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AEES is a Technical Society of IEAust The Institution of Engineers Australia and is affiliated with IAEE

1/2006

AEES Newsletter

Contents

President's Column ………………………………………. 1
AEES2005 Conference - Albury …………….……….….. 2
Col Lynam's Column ……………………………………. 4
Earthquakes in Australia …………………………………. 6
Other News:
EarthByte , RNSA and predicting tsunami effects ..……. 7
From the States ………………………………………….. 8
..Conferences and Seminars ……………………………… 9
New Books and Recent Journal Publications ……………. 10
More presentations and discussions on the earthquakes and tsunami in southeast Asia:
Effects in Singapore ……………………………..……. 11
Protection against multiple hazards ………….……….. 13

President's Column

Welcome and greetings to all our members to the first newsletter of 2006. I'm sure I speak for all members in thanking Barb Butler our devoted Secretariat for the past 10 years for the fine contribution she has made to the smooth running of the society and in particular the annual conferences. We formally thanked Barb at the 2005 conference in Albury on behalf of all members. A long standing member of AEES, Kevin McCue, who will be known to most of the membership, has been appointed the Secretariat for 2006. We thank Kevin for undertaking this important role and his continued contribution to AEES which he helped found in 1990. Another important change announced at the AGM was that Dee Ninis has replaced Vaughan Wesson as Treasurer. We thank Vaughan for his great contribution to AEES which has involved the role of treasurer but also as web master who developed the original web site and email communications for AEES.

The 2005 Conference held in Albury 25-27 November was attended by around 65 delegates and is reported in this newsletter by Kevin McCue. The conference we believe was quite a success with more opportunity for delegates to interact with a mixture of general oral presentations and more specific poster presentations. Members voted overwhelming to repeat the format for 2007 in Canberra, where Geoscience Australia will host the event under the Chairmanship of Mark Edwards. The annual conference is our flagship event and provides a great opportunity for sharing and discussing the latest developments in seismology, earthquake engineering and related fields such as blast engineering, USAR, insurance, and emergency response management.

The society is working to upgrade the web page and in particular to provide electronic copies of conference papers to interested persons. ES&S have generously sponsored our web page and providing technical support for the development and maintenance of the site through Adam Pascale. Engineers Australia now manages all subscriptions and the membership database and the latest listing indicates we have some 220 members in AEES.

There is a need for AEES to raise community awareness in earthquake education in this country and to develop a response plan for emergency support and reconnaissance missions which could include the development of a register of professionals willing to be trained in undertaking reconnaissance missions and in assisting USAR (Urban Search and Rescue) taskforce teams. This issue has been raised over the past few years and USAR training of engineers and associated register is growing momentum with Adelaide established and Level 1 training of engineers in Melbourne scheduled for June 5 2006. This is a significant development for AEES and should result in the roll-out of training for specialist USAR engineers around Australia over the next few years, with AEES co-ordinating the training and maintaining a register of engineers trained to either Level 1 or 2.

The updated Earthquake Loading Standard AS1170.4 is complete and awaiting ratification by the Loading Standards Committee BD6 in March 2006. Publication has been delayed due to a number of important clauses on masonry being shifted to the Masonry Standard AS3700 which then required approval before BD6 and the ABCB (Australian Building Control Board) would approve AS1170.4. The process of updating the 1993 version of AS1170.4 has been slow, particularly after the original proposal of having a joint Standard with New Zealand was abandoned late in the period. Many thanks for the hard work and great stamina of Committee BD/6/11, all of whom are members of AEES, in developing the revised AS1170.4.

The Melbourne Executive Committee (John Wilson, Nelson Lam, Dee Ninis, Gary Gibson and Amy Brown and our new secretariat Kevin McCue) is looking forward to working with you to further develop AEES. Good luck to all our members for 2006 and we look forward to future interaction, comments and feedback.

John Wilson
AEES President
February 2006

AEES Executive

President	John Wilson
Secretary	Amy Heath
Treasurer	Dee Ninis
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Qld	Russell Cuthbertson
NSW	Michael Neville
ACT	Mark Edwards
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SA	David Love
WA	Hong Hao
Web master	Adam Pascale
Newsletter Editor	Nelson Lam

Management of the membership database and subscriptions is in the care of Engineers Australia and ALL members, whether they be members of Engineers Australia or not, will be issued with subscription notices by that organisation. Please direct any enquiries regarding subscriptions to Lois Wurzer at Engineers Australia: (email: LWurzer@engineersaustralia.org.au*)*

The mailing address for other matters has changed! To contact Kevin McCue at the Secretariat see the address top left front page.

AEES 2005 Conference - Albury

It's over for another year, and once again the annual AEES conference, our 14th, would have to be rated a great success. The new format was almost universally accepted with more poster and fewer oral presentations but a single stream – very important. For the second year in a row the venue was held in a regional rather than a capital city and again the number of attendees in Albury was more than satisfactory. Congratulations to the organising committee; John Wilson, Gary Gibson, Nelson Lam, Amy Heath and Barb Butler.

The usual diet of papers on engineering seismology, earthquake engineering, earthquakes and tsunamis, the loading code and insurance were delivered but supplemented for once with two presentations on building response to blasts, contracting the load imposition from seconds or tens of seconds to milliseconds. There was also a paper on responding to the growing terrorist threat and yet another on the disaster response to the Canberra bushfires of 2003.

One former AEES President made it to Albury, Bill Boyce, and he showed us how to be an effective and contributary session chair. Students and younger researchers were prominent and their contributions valued and applauded. I am each year surprised and thrilled that the energy and buzz are still there, that younger academics and practising engineers are replacing the few *grandfather* figures (thanks Nelson) who have striven since 1968 to get the practice of earthquake engineering accepted as a normal part of engineering design and construction in intraplate Australia.

At least 64 people registered for the conference held at the Commercial Club in downtown Albury between 25th and 27th November. Members came from WA, SA, Vic, Tasmania, NSW and Queensland, two from New Zealand, one each from Japan and China, one true world citizen and one with shared loyalties in Australia and the US. Our invited speaker from Europe didn't materialise but maybe next year!

Publication of the new loading code may be only months away but is, even at this stage, subject to political pressure from vested interests who will lobby to remove any clauses with which they don't agree. And that's after the public comment phase has passed. Apparently this happened before the last draft was published and even after it had been approved by Standards and the ABCB.

This year in the corridors of the Commercial Club I learned that: the SA government is upgrading schools in Adelaide in recognition of their special status and perhaps the political imperative of not being seen to be responsible for exposing Adelaide children to undue risk; that even in Canberra, the vulnerability of some older structures to earthquake loads is recognised, and strengthening of one heritage chimney has been undertaken to reduce the threat to local residents; that our members care about the plight of overseas communities where lives have been so rudely taken during recent earthquakes and survivors are threatened by the freezing winter without shelter.

It was a sad occasion on one count: Barbara Butler, after 10 years of incredible devotion and loyalty, has decided to resign and devote more time to husband Paul, to travel, and to indulge her passion for photography. We wish her well whilst lamenting her departure.

On Saturday night we were bussed to the conference dinner at St Leonards winery across the border. Who would have missed the comraderie, the excellent wine including a superb after-dinner port and the dinner itself. In what is becoming a burgeoning tradition, the bard from CQU, Mike Turnbull gave us a moving and illustrative rendition of a classic Australian poem, *The Man from Snowy River*, complete with his name and country of origin.

Next year Geoscience Australia will host and organise the conference in Canberra. I hope to see you all there again to hear about further progress and change in our most interesting and useful profession.

More news items and photographs of the effects of past Australian earthquakes is also more than welcome as you will see below.

AEES Conferences

	Year		Theme
1	1992	Sydney NSW	Earthquake Resistant Design and Insurance in Australia
2	1993	Melbourne Vic	Earthquake Engineering and Disaster Reduction
3	1994	Canberra ACT	Survival of Lifelines in Earthquakes
4*	1995	Melbourne Vic	PCEE'95
5	1996	Adelaide SA	The Australian Earthquake Loading Standard
6	1997	Brisbane Qld	Earthquakes in Australian Cities - can we ignore the risks?
7	1998	Perth WA	Meckering 30 years on – how would we cope today?
8	1999	Sydney NSW	The 10th Anniversary of the Newcastle Earthquake - Lessons learnt
9	2000	Hobart Tas	Dams, Fault Scarps and Earthquakes
10	2001	Canberra ACT	Loading Codes in the Real World
11	2002	Adelaide SA	Total Risk Management in the Privatised Era
12	2003	Melbourne Vic	Earthquake Risk Management
13	2004	Mt Gambier SA	Australian Earthquake Engineering in the new millenium – where to from here?
14	2005	Albury NSW	Earthquake Engineering in Australia
15	2006	Canberra ACT	tba

- ***held jointly with NZSEE***

At the Albury conference Bill Jordan mentioned that he was on the beach during the 1989 earthquake at Newcastle and observed a large deflection (! 1m) of the top of a 25 – 30 m high tower at the hospital. He followed this up with a letter and photo:

Brick tower at the Royal Newcastle Hospital

On 06/01/2006, at 3:34 PM, Bill Jordan again wrote:
I attach 3 photos you might find of interest:
Photo 1 shows the finials on the nave columns on the north side of Christ Church Cathedral a few days after the earthquake. The ones down the south side showed a similar phenomenon. You'll see that the finials are alternately twisted about 20 degrees, they were not pinned, just resting on a bed joint. It was not the same joint which failed in all finials, but most were the joint at the base of the tapered section. As the strata under the Cathedral are steeply dipping I believe that what we are seeing is the vertical component of the alternately circulating Rayleigh waves which would have been in a plane perpendicular to the "half space" surface which would be sloping downwards to the north.

Photo 1 Finial twisting, Christ Church Cathedral

Photo 2 of the NW tower shows the condition of the tower at the same time. A fleur-de-lis had come off the top. The lesson to be taken from this photo is that a year later, with work nowhere near starting and the steel bands having rusted through, somebody decided the towers were unstable and they were demolished. Unfortunately no-one had recorded them and the photo concerned, which I was able to find in my collection, was the only evidence available to allow their reconstruction!

Photo 2 Typical block rotations, fleur-de-lis off top

Photo 3 I have included this picture because it shows the typical out-of-plane failure of the high wall beside the stair and no sign of any connection between the roof structure and the destroyed end wall. The toppling of this wall must have been quite traumatic for a person in the bathroom on the right: I saw bare footprints in the dust on the floor leading from the shower to the door!

Photo 3 Building damage, lack of connectivity

Many thanks to Bill from Jordan and Assoc., Newcastle!

Kevin McCue

Col Lynam's Column

(Extracted from the daily blog of a "seismetrician")

(Col Lynam of Earthquake Services has over 35 years experience in observatory seismology in Brisbane lynam@uq.edu.au)

Item 1 Sydney most at risk (the Ed thought the following postings from the Australian seismology bulletin board might interest a wider audience).

SYDNEY is the Australian city most at risk of an earthquake, while Brisbane and Townsville are the most likely to be hit by a tropical cyclone, according to a global insurance company.

Swiss Reinsurance Co today launched Australia's first natural catastrophe bond as a way of covering against disasters. The bond offers local capital markets $US100 million ($133.51 million) worth of protection against Australian earthquake and tropical cyclone risk.

"How real are the risk exposures covered by this capital?" the Swiss Re head of Australia and New Zealand property and casualty business, Keith Scott, asked. "Very real," he said. "They are very remote occurrences, we expect maybe – in terms of frequency – that this cat bond would not be exposed to loss more than twice in 100 years," he said. "They are very large events when they occur and they are very infrequent."

Mr Scott said most of Australia's capital cities were at risk of an earthquake, some of them more than others.

"The biggest (risk) is Sydney," he said.

"I'm not scaremongering here, I'm not saying we are anticipating an earthquake – we are not – but you cannot discount this fact."

Mr Scott said the tropical cyclone risk in Australia was also more likely on the east coast, with Brisbane and Townsville the most exposed. "The cyclone risk is a very real risk," he said.

The bond, titled Australis Ltd, has a three-year life span and is the first of its kind in Australia. Insurance-linked securities (ILS) transfer insurance risk into the capital markets by packaging up a particular type of risk such as an earthquake, a hurricane or a human disease pandemic into an investment vehicle bought by institutional investors.

If the event covered by the ILS does not occur, investors receive their capital back with interest, but if it does occur, investors may lose some of their interest and/or their principal in the investment.

Swiss Re, which insures insurance companies around the world, said it was a way of helping insure against disasters that can cost tens of billions of dollars.

"The reinsurance industry's aggregate capital totals approximately $US170 billion ($227 billion) and there are real questions about how the industry is going to pay for events of this magnitude into the future," the company said.

Swiss Re said the destruction of the World Trade Centre in September 2001 and the damage caused to New Orleans by Hurricane Katrina in August 2005 represented the two largest insured catastrophes in history, each costing the global insurance industry well over $US30 billion.

Gary Gibson, senior hazard analyst at ES&S responded:

"Note that the Swiss RE study concerns risk, not hazard. It means that Swiss RE is likely to have to pay out more money after a Sydney earthquake than for any other Australian earthquake. It does not mean that Sydney is more likely to experience an earthquake than other places in Australia.

Risk = Hazard * Vulnerability * Exposure

Being a large city with many buildings and people, Sydney has a high exposure. Being relatively old, its buildings may have above average vulnerability. Its hazard is about average when compared with other Australian cities. That is, its probability of experiencing an earthquake is about average for Australia, and low compared with cities at plate boundaries."

George Walker, Senior Risk Analyst - Aon Re Services, then added:

"Gary is correct. Swiss Re is talking about catastrophe insurance risk. In Australia Sydney is the number 1 earthquake risk because of the concentration of population. Because in Australia earthquake losses are fully covered by insurance, and almost all property is covered against earthquake losses, which is not the case in most countries, from an insurance point of view Sydney is one of the highest earthquake risks in the world. Combined with the risks from Melbourne, Perth and Adelaide which are not far behind, and from Wellington, which is not much larger than Sydney, and Auckland, which is less than Sydney, and which are also covered by the major Australian insurance companies, this results in Australian insurance companies being among the largest purchasers of earthquake reinsurance in the world."

Mike Turnbull (senior lecturer, CQU) chipped in with:

"This is an interesting and important thread of conversation. I read current literature (academic literature, that is, not the public media or other uninformed sources) that use the terms hazard and risk as if they are interchangeable; which of course, they are not. As has been highlighted in these few emails, we also need to use both terms in the true context of what it is they are being used to describe. In this case, it is the insurance pay-out risk posed by an ambient earthquake hazard in the Sydney area - not the earthquake hazard, nor the earthquake risk itself (although the EQ risk is undoubtedly an input into the insurance risk equation)."

To which George Walker added:

"Mike makes an excellent point which should be lesson number 1 of any course. The word 'risk' is a generic term which means very little unless qualified by the subject of the risk. I participated in several discussions on risk last year involving people from widely differing backgrounds which went round and round in circles without getting very far because everyone was assuming that the risk being talked about was the risk of concern to them, and there had been no attempt to define clearly what risk was being talked about.

For scientists, it is often the hazard risk which is of paramount interest; for engineers it is damage risk, which involves both hazard risk and the vulnerabilty risk, or the risk of damage occurring given a hazard of a certain intensity occurs; for insurers it is the risk of financial loss to individual property from a hazard which involves the hazard risk, vulnerability risk, and risk of financial loss if damage occurs; for reinsurers it is the risk of financial loss to insurance companies from hazards, which involves an integration of the risks to individual properties over the whole area of impact of the event causing the hazard, for DOTARS it is national economic risk; for EMA, who are primarily concerned with strategic issues of disaster management, it is disaster risk, which involves an integration of individual physical and psychological impacts, as well as overall economic and social impacts on the community in total; for emergency management personnel at the local level it is the risks associated with emergency operations; for politicians it is the political risks associated with disasters, which are a combination of both disaster risks and the political influence of those affected.

It is possible to determine some generic approaches to risk, the most successful being the Risk Management Standard, but like anything generic for application the generic approach has to be customised to the risk which is of concern. Most critics of the Standard do not appreciate this, and criticise it because they expect it be directly applicable to their risk of concern without any customisation. It is the same with risk assessment. It is possible to develop a generic framework, but the framework cannot include the methodology since this will vary with type of risk.

A similar word is 'mitigation'. It is also the cause of much confusion in discussions because again it is a purely generic term and without a subject has no meaningful application. The problem has been highlighted by climate change issues where it is common among climate change scientists to talk of mitigation and adaptation. What is meant is mitigation of the risk of climate change by limiting the production of greenhouse gases, and adaptation to climate change resulting from the increasing concentrations of greenhouse gases in the atmosphere. But if the subject is the risk of disasters from climate change, then both mitigation of climate change and adaptation to it are means of mitigating this risk.

Maybe every time someone uses the word 'risk' if they haven't defined the subject of the risk someone should interject and ask "risk of what?" and every time someone uses the word 'mitigation' without defining the risk being mitigated someone should interject and ask "mitigation of what?" It could save many hours of directionless discussion and lead to much more productive committee meetings."

Item 2 The 2004 Great Sumatra Earthquake and Tsunami

The special issue of Earth Planets and Space, "The 2004 Great Sumatra Earthquake and Tsunami", is finally published online.

http://www.terrapub.co.jp/journals/EPS/frame/58.html

Item 3 Japan shakes up building rules

Author: Greg Earl TOKYO Asia-Pacific editor

Date: 31/01/2006

Publication: The Financial Review

Japan introduced new earthquake-related building standards yesterday amid signs the Koizumi government's economic reform momentum is being hampered by a series of controversies over regulation.

The new rules for architects follow a scandal late last year over the falsification of earthquake safety data that has forced the evacuation of some buildings.

Some analysts have warned the construction scandal is a more serious economic issue than the higher profile Livedoor company investigation because of the effect it could have on recent property market confidence after a 15-year slump.

"If people started to believe there were systemic problems in construction projects, you could see an economic impact," Macquarie Securities chief economist Richard Jerram said yesterday.

Sales data so far hasn't shown any downturn in the property market, but opinion polls show a decline in support for the government as voters express concern about regulatory inadequacies shown by the construction scandal, the Livedoor affair and US beef imports.

Under the building standards, third-party building surveyors will have to sign off on earthquake compliance data submitted in building applications by developers and their architects. Three-year jail terms and Y3 million ($34,135) fines will be introduced for breaking the rules.

The series of regulatory controversies is also becoming an issue in the battle to succeed Prime Minister Junichiro Koizumi, with key government figures trying to distance themselves from the problems or offering ritualised apologies.

The regulatory debate is also having a wider impact, with foreign business representatives told last week that the government would not be pushing ahead on schedule with promised changes to registration rules for foreign subsidiaries.

The foreign lobbyists were told it was impossible to push lighter-touch regulation for foreign companies through the Diet when the political focus was on tougher regulation for architects, stockmarket disclosure and food inspection.

The Koizumi camp favours an independent securities regulator but the Finance Ministry camp is arguing for a better funded Securities and Exchange Surveillance Commission, which it says should remain within the ministry's Financial Services Agency.

Earthquakes in Australia

Earthquakes of magnitude 2.5 or more in 2005 and located by Geoscience Australia, ES&S or PIRSA are shown in the following table. There were no M 5^+ events but thirteen exceeded M 3.9. No damage was reported. Three man-made events are included (marked *), all resulting from a hydrofracture experiment for geothermal energy near Innaminka SA. (Ed - apologies for the corrupted table in the last Newsletter).

Date	*TIME(UTC)*	*LAT*	*LON*	M	*Location*
Jan					
02	15643.9	35.388	148.65	2.9	Brindabella ACT
03	4030.16	30.652	117.479	3.5	N Koorda WA
05	83102.87	26.122	153.412	3.6	Off Sunshine Coast, Qld.
08	43719.2	19.796	134.009	2.5	Tennant Ck NT.
12	191717.2	23.004	127.876	2.8	SW L Mackay WA
12	225316.6	33.095	138.574	2.7	Jamestown, SA.
18	100912.7	33.845	147.191	3.7	N West Wyalong NSW.
20	94610.96	36.311	146.146	3.3	W Wangaratta VIic
24	94357.95	17.53	122.587	3.8	NE Broome WA
27	171734.2	31.416	119.236	3.5	W of Southern Cross WA
27	172901.0	32.467	122.381	3.3	SE Norseman WA
31	132247.7	30.806	121.453	2.6	S Kalgoorlie WA
Feb					
12	2306.56	19.817	133.994	2.7	SW Tennant Ck NT
12	83010.11	30.647	117.539	2.7	N Koorda WA
12	144919.0	19.762	133.932	2.7	SW Tennant Ck NT
12	162501.7	19.723	133.936	2.6	W Tennant Ck NT
12	162527.2	19.742	133.898	3.1	W Tennant Ck NT
13	183536.6	30.652	117.539	2.8	N Koorda WA
13	192628.9	30.647	117.506	2.5	N Koorda WA
18	175743.1	32.827	121.085	3.3	SW Norseman WA
20	91627.26	34.013	148.683	2.9	N Breakfast Ck NSW.
20	173340.9	30.659	117.535	2.8	Koorda WA
23	193505.3	14.632	122.064	3.9	Scott Reef.
24	165741.9	30.629	117.485	3.3	N Koorda WA
27	61735.98	33.606	118.282	3.6	NE Gnowangerup WA
Mar					
03	105701.4	30.899	139.139	**4.0**	SE Leigh Ck SA.
04	3850.67	33.046	139.547	3.2	E Peterborough SA
06	53740.71	28.097	115.73	2.5	NE Geraldton WA
07	145225.2	24.309	112.565	3.3	NW Carnarvon WA
07	162236.7	26.469	151.482	3.6	Durong QLD
08	45425.92	14.663	122.168	3.6	Scott Reef.
08	50012.37	34.328	148.427	2.5	E Young NSW.
12	155518.4	30.663	117.447	2.9	Koorda, WA
13	20949.03	26.155	131.644	**4.6**	W Ernabella SA
15	124955.5	32.527	116.844	2.7	SW Brookton WA
16	12717.36	30.639	117.464	4.2	N Koorda WA
17	163611.6	31.116	116.604	2.7	Calingiri WA
18	110449.9	30.717	117.343	2.8	NW Koorda WA
19	72928.07	26.091	130.868	**4.1**	Central Desert NT.
19	213850.1	20.465	115.508	3.7	Barrow Is WA
22	195153.7	21.004	119.61	**4.4**	NW Marble Bar WA
23	100425.9	19.777	134.071	3.1	Tennant Ck NT.
25	41645.93	31.16	117.217	2.9	Dowerin WA
25	91032.07	20.353	145.8337	2.7	SW Charters Towers Qld.
29	161558.4	22.144	126.605	3.5	W L Mackay WA
Apr					
02	91447.59	16.645	127.241	2.9	N Halls Ck WA
04	35839.4	30.576	117.004	2.5	Burakin WA
04	52129.3	30.568	116.999	2.6	Burakin WA
05	192956.2	10.596	124.11	3.9	Timor Sea.
09	233408.9	19.782	133.961	2.6	Tennnant Ck NT
12	115935.0	30.588	117.005	3.5	SW Burakin WA
12	120002.0	30.564	117.005	**4.0**	W Burakin WA
14	20303.52	30.574	117.005	2.7	W Burakin WA
14	131626.8	28.55	149.272	3.2	SE St George Qld.
14	171759.8	33.507	118.344	2.8	S L Grace WA
15	81233.2	31.968	116.714	2.5	Beverley WA
18	90219.75	30.567	117.0	3.2	W Burakin WA
18	135332.3	33.614	118.273	2.8	Gnowangerup WA
18	150107.1	30.574	116.995	2.8	Burakin WA
18	211814.4	38.299	146.354	2.6	NE Yinnar Vic
20	215322.4	38.533	146.534	3.5	Hiawatha Vic
21	114809.4	30.579	116.998	2.5	Burakin WA
21	115722.5	30.587	117.005	2.5	Burakin WA
22	11256.45	30.235	117.861	3.1	N Beacon WA
22	194553.0	30.572	117.007	2.7	W Burakin WA
26	112944.4	19.844	134.001	2.6	SW of Tennant Ck NT.
May					
01	94316.38	30.194	117.912	**4.1**	N Beacon WA

01	153840.9	30.198	117.887	3.6	N Beacon WA
02	194242.7	32.868	139.403	2.7	E Peterborough SA.
04	184516.1	25.932	117.319	3.2	SE Erong Springs WA
06	65904.2	31.635	115.963	2.8	S Bindoon WA
09	145243.4	30.583	116.98	3.2	W Burakin WA
12	11837.01	31.953	117.203	2.6	NE Beverley WA
14	133328.3	28.744	136.567	3.8	William Ck SA.
14	195305.9	31.0	139.153	**4.5**	N Flinders SA.
15	215426.4	30.689	117.423	2.8	N Koorda WA
17	53431.38	30.205	117.915	3.3	N of Beacon WA
18	233947.5	20.108	119.374	**4.6**	E Pt Hedland WA
21	30012.9	30.664	117.435	2.5	N Koorda WA
27	121044.8	30.65	117.447	3.3	N Koorda WA
27	124819.1	30.632	117.461	3.0	N Koorda WA
27	140845.9	30.635	117.47	2.8	N Koorda WA
29	154819.4	30.658	117.434	2.5	N Koorda WA
Jun					
02	120429.5	31.509	117.207	3.0	N Cunderdin WA
08	210053.7	32.9	140.015	3.3	S Manna Hill SA
09	164445.92	23.093	115.068	3.5	SE Exmouth WA
09	224716.8	30.773	117.05	2.5	W Cadoux WA
11	14737.6	35.843	148.595	2.6	E Kiandra NSW
12	105119.6	30.802	117.108	**4.3**	SW Cadoux WA
12	203644.5	30.558	117.03	**4.5**	W Burakin WA
13	131116.4	30.58	117.006	2.8	SW Burakin WA
16	42906.31	34.13	135.59	3.6	NW Cummins SA
24	85148.8	31.304	116.604	2.5	E Bolgart WA
27	3837.4	30.219	117.873	2.7	N Beacon WA
30	141346.3	39.178	142.129	3.5	S Warrnambool Vic
Jul					
04	202143.2	34.558	148.509	2.5	SW Boorowa NSW.
09	134852.2	14.953	124.659	2.5	NE of Kuri Bay WA
11	201958.3	31.253	144.777	3.0	W Cobar NSW.
12	75749.4	31.491	138.519	3.5	N Hawker SA.
14	62338.18	34.085	147.16	2.8	S of West Wyalong NSW.
30	165609.9	28.544	148.576	2.8	S St George Qld
Aug					
03	50213.45	19.905	133.875	3.8	Tennant Ck NT.
13	151612.8	22.86	127.74	2.7	W L Mackay WA
15	95650.7	30.75	118.236	2.5	N Mukinbudin WA
16	73338.93	34.125	139.357	2.9	Eudunda SA.
24	33733.0	32.319	138.73	3.3	Hawker SA.
Sep					
03	230506.5	34.401	148.654	3.5	Boorowa NSW.
08	145706.5	30.76	117.144	2.9	Cadoux WA
09	40108.7	30.328	142.166	3.3	S of Tibooburra NSW.
11	214041.9	16.518	128.73	2.6	S Kununurra WA
12*	160404.5	27.737	140.558	3.0	Innamincka SA
12*	163658.0	27.744	140.564	2.5	Innamincka SA
13*	32104.6	27.853	140.76	2.9	Innamincka SA
14	51222.39	19.868	134.102	**4.4**	Tennant Ck NT.
18	103643.1	32.663	138.565	3.2	Peterborough SA
20	45015.0	30.135	117.181	2.5	Kalannie WA
21	213915.4	30.146	117.173	2.7	N Kalannie WA
21	224641.8	30.148	117.159	**4.0**	N Kalannie WA
21	225925.3	30.151	117.167	3.7	N Kalannie WA
21	230355.4	30.136	117.15	2.6	N Kalannie WA
22	2847.16	30.172	117.153	3.0	N Kalannie W.
22	35259.77	30.126	117.173	**4.1**	NE Kalannie WA
22	183434.3	30.142	117.159	3.9	N Kalannie WA
23	95640.18	30.142	117.169	2.7	N Kalannie WA
23	114315.5	30.123	117.202	2.9	N Kalannie WA
28	213732.2	38.601	145.965	2.7	SW Tarwin Vic
29	215014.2	31.8	138.762	2.5	Hawker SA.
Oct					
02	175008.2	30.034	150.726	2.5	Bingara NSW
03	72217.41	30.517	117.05	2.7	W Burakin WA
04	92332.65	19.722	134.015	3.2	SW Tennant Ck NT.
05	193612.3	30.166	117.171	3.3	N Kalannie WA
18	161330.4	19.868	134.101	3.4	S Tennant Ck NT
20	40104.76	30.165	117.143	2.9	N Kalannie WA
22	63819.44	30.225	117.878	2.7	N Beacon WA
31	181337.7	33.571	150.158	3.1	W Katoomba NSW
Nov					
05	114912.1	30.133	117.175	2.9	N Kalannie WA
06	112809.7	30.135	117.155	3.1	N Kalannie WA
06	150651.0	31.751	117.073	2.9	Meckering WA
11	5844.28	30.137	117.186	2.5	N Kalannie WA
15	145044.8	16.486	128.666	3.0	S Argyle WA
20	213857.2	30.143	117.153	2.6	N Kalannie WA
25	203221.5	30.134	117.195	3.6	N Kalannie WA
28	45743.24	20.074	133.86	3.4	SW of Tennant Ck NT.
Dec					
01	15203.25	30.536	117.038	2.9	Burakin WA
14	110226.3	21.889	113.701	2.6	W Exmouth WA
17	625.57	19.821	133.008	2.9	SW of Tennant Ck NT.
20	132352.0	30.134	117.204	2.5	N Kalannie WA
20	194926.4	29.4	114.102	3.8	SW Geraldton WA
22	135321.1	37.686	139.413	3.4	Off Beachport SA.
26	75018.02	16.133	128.746	3.0	S Kununurra WA
27	93205.95	24.86	112.757	3.5	W Carnarvon WA
28	205452.3	28.191	147.894	3.6	W St George Qld

Other News

New Resources in 2006 - EarthByte

The EarthByte research group at the University of Sydney, headed by A/ Prof. Dietmar Müller, aims to connect geodynamic modelling tools to geological and geophysical data in space and geological time.
For more information on EarthByte Research and Resources, visit: <http://www.geosci.usyd.edu.au/research/earthbyte/>

Briefing from Professor Priyan Mendis Research Network Secure Australia (RNSA)

Website: http://www.SecureAustralia.org

The RNSA has been able to bring together the majority of Australia's leading researchers, government and industry leaders involved in Critical Infrastructure protection. Protection against Earthquakes and Tsunamis has been identified as one of the research areas for networking. As well, the RNSA has been able to facilitate a knowledge-sharing network for research organisations, government and the private sector to develop research tools and methods to mitigate emerging safety and security issues relating to critical infrastructure. The network has also been able to integrate complementary, yet diverse research areas including physical and information infrastructure security, and surveillance and intelligent systems. Since the launch 160 Network Participants have registered. "

The Science, Engineering and Technology (SET) Summit organised by the RNSA" was held in Canberra" in July 2005. Over 300 people attended this event. The first focus group meeting was held in Feb. 2005 at ADFA. The RNSA organised" 20 other seminars, workshops and collaborative research discussions related to CIP area. A Tsunami Technical Forum on Understanding Tsunami Threat and Mitigation Technologies "Boxing Day Tsunami: Six Months On" was organised in June. The 2005 RNSA program concluded with the Risk Assessment workshop and the Counter Terrorism Closed Session workshop held in UNSW, Sydney (November). More details are given in the website under the heading News and Events. "

Many events are planned for 2006, such as the Counter-Terrorism collaborative research workshop in February 2006 at the University of Melbourne, Social Implications workshop in May 2006 at the University of Wollongong and the annual conference in Sept. 2006 in Canberra.

Regards
Priyan

Model to help predict tsunami effects

(from Civil Engineers Australia, January 2006)

The University of Queensland has developed a new tsunami impact model to help emergency response teams plan what to do if the next big wave hits.

The mathematical model was developed by Dr Tom Baldock, PhD student Paul Guard and Associate Professor Peter Nielsen from UQ's coastal engineering group. It can predict the initial run-up and impact as the leading waves hit the coast.

Baldock says the model represents a significant leap forward from classical tsunami impact research that is based on non-breaking waves.

'By watching videos of the Boxing Day tsunami, we realised that conventional non-breaking wave models were not suitable for describing the leading breaking waves,' he said.

'Our new research is able to calculate the motion of the leading edge of the breaking-wave run-up on dry land, together with the flow depth and flow velocities in the inland region during the inundation.'

'The model can help with planning for a tsunami event by providing estimates of inundation depths, the force exerted by the water on structures, and forces from debris that may be picked up and carried in the flow.'

Baldock says the new model only requires information about water depths at the original shoreline location, which is usually the most widespread data available.

The team is currently carting out experiments using a recently built tsunami generator in UQ's Coastal Wave Flume, which forms part of the Division of Civil Engineering's Geohazard Research Laboratory. The generator produces breaking and non-breaking tsunami type waves on a laboratory scale.

From the States

• South Australia: New network around Adelaide

With funding from State and Federal government under the Natural Disaster Mitigation Program, a new earthquake monitoring network is being installed in and around Adelaide.

There will be five new, and two upgraded stations around the Mt Lofty Ranges and Yorke Peninsula. Each station will include a seismometer and accelerometer, and will transmit data in near-real time to Adelaide for rapid calculation of earthquake details. This network will rapidly locate earthquakes in the area that could possibly affect Adelaide in case of a large event. It is hoped that many more small earthquakes than is presently possible will be located, and with much increased accuracy.

There will be three extra recorders (again with accelerometer and seismometer) within the metropolitan area. These are intended to measure amplification and resonance. They are likely to be moved every one or two years.

The recorders will be Kelunji Echos from ES&S in Melbourne. They will be equipped with internal accelerometers. Seismometers will be mainly Guralp 1Hz triaxial, with two sites having broadband Guralps.

Sketch showing station distribution, solid triangles – new. open squares – existing. The 1954 epicentre is in the southern-most section of the hatched urban area. The distance across the Gulf at Adelaide is about 70 km.

The existing sites at Sedan (currently a dial-up Kelunji Classic) and Mt Bonython (currently an analogue station) will be upgraded. A site south of Myponga is currently being installed, and a site survey is being carried out for a location near Strathalbyn.

David Love, South Australian representative

Commonwealth – Workshops held at GA Canberra

On 21st and 22nd of February, Geoscience Australia hosted two workshops to identify future directions for earthquake hazard research in Australia. The first meeting focussed on ground-motion modelling and the development of Australian specific attenuation relations for hazard and risk assessments. A specialist group that included several international experts was assembled. The day covered many topics including;

- early ground-motion research in Australia
- application of ground-motion models for major engineering projects in Australia
- current research and its implications for engineering methods adopted in other regions of sparse ground-motion records.

The meeting was closed with some general discussion on future research. The key outcome from the discussion was that a greater emphasis should be placed on recording strong and weak-motion records across the continent to improve our ground-motion database. Other outcomes included developing more detailed crustal structure models to aid the generation of synthetic seismograms and re-analysis of isoseismal data.

The ground-motion meeting coincided with the preliminary release of an Australian Ground-Motion Database (AGMD). This database, a joint initiative between Geoscience Australia, The Australian National Committee on Large Dams (ANCOLD) and Environmental Systems and Services (ES&S), will become freely available to all interested parties. It is hoped that the database will provide a valuable resource for ground-motion attenuation studies in Australia.

The Wednesday 22nd February meeting was an open forum among the key Australian seismologists and observatory operators to discuss the development of a holistic Australian earthquake and instrument metadata catalogue to support earthquake hazard research. The key aim of the meeting was to gain support for the catalogue from the seismological community and to establish who could provide useful information for the catalogue.

The envisaged catalogue would be based on the CSS 3.0 schema and would comprise all available seismological data, including, but not limited to; hypocentres, phase picks, waveforms, focal mechanisms and isoseismal information. These would be linked to time-dependent site information, including; site coordinates, the type of transducer, recorder, gains, filters, etc.

Highlighted in the meeting was the need to retrieve archived data where it still exists (particularly in Western Australia) and the need for a standard data exchange format. It was agreed that Geoscience Australia would be the custodian of the catalogue with support from state authorities. A working group was set up to consider the requirements and potential issues associated with developing the database. One of the key issues to be examined will be the merits of developing a central or virtual database that can be revised by various contributors.

For further information regarding either of these workshops, or the AGMD, please contact either Trevor Allen (trevor.allen@ga.gov.au) or Mark Leonard (mark.leonard@ga.gov.au).

Victoria: Early earthquake in the colony

At about 03:15 am on 17 September 1855 (1885-09-16 1712 UTC), an earthquake was felt strongly along the south-central Victorian coast, especially in the Cape Schanck area. It was also felt in Melbourne. The distribution of felt reports suggests that the epicentre was in Bass Strait south of Cape Schanck, and the magnitude derived from the radius of perceptibility would have been about 5.5. Maximum intensities were about Modified Mercalli 5 to 6.

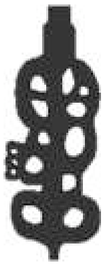
A wonderful cartoon was published in the Melbourne punch. It shows Punch, dressed as Zeus, the Greek god of lightening, and Toby sitting on a stormcloud, Punch is holding arrows which are sending bolts of lightening (new constitution written on one lightening bolt) to the ground, below him five men are falling into a crevice; one of the men appears to be the Governor, Hotham.

http://www.slv.vic.gov.au/miscpics/0/2/4/doc/mp024496.shtml

Gary Gibson, Victorian representative

Conferences and Seminars

Readers are encouraged to provide information to the editor on upcoming conferences and seminars.



- **2006/03/10-12 Remembering Napier 1931 – Building on 75 years of Earthquake Engineering in NZ.** Century Theatre, Napier New Zealand. Les Megget will give the keynote address: From Brittle to Ductile: 75 Years of Seismic Design in NZ.

- **2006/04/18-22 100th Anniversary Earthquake Conference: Commemorating the 1906 San Francisco Earthquake.** San Francisco, California
  Contact: EERI, 499 14th Street, Suite 320, Oakland CA 94612-1934, eeri@eeri.org
  http://www.1906eqconf.org or
  http://www.quake06.org/quake06.html

- **2006/05/23-26 Canadian Society of Civil Engineers Conference : Towards a Sustainable Future**
  Hyatt Agency Hotel, Calgary, Alberta, Canada.
  Contact: Dr. Mamdouh El-Badry. University of Calgary, 2500 University Drive, Calgary, AB , T2N 1N4.
  Tel: 403-220-5819; Fax: 403-282-7026
  Email: tech@CSCE2006.ca, website http://csce2006.ca

- **2006/06/22-25 11th Symposium on Natural and Human-Induced Hazards**, Patras University, Greece.

I am glad to let you know that the *International Society for the Prevention and Mitigation of Natural Hazards* (known as NHS) organizes the 11th Symposium on Natural and Human-Induced Hazards at the Univ. of Patras, Greece, the cultural capital of Europe for 2006, from 22 to 25 June 2006. In parallel with this event, the 2nd Workshop on Earthquake Prediction (European Seismological Commission) will take place from 22 to 23 June 2006. Detailed information can be obtained from the website https://www.rr.upnet.gr/Hazards2006/
I hope to see you all in Patras next June.
Regards,
Gerassimos Papadopoulos
NHS President

- **2006/07/2 - 6 Australian Earth Sciences Convention 2006**. Melbourne Convention and Exhibition Centre. This convention will be organised into broad themes to integrate the scientific interests of the GSA and ASEG. The aim is to foster increased collaboration and innovation in addressing major contemporary and geological issues facing Australian society and the Australian earthscience community. /Please note that an SG^2 AGM to be held during the Conference/. For more information: http://www.earth2006.org.au/

New Books and Journal Publications

Books

A Voyage of Discovery. Published 2005, Frankston, Victoria, Australia by Lance Endersbee (Publisher and author).

A former president of IEAust, Civil Engineer and world-renowned expert in rock mechanics, Professor Endersbee has some controversial slants on climate change, the origin of the world's water, oil, deep earthquakes and other things.

The book, hard cover with 263 pages, has many colour photographs and a good reference list and, despite the lack of an index, is excellent value for $50 plus $10 postage. It is available from the Monash University bookshop online at www.bookshop.monash.edu.au.

Journal articles (could authors please send us the references to any relevant research publications – you are usually the first to know).

Earthquake Design of Buildings in Australia using Velocity and Displacement Principles by John Wilson and Nelson Lam *Australian Journal of Structural Engineering*, Vol.6 No.2 pp. 103-118.

Displacement-Based Design of the Seismic Capacity of Unreinforced Masonry Walls in Bending by Mike Griffith, Nelson Lam and John Wilson *Australian Journal of Structural Engineering* Vol.6 No.2 pp. 119-132.

The Society website/email list

Dear AEES Members,

The AEES web site (www.aees.org.au) will soon be overhauled and new content added. Any contribution from you on the following topics is most welcome:

- details of interesting recent publications
- significant research projects in earthquake engineering (in Australia?)
- links to other relevant Web sites.

Please send me your contributions/suggestions via email.

The AEES email list is operated by the ES&S Seismology Research Centre, Melbourne. If you would like to register please notify me at adam.pascale@esands.com

Regards
Adam Pascale

Presentations and discussions on earthquakes and tsunamis in southeast Asia

A BRIEF REPORT ON REPUBLIC PLAZA RESPONSE TO THE GREAT SUMATRA-ANDAMAN ISLANDS EARTHQUAKE (M_W = 9.0) OF DEC 26, 2004

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Protective Technology Research Centre, School of Civil and Environmental Engineering
Nanyang Technological University, Singapore

1. Introduction

The massive undersea earthquake (moment magnitude M_w = 9.0) of 26 December 2004 occurred off the north-west coast of Sumatra, Indonesia (Figure 1). It caused a tsunami around the Indian Ocean with a global death toll approaching 290,000 (as of 22 March 2005), making it the deadliest tsunami ever recorded. The epicenter of the recent earthquake is 908 km north-northwest from Singapore. Singapore is located in a low seismicity region of the Sunda plate with the Sumatran fault and the Sumatran subduction zone located more than 350 km away. While earthquakes have never posed any real problems for Singapore, previous large earthquakes have been felt in Singapore [1-4]. The main tremors and a series of aftershocks from the recent earthquake were also reported felt in several areas of Singapore. A local newspaper reported that the tremors were felt are Tanjung Rhu, Marine Parade, Toa Payoh, Siglap and Meyer Road (*Today*, December 27, 2004). At these locations, the tremors caused no damage.

2. Republic Plaza Response

Since 1996, one of the tallest buildings in Singapore, the Republic Plaza (Figure 2) has been instrumented to study the building responses due to dynamic loadings from both wind and long-distance earthquakes [5].

The Republic Plaza is a 66-storey, 280 m high tower that consists of a frame-tube structural system with a central core wall, in turn connected to a ring of external columns by a horizontal steel framing system at every floor. The structure sits on a deep, stiff caisson foundation system. The foundation system consists of six 60 m deep interior caissons connected by a 5.5 m thick concrete mat, and eight 40 m deep exterior caissons linked by transfer beams. From ambient vibration tests, the first vibration frequencies of the building are 0.19 Hz and 0.20 Hz, in the two horizontal x- and y-direction. The instrumentation system consists of four servo-accelerometers, two 3-component anemometers and other hardware for the purpose of converting analogue to digital data, storage and remote accessing. Two servo-accelerometers are installed at the basement level (B1) along the two principle directions of the building, and the other two are at the roof level. The signal ranges of the accelerometers are set to ±10 mm/s^2 at the B1 level and ±50 mm/s^2 at the roof level.

During the main shock of the Sumatra-Andaman Islands earthquake, the instrument system in the Republic Plaza was triggered by the ground wave propagating to Singapore from the epicentre. The motion signals were recorded at both the basement and the roof of the building. The maximum accelerations at the basement are about 5.3 mm/s^2 and 4.1 mm/s^2 in the x- and y-directions, respectively. The maximum roof accelerations are about 18.7 mm/s^2 and 18.1 mm/s^2 in the x- and y-directions.

The ground signals recorded at the basement were used as input to the finite element (FE) model shown in Figure 2. The roof displacement were determined numerically and compared with the recorded roof displacement. The left side of Figure 3 represents the numerically determined response from the FE model, and the right side the recorded response.

3. Conclusion

Singapore is located in a low seismicity region of the Sunda plate, with the Sumatran fault and the Sumatran subduction zone, located approximately 350 km away. While earthquakes have never posed any real problems for Singapore, previous large earthquakes have induced tremors felt in Singapore. This article has compared the recorded roof displacement of a tall building in Singapore with that determined numerically. It has been shown that the numerically determined, and recorded roof displacement, match well.

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[3] Graduate Project Officer, Protective Technology Research Center, Nanyang Technological University

In Singapore, limited land and rapid economic development have prompted the construction of tall buildings. These tall and soft buildings may respond significantly to long period, far-field earthquake ground motions.

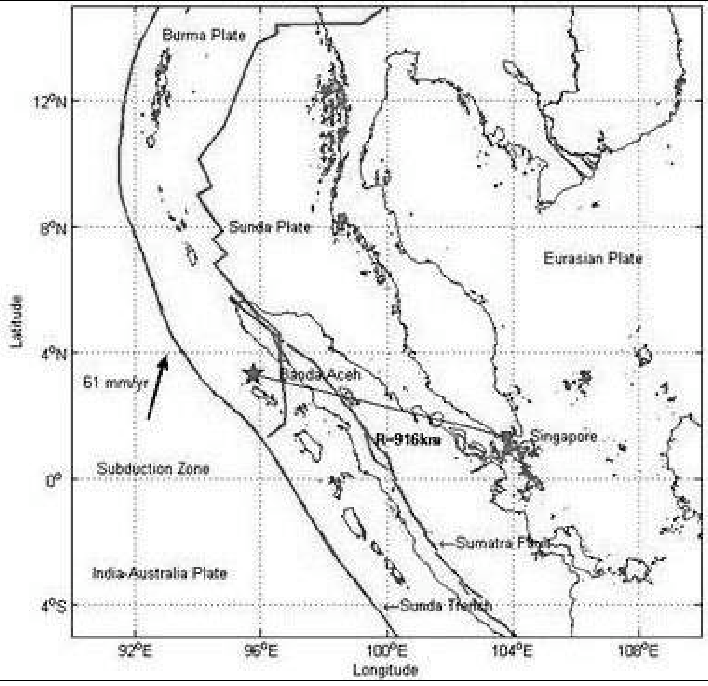
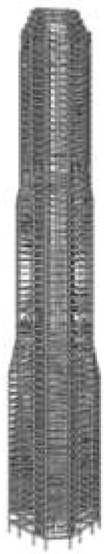


Figure 1 – Epicenter of the Great Sumatra-Andaman Islands Earthquake (M_W = 9.0) of December 26, 2004

(a) Republic Plaza



(b) FE model of Republic Plaza

Figure 2 – Republic Plaza and FE model of Republic Plaza

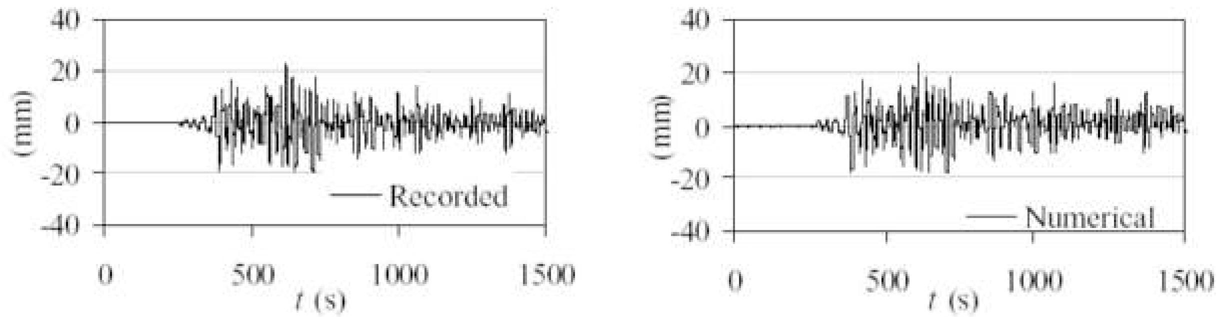


Figure 3 - Numerically determined displacement compared with the recorded displacement

Acknowledgments

The authors wish to thank Prof. J.M.W. Brownjohn of the University of Sheffield, City Developments Ltd, Meteorological Service Singapore, and Shimizu Corporation, Japan. Without their help, this work would not have been possible.

Reference

1. Pan, T.-C. "When The Doorbell Rings – A Case of Building Response to Long Distance Earthquake" *J. of Earthquake Engineering and Structural Dynamics*, International Association for Earthquake Engineering, Vol. 24, No. 10, pp. 1343 – 1353 (1995).
2. Pan, T.-C. and Sun, J. C. "Historical Earthquakes Felt in Singapore," *Bulletin of Seismological Society of America*, Vol. 86, No. 4, pp. 1173 – 1178 (1996).
3. Pan, T.-C. "Site-dependent Building Response in Singapore," *Earthquake Spectra*, Earthquake Engineering Research Institute, Vol. 13, No. 3, pp. 475-488 (1997).
4. Pan, T.-C., Megawati, K., Brownjohn, J. M. W. and Lee, C. L. "The Bengkulu, Southern Sumatra, earthquake of 4 June 2000 (M_w = 7.7): Another warning to remote metropolitan areas." *Seismological Research Letter*, Vol. 72, No. 2, pp. 171-185 (2001).
5. Pan, T.-C., Brownjohn, J. M. W. and You, XT. "Correlating Measured and Simulated Dynamic Responses of a Tall Building to Long-Distance Earthquake," *J. of Earthquake Engineering and Structural Dynamics*, International Association for Earthquake Engineering, Vol. 33, No. 5, pp. 611-632. (2004).

BUILDING PROTECTION AGAINST MULTIPLE HAZARDS

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Introduction

Reflecting the rapid economic growth and development, many high-rise buildings and complex infrastructure systems have been constructed in recent decades in almost all mega cities of Asia. Of concern is the high concentration of population and commercial activities taking place in these cities. Therefore, the consequences of even a moderate disaster may be enormous in these cities. Recent technological development has motivated the devising of new methodologies for sustainable development of Asian mega cities with adequate safety and security.

The Fourth International Symposium on New Technologies for Urban Safety of Mega Cities in Asia was held in the Nanyang Technological University (NTU), Singapore, during October 18-19, 2005. It was co-organized by the Protective Technology Research Center, NTU, Singapore, and the International Centre for Urban Safety Engineering, University of Tokyo, Japan. There were about 100 participants from various countries, and the participants included researchers, engineers and officers of ministries. The objective was to encourage communication and enhance understanding among researchers, practitioners and policy-makers.

Within the Singapore community, the concerns about urban safety include: (a) the response of buildings subjected to far-field earthquake ground motions; (b) damage assessment of buildings subjected to ground shocks; and (c) blast response of buildings.

Far-field earthquake motions

Singapore is located in a low seismicity region of the Sunda plate, with the Sumatran fault and the Sumatran subduction zone located approximately 350 km away. While earthquakes have never posed any real problems for Singapore, previous large earthquakes have induced tremors felt in Singapore. In Singapore, limited land and rapid economic development have prompted the construction of taller buildings.

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[6] Project Officer, School of Civil and Environmental Engineering, Nanyang Technological University

These taller and softer buildings may respond more significantly to long-period, far-field earthquake ground motions.

A great earthquake with an estimated moment magnitude (M_w) between 8.7 and 8.8 occurred in 1833 [1]. Another great earthquake with M_w between 8.3 and 8.5 occurred near Nias Island in 1861 [2]. Both earthquakes occurred in the subduction zone. The great earthquakes occurring more recently in the subduction zone were the Bengkulu earthquake (M_s=8.0) of 4 June 2000 [3] and the Great Sumatra-Andaman Islands earthquake (M_w=9.0) of 26 December 2005.

Recently, another great earthquake (M_w = 8.7) occurred near Nias, North Sumatra, Indonesia, on 28 March 2005, at 16:09:36 UTC. The epicenter of the earthquake was located at 2.07° N and 97.01° E, and was about 757 km west-northwest of Singapore (Figure 1). The earthquake of 28 March 2005 occurred principally on the interface between the Australia plate and the Sunda plate. There were about 65 aftershocks with magnitudes exceeding 5 (Figure 1).

In Singapore, it was reported by two local newspapers that tremors lasted for about two minutes, due to the Great Nias, North Sumatra earthquake. The tremors were felt in many parts of Singapore as reported in local news reports and determined by a survey. Prior to the Great Nias, North Sumatra earthquake, and excluding the Bengkulu earthquake, many buildings in Singapore have reportedly responded to the Sumara earthquakes (Figure 2). They are mostly high-rise reinforced concrete structures founded in Quaternary deposits and reclaimed land. In the case of the Nias, North Sumatra earthquake, occupants of more than 200 buildings reportedly felt the tremors, almost all over the whole island.

Ground Shocks

Most mega cities have limited free surface land, and Singapore's national effort is to intensify its land use. This has prompted underground space development, leading to the construction of ammunition storages underground. As a result, ground shocks due to accidental underground explosions and their effects on surrounding buildings are investigated.

Ground shock characteristics can be segmented into two parts: the major shock duration (Phase 1) and the ensuing duration (Phase 2). It was shown that the high frequency nature of a ground shock leads to a large shear force with small deformation during Phase 1, followed by significant deformation during Phase 2 [4]. In Phase 2, the response of global modes is significant, and this would possibly cause beam-column joint failure. For non-seismically designed beam-column sub-assemblies, it has been experimentally observed that the beam-column joints may fail at an inter-storey drift ratio of about 3 % of the storey height.

A non-seismically designed 6-storey reinforced concrete (RC) frame was subjected to a simulated ground shock. For the simulated ground shock, the peak ground acceleration (PGA) is 124 g, the peak particle velocity (PPV) is 0.9 m/s and the principal frequency is about 200 Hz.

By considering the failure mechanisms of flexural failure (FF), diagonal shear failure (SF) and joint failure (JF), the damage to the 6-storey RC frame subjected to the simulate ground shock was assessed. A parametric study was undertaken which involved the scaling of the PGA, PPV and principal frequency of the simulated ground shock. The characteristics of the scaled ground shock leading to the various failure mechanisms are shown in Figure 3.

Air blasts

Effects of an air blast, from an explosion, on a high-rise commercial RC building resulting from a vehicle bomb at ground level were investigated. The objective was to investigate the effect of standoff distance on building damage. The high-rise commercial building selected for the study was a 30-storey RC structure with frames and a shear wall core.

For a long standoff distance case, while the deformation was concentrated at the ground column and the beams of the second and the third storeys, the stress waves propagating towards the roof direction caused vibration of the upper storeys. The beam deformation was focused at its ends where local damages occurred (Figure 4).

However, for a short standoff distance, the dynamic deformation was localized at the blast-loaded columns spanning between the first and the third storeys. The beams connected with these columns might thus be damaged. Large residual deformations were observed for the blast-loaded columns and the beams connected to them (Figure 5). Compared with the case of long standoff distance, the global response hardly existed in the short standoff distance case.

Conclusions

In summary, there is a need to investigate systematically the effects of multiple hazards which may include both natural and man-made events. In this article, the multiple hazards investigated comprise the effects of long-distance major Sumatra earthquake, ground shocks, and air blasts. The dynamic response of the non-seismically designed building structures in Singapore to these multiple hazards shows varying characteristics.

This will pose a challenge to the engineering community who must strike a balance between safety and economy in designing and constructing a building to resist the multiple hazards. The consequences from any extreme event of the multiple hazards could be devastating to mega-cities due to the high concentration of population as well as the high-value commercial and financial activities. However, it is important to realize that the dynamic effects of these events have varying characteristics and frequency of occurrence.

References

1. Zachariasen, J., K. Sieh, F. W. Taylor, R. L. Edwards, and W. S. Hantoro. Submergence and uplift associated with the giant 1833 Sumatran subduction earthquake: Evidence from coral microatolls, J. Geophys. Res. 1999;104: 895-919.
2. Newcomb K. R. and W. R. McCann. Seismic history and seismotectonics of the Sunda Arc, J. Geophys. Res. 1987;92: 421-439.
3. Pan, T.-C., K. Megawati, J. M. W. Brownjohn, and C. L. Lee. The Bengkulu, Southern Sumatra, earthquake of 4 June 2000 (M_w = 7.7): Another warning to remote metropolitan areas. Seismological Research Letter 2001;72: 171-185.
4. Dhakal, R.P., and Pan, T.-C. Response characteristics of structures subjected to blasting induced ground motions. Int J Impact Eng 2003;28(8):813-828.

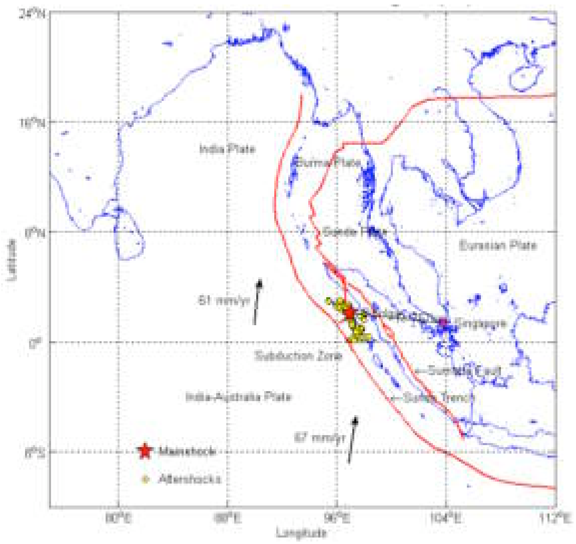


Figure 1. Epicentral locations of the main shock and major aftershocks (M_w = 8.7) of 28 Mar 2005

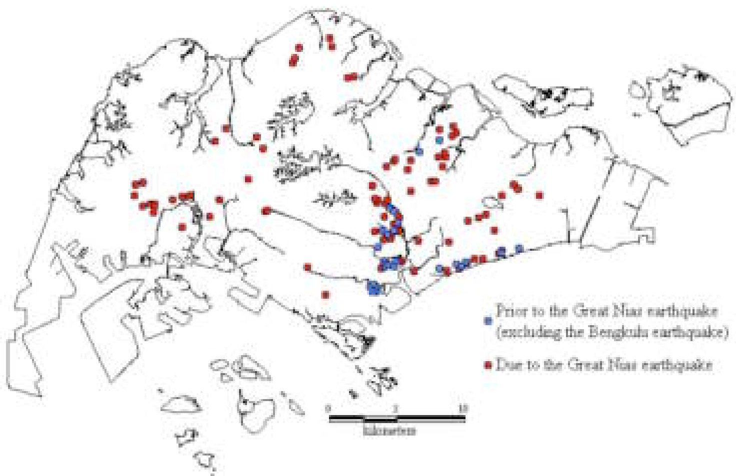
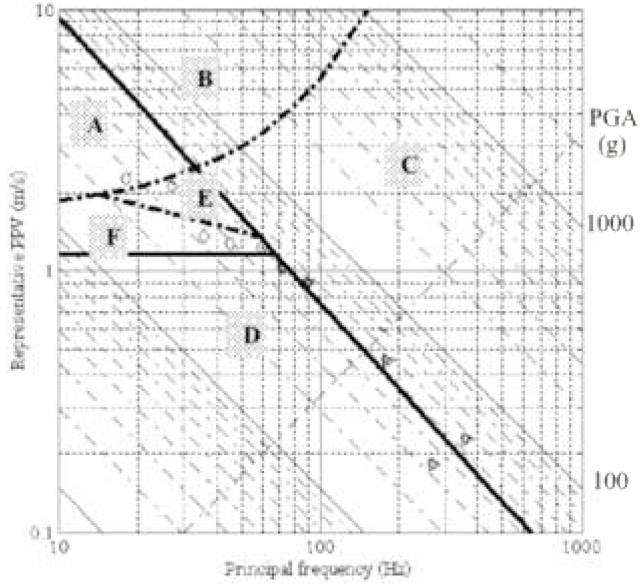


Figure 2 - Locations of buildings reportedly responding to the earthquake events felt in Singapore



A: Phase 1 JF only
B: Phase 1 JF or SF
C: Phase 1 SF
D: no failure
E: Phase 2 JF
F: Phase 2 SF

Figure 3 – Damage characteristics of a 6-storey RC frame due to ground shocks

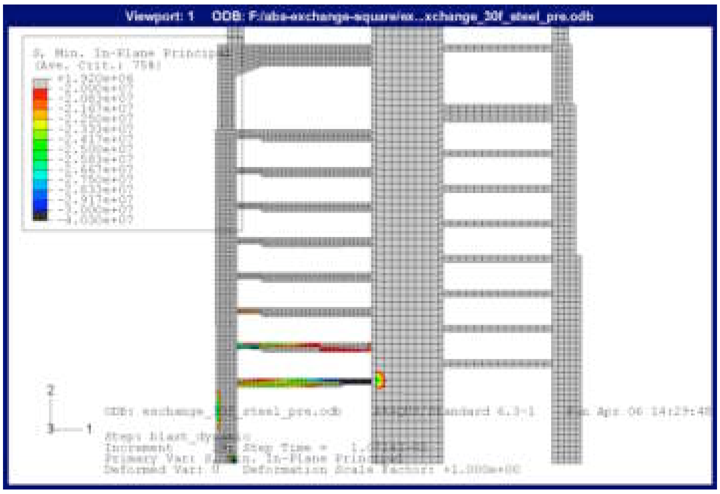


Figure 4 - Stresses and deformation for long standoff

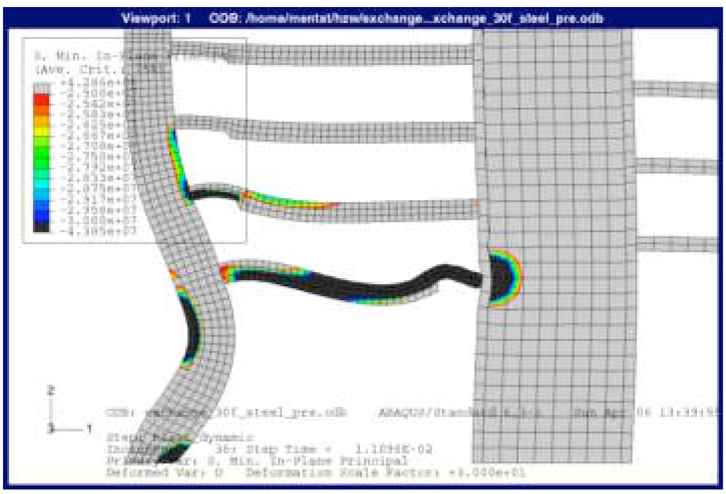


Figure 5 - Stresses and deformation for short standoff