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Earthquake Disasters and the Significance of Liquefaction

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In this issue

Earthquake's 'comms' problem #1: the name of the phenomenon

I believe the subject of earthquake disasters has a communication (or 'comms') problem that no agency seems to be in position to correct.

This problem is manifest at the heart of the scientific understanding of earthquake generation.

An 'earth-quake' is the experience of vibrating, or 'quaking', ground, in much the same way that thunder is the experience of the noise caused by the electrical discharge we can observe in lightning. Even when we cannot see the lightning we know it will have been the cause of the thunder. So what is the name of the equivalent causal process for an earthquake?

We know from the theory of 'elastic rebound' that fault rupture occurs after a long period of shear-strain accumulation. The process is much like the workings of a crossbow involving the accumulation of shear-strain and its sudden release propelling the bolt. A dense network of automatic GPS stations in Japan reveals that the M_W 9 Tohoku earthquake in 2011, was accompanied by sudden vertical and horizontal displacements over an enormous area – at least

Editor's note: on 28th April 2021 Dr Robert Muir-Wood gave a talk on earthquake disasters and the significance of liquefaction at a SECED online evening event. Dr Muir-Wood kindly provided the following article as a summary of his presentation.

500 km in radius, accompanying the fault displacement on the Pacific subduction zone. Locations on the Pacific coast of northern Honshu moved more than 4 m closer to North America, while also subsiding up to 1 m, as the plate boundary ruptured and underwent an estimated 40 m of displacement.

The earthquake-generating process involves this sudden transfer of a volume of elastic shear strain, into permanent displacement on the fault. The shaking may be generated at the rupturing fault, but the accompanying tsunami is generated throughout the region in which there is a change in bathymetry. Strain changes hundreds of kilometres from the fault can lead to profound changes in local hydrology – many thermal springs shut down for some time after the 2011 earthquake as a result of the dilation of underground cracks.

So what is the name of the equivalent to the way that lightning generates thunder? What is 'earthquake's lightning'? There is no term or word that combines the processes of fault rupture and elastic rebound. At the heart of the discipline of earthquake studies we have this empty space. How can we communicate the concepts and the mechanism without the necessary vocabulary?

Earthquake's 'comms' problem #2: the 'epicentre'

Another 'comms' problem exists around the term 'epicentre'. In the mid 19th Century, when earthquakes were widely believed to be caused by some kind of subterranean explosion, the epicentre was the point at the surface above the explosion's location. At the beginning of the 20th Century, when earthquakes were understood to be generated by fault rupture, one might have assumed that the terminology that accompanied the old paradigm, would, like other old paradigm terms such as 'phlogiston' and 'the ether', simply fade away. But seismologists gave the 'epicentre' an unexpected second life.

When asked by journalists the location of the latest earthquake, seismologists studied the arrival times of the first vibrations at a regional network of recorders. By back-tracing these arrival times it was possible to identify where the fault rupture initiated. And so, seismologists encouraged journalists to ask for 'the epicentre' because it was the only location they were able to provide. Of course, for large earthquakes, we now understand the fault rupture may extend for tens and even hundreds of kilometres from where it began. Sometimes the epicentre is in the middle of the fault rupture and sometimes at one end. For a long time there was no quick way to identify the extent of the fault rupture, but today studying the full digital train of vibrations at each recorder it is possible to rapidly identify the whole geometry and length of the fault that broke.

Yet even in the 21st century, no-one has explained to the media to ask for the fault rupture and not the epicentre. And having got their epicentre, media organisations post maps and dress up the location with concentric rings as though these are the ripples from a stone thrown into a pond. This is not simply scientific illiteracy but could have fatal consequences when the media are reporting an epicentre for a larger M_W 8 earthquake.

At the time of the Nepal earthquake of April 2015, my niece was working as a doctor in a village on the route to Everest Base Camp. On the BBC, the epicentre of the shock was identified to be located in western Nepal. I managed to communicate with her that the fault rupture had in fact extended far to the east, reaching close to Mt Everest, and that this was likely to be a location of larger aftershocks, so that she should avoid sleeping in an unreinforced masonry building.

Earthquake's 'comms' problem #4: size ranking and naming

My next earthquake 'comms' problem concerns the size ranking of the earthquake magnitude scale. Richter's 1933 definition of magnitude is enormously compressed, giving no idea of the vast size difference between one rung on the magnitude scale to the next. Imagine if a big earthquake was scaled in the tens of thousands of some unit while a small earthquake was scaled less than 1 and we would be communicating much more effectively. One rung increase on Richter's scale means about a thirtyfold difference in energy release. The Richter scale from 1 to 9 therefore encompasses twelve orders of magnitude of size difference. And this has encouraged the idea that one word 'earthquake' can be applied to define phenomena across twelve orders of magnitude. This 'comms deficit' has been the death of the fracking industry, when a tiny seismic shock, too small to be felt, is termed the same phenomenon as the M_W 9 earthquake in Japan that caused a 30 m tsunami and killed 20,000 people. It would be like only having one word to describe human vocalisation, from the lightest whisper to the loudest scream.

If replacing the Richter scale sounds like too much of a challenge then, we could at least provide some expanded terminology to replace the hugely over-used term 'earthquake'. For example, we could call events of magnitude 1 to 2 'microtremors', magnitude 3 to 4 'tremors', 5 to 6 'temblors', 6 to 7 'earthquakes' and 8 to 9 'megaquakes'.

The methodology of seismic hazard: the problem of aftershocks

My next challenge is not a 'comms' problem but rather a methodology problem around earthquake hazard.

In probabilistic earthquake hazard assessment the standard procedure is to prune an earthquake catalogue of all its aftershocks. The argument is that these earthquakes are all causally related to the original mainshock, that the magnitude frequency distribution of aftershocks is different to that of the population of mainshocks, and that for engineering assessment of the hazard at a single location, the strong motion from smaller aftershocks will never exceed that of the main shock.

However, when developing a probabilistic hazard model for the assessment of insurance loss, we will be interested in the damage caused by aftershocks as well as the mainshock, in particular when loss assessment or repairs are proceeding faster than the decay in aftershock frequency. In particular we have the situation of the Christchurch, New Zealand earthquakes of 2010–2011 when the M_W 7.1 mainshock was in a rural area, and the largest of the aftershocks on February 11th 2011 at M_W 6.3 was at shallow depths on the edge of the city. The aftershock caused an estimated four times the loss of the original mainshock, as well as generating much higher ground motion parameters in Christchurch. In the aftermath of the M_W 9 Tohoku earthquake in Japan aftershocks above magnitude 7 were still occurring ten years after the original mainshock, causing damage to properties long fully repaired.

Clearly the larger aftershocks should be included in hazard modelling intended to capture all sources of loss in space and time. However, that means that a single standard, aftershock-pruned, hazard model is not capable of satisfying the needs of both the earthquake engineering and earthquake loss modelling communities. If we want to have a hazard model that can be applied for all users, then at least it should include the larger aftershocks.

Earthquake liquefaction: a different damage mechanism

Earthquake liquefaction drives a different damage mechanism, which brings us on to the particular set of data collection and modelling challenges around the phenomenon of liquefaction.

Today liquefaction is a well understood process. Take a water saturated soil comprising silt or sand which has not been compacted and has a high porosity. If shaken or disturbed in some way, the particles may pack together more tightly. This will cause the water pressure to rise, and if that pressure is not immediately relieved, will cause the grains to move apart, causing the material to lose its strength and behave as a liquid. Heavy objects, such as buildings, resting on the liquefied layer may then sink into the ground. If on a slope, the overlying soil may move downslope, leading to landslides.

The layer undergoing liquefaction needs to be fairly shallow, maybe less than 10 m underground, but can be discontinuous or lensoid. Liquefaction will be sustained for longest when the excess water pressure cannot be rapidly relieved, but typically water will burst out at the surface depositing silt or sand in characteristic sand volcanoes.

We can identify seven causes of damage linked with liquefaction:

- settlement into the ground,
- differential settlement tilting the floors of a building,
- lateral movement of a building, rupturing pipes and potentially shifting the property into a flood zone
- differential lateral movement, tearing open a building,
- landsliding,
- causing pipes and tanks filled with air to become buoyant and rise to the surface, and
- damage from the silt, sand and water escaping at the surface.

Perhaps the most important lesson we can take is that liquefaction drives a completely separate set of damage mechanisms to those caused by shaking. Liquefaction damage is as different to shaking damage as tsunami damage. Many buildings in Christchurch were completely undamaged by shaking, but for insurance purposes were declared total losses, because of differential settlement and tilting. The threshold for unacceptable floor tilting was typically 1 in 200.

In the past, the fact that liquefaction drives an entirely separate set of damage mechanisms has not been widely appreciated. In devising earthquake intensity scales in the late 19th Century, and then in their refinement in the 20th Century, the assumption has been that one scale can be developed to cover all the observations of damage. We can see in the 1931 'Modified Mercalli scale' (MMI), from rung VIII and above, the indicators appear to be describing liquefaction effects as though these define the higher levels of earthquake shaking.

- VIII: 'sand and mud ejected in small amounts'
- IX: 'well designed frame structures thrown out of plumb', 'buildings shifted off foundations', 'ground cracked conspicuously', 'underground pipes broken',
- X: 'most masonry and frame structures destroyed with foundations', 'ground badly cracked', 'landslides considerable', 'shifted sand and mud'.
- XI: 'broad fissures in ground, underground pipes completely out of service' and 'earth slumps and land slips in soft ground'.

Intensities VIII to XI read like a liquefaction-related damage intensity scale superimposed on an earthquake shaking intensity scale. In the traditional paradigm: ground deformation reflects the amplification of ground motions, not a different liquefaction-related damage mechanism.

Liquefaction indicators, which reflect the condition of the ground materials as much as the severity of the shaking, should not be used in this way. Even the more recent European Macroseismic Scale (EMS) seems to have inherited some of the same liquefaction indicators found in the MMI scale, for example:

- X: 'cracks and landslides',
- XI: 'most buildings collapse',
- XII: 'the ground changes' while 'almost all structures are destroyed'.

In the development of the EMS, the fourth of five considerations was: 'the rejection of any intensity corrections for soil conditions or geomorphological effects, because detailed macroseismic observations should just be a tool for finding and elaborating such amplification effects'. However, no point is made about avoiding intensity observations from where liquefaction is present.

In performing a field survey, we first need to identify where liquefaction is the primary damage agent. We require two intensity scales: one for shaking-related damage and a separate 'field survey standard' for liquefaction-related damages. Intensity-based attenuation functions should be developed from data only on hard rock and firm ground conditions.

Where no mapping was made of the extent of underlying liquefaction, it is difficult to revisit the separation of shaking damages from liquefaction damages in past field investigations. Like the intensity scales, we have to accept that older 'high intensity' shaking damage data is contaminated by liquefaction-related damages.

Ultra-liquefaction

There is a circumstance of liquefaction which I believe should be called out and separately named. That is when the scale of liquefaction comes to have caused a significant proportion of the overall impacts. Two recent earthquakes manifest such 'ultra–liquefaction'.

In the M_W 6.3 11th February 2011 earthquake in Christchurch, New Zealand, one leading engineer identified more than half the total damage cost was attributed to liquefaction. Sand and silt ejecta covered the ground to a depth of 50–60 cm and required the removal of 400,000 tons of materials, as well as accompanying flooding 20–30 cm deep.

In the M_W 7.5 3rd October 2018 earthquake, on a fault that passed through Palu, in Sulawesi, liquefaction triggered landslides, lubricated by a leaking irrigation canal, ploughed buildings and even whole villages into the ground, causing more fatalities than the direct shaking and tsunami combined. A total of 1,700 houses were swallowed up in one neighbourhood Balaroa, while 2,000 housing units were engulfed in Petobo on the outskirts of Palu.

We can also look back into history and identify earthquakes in which similar 'ultra–liquefaction' was manifest. In the 1964 Niigata (Japan) earthquake 60,000 houses and buildings were destroyed, the majority as a result of liquefaction, causing whole apartment buildings to tilt and tumble.

However, the largest extent of ultra-liquefaction may have been in the 1934 Bihar (North India) M 8 earthquake which caused a 'slump – belt' to form over 10,000 km^2 where the soil became covered in sand deposits erupted from underlying liquefaction. Over an area of 800 km^2, the ground was covered by more than 30 cm of sand, ruining agriculture. A similar area of extreme liquefaction was generated by the 1811–1812 New Madrid earthquakes in the central US.

The first major earthquake in British territory struck the eastern end of Jamaica in 1692. The principal town of Port Royal was full of newly constructed brick buildings, located at the end of a long sand spit, at the entrance to the natural harbour of Kingston. The shaking caused liquefaction and landsliding on the sheltered inner side of the spit, directly under the town, where the sand had not been consolidated by wave action. Many hundreds of the inhabitants were either swallowed into the landslides or drowned as the slides passed underwater.

In an earthquake in Port au Prince, Haiti in 1770 the descriptions are suggestive of widespread liquefaction swallowing up whole buildings, as in Palu. 'A village called Croit du Bouquets (containing about 100 families) had wholly sunk and disappeared.' 'A huge inn, about a mile from Leogane, with a number of people in it, was instantly taken in by the opening of the earth, so that no remains of it could be seen.' 'The trembling of the earth… lasted about two days, all which time great numbers of people, who had escaped out of the towns, continued sitting and walking on the hills and sides of the mountains in continual fear of being swallowed down.'

At this period in the 18th century, people widely believed that the consequence most to be feared in an earthquake was to be swallowed into the ground. The theories of Aristotle dominated explanations for earthquakes that he attributed to underground cavern collapse. Also, the stories from Port Royal became widely assumed to be typical. (More of these theories to make sense of disasters and how we can use risk modelling to measure progress in disaster risk reduction can be found in my 2016 book: 'The Cure for Catastrophe; How We Can Stop Manufacturing Natural Disasters'.)

If we want to do better at identifying where 'ultra-liquefaction' is to be expected in future disasters, we need to understand what drives the conditions for significant porosity reduction in water-saturated near-surface sediments. At last glacial maximum, 20,000 years ago, sea level was 130 m lower than today. Major rivers on soft bedrock cut valleys that extended hundreds of kilometres inland. Where the river had a high sediment load, these valleys were subsequently infilled and today we find deltas. For rivers principally sourced in ice – sheets, or ice-eroded mountains, the 'sharp' grains of silt and sand that settled into still water had the potential for significant porosity reduction. This post-glacial process created large areas, both inland along infilled glacial valleys, and close to the coast in deltas, with the potential for ultra-liquefaction. Delta rivers, with medium to high latitude mountainous catchments include the Fraser River in British Columbia, the Ganges, Brahmaputra, Mississippi, Pearl River, Yellow River, Yangtze. All it needs to 'light the ultra-liquefaction fuse' is an M_W 6+ earthquake. However, too many earthquakes and there will be less opportunity for further porosity reduction.

Where will the next ultra–liquefaction occur? Perhaps beneath a densely populated river – margin or delta city?

Dr Bryan Openshaw Skipp: Celebrating a Life

Andy Coatsworth

Unusually for today, Bryan Skipp excelled in multiple engineering disciplines, including geotechnical, earthquake, vibration, blast and impact. Although mainly known in later years for his contributions to earthquake engineering, and particularly engineering seismology, he was an innovative geotechnical engineer and engineering geophysicist. At Soil Mechanics Ltd, for whom he worked for almost his entire working life, he pioneered inclinometers and telemetry for the monitoring of slopes above highways. He had a specific interest in geotechnical processes, such as grouting. One exciting development from his fertile mind was the use of very large thermite charges to bake London Clay in situ so as to enhance ground anchor capacity. The project was a technical success, but a degree of local panic ensued as there erupted from the banks of the River Thames vast dense clouds of condensing steam.

Indeed Bryan never did things by halves, though I am a little uncertain as to whether the following two examples are attributable to Bryan Skipp or Noel Hobbs: oedometer tests on huge 900 mm diameter samples of the Sherwood Series; secondly the use of a massive dragline excavator in the Republic of Ireland to dig a trench ever deeper until it failed in heavily instrumented clayey silts that had not proved amenable to laboratory testing.

Bryan explored the use of Rayleigh waves in engineering geophysics perhaps two decades before the technique became mainstream. He was an early adopter of probabilistic risk assessment, for example in multiple groundbreaking studies related to hazardous facilities at Canvey Island. Bryan was also, in comparison to many of his peer group, quick to embrace the use of micro-computers, as the forerunners of PCs were then known. We quickly learned however not to entrust a single copy of a floppy disk to Bryan, as it might be lost, returned with jam smeared on it, or on one memorable occasion neatly folded in half. Bryan was author or coauthor of over seventy academic papers and of several chapters contributed to books. He read very widely outside the confines of geotechnical and earthquake engineering, and although somewhat disorganized he could always direct those he mentored to unlikely publications that might be of relevance.

Soil Mechanics Ltd used to give all members of staff a capon on the last working day before Christmas. One year a member of staff – probably Ken Earley (Chief Geologist) – could not be present to collect his capon, but Bryan offered to deliver it to the recipient's local railway station on his route home. Unfortunately the train Bryan took that day did not stop at that station. Bryan therefore flung the capon out of a window of the moving train, shouting at a station porter to deliver the bird to its intended recipient, or as in another version from Bryan with an address label attached to the leg of the bird.

Bryan had a rather theatrical manner of speaking, with audible punctuation marks that sometimes left the listener in doubt as to whether he was making an emphatic point, pausing for thought or asking a question.

Bryan Skipp introduced me to earthquake engineering in the early 1980s, while we were working in a remote area of Northwest Pakistan, where he proved skillful at influencing our client. Bryan's seismic hazard assessments for sites in Spain, although simple by present day standards, deserve a place in the history of engineering seismology. He subsequently led one of the two parallel studies of UK seismicity on behalf of the UK nuclear industry. He was thereafter a key member of the Seismic Hazard Working Party, which resulted in he being a co-recipient of the George Stephenson Medal awarded by the Institution of Civil Engineers. Bryan was a former Chairman and Life Member of the Society of Earthquake and Civil Engineering Dynamics, and very active in the Geological Society. I subsequently served under his diplomatic chairmanship on the BSI Eurocode 8 Committee, where he proved adept at influencing European counter-parts on several key aspects.

Bryan Skipp was both a researcher and a practitioner, whose successes and failures were tested in the days when perhaps both commercial engineering companies and sometimes their clients were more willing to take risks than today.

We will not see the like of Bryan Skipp again.

Figure 1: Photo of Dr Bryan Skipp

Editor's note: On 14th June 2021, the SECED YMs Group hosted the inaugural SECED chartership event with a panel of six members. Fiona Hughes, president of the SECED YMs, who chaired the session, kindly provided a summary of the event and discussion points.

Professional Accreditation in the Field of Engineering Dynamics

Fiona Hughes
Arup, London

The route to chartership is a journey that the majority of the SECED Young Members (YMs) Subcommittee are currently engaged with or have recently completed. There is a plethora of resources available from professional institutions to provide guidance through this process. However, the YMs subcommittee identified a gap in the available resources and believed that an event focussing on specific challenges and opportunities that those working in dynamics may encounter would be beneficial to SECED members. In June 2021, the SECED Young Members' Subcommittee hosted the inaugural SECED chartership event, titled "Professional Accreditation in the Field of Engineering Dynamics: Chartership Panel Discussion and Q&A".

Six chartered engineers from the SECED Committee and YMs Subcommittee volunteered to be on the panel for the event:

- Andreas Nielsen: Principal Engineer, Atkins
- Dr Barnali Ghosh: Technical Principal, Mott MacDonald
- Dr Chris Pearce: Principal Engineer, Atkins
- Dr Damian Grant: Associate Director, Arup
- Manuela Davì: Principal Geotechnical Engineer, Jacobs
- Ziggy Lubkowski: Associate Director, Arup

The event started with the panel discussing challenges they had overcome during their routes to chartership and advice they would give to someone currently working towards chartership. The second half of the event consisted of a Q&A session where participants asked the panel a range of questions. The event was designed to be applicable across the range of professional institutions that SECED members encompass.

The route to chartership was different for each of the panel. This initiated interesting discussions about different routes and combining experience from a range of activities. Barnali shared advice on how to utilise skills developed during a PhD and combine it with experience gained in a design consultancy to meet the competencies required for chartership. Chris shared examples of how non-project initiatives, such as community outreach and recruitment, can be valuable opportunities for developing new skills and gaining different experience.

One of the key messages from all the panel was for developing engineers to be proactive about their careers and experiences. Manuela recommended viewing the chartership process as a great opportunity to develop as an all-round professional. Likewise, Damian recommended people to look for opportunities to diversify their work. The panel discussed the temptation to utilise specialist skills in comparison to trying new and different things, and how to balance this at different stages of your career.

Figure 1: Snapshot of the online Teams event with the six panelists, from top left Ziggy Lubkowski, Damian Grant, Chris Pearce, Andreas Nielsen, Barnali Ghosh and Manuela Davì.

Many people working in dynamics find themselves working on earthquake engineering projects overseas in highly seismic regions. Whilst this project work can be extremely interesting and rewarding for seismic engineers, it can also limit opportunities to get experience working on site, which is an important aspect of understanding the practical aspects of construction processes. Both Manuela and Andreas shared valuable experience they had gained from periods working on site and the panel gave advice on how to find and maximise these opportunities.

Commercial experience was a common theme in the discussions and questions asked by attendees. Ziggy recommended understanding all the aspects of jobs in their totality: the contract being used, specific client Key Performance Indicators (KPIs), and how an individual's work fits into the bigger picture. This approach to gaining an understanding and broadening knowledge through project work was compared to knowledge that is often learnt in the classroom or by self-study, and the merits of each were discussed.

The event was informative and engaging and was enjoyable for the panel and attendees. Following the success of this inaugural event, the SECED Young Members Subcommittee are looking to host future events to support members on their routes to chartership.

18th Mallet–Milne Lecture Announcement

We are delighted to announce that Prof Alain Pecker has agreed to deliver the 18th Mallet–Milne Lecture in 2023, having been nominated as the preferred speaker for this event by the SECED Committee. The nomination was given in recognition of Prof Pecker's long and distinguished career and his significant contributions to the theory and practice of geotechnical earthquake engineering.

Prof Pecker graduated from Ecole Nationale des Ponts et Chaussées in 1972 and obtained a Master of Science degree from the University of California, Berkeley, in 1973. Until 2015 he was Chairman and Managing Director of Géodynamique et Structure, a French engineering consulting firm he founded 40 years ago; upon retiring he became independent consultant. He has contributed to several major worldwide civil engineering projects in seismic areas. He is Past President of the French Society of Soil Mechanics and Geotechnical Engineering, Honorary President of the French Association on Earthquake Engineering and member of the executive committee of the European Association for Earthquake Engineering. He was elected to the French National Academy of Technologies in 2000. He is a member of the drafting panel of Eurocode 8 and President of the French Committee for seismic codes. He is currently Professor at Ecole Nationale des Ponts et Chaussées and at the European School for Advanced Studies in Reduction of Seismic Risk (IUSS of Pavia, Italy). He has authored more than 150 technical papers, been invited as keynote speaker in conferences and received several awards for his work, most notably twice from the French National Academy of Sciences.

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SECED Newsletter

The SECED Newsletter is published quarterly. Previous issues of the SECED Newsletter are available online. All contributions of relevance to the members of the Society are welcome.

Manuscripts should be sent by email. Diagrams, pictures and text should be attached in separate electronic files. Hand-drawn diagrams should be scanned in high resolution so as to be suitable for digital reproduction. Photographs should likewise be submitted in high resolution. Colour images are welcome.

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Please contact the Editor of the Newsletter, Damian Grant, for further details. This edition of the Newsletter was co-edited by Manuela Daví.

Notable Earthquakes
April 2021 – October 2021

Reported by British Geological Survey

Issued by: Davie Galloway, British Geological Survey, November 2021.
Non British Earthquake Data supplied by: United States Geological Survey.

			Time			Dep	Magnitude			
Year	Day	Mon	UTC	Lat	Lon	km	ML	Mb	Mw	Location
2021	01	APR	09:56	29.96S	177.68W	20			6.5	KERMADEC ISLANDS
2021	01	APR	22:25	56.41N	6.21W	7	1.4			MULL, ARGYLL & BUTE
Felt Pennyghael, Mull (2 EMS).										
2021	03	APR	01:16	58.01S	7.84W	10			6.6	SOUTH SANDWICH ISLANDS
2021	10	APR	07:00	8.57S	112.51E	67			6.0	JAVA, INDONESIA
At least nine people killed, over 100 others injured and some 4,500 buildings damaged or destroyed on East Java.										
2021	24	APR	00:23	18.88S	176.25W	301			6.5	TONGA
2021	25	APR	22:28	21.59S	177.12W	246			6.5	TONGA
2021	28	APR	02:21	26.78N	92.46E	34			6.0	ASSAM, NORTHEAST INDIA
Two people killed, ten others injured and widespread damage to buildings and roads in Assam and a further two people injured and over 100 houses damaged in Bhutan.										
2021	01	MAY	01:27	38.20N	141.60E	43			6.8	OFFSHORE HONSHU, JAPAN
2021	12	MAY	14:05	17.39S	66.31E	10			6.7	INDIAN OCEAN
2021	13	MAY	10:25	56.64N	6.19W	7	1.6			MULL, ARGYLL & BUTE
2021	14	MAY	06:33	0.14N	96.64E	11			6.7	NIAS REGION, INDONESIA
2021	15	MAY	15:02	58.55N	4.72W	7	2.5			DURNESS, HIGHLAND
2021	15	MAY	20:05	55.91N	6.15W	8	1.6			ISLAY, ARGYLL & BUTE
2021	19	MAY	00:42	33.07S	109.39W	10			6.7	SOUTH PACIFIC OCEAN
2021	16	MAY	15:16	51.60N	2.80W	9	2.9			CALDICOT, MONMOUTHSHIRE
Felt in several towns and villages in the counties of Monmouthshire, South Gloucestershire and City of Bristol (3EMS).										
2021	17	MAY	15:37	55.92N	6.17W	8	1.8			ISLAY, ARGYLL & BUTE
2021	21	MAY	13:48	25.74N	100.02E	9			6.1	YUNNAN, CHINA
Three people killed, at least 27 others injured and over 12,000 homes were damaged in Yangbi and Yongping counties, Yunnan.										
2021	21	MAY	18:04	34.59N	98.24E	10			7.3	SOUTHERN QINGHAI, CHINA
At least 19 people injured and over 640 buildings and several bridges were damaged or destroyed in Madou and Maqin counties, Qinghai.										
2021	21	MAY	22:13	16.60S	177.37W	10			6.5	FIJI ISLANDS REGION
2021	02	JUN	14:58	53.12N	0.06W	11	2.1			MAREHAM-LE-FIN, LINCS
2021	17	JUN	06:55	49.90N	2.86W	5	1.8			ENGLISH CHANNEL
2021	20	JUN	17:05	30.21S	177.81W	10			6.5	KERMADEC ISLANDS

			Time			Dep	Magnitude			
Year	Day	Mon	UTC	Lat	Lon	km	ML	Mb	Mw	Location
2021	23	JUN	00:02	55.52N	3.82W	7	1.7			DOUGLAS, S LANARKSHIRE
Felt Campswater, Crawford (2 EMS).										
2021	26	JUN	20:03	49.50N	7.13W	9	2.0			CELTIC SEA
2021	02	JUL	13:14	58.55N	3.91W	7	2.1			MELVICH, HIGHLAND
Felt Melvich, Reay, Westfield and Dounreay (3 EMS).										
2021	10	JUL	03:10	62.54N	3.51E	14	3.2			NORWEGIAN SEA
2021	18	JUL	23:27	56.74N	5.94W	9	0.9			KENTRA, HIGHLAND
Felt Kentra and Acharacle (3 EMS).										
2021	19	JUL	04:29	52.37N	2.89W	7	1.8			LEINTWARDINE, HEREF
2021	21	JUL	21:15	7.42N	82.79W	10			6.7	OFFSHORE PANAMA
2021	23	JUL	20:48	13.70N	120.74E	110			6.7	PHILIPPINES
2021	26	JUL	10:01	55.81N	3.20W	5	2.5			PENICUIK, MIDLOTHIA
Felt in Penicuik and in several surrounding villages and hamlets (4 EMS).										
2021	29	JUL	06:15	54.82N	158.87W	33			8.2	ALASKA PENINSULA
2021	05	AUG	14:27	55.80N	3.18W	6	1.5			PENICUIK, MIDLOTHIAN
2021	08	AUG	03:21	53.52N	0.30W	23	1.7			CAISTOR, LINCOLNSHIRE
2021	11	AUG	17:46	6.46N	126.74E	65			7.1	PHILIPPINES
2021	12	AUG	18:32	57.60S	25.19W	63			7.5	SOUTH SANDWICH ISLANDS
2021	12	AUG	18:35	58.42S	25.32W	48			8.1	SOUTH SANDWICH ISLANDS
2021	14	AUG	11:57	55.22N	157.69W	33			6.9	ALASKA PENINSULA
2021	14	AUG	12:29	18.41N	73.48W	10			7.2	HAITA
At least 2,200 people killed, around 10,000 others injured and thousands of homes and buildings either damaged or destroyed. The majority of the damage and casualties occurred in the Nippes department in the southwest region of Haiti.										
2021	16	AUG	11:10	58.37S	23.34W	14			6.9	SOUTH SANDWICH ISLANDS
2021	18	AUG	10:09	14.86S	167.11E	89			6.9	VANUATU
2021	20	AUG	20:36	54.75N	4.62E	10	3.8			SOUTHERN NORTH SEA
2021	22	AUG	00:45	60.12S	24.34W	11			6.8	SOUTH SANDWICH ISLANDS
2021	22	AUG	21:33	60.29S	24.90W	14			7.1	SOUTH SANDWICH ISLANDS
2021	25	AUG	08:39	49.93N	2.91W	5	2.0			ENGLISH CHANNEL
2021	29	AUG	19:04	56.38N	3.98W	3	1.6			COMRIE, PERTH & KINROSS
Felt Comrie (3 EMS).										
2021	08	SEP	01:47	16.97N	99.74W	20			7.0	GUERRERO, MEXICO
One person was killed, 23 others were injured, many buildings were damaged and several landslides occurred in Acapulco.										
2021	08	SEP	04:18	54.39N	2.87W	8	1.0			WINDERMERE, CUMBRIA
Felt Windermere and Staveley (3 EMS).										

			Time			Dep	Magnitude			
Year	Day	Mon	UTC	Lat	Lon	km	ML	Mb	Mw	Location
2021	22	SEP	09:57	12.16N	87.85W	30			6.5	OFFSHORE NICARAGUA
2021	27	SEP	06:17	35.25N	25.26E	9			6.0	CRETE, GREECE
One person was killed, 20 others were injured and many of the older homes, buildings and churches on the island suffered major damage.										
2021	28	SEP	04:14	51.74N	4.63W	6	1.9			AMROTH, PEMBROKESHIRE
2021	02	OCT	06:29	21.13S	174.90E	527			7.3	FIJI ISLANDS REGION
2021	04	OCT	09:33	60.66N	2.88E	10	2.8			NORTHERN NORTH SEA
2021	06	OCT	22:01	30.19N	68.00E	9			5.9	PAKISTAN
At least 24 people killed, 300 others injured and 100 homes damaged or destroyed in Harnia and Shahrag, Balochistan province.										
2021	09	OCT	10:58	21.19S	174.52E	535			6.9	FIJI ISLANDS REGION
2021	11	OCT	09:10	56.26N	156.55W	69			6.9	ALASKA PENINSULA
2021	15	OCT	22:26	53.10N	2.96E	10	2.0			SOUTHERN NORTH SEA
2021	17	OCT	04:45	53.05N	2.06E	10	2.1			SOUTHERN NORTH SEA
2021	22	OCT	09:24	35.19N	26.26E	10			6.4	CRETE, GREECE
Several people were slightly injured and some of the older homes, buildings and churches on the island suffered damage.										
2021	12	OCT	14:27	56.60N	6.23W	7	1.1			MULL, ARGYLL & BUTE
Felt Kilchoan, Mull (2 EMS).										
2021	14	OCT	06:30	56.28N	3.74W	3	1.5			BLACKFORD, PERTH & KINROSS
2021	17	OCT	15:18	56.15N	4.93W	2	1.3			CORROW, ARGYLL & BUTE
Felt Carrick Castle (3 EMS).										
2021	17	OCT	21:10	53.21N	3.83W	5	1.0			DOLGARROG, CONWY
Felt Dolgarrog and Tal-y-bont (3 EMS).										

Forthcoming Events

Evening Lectures

VSimulators: Cutting-edge facilities for human factors research in relation to vibration serviceability for structures

24 November 2021 (5:15 pm) ,
Institution of Civil Engineers

Synopsis

VSimulators was created primarily to support a major overhaul of design guidance for vibration serviceability in two major applications: the low frequency sway of tall buildings and the higher frequency bounce of lively floors. Existing guidance, which is well past its sell-by date, was usually developed based on limited and sometimes compromised experimental observations, primarily aimed at perception thresholds. The chain of evidence is often tenuous, with highly subjective observations and acceptance criteria that are demonstrably inappropriate.

VSimulators research will adopt a cross-disciplinary scientific approach and appropriate testing protocols but, most importantly, accounting for environmental factors in buildings which are known to have significant influence on user experience. Environment is simulated through different forms of physical and virtual reality in VSim@Bath (tall building sway) and VSim@Exeter (floor and other high frequency vibration).

The first users of VSim@Exeter are undergraduate students studying use of response factors in design and a PhD student studying human lateral stability relating to human-structure interaction. VSim@Bath currently supports two ongoing PhD projects, one dealing with assessing acceptability of wind-induced vibrations in tall building office environments, focusing on a phenomenon known as sopite syndrome, the other relating to the impact of indoor air quality on productivity in offices. We will describe the VSimulators facility, show the research in action and present early results.

Prof James Brownjohn

Prof James Brownjohn (DEng, FIMechE, FIStrutE) is a member of the Vibration Engineering Section, based at the University of Exeter. His academic career has focused on experimental assessment of the performance of a wide range of civil structures using full-scale dynamic testing, long-term monitoring and physical motion simulation. He is a director of Full-Scale Dynamics Ltd, a University spin-off company that specialises in managing performance of civil structures dynamically excited by actions of machinery, humans and wind. He is Principal Investigator for the new Exeter VSimulators facility (VSim@Exeter) which will study human experience with moving structures in virtual reality.

Dr Antony Darby

Dr Antony Darby (BSc Hons, PhD, MIStructE) is a Reader in Structural Engineering within the Department of Architecture & Civil Engineering at the University of Bath and is Head of the Civil Engineering Group. His research expertise lies in dynamic testing, active and passive control of structures and, more recently, human perception and acceptability of dynamic motion. Prior to coming to Bath 20 years ago, he was instrumental in pioneering the real-time dynamic substructure testing at the University of Oxford. He is Principal Investigator for the new Bath VSimulators facility (VSim@Bath), developed to allow multi-disciplinary research into human experience to tall building sway incorporating environmental influences and virtual reality.

Further information

This event is organised by SECED. The event will be chaired by Ian Smith (Atkins). The event will be held in-person at the Institution of Civil Engineers. Attendance at this meeting is free. Seats are allocated on a first come, first served basis. Tea, coffee and biscuits will be served from 5.30pm–6pm. The event will also be broadcast online.

EEFIT Research Grant winners showcase

8 December 2021 (5:15 pm) , online event

Synopsis

This event will showcase the findings of two research projects undertaken by the 2019 EEFIT Research Grant winners:

- "Optimal design of rubber joints for seismic protection of masonry-infilled frame" by Enrico Tubaldi
- "Integrating earthquake early warnings into organisational resilience" by Gianluca Pescaroli, Carmine Galasso and Omar Velazquez Ortiz.

Dr Enrico Tubaldi

Dr. Enrico Tubaldi is Senior Lecturer of Structural Engineering in the Department of Civil and Environmental Engineering and member of the Center for Intelligent Infrastructure at University of Strathclyde. Before joining University of Strathclyde in October 2017, he was Marie Curie Reaserch Fellow at Imperial College London (UK) and post-doctoral researcher at Polytechnic University of Marche, University of Camerino, Lousiana State University and at the Institute of Risk and Uncertainty of University of Liverpool. He is author or coauthor of more than 50 journal papers in the field of earthquake engineering, structural dynamics, infrastructure risk assessment and monitoring, and has supervised more than 10 PhD students and post-doctoral researchers.

Dr Carmine Galasso

Dr. Carmine Galasso is a Professor of Catastrophe Risk Engineering at University College London.

Dr Gianluca Pescaroli

Dr. Gianluca Pescaroli is a Lecturer in Business Continuity and Organisational Resilience, University College London.

Omar Velazquez

Omar Velazquez Ortiz is a PhD student at University College London.

Further Information

This event is organised by the UK Earthquake Engineering Field Investigation Team (EEFIT), which is serviced by The Institution of Structural Engineers (IStructE). Non-members of EEFIT are welcome to attend. This event will take place online. Please register for the event prior to joining via the IStructE's website. The registration process will provide you with the link you need to join the main event.

For up-to-date details and further information on events organised by SECED,
visit the SECED website or contact Shelly-Ann Russell (020 7665 2147, societyevents@ice.org.uk)