Sue Nelson
Hello, I'm Sue Nelson and thanks for joining me on 'Create the Future', a podcast brought to you by the Queen Elizabeth Prize for Engineering. Each year, there are an estimated several million earthquakes around our planet. Most of them go undetected, either because they're in remote areas or because they're so small, but there are around 17 major earthquakes annually that are magnitude 7 on the Richter scale and one that is magnitude 8. To give you an idea of that scale, when an 8.9 magnitude earthquake hit Japan in 2011, it actually altered the distribution of the Earth's mass and caused the earth to rotate slightly faster, shortening the day by 1.8 microseconds. My guest – Zigmund or 'Ziggy' Lubkowski – is a seismic expert at Arup and a Royal Academy of Engineering Visiting Professor in geotechnical earthquake engineering at University College London. Ziggy, welcome to Create the Future.

Ziggy Lubkowski
Thank you.

Sue Nelson
Let's start with what a seismic expert like yourself actually does.

Ziggy Lubkowski
I look at many different projects, from building projects through to bridges, power stations, and the like. And I'm looking at trying to prevent the effects of earthquakes on those projects, to minimize the impact, to ensure that key facilities remain operational so that society is more resilient to these events.

Sue Nelson
Sounds like you're somebody who protects the destruction of the planet.

Ziggy Lubkowski
Well I think that's probably going a little bit too far, but Mother Nature is not something that we can treat lightly. We've got to assume that these events occur, we have to understand where they can occur, how big they can be, and then we have a chance to actually design against them. Our knowledge and engineering skills are improving all the time to allow us to do that.

Sue Nelson
Have you ever actually experienced earthquake?

Ziggy Lubkowski
Though I live in the UK, yes I have – both here but also abroad. In Montenegro for example, on a project out there, and also out in California when I was part of a team investigating the after-effects of the Northridge earthquake in 1994.

Sue Nelson
How did it feel, what was it like?

Ziggy Lubkowski
Well this was one of the aftershocks following that earthquake. I was in a tall building at the time and it was very much a swaying feeling like you may get on a boat when it's in a storm. That lasted for 30 seconds, or something like that, and then calmed down.

Sue Nelson

So, for you actually, at least you've got an experience of what it's like – but it was nothing on the scale in terms of that one that, you know, actually altered the earth.

Ziggy Lubkowski
No I haven't been in a destructive event, and I haven't felt it from that perspective but I've very much seen the after-effects. For example, I was out in Indonesia, in Aceh following the Indian Ocean Tsunami in 2004 and was working in trying to help the reparations following that earthquake and tsunami which really devastated wide swathes of the region.

Sue Nelson
I've travelled round Indonesia, on the whole apart from maybe Java, a lot the buildings are very low and yet it still caused this huge devastation.

Ziggy Lubkowski
Yeah I mean, in the case of Aceh they had the earthquake and it was a major earthquake – magnitude 9.3, so a lot of buildings suffered damage. Some collapsed. The earthquake was some distance offshore, but then the big impact was the tsunami waves. When you walk along the coast along the north of Aceh province, there are areas where you can see the water levels were about ten meters above land so it just ripped the vegetation away. Any buildings within that region were just swept off their foundations, and you can see these villages and towns where the slate was wiped clean, literally. Some of the bigger buildings, some of the mosques survived because of the way they're constructed: they're on stilts, and the water blew out the walls but then flew through the building and they survived. Pretty much everything else was just wiped clean of the off the slate and that meant a lot of people suffered as a result.

Sue Nelson
Is there a sort of scale in terms of, a bit like the Beaufort scale, is there a scale from an engineering point of view that you know that if an earthquake is going to be Richter 5 then you're likely to get some building damage, if it's 6 you definitely will – when do you as an engineer start to worry?

Ziggy Lubkowski
It's unfortunately not as simple as that because it's not just the size of the earthquake – it's where it's located and also what the vulnerability of the building stock is. So, in a country like the UK, buildings because they're not designed specifically for earthquakes, if there was an earthquake – and we do get them – and if it would hit a town, we would see quite a bit of damage. If you get that same earthquake hitting... let's say Los Angeles, you'd get very little damage because the buildings are built to resist those earthquakes, and are therefore more resilient. Likewise, you could get a magnitude 8 in the middle of a desert without any buildings, so you might feel it but nothing would be destroyed. It's that balance between the size of the earthquake, the resilience of the infrastructure, and where it's located.

Sue Nelson
I'd read that in traditional architecture, both in Japan and also the Incas, that their buildings were built to withstand earthquakes? You can tell me whether that's true or not, but I'd like to know what you consider to be, from an engineering point of view, a good building to withstand an earthquake. Is it purely about foundations or flexibility or composition?

Ziggy Lubkowski
Okay, answering the first question in terms of older buildings – in Japan, some of the pagodas were designed so each story – let's say, on a five or six story pagoda – slid on the roof of the previous story and had a large

tree trunk running through the top to limit the amount of sliding. That created quite a flexible structure that, in itself, was more resilient. The Incas, the Egyptians with the pyramids, they built massive structures – the ziggurats in South America, and they were constructed in such a way that they would be resilient to earthquakes. What we see is what remained from that era, what you don't see are all the small buildings that people lived in.

Sue Nelson
Which probably got destroyed.

Ziggy Lubkowski
And likewise, historically, people learnt about how, when something survived an earthquake, they built like the thing that survived. That created a sort of a memory of what works, but that didn't stop things being built which didn't survive.

Sue Nelson
No, you're right, the practicalities of the pyramids for instance is not a place to live anyway.

Ziggy Lubkowski
No.

Sue Nelson
Unless you count the afterlife.

Ziggy Lubkowski
In terms of current design, what we've been trying to do is ensure buildings are as flexible as possible. If you think about the difference between something like a large oak tree and bamboo shoots – bamboo in wind moves quite a lot. The wind goes, it's back standing upright. A large oak tree will sway in a large wind, but at a certain point it will crack and fall over. We want to ensure buildings are flexible, so they sway in the earthquake but, when the earthquake stops, they come back to where they were. Now we do that in a number of different ways, we can design reinforced concrete to be flexible, we can use steel to do that, we can use timber, and it's all dependent on the detailing that we apply to the steel or the concrete elements that achieves that.
Where we're moving to in the future, and people are doing it already, is using anti-seismic devices. Your car has shock absorbers, but imagine driving it without shock absorbers – it'd be very painful. So, we put buildings on building-sized shock absorbers to take the energy out of the earthquake and allow the building to survive. There are very different techniques [to achieve this]. There are things called friction pendulum bearings that allow the building to sway, there are unbonded braces that allow certain elements of the building to be damaged in the earthquake and then replaced. There are many different systems that allow that more resilient building type to be created.

Sue Nelson
This is perfect your background because you studied civil engineering to begin with before you did your masters in earthquake engineering, but even as a child you were into building things?

Ziggy Lubkowski
Yeah, I loved helping both my father in terms of DIY and a local tradesmen who was doing stuff in the local community. I was always there as the builder's mate carrying bricks around and helping mix the concrete and so forth. I liked getting my hands dirty and I still do, much to my wife's annoyance when I don't get things done as soon as I promise I will.

Sue Nelson
That's perfectionism isn't it. Were any family members within the profession?

Ziggy Lubkowski
My father was an electrical engineer and a number of my parents' friends were civil engineers, so engineering was always part and parcel of what I grew up with. My first cousin also went into civil engineering then he gave that up and went into finance to make more money.

Sue Nelson
Traitor. So what made you make that move them from civil engineering to earthquake engineering?

Ziggy Lubkowski
Well I was always interested in the physical planet, so actually I did geography as one of my A Levels, unlike the normal 'maths, physics, chemistry', I did maths, physics, and geography. I was always interested in physical geography and then I was very much taken by my soil mechanics lecturer at Kingston Polytechnic, Dr Edward Bromhead, who was very much into slopes and suchlike. I did my dissertation on his ring shear apparatus, so that really got me very much interested in that and then I was very fortunate in my first job with Building Design Partnership. I worked on the Folkestone terminal of the Channel Tunnel and designed a number of the structures around that, including the earthworks which we had to design for earthquake loading. The Channel Tunnel itself was designed for earthquake loading because there were two UK-major magnitude 5 events in the English Channel in the 14th and 16th centuries and, as a consequence, I needed to design the Channel Tunnel for earthquakes. Then I did some work on the earthworks at the Folkesonte terminal and that was really what got me into my first bit of earthquake engineering.

Sue Nelson
That's a good combination isn't it because obviously when you see a geological map of the UK, it's quite interesting in terms of the differences in structure around the UK is there any particular type of soil where you just think, or rock and soil and structure or part of the UK where you think: "no, that is not a good place"? Is the channel tunnel particularly resilient in any way or did it just need help?

Ziggy Lubkowski
I think there are places in the world which are more at risk from earthquakes because of the geology. The UK I wouldn't say it's one of those. For example, Mexico City – that's built, for a historical socio-economic reason, on an old lake bed. It's about 40 metres deep, full of very soft materials. What was observed in the large earthquake in 1985 was an amplification of the earthquake that was actually on the Pacific coast of Mexico about 180 kilometres away from Mexico City. It was an amplification of motions between a natural period of about one and two seconds, equivalent to buildings with 10 to 20 storeys and, just like the residents on the Tacoma Nana Narrows Bridge with the wind, there was a resonance in 10 to 20 storey buildings in Mexico City as a result of that earthquake and pretty much all of them collapsed. Small shacks stayed quite happy and weren't affected by that earthquake, but those 10 to 20 storey buildings were really badly affected. That changed the way we actually addressed the impact of soft soils on earth motions in the codes.

Sue Nelson
Now we sort of briefly touched on the after-effects of earthquakes that can be equally problematic such as a tsunami. The most sort of 'well-known' recent one was the one with in Japan with Fukushima. Were you involved in that in terms of studying it?

Ziggy Lubkowski
I've read around the subject because it's always important to keep learning more about these events. I also work on nuclear power stations, so Fukushima is a great case study as to what went right and what went wrong. In the case of Fukushima, the earthquake occurred, and the actual plant survived the earthquake very well. The motions were greater than it had been designed for yet it performed adequately – it shut down and was going through that shutdown process. Unfortunately then the tsunami wave hit. The tsunami wave was much bigger than the local academics had predicted and it inundated the plant. The plant was still was performing well, but the water got into the diesel tanks and diesel generators were being used as part of the shutdown process. That power was then cut to the plant and it was the water getting into the diesel tanks that was actually the cause of the problem. So, in a way, it wasn't an engineering problem – it was a problem with getting the assessment of how big the tsunami was or could be. It was getting that wrong.

Sue Nelson
You work with, as you say, nuclear companies and the future for the UK's is likely to involve new nuclear power stations. As an engineer, can you use things like flexible concrete on a nuclear power station? Because obviously you've got to worry about radiation and things like that. How do you approach a nuclear power station?

Ziggy Lubkowski
There are very specific guidelines which are laid down in the Office for Nuclear Regulation in the UK. These guidelines set limits as to how much radioactive release you can have per annum as a result of external events – those include earthquakes, aircraft impact, and so forth. As you quite rightly say, we don't want to have large radioactive releases. So, actually you stay away from designing things flexibly, you design things to remain elastic. You really want the concrete in the principal reactor vessel not to crack, not to release radioactivity, and that requires very good quality of design and construction to achieve.

Sue Nelson
You do a lot of work for Arup in the UK, Middle East and Africa. Do the threats, the earthquake threats, there's obviously fault lines we know that, but how are the threats for the Middle East slightly different to parts of Africa for instance?

Ziggy Lubkowski
When we look at any site we think about how big the earthquakes can be and the first thing we look at is the tectonics and the geology. If we're looking at Africa, for example, you actually have a situation where you've got the East African Rift Valley which is trying to rip Africa apart. The eastern part of Africa – Kenya, Tanzania, Mozambique – is actually moving towards the east, towards the Indian Ocean. The western side of Africa is remaining where it is. That split along the Rift Valley is a source of earthquakes, so we know if we've got a site in the near vicinity of that, the earthquake levels that we have to design for are greater. Likewise, in the Middle East you have the Red Sea spreading which is associated with the East African Rift Valley and you also have a major fault running down through Israel and Jordan and in the Gulf of Aqaba (which is causing that to spread). The key thing is having an understanding of where your site is, relative to these major tectonic structures. Once you understand that, you can try to assess the level of earthquakes that you have to design for.

Sue Nelson
As a job though this must be really interesting because you've got something slightly different each time and you've got to apply your knowledge and technical skill in a slightly different way, is that right?

Ziggy Lubkowski

I think you've got to keep your eyes open. A lot of people you know will pick up a code of practice for a particular country and just follow it like a cookbook. For my mind, that doesn't lead to good engineering. Good engineering is about understanding how the forces that mother nature provides affect your structure. I look at it from an earthquake perspective, but I also work with colleagues who look at it from terms of flooding or winds, or other natural impacts. You actually have to provide a holistic approach to how you ensure that those buildings or bridges or power stations remain resilient.

Sue Nelson
What would you say has been the most important lesson you've learned in your career so far?

Ziggy Lubkowski
That's a big question. I would go back to what I observed in Indonesia following the Indian Ocean tsunami. You cannot design against Mother Nature. You have to understand the threats and you then have to accommodate your design within those threats. I get frustrated by projects such as the Palm (Islands) in the Middle East where they now have a dredger that's constantly moving sand from one side of the palm to the other. The longshore drift that causes the shape of the coast there is causing erosion on one side and secretion on the other side, so you need to put a dredger in to constantly move the sand. That's not a sensible sustainable piece of engineering. We often get caught up "oh that looks fantastic", rather than thinking about how it impacts our environment. I think we've got to balance clever and good engineering with the forces that are naturally there and work together for a solution.

Sue Nelson
It's interesting that you did geography as an A Level, in a way it sounds perfect for this type of engineering. Would you recommend that to people considering a career in engineering if they you know they do love a subject that might not be your three or four sciences and maths.

Ziggy Lubkowski
I mean I did it by chance. I think the most important thing is people do what really interests them and then see where that takes them. So, if you are interested in earthquakes and you are interested in engineering, then geography does fit better than, say, chemistry.

Sue Nelson
It's also sort of geotechnical engineering with climate change as well.

Ziggy Lubkowski
Oh very much so, that's where we're all looking at the moment and ensuring that we minimize the impacts of climate change in all that we do. I think for me, don't specialize too quickly. And actually, I'm not a great fan of the module system at university. I think everybody needs a good grounding in all the subjects. Only once they've got that grounding in all the subjects is where you can start to specialize. But that's my personal preference.

Sue Nelson
I know that there are certain projects that you're unable to speak about because of client confidentiality, but you are working on a power station at the moment that you can talk about.

Ziggy Lubkowski
Yeah, well we've just finished work on the Wylfa Newydd nuclear power station. We've been assessing the size of earthquake that we have to design for, the potential for tsunami inundating the site, and also the potential

for any of the faults that exist under the fault location of being what's known as 'capable' (that means that they could move in an earthquake and cause a rupture at the surface). So we've gone into a lot of very detailed analysis, together with a lot of other companies and academics, to assess all those issues to ensure that the site is very safe and appropriate to design the nuclear power station. We've actually, very much supported by our clients at Horizon, we've shared all our experiences on that project through presentations at the Institution of Civil Engineers, papers that we've written at conferences, and also other journal papers. We've really been given a very much a 'green light' to share our experiences and hopefully help other similar projects in the UK and elsewhere.

Sue Nelson
That leads nicely onto the fact that you became the Royal Academy of Engineering Visiting Professor in geotechnical earthquake engineering at UCL in 2018. Are you enjoying that? The sharing of knowledge?

Ziggy Lubkowski
Oh very much so and I think it's one of those things that you really need to do as a senior engineer because we need to encourage the next generation to carry on doing the work that we're doing. I don't particularly want to encourage people to do earthquake engineering, though that's what I'm teaching, I want to encourage people to do civil engineering as a totality. Whether they get into fluid dynamics or earthquake engineering or any other subject – I really don't mind, but we need more and more engineers and I get the feeling that people are moving to those areas which are maybe where they will earn more money, rather than actually give back more to society. I think that we as engineers have a great opportunity to give back lots to society.

Sue Nelson
Ziggy Lubkowski thank you very much for joining me on Create the Future, do you join me next month for another insight into the world of engineering in our Create the Future podcast.