NARROW-BAND ANALOGUE TO BROAD-BAND DIGITAL ACCELEROGRAMS ON THE WEB – THE AUSTRALIAN EXPERIENCE

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Abstract: This year marks the 25th year since AS2121-1979 was published. The disciplines of Earthquake Engineering and Engineering Seismology in Australia have matured in that time. Our focus is on the development of strong motion data collection and instrumentation in Australia; from a zero data-base and no instruments in 1975 to a significant strong motion data collection and approximately 100 operational accelerographs in Australia today.

This turnaround was initially driven by engineers on the 1979 earthquake code committee with their requirement for spectral data, although timing for them was not an issue. Ultimately seismologists took over the development of instrumentation with their need for both near-source and distant, time-stamped observations thereby providing for both needs. Attenuation studies require ground motion measurements at a wide range of distances from *each* earthquake, so a high density of instruments is needed to ensure that near-field motion is recorded from the *next* moderate to large magnitude event.

Each earthquake demonstrates that there is never enough data - more instruments are still required and the only way to achieve that is with cheaper and more versatile instrumentation, with a committed program for routine maintenance and operation. Today's networks need modern recorders that are cheap, rugged, reliable, flexible, networked and accessible.

Background History of Strong Motion Monitoring in Australia

Strong motion is defined (Lee and others, 2003) as ground motion having the potential to cause significant risk to a structure's architectural or structural components, or its contents. Lee and others (2003) define a strong motion instrument as a strong motion accelerograph.

The unprecedented damage caused by the Meckering WA earthquake of 14 October 1968 prompted engineers in Australia to write the first Earthquake Code for this country, published as AS1170.4. The code writers knew little about Australian ground shaking, its frequency, amplitude and duration, data essential for constructing new earthquake-resistant buildings. They lobbied the Australian Government to install some accelerographs in seismically active areas of Australia to compare spectra and attenuation with those from equivalent sized earthquakes overseas, principally California where such instrumentation had been operating since late 1932.

Three New Zealand-made analogue MO-2 recorders were installed in southwest Western Australia between August and November 1971 (Gregson, 1972), three years before any were installed in Eastern Australia. Paradoxically the first Australian accelerogram was actually recorded in Eastern Australia on a farm near the Oolong NSW railway siding about 50 km from Canberra where a close magnitude 3.1 earthquake triggered the US-made Kinemetrics SMA-1 triaxial analogue recorder there on 23 November 1976 (Smith and McEwin, 1980).

These analogue recorders were quite insensitive, triggering when the intensity reached about MMIV (by observation) or pga reached 0.01g (nominal). Recorded time was relative to the trigger time; real time was one parameter not considered necessary by the engineers or equipment designers at the time.

Four records from the Oolong SMA-1 recorder obtained between November 1976 and February 1979 were analysed by Smith and McEwin (1980). Two of these four records are shown in Figure 1.

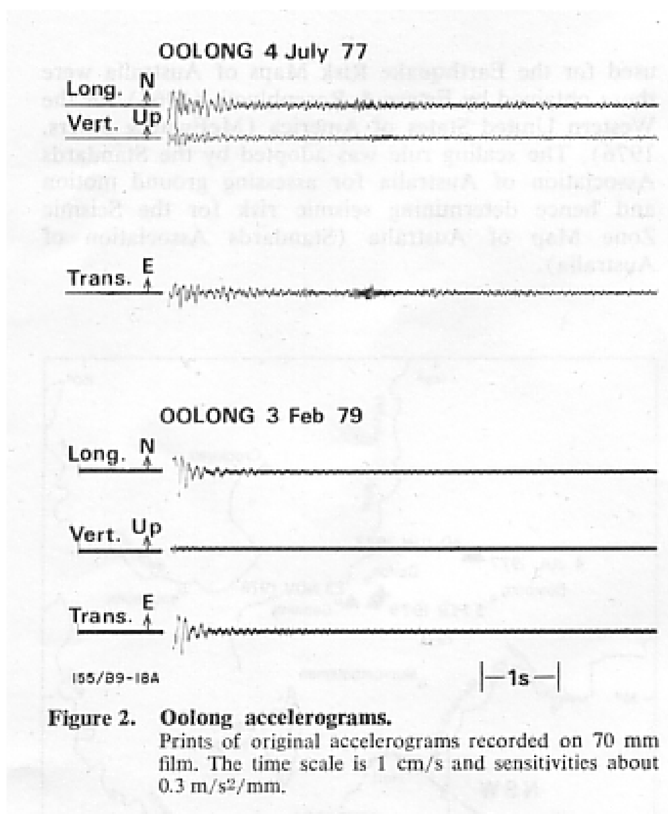

Figure 1 Reproductions of analogue accelerograms recorded at Oolong NSW, 1977 & 1979 (after Smith and McEwin, 1980, their Figure 2).

Subsequent recordings at the same site in 1984 (Figure 2) show that the maximum part of the coda had been lost during start up as Smith and McEwin suspected.

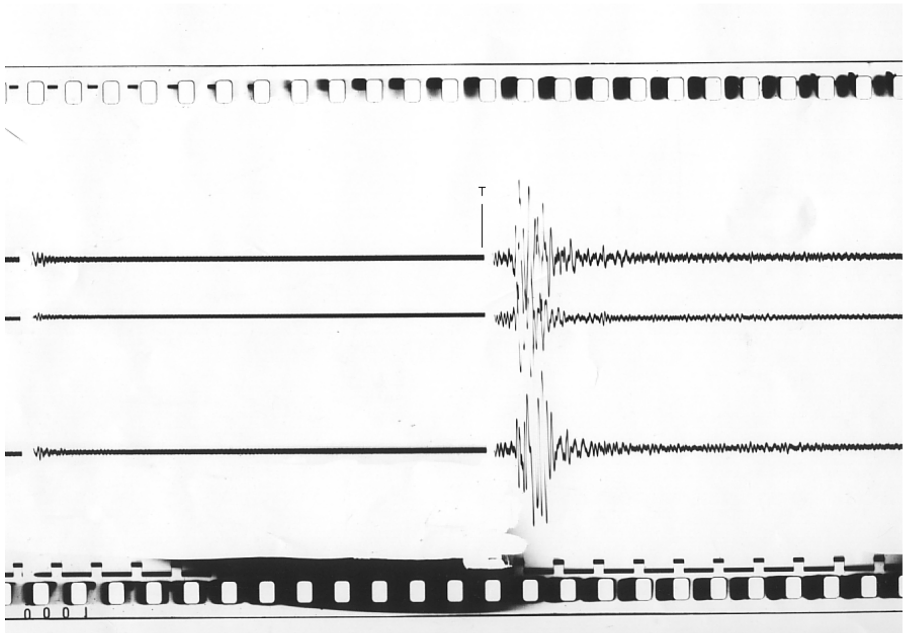

Figure 2 Oolong 9 August 1984 accelerogram on 70 mm wide film. SMA-1 recorder. T is the trigger time. The central trace is the vertical component, the lowest the time mark trace, offset twice per second. The SMA-1 used here had a 1/2 g transducer (ie ~38mm/g) sensitivity, recorded pga (horizontal) was ~ 0.25g.

The West Australian Water Authority and South Australian Government purchased several MO-2 analogue recorders in the late 1970s but the South Australian instruments were never triggered by an earthquake.

From the mid 1980s, several types of digital accelerograph were chosen to replace the analogue recorders that had proved difficult to maintain, and whose records were even more difficult to process. In WA the MO-2s were replaced by the US-built A700s but several years of recordings were lost trying to get them to work. The six A700 recorders purchased by the Queensland Government never worked. In Eastern Australia, the Melbourne-made Yerilla recorder was chosen which, like the A700, used magnetic tapes for data storage. The Yerilla was soon replaced with the next generation Kelunji that introduced solid-state memory and more functionality.

Local manufacture solved a number of problems with overseas manufactured and maintained equipment. Recorders returned to the US or New Zealand for repair often took more than a year for the round trip and often didn't work on return. Getting the instruments through customs at each end added to the time delays and data loss.

The timely societal focus on risk and the advent of digital recording led to monitoring of assets by SRC (now part of ES&S) for utilities such as dam owners. Consequently, many more accelerograms were collected, mostly near small earthquakes or at large distances from moderate to large earthquakes. By now, accurate timing was deemed necessary by the users and designers, mostly seismologists, so that the instruments could be used not only for ground motion and structural response monitoring, but also for earthquake location.

Local Australian design and construction of accelerographs meant that equipment faults could be quickly fixed with minimal instrument turn around time and feedback incorporated into equipment and software upgrades.

Modern Digital Accelerographs

The digital accelerographs first introduced in the 1980's, and significantly improved each decade since, provide a number of features not possible with the earlier analogue instruments (McCue and others 1988, Wesson and Bricker 1996a, Wesson and Bricker 1996b). The first is a much larger dynamic range – that is the range from the smallest to the largest useful signal. For most analogue instruments, this was a range of approximately 100:1, which means that the instruments could only usefully record a range of two units of magnitude at a given distance (e.g. ML 5 to ML 7). By comparison, modern digital instruments have a dynamic range of greater than 1,000,000:1 meaning that they can record earthquakes covering a range of six magnitude units for a given distance (e.g. ML 1 to ML 7). What this means in practise is that they will record many more earthquakes than the earlier instruments. In addition to a larger dynamic range, modern accelerographs are capable of recording a wider range of frequencies (or periods). A typical modern accelerograph can measure and record all frequencies from DC (0 Hz) up to 50Hz or 100Hz.

The second major feature of digital accelerographs is the ease with which the recorded signals can be further processed. In many cases, the recorded signal is used as input to an engineering design where a (digital) computer must process the data. With the analogue instruments, this meant digitising the analogue signal leading to many numerical problems, particularly at longer periods (greater than 0.25 seconds) or on records where the traces overlapped. With digital recordings, it is much easier to process the recorded signal to determine the time history of ground velocity or displacement.

The third major feature of modern accelerographs is data accessibility. Modern instruments can be connected directly to the Internet. This allows the instrument to send data to a processing centre in close to real time and allows suitably authorised operators immediate access to the data. This provides a significant reduction in the cost of operating instruments and makes it easy to monitor the state-of-health of instruments to ensure that they are operating correctly. Both of these are very important aspects of practical accelerograph installations.

The fourth and final feature to be discussed here is the lower capital cost of modern accelerographs. Technological advances over the last few decades have significantly reduced the cost of high precision motion sensing devices and the electronics associated with these necessary to provide a complete accelerograph. In absolute dollar terms, a typically modern accelerograph is only about one third the cost of a comparable instrument twenty years ago. Allowing for inflation over that time, the difference in real terms is even greater.

Australian Accelerograms

As mentioned above, there were only a handful of accelerograms recorded in Australia on the early analogue accelerographs. Similarly, the early digital accelerographs purchased overseas provided only a small number of recordings. The vast majority of accelerograms recorded in Australia have been on the Yerilla and Kelunji instruments manufactured by ES&S. These used sensors manufactured by either Sprengnether Instruments in the USA or Guralp Systems in the UK.

A complete catalogue of Australian accelerograms has not been performed, but we estimate that about a thousand accelerograms have now been recorded in Australia. These are from earthquakes ranging in magnitude from about ML 0 up to ML 8.2 and for distances ranging from about one kilometre up to 800 kilometres. The highest acceleration recorded in Australia to date was just under 1g from the magnitude ML 4.2 earthquake that was the largest event in the swarm of events near the town of Eugowra in central NSW in 1994. The site was less than two kilometres from the hypocentre of the event.

Conclusion

Important advances have been made in the recording of strong earthquake motions in Australia over the last few decades. These advances have made it possible to record more events, with better quality recordings at lower cost than ever before. These recordings are the key raw data required for all seismic hazard estimates performed in Australia.

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