
13th World Conference on Earthquake Engineering
Vancouver, B.C., Canada
August 1-6, 2004
Paper No. 159

# MICROTREMOR MEASURMENTS IN THE AFFECTED AREA OF THE CHANGUREH-AVAJ, IRAN EARTHQUAKE OF JUNE, 2002

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## SUMMARY

A great many buildings were severely damaged or collapsed mostly in rural areas during the earthquake that struck the northwestern part of Iran on June 22, 2002. The authors carried out microtremor measurements during a reconnaissance visit dispatched by the Japan Society of Civil Engineers (JSCE) about one month after the earthquake. To examine the ground surface and structural seismic response characteristics in the stricken area, microtremor measurements were conducted on the ground surface in several locations in Abdareh Village, in which almost 100% of the adobe dwellings were completely destroyed, and on an adobe house in Tablashkin Village. A Fourier analysis, based on the H/V spectral ratio, was made to explore the relationship between the strong ground motion of the earthquake and the damage done which may have been affected by local site conditions. Building damage could be explained by the good compatibility between ground microtremor findings and the dynamic characteristics of adobe buildings which collapsed in many places but survived in part of Abdareh.

## INTRODUCTION

The Changureh-Avaj earthquake of 22 June, 2002, $M_w$ = 6.3 (07:28 local time, 02:58 GMT) was strongly felt in most parts of northwest Iran. The epicenter, about 250 km west of Tehran, was in a roughly east-west oriented valley just west of Abegarm Village (Fig. 1, IIEES, [1]). The greatest damage occurred in the villages of Abdareh and Changureh. The official report lists 230 fatalities, 1,466 injured, and more than 50,000 people left homeless. The earthquake affected 4 cities and 50 villages (most of which were partially damaged) in four provinces. The macroseismic intensity of VIII+ (EMS-98 scale) was assigned to Abdarreh and Changureh in the epicentral area. Based on the length of the surface fissures and estimated focal depth of 7 km, the magnitude $M_w$ = 6.3 was estimated for this event. Preliminary source parameter estimates indicate a high stress drop and fast ground motion attenuation (Zare, [2]).

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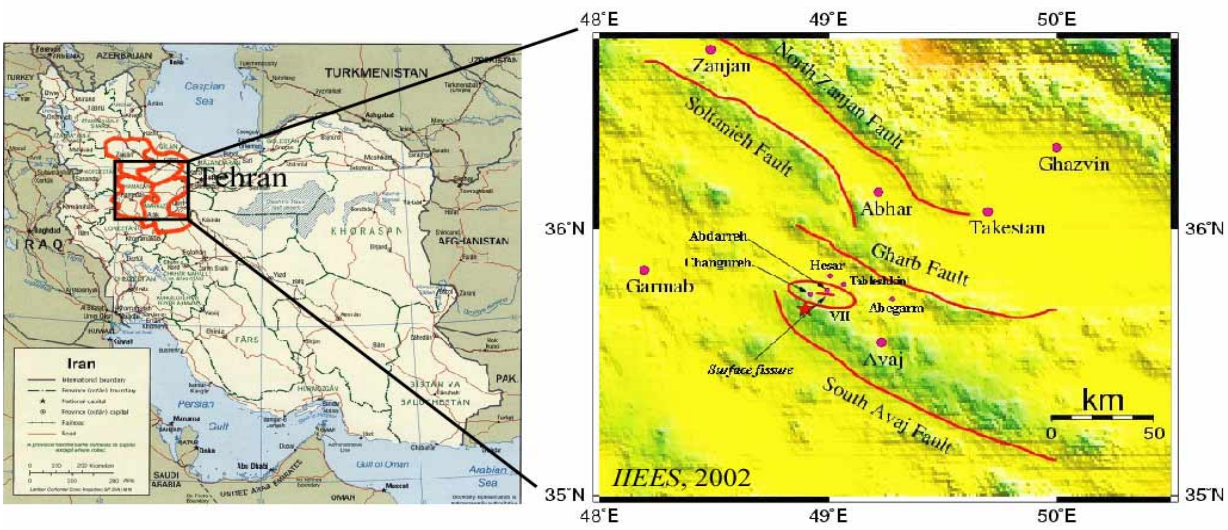



**Fig. 1 Site map showing the earthquake affected area**

## MICROTREMOR MEASURMENTS

Microtremor measurement is a very useful method for obtaining ground dynamic characteristics, including the predominant period and the site amplification factor (Enomoto, [3]). To examine the ground surface and structural seismic response characteristics in the earthquake-stricken area, microtremor measurements were conducted in several locations in Abdareh Village, in which almost 100% of the adobe dwellings were destroyed, as well as on an adobe house in Tablashkin Village. Moreover, a forced vibration test that used human strength was conducted on an adobe house. The dynamic characteristics of the house were determined from the free vibration results. To make these measurements, highly sensitive SPC-35N (Tokyo Sokushin) seismometers with three orthogonal components each, two horizontal (H) and one vertical (V), were used. Velocity amplitudes of microtremors at a sampling frequency of 100 Hz with a 0.1 Hz high pass filter were measured. Each record at a point had a time history duration of 300 seconds which, after excising the visible noise, was divided into 5 segments with 1024 data each. A Fourier analysis, based on the H/V spectral ratio, was made for each segment. The mean spectrum was smoothed by a Parzen window of the 0.4 Hz band. Because of the valley-shape topography of Abdareh, there the Fourier spectra were considered separately for the EW and NS directions and the geometric average of the two directions was calculated to determine the predominant period of the ground surface at each measurement site. Taking into account the natural period of a typical adobe house, the relationship between the strong ground motion of the earthquake and the damage done, which may be affected by local site conditions, is discussed.

## MICROTREMORS ON THE GROUND SURFACE IN ABDAREH

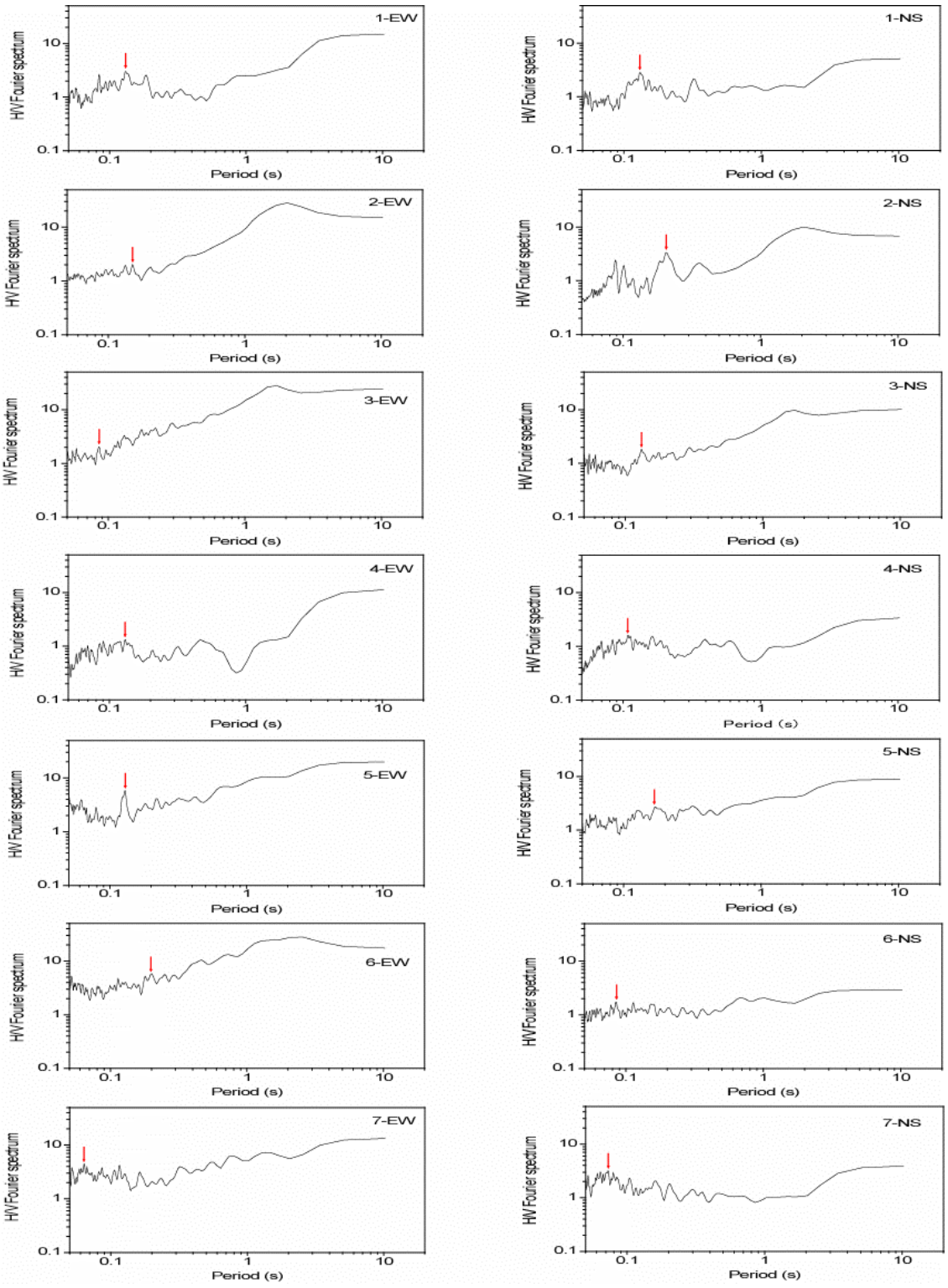
In Abdareh, tremors were measured on the ground surface at 7 stations, whose positions are roughly indicated in Photo 1. These stations were chosen because they all are located approximately along the fault trace. In each measurement, two horizontal (H: EW and NS) and one vertical (V: UD) components of the tremors were recorded.


**Photo 1 Microtremor measurement station sites in Abdareh**
**(Photo: Majid Noorallahpoor, Iran)**

The smooth mean H/V Fourier spectral ratios of the noise-free segments of the tremors at stations Nos. 1-7 in the two EW and NS directions are shown in Fig. 2. This figure shows that amplitudes in the EW direction, along the cross section of the valley and roughly along the fault trace, are larger than those in the NS direction. Considering that the predominant period range of ordinary ground is less than 1 s and according to the dynamic characteristics of the sensors, the predominant periods of the ground surface at the measurement sites, the highest peaks on the H/V graphs, were from 0.05 s to about 1 s shown by the arrows in Fig. 2. The Fourier spectra of the geometric average (square root of the products) of the EW and NS components were used to determine the predominant periods of the ground surface at the measurement sites (Fig. 3). Based on the criteria in Kanai [4], the ground conditions were evaluated as Class 2 (medium) at station No. 2, and as Class 1 (good) at the others. As seen, station No. 7 which had the lowest predominant period, 0.06 s, has the hardest ground surface of all the sites, which is in good agreement with the earthquake-induced damage, because in that area of Abdareh alone, some 50 % adobe houses survived (Photo 1). Another factor in damage interpretation is the taking into account of the dynamic characteristics of structures. A forced vibration test therefore was conducted on an adobe house in Tablashkin Village.

## MICROTREMORS AND FORCED VIBRATION TEST ON AN ADOBE HOUSE IN TABLASHKIN

Microtremor measurement and forced vibration test were conducted on an adobe house in Tablashkin Village, which is located far from the epicenter unlike the villages of Abdareh and Changureh. Whereas in the latter villages almost all the adobe dwellings were destroyed, Tablashkin Village had a different appearance although there were some collapsed and many damaged dwellings. A typical adobe house was selected, and the measurements were made to obtain its natural period. The plan and view of the test




(a) EW components (b) NS components

**Fig. 2 H/V Fourier spectral ratios of microtremors at stations Nos. 1-7**

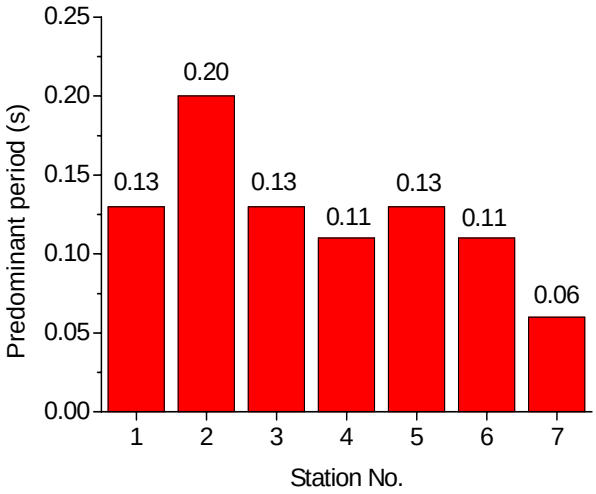



**Fig. 3 Predominant periods of the ground at the microtremor measurement stations in Abdareh**

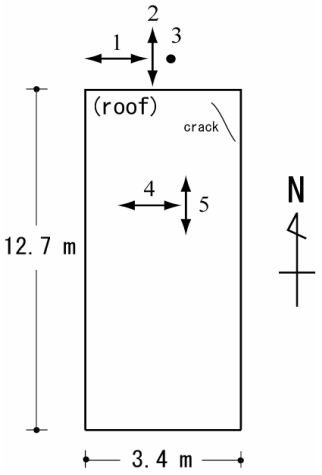



**Fig. 4 Plan of the adobe test**

**Photo 2 View of the adobe test**

house respectively are shown in Fig. 4 and Photo 2. The house height is 2.9 m, the lower 0.8 m of which is stone wall and the upper 2.1 m adobe.

The first set of measurements made was for simultaneous microtremors in five channels (Chs.1 to 5 in Fig. 4): three on the ground surface (two horizontal, one vertical), and two horizontal on the roof of the house in the transverse and longitudinal directions. The two horizontal channels on the ground (Chs.1 and 2) were set parallel to those on the roof (Chs.4 and 5). In a 300 s-duration recording, an analysis similar to that explained previously was followed. The H/V Fourier spectrum for the ground surface was determined, which showed the predominant period of the ground 0.2 s. The spectral ratios of Ch.4/Ch.1 and Ch.5/Ch.2 respectively give the amplification spectra in the transverse and longitudinal directions (Fig. 5), in which the respective natural periods of the house in the transverse and longitudinal directions are 0.2 s and about 0.08 s.

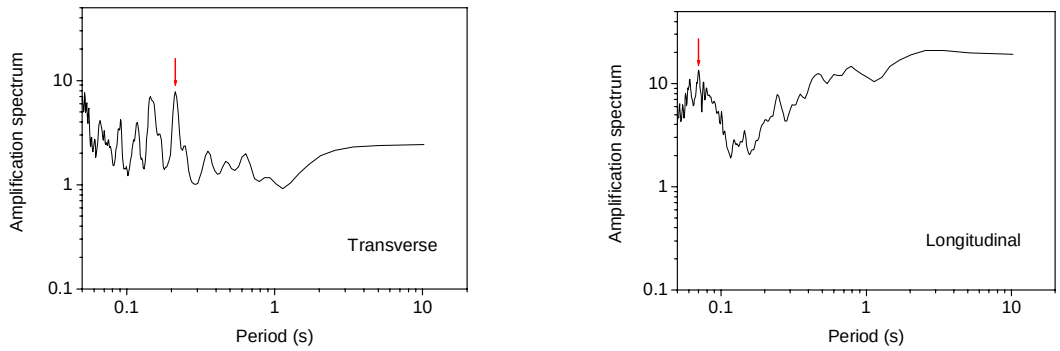



**Fig. 5 Amplification spectra of the adobe test house in the transverse and longitudinal directions**

**Photo 3 Forced vibration test on the adobe**

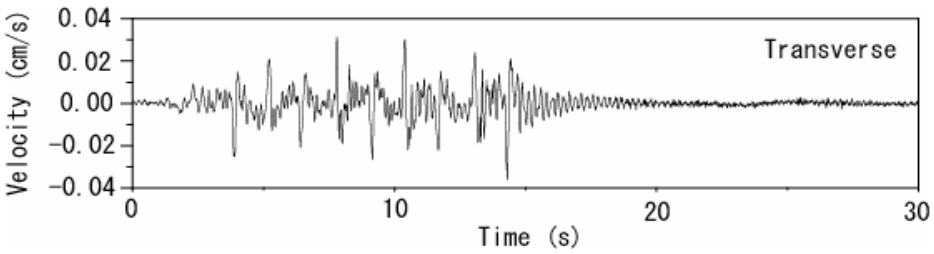



**Fig. 6 Transverse recording of shaking by forced vibration on the roof of the adobe test house**

A forced vibration test was performed on the adobe house for tremors generated by human swaying on the roof in the transverse direction (Photo 3) to distinguish the natural period and damping ratio of the house in that direction from the ensuing free vibration. The transverse direction dealt with in Fig. 6, shows the recorded time history, in which about the last 15 s is that of free vibration. The Fourier spectrum of this part gives the natural period of the house as 0.2 s, which is the same as the results of the microtremor experiment. Furthermore, using that part, the damping ratio of the house was calculated to be about 3%.

## CONCLUSIONS

Microtremor measurements were made on the ground surface in Abdareh Village and on an adobe house in Tablashkin Village. The measured microtremors in Abdareh were in good agreement with the damage done by the earthquake. The focus here was on adobe houses, because, although adobe houses are very vulnerable even to mild earthquakes, the remarkable difference in ground conditions in one area of the village was the main reason for relatively less damage being done to adobe houses there (Fallahi, [5]).

In rural areas, adobe houses are very similar in size, usage, and method of construction, and therefore in their dynamic characteristics. Because no undamaged adobe house survived in Abdareh, microtremor and forced vibration tests were carried out on a typical adobe house in Tablashkin. From the findings for that house, its natural period was 0.2 s and the damping ratio about 3%. Because the predominant period of ground during an earthquake is larger than during microtremors owing to the nonlinear effect, most of the predominant periods of the ground surface at the measurement stations in Abdareh (Fig. 3) are concluded to have shifted to 0.2 s or more, and therefore amplification led to widespread severe damage.

## ACKNOWLEDGMENTS

The authors greatly appreciate the funding by the Japan Society of Civil Engineers (JSCE) which enabled the reconnaissance. We also are grateful for assistance provided by Dr. R. Alaghebandian, Assistant Professor of Tehran University, during all measurements. And, valuable comments of Dr. T. Ikemoto, Research Associate of Kanazawa University, on the microtremor analysis are highly acknowledged.

## REFERENCES

1. International Institute of Earthquake Engineering and Seismology (IIEES) website. *http://www.iiees.ac.ir/*.
2. Zare M. “A seismological overview of the Changureh (Avaj, Iran) earthquake of 22 June 2002, $M_w$=6.3.” Observatories and Research Facilities for European Seismology, Orfeus Newsletter 2002; 4(2): 1-12.
3. Enomoto T, Kuriyama T, Abeki N, Iwatate T, Navarro M, Nagumo M. “Study on microtremor characteristics based on simultaneous measurements between basement and surface using borehole.” Proceedings of the 12WCEE, Auckland, New Zealand, Paper No. 0918, CD-ROM, 2000.
4. Kanai K. “Engineering seismology.” Tokyo: University of Tokyo Press, 1983.
5. Fallahi A, Alaghebandian R, Miyajima M. “Microtremor measurements and building damage during the Changureh-Avaj, Iran Earthquake of June 2002.” Journal of Natural Disaster Science 2003; Vol.24(2): 43-52.