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SEISMIC MICROZONATION FOR THE CITY OF ADDIS ABABA BY USING MICROTREMORS

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SUMMARY

Addis Ababa, the capital city of Ethiopia is located in the seismic region of the Country. The zoning map of the country was prepared earlier. However, the city has a varied ground formation ranging from rock to soft soil deposit, consequently a seismic microzonation map is essential. In the absence of strong ground motion records and scarce soil data, microtremor is found to be adequate. Microtremor measurements were made and analyzed. The Fourier amplitudes and predominant periods of microtremors are plotted on a GIS based map of the City and a seiesmic microzonation map of the city is produced.

INTRODUCTION

In East Africa a stress system has operated starting pre-Cambrian times (>570 million years). From early Tertiary (~65 million years) until the end of Eocene (38-37 million years) the region had been under intense vertical uplift producing the Afro-Arabian dome. As a result the region was trisected in to distinct crustal segments; The Arabian Segment, Nubian (African) Segment and, The Horn of Africa (Somalian) Segment. The main zones of weaknesses are located along the Red Sea, Gulf of Aden and East African rift system. From early Tertiary onwards these zones of weaknesses have been under tensile stress causing boundaries to diverge and are moving apart from each other. This movement, which became predominantly lateral in the Miocene (12 million years) is continuing to the present time without interruption, Gouin [1]. This spreading is a tectonic deformation which as consequence made the region an active tectonic and volcanic zone. According to some estimates the relative motion between Arabian

and Nubian plates is about 2 cm per year and in the Afar region about 0.31-0.58cm per year Oliver and Boyd [2]. Due to these phenomena 90% of the seismicity and volcanic activity of Ethiopia is related to the East African rift system

The city of Addis Ababa which is located at about N9.02 and E38.45 is near the western escarpment of the rift valley. The city is the Economic, Political and Social center of the Country- a center where catastrophe of any sort will have a server consequences. Since its founding a century ago, a number of seismic activities have occurred. Theoretically the city is not the most seismically active region of the country. However if one projects the possible damage that could occur with in possible range of its' seismic activity, it would be severely hit. An earthquake of lesser magnitude occurring near a population center will have a significant effect while an earthquake of magnitude hundred times bigger in a remote place will pass un noticed except by seismic stations and seismologists. Addis Ababa has witnessed a number of earthquakes in 100 years of its existence, some are: the 1906 an earthquake of magnitude 6.8 at epicentral distance of about 100 km south of Addis , the 1961 an earthquake of magnitude 6.6 occurred at a distance of 200km (Karakore Earthquake), the July 1997 an earthquake with magnitude 4.0 at a distance of 22 km to the south west of the city. Some other earthquakes of smaller magnitude and at far distance (in 1977, 1984 and 1985) were felt at upper story of high rise buildings, Asfaw,[3]

A critical case for Addis Ababa could be the reoccurring of an earthquake like that of 1906. In 1906 an earthquake of magnitude 6.8 occurred at epicentral distance of 100 kms or less from Addis Ababa, then an intensity of greater than VII (M.M) is expected and with concentration of population and multi-story buildings here and there the lift loss and property damage could be disastrous unless the awareness and the preparedness exists.

Seismic zoning map was prepared for Ethiopia based on past earthquake data and applying attenuation relations expressing tectonics and seismicity of regions having geological similarity with Ethiopia, .Gouin, [4], Asfaw [5} Seismic microzonation maps provide information on return period of earthquakes with given magnitude, intensity and acceleration.

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At its source, earthquake is influenced by source stress, rapture propagation radiation pattern etc. After emanating from the source, waves traveling along different travel paths are modified depending on path parameters such as geometric spreading, absorption, inhomoginity etc. At sites of interest further modifications are made by surface conditions, topography and by soil structure interaction (where structures exist). The general zoning map , MoWUD [6] is produced in a regional basis for the whole of Ethiopia. Areas in one seismic hazard zone in this map can be further divided into sub zones to account for the effect of a site on an incoming earthquake this is what is known as seismic microzonation. Site response is widely recognized as an important factor that must be accounted for in micrzonation or specific site effect evaluation studies for important facilities.

In regions where seismicity is low to moderate, recording a representative sample of earthquake is difficult. Moreover, it may be difficult to obtain simultaneous records on the soft soil stations and on the hard rock reference stations; a proposed alternative is to use records of ambient seismic noise called microtremors. This technique is used in this study because of the following reasons:

1. The city of Addis Ababa has moderate seismicity and strong ground motion data are not available.

2. Even if low to moderate earthquake occurred several times in the past they were not recorded so as to be used for microzonation purpose.

3. Microtremor reading does not need subsurface exploration, expensive laboratory tests and expensive computation. It is also possible to cover a large area within a short period of time.

From the above it was more apparent that the seismic microzonation of Addis Ababa by using microtremors is the most suitable

INSTRUMENT USED AND IT'S OPERATION

Instruments used for this study can generally be presented schematically as shown in (Fig. 2). A set of three highly sensitive seismometers(Fig 3) which are arranged in two orthogonal directions i.e., UD (up-down) and NS (north-south), were used to pick up the noise from the ground.

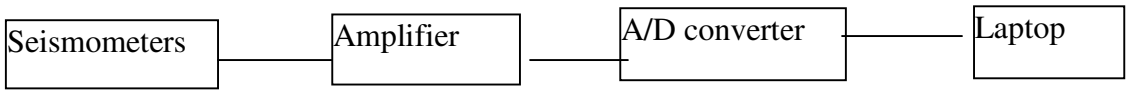

Figure 2. Instrument arrangements for microtremor reading.

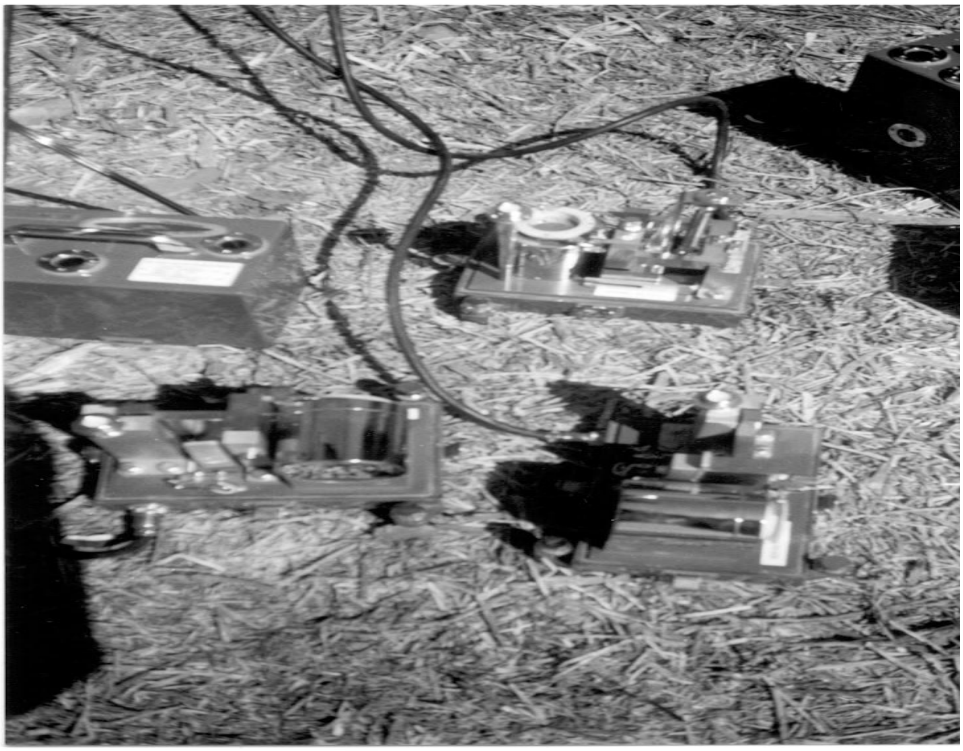

Figure 3 Seismometers used in the study after removing the cover.

Various instruments are available for ground motion measurement. The simplest type of all can be illustrated by a mass-spring-damper single-degree-of-freedom (SDOF) system.

A rotating drum is connected to the housing by a spring and dashpot arranged in parallel, and the housing is connected to the ground. Since the spring and dashpot are not rigid the motion of the mass will not be

identical to the motion of the ground during movement. The relative movement of the mass and the ground will be indicated by the trace made by the stylus on the rotating drum. This arrangement can be designed to measure various ground motion characteristics. The results obtained are AD converted and rerecorded on laptop computer and analyzed directly

PHASES OF THE STUDY

This study has four phases to come to the final stage.

1. A continuous microtremor reading was done for twenty-four hours at the Technology Faculty of Addis Ababa University. This was done in order to confirm the stability of microtremors in 24 hours duration, i.e, to study the effect of time of the day on amplitudes of microtremors. In this case the microtremors showed variation confirming to human cultural activity. The showed maximum amplitude in the morning between 7 and 9 am, Mid day and end of working hours, 4-6 p.m. They showed some decrease when people are at work. More decrease was observed in the evening and after mid night until 7 am in the morning the amplitudes where small. The predominant periods remained constant. As this is a normal pattern for microtremors, it was proceeded to the second step
2. Conformation of applicability of microtremor for the purpose of site effect indication or seismic microzonation in Addis Ababa by comparing anlytical method for locations where borehole data is available and comparing with the results obtained from microtremor measurments for the same spot. In this study 5 places for which bore hole data are available are chosen and 1D equivalent linear analysis was made by using the software SHAKE , Schanbel [5]. The predominant periods obtained for this sites from microtremor and analytical method are compared (Table 2). The results showed acceptable level of similarity. The difference are attributed to the fact that the multiple layers with little velocity contrast, that are properly considered in the analytical procedure are in some cases overlapped in microtremors method of measurement and analysis

Table 2 Comparison of predominant period for the top layers obtained from analytical procedure and microtremor measurement. The predominant period of the upper layers from both cases is considered for easy comparison purpose

Location of site in Addis Ababa	Predominant period Analytical procedure	Predominant period Microtrmors
NISCO Head office building	0.1	0.1-0.13
Finfine Furniture Factory	0.06	0.05

Awash Insurance/Bank Building	0.1	0.11
Alem Building	0.1	0.1
Bekele Abshiro building	0.08	0.1

1. Completing the first two phases confirmed applicability of microtremor in Addis Ababa for seismic microzonation purposes satisfactorily. The next step was to take microtremor reading of point data at selected points far apart but which cover the whole city. By tahing a grid of 5 by 5km. The result gives very rough idea on amplitude and predominant period of microtremors in the city. The exact location of the points is determined as marked with GPS receiver. After that Fourier analysis was performed to these data and site period as well as relative amplifications were identified for each reading site. The results for the Fourier Amplitude for this stage is presented in Fig 4.

Symbol	Fourier Amplitude
diamond	> 10
square	5-10
circler	4-5

star	3-4
plus	2-3

Fig.4 Maximum Fourier Amplitude of Microtremors

1. If the three above sites indicates the possibility of applicability of microtremor measurements for seismic microzonation purposes in the city, then the next step is to make more dense measurements and to prepare seismic microzonation maps. In this step microtremor measurements were done for the main part of city of Addis Ababa. Some areas that are not densely populated are not included in this study. Each point of measurement was marked in x, y, Z by a GPS and the points are transferred to a GIS map of the City. Fourier amplitude and predominant periods are determined for each measurement site. The numerical value for locations between measurement sites is obtained by interpolation. Finally the seismic microzonation map of the more developed part of Addis Ababa is prepared by using Fourier amplitude(Fig 5) and Predominant period(Fig 6)

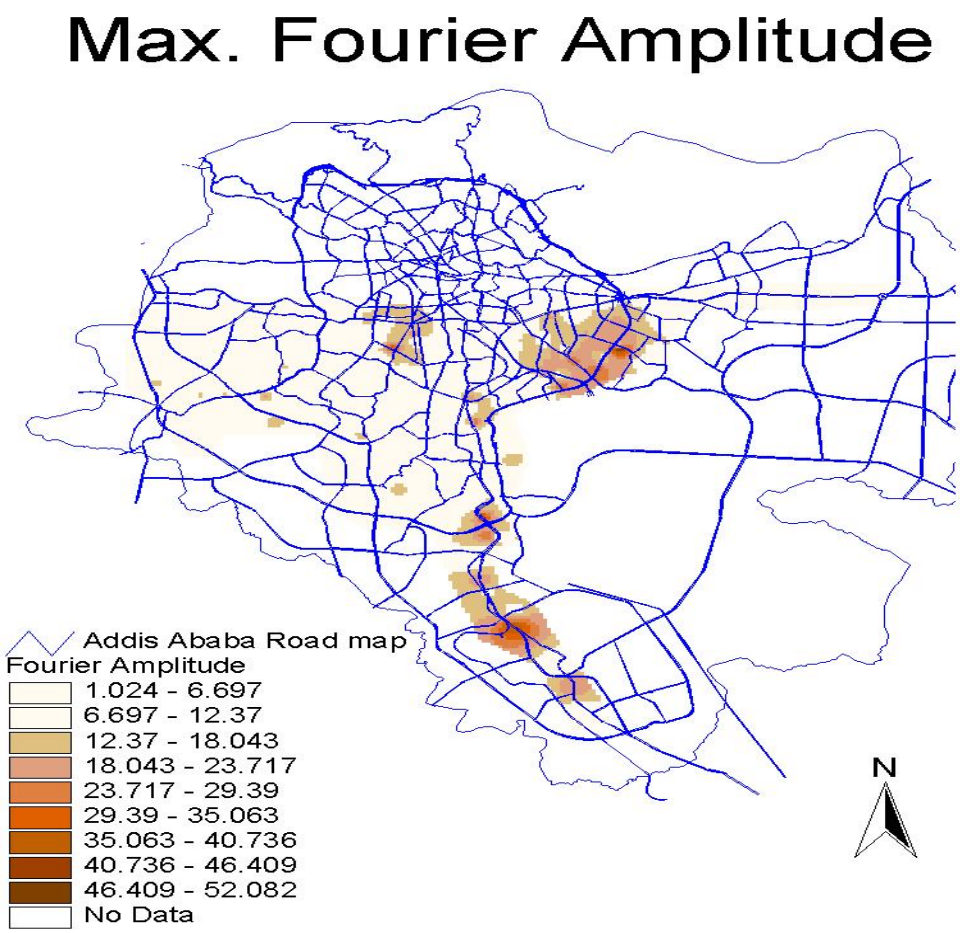

Fig 5 Fourier Amplitude Spectra of Microtremor Measurements for The City of Addis Ababa

It should be noted that such rigorous steps are followed first to confirm if microtremors can be used in Addis Ababa. In areas where the ground formation is extremely irregular and the velocity contrast between base and deposits and among the layers is small, the use of microtremors is very difficult. Therefore before applying microtremors for site use one should confirm its applicability for the particular locality

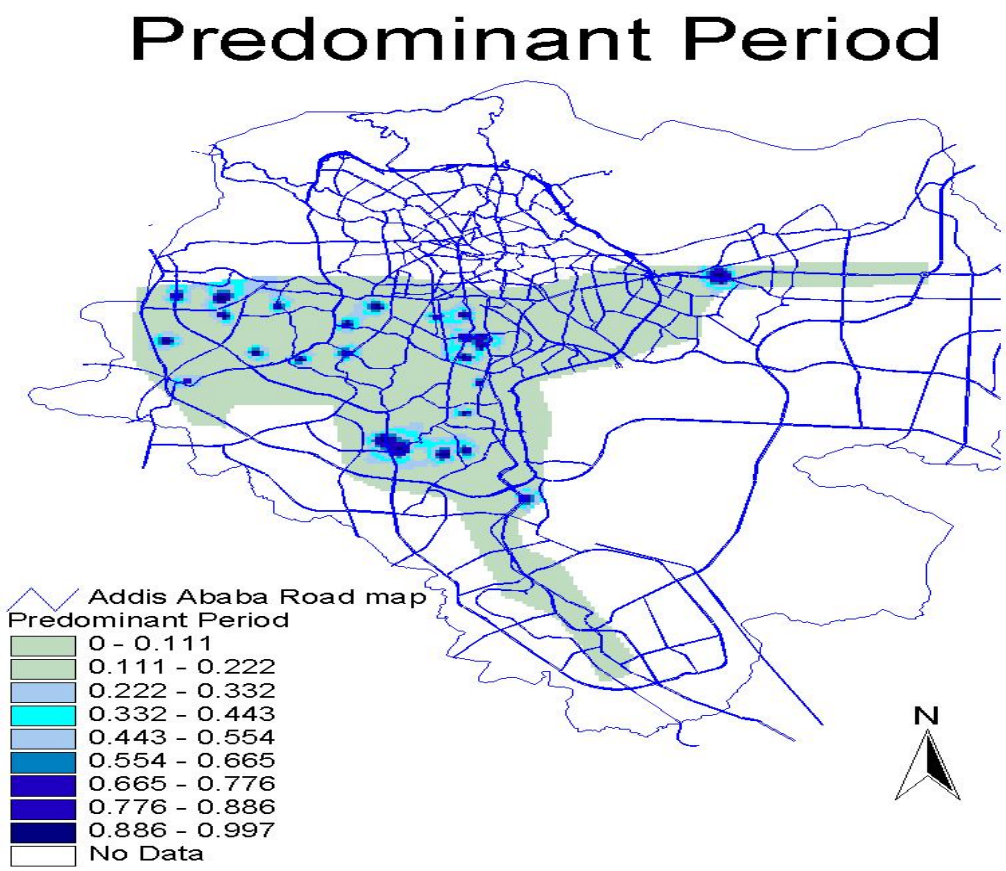

Fig 6 Predominant Periodof Microtremor Measurements for The City of Addis Ababa

CONCLUSION

1. The above study showed that microtremors are applicable for seismic microzonation proposes in Addis Ababa
2. It showed that carefully measured microtremors and analytical method based on borehole date could give close results
3. The study clearly showed that microtremors are effective in areas where strong ground motion is scares or is not available, specially in areas of moderate seismicity.

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