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A Summary of Earthquakes in 2005

David Galloway presents a summary of seismic activity in 2005

Overseas

This year was not exceptional in terms of the number of worldwide earthquakes (Figure 1). There was one 'great' earthquake (magnitude over 8.0), fourteen 'major' earthquakes (magnitudes between 7.0 and 7.9) and 149 'strong' earthquakes (magnitudes between 6.0 and 6.9). These numbers are comparable with the long-term averages for these magnitude ranges, which are, one, seventeen and 134, respectively. The number of people reported killed by earthquakes during 2005 was 76,649 (Table 1).

Without doubt, the magnitude 7.6 Mw Pakistan earthquake on 8 October at 03:50 UTC was the most disastrous during 2005, accounting for over 97% of the fatalities. The earthquake caused the deaths of at least 74,647 people, injured more than 76,000 others, left nearly three million homeless and caused extensive damage in northern Pakistan, India and Afghanistan. The heaviest damage occurred in the

Magnitude Key

●	**8.0 and above**
●	**7.0 to 7.9**
●	**6.0 to 6.9**
●	**4.0 to 5.9**

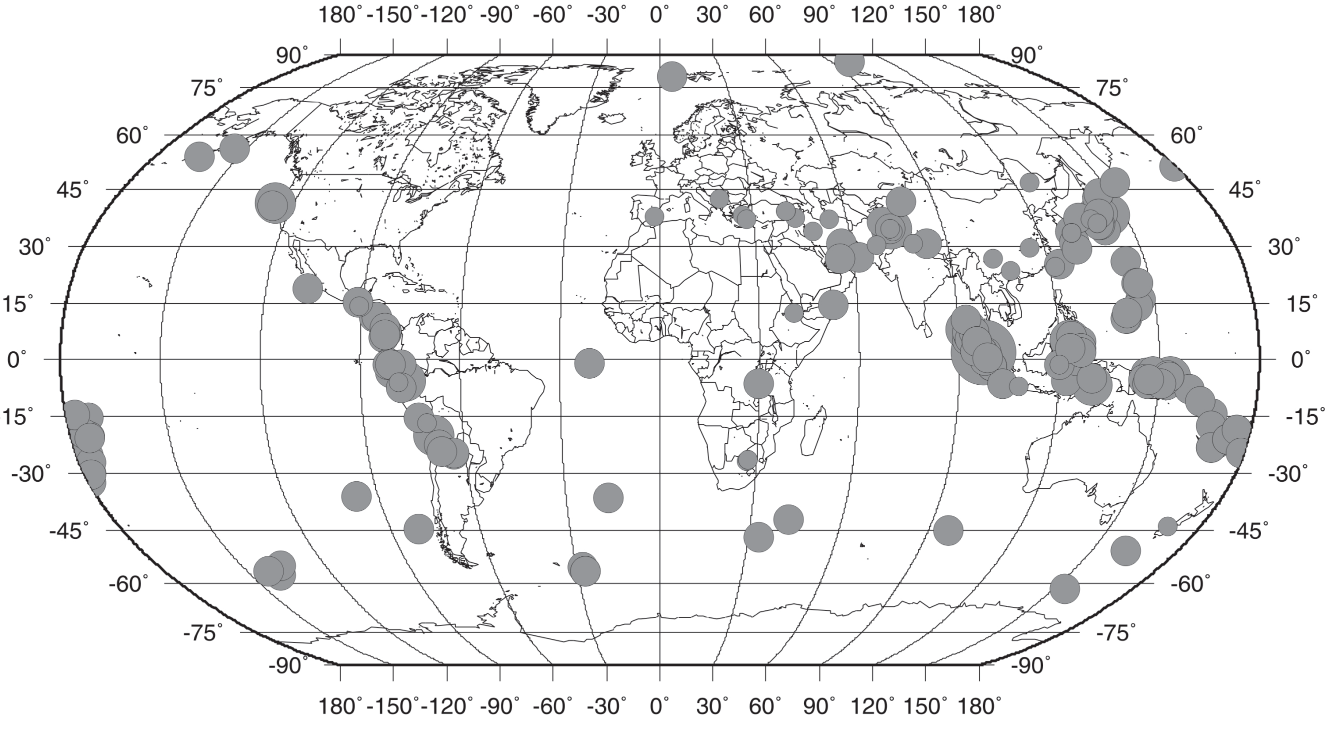

Figure 1 Notable World Earthquakes of 2005

DATE	LAT	LON	MAG	LOCATION	DEATHS
23 January	1.25 S	119.92 E	6.2 MW	Sulawesi, Indonesia	1
25 January	37.63 N	43.70 E	5.9 MW	Turkey / Iraq Border	2
2 February	7.04 S	107.82 E	4.8 MB	Java, Indonesia	1
5 February	5.29 N	123.34 E	7.1 MW	Celebes Sea	2
22 February	30.74 N	56.83 E	6.4 MW	Central Iran	612
9 March	26.91 S	26.79 E	5.0 MB	South Africa	2
20 March	33.81 N	133.13 E	6.6 MW	Kyushu, Japan	1
28 March	2.09 N	97.11 E	8.7 MW	Northern Sumatra	1,313
3 May	33.71 N	48.69 E	4.9 MB	Western Iran	4
4 June	6.34 S	146.81 E	6.1 MW	Papua New Guinea	1
13 June	19.99 S	69.20 W	7.8 MW	Tarapaca, Chile	11
5 July	26.47 S	27.43 E	2.7 ML	South Africa	1
25 July	46.83 N	125.06 E	5.0 MB	Heilongjiang, China	1
26 September	5.68 S	76.40 W	7.5 MW	Northern Peru	5
8 October	34.54 N	73.59 E	7.6 MW	Pakistan	74,647
15 October	34.01 N	74.00 E	5.2 MB	SW Kashmir	2
20 October	38.15 N	26.57 E	5.9 MW	Western Turkey	1
27 October	23.60 N	107.80 E	4.2 MB	Guangxi, China	1
26 November	29.70 N	115.69 E	5.2 MW	Jiangxi, China	16
27 November	26.77 N	55.86 E	6.0 MW	Southern Iran	13
5 December	6.22 S	29.83 E	6.8 MW	Lake Tanganyika, Congo	6
12 December	36.36 N	71.09 E	6.5 MW	Hindu Kush, Afghanistan	5
14 December	30.48 N	79.26 E	5.3 MB	Uttaranchal, India	1
					76,649

Table 1. Earthquakes causing deaths in 2005.

Muzzaffarabad area of Kashmir where entire villages were destroyed and in Uri where nearly 80% of the town was destroyed. Around 32,000 buildings collapsed in Anantnag, Baramula, Jammu and Srinagar in Kashmir and many other buildings collapsed in Abbottabad, Gujranwala, Gujrat, Islamabad and Lahore in Pakistan. Landslides and rock falls destroyed or damaged many mountain roads and highways, cutting off access to the region for several days. Landslides were also reported from further afield near the towns of Gilgit and Skardu, Kashmir and liquefaction occurred in the western region of the Vale of Kashmir. Seiches were observed in Haryana, Uttar Pradesh and West Bengal, India and in many places in Bangladesh.

The earthquake occurred as a result of the collision of the Indian sub-continent with Eurasia. India is moving north at a rate of around four cm/year. The collision causes compression and uplift, forming the Himalaya, Karakoram and Hindu Kush mountain ranges. Compression is also accommodated by slip on a number of major thrust fault zones, resulting in earthquakes over a wide area along the collision zone. The earthquake on 8 October probably occurred on one of these thrust faults.

Several fatal and damaging earthquakes occurred in Iran during the year. A magnitude 5.4 Mw earthquake, on 10 January, caused injury to a least 110 people in the Gorgan area, northern Iran. On 22 February, an earthquake with a magnitude of 6.4 Mw, occurred near Zarand in the Kerman Province of Iran and resulted in the deaths of some 612 people. Over 1,400 others were injured and thousands more were made homeless in several villages in the region as an estimated 8,000 homes were either damaged or destroyed. Four villages, each having around 1,000 inhabitants, were completely destroyed, and 30% to 70% of buildings suffered damage in more than 40 other villages. On 3

May, an earthquake with a magnitude of 4.9 Mb, killed four people, injured 26 others and caused extensive damage in the Borujerd area of western Iran. Another earthquake, on 27 November, with a magnitude of 6.0 Mw, occurred near the island of Qeshm in southern Iran. It killed thirteen people, injured 100 others and caused extensive damage throughout the island. More than 80% of buildings in Zirang were destroyed and at least seven other villages on the island, including the capital Qeshm City, were severely damaged. It was felt strongly in the nearby countries of Oman and the United Arab Emirates, where many buildings were evacuated and people ran into the streets.

On 23 January, an earthquake, with a magnitude of 6.2 Mw, occurred offshore the island of Sulawesi, Indonesia and killed one person, injured four others and damaged around 177 buildings in the Palu area.

Along the Turkey/Iraq border region, a magnitude 5.9 Mw earthquake on 25 January, killed two people, injured 22 others and damaged 80 buildings in the Hakkari area, Turkey. According to local sources the majority of casualties occurred as people jumped off balconies in panic. The earthquake was felt strongly in the cities of Batman, Siirt, Sirnak and Van, Turkey and was also felt as far away as Baghdad, Iraq. On 6 June, in the Karliova area of eastern Turkey, 54 people were injured (of which 5 were serious), several buildings collapsed and another 60 were damaged as a result of a magnitude 5.7 Mw earthquake.

An earthquake, on 2 February, with a relatively small magnitude of 4.8 Mb, killed one person, injured several others and damaged or destroyed many buildings in Garut on the island of Java, Indonesia.

A 'major' earthquake, with a magnitude of 7.1 Mw, occurred in the Celebes Sea on 5 February and killed two people in Sabah, Borneo, Malaysia. It was felt throughout Malaysia and was also felt on the island of Mindanao in the Philippine Islands.

Near the south coast of Honshu, Japan, on 15 February, 27 people were injured during a magnitude 5.5 Mw earthquake in the region. The injuries occurred in the Prefectures of Ibaraki, Chiba, Tokyo, Saitama and Kanagawa. On 23 July, another 27 people were injured and one building was damaged in the Tokyo area during a magnitude 6.0 Mw earthquake, in the same region. Another earthquake, with a magnitude of 7.2 Mw, occurred on 16 August, in Honshu, Japan and caused injury to 56 people in the Prefectures of Miyagi, Iwate, Fukushima and Saitama.

On 9 March, a magnitude 5.0 Mb earthquake in the Klerksdrop/ Stilfontein area of South Africa, killed two people, injured 58 others and caused damage to over 50 buildings. Another earthquake, with a small magnitude of 2.7 ML, occurred in South Africa on 5 July, and killed one person and injured another in a mine in Carletonville.

In the Kyushu region of Japan, on 20 March, one person was killed and over 500 others were injured in the Fukuoka Prefecture, during a magnitude 6.6 Mw earthquake. The majority of injuries occurred when some 65 houses were damaged as the result of a landslide in the region. A magnitude 5.5 Mw earthquake in the same region, on 19 April, caused injury to at least 58 people and damaged another 279 buildings in the Fukuoka Prefecture.

The one 'great' earthquake during the year, with a magnitude of 8.7 Mw, occurred in the Sumatra region of Indonesia, on 28 March, and caused a mass panic as the population thought the nightmare tsunami of 26 December 2004 was coming again. Death and casualties occurred throughout the region but not in the same numbers as three months earlier. However, at least 1,000 people were killed and 300 injured on Nias, 100 people were killed and many more were injured on Simeulue, 200 were killed on Kepulauan Banyak and three people were killed and 40 others injured on Sumatra. It was also reported that ten people were killed in Sri Lanka during an evacuation of the coastal areas. Damage, both severe and minor, was reported throughout the region. The port and airport on Simeulue were both damaged as the result of a three metre tsunami wave and tsunami runup heights of as much as two metres were observed on the west coast of Nias. This earthquake locates approximately 200 km southeast of the magnitude 9.3 Mw earthquake on 26 December 2004. It occurred principally on the interface of the Australia plate and the Sunda plate and was caused by the release of stresses that develop as the Australia plate subducts beneath the overriding Sunda plate. The earthquake occurred as the result of thrust faulting and was most likely triggered by stress changes caused by the 26 December 2004 earthquake.

On 4 June, in the eastern region of Papua New Guinea, one person was killed when a magnitude 6.1 Mw earthquake occurred. Several others were injured and many houses were either damaged or destroyed in and around the Lae area.

A 'major' earthquake, with a magnitude of 7.8 Mw, occurred on 13 June in the border region between northern Chile and southern Peru. The epicentre was located in the Andes, approximately 125 km ENE of Iquique, Chile and 250 km SSE of Tacna, Peru. Eleven people were killed, another 200 were injured, and over 9,000 houses were either destroyed or damaged in the Iquique area as a result of this earthquake. Six of the deaths occurred in one family when a boulder struck their vehicle during a landslide near Iquoque and the other five deaths occurred when buildings collapsed. Water, power and communications were severely disrupted in the area and several landslides blocked roads throughout northern Chile. It is estimated that more than 60% of the houses suffered irreparable damage in several of the small towns in the Andes region. This earthquake resulted from the release of stresses that were generated by the subduction of the oceanic Nazca plate beneath the South American plate. In this region, known as the Peru-Chile subduction zone, ongoing subduction occurs at a rate of about 7.8 cm/year in a ENE direction. The subduction process generates numerous earthquakes and volcanism, and actively builds the Andes mountains. The largest earthquake, the magnitude 9.5 Mw, Chile earthquake on 22 May 1960, occurred in the Peru-Chile subduction zone approximately 2,000 km south of the 13 June earthquake.

Three fatal earthquakes occurred in China during the year. The first, on 25 July, with a magnitude of 5.0 Mb, occurred in the Heilongjiang Province, northern China and killed one person and injured twelve others in Daqing. The second, on 27 October, with a magnitude of 4.2 Mb, killed one person and injured another in Bose, Guangxi Province, southern China. The final and largest, with a magnitude of 5.2 Mw, occurred on 26 November, and killed sixteen people, injured around 8,000 and destroyed 150,000 houses in the Jiujiang Province, southern China.

On 26 September, five people were killed, 60 others were injured and at least 200 buildings were damaged in the Lamas area of Peru during a magnitude 7.5 Mw earthquake in the region. Minor damage was also reported from Chachapoyas, Moyobamba and Tarapota. It was felt throughout Peru and Ecuador and was also felt in the states of Acre, Amazonas and Rondonia in Brazil.

In southwest Kashmir, on 15 October, two people were killed, scores were injured and several homes were damaged in the Uri area when a magnitude 5.2 Mb earthquake occurred in the region. The epicentre of this earthquake is approximately 70 km southeast of the magnitude 7.6 Mw event which occurred the previous week on 8 October, killing some 74,647 people.

A magnitude 5.9 Mw earthquake, with an epicentre near the coast of western Turkey, on 20 October, was reported to have caused the death of one person in Izmir, Turkey. The death was as a result of a heart attack. Fifteen others were injured and minor damage to buildings occurred in both Izmir and Urla in the Aegean region, Turkey.

On 5 December, a magnitude 6.8 Mw earthquake in the Lake Tanganyika region on the border between Congo and Tanzania, killed six people, destroyed 300 houses and collapsed a church in Kalemie, Congo. It was felt strongly throughout Congo and Tanzania and was also felt in the countries of Burundi, Rwanda, Zambia, Uganda, Kenya and Mozambique.

In the Hindu Kush region (near the Afghanistan and Pakistan border), on 12 December, an earthquake with a magnitude of 6.5 Mw killed five people in Tili and injured three others in Jalalabad, Afghanistan. At least 300 livestock were killed and 100 houses damaged in the Badakhshan Province, Afghanistan and several other houses were damaged in Baramulla, Fariabad and Uri in India.

An earthquake, with a magnitude of 5.3 Mb, occurred in the state of Uttaranchal, India on 14 December. One person was killed and four more were injured in the district of Chamoli and widespread damage, mostly minor, was reported from several other districts in the region. A landslide also occurred in the Chamoli district between Jausari and Rudraprayag.

UK Earthquakes

There were 112 earthquakes in the UK region which were located by the monitoring network during the year (Figure 2), with 27 having magnitudes of 2.0 ML or greater and six having magnitudes of 3.0 ML or greater. Twelve of the events with a magnitude of 2.0 ML or greater were reported felt, together with a further three smaller ones, bringing the total to fifteen felt earthquakes in 2005.

The largest onshore earthquake, with a magnitude of 3.3 ML, occurred at Conwy, Gwynedd, North Wales on 14 February, at a depth of around 10 km. Several reports were received by the BGS, via the North Wales Police and a number of residents in the Llandudno, Betwys-y-Coed, Bethel, Abergele and Conwy areas of North Wales which described, “we heard a loud bang and all the windows shook” and “it sounded like a massive explosion and the whole house shook” indicating an intensity of at least 4 EMS.

The largest offshore earthquakes occurred in the northern North Sea on 27 June and in the central North Sea on 7 September, both with magnitudes of 3.2 ML. The northern North Sea event was located approximately 270 km east northeast of Lerwick, Shetland Islands and the central North Sea event was located approximately 390 km east of Newcastle, Tyne and Wear. A further nine events occurred in the North Sea and surrounding waters during the year, with magnitudes ranging between 1.2 and 3.0 ML.

An earthquake, with a magnitude of 2.8 ML, occurred on 19 January, near Doncaster, South Yorkshire. No felt reports were received by the BGS for this event. The earthquake was the largest event in the area since a magnitude 3.1 ML event on 19 August 2003, which was felt with intensities of 3 EMS in the Retford area of South Yorkshire.

The following day, on 20 January, a magnitude 2.7 ML earthquake occurred in Killin, Central region. The BGS received a number of reports, via the Central Police, the Fire Service and local residents in Killin and Kenmore, which described, “we heard a loud noise and the windows shook” and “it sounded like an explosion which got me out of bed” indicating an intensity of at least 4 EMS.

On 28 and 29 April, two earthquakes, with magnitudes of 2.0 and 2.1 ML, respectively, occurred near Eskdalemuir, Dumfries and Galloway. A few residents in Eskdalemuir, Wester Kirk and Langholm reported both events to the BGS. Their reports described, “gradually increasing rumble”, “the whole house shook” and “all glasses in a cabinet rattled” indicating

Figure 2. Epicentres of all UK earthquakes located in 2005 (from the Bulletin of British Earthquakes 2005).

intensities of at least 3 EMS for both events. A swarm of 39 earthquakes was recorded in the same area between 13 October and 30 December 2004 and these two events (April 28 and 29) showed characteristics similar to the swarm of 2004. The two largest events in the swarm occurred on 3 and 28 November 2004, with magnitudes of 2.7 and 2.9 ML, respectively.

Near Stoke-on-Trent, Staffordshire, an earthquake with a magnitude of 2.6 ML, occurred on 8 June. The BGS received several reports from residents in the Stoke-on-Trent area which described, "the windows and house shook" and "we could feel the movement beneath our feet" indicating an intensity of 4 EMS. The event locates within a kilometre of the magnitude 2.8 ML Stoke-on-Trent earthquake on 6 May 1996, which was also felt with intensities of 4 EMS in the epicentral area.

On 18 and 19 June, and again on 16 July, three earthquakes occurred near Billinghurst, West Sussex with magnitudes of 1.4, 1.6 and 2.2 ML. These are the first events to be detected in the area since a series of high-intensity events that took place in the Chichester region between 1833 and 1835. The largest of these events, with a magnitude of 3.3 ML, occurred on 27 August 1834, and caused severe damage in the area, when many chimneys and chimney pots fell down, numerous windows were broken and alarm was extreme. Another event in the series, on 18 September 1833 was reported to have collapsed a few chimneys in Chichester and caused a fall in a chalk pit at Cocking, killing a man who was working there.

An earthquake, with a magnitude of 3.0 ML, occurred in the English Channel, approximately 50 km south of Plymouth, Devon on 24 August. Residents in south Devon reported the event, describing, "ornaments moved and the whole house shook" and "sitting at a desk which began to move" indicating an intensity of 3 EMS. A magnitude 2.7 ML earthquake also occurred in the English Channel, about 100 km south of Penzance, Cornwall earlier in the year on 28 March.

On 10 December, a magnitude 3.0 ML earthquake was located in Fort William, Highland, at a depth of around 8 km. The BGS received many reports from residents in the Fort William who felt the event therefore a macroseismic survey was launched on the BGS 'Earthquakes' web site and 210 responses were received. The highest intensity experienced was 5 EMS, which was observed over an area extending approximately fourteen kilometres to the northeast and southeast of the epicentre. The most distant reports were from the following places: to the southwest, the earthquake was felt in the south of Mull; to the west, it was reported as having been felt on the northern tip of Mull; to the east, it was felt at Tulloch Station; and to the northeast it was felt at the northern-most limits of Loch Lochy. The total felt area was over 7,300 km^2.

A magnitude 2.8 ML earthquake occurred on 14 December, with an epicentre in the Irish Sea. A single report was received for this event from Greystones, a coastal town in County Wicklow, Ireland describing, "we were awoken from sleep", "the whole house rattled, pictures moved and lights swayed" indicating an intensity of 4 EMS. This is the largest event in the area since a magnitude 3.7 ML earthquake on 11 January 1951, which was felt with intensities of around 5 EMS in southeast Ireland.

Two earthquakes, within 90 minutes of each other, were detected on 23 December in the Sunart area of the Highlands. They occurred at 03:25 and 04:58 UTC with magnitudes of 2.7 and 2.4 ML, respectively. Several reports were received from residents in the epicentral area who described, "a rumbling noise as if a severe gust of wind had hit the house" and "the bedside table vibrated" indicating intensities of at least 3 EMS.

The final UK earthquake of the year, with a magnitude of 2.5 ML, occurred on 31 December in Blackford, Tayside. Reports, received by the BGS, described, "felt and heard a sound and shaking similar to a heavy lorry passing by" and "all the windows rattled" indicating an intensity of 4 EMS. Blackford is an area that has continued to be active in recent years, the most active year being 1997 when 50 events, of which five were felt, were located in the area. All these events are in the same general area as the magnitude 3.2 ML Ochil Hills earthquake in 1979, which had a maximum intensity of 5 EMS.

The 'Bulletin of British Earthquakes 2005' edited by **D D Galloway** is now available. Copies of this and previous years' bulletins can be obtained from the Earthquake, Seismology and Geomagnetism Group, from BGS bookshops or from the Seismology Website at http://www.earthquakes.bgs.ac.uk/. For further details contact: D D Galloway, Earthquake Seismology and Geomagnetism Group, British Geological Survey, Murchison House, West Mains Road, Edinburgh, EH9 3LA, Scotland, UK.

Field Investigations of the Machaza, Mozambique, Earthquake

Julian Bommer and Clark Fenton provide a personal account of their experience.

Launching the Field Mission

A major earthquake struck western Mozambique, close to the border with Zimbabwe, 20 minutes after midnight on Thursday 23rd February 2006. When we arrived at our offices later that morning, there was the obligatory NEIC notification email in our in-boxes, reporting the event as having a magnitude of Mw 7.5 (issued as a revision 40 minutes after the first estimate of Mw 6.9). An earthquake of this size, and of shallow focus, in a country not considered to be highly active, caught our attention immediately and we met each other half-way between our offices as we both went to ask the other if they wanted to carry out a field reconnaissance. The decision was taken there and then, and we set our departure date for Friday of the following week, just 8 days after the earthquake.

The following days were occupied by trying to clear our desks and get the necessary vaccines and anti-malarial tablets, obtain our visas for Mozambique, establish local contacts and generally prepare ourselves for the field work. We were informed that a travel grant could not be provided by the Royal Academy of Engineering at such short notice and that retrospective awards are no longer made. Given the choice between spending time and effort on preparing an emergency proposal to the Research Councils (with Full Economic Costing) and making useful preparations for field work, we opted for the latter and decided to fund the field mission ourselves from funds earned through consultancy.

By the time we sat down at our desks again to gather background information, we discovered that NEIC had once again revised the magnitude of the earthquake down to Mw 7.0, which turned out to be the definitive estimate. We wondered for a little while if we would have launched a field reconnaissance on the basis of this revised estimate rather than the initial value of M 7.5. Regardless, the plane tickets were already paid for and we were still convinced that the combination of magnitude and depth made surface rupture very likely.. However, the event had happened in the middle of a busy teaching term ensuring maximum inconvenience therefore we had fixed our travel to be in Mozambique for just one week, so getting to the epicentral region in a timely manner and making useful observations was going to depend critically on good local contacts.

Establishing Contacts in Mozambique

Neither of us had ever been to Mozambique and we had absolutely no in-country contacts. We opened various lines of enquiries, starting with emails to colleagues in Lisbon (we subsequently found out, perhaps not surprisingly, that there is very little contact between Mozambique and Portugal) and to Dr Jo Mankelow at the BGS, who has delivered many training courses in Mozambique. However, in parallel with these enquiries, we also invoked the universal power of Google, through which it was possible to identify the largest university in the capital city, Maputo (Universidade Eduardo Mondlane), and get on to the homepage of the Geology Department. An email message was composed (in Portuguese, with the help of some of our students from Portugal, on the assumption that this would make replying easier and hence increase our chances of establishing contact in the few remaining days before we travelled) and sent to the entire faculty of the Geology Department. We were delighted to receive a reply a couple of days later from Dr Elónio Muiuane, who in turn provided us with numerous other contacts who proved absolutely indispensable to the success of our field investigation.

Dr Muiuane very kindly reserved hotel rooms for us in Maputo for the day of arrival, and there we met with him and his colleagues Dr Daud Jamal and Dr Lopo Sousa e Vasconcelos, as well as Dr Elías Daudi, Director of the Direcção Nacional de Geologia (DNG), who by coincidence Jo Mankelow had also told us would be a useful contact (once we had received the positive response from Dr Muiuane we had not pursued any other channels since we thought it would just create confusion). We were, however,

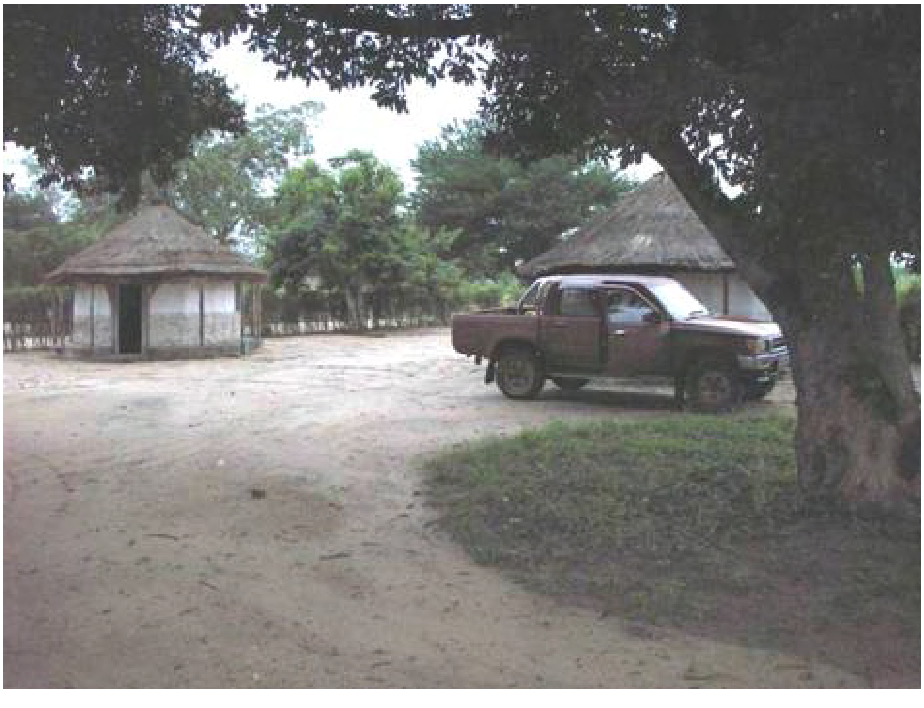

Figure 1 Our accommodation in Chitobe. Located about 30 km from the fault rupture, these traditional dwellings were completely undamaged by the earthquake.

somewhat disappointed to learn that none of these gentlemen were prepared to come to the field with us. They also spoke at length about how remote and inaccessible the affected area was by any means of transport other than helicopter! Undeterred – and with the clock ticking – we had already decided to head out the next morning and to do everything in our power to get to the epicentral region.

Although the epicentre was 500 km from Maputo, we had by this time worked out that by road the distance was much closer to 1,000 km. To save time we purchased tickets to fly up to Mozambique's second city, Beira, located on the coast and just 220 km from the epicentre. We flew up to Beira early on Sunday morning, hired the last 4-wheel drive vehicle available from any of the car rental firms operating in the airport, and headed west to the town of Chimoio, the capital of Manica province, where the earthquake had occurred. Before leaving Beira airport, we struck a deal with the owner (and sole pilot) of a light aircraft firm, and deposited $1,000 for a flight over the epicentral region later in the week. We were going to try to reach the epicentral region directly, but if this failed we wanted to at least try and find the surface rupture from the air.

The route from Beira to Chimoio is heavily transited, being the main communication artery (by both road and rail) with neighbouring Zimbabwe. However, the road was surprisingly poor in places; unsurfaced and completely chewed up by the lorries that use the route. It was raining for much of the journey, March being the last month of the raining season in Mozambique. By mid-afternoon we had reached Chimoio – an unspectacular small town – where it was now drizzling pretty constantly, and booked ourselves into a small hotel. Before leaving Maputo, Dr Daudi had given us the contact details for the Director of the Direcção Provincial de Minas e Energia in Chimoio, Geraldo Simão Valoi, but he had not responded to calls to his mobile phone at any point. We had dinner on Sunday night in a cold and rainy Chimoio, wondering if we had not been a little foolhardy in setting out on such a mission so precipitously. Our plan was to go the Senhor Valoi's office the following morning and take things from there. Neither of us was feeling particularly optimistic at this point and the first few hours of Monday morning did nothing to raise our hopes.

Figure 2 Our field guides, Celestino (*left*) and Pita Dom Carlos (*right*)

Finding the Fault

We located the government building where the Provincial Geological Survey was located shortly after the time at which we were told people started work. On arrival we were told that Senhor Valoi had been travelling, and hence not responding to phone calls, and may not be coming in to the office. We pleaded with his secretary to ask him to come and meet us, and went off to find an internet café to kill the 90 minutes now available until our appointment. When we returned to his office, Senhor Valoi had arrived and things very quickly began to look up; he had actually spent the weekend travelling in the epicentral region. He opened up his laptop to show us the digital photographs he had taken. The very first shot was clearly surface fault rupture and we almost jumped up and told him we were heading there immediately. At this point we called our pilot in Beira to cancel the flight and to make an arrangement to meet him later in the week to negotiate the return of our not-so-inconsiderable deposit – or at least some part of it! Senhor Valoi was clearly taken aback with how enthusiastic we were about his photos of cracks in the ground, and very kindly instructed one of his staff members, Celestino Mariano de Sousa, to accompany us to the field. Celestino looked much less than enchanted when told to go home and pack some clothes for the field, but graciously accepted his assignment. Two hours later, with the pick-up filled with jerry cans of fuel and many bottles of water, we were on the road to the small town of Chitobe, capital of the Machaze district where the epicentre – and more importantly, the location of Senhor Valoi's photographs – was located.

Although a long drive, once we got off the main road that connects the east-west Beira-Chimoio road with the Maputo, going was reasonably good (at least once we had cleared the 40-km-long section of roadworks) because the dirt roads were surprisingly smooth, a direct result of the overwhelming majority of local traffic being bicycles. In Chitobe, we checked into the nearest local equivalent to a 'hotel' (Figure 1), where we were each assigned a mud hut, without water or electricity. After a simple meal of something similar to polenta and a stew consistingly mainly of goat's intestines and other unidentified offal, we went to sleep feeling very positive about things.

Figure 3 Clark measuring total offset on the fault at the location of maximum slip.

Seventy-two hours after leaving London, we were within driving distance of the fault rupture.

The next morning we met the district administrator Senhora Alice Tamele, whose hospitality and interest in our work were very encouraging. As a result of our meeting, we picked up the fourth member of our field team, a local health worker called Pita Dom Carlos Toalha. Pita proved to be invaluable to us, knowing the local area like the back of his hand and having already visited the locations where locals had informed him of large cracks in ground. By mid-morning we were at the surface rupture (Figure 2), taking photographs, GPS readings and measuring displacements and the orientation of the fault traces. We followed the rupture a short distance to the north, finding a vertical offset of more than 2 metres at one location (Figure 3), and then followed it south – until warned by Pita to stop mapping the fault rupture as it was entering an area of landmines, an unwelcome legacy from the civil war that ravaged Mozambique from 1977 to 1992. We drove a short distance south and then re-entered the bush on foot and with the assistance of several local people, found other sections of the fault scarp. For this also, Pita provided invaluable assistance: although Portuguese is the official language of Mozambique, it is actually spoken by only one quarter of the population, and as a first language by less than 10%; Pita was able to converse in the local Ndau (Bantu) language, and thus enable us to gather additional information about the effects of the chigiddigiddi (earthquake).

The strike of the fault rupture was measured NNW, dipping steeply to the west and displaying predominantly normal displacement, with a small component (clearly visible in only one location where the rupture had displaced tracks, Figure 4) of left-lateral strike-slip, consistent with the Harvard CMT solution for the earthquake. Having established subsequently that the fault was previously unmapped, we had the privilege of being able to baptize this seismogenic structure, opting, in the absence of any prominent geographical feature or settlement in its immediate vicinity, for the Machaze fault.

The following morning, we headed south from Chitobe once again, this time looking for sites of reported damage and liquefaction. At one location, near the village of Macone, amongst liquefaction fissures, we found some fractures that displayed vertical offset and whose orientation and location made them approximately collinear with the ruptures observed the previous day some 15 km to north. We concluded that this is most likely the southern limit of the fault rupture.

Figure 4 Evidence of left-lateral slip on the fault as well as normal offset.

Figure 5 Liquefaction fissure.

Liquefaction, Damage and Rumours of Damage

Evidence of liquefaction was widespread along the fault rupture, with sand blows and large fissures (Figure 5) surrounded by several metres of ejected sand which was more than half a metre thick in places (Figure 6).

This did not come as a particular surprise, given that the earthquake occurred in a late Quaternary flood plain, in the vicinity of a river and a number of small lakes, towards the end of the rainy reason. We recovered a number of samples of the liquefied material in order to produce gradation curves on our return to Imperial College. These tests confirmed that the liquefied material was essentially poorly graded medium to coarse sand. Although extensive liquefaction occurred, and in some cases the fissures actually entered dwellings, there was almost no damage directly attributable to this phenomenon.

Damage in the epicentral region was actually very limited, with about 300 houses being damaged to some degree; only four people were reported killed, and another 30 injured. There are several factors contributing to this low impact, the first being that the earthquake occurred in a sparsely populated rural area. The second factor is the inherent earthquake resistance of the traditional construction system of wattle-and-daub, with light sheet metal roofs (Figure 7). However, there is an appreciable proportion of dwellings, shops and school buildings constructed from non-reinforced brick and cement masonry; although there was damage in many of these buildings, the modal observation was of light or no damage. The soft ground conditions and the nature of the earthquake source (a normal faulting event rupturing to the surface) may both have contributed to the limited damage in these low-rise short-period structures.

On our arrival in Mozambique, we found that many people – and the

Figure 6 Cutting through liquefied material exposing more than 0.5 m of ejected sand above the original ground surface.

press – were referring to the event as the Espungabera earthquake, citing this town on the border with Zimbabwe as the location of the epicentre and the main concentration of damage. We did not travel to Espungabera, but given that it is located at a significant distance from the causative fault rupture (greater than the distance to Chitobe where the only important damage was the collapse of a heavy water tank perched on four poorly reinforced concrete columns without footings), we suspect that damage there will not have been particularly significant. We also read, again in the Mozambican press, of damage to structures in Beira. On our return to that city, our enquiries on this point were met with amusement; we were told that most buildings in Beira have cracks, some of them significant. We travelled around the city for a while and found this to be true, but locals informed us that all of these cracks (which are probably due to differential settlement – Figure 8) existed long before the earthquake!

Reporting Our Findings and Extending Our Study

Our final day in Mozambique was spent in Maputo, meeting with geologists and engineers from the DNG and the Universidade Eduardo Mondlane, reporting on our field observations and acquiring additional information. We were also introduced by Dr Daudi to the seismology group at DNG, led by Eng. Severino Marcos and comprising Virgílio João de Magalhães, Andrés Sibambo, Abdul Majid Faquir and Manuel Farnela. We had valuable discussions with this energetic group, who generously provided us with earthquake catalogues for Mozambique and details of their small seismograph network. We subsequently learnt that an official field mission to the epicentral region was launched a couple of weeks later, largely on the basis of our experience and the photographs we were able to show to our Mozambican colleagues.

After just one week in Mozambique – and just two days in the epicentral region – we had gathered a significant amount of information, but also raised a number of interesting questions. The decisions facing us therefore were to identify the most appropriate way to report our initial findings and how to continue our study to complete the picture and search for answers to the questions that the Machaze earthquake opens up. For reporting our findings, we decided that the best option was an article in Seismological Research Letters, an option we had actually discussed – in the hope that we would find the fault rupture – with editor Dr Susan Hough before our departure from London. This seemed to us the best way of making our observations available to a wide audience in an appropriate short time scale. With Dr Hough's provisional

Figure 7 Partial collapse of a badly deteriorated wattle-and-daub dwelling. Most houses constructed from this material performed very well in the earthquake.

Figure 8 Major shear crack in a building in Beira, more than 200 km from the epicentre. Earthquake damage? We were informed by locals that these cracks had existed for a long time.

agreement that an article would be welcome, and a few days of concerted effort upon our return, a paper is now accepted and will appear in the July/August issue of the journal (vol. 77, no. 4). We have also made presentations on our findings and the background to the earthquake in many places, including Ankara, Istanbul and Oxford, and at the EERI/SSA 100th Anniversary 1906 San Francisco Earthquake Conference. The last presentation was actually to a meeting of the NERC-sponsored Centre for the Observation and Modelling of Earthquakes and Tectonics (COMET), involving seismologists and geologists from Oxford and Cambridge, as well as the remote sensing group at UCL. This triggered very interesting discussions and we found out that James Jackson (former Mallet-Milne lecturer and Professor at Cambridge) was already working on source inversions for the main shock and principal aftershocks. Prof. Jackson was on sabbatical at Caltech at the time, and we were informed that researchers there, and at Oxford, were exploring the possibilities of using satellite imagery to measure the displacement field associated with the earthquake. Other researchers from within COMET have also begun the relocation of aftershock epicentres using double difference techniques.

Since we were unable to map the entire fault rupture, because of time constraints and landmines, we are planning to return to the field in September, which will be several months into the dry season and the vegetation cover should be significantly reduced. Moreover, with the results of the source inversions, aftershock relocations and the interferometry, combined with our own field observations, should make it relatively easy to locate and map the remaining surface features. If funding can be secured, we shall also trench the fault to look for evidence of previous earthquakes through displacements or paleo-liquefaction. The second field investigation is likely to be carried out together with James Jackson and his team from Cambridge. In parallel with this work, one of our MSc students will begin a careful re-evaluation of the seismicity of Mozambique, since the data on previous earthquakes is inconclusive. Three events of magnitude close to 6 are reported to have occurred in the same region (slightly to the north) in the 1950s, but the information given in different sources varies considerably.

Giving Something Back

Mozambique is not usually considered a seismically active country, and the Machaze earthquake has generated considerable interest and, understandably, some concern. None of the geologists or engineers we met with has formal training in seismicity, seismic hazard or earthquake resistant-design, and we discussed how some input could be provided to address this current gap in their knowledge. A potential candidate for the European Masters in Earthquake Engineering (www.meees.org) was identified, a young engineer at the Eduardo Mondlane University, and he will be applying for entry to the course in October 2007. However, in the short-term there is a need for training in the basics of engineering seismology and earthquake engineering. Our intention is to deliver some short courses, accompanied by field demonstrations in the epicentral region, as part of our next visit to Mozambique.

A Probability-Based Prediction of Footbridge Vibration

Phil Cooper reports on an entertaining and enlightening evening meeting which looked at a new concept for dealing with human-induced vibrations of footbridges that addresses shortcomings of current UK guidance.

Up to 100 people turned up on the evening of 22 February 2006 to listen to **Professor Aleksandar Pavic** (Figure 1) describing prolific and highly visible vibration engineering research at the University of Sheffield and its latest deliverable: a probability-based framework for prediction of footbridge vibration due to walking. I do not think anybody regretted showing up at One Great George Street as one of the most entertaining and informative lectures SECED had in recent times was delivered that evening.

Firstly, a background to this probability-based framework was given by a description of the research environment and philosophy of the 10-strong Vibration Engineering Section (VES) in the Department of Civil and Structural Engineering, University of Sheffield (http://vibration.shef.ac.uk). Since its establishment in 1993, VES was focused on vibration performance of civil engineering structures. In particular, rather narrow and unique expertise was developed in vibration serviceability of slender civil engineering structures, such as long-span floors, footbridges, grandstands and staircases, which are occupied and dynamically excited by humans. This portfolio is underpinned by advanced research tools such as vibration testing and system identification of as-built large civil engineering structures using full-scale modal testing and finite element model correlation and updating based on experimental measurements [Ref 1]. This is a high-tech approach to structural vibration widely used in mechanical and aerospace engineering disciplines, parts of which have been adapted and transferred into civil engineering applications by Professor Pavic and his team. Although difficult to master and apply in practice, this dual analytical and experimental approach to vibration serviceability problems has yielded some quite interesting results in the last decade and has the potential to move things forward in this sparsely researched area of rapidly growing importance. Having capabilities to conduct practically any conceivable type of dynamic testing of large civil engineering structures, from multi-channel ambient vibration surveys, via ultra-low level vibration measurements to multi-shaker frequency-response-function (FRF) based modal testing, VES is nowadays arguably the leading UK outfit specialised in linking dynamic testing and numerical analysis of large civil engineering structures for the purpose of vibration serviceability assessment.

In essence, the VES research philosophy treats every real-life large scale civil engineering structure which is occupied and dynamically excited by people as a potential ‘laboratory’. Over the years, this approach yielded data on in-service vibration performance of dozens of structures on which two types of tests were typically carried out: some form of dynamic testing yielding key as built modal properties (natural frequencies, mode shapes, modal damping ratios and, whenever feasible, modal masses) and dynamic response measurements due to various activities like walking, running and jumping. By re-analysing collections of such modal and vibration response data gathered from a number footbridges (examples shown in Figure 2), the probability-based approach to human-induced vibrations emerged. Before this is described, a few facts on the current state-of-the-art regarding human-induced vibrations of footbridges are worth noting.

Due to their slenderness, many modern footbridges may vibrate significantly under pedestrian traffic. Consequently, the vibration serviceability of these structures under human-induced loading is becoming their governing design criterion. Most current design codes in the world, including the relevant British code BD37/01, consider the dynamic force induced by a single pedestrian as the relevant loading scenario when predicting footbridge vibration response in the vertical

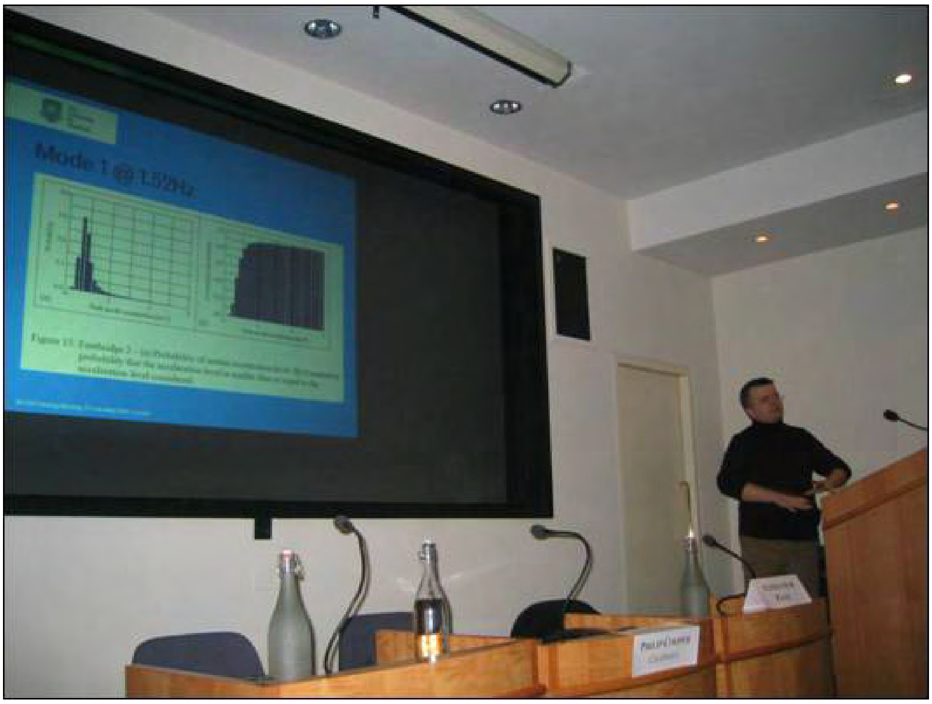

Figure 1 Aleksandar Pavic explains the framework for calculating probability of various vibration responses of footbridges during single-person walking.

Figure 2 Examples of lightweight footbridges studied with experimental and analytical methods by Sheffield VES

direction [Ref 2]. This excitation is modelled as a deterministic harmonic force tuned to match a footbridge natural frequency with amplitude defined as a certain percentage of the pedestrian's weight.

However, the extensive in-situ and other data gathered by VES and other researchers in the last decade have demonstrated without any doubt that walking is not a deterministic phenomenon since the force induced by human walking is a narrow band random process, rather than a periodic force representable by a Fourier series. Also, different natural frequencies will have different probabilities of being significantly excited by walking. This is a consequence of the fact that all human beings are different and therefore generate different dynamic forces, both in terms of their amplitude and frequency. Professor Pavic effectively proved this point by showing animations of various body motions during walking. These graphically demonstrated the effect of mood and sex on walking: a satisfied relaxed and happy female walks in a very different way than her male counterpart who is not in the same mood. Once the laughter subsided, it was clear to the audience how different gaits lead to wide variations of body accelerations and hence reaction forces between the feet and the structure. Considering the different shapes, sizes, ages and moods in which people come, it is clear that their walking is indeed a random process which cannot be modelled deterministically as currently prescribed by many codes and guidelines around the world.

A way to deal with this randomness more realistically and take into account these uncertainties, which influence force modelling and response prediction, is to represent them by probability density functions. A formulation of these probability density functions and their implementation into a procedure for vibration response prediction are key elements of a novel probabilistic approach which was presented at this meeting. The approach considers the following four factors as the key sources of randomness of the walking force:

1. the pacing frequencies,
2. walking velocities (expressed as the number of steps to cross the footbridge),
3. dynamic loading factors and
4. intra-subject variability in the walking force (i.e. the difference between subsequent steps of the same person).

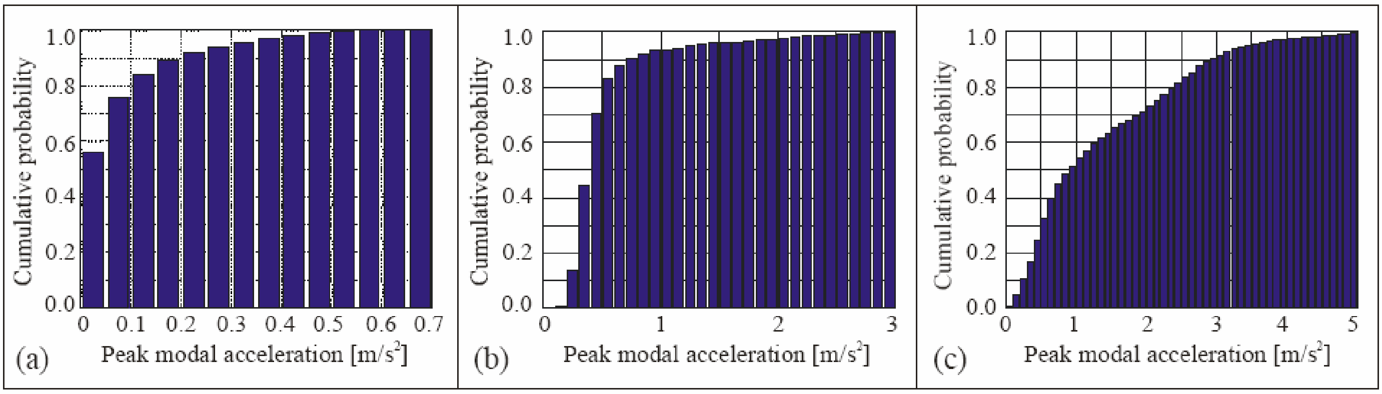

Figure 3 Examples of cumulative probabilities that certain levels of vibration will not be exceeded which can be calculated easily knowing footbridge modal properties.

Probability distribution functions are proposed for each of these factors and then used to calculate probabilities of various peak accelerations of a footbridge treated as a single degree of freedom system with a known natural frequency, mode shape, modal damping and modal mass. (See [Ref 3] for further details.)

In essence, this is just a sophisticated extension of the current UK provision in BD37/01. However, the key enhancement is that instead of a single response value obtained using BD37/01, this new analytical approach yields a probability that a certain level of vibration response will not be exceeded for a single person walking. Figure 2 shows examples of cumulative probabilities indicating probability that a certain level of vibration will not be exceeded.

Figure 3a corresponds to a fundamental mode of vibration of a real-life footbridge having natural frequency of 2.04 Hz, modal damping ration of only 0.26%, modal mass of 58,000 kg and a beamlike modeshape. It can be seen that, say, 0.2 m/s^2 acceleration has probability of 80% of not being exceeded. It is interesting to note that, following BD37/01 recommendations, the limiting acceleration for this rather lively and problematic footbridge is 0.7 m/s^2. Figure 2a indicates that this acceleration is almost certain not to be exceeded despite the fact that the footbridge is perceived as unpleasantly lively by many of its directly interviewed everyday users at lower accelerations. This indicates that the BD37/01 limit for acceptable vibration may not be on the safe side, which should not be that surprising considering that it was in fact a compromise between two sets of data available 30 years ago when the guideline was first written. A strong case for not only a probability-based forcing function, but also a probability-based limit of footbridge vibration was made during the lecture.

Figure 3b and c present cumulative probability curves of the vibration response of an ultra-light footbridge. Figure 3b corresponds to the fundamental mode of vibration having natural frequency of 1.52 Hz whereas Figure 3c shows modal response of the mode having almost identical modal damping, mass and shape properties, but frequency of 1.86 Hz. Considering that pacing frequencies for footbridges are normally distributed around approximately 1.9 Hz, with a small probability of slow walking around 1.5 Hz to occur, it should not be surprising to see that probability of the same level of vibration (say, 1 m/s^2) being exceeded for the 1.52 Hz mode is always lower than for the 1.86 Hz mode. Therefore, the probability-based approach leads to a lower probability of liveliness of footbridges having natural frequencies away from mean pacing rates, which is what has been observed in practice. However, following the BD37/01 provision, these two modes would lead to practically the same peak responses which would not reflect what happens in reality. Not modelling reality in vibration serviceability could lead to considerable errors in vibration serviceability assessments.

In conclusion, this evening lecture more than achieved what was outlined in its synopsis. It outlined a strong proposal for a possible framework which could be the way forward when updating some aspects of the British code provision for footbridge vibration serviceability check which is almost 30 years old. Moreover, it is clear that this philosophy is equally applicable to multi-harmonic excitation and multi-modal responses not only of footbridges, but also of long-span floors in buildings which are dynamically excited by walking humans.

References

1. Zivanovic, S., Pavic, A. and Reynolds, P. (2006) Modal Testing and Finite Element Model Tuning of a Lively Footbridge Structure. Engineering Structures, Vol. 28, No 6, pp. 857-868.
2. Zivanovic, S., Pavic, A. and Reynolds, P. (2005) Vibration Serviceability of Footbridges under Human-Induced Excitation: A Literature Review. Journal of Sound and Vibration, Vol. 279, No 1-2, pp. 1-74.
3. Zivanovic, S., Pavic, A. and Reynolds, P. Probability Based Prediction of Multi Mode Vibration Response to Walking Excitation. Engineering Structures, Elsevier. In press.

NOTABLE EARTHQUAKES APRIL – JUNE 2006

Reported by British Geological Survey

<table>
<tr><th>YEAR</th><th>DAY</th><th>MON</th><th>TIME UTC</th><th>LAT</th><th>LON</th><th>DEP KM</th><th colspan="3">MAGNITUDES</th><th>LOCATION</th></tr>
<tr><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th>ML</th><th>MB</th><th>MW</th><th></th></tr>
<tr><td>2006</td><td>1</td><td>APR</td><td>10:02</td><td>22.87N</td><td>121.28E</td><td>9</td><td></td><td></td><td>6.2</td><td>TAIWAN REGION</td></tr>
<tr><td colspan="11">At least 42 people injured and several buildings damaged in T'ai-tung County.</td></tr>
<tr><td>2006</td><td>4</td><td>APR</td><td>09:12</td><td>34.65N</td><td>73.18E</td><td>10</td><td></td><td>4.7</td><td></td><td>PAKISTAN</td></tr>
<tr><td colspan="11">Around 28 people injured and some buildings damaged or destroyed in Batgram.</td></tr>
<tr><td>2006</td><td>14</td><td>APR</td><td>20:56</td><td>62.01N</td><td>2.41E</td><td>15</td><td>3.3</td><td></td><td></td><td>NORWEGIAN SEA</td></tr>
<tr><td>2006</td><td>20</td><td>APR</td><td>01:45</td><td>56.68N</td><td>5.23W</td><td>8</td><td>1.9</td><td></td><td></td><td>BALLACHULISH</td></tr>
<tr><td colspan="11">Felt in Ballachulish, Highland region (3 EMS).</td></tr>
<tr><td>2006</td><td>20</td><td>APR</td><td>23:25</td><td>60.95N</td><td>167.09E</td><td>22</td><td></td><td></td><td>7.6</td><td>KORYAKIA, RUSSIA</td></tr>
<tr><td colspan="11">Around 40 people injured, the villages of Apuka, Khailino and Vyvenka were destroyed and several buildings damaged in the Korf and Tilichiki areas. Damage estimated at $US55 million.</td></tr>
<tr><td>2006</td><td>25</td><td>APR</td><td>11:26</td><td>41.16S</td><td>146.86E</td><td>4</td><td>2.2</td><td></td><td></td><td>TASMANIA,AUSTRALIA</td></tr>
<tr><td colspan="11">A rockfall, in a mine near Beaconsfield, killed one person.</td></tr>
<tr><td>2006</td><td>29</td><td>APR</td><td>16:58</td><td>60.49N</td><td>167.52E</td><td>11</td><td></td><td></td><td>6.6</td><td>KORYAKIA, RUSSIA</td></tr>
<tr><td>2006</td><td>30</td><td>APR</td><td>19:17</td><td>27.01S</td><td>70.96W</td><td>27</td><td></td><td></td><td>6.7</td><td>ATACAMA, CHILE</td></tr>
<tr><td>2006</td><td>30</td><td>APR</td><td>21:40</td><td>27.21S</td><td>71.06W</td><td>12</td><td></td><td></td><td>6.5</td><td>ATACAMA, CHILE</td></tr>
<tr><td>2006</td><td>3</td><td>MAY</td><td>15:26</td><td>20.19S</td><td>174.12W</td><td>55</td><td></td><td></td><td>7.9</td><td>TONGA</td></tr>
<tr><td colspan="11">One person injured and a church suffered minor damage in Nuku'alofa. A tsunami was generated with wave heights (peak-to-trough) of up to 0.54 metres.</td></tr>
<tr><td>2006</td><td>7</td><td>MAY</td><td>06:20</td><td>30.79N</td><td>56.70E</td><td>14</td><td></td><td>4.8</td><td></td><td>CENTRAL IRAN</td></tr>
<tr><td colspan="11">At least 70 people slightly injured and some buildings and roads damaged in the Zarand area.</td></tr>
<tr><td>2006</td><td>16</td><td>MAY</td><td>10:39</td><td>31.78S</td><td>179.31W</td><td>152</td><td></td><td></td><td>7.4</td><td>KERMADEC ISLANDS</td></tr>
<tr><td>2006</td><td>16</td><td>MAY</td><td>15:28</td><td>0.09N</td><td>97.05E</td><td>12</td><td></td><td></td><td>6.8</td><td>NIAS, INDONESIA</td></tr>
<tr><td>2006</td><td>22</td><td>MAY</td><td>11:12</td><td>60.77N</td><td>165.74E</td><td>17</td><td></td><td></td><td>6.6</td><td>KOYAKIA, RUSSIA</td></tr>
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<tr><td colspan="11">Felt in southern Anglesey, North Wales (3 EMS).</td></tr>
<tr><td>2006</td><td>26</td><td>MAY</td><td>22:53</td><td>7.96S</td><td>110.45E</td><td>13</td><td></td><td></td><td>6.3</td><td>JAVA, INDONESIA</td></tr>
<tr><td colspan="11">At least 5,749 people killed, another 38,568 injured and more than 578,000 houses either destroyed or damaged, leaving over 600,000 homeless, in the Bantul and Yogyakarta areas. The total loss has been estimated at $US3.1 billion.</td></tr>
<tr><td>2006</td><td>28</td><td>MAY</td><td>03:12</td><td>5.72S</td><td>151.13E</td><td>34</td><td></td><td></td><td>6.5</td><td>PAPUA NEW GUINEA</td></tr>
<tr><td>2006</td><td>3</td><td>JUN</td><td>07:15</td><td>26.76N</td><td>55.84E</td><td>12</td><td></td><td>5.4</td><td></td><td>SOUTHERN IRAN</td></tr>
<tr><td colspan="11">Two people killed and 4 others injured on Qeshm.</td></tr>
<tr><td>2006</td><td>8</td><td>JUN</td><td>12:23</td><td>57.53N</td><td>5.64W</td><td>8</td><td>2.9</td><td></td><td></td><td>SHIELDAIG</td></tr>
<tr><td colspan="11">Felt in Achnasheen, Ardaneaskan, Gairloch, Stromeferry and Sheildaig, Highland region (4 EMS).</td></tr>
<tr><td>2006</td><td>11</td><td>JUN</td><td>20:01</td><td>33.13N</td><td>131.14E</td><td>140</td><td></td><td></td><td>6.3</td><td>KYUSHHU, JAPAN</td></tr>
<tr><td colspan="11">Eight people injured in Miyazaki Prefecture.</td></tr>
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<tr><td colspan="11">One person injured and 12 houses damaged in Tepelene.</td></tr>
<tr><td>2006</td><td>20</td><td>JUN</td><td>16:52</td><td>33.07N</td><td>104.95E</td><td>24</td><td></td><td>5.1</td><td></td><td>GANSU, CHINA</td></tr>
<tr><td colspan="11">Five people injured in Gansu, some 31 houses damaged in Xinsi, Linjiang and Liping and a landslide caused major damage roads between Wen Xian and Wudu Counties.</td></tr>
<tr><td>2006</td><td>28</td><td>JUN</td><td>21:02</td><td>26.82N</td><td>55.90E</td><td>10</td><td></td><td></td><td>5.8</td><td>SOUTHERN IRAN</td></tr>
<tr><td colspan="11">Nine people injured and major power outages occurred on Qeshm.</td></tr>
</table>

Issued by: Davie Galloway, British Geological Survey, August 2006.
Non British Earthquake Data supplied by: The United States Geological Survey.

Forthcoming Events

21 to 22 September 2006
Short Course: Seismic Design to Eurocode 8
Imperial College, London
www.imperial.ac.uk/cpd/seismic/index.htm

27 September 2006
Earthquake Engineering in the 21st Century
ICE 6.00pm

25 October 2006
Disaster Management

November 2006
Stadia Dynamics

SECED Newsletter

The SECED Newsletter is published quarterly. Contributions are welcome and manuscripts should be sent on a PC compatible disk or directly by Email. Diagrams, pictures and text should be in separate electronic files.

Copy typed on paper is also acceptable. Diagrams should be sharply defined and prepared in a form suitable for direct reproduction. Photographs should be high quality (black and white prints are preferred). Diagrams and photographs are only returned to the authors on request.

Articles should be sent to:

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Editor SECED Newsletter,
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Institution of Civil Engineers,
Great George Street,
London
SW1P 3AA, UK.

E: john.sawyer@projectservices.com

SECED

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It is also sponsored by the Institution of Mechanical Engineers, the Institution of Structural Engineers, and the Geological Society. The Society is also closely associated with the UK Earthquake Engineering Field Investigation Team. The objective of the Society is to promote co-operation in the advancement of knowledge in the fields of earthquake engineering and civil engineering dynamics including blast, impact and other vibration problems.

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