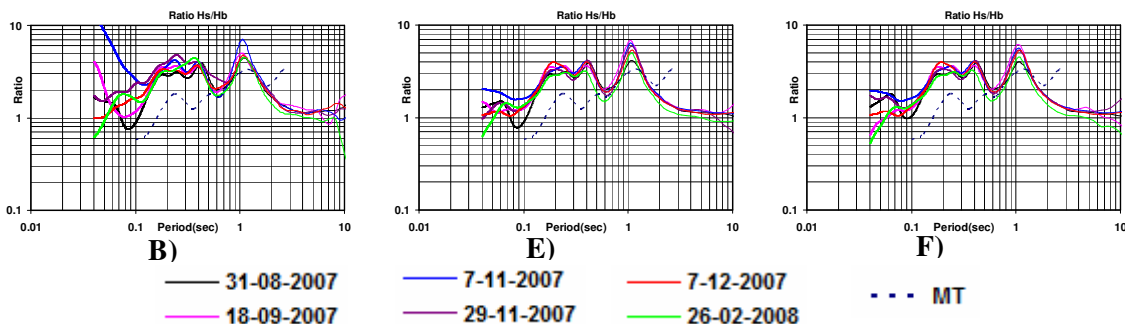


Figure 2 (a). Spectral Ratio for horizontal transfer function ( $H_s/H_b$ ) for Case B), Case E) and Case F).

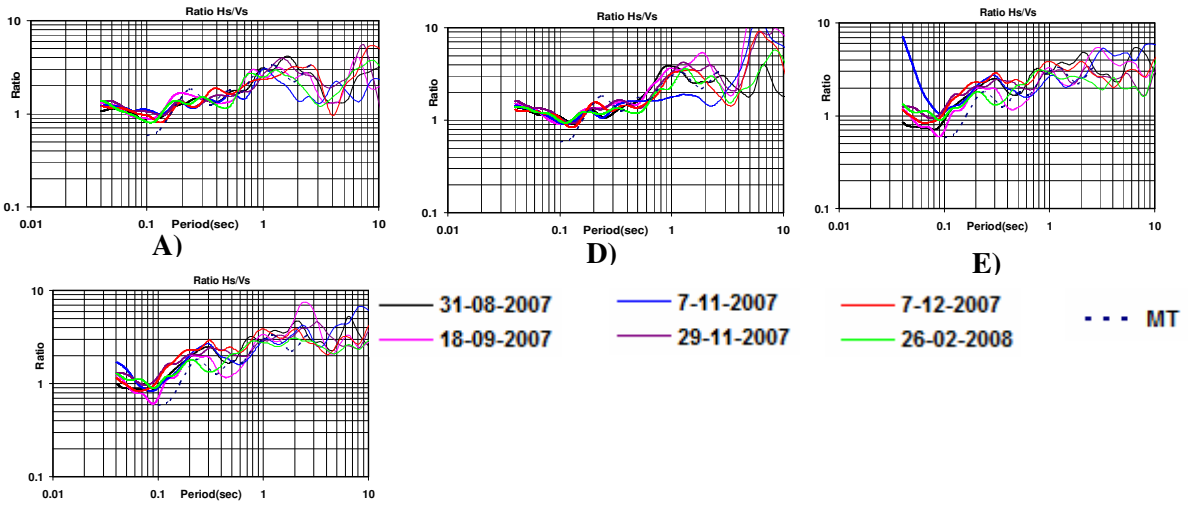


Figure 2 (b). Spectral Ratio for horizontal to vertical at surface (Hs/Vs) for Case A), Case D), Case E) and Case F).

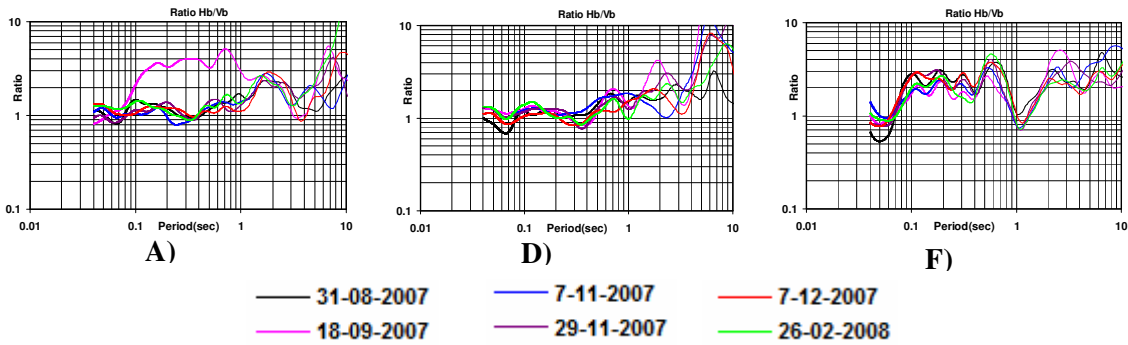


Figure 2 (c). Spectral Ratio for horizontal to vertical at borehole (Hb/Vb) for Case A), Case D), Case F).

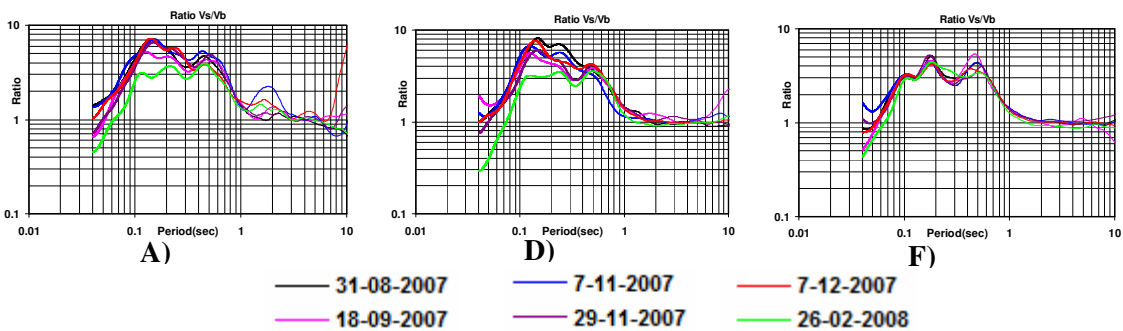


Figure 2 (d). Spectral Ratio for vertical transfer function (Vs/Vb) for Case A), Case D), and Case F).

### 3.4 PGV amplification and Peak Values of Spectral Ratio

Figure 3 (Left) shows the relation of the peak amplitude of Hs/Vs for S coda and for noise and Hs/Hb for earthquake. It can be confirmed that the peak amplitude of Hs/Vs for S coda and for noise have a correlation with PGV amplification better than those of Hs/Hb for earthquake. That of the existing H/V for microtremor results shows similar value to peak amplitude of Hs/Vs for S coda and for noise. Further, Figure 3 (Right) shows the same information as that of Figure 3 (Left) but the horizontal components are merged by geometrical average. It looks that the peak amplitudes of Hs/Hb for earthquake are similar as that shown in Figure 3 (Left), but the peak amplitudes of Hs/Vs for S coda become smaller and show a better correlation with PGV amplifications. In contrast, Hs/Vs for noise show a worse correlation in Figure 3 (Right). For both of those figures, Hs/Vs for S-coda and for noise almost fall within the factor of about 1.5 from PGV amplification.

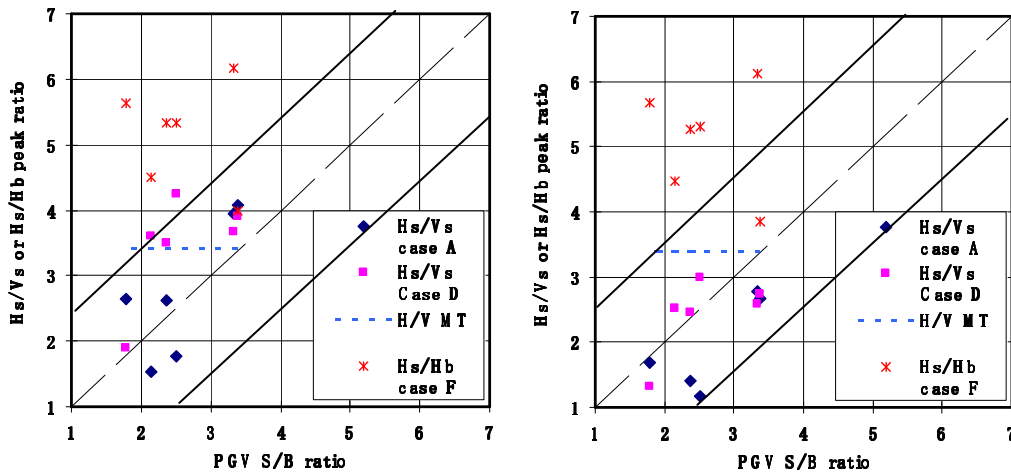


Figure 3. Relation of the existing H/V for microtremor results and the peak amplitude of Hs/Vs for S coda and for noise, Hs/Hb for earthquake with PGV amplification: horizontal components are merged (Left) by square root average and (Right) by geometric average

## 4. CONCLUSION

Based on the results of analysis using the earthquake records obtained at BMD, Dhaka, microtremor data of which duration is longer than 40 seconds with sampling frequency 100 Hz provide stable spectra for the period range from around 0.1 to 3 seconds. Thus, when targeting this period range, such duration is recommendable for getting stable spectra.

Predominant period estimated by H/V for microtremor is consistent with that of horizontal transfer function of earthquake motions Hs/Hb. This may be useful information for site characterization. Amplitude of H/V for microtremor at its predominant period shows a similarity with the peak amplitude of Hs/Vs of earthquake records, but significantly smaller than that of horizontal transfer function Hs/Hb.

The shapes of Fourier spectra as well as the spectral ratios except Hs/Vs are affected by the difference of wave contents between microtremor and earthquake motion, namely, the former is composed of mainly surface waves and the latter of body waves rather than surface waves. Even though shapes of H/V for microtremor and that of Hs/Vs of earthquake motions look similar, the

former cannot be directly used in place of horizontal transfer function  $H_s/H_b$ . The basic assumption for Nakamura method is that  $H_b/V_b$  is unity or two and  $V_s/V_b$  is unity.  $H_b/V_b$  of microtremor becomes roughly unity perhaps because of surface waves' dominance, whereas that of earthquake motions becomes a little bit larger and complicated perhaps because of mixture of body waves. Vertical transfer functions  $V_s/V_b$  for both of microtremor and earthquake motions become unity in period range longer than 1 sec., whereas they have amplitudes from 3 to 5 in the shorter period range. Horizontal transfer function  $H_s/H_b$  for earthquake motions has clear peaks but that of microtremor show a broad peaks perhaps due to difference of wave contents mentioned above.

There are various problems to be solved for using H/V for microtremor as an estimate of horizontal transfer function  $H_s/H_b$  or PGV amplification factor. A conversion function if established, however, would enable us to estimate an amplification factor or spectra of amplification using H/V for microtremor. This suggests the necessity of conducting studies using much more vertical array observations for earthquake on applicability of seismograms and microtremor, and on effectiveness of non-linearity of soils during much stronger earthquake motion.

Even though several problems remain unsolved, this study introduces for the first time to Bangladesh the site characteristics during earthquake using actual earthquake records, by comparing microtremor with the actual earthquake motions.

## 5. RECOMMENDATION

For further studies it is necessary to collect more earthquake motions recorded at various sites including vertical arrays. The first priority, however, should be put on clarifying the soil structure, especially shear wave velocity structure, at BMD, Dhaka. The existing records may be useful to estimate the average velocity, but PS logging, seismic exploration or microtremor array measurement are highly recommended for further study.

Finally, this paper can give a clue for applicability of H/V for microtremor that is popularly conducted for practical seismic microzonation for Dhaka city, Bangladesh.

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