4th Annual Paper Meet and 1st Civil Engineering Congress, December 22-24, 2011, Dhaka, Bangladesh ISBN: 978-984-33-4363-5
Noor, Amin, Bhuiyan, Chowdhury and Kakoli (eds) www.iebconferences.info

Microtremor measurements of two historical mosques in Bangladesh

M.A. Noor
Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh

M. Kamruzzaman
Department of Civil Technology, Chittagong Polytechnic Institute, Chittagong, Bangladesh

ABSTRACT: Ancient masonry structures are particularly vulnerable to dynamic actions, especially seismic actions. In this paper, microtremor measurements were conducted in the two selected historical masonry mosques which are situated in Dhaka city of Bangladesh, to determine the period of the site and assess the potential effects of soil structure interaction, which could have a significant effect on the seismic performance of the buildings during a severe earthquake.

1 INTRODUCTION

Bangladesh is located in a moderately seismic zone. During the last 240 years, a number of earthquakes including seven major earthquakes (M>7) have affected Bangladesh. In Figure 1 is shown Location of earthquake epicenter, at and near Bangladesh, occurrence period 1869 to 2000 (Yasin 2008). In 1897, The Great Indian Earthquake of magnitude 8.7 caused serious damages to buildings in the northeastern part of India (including Bangladesh) and 1542 people were killed. The 1999 Moheskhali Earthquake and the 2003 Rangamati Earthquake (Ansary et al. 2003) caused damages in cities and villages in southeastern part of Bangladesh. The extensive loss of life and property caused by earthquakes may be reduced to a considerable degree by the adaptation and implementation of improved design and construction procedures in this country.

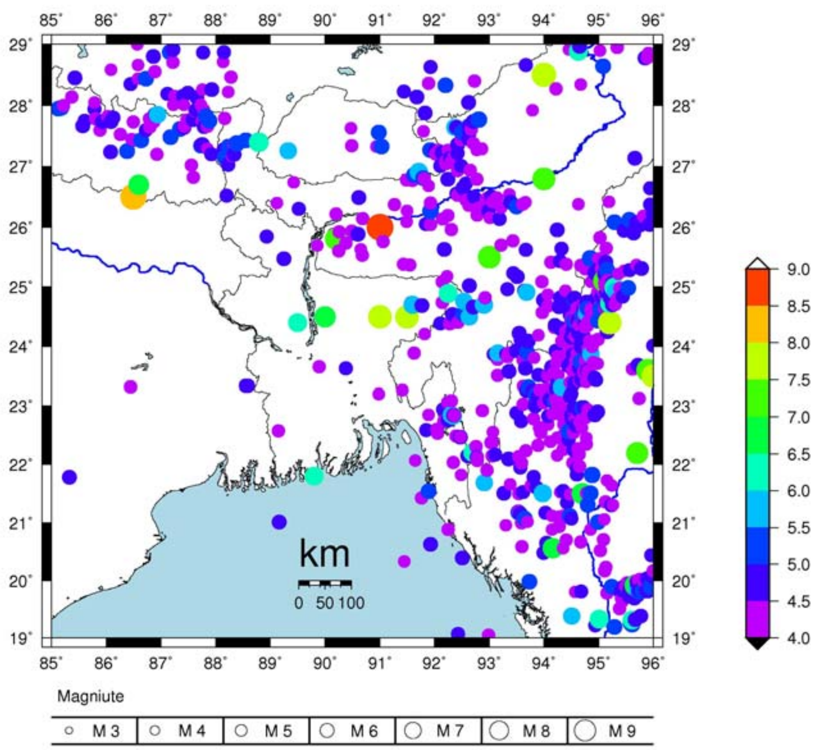

Figure 1. Location of earthquake epicenter, at and near Bangladesh, occurrence period 1869 to 2000 (Yasin 2008)

Ancient masonry structures are particularly vulnerable to dynamic actions, especially seismic actions. The identification of dynamic properties of buildings is therefore required and it will provide useful information to care for historical masonry structures in Bangladesh. The aim of this paper is to assess the seismic vulnerability of historical masonry mosques by using Microtremor measurements. Frequency of soil and structure can be assessed by microtremor measurement. Hard soil gives high frequency and soft soil gives low frequency. A structure may experience a vibration period at which it oscilates in the earthquake vibration motion and will tend to response to that. Natural frequency of structure is obtained based on the spectral ratio of horizontal component of the building to that of ground. Wave propagation mechanism of microtremor and its relation with ground vibration characteristics were studied from the beginning of microtremor studies (Aki 1957). Meanwhile practical application of microtremor in the field of engineering has advanced tremendously. One of the powerful and simplest applications of microtremor observation is in seismic micro zoning. This paper describes the building tested, the test and results, and the methodology and equipment used.

2 MICROTREMOR MEASUREMENTS

The purpose of conducting microtremor measurements is to obtain an estimation of site response for a particular location. Three approaches are commonly used to analyze microtremor data; power spectral densities obtained directly from the Fourier amplitudes, spectral ratios relative to a reference site, and Nakamura's technique2, which is defined as the spectral ratio of horizontal components to vertical components recorded at the same site. It is common to perform tests over a period of time to observe the stability of the measured site response, in order to provide a reliable prediction of the period of potential earthquake motion at that site.

Nakamura's technique describes the microtremors as Rayleigh waves propagating in a single layer over a half space, and assumes that the microtremor motion is due to local sources such as traffic and human and construction activity nearby. It further assumes that the vertical component of ground motion is not amplified by the soil layer. Hence, the spectral ratio of the horizontal to the vertical components at the surface gives an estimate of the period at which it peaks, corresponding to the site period.

The microtremor equipment consists of six velocity transducers; two horizontal and one vertical, an amplifier, an analog-to-digital (A/D) converter and a laptop computer used for data acquisition. For the selection of the test location, care is taken to avoid heavy traffic, manholes, foundations and other underground structures. The sensors are placed so that the two horizontal sensors are orthogonal, preferably facing North and East. The analysis is carried out using Nakamura's method, plotting the Fourier spectrum of the buildings. The most significant peak of the Fourier spectrum is taken to be the dominant frequency of the site.

For the purpose of the microtremor measurements, one sensor was placed on the top of the mosque and another one at the free field near this mosque. After taking the observation with the help of a program the time domain velocity data is converted to frequency domain data and find out the natural period of the mosques. Microtremor instrument with Battery, 3-component velocity sensor and microtremor observation are shown in Figure 2.

Figure 2. Microtremor equipment with Battery, 3-component velocity sensor and microtremor observation

3 DESCRIPTION OF SELECTED MOSQUES

The microtremor measurements were performed on two mosques in the Dhaka city of Bangladesh. Figure 3 shows the map of Bangladesh gives the location of the two selected historical mosque sites covered in this paper. The two mosques feature similar structural system with unreinforced masonry load bearing walls. And each of the two mosques were built in the early 17^{th} centuries. The following articles detailed descriptions of these Mosques are provided.

Figure 3. Map of Bangladesh showing the location of selected mosques

3.1 *Aambour Shah Shahi Mosque*

One of the most well preserved mosque complex of Dhaka city is the Aambour Shah Shahi Mosque. It is located at kawran bazaar in Dhaka City.

The mosque proper has the usual oblong shaped plan measuring 13.41m by 7.30m externally with a 1.2m thick along east-west direction and 1.6m thick along north-south direction brick wall. The prayer hall is entered from the eastern side by three archways and the other two side walls have also one arch opening each. Corresponding to the three frontal openings, the kibla wall is niched with three mihrabs. The rectangular shaped prayer room is divided into three square bays by two wide transverse corbelled cusped arches supported by twin brick pilasters embedded in the east and west walls. With the help of half domed squinch at each corner, each square area is transformed into a circular supporting area, upon which the dome supports. All the three domes, with a very low shouldered dome on a cylindrical drum, are crowned with lotus and kalasa finial. The central one is slightly higher than the flanking ones. Photo, plan and front elevation of the mosque are shown in Figure 4.

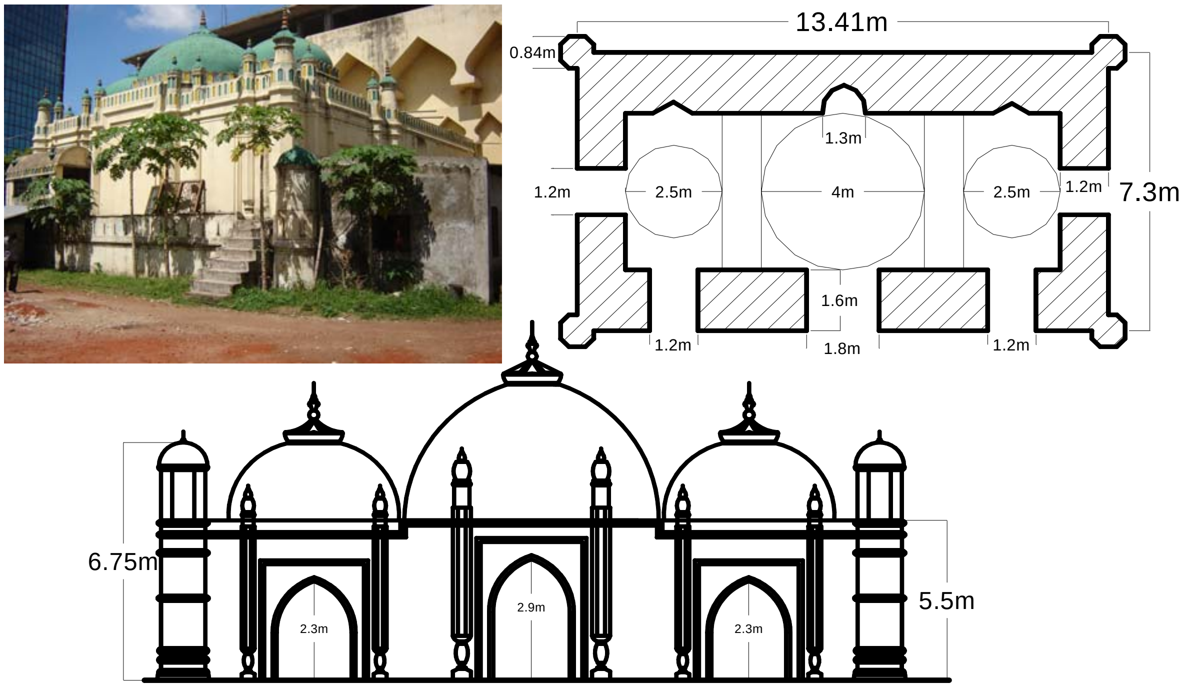

Figure 4. Fourier Spectrum of Aambour Shah Shahi Mosque with Photo, Plan and Elevation.

3.2 *Musa Khan Mosque*

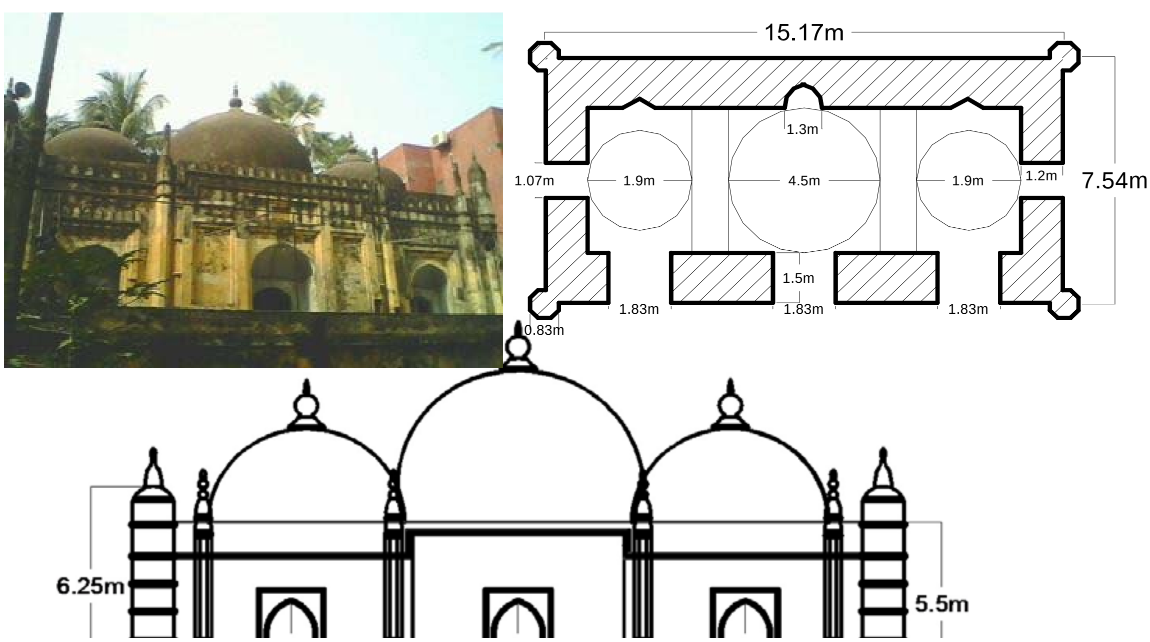

Figure 5. Fourier Spectrum of Aambour Shah Shahi Mosque with Photo, Plan and Elevation.

This mosque is located at karzon hall in Dhaka University. The musa khan mosque belongs to oblong shaped plan measuring 15.17 m by 7.54 m externally with a 1.52 m thick surrounding brick wall. The prayer hall is entered from the eastern side by three archways and the other two side walls have one pointed-arch openings each. To articulate the main mihrab niche from outside, the kibla wall is projected in the centre towards the west. The whole length of the rectangular hall is divided into three unequal bays by means of two 1.06 m wide arches springing from the east and west walls. The side bays are rectangular in shape and smaller in width, but the central one is bigger and square. With the help of brick pendentives the square central bay is transformed into an octagonal area. By introducing a series of sequences the octagonal area is transformed into a circular supporting area, upon which the dome supports. The two smaller rectangular side bays are converted into square supporting areas for the dome by using two half domed vault springing from the eastern and western walls. Photo, plan and front elevation of the mosque are shown in Figure 5.

4 RESULTS AND DISCUSSION

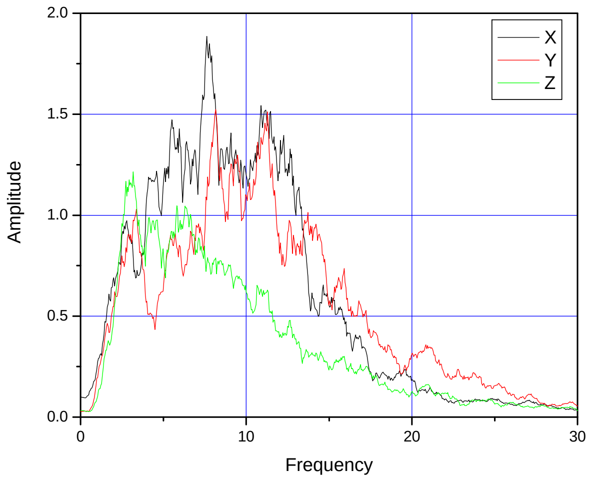

Figure 6. Fourier Spectrum of Aambour Shah Shahi Mosque

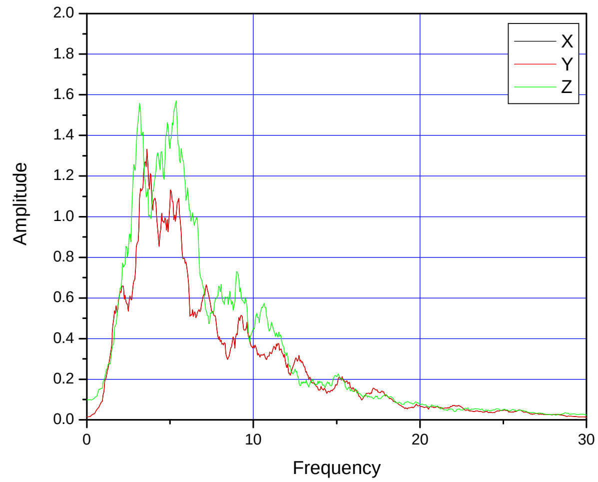

Figure 7. Fourier Spectrum of Musa Khan Mosque

The structural vibrations of the historical mosques are measured using Microtremor equipment. For the two locations described earlier in this paper, both vertical and horizontal measurements were recorded, with a sampling rate of 100Hz at Musa Khan Mosque, Karzan Hall, Dhaka university and Aambour Shah Shahi Mosque, Kawran bazar, Dhaka, and a duration of 10 minutes for each. The data processing was done with Origin software. Fourier Spectrum of Aambour Shah Shahi Mosque and Musa Khan Mosque are shown in Figure 6 and 7 (X, Y and Z represent North-South direction, East-West direction and Up-Down direction respectively), the pertinent information obtained is presented in Table 1.

Table 1. Microtremor Results

Test Location	Most Significant Peak of structures	Soil frequency
Musa Khan Mosque, Karzan Hall, Dhaka university, Dhaka	3.76 Hz	3.2 Hz
Aambour Shah Shahi Mosque, Kawran bazar, Dhaka	7.66 Hz	3.06 Hz

The Aambour Shah Shahi mosque is located at kawran bazar in Dhaka city. In this mosque, Building and soil frequencies are not nearest, 7.66 Hz and 3.06 Hz respectively. So it is not resonance frequency.

The Musa khan mosque is located at karzon hall in Dhaka University. The frequency of structure and soil of the mosque were found very close, 3.76 Hz and 3.2 Hz respectively. So, it is resonance frequency. And we also found similar Fourier spectrum in the North-South and East-West direction.

It was evident from the results of the microtremor tests that the site frequency for the Dhaka district is in the range of 7.66 Hz. This raises the possibility of soil-structure interaction and should be addressed for retrofit design considerations. The dynamic response of the buildings during a severe earthquake can be significantly affected by soil-structure interaction effects. This can also be of extra significance for older unreinforced buildings such as those in this study.

5 CONCLUSIONS

The intention of the tests described in this paper was to provide some preliminary information about the dynamic behaviour and the dynamic site conditions for two buildings in the Dhaka City. The results of the Microtremor tests were successful at obtaining the site periods for the two locations, which were 0.26 second for Musa khan mosque and 0.13 second for Aambour Shah Shahi mosque. The frequency found is in the range of the higher modes of the buildings and soil-structure interaction may be an issue, and should be considered for possible retrofit design.

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