# PRELIMINARY RESULTS OF BRISBANE MICROTREMOR SURVEY

R. CUTHBERTSON, M. WINTER AND S. JAUME
QUEENSLAND UNIVERSITY ADVANCED CENTRE FOR EARTHQUAKE STUDIES

## AUTHORS:

Russell Cuthbertson obtained his B.Sc. (hons) in Seismology from the University of Melbourne in 1979. He worked at the Seismology Research Centre, RMIT from 1976 to 1979, and at the Queensland Department of Minerals and Energy from 1979 to 1993. He joined QUAKES as a staff seismologist in 1993.

Michael Winter obtained a B.Sc. in Geophysics from the University of California at Los Angeles. He is currently working on a Ph.D. in Seismology at The University of Queensland, studying intraplate earthquake hazard at QUAKES.

Steven C. Jaumé received a Ph.D. in Geological Sciences (Seismology) from Columbia University in 1994. He was a postdoctoral seismologist at the University of Nevada-Reno's Seismological Laboratory from 1994 through 1995. In 1996 he joined the staff of QUAKES and began working on earthquake hazard in Queensland.

## ABSTRACT:

A detailed microtremor survey of Brisbane has involved personnel from both the Australian Geological Survey Organisation (AGSO) and the Queensland University Advanced Centre for Earthquake Studies (QUAKES). Data from over 900 sites, which are being analysed using the Nakamura Ratio technique, has shown that while the technique is simple and quick there are severe restrictions on its applicability. The technique has shown resonances in some locations where a flat response would be expected and inconsistent results in others. The only area where the technique produced consistent resonances in line with expectations was around the Brisbane airport and port areas. These areas are characterised by having significant depths of man-made fill overlying unconsolidated Cainozoic sediments. It is concluded that the condition of flat-lying layers with a high velocity contrast between the basement and surface layers is an essential requirement for the technique to be successful.

# 1 INTRODUCTION

The Brisbane microtremor survey is being conducted jointly between the Australian Geological Survey Organisation (AGSO) and the Queensland University Advanced Centre for Earthquake Studies (QUAKES) as part of the AGSO Cities Project. Recordings of microtremors, taken at over 900 sites, are being analysed using the Nakamura Ratio technique with the aim of producing maps showing the effect of local geologic conditions on the degree of shaking during an earthquake. These maps will be of use to town planners, engineers and emergency services personnel and they may also be incorporated into future building codes.

# 2 NAKAMURA RATIOS

A microtremor survey involves using a three-component seismograph system to record the seismic background noise (termed microtremors) that originates both from man-made sources (eg. traffic, trains, pumps, generators) and natural sources (eg. surf, wind). The ratio between the spectrum of the horizontal motion and the spectrum of the vertical motion (Nakamura Ratio) has been used by numerous researchers as an indication of the seismic response at a site.

The technique assumes that the microtremor noise is composed primarily of surface waves propagating as Rayleigh waves. It further assumes that the response function obtained, which is an indication of Rayleigh wave response, also represents the response function to vertically incident S-waves. It has also been shown that the technique requires there to be a significant velocity contrast between the surface layers and the bedrock[(1)], and that the layers be essentially flat lying[(2)].

There is considerable debate as to the applicability of the technique[(3,4)] with the success or failure of its application depending in some degree o the assumptions noted above. There is some agreement that, while the degree of amplification is not well represented by the Nakamura Ratio, the fundamental resonant frequency can be estimated within reasonable limits[(3)].

While the technique makes several assumptions and is only applicable in particular circumstances it does have the advantage of being very quick compared to other site response techniques. This means that an area can be covered with a large number of sites to find those sites that require more detailed study with other techniques.

# 3 BRISBANE MICROTREMOR SURVEY

## 3.1 FIELD PROCEDURE

The field plan concentrated on the suburbs closest to Moreton Bay, that are situated on deep Cainozoic sediments, as well as those suburbs situated on Mesozoic beds. The areas of Palaeozoic sediments, metamorphics and intrusives to the west of the city centre were assumed to have no resonance effects and so were sampled at more widely spaced intervals.

Personnel from AGSO and QUAKES took recordings at over 900 sites covering Brisbane city and surrounding areas. Sites were generally selected to be away from very busy roads. Sensors used were short-period (1 Hz) Sprengnether L4C-3Ds and broad-band (30 s) Guralp CMG-40Ts. These were simply placed on compact, level ground – usually by the roadside or on the footpath.

## 3.2 PROCESSING

The recorded seismograms were divided into subsets (or "windows") so that multiple Nakamura Ratios could be estimated. This provided an estimate of the stability and quality of the ratio which could not be obtained with a single ratio from the entire seismogram.

Seismograms were first detrended and cosine tapered (at 5%), then high-pass filtered before being divided up into windows with a 20% overlap between successive windows. Detrending and cosine tapering (at 5%) was then again performed on each individual window. The spectra for the horizontal and vertical components were then calculated and smoothed using two passes of a box-car filter of width 0.2 Hz before the Nakamura Ratio was determined. A mean and standard deviation of the Nakamura Ratio was then calculated at each frequency by assuming the variation of the ratios estimated from each window was distributed log-normally.

## 3.3 TESTS

Analysis of recordings showed that a record of 150 seconds duration was sufficient to satisfactorily determine a stable mean. Longer records only served to reduce the standard deviation of the ratios about the mean. The majority of the survey was conducted using records of 200 seconds duration.

Large amplitude noise bursts created by nearby sources of seismic noise (usually traffic or pedestrians) had little effect on the calculated mean ratio but were nonetheless removed from further analysis.

We found that the method used to combine the two horizontal components into a single spectrum did not affect the results. We chose to combine the horizontal components by summing them in quadrature.

Several seismograms were processed by varying the length of the windows into which they were divided from 5 to 50 seconds. The means of the ratios obtained using the shorter length windows were generally smoother than those from the longer windows. This was because of the higher number of windows from which to determine the mean. The spectral resolution was reduced for the shorter windows which resulted in significantly more random fluctuations of the individual ratios after processing with the constant-width smoothing filtering. This resulted in large standard deviations for records processed with the shorter length windows. As the window lengths were increased the standard deviations decreased but the means became more irregular. A compromise was reached with a window length of 20 seconds which meant there were up to 12 windows for a 200 second record (with 20% overlap between windows).

There was some variation in the results obtained when sites were reoccupied on different days and sometimes with different equipment. Some of this variation may be due to the different sensor responses but we feel there is also an inherent variability in the background noise field. This lack of repeatability is a serious limitation of the Nakamura Ratio method which must be recognised when the results are being analysed.

# 4 RESULTS

The final Nakamura Ratio plots were assigned codes to indicate the presence or absence of resonance peaks as well as the "quality" of the peaks. These codes were assigned using quantitative rules in an effort to reduce subjective influence and variability.

Some of the recordings on the Palaeozoic metamorphic and even on the intrusive rocks showed responses which varied markedly from the flat response expected of relatively high-velocity bedrock. The anomalous responses obtained on the metamorphics may be because these beds are highly foliated and steeply dipping but this explanation cannot be used to explain the responses obtained on the intrusive rocks. Another possibility is that one of the assumptions made (ie. noise travelling as Rayleigh waves) is violated by having cultural noise generated on the bedrock rather than on sedimentary material.

Nakamura Ratios taken on the Mesozoic units were varied, with some sites showing a flat response and other sites exhibiting degrees of resonance. One area that exhibited a consistent low frequency response could not be correlated to any geological or geotechnical occurrences. Results from sites on the Cainozoic sediments also showed some variation but resonances at frequencies between 0.5 and 5 Hz were frequently observed.

The only area where there was consistent resonance was in the Brisbane port and airport areas which have significant depths of fill overlying Cainozoic sediments. Results from these areas exhibited quite significant amplifications at frequencies of 0.3 to 2 Hz.

## 5 CONCLUSIONS

While the Nakamura Ratio technique is relatively simple, quick and cheap it cannot be used in isolation as a reliable estimate of site response. Results are difficult to analyse and show variability that does not correlate well with known geological and geotechnical parameters. The results are more consistent in areas where the sedimentary layers are relatively flat lying and where there is assumed to be a reasonable velocity contrast between the sedimentary layers and the bedrock.

Future work will involve comparing the results of the microtremor survey with those obtained from alternative site response techniques being carried out in Brisbane(5). This work will provide a better estimate of the hazard of the Brisbane area and lead to an improved understanding of the limitations and accuracies of the various site response techniques.

## 6 REFERENCES

1. Konno, K. and Ohmachi, T. (1998). "Ground-motion characteristics estimated from spectral ratio between horizontal and vertical components of microtremor", *Bull Seism Soc Am*, Vol 88, pp 228-241.

2. Coutel, F. and Mora, P. (1998). "Simulation-based comparison of four site-response estimation techniques", *Bull Seism Soc Am*, Vol 88, pp 30-42.

3. Bard, P-Y. (1995). "Effects of surface geology on ground motion: Recent results and remaining issues", *Proc of 10th European Conference on Earthquake Engineering*, Duma (Ed).

4. Field, E.H. and Jacob, K.H. (1995). "A comparison and test of various site-response estimation techniques, including three that are not reference-site dependent", *Bull Seism Soc Am*, Vol 85, August 1995, pp. 1127-1143.

5. Jaumé, S.C., Winter, M., and Cuthbertson, R. (1998). "Using Long Distance Earthquakes to Study Local Site Amplification", *ibid.*