1. INTRODUCTION

Modelling of peak ground acceleration from typical intra-plate earthquakes in Australia is faced with numerous problems including the lack of quality instrumental data for large earthquakes recorded at close distance. The significant variation of crustal structure across the continent may mean that various attenuation relationships are required for different parts of Australia.

The Burakin sequence of 2001/02 presented a unique opportunity to study small-to-moderate magnitude earthquakes recorded at very small hypocentral distances (for example, Allen *et al.*, 2004). However, given the narrow magnitude range of the data, the validity of the model behaviour to larger magnitudes should be carefully examined.

In this study a moderate to large magnitude earthquake was simulated from a magnitude 5.2 sub-event recorded in 2002 at distance of around 10km, using the empirical Green's Function method. This method of superposition assumes that the source parameters, path and site effects for the main event and its aftershocks are equivalent. Previous validation studies for similar events in Australia have shown that synthetics produced by this method are comparable with the Loading Code AS 1170.4, and can realistically represent ground motion during intra-plate earthquakes (Jankulovski *et al.*, 1996; Sinadinovski *et al*., 1996).

A set of spectral curves derived from the synthetics was normalised to approximate a magnitude 6 event being recorded at a distance of 20 km in order to be compared with the Design Spectrum recommended in the Australian Loading Code. A similar size earthquake occurred in Cadoux in 1979 and an even bigger earthquake, magnitude M_w6.7 in Meckering in 1968.

Although firm conclusions are yet to be made, Hao and Gaull’s (2004a) initial study found that the Atkinson and Boore (1995) earthquake spectra model from Eastern North America best matched the accelerograms obtained in Southwest of WA. That is basically consistent with the conclusions of Lam *et al.* (2003) and therefore the results of these papers with Green’s Function simulation can be used in further testing of structural behaviour during typical earthquakes.

2. SEISMIC DATA

The Burakin, WA earthquake sequence has been one of the most prominent seismic activities in Australia in the last decade (Leonard, 2002). It started back in 2000 with a swarm of earthquakes with a major event on 28th of September 2001, M_L5.0, followed by some 16,000 aftershocks culminating on March the 30th with a magnitude M_L5.2 event. The centre of seismic activity was the town of Burakin some 180 km northeast of Perth.

Following the first magnitude 5 earthquake in September 2001, Geoscience Australia deployed a number of seismographs/accelerographs in the area in addition to the existing ones from the National Network and the Joint Urban Monitoring Program. For most of

2002 nine temporary seismographs/accelerographs have been at sites within 100 km of Burakin.

The seismogram of the 30th of March 2002 event at 21:15 UTC as shown in Figure 1 is the horizontal component of the M_L5.2 earthquake recorded by ten stations (where a reduced travel time of (t-Δ/8) was used to plot the ordinate). The three component accelerogram of the event recorded by station BK5 was used in the simulation. The earthquake was located, using the Australian National Seismic Network stations, at longitude 117.049°E and latitude 30.524°S, about 12 km west of Burakin. All of the earthquakes in the sequence were shallow, the computed focal depths in the top 5 km of the crust. The earthquake was recorded at distances from 5 to 190 km.

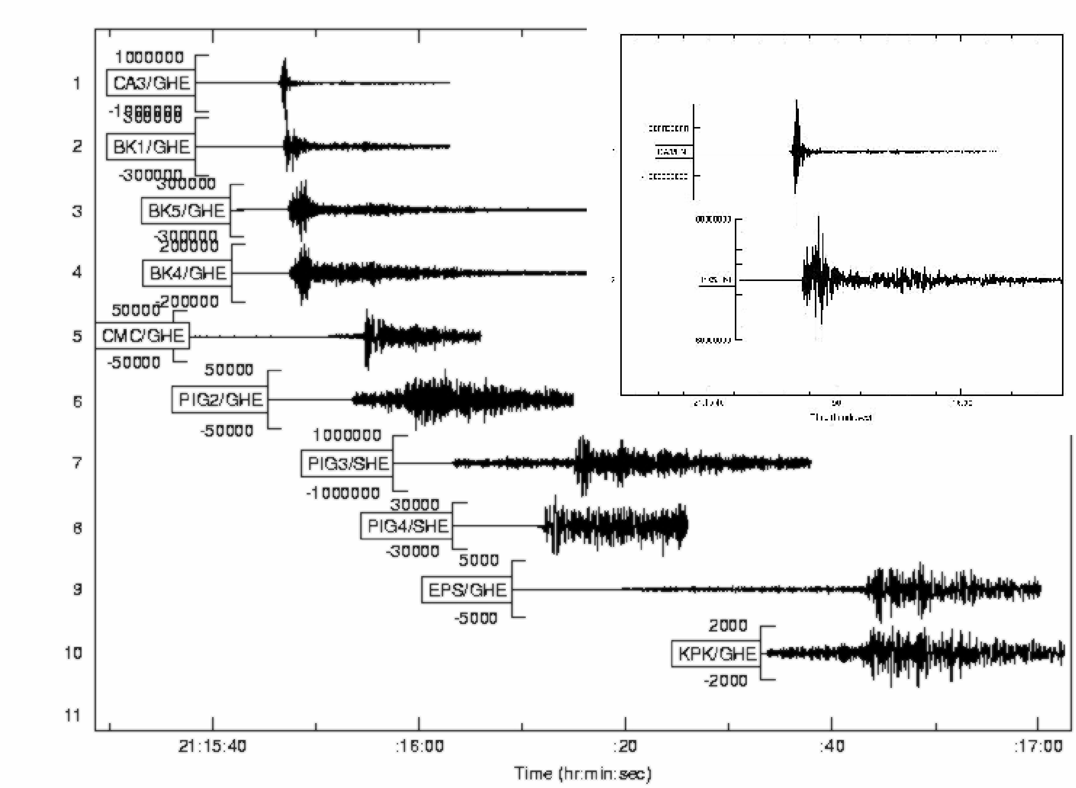

Figure 1: Seismic records (horizontal component) of the M_L5.2 earthquake (inset: enlarged waveforms)

Fourier Amplitude spectra (Fig. 2) for the records were divided into three ranges according to the epicentral distance: close range up to 25 km, middle range 26 to 90 km, and longer range greater than 90 km, which included the stations EPS and KPK in the Perth basin. A typical shift from 30-50 Hz in the close stations towards lower frequency (5-8 Hz) for the more distant stations can be noticed on the graphs. (EPS and KPK are not on hard rock site. Local site condition will also affect principal frequencies of the record).

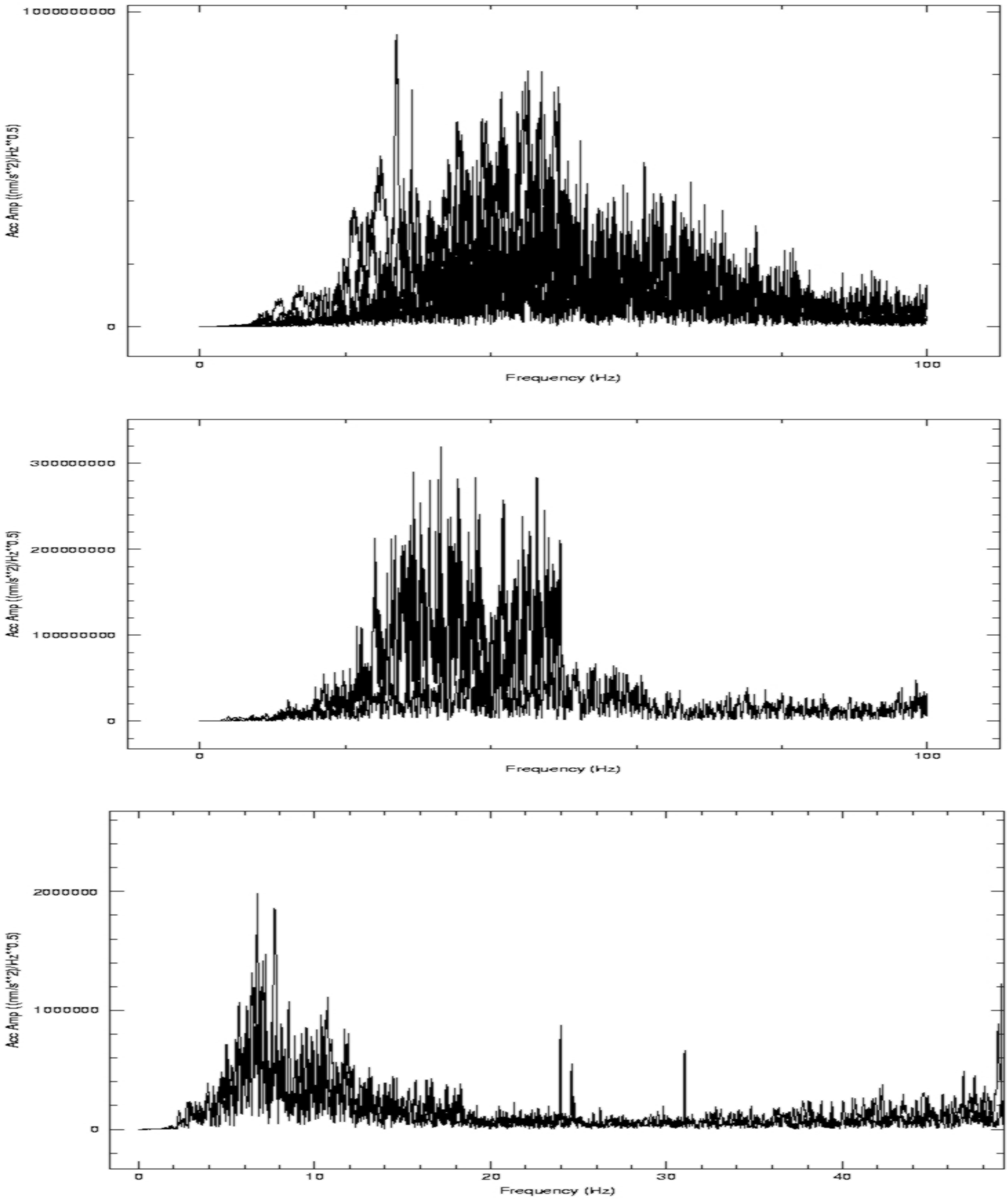

Figure 2: Fourier Amplitude spectra of the M_L5.2 earthquake:
Top – epicentral distance up to 25 km;
Middle – epicentral distance 25 to 90 km; and
Bottom – epicentral distance greater than 90 km.

3. SYNTHETICS

The accelerogram of the 30th of March 2002 event of the M_L5.2 earthquake recorded by station BK5 was used in the simulation. BK5 station is precisely located at longitude 117.122°E and latitude 30.519°S, 8±1 km from the epicenter.

The empirical Green's Function method of superposition assumes that the source parameters, path and site effects for the main event and its aftershocks are equivalent. That is especially important in producing realistic synthetics for the more distant stations as the local variations are very hard to match by models. Thus Green's Function simulation technique can be theoretically applied to records from any epicentral distance as long as the initial assumptions hold.

In extrapolating to the stronger earthquake, the source parameters were set to a rupture length of 2 km, keeping the terms in the spectral formula to satisfy both the low-frequency and high-frequency constraints. In the production of these synthetics (Fig. 3) a rupture velocity of 2.25 km/s was used and a surface rupture was oriented perpendicular to the source-receiver line. The procedure was applied in one step summing over an area for 10 sub-events which progressively brought the magnitude to around 6. The values in *g* are normalised in order to be compared with the curves in the Loading Code.

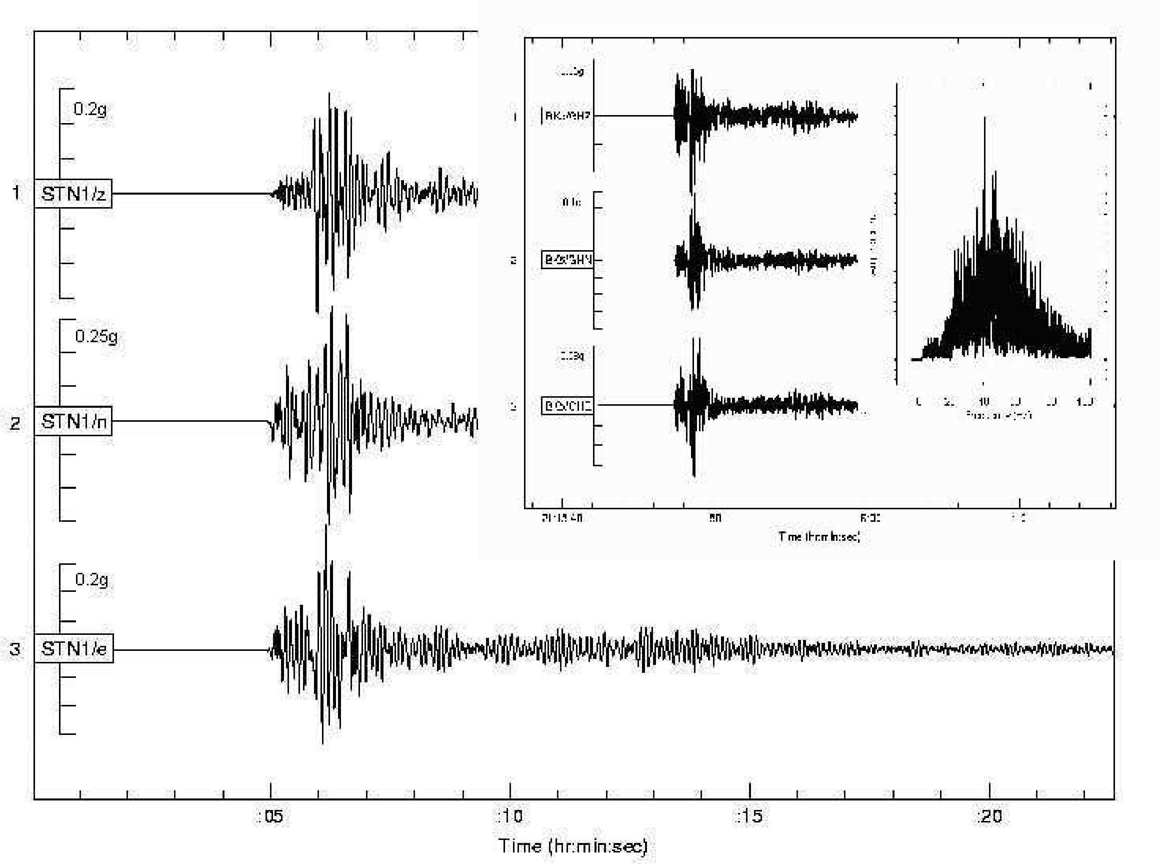

Figure 3: Synthetic output for the Burakin record (inset: the sub-event)

4. RESPONSE SPECTRA

The standard Response Spectrum program was used as described by the U.S. Geological Survey procedure (Converse, 1992). In the processing step, the response of a simple harmonic oscillator with a single degree of freedom was calculated for the synthetic input.

The maximum response was calculated for oscillators with different natural periods having damping ratios of 0%, 2%, 5%, 10% and 20% of the critical damping. Figure 4 represents the acceleration response spectra for the BK5 synthetic record for all three components, for an oscillator with natural periods between 0.01 and 10 seconds, and for five defined damping ratios.

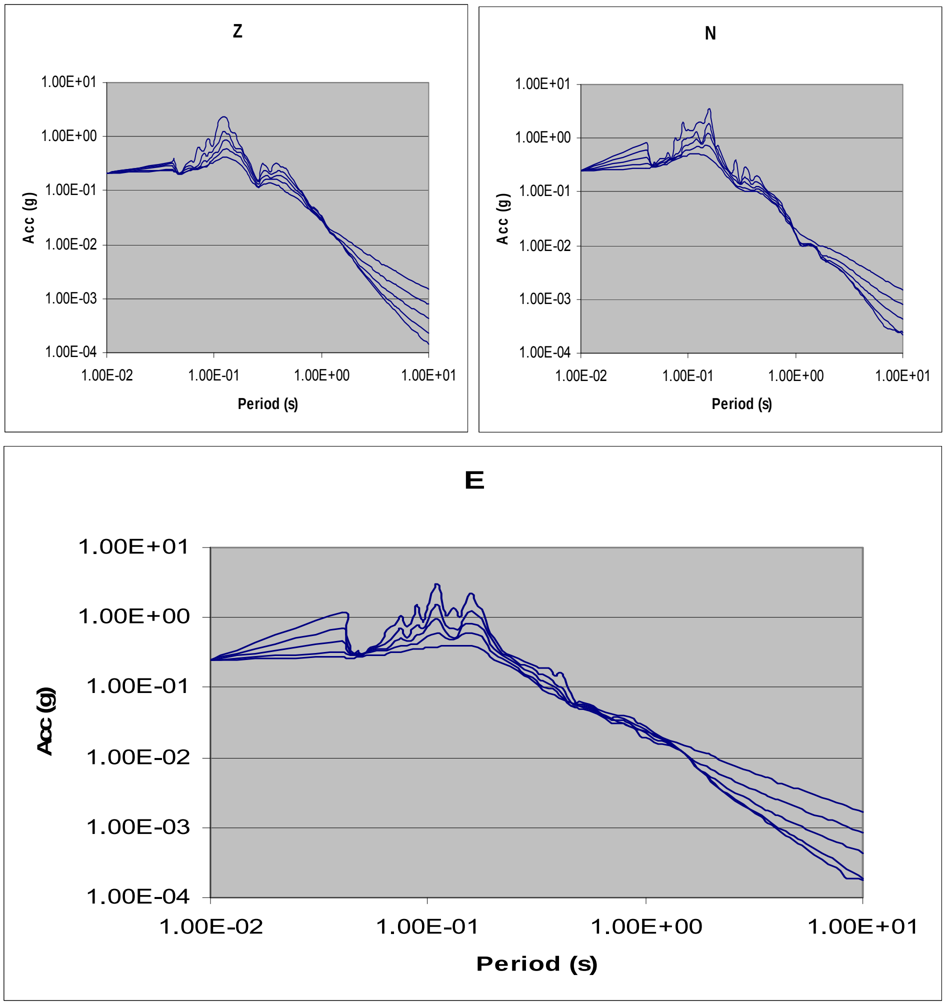

Figure 4: Response spectra for the synthetics based on the synthetic BK5 record

In Western Australia, due to the lack of strong ground motion data, it is difficult to derive response spectra based on them alone with high confidence. In the past the peak ground acceleration on rock were based on some of the large events recorded in SWWA using probabilistic hazard analysis with attenuation functions from elsewhere (Sinadinovski, 2004; Hao and Gaull, 2004b). Amplitudes of the spectra were derived using the rules outlined in the 1993 Australian Standard AS1170.4, while the transfer function was based on that suggested by Gaull *et al.*, (1995).

Here, the acceleration response spectra of the simulated BK5 record with 5% damping normalized with the code spectrum (Fig. 5) gives an indication of the suitability of the shape of the response spectrum given in the Loading Code for rock site.

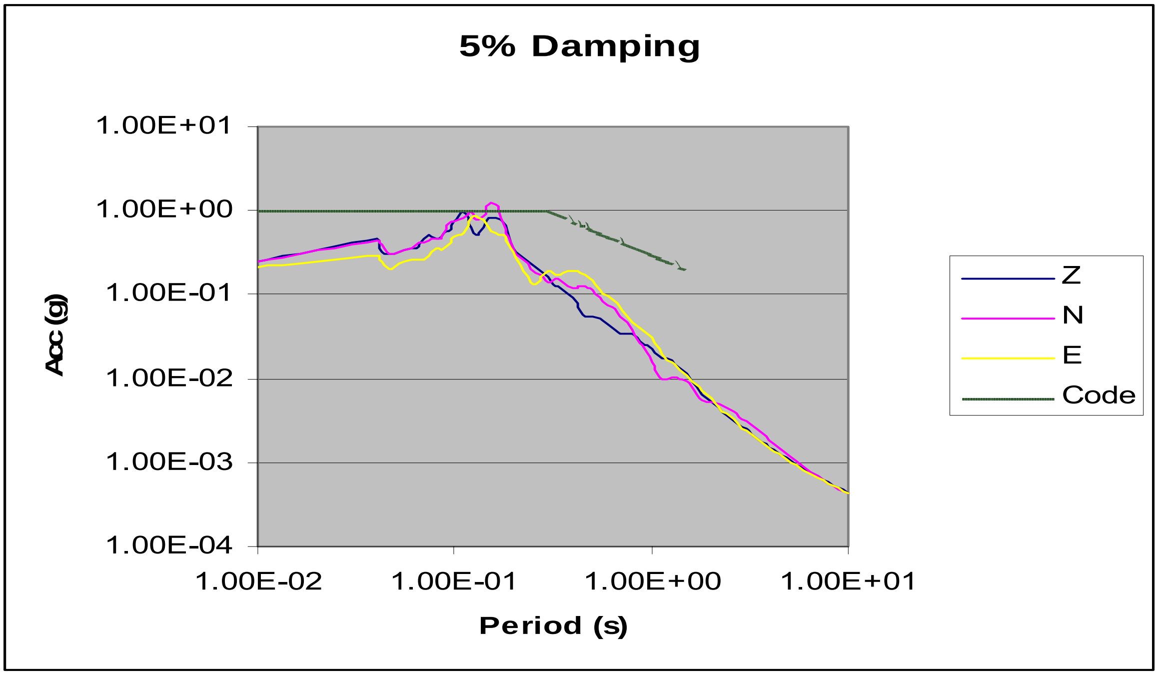

Figure 5: Combined acceleration spectra for the Burakin synthetics with 5% damping

The code spectra in general overestimates the spectral acceleration of the synthetics, including in the period range of 0.3 to 3 sec which covers the fundamental natural periods of most of common structures. It is consistent with the findings of Hao and Gaull (2004a) about the spectral acceleration of another larger set of records from SWWA. In the high frequency range the spectral characteristics of the simulated event do not largely underestimate the design code, so that fact can be of significance in testing of stiffer structures.

Spectral response is considered the preferred method of analysis for bridges (Jankulovski *et al.*, 1996). It provides a realistic distribution of forces and reactions and it is assumed as more appropriate than a single static force approach. Although the earthquake forces may not be critical for the structural design in terms of strength, other aspects in respect to the Design Code and its revisions should be continuously considered. Then the dynamic characteristics of a structure can be examined by extracting the values of the natural periods and associated mode shapes.

We note that these simulations are subject to many assumptions about the seismic propagation from the source to the receiver and even slight modifications may produce impractical results. It is thought that a combined approach using rock spectra from various authors would provide a quality check on the spectra developed by one method.

5. SUMMARY AND DISCUSSION

In this work we evaluated the spectral acceleration of the recorded ground motion from the magnitude 5.2 earthquake which occurred during the 2001/02 sequence near Burakin in the Southwest of Western Australia (SWWA). The ground motion records recorded at short, medium and larger distances were considered in the process of determination of the basic characteristics such as frequency in order to define the parameters for simulation.

Then a moderate to large magnitude earthquake is simulated with Green's Function method using the selected SM records as sub-events. Previous validation studies for similar events in Australia have shown that synthetics produced by this method are comparable with the current Australian Building Code (Sinadinovski *et al.*, 2000) and can be used to realistically represent ground motion during typical intra-plate earthquakes.

These results can be further used to examine the characteristics of the dynamic response of specific structures such as bridges during the typical intra-plate earthquake excitation and to estimate the most probable level of seismically induced force.

6. REFERENCES

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