RECORDS OF ENGINEERING SIGNIFICANCE FROM THE NEW ZEALAND STRONG-MOTION NETWORK

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SUMMARY

Thirty years of operation of the New Zealand strong-motion network has produced a significant database of peak accelerations and several acceleration histories of engineering importance. There are considerable differences between the accelerations recorded in the basement of the 17-storey Vogel building and at a nearby "remote" site. Striking soil and topographic effects have been demonstrated by a dam-site investigation in silt-stone hill country. Instrumentation of the base-isolated Clayton building and the stepping-pier South Rangitikei rail viaduct is described. Two extremely simple and nearly identical acceleration records from Oaonui appear suitable for source synthesis studies.

INTRODUCTION

The New Zealand strong-motion earthquake accelerograph network was established over thirty years ago, and since 1965 has operated New Zealand MO (mechanical-optical) instruments capable of photographically recording three-component acceleration histories. The network has grown gradually from a single Wenner seismograph between 1948 and 1954 to now include about 150 MO instruments, supplemented by about 70 simple SP (scratch-plate) instruments. Digital instruments are being evaluated in field tests.

Although very strong ground shaking has yet to be recorded on MO instruments (a maximum of 0.19 g to date), supplementing the MO records with those obtained on the essentially peak acceleration recording scratch plates and earlier instruments increases the maximum to 0.42 g and gives fifteen ground acceleration records in excess of 0.2 g from twelve earthquakes. There are another 51 records in the 0.1 to 0.2 g range, including 15 MO records. Approximately 500 ground acceleration records greater than 0.01 g have been retained. Although still lacking records of very strong shaking from close to the source, the magnitude-distance distribution of the data rivals that from any region in the world, with eight records apparently within 10 km epicentral distance (but with a nominal source depth of 12 km), and twenty-one from four shallow events of magnitude 7 or greater from 25 to 350 km epicentral distance. There are a further 33 records from a single deep event (173 km) of magnitude 7.0.

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This collection represents a significant database for peak acceleration attenuation studies, and also contains several sets of records of engineering significance in their own right. Included among the instrumented structures are several incorporating novel seismic design features, such as the base-isolated William Clayton building in Wellington and the South Rangitikei rail viaduct which has stepping piers with steel torsional beam energy dissipators.

ATTENUATION OF REMOTE SITE ACCELERATIONS IN THE VOGEL BUILDING BASEMENT

Two sets of digitized records from the 17-storey reinforced concrete Vogel building in Wellington show considerable differences between the accelerations recorded by the basement and "remote" site instruments fifty metres apart. In both the large distant Central North Island earthquake of 1973 January 5 (magnitude 7.0 at 240 km epicentral distance and 173 km depth) and the smaller local Cook Strait earthquake of 1977 January 18 (magnitude 6.0 at 64 km epicentral distance and 33 km depth), the records obtained on the massive box foundation are considerably attenuated for most frequencies above 1 Hz (Figure 1), with peak horizontal accelerations ranging from 54% to 85% of the corresponding remote site values.

For both earthquakes, which produced moderate, non-damaging response of the structure with peak horizontal roof accelerations of 0.10 g in 1973 and 0.17 g in 1977, excellent reproductions of the measured responses were obtained when two-mode models were optimally identified using either the remote site or basement inputs (e.g. Figure 2a). However, for all the response records, the optimal model with basement input provided a better match than the optimal remote site input model.

An appreciation of the effects of the difference in the inputs on the response was gained by calculating the response of the optimal basement input model to the remote site excitation, compared to the measured response in Figure 2b. The maximum calculated acceleration response with remote site input exceeded the measured value, which was reproduced by the calculation using the basement input as shown in Figure 2a, by about 60%. The marked reduction of the structural response by the modification of the basement excitation from that at the external site was achieved even though most of the excitation modification occurred in the 4 to 6 Hz range while the response was strongly concentrated around the fundamental frequency of 1.3 Hz.

Similar modifications of the "free-field" excitation by rigid foundation slabs in the basements of buildings with fundamental periods of around 0.2 to 0.3 seconds, likely to be typical of many one-to-three storey commercial buildings common in New Zealand towns, would be of substantial benefit in reducing their response. The present instrument deployment is being rearranged to monitor excitation modification in such buildings.

SOIL AND TOPOGRAPHIC EFFECTS AT ATENE

Striking local soil and topographic effects have been demonstrated by an accelerograph array at Atene (Figure 3), originally set up for a dam site investigation in the papa (silt-stone) hill country of the Wanganui river. The motions on the alluvial sediments of an old ox-bow bend are generally considerably amplified, by factors of 3.5 or more for the peak acceleration, with respect to those of a rock site near the base of a roughly conical hill about 100 metres away, and are of more periodic appearance. The major amplification is spread over a broad period range of about 0.2 to 0.8 seconds rather than concentrated in narrow resonant peaks. Two hill-top sites separated by 1200 metres horizontally on opposite sides of the valley about 250 metres above the former river bed produce records which are similar to each other but are generally about twice the amplitude of the rock site records. Typical sets of accelerograms and spectral plots are shown in Figure 3.

Such dramatic variations in motion over a short distance pose difficulties for the structural design of a dam in specifying the excitation to be used for dynamic analysis and in accommodating the differential motion. Although dam construction at this particular site has been postponed indefinitely (because a set of local site factors make the provision of adequate seismic resistance uneconomic), other potential dam sites are located in similar papa country which is widespread through the central North Island. Further instruments are being installed on similar rock for a dam investigation in the Hawkes Bay district.

INSTRUMENTATION OF BASE-ISOLATED STRCTURES

The base-isolated William Clayton building (Figure 4a), which is mounted on rubber bearing pads with energy-dissipating lead plug inserts, was completed in June 1982. This brought to fruition PEL's research and development work which through close cooperation with the building designers from the Ministry of Works and Development pioneered the practical application of the base-isolation concept of earthquake-resistant design. With considerable interest in the performance of this structure, five interconnected MO2A accelerographs have been installed. Two accelerographs are located alongside bearings on the foundation grid, one in the centre of the building and the other at the south corner. Two more MO2As are located immediately above these instruments on the base of the superstructure, and one near the centre of the building at roof level. Two smoked-plate devices have been fitted next to the sub-basement accelerographs to scratch records of relative displacement between the bottom foundation pad and the base of the superstructure, while a further pair of devices gives readings which indicate any drift or permanent offset across one of the bearings. The instrumentation on the foundation grid at the centre of the building is shown in Figure 4b.

Another type of base-isolating and energy-dissipating mechanism is utilized in the 315 metre span and 70 metre tall South Rangitikei railway bridge (Figure 5), opened in October 1981. The stresses which can be transmitted into the slender reinforced concrete piers under earthquake loading are limited by allowing a transverse stepping action at the base.

Energy dissipation to limit the extent of the stepping and the associated lateral movement of the prestressed concrete hollow box-girder bridge deck is provided by hysteretic working of torsionally yielding steel beam *devices connected between the bottom of* the stepping piers and the top of the supporting piles.

Interconnected MO2 accelerographs are installed near the steel damper energy dissipator at the base of pier 4 (the tallest), in the deck above this pier and at a remote site 300 metres from the bridge on a large concrete block attached to papa siltstone bedrock. During bridge construction, which was delayed considerably by a formwork collapse, an MO2 installed close to the site produced earthquake records with peak accelerations of 0.069 g (1975 June 10) and 0.052 g (1980 June 23). Three records exceeding 0.1 g have been obtained from the scratch plate installed since 1966 in the nearby town of Taihape.

To monitor the performance of the energy absorbers themselves, a prototype mechanical movement recorder has been produced at PEL and installed beside the steel dampers at the bottom of pier 4. This device uses the movement of the pier leg to advance the recording paper and write a record of the distance travelled every time the leg uplifts. It is planned to fit this type of inexpensive recorder to the other pier legs.

SIMPLE ACCELERATION PULSE RECORDS FROM OAONUI, 1983 APRIL 16

Two acceleration records (peak values of 0.132 g and 0.171 g) of remarkably simple and similar form (Figure 6a) were obtained from Oaonui, *the shore station for the Maui offshore platform, for events of magnitude* 5.2 and 5.5 from the same source region at 20:52 and 21:59 UT on 1983 April 16. The source was at an epicentral distance of approximately 40 km, bearing N25W and geophysically restricted depth of 12 km. The simple form of the records carries through to the spectra, consisting of two straight line segments with a corner frequency of 5 Hz. Figure 6 shows one set of velocity response spectra. The simplicity of the records and their near repetition in the two events suggest they may be of value for source synthesis studies.

CONCLUSIONS

While acceleration histories of very strong near-source motion have yet to be recorded, the New Zealand strong-motion network has produced about 500 records exceeding 0.01 g ground acceleration. Some of the more important records have been reviewed, and instrumentation of two recently completed base-isolated structures which will produce valuable data for designers has been described.

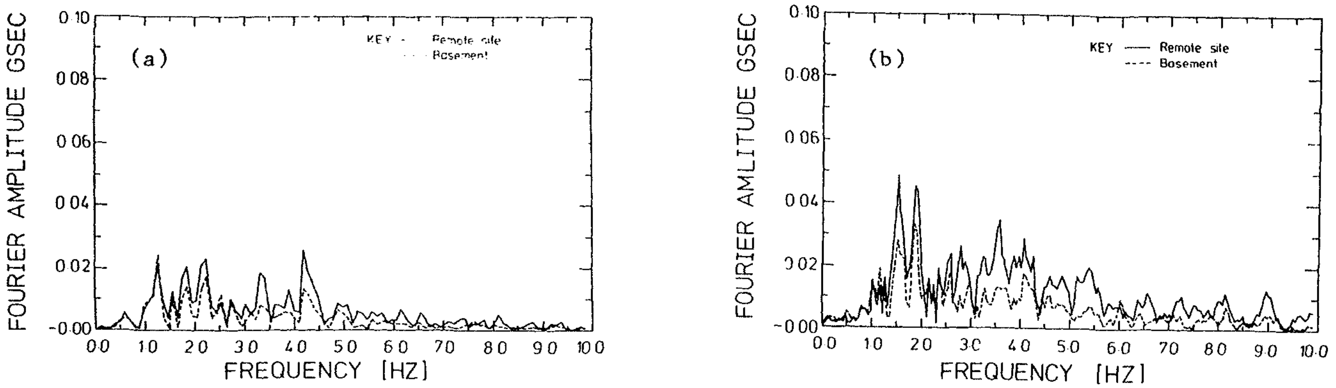


Figure 1: Fourier amplitude spectra of remote site and basement accelerations, Vogel building, S88E component
(a) Central North Island earthquake, 1973 January 5
(b) Cook Strait earthquake, 1977 January 18.

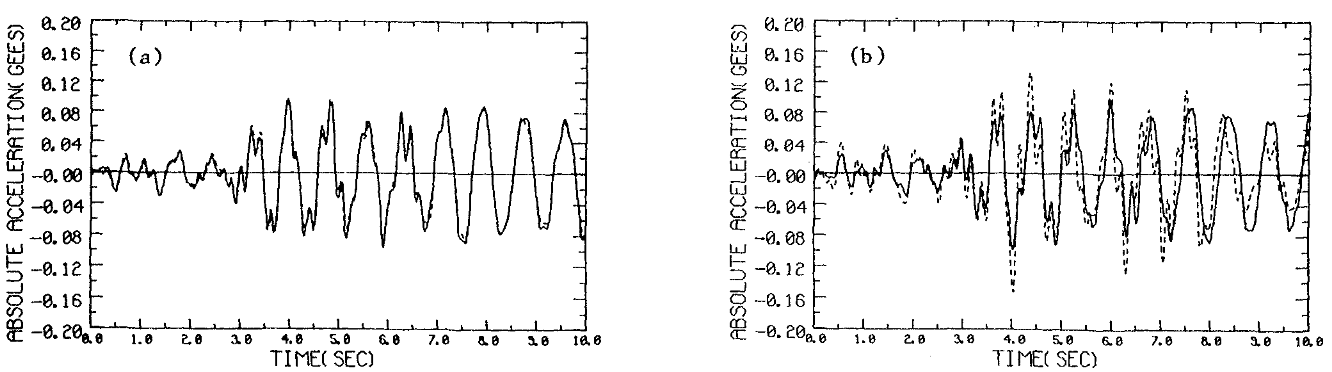


Figure 2: Measured (——) and calculated (----) 14th floor accelerations of Vogel building, 1973 January 5, S88E component
(a) Optimal two-mode basement excitation model
(b) Optimal basement model subjected to remote site acceleration.

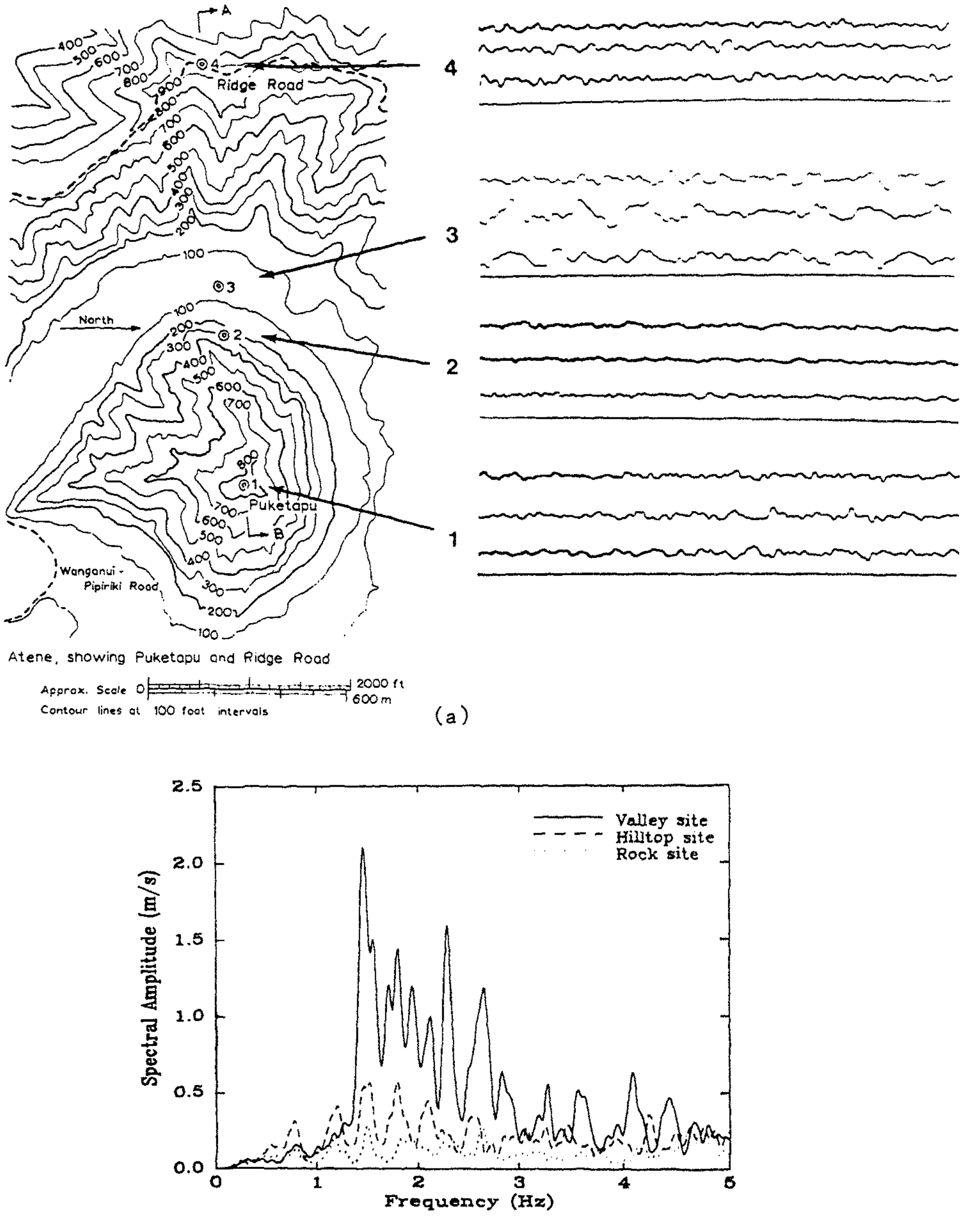


Figure 3: (a) Topography and accelerograph locations at Atene, with portions of typical accelerograms (1972 January 5 event) alongside.
(b) Comparison of Fourier acceleration spectra from the valley, hill-top (Puketapu) and rock sites for 1973 January 5 event.

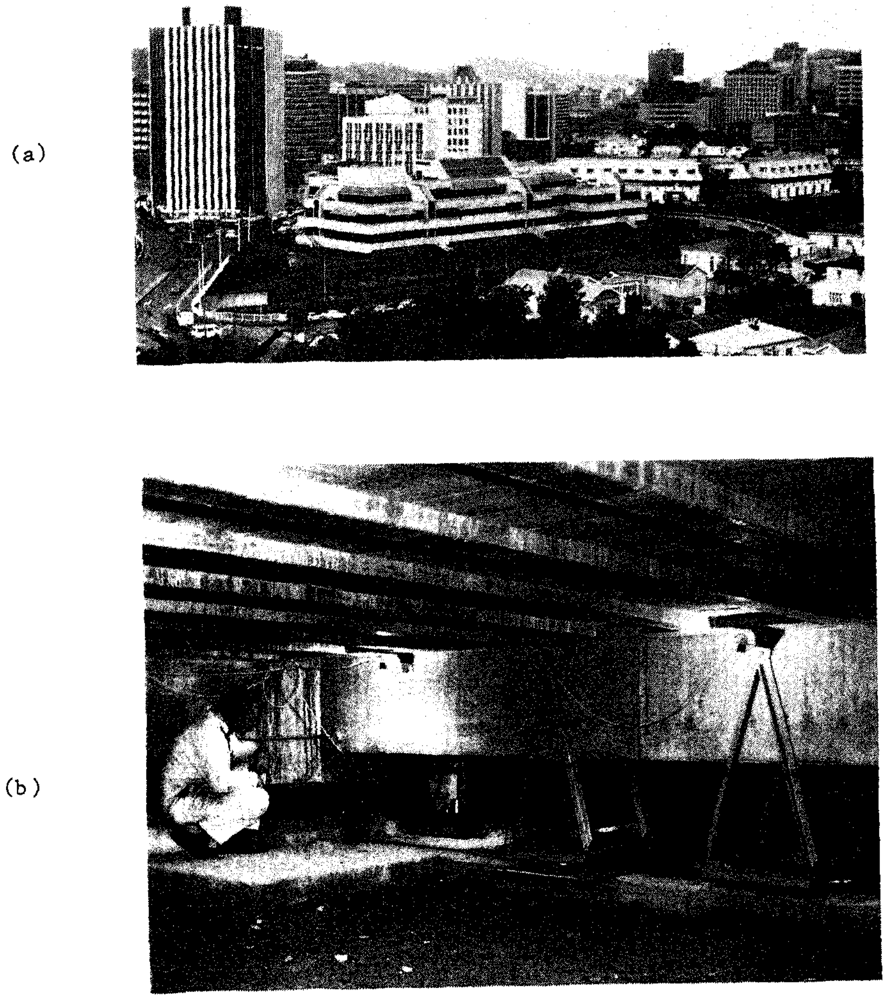


Figure 4: (a) The base-isolated William Clayton building (foreground), which is supported on laminated natural rubber bearings with lead-plug inserts.
(b) Instrumentation on the foundation grid at the centre of the Clayton building, showing a rubber bearing, M02A accelerograph and relative displacement recording devices.

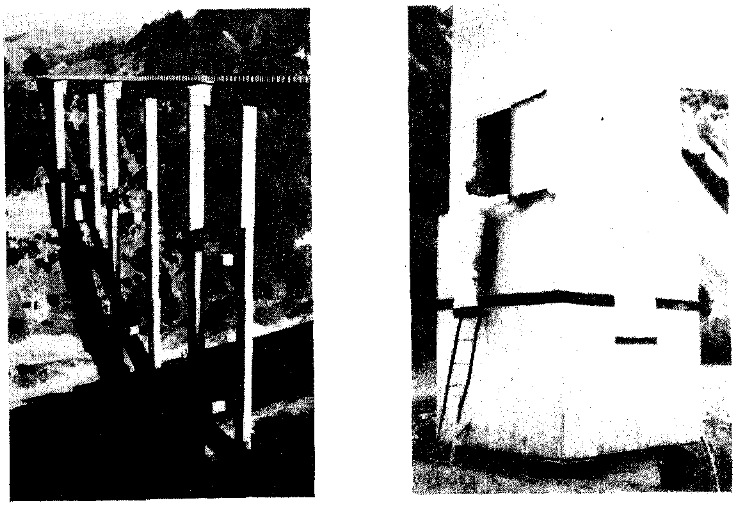
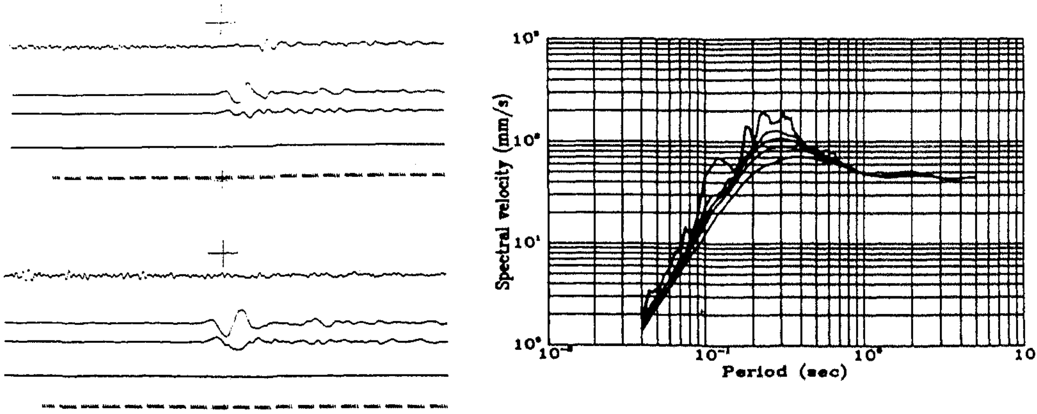


Figure 5: South Rangitikei rail bridge, base-isolated using a stepping-pier transverse rocking action.



(a)

(b)

Figure 6: (a) Oaonui accelerograms of the two events of 1983 April 16.
(b) Velocity response spectra for the first event.