GROUND RESPONSE OF KATHMANDU VALLEY ON THE BASIS OF MICROTREMORS

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SUMMARY

Devastation of Kathmandu valley from historical earthquakes, the M8.3 Bihar - Nepal Great Earthquake of 1934 in particular, suggest that spectral ground amplification due to unconsolidated quaternary sediment is playing the major role in the enhancement of ground motion. The valley has a maximum 500 – 550 meter thickness of unconsolidated sediment in the central part. The quaternary sedimentary history is consistent with two major sedimentary stages. The lower fluviatile stage consisting of 200-250 m thick granular sediment is overlain by lacustrine sedimentary stage of 200-300m section of clay sediment. This sedimentary scenario existing in central part of the basin transitions into fluviatile facies in the northern part of the valley. Southern part is characterized by fluviatile and proximal lacustrine deposit.

Share wave velocity of the granular section is about 1200 m/sec and the adverse role is played by the 600m/sec share wave velocity of the lacustrine clay. Microtremor measurement in 60 sites of the valley exhibit different level of horizontal peak power spectrum ratio to bed rock in the lacustrine and fluviatile domain. High contour of peak power spectrum is correlated with lacustrine sedimentary domain characterized by high intensity of 1934 earthquake.

The quantitative assessment of site amplification is made from horizontal relative site spectra of the microtremor in reference to the spectra at bedrock. The site spectra are first normalized to take into account the background effect in different sites. Spectral site amplification is the square root of the relative power spectra. The spectra are quite consistent in the lacustrine sedimentary domain with maximum peak value at about 2 Hz. The peak amplification is about 12-15. Root mean square amplification in the frequency range of 0.6 – 5.0 Hz is 5–6 in lacustrine area, 2-3 in transitional and 1-2 in fluviatile area. Theoretical spectra of vibration build up corresponding to the prevailing quaternary geological model in lacustrine area matches well with the spectral amplification derived from relative horizontal microtremor spectra. Theoretical root mean square amplification is about 4.8 for 0.6 – 5.0 frequency range. Observed earthquake acceleration in the northern marginal area is consistent with rms. amplification of 4.4 in the same band of frequency.

INTRODUCTION

Kathmandu valley is an intermontane tectonic basin in the Lesser Himalaya of Central Nepal. The valley has three main city Kathmandu, Patan and Bhaktapur and many newly developing urban areas. The total population of the valley in urban and rural area comprises about 2 million.

The valley has been devastated many times by historical earthquakes. The pattern of devastation by 1833 earthquake (M7.8) and by the Great earthquake of 1934 clearly evidences intense site amplification due to unconsolidated sediments in the basin. The intensity distribution in the valley by the 1934 Great earthquake varies from VIII to X MM (Dunn et. al., 1939) within different sedimentary facial domains of unconsolidated sediments. Acceleration data for different parts of the valley is still missing to allow a quantitative assessment of ground amplification. Microtremor study is being widely used to provide site amplification information in many geological scenario and serves as a cheap and quick geophysical tool for the preliminary study. Theoretically

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microtremor can be considered as a convoluted white noise with the response of the unconsolidated package and therefore should contain information about the filtering and amplifying property of the sediment. Seismological Laboratory (now National Seismological Center), Department of Mines and Geology carried out microtremor survey of Kathmandu basin in 1985-86 in 60 sites. (Pandey et. al, 1986). Observations were carried out by Microtremor Observation Equipment Model MA-103, TS-1 of Katsujima Seisakosho CO, Ltd. Tokyo, Japan donated by Japan International Cooperation Agency (JICA), Japan to the department. The field observation system consisted of three component short period velocity transducers (seismometers) with analog recording in magnetic tape. Field observations were made in calm period of the day for 2 to 3 minutes of continuous measurement. A segment of 20.4 second was digitized (1024 samples with 50 Hz.) and processed for various outputs. In this paper a reassessment of the digitized data is done for some sites of the valley and compared with model and real recorded acceleration data.

GEOLOGICAL SETTING

Kathmandu basin has been evolving as a tectonic basin in Lesser Himalaya of Central Nepal since the neogene-quaternary period. The lesser Himalaya is the terrain with altitude less than 3000 meter bounded in the north by Main Central Thrust (MCT) and in the south by Main Boundary Thrust (MBT). Based on surface geological and subsurface information from drilling data a quaternary geological sedimentary model for unconsolidated sediment has been developed in connection with gas exploration in the valley. (Matojima et. al., 1980). The evolution of the basin started in neogene - quaternary time as a consequence of higher rate of uplift in the south in relation to north as a response to evolving Himalaya thrust tectonics. The initial sedimentation occurred in a fluviatile basin and blankets the buried bedrock topography. The fluviatile facies is characterized by granular sediments mainly consisting of silts and sands with some patches of clay sediments. After sedimentation of 200-300 meter thickness the fluviatile basin evolved into a lacustrine basin in the central part of the valley. The lacustrine sedimentary facies is characterized by unconsolidated sediments consisting mainly of clay and silty clay. Its thickness is quite consistent within the lacustrine domain and is about 200 meters. The northern of the present valley has been evolving all the time as a fluviatile basin while proximal lacustrine facies consisting of sandy, silty and clayey sections are occuring in the southern part. The transition zone in the north near the boundary of lacustrine domain is characterized by lake - delta deposit. After the draining out of the lake a sandy section of about 20 m. thickness has been deposited at the top of lake deposit.

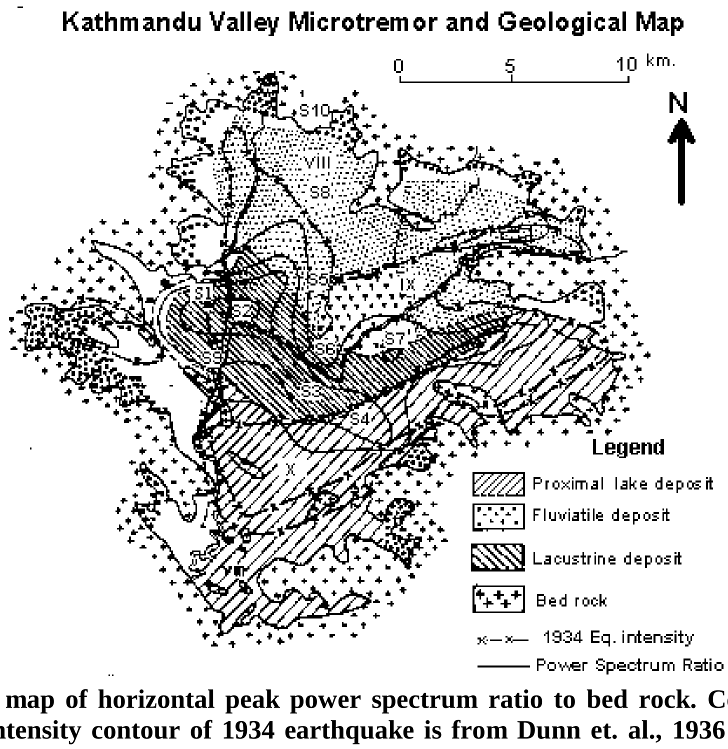


Fig. 1 – Contour map of horizontal peak power spectrum ratio to bed rock. Central lacustrine area is shown by dots. Intensity contour of 1934 earthquake is from Dunn et. al., 1936 Sites- S1- Chhauni, S2-Hyumat, S3-Imadol, S4-Sanagaon, S5-Gausala, S6-Koteswor, S7-Sanothimi, S8-Bansbari, S9-University, S10-Budhanilakantha

On the basis of P-wave velocity information obtained from CDP reflection survey the clayey sediments of lacustrine facies is attributed to have 1600-1650m/sec. while the fluviatile granular section has 1850-1900 m/sec velocity. The bedrock P-wave velocity is taken as 5600 m/sec.

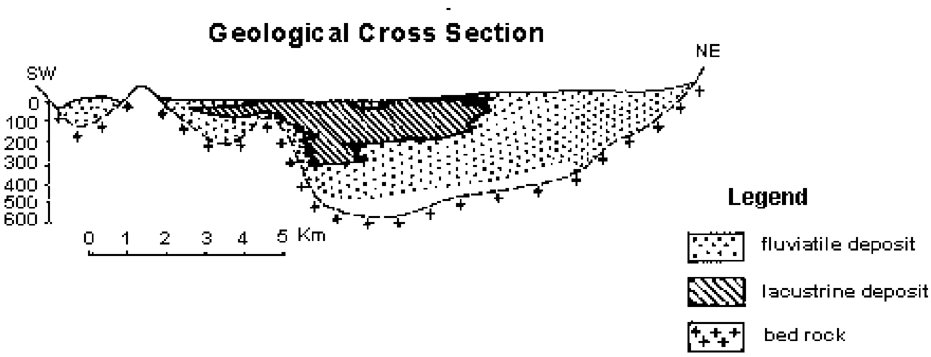


Fig. 2

DISCUSSION AND CONCLUSIONS

The frequency response of the equipment, the stability of the stochastic microtremor noise and the sampled segment of 20.4 sec for digitization and analysis constrain the frequency band of the obtained response from the microtremor analysis. The results, therefore, are applicable mainly to 1 – 6 Hz frequency band of the response.

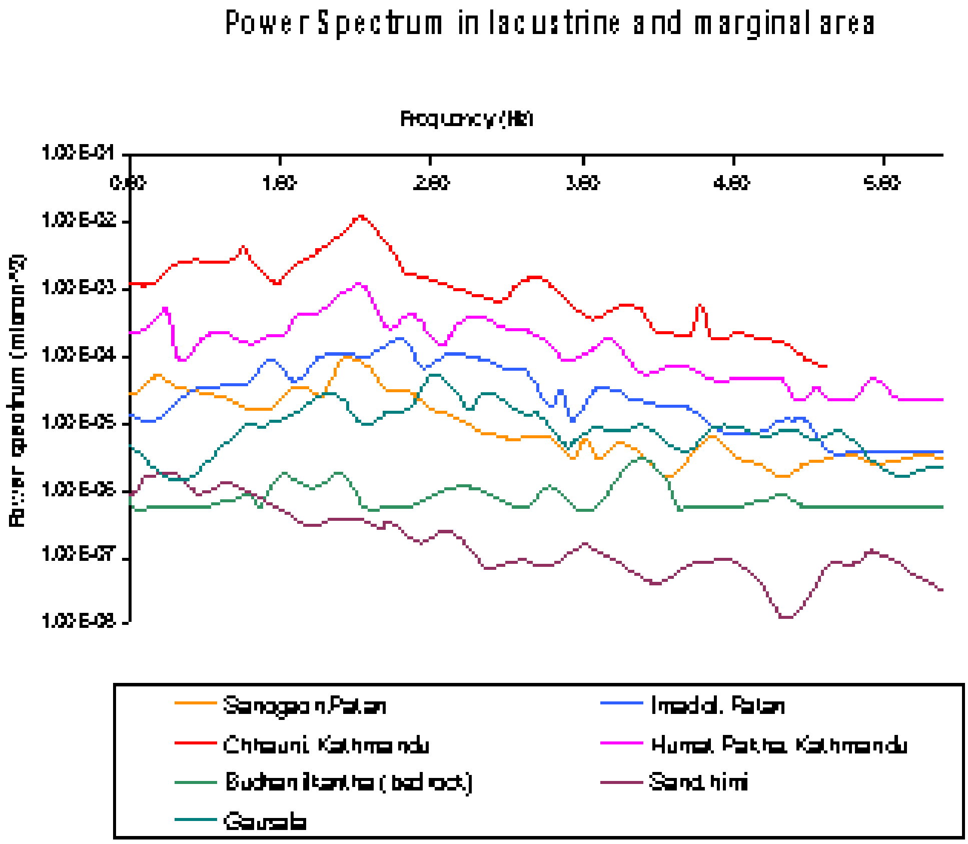
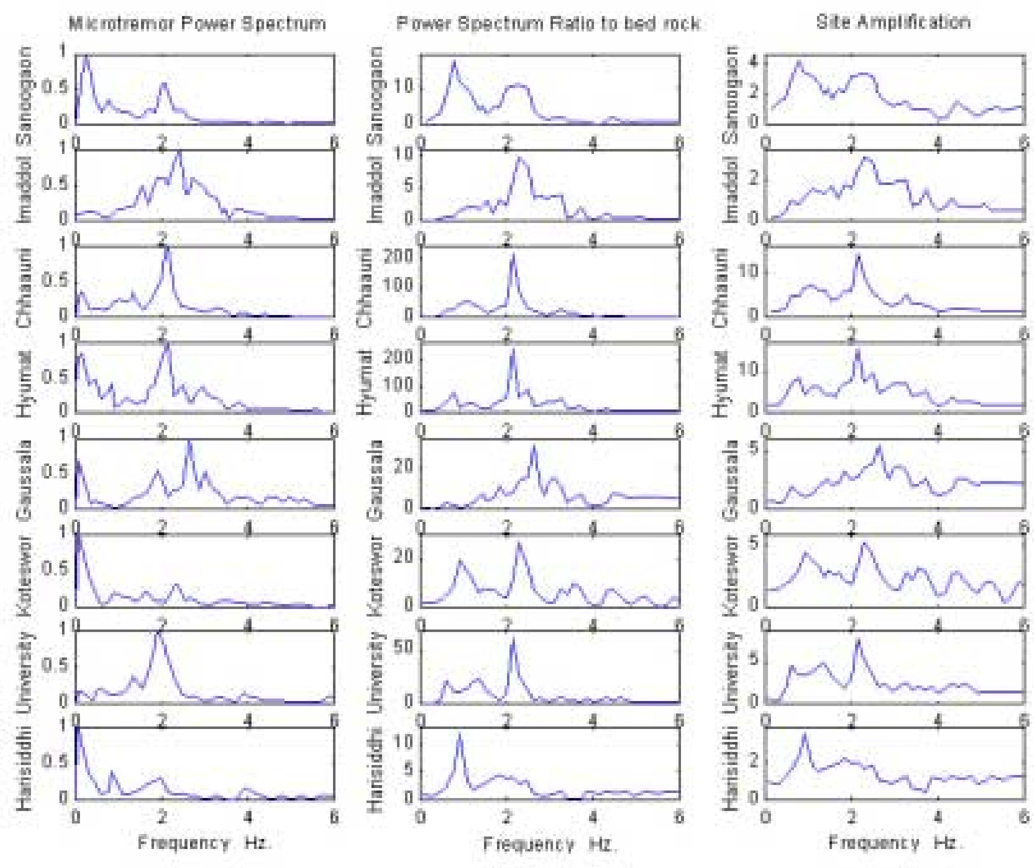


Fig. 3 - Horizontal component microtremor power spectrum at different sites. Sites Chhauni, Hyumat, Imadol located at lacustrine area. Gausala, Koteswor at the northern marginal area and Budhanilkantha at bedrock.

The brute horizontal microtremor noise is first processed for power spectrum (p.s.) output. Level of p.s. varies considerably in different sedimentary domain and within the same sedimentary domain. (Fig. 3). P.s. observed in bed rock exposure in the north of the basin (site Budhanilkantha) is taken as the reference spectrum for contouring the ratio of peak p.s. and spectral amplification study. The contouring of the ratio of peak p. s. at different sites to peak p. s. at the reference site is shown in Fig. 1. The high ratio of 10 to 200 is confined to the distribution of lacustrine facies characterized by high IX-X intensity in 1934 M8.3 earthquake. The northern and southern fluviatile area is generally characterized by low values. Some local clusters of contour 10 is observed at places.

Spectra of p. s. exhibit well correlated peak amplitude in the vicinity of 2 Hz. in different sites within the lacustrine and marginal sedimentary facies domain in the valley. (Fig. 4a). However, the background level of brutal spectra at different sites varies considerably at various sites and therefore needs to be normalized for quantitative estimation (Fig 3). Square root of the spectral ratio of normalized p. s of the site to the p. s. at bedrock at station Budhanilkantha is used for the quantitative assessment of site amplification.



(a) (b) (c)

Fig. 4 - (a) Brutal horizontal power spectrum (b) Horizontal power spectrum ratio to bed rock. Site spectrum are normalized to take into account difference in background level. (c) Site amplification as given by the square root of ratio in (b)

Theoretical amplification of SH - waves due to vibration build up corresponding to the geological section in lacustrine domain is quite consistent with spectral amplification curve derived from microtremor analysis for the Chhauni and Humat sites in lacustrine domain. (Fig. 5) The S - wave velocity of the adversely behaving lacustrine sediment is taken to be 600 m/sec. Bedrock velocity is 3000 m/sec. Peak spectral amplitude of soil amplification for 2 Hz. is in the range of 12 to 15. Root mean square amplification in the band 0.6 – 5 Hz. is 4.8 from model study and 5 - 6 from microtremor analysis. Comparision with real earthquake acceleration data is made for the 31 Jan. 1997 M5.5 earthquake with epicentre at latitude 28.08 N and longitude 85.29E. Spectral ratio of the acceleration data recorded at bedrock and at the site Lainchour located in the northern part of the lacustrine domain also exhibit a rms amplification of 4.4 for the 0.6 – 5 Hz. band.

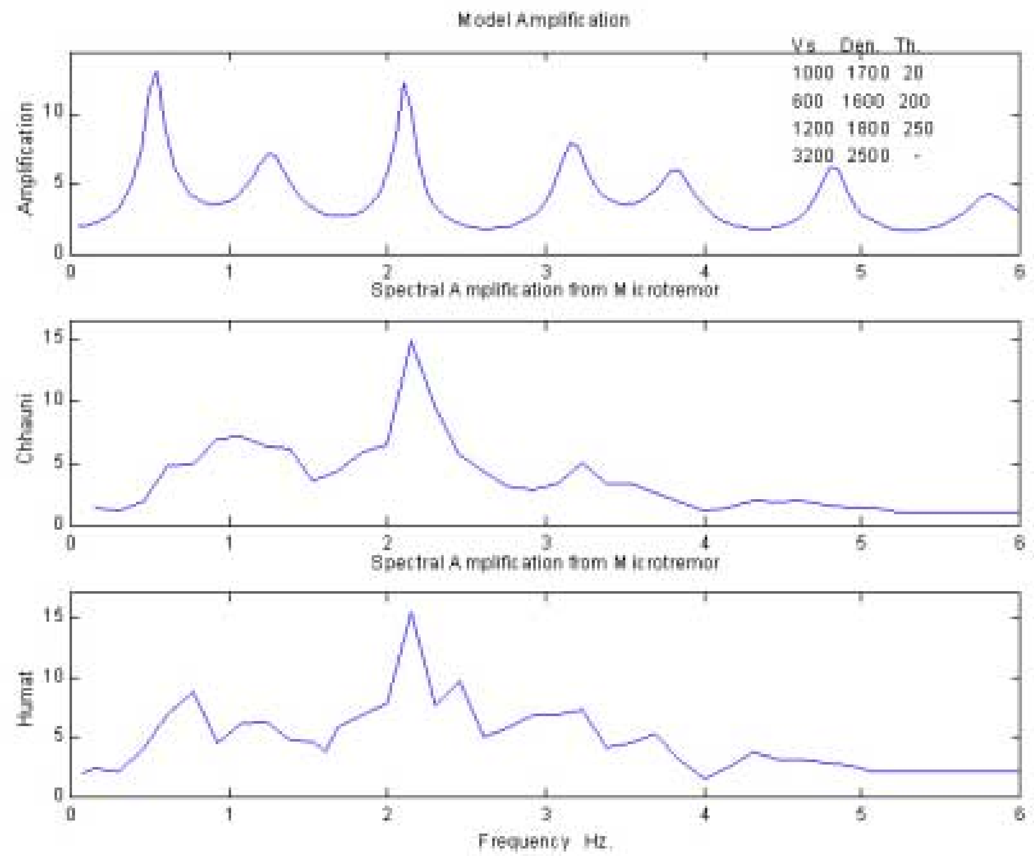


Fig. 5 - (Top) Theoretical amplification for vertical incidence SH – wave build up by multiple reflections. The model corresponds to lacustrine area. Model values in the right corner are S- wave velocity (m/sec), density (kg./m^3) and thickness (m). (Middle and bottom) Site amplification in Chhauni and Hyumat as derived from microtremor.

The consistency of model amplification spectra and the spectra of amplification from microtremor data in the adverse lacustrine area in frequency and amplitude suggests that the microtremor response can be used for the assessment of earthquake ground motion spectral amplification in the discussed band of 1-5 Hz. A rms amplification of 5 can be proposed supported by real acceleration data for the lacustrine area. The marginal northern and southern area seems to have a rms amplification of 2 to 3. The northern fluviatile area has no significant amplification due to unconsolidated sediment. However the peak amplification is as high as 15 for resonancing frequency near 2 Hz in the lacustrine area and may be responsible to cause worst earthquake hazard in the most vulnerable part of Kathmandu City.

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