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NEWSLETTER

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In this issue

Sellafield Site Earthquake Liquefaction Assessment

Angelo Farnetano, Kerry Clinton
Sellafield Ltd, Warrington, UK

Abstract

A new seismic liquefaction vulnerability assessment for the Sellafield site was carried out considering the latest developments from technical literature and up-to-date geotechnical / geological information from exploratory borehole logs. This is an update to the original liquefaction risk studies carried out in the 1980's. The following were evaluated in turn: soil susceptibility to liquefaction; potential of initiation (triggering) and the vulnerability parameters for the soil strata as described in the boreholes utilised in the triggering analysis. Both the Sellafield earthquake ground motion (10^{-4} annual exceedance probability; 0.25g peak ground acceleration, PGA) and a 40% higher PGA (0.35g) extreme earthquake were considered in the analysis. The study concluded that only a few areas of the site are susceptible to liquefaction, but only in the central area (less than 2% of the whole site) there is a risk of damage occurring to buildings and infrastructure for the higher peak ground acceleration. However, this risk is deemed to be low.

SECED Newsletter

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1. Introduction

Liquefaction is an earthquake hazard, which occurs predominantly in loose saturated fine-grained non-cohesive soils such as silts and sands. The excess pore pressure, generated in such a soil by intense ground shaking, can cause large ground deformations or even soil failure due to its loss of stiffness and shear strength. Damage to constructed works caused by the complete loss of soil strength associated with liquefaction varies from minor settlement-induced cracking to complete failure of entire geotechnical systems (building foundations, dams, retaining walls, etc.).

2. Seismic hazard

Nuclear safety related structures in the UK such as those sited at Sellafield are required to be designed to resist extreme hazards including those associated with 1 in 10,000-year return period ground motions. An assessment of the earthquake soil liquefaction hazard at Sellafield is carried out in this paper.

The likelihood of seismic liquefaction at the Sellafield site was originally investigated in the 1980's by Principia Mechanica Limited (PML). Their first assessment report was issued in 1983 (Principia Mechanica Limited, 1983) followed by a more detailed one for an area deemed to be the highest risk in 1985 (Principia Mechanica Limited, 1985). They concluded that even when the beyond design basis earthquake is considered, the probability of liquefaction occurring at Sellafield is very low.

In 2011, a soil liquefaction assessment was carried out using latest research formulations at the location of a proposed facility at Sellafield which happened to be in the area deemed the highest risk in PML's studies. The results concurred with the earlier studies that there was a low probability of liquefaction occurring under both the 0.25g PGA and the 0.35g earthquake ground motions.

Due to the age of the PML studies, it was decided that a new study should be carried out for the Sellafield site as a whole, taking into account the latest developments from technical literature and the significant increase in the amount of geotechnical / geological information from exploratory borehole logs since that time.

An earthquake magnitude of 6 for both 0.25g and 0.35g PGAs was considered for the assessment. The new study is contained in a technical report produced by Sellafield Ltd (Farnetano, 2022) whose main results and conclusions are shown in the present article.

3. Ground conditions and hydrogeology at the Sellafield site

The regional geology and simple stratigraphic sequence of the area around the Sellafield site is recorded on the 1:50000 British Geological Survey map, Gosforth Sheet 37. It shows the site to be predominantly covered with recent (Quaternary) glacial drift deposits and postglacial Alluvium and River Terrace gravels. Along the northwest boundary of the site and to the east Pleistocene Sand and Gravel and Boulder clay are present where higher ground exists.

The thickness of these superficial deposits over the Sellafield site ranges from less than 1m to over 45m. The deposits comprise mainly sand and gravel over the majority of the site. Lenses of clay are present, in particular, over the central area of the site. Standard Penetration Test (SPT) data from boreholes over the site generally show large variability within the first 10m of depth followed by a gradual increase with increased depth.

Made ground is a frequent occurrence over the site due to its historical development. It typically comprises reworked natural ground and building debris.

Underlying the Superficial deposits is the regional Calder and Ormskirk Sandstone formation dating from the Triassic Period.

Regional Groundwater flows in a generally south westerly direction towards the Irish Sea. Typically, the ground water is located between 3m and around 20m below ground level.

A detailed description of the geology and the hydrogeology of the Sellafield site is contained in the Geological Conceptualisation of the Sellafield Site and the Interpretative Reports (Serco Consulting and Golder Associates, 2010a).

4. Earthquake liquefaction assessment

The liquefaction vulnerability assessment was carried out utilising the information contained in 622 borehole logs from across the site together with the average ground water levels measured from wells as presented in the Groundwater elevation factual report produced by Sellafield (Serco Consulting and Golder Associates, 2010b). In turn, soil susceptibility to liquefaction, potential of initiation (triggering analysis) and finally the vulnerability parameters for each of the holes considered in the triggering analysis were evaluated. This approach is well established within the technical community and it was recently utilised for the Christchurch (New Zealand) Liquefaction Vulnerability Study carried out following the 2010–2011 earthquake sequence (Tonkin & Taylor, 2013; 2015).

4.1. Susceptibility analysis

Liquefaction susceptibility is a physical characteristic of a soil that determines whether it is liquefiable. Soils that are susceptible to liquefaction typically have no to low plasticity and low to moderate permeability. Liquefaction susceptibility is independent of the level of shaking required to trigger liquefaction and if a soil layer is not susceptible to liquefaction, by definition, liquefaction cannot be triggered, and that layer will not contribute to liquefaction vulnerability.

Criteria to define susceptibility of soil deposits can be found in the technical literature (Kramer, 1996) and within international seismic codes.

The susceptibility analysis was conducted using borehole description data (i.e., nature of soils, depth to groundwater) and the relative density of the soil (i.e., SPT blow counts). Soil was considered not susceptible to liquefaction if:

- It is predominantly cohesive,
- It is predominantly gravel,
- The depth to groundwater is greater than 15m,
- The soil is dense with $(N_1)_{60}>30$.

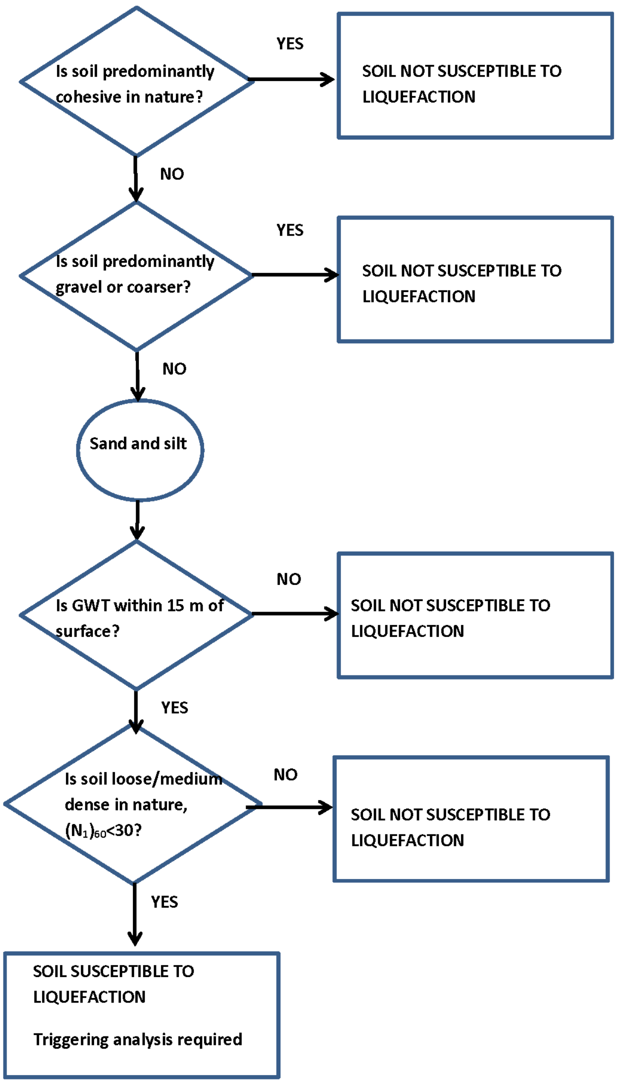

Figure 1: Decision tree for determining liquifaction susceptibility.

4.2 Triggering analysis

Once a soil deposit has been found susceptible to liquefaction, liquefaction triggering must be investigated. Liquefaction triggering is the initiation of liquefaction from ground shaking, commonly caused by earthquakes. This shaking must be sufficiently intense to trigger liquefaction for the particular soil. Smaller earthquakes do not tend to trigger liquefaction as readily as larger earthquakes. The magnitude of shaking level that triggers liquefaction depends on the resistance of the soil layer.

For the evaluation of whether liquefaction will occur or not the simplified method shown in (Idriss and Boulanger, 2010) has been applied: the ratio of the seismic resistance at a determinate point in the ground expressed in terms of Cyclic Resistance Ratio (CRR) to the seismic demand at that point, expressed in terms of Cyclic Stress Ratio (CSR) was calculated in order to obtain a factor of safety against liquefaction (*FSL*) at that point.

Locations where loading exceeds the resistance are expected to liquefy (i.e. $FSL<1$).

4.3 Vulnerability analysis

The effect of liquefaction at the ground surface could be zero or insignificant even if *FSL* is calculated as less than 1, because other factors need to be considered, such as the thickness of the liquefiable soil layers combined with the thickness of any non-liquefiable crust. This affects the overall risk of liquefaction related damage to buildings and civil engineering infrastructure and one way to assess the magnitude of this risk is to use liquefaction vulnerability parameters.

The vulnerability parameters utilised in this study are: the Liquefaction Potential Index (LPI), defined by Iwasaki et al. (1978), the Liquefaction Severity Number (LSN), developed by Tonkin & Taylor (2013), and the one-dimensional volumetric reconsolidation settlement (S_v), defined by Ishihara and Yoshimine (1992). Equations 1 to 3 give these expressions and Tables 1 to 3 contain descriptions of liquefaction effects, associated with ranges of values of the parameters themselves.

$$LPI = \int_0^{20} F(z)w(z)dz \tag{1}$$

$$LSN = \int_0^{H} \frac{\varepsilon_v}{z} dz \tag{2}$$

$$S_v = \int_0^{H} \varepsilon_v dz \tag{3}$$

where *F(z)* is a function of the Factor of Safety against liquefaction, *w(z)* is a function of the depth, ε_v is the volumetric reconsolidation strain defined by Ishihara and Yoshimine (1992) and *H* is the thickness of the ground affected by liquefaction. A detailed description of all parameters can be found in their original studies.

Using the strategy defined for cone penetration test (CPT) by Zhang et al. (2002) to derive ε_v from the chart provided by Ishihara and Yoshimine (1992), the following correlations (Equations 4 to 17) were obtained in order to determine the volumetric reconsolidation strain ε_v once the SPT blow counts N_1 and the factor of safety against liquefaction (*FSL*) are known.

$$if\ FSL \leq 0.5 \quad \varepsilon_v = -1.95\ln(N_1) + 7.97 \qquad \text{for} \quad 3 \leq N_1 \leq 30 \tag{4}$$

$$if\ FSL \leq 0.6 \quad \varepsilon_v = -1.95\ln(N_1) + 7.97 \qquad \text{for} \quad 3 \leq N_1 \leq 25 \tag{5}$$

$$if\ FSL = 0.6 \quad \varepsilon_v = -3.43\ln(N_1) + 12.77 \qquad \text{for} \quad 25 \leq N_1 \leq 30 \tag{6}$$

$$if\ FSL = 0.7 \quad \varepsilon_v = -1.95\ln(N_1) + 7.97 \qquad \text{for} \quad 3 \leq N_1 \leq 20 \tag{7}$$

$$if\ FSL = 0.7 \quad \varepsilon_v = -3.04\ln(N_1) + 11.23 \qquad \text{for} \quad 20 \leq N_1 \leq 30 \tag{8}$$

$$if\ FSL = 0.8 \quad \varepsilon_v = -1.95\ln(N_1) + 7.97 \qquad \text{for} \quad 3 \leq N_1 \leq 14 \tag{9}$$

$$if\ FSL = 0.8 \quad \varepsilon_v = -2.75\ln(N_1) + 10.03 \qquad \text{for} \quad 14 \leq N_1 \leq 30 \tag{10}$$

$$if\ FSL = 0.9 \quad \varepsilon_v = -1.95\ln(N_1) + 7.97 \qquad \text{for} \quad 3 \leq N_1 \leq 10 \tag{11}$$

$$if\ FSL = 0.9 \quad \varepsilon_v = -2.50\ln(N_1) + 8.94 \qquad \text{for} \quad 10 \leq N_1 \leq 30 \tag{12}$$

$$if\ FSL = 1.0 \quad \varepsilon_v = -0.88\ln(N_1) + 3.43 \qquad \text{for} \quad 3 \leq N_1 \leq 30 \tag{13}$$

$$if\ FSL = 1.1 \quad \varepsilon_v = -0.34\ln(N_1) + 1.53 \qquad \text{for} \quad 3 \leq N_1 \leq 30 \tag{14}$$

$$if\ FSL = 1.2 \quad \varepsilon_v = -0.27\ln(N_1) + 1.18 \qquad \text{for} \quad 3 \leq N_1 \leq 30 \tag{15}$$

$$if\ FSL = 1.3 \quad \varepsilon_v = -0.20\ln(N_1) + 0.86 \qquad \text{for} \quad 3 \leq N_1 \leq 30 \tag{16}$$

$$if\ FSL = 2.0 \quad \varepsilon_v = 0 \tag{17}$$

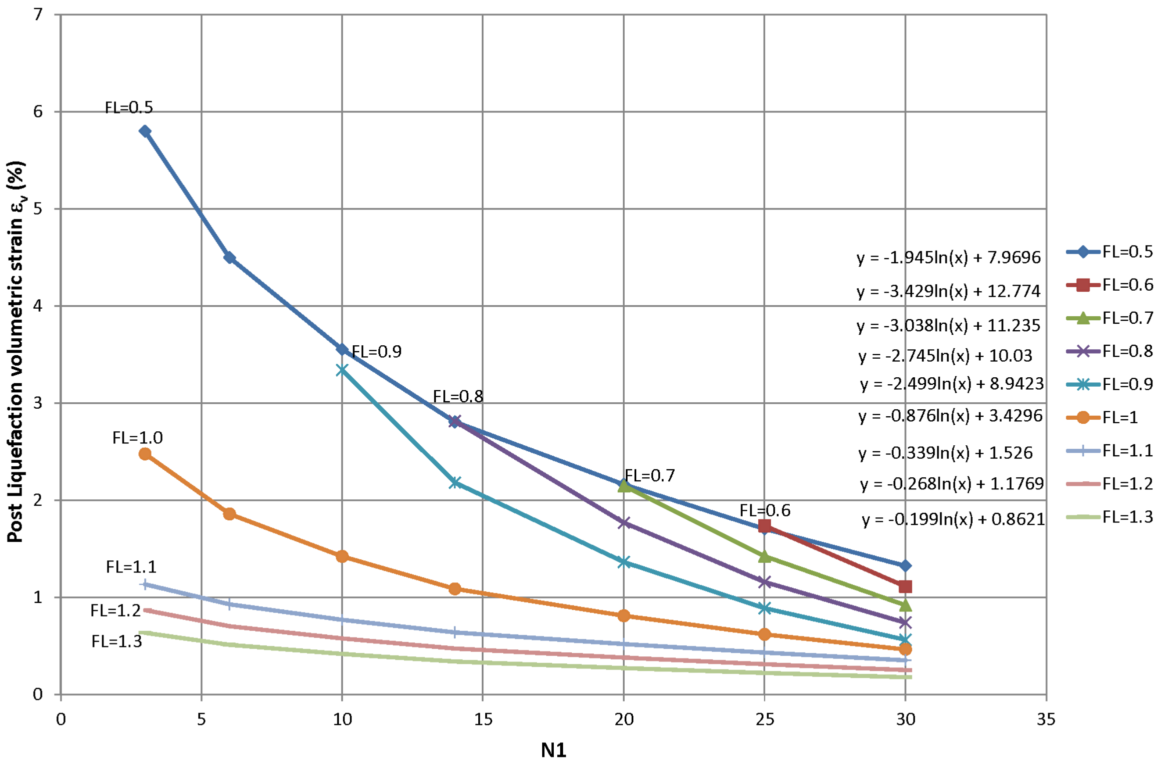

Figure 2: Post Liquefaction Volumetric strain vs N1.

5. Results

The liquefaction vulnerability assessment was carried out utilising the information contained in 622 borehole logs. The majority of these (around 500) were found not susceptible to liquefaction. For the remaining, the triggering analysis for free field conditions was carried out at locations within a 20 m depth where SPT values were available and vulnerability parameters could be calculated. For the triggering analysis an earthquake magnitude of 6 and the relevant peak ground acceleration are used to define the Cyclic Stress Ratio (CSR) (i.e., 0.25g or 0.35g).

The triggering analysis derives factor of safety profiles for the 0.25g and 0.35g assumed earthquakes, respectively, for each borehole which were then used to assess the Liquefaction Potential Index (LPI) and the Liquefaction Severity Number (LSN). For boreholes where the calculated LPI and LSN values were high (central area of the site), the likely resulting settlement was calculated using the S_V parameter.

Results of the assessment for 0.25g and 0.35g peak ground acceleration are summarised in Tables 1 to 3 and Figures 3 to 6.

Table 1: Number of boreholes observed for 0.25g and 0.35g PGA scenarios corresponding to LPI ranges

LPI	Liquefaction probability at ground surface (Iwasaki et al., 1978)	Number of boreholes found in the range (0.25g)	Number of boreholes found in the range (0.35g)
~0	Very Low	587	563
<5	Low	28	35
5–15	High	5	19
>15	Very High	1	3

Table 2: Predominant performance of sites corresponding to LSN ranges

LSN	Expected extent of liquefaction (Tonkin & Taylor, 2013)	Number of boreholes (0.25g)	Number of boreholes (0.35g)
0–10	Little to no indication of liquefaction, minor effects	604	588
10–20	Minor indication of liquefaction, some sand boils	12	27
20–30	Moderate indication of liquefaction, presence of sand boils and minor damage to building structures	1	3
30–40	Moderate to severe indication of liquefaction. Magnitude of settlements sufficient to cause structural damage to buildings	1	0
40–50	Major indication of liquefaction; presence of undulations and damage to ground surface; causes severe total and differential settlements to building structures	0	1
>50	Extensive evidence of liquefaction at surface and large values of total and differential settlements causing severe damage to building structures and services.	1	1

Table 3: Relation between damage extent and approximate settlements with number of boreholes observed

Extent of damage	Settlements (cm)	Phenomena at the surface (Ishihara and Yoshimine, 1992)	Number of boreholes (0.25g)	Number of boreholes (0.35g)
Light to no damage	0–10	Minor cracks	47	41
Medium damage	10–30	Small cracks, oozing	7	12
Extensive damage	30–70	Large cracks, spouting of sands, large offsets, lateral movements	1	2

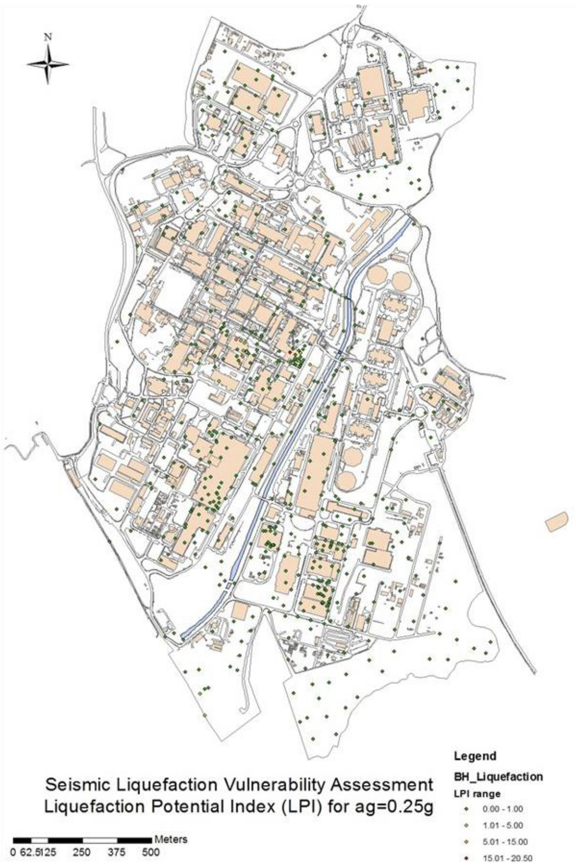

Figure 3: Distribution of the Liquefaction Potential Index at Sellafield for 0.25g peak ground acceleration

Figure 5: Distribution of the Liquefaction Potential Index at Sellafield for 0.35g peak ground acceleration

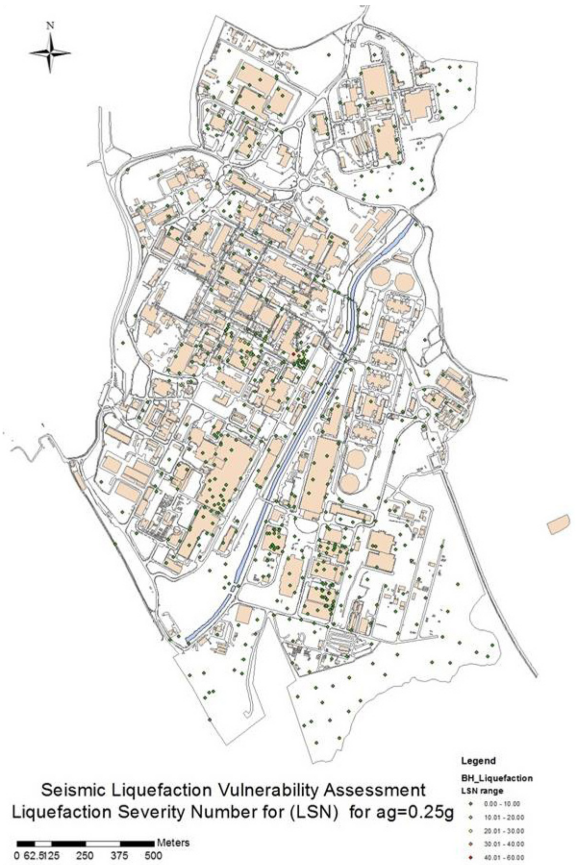

Figure 4: Distribution of the Liquefaction Severity Number at Sellafield for 0.25g peak ground acceleration

Figure 6: Distribution of the Liquefaction Severity Number at Sellafield for 0.35g peak ground acceleration

6. Conclusions

A seismic liquefaction assessment considering the latest researched formulations has been carried out for the Sellafield site. Based on the criteria depicted in Figure 1 most of the site is deemed not susceptible to liquefaction.

Triggering analysis was carried out using data from boreholes in locations assessed to have ground conditions susceptible to liquefaction using the method of Idriss and Boulanger (2010) from which were derived the liquefaction vulnerability parameters LPI and LSN.

LPI and LSN were calculated over a depth of 10–20m depending on data available in the logs. It has been noted that liquefaction effects could be significant if liquefaction occurs within the first 10m depth.

The two parameters have shown a good agreement in predicting liquefaction vulnerability at the Sellafield site giving the highest values over the central area. Calculations of the expected settlement (S_v) have been derived for those boreholes where the derived parameter values were high. Note, however, that use of the unidimensional settlement parameter is in general very conservative.

From the above, it can be concluded that:

1. For a 10^{-4} annual exceedance probability design basis earthquake (0.25g) there is an extremely low risk of building and infrastructure damage occurring anywhere over the Sellafield site.

2. For an extreme earthquake event (0.35g), the risk of building / infrastructure damage occurring is still very low for over 98% of the Sellafield site; for the remainder of the site (central area) the risk is still deemed low considering the robustness of structures and infrastructures on the Sellafield site.

Acknowledgement

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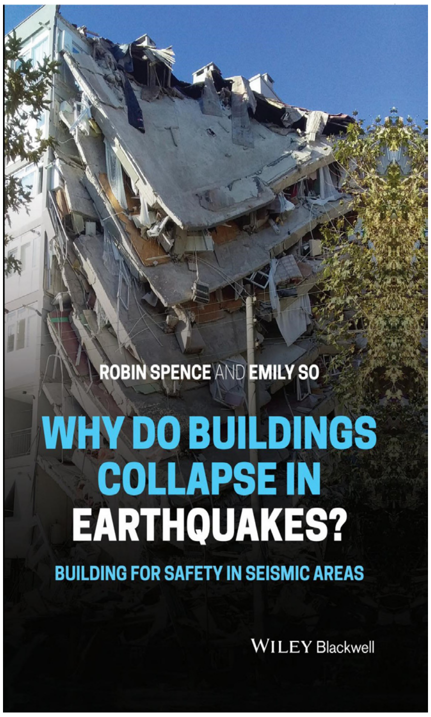
Book Review: 'Why do Buildings Collapse in Earthquakes?' by Robin Spence & Emily So

Damian Grant
Arup, London, UK

1. Introduction

This book starts with the conundrum posed in its title: given that engineers and seismologists have taken such huge strides over the last five or six decades in developing technical solutions for seismic-resistant buildings, why has the global earthquake mortality rate barely reduced? The answer that the authors develop over the next three hundred or so pages is that implementing seismic safety measures is not just a technical problem, but fundamentally a social, economic and political one. They argue that engineers are just one of many stakeholders that bear responsibility for solving the earthquake problem, and that governments, the private sector and individuals and homeowners all have an important role to play.



Throughout the book, they draw examples from across the seismically hazardous areas of the globe – both in describing the impact of destructive earthquakes from the last few decades, and in highlighting successful programmes of seismic risk reduction. They stress the important role of field reconnaissance in learning lessons from earthquakes – perhaps not surprisingly, given the authors' prominent involvement in the UK-based Earthquake Engineering Field Investigation Team, and their role in setting up the

Global Earthquake Consequences Database.

The book also covers common construction materials and typologies used around the world, and how these different construction types typically fare in earthquakes. An important lesson – especially for me, a smug engineer from temperate New Zealand – is the role that climate plays in construction typologies that are found in a region. For example, thick mud or stone walls, valuable for their thermal mass in arid climates, are heavy and brittle – terrible properties when considering seismic resistance.

Of course, unfavourable climate is not the only feature contributing to building collapses in earthquakes. After extolling the successes of building code development, particularly over the last half century, the authors discuss how codes have had less success in reducing risk in the developing world. They cite gaps in the codes themselves, such as not accounting for culturally-appropriate and locally-available materials, and implementation hurdles, such as corruption and failure to enforce the codes, as examples of what has gone wrong.

Another novel feature of this book is the inclusion of biographical profiles of nine people (seven individuals and one couple) who have all made strong contributions to seismic risk reduction in their communities. Interestingly, of the nine, only two are engineers. For what it's worth, only one (Dr Lucy Jones, an eminent California-based seismologist) has been recognised with awards from the US Earthquake Engineering Research Institute (EERI). This again reflects the emphasis of the book on the role of non-engineering stakeholders, and non-technical solutions to the earthquake problem.

The intended audience for this book is tricky to define. According to the authors, it could be read by government officials, political representatives, business managers and homeowners, as well as architects and engineers. I find it difficult to imagine a homeowner in earthquake country purchasing a 300-page hardcover textbook by UK-based academics, but that is not to say that such a reader would not find the contents valuable. Certainly Chapter 9, which describes how different stakeholders can contribute to seismic risk reduction, should be required reading for those who are being called to arms: government officials and international agencies, business owners, non-governmental organisations (NGOs), insurers, individual citizens, and of course engineers.

As a practising earthquake engineer, I have a few minor quibbles with the book, but they probably reflect more a difference in emphasis in my own work – often carried out at the higher end of the economic development ladder for private clients – compared to that of the authors. There is only brief mention in the book of a shift of engineers' focus, particularly since the 2011 Christchurch earthquake, towards resilience-based design and a 'functional recovery' seismic design objective – beyond the typical 'life safety' objective we've targeted for four or more decades. And seismic-resistant technologies that can help us achieve these stretch goals, such as base isolation, supplemental damping devices and unbonded post-tensioning systems, are also given only a few passing mentions.

That said, there are many books on the market covering these innovative technical solutions to the earthquake problem. The value of this book is in reminding us of many other important qualities that seismic safety advocates, including engineers, must embody: cultural sensitivity, flexibility, empathy, communication skills, persistence and bravery. To this end, the nine individuals profiled in the book – and the two authors – are edifying role models.

Notable Earthquakes November 2021 – June 2022

Reported by British Geological Survey

Issued by: Davie Galloway, British Geological Survey, September 2022
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	04	NOV	02:00	53.22N	2.60E	10	2.4			SOUTHERN NORTH SEA
2021	10	NOV	15:45	23.59N	126.45E	12			6.6	RYUKYU ISLANDS, JAPAN
One person killed, around 100 others injured and over 3,000 homes either damaged or destroyed in Hormozgan										
2021	16	NOV	01:44	56.03N	5.54W	12	3.4			ACHNAMARA, ARGYLL & BUTE
Felt Achnamara, Tayvallich, Lochgilphead, Tarbert, Ardrishaig and many other villages and hamlets in the region, mainly from within around 40 km of the epicentre (5 EMS).										
2021	16	NOV	02:42	56.91N	4.74W	7	1.6			ROYBRIDGE, HIGHLAND
2021	19	NOV	21:29	56.91N	4.74W	7	2.2			ROYBRIDGE, HIGHLAND

Year	Day	Mon	Time UTC	Lat	Lon	Dep km	Magnitude ML	Mb	Mw	Location
Felt Roybridge, Spean Bridge and Gairlochy (3 EMS).										
2021	24	NOV	18:18	53.15N	0.81E	16	1.6			SOUTHERN NORTH SEA
2021	28	NOV	10:52	4.47S	76.81W	126			7.5	NORTHERN PERU
One person killed, 17 others injured, over 5,680 buildings damaged or destroyed and several roads damaged in Amazonas, Cajamarca, Loreto and San Martin regions.										
2021	03	DEC	12:40	52.54N	0.62W	8	1.7			LAXTON, NORTHAMPTONSHIRE
2021	03	DEC	13:30	57.83N	5.10W	8	1.5			ULLAPOOL, HIGHLAND
2021	11	DEC	17:32	57.85N	5.11W	6	2.5			ULLAPOOL, HIGHLAND
Felt Ullapool and in a few nearby settlements (3 EMS).										
2021	11	DEC	17:37	57.85N	5.11W	7	2.5			ULLAPOOL, HIGHLAND
Felt Ullapool and in a few nearby settlements (3 EMS).										
2021	12	DEC	08:58	60.80S	154.14E	10			6.6	MACQUARIE ISLAND REGION
2021	14	DEC	03:20	7.60S	122.23E	14			7.3	FLORES SEA, INDONESIA
One person killed, at least 5 others injured and 736 buildings damaged on South Sulawesi and one person injured on Flores.										
2021	14	DEC	18:28	57.09N	5.75W	8	1.7			LOCH HOURN, HIGHLAND
2021	21	DEC	00:01	56.64N	6.13W	7	2.1			MULL, ARGYLL & BUTE
Felt Tobermory (Mull), Glenborrodale and Kilchoan (3 EMS).										
2021	23	DEC	06:04	62.27N	2.13E	10	2.7			NORWEGIAN SEA
2021	25	DEC	02:07	54.29N	0.45E	18	2.2			SOUTHERN NORTH SEA
2021	27	DEC	02:15	51.44N	1.03W	6	1.8			READING, BERKSHIRE
2021	29	DEC	18:25	7.55S	127.58E	162			7.3	BANDA SEA, INDONESIA
2022	01	JAN	05:05	53.97N	3.32W	3	1.6			IRISH SEA
2022	01	JAN	13:57	58.58N	4.79W	6	2.1			DURNESS, HIGHLAND
2022	04	JAN	08:04	57.00N	1.85E	14	2.4			CENTRAL NORTH SEA
2022	07	JAN	17:45	37.83N	101.29E	13			6.6	NORTHERN QINGHAI, CHINA
At least nine people were injured, over 4,800 homes were damaged and a small section of the Great Wall of China collapsed in Gansu and at least another 4,000 homes and 25 schools were damaged in Qinghai.										
2022	09	JAN	18:34	54.28N	0.11W	11	2.2			SOUTHERN NORTH SEA
2022	11	JAN	01:07	35.23N	31.94E	21			6.6	OFFSHORE CYPRUS
Three people killed, one injured and one building destroyed in Damietta, Egypt.										
2022	11	JAN	11:35	52.34N	167.76W	20			6.8	ALEUTIAN ISLANDS
2022	11	JAN	12:39	52.58N	168.33W	19			6.6	ALEUTIAN ISLANDS
2022	14	JAN	09:05	6.86S	105.29E	33			6.6	OFFSHORE JAVA, INDONESIA
2022	16	JAN	22:46	61.04N	3.83E	10	1.8			NORWEGIAN SEA
2022	17	JAN	11:40	34.93N	63.62E	11			5.3	AFGHANISTAN
At least 26 people killed, many others injured and hundreds of houses were damaged or destroyed in Quadis district, Badghis province. Heavy rains in the area prior to the earthquake reportedly rendered mud brick houses more vulnerable to damage.										
2022	19	JAN	12:33	61.33N	3.34E	10	2.0			NORWEGIAN SEA
2022	22	JAN	00:22	53.84N	0.45W	9	1.6			BEVERLEY, EAST YORKSHIRE
2022	29	JAN	02:46	29.56S	176.72E	8			6.5	KERMADEC ISLANDS
2022	31	JAN	14:37	56.98N	1.84E	15	3.6			CENTRAL NORTH SEA
2022	01	FEB	19:23	56.18N	4.79W	11	1.8			ARDGARTAN, ARGYLL & BUTE

Year	Day	Mon	Time UTC	Lat	Lon	Dep km	Magnitude ML	Mb	Mw	Location
2022	02	FEB	14:01	55.86N	5.43W	5	1.6			TARBERT, ARGYLL & BUTE
Felt Tarbert (2 EMS).										
2022	03	FEB	15:58	4.47S	76.93W	110			6.5	NORTHERN PERU
At least 80 houses and eight public buildings damaged in the Barranca area										
2022	16	FEB	20:21	23.77S	179.99E	535			6.8	SOUTH OF FIJI ISLANDS
2022	21	FEB	00:43	55.26N	5.10E	21	2.4			CENTRAL NORTH SEA
2022	21	FEB	22:59	52.54N	1.94W	8	2.8			WALSALL, WEST MIDLANDS
Felt Walsall, Wolverhampton, Birmingham, Dudley and surrounding areas, mainly from within approximately 20 km of the epicentre (5 EMS).										
2022	23	FEB	01:54	54.12N	1.80W	7	2.2			RAMSGILL, NORTH YORKSHIRE
2022	23	FEB	04:13	54.12N	1.80W	7	1.5			RAMSGILL, NORTH YORKSHIRE
2022	25	FEB	01:09	54.28N	2.36W	4	1.6			COWGILL, CUMBRIA
2022	25	FEB	23:35	51.33N	2.81W	10	1.5			SANDFORD, SOMERSET
2022	02	MAR	12:52	30.08S	177.73W	24			6.6	KERMADEC ISLANDS
2022	05	MAR	13:01	50.38N	4.75W	5	1.5			BODELVA, CORNWALL
2022	09	MAR	21:22	50.38N	4.74W	4	1.7			BODELVA, CORNWALL
Felt Garker and Luxulyan (3 EMS).										
2022	13	MAR	21:09	0.63S	98.63E	28			6.7	SUMATRA, INDONESIA
2022	16	MAR	14:36	37.71N	141.58E	41			7.3	OFFSHORE HONSHU, JAPAN
Three people killed, 225 others injured and over 350 buildings and a bridge damaged across eleven prefectures. A tsunami was generated with maximum recorded wave heights of 30 cm at Ishinomaki, 20 cm at Sendai and Soma, 12 cm at Ofunato and 10 cm at Ayukawahama.										
2022	21	MAR	05:32	61.57N	2.28E	10	5.2			NORWEGIAN SEA
Felt Norway, Shetland Islands and NE Scotland (Aberdeen, Ellon, Stonehaven, Helmsdale, Inverurie, Lairg, Huntly, Banff and Fraserburgh) (4 EMS).										
2022	21	MAR	08:06	61.55N	2.28E	10	2.5			NORWEGIAN SEA
2022	22	MAR	02:29	61.52N	2.29E	10	2.7			NORWEGIAN SEA
2022	22	MAR	06:08	61.54N	2.28E	10	2.5			NORWEGIAN SEA
2022	22	MAR	09:51	61.54N	2.29E	10	2.2			NORWEGIAN SEA
2022	22	MAR	16:35	10.75N	43.38W	10			6.7	NORTH ATLANTIC OCEAN
2022	22	MAR	17:41	23.38N	121.61E	24			6.7	TAIWAN
2022	24	MAR	04:59	55.44N	5.23W	8	1.5			ARRAN, NORTH AYRSHIRE
2022	25	MAR	04:56	58.39N	1.72E	10	3.4			CENTRAL NORTH SEA
2022	25	MAR	16:04	61.50N	2.34E	10	3.2			NORWEGIAN SEA
2022	30	MAR	20:56	22.67S	170.37E	10			6.9	LOYALTY ISLANDS REGION
2022	31	MAR	05:44	22.59S	170.37E	10			7.0	LOYALTY ISLANDS REGION
2022	17	APR	18:48	55.60N	9.59W	8	2.4			NORTH ATLANTIC OCEAN
2022	19	APR	03:03	57.77N	5.57W	8	1.7			POOLEWE, HIGHLAND
2022	19	APR	11:26	57.79N	5.51W	8	1.5			CLACHAN, ARGYLL & BUTE
2022	21	APR	00:53	53.58N	2.44E	10	2.6			SOUTHERN NORTH SEA
2022	21	APR	07:42	11.55N	86.96W	27			6.6	OFFSHORE NICARAGUA
2022	22	APR	21:07	43.07N	18.18E	10			5.7	BOSNIA & HERZEGOVINA
One person killed, many others injured and some 300 homes damaged in Stolac.										

			Time			Dep	Magnitude			
Year	Day	Mon	UTC	Lat	Lon	km	ML	Mb	Mw	Location
2022	24	APR	09:48	56.50N	4.22W	3	1.9			KILTYRIE, PERTH & KINROSS
Felt Milton Morenish and Ben Lawers (3 EMS).										
2022	06	MAY	10:31	52.48N	0.59W	6	2.3			CORBY, NORTHAMPTONSHIRE
Felt Corby, Oundle and in a few other villages in Northamptonshire, mainly from within around 10 km of the epicentre (3 EMS).										
2022	08	MAY	12:12	57.13N	5.62W	4	1.6			LOCH HOURN, HIGHLAND
2022	10	MAY	00:40	52.48N	0.58W	7	2.1			CORBY, NORTHAMPTONSHIRE
Felt Oundle and Brigstock (3 EMS).										
2022	10	MAY	23:06	23.50S	66.65W	220			6.8	ARGENTINA
2022	12	MAY	03:57	53.12N	0.04W	14	2.2			MAREHAM-LE-FEN, LINCS
2022	19	MAY	10:13	54.13S	159.06E	10			6.9	MACQUARIE ISLAND REGION
2022	21	MAY	07:47	56.39N	5.47W	9	1.8			OBAN, ARGYLL & BUTE
Felt Oban, North Connel, Glencruitten, Baracaldine and Lismore (3 EMS).										
2022	25	MAY	10:26	58.82N	1.44E	14	3.0			CENTRAL NORTH SEA
2022	26	MAY	04:50	53.69N	1.31E	10	2.1			SOUTHERN NORTH SEA
2022	26	MAY	12:02	13.70S	71.11W	236			7.2	SOUTHERN PERU
2022	26	MAY	15:28	57.77N	5.62W	8	1.6			POOLEWE, HIGHLAND
Felt Poolewe (2 EMS).										
2022	26	MAY	15:37	22.83S	172.13E	15			6.6	LOYALTY ISLANDS REGION
2022	27	MAY	08:18	54.12N	1.80W	8	2.2			RAMSGILL, NORTH YORKSHIRE
2022	29	MAY	20:40	53.43N	2.35W	6	2.3			SALE, GREATER MANCHESTER
2022	30	MAY	07:59	55.48N	5.10W	8	2.1			ARRAN, NORTH AYRSHIRE
Felt Whiting Bay, Arran (2 EMS).										
2022	30	MAY	14:36	52.84N	2.65W	9	3.8			WEM, SHROPSHIRE
Felt Shropshire and surrounding areas, mainly from within around 50 km of the epicentre (5 EMS).										
2022	30	MAY	16:15	56.96N	1.79E	11	2.4			CENTRAL NORTH SEA
2022	01	JUN	01:51	53.88N	2.14W	16	2.7			COLNE, LANCASHIRE
Felt Colne, Skipton, Earby, Barnoldswick and surrounding towns and villages, mainly from within around 15 km of the epicentre (4 EMS).										
2022	01	JUN	09:00	30.40N	102.96E	12			5.8	SICHUAN, CHINA
Four people killed, 42 others injured and over 4,500 homes and five hydropower stations damaged in the Baoxing and Lushan regions										
2022	01	JUN	19:43	49.64N	1.93W	2	1.7			ENGLISH CHANNEL
2022	01	JUN	19:47	49.63N	1.93W	2	1.8			ENGLISH CHANNEL
2022	08	JUN	00:55	9.05S	71.18W	622			6.5	BRAZIL
2022	17	JUN	17:32	53.15N	0.83E	11	1.6			SOUTHERN NORTH SEA
2022	19	JUN	06:53	54.12N	1.81W	7	1.9			RAMSGILL, NORTH YORKSHIRE
2022	21	JUN	11:53	53.98N	3.07W	8	1.7			IRISH SEA
2022	21	JUN	15:56	59.14N	1.34E	6	2.7			NORTHERN NORTH SEA
2022	21	JUN	20:54	33.02N	69.46E	10			6.0	AFGHANISTAN
At least 1,162 people killed, over 3,000 others injured and around 10,000 homes destroyed or damaged. The majority of the casualties and damaged occurred in the provinces of Paktika and Khost.										
2022	23	JUN	20:00	52.58N	2.88W	12	1.6			WENTNOR, SHROPSHIRE
2022	24	JUN	14:49	49.00N	2.35W	4	1.9			ENGLISH CHANNEL

Forthcoming Events

Evening Lectures

SECED Young Members Annual General Meeting 2022

26 October 2022 (6:00 pm) at the Institution of Civil Engineers, London

Agenda

All SECED Young members are invited to attend the Annual General Meeting (AGM) of the group. Non-members and ordinary SECED Members are also welcome to attend, but will have no voting rights. The agenda for the meeting is as follows.

1. Apologies for absence
2. Minutes of the AGM 2021
3. Matters arising
4. Chair's annual report 2021-2022
5. Election to the YMSC
6. Any other business
7. Date of next meeting

The outcome of the SECED YMSC Elections will be announced at the AGM.

The event is open to all and is free to attend. You can also attend the meeting online. The link for online attendance is here.

The AGM is followed by the evening meeting, Insights from recent experimental and numerical research on steel frame buildings.

Insights from recent experimental and numerical research on steel frame buildings

Ahmed Elkady
26 October 2022 (6:30 pm) at the Institution of Civil Engineers, London

Synopsis

Achieving structural resilience relies on understanding the physical phenomena and structural mechanisms controlling the response of structural components and systems under different loading scenarios. This understanding is fundamental to the development of robust and efficient design guidelines and to the accurate prediction of structural behaviour. To that end, this talk will cover observations from recent coordinated experimental and numerical research on the behaviour of steel columns, rigid and semi-rigid composite connections and steel moment frame buildings. These observations are used to develop design recommendations, numerical modelling guidelines and computer tools aiming to improve structural ductility, reduce collapse risk and direct economic loses under extreme events.

About the speaker

Dr. Elkady earned both his MSc and Phd from McGill University, Canada. He then joined EPFL, Switzerland as a postdoctoral researcher in the Resilient Steel Structures Laboratory. Currently, he is a Lecturer in Structural Engineering at University of Southampton's National Infrastructure Laboratory in the UK. He specializes in steel and composite steel/concrete structures, performance-based earthquake engineering, and performance evaluation of structural components and systems through large-scale testing and advanced numerical modelling.

Further information

This event is organised by the SECED Young Members' Subcommittee and will be chaired by Tina Marinatou. The event will be preceded by the AGM for the Young Members of SECED (at 6pm). The event will 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 to 6pm. The event will also be broadcast online. To attend the presentation online, please register for the event here. The registration process will provide you with the link you need to join main event. For further information, please contact Tina Marinatou (seced.ymsc@gmail.com)

SECED

SECED, The Society for Earthquake and Civil Engineering Dynamics, is the UK national section of the International and European Associations for Earthquake Engineering and is an Associated Society of the Institution of Civil Engineers. 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.

For further information please contact the SECED Secretary at the Institution of Civil Engineers and visit SECED Website.

The Eighteenth Mallet-Milne Lecture

Alain Pecker

Interrelationship between Practice, Standardization and Innovation in Earthquake Engineering

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.

Synopsis

Any large civil engineering project has the peculiarity of being a prototype. While experience gained from previous works is undoubtedly useful and fundamental, each new project must take into account technical factors, such as the environmental conditions in a broad sense, but also specific non-technical factors which can have a profound impact on the design. The situation is even more critical in seismic areas because very few similar structures, if any, have suffered from earthquakes. Facing this situation the designer may feel helpless because, on the one hand, seismic (building or bridge) codes do not cover their problem and, on the other hand, precedents are unavailable and research has not yet progressed to a point where its results can be used. However, one should always keep in mind Louis Pasteur's address, "Often engineers are bound to solve problems although on those specific issues science is not achieved. Gentlemen, you must find practical solutions, even facing uncompleted science." This is clearly the place where innovation can come to the rescue of the designer. Innovation must not be confused with research: research is a long term process, often conducted by academics, while innovation comes from an outstanding idea promoted by one person, or a small group of persons, usually issued from practitioners. Nevertheless, practice, innovation and research do not belong to different worlds. Obviously, they are interrelated; they benefit from a close understanding and collaboration between the different communities, and they have important implications for the initial formation of engineers, continuing education, code development, etc… To be accepted by the scientific community, innovation must obey certain rules: scientific soundness, simplicity to be easily understood, due recognition of uncertainties, collaboration between concerned parties (owner, designer, checker, construction engineers) and should consider constraints related mainly to the available time frame for its development, safety of the built structure and, to a lesser extent, economy.

Based on a few examples encountered during Prof Pecker's professional career (Rion Antirion bridge, administrative building in Fort de France, Atlantic bridge in Panama), the lecture will attempt to highlight these different aspects and try to illustrate the domain of application and interrelationship between standardization, innovation and research.

About the speaker

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 an 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.

Further information

The 18th Mallet-Milne Lecture will take place in the Thomas Telford Theatre in the ICE Headquarters in Westminster, London, on 31st May 2023. Further information will be published here in due course.

Announcing the SECED 2023 Conference

Earthquake Engineering & Dynamics for a Sustainable Future
Cambridge 2023
SECED

14–15 September 2023 in Cambridge — Chair: Prof. Ahmed Elghazouli

Overview

The SECED 2023 Conference entitled *Earthquake Engineering and Dynamics for a Sustainable Future* will take place on 14–15 September 2023 at Churchill College in the University of Cambridge (UK), with the conference dinner held in the Georgian Gothic Hall of King's College.

The 2023 Conference follows in the footsteps of the hugely successful 2019 Conference, which was held in Greenwich. The 2023 conference will cover a wide range of topics in earthquake engineering and dynamics, including seismic hazard and engineering seismology; induced seismicity; geotechnical earthquake engineering; vibrations; blast and impact loading; seismic assessment and retrofit of engineered and non-engineered structures; innovations in seismic analysis and design; seismic design for nuclear facilities; risk and catastrophe modelling; earthquake reconnaissance; and social impacts and community recovery.

Keynote speakers

SECED are delighted to announce the attendance of the following keynote speakers:

- Prof. Sebastiano Foti, Politecnico di Torino, Italy
- Prof. Stavroula Kontoe, Imperial College London, UK
- Dr. Andrew Mair, Jacobs, UK
- Prof. Eduardo Miranda, Stanford University, US
- Prof. Ellen Rathje, Texas University, Austin, US
- Prof. Emily So, Cambridge University, UK
- Prof. Dimitrios Vamvatsikos, NTU of Athens, Greece
- Dr. Irmela Zentner, EDF R&D Lab Paris-Saclay, France

Key dates

Call for Abstracts	September 2022
Abstract Submission	30 November 2022
Paper Submission	March 2023

Registration

Registration for the conference is now open with attractive early bird rates. Please visit seced.org.uk/2023 for more information. The registration fees are listed in the following table. All prices include VAT. Early Bird rates apply until midnight 15th June, 2023 (BST).

Fee Type	Early Bird Fee	Standard Fee
Non-SECED Member	£550	£600
SECED Member	£475	£525
Students or Retired	£300	£350
Day Ticket	£300	£350
Students/Retired Day Ticket	£175	£200
Dinner Ticket	£90	£90

Georgian Gothic Hall of King's College Cambridge. © Mark Leonard, Churchill College