Sue Nelson
Hello, I'm Sue Nelson and thanks for joining me on the 'Create the Future' podcast brought to you by the Queen Elizabeth Prize for Engineering. London's skyline has continually changed over the centuries, and my guest is a structural engineer who has worked on one of the capital's most recent and distinctive additions: the Shard. Roma Agrawal is a former Young Structural Engineer of the Year, made the Telegraph's top 50 women engineers in the UK list, and is probably one of the few engineers who's been photographed by Annie Leibowitz. An associate director and framework manager at Aecom, Roma is also the author of the award-winning book 'Built: The Hidden Stories Behind Our Structures'. Okay, let's start with the Shard, that wonderfully elongated pyramid structure that is currently the tallest building in Western Europe, which parts did you work on?

Roma Agrawal
I actually spent about six years of my career working on the design of the Shard as part of a larger team of structural engineers and other engineers. And I spent the first couple of years actually working on what we describe as the enabling works. Before you can even build a structure, especially in a city like central London, you have to think about what all the other structures are that are around that site. So, we had Victorian brick arches, we had some tube tunnels running adjacent to the site, and we had like a 1960s block, we had a bus station, there was all sorts of stuff. And we had to kind of cut and carve all these historical structures before we could actually even build the new tower. So that's a bit like forensic engineering, I guess in some ways, because I was looking at these drawings, even from the 1800s, trying to understand how these historical structures worked before we even made any changes to them. So that was super interesting, but not something that really gets talked about.

Sue Nelson
Was it like being an archaeologist as well, in a way?

Roma Agrawal
So literally archaeologists got involved as well, at some point, usually in London, they want to have a look at the records and what the likelihood of, you know, Roman ruins or something being there, it is a little bit. You're looking at little microfiche, so they're like little bits of film that are about an inch wide, where, you know, librarians and archivists have recorded these old drawings from over 100 years ago. And you kind of look at them and try and understand how these structures would have been built. And you also have to do tests on the materials to make a judgement of how strong those materials are. So, I think that's a really interesting part of, particularly the engineering of something like the Shard, where there's a lot of background work that happens before the kind of the shiny steel tower even goes up. But then I was involved in the shiny steel tower as well. So, I helped with the design of the foundations. And I helped with the design of the very top, you know, the tip of the tower, which is where the viewing gallery is, that we call the spire.

Sue Nelson
That's quite lucky in a way, isn't it? Because you were involved in a way that often with engineers is the hidden part, the bits that people don't see and take for granted, the foundations, but actually, you not only got that, but you got the sort of bling at the top, the thing that's most recognisable as well.

Roma Agrawal
Yeah, I mean, because I had been on the project for so long, I started off as one of the most junior engineers on the project. And I'd always throughout that whole process wanted to be involved in the design of the spire. So, I used to just keep nudging my boss and reminding my boss every few months like "yeah, you know, when we start the spire I'd really like to be involved" and I think that's one of the lessons I learned, you know, when you

start working is that if there is something that you want to do in your career, if there is a particular material you want to be involved in designing, or particular part of a tower, or whatever that might be, it's really important to kind of advocate for yourself and ask for what you want and you never know you might get it.

Sue Nelson
Absolutely, in fact my grandmother always used to say, or my Nana, “if you don't ask you don't get”.

Roma Agrawal
Yep, that's very good advice.

Sue Nelson
You can't just sit there thinking “I'd really like to do this, please choose me” because if you don't say it, people don't know. That's really good advice. How did you actually do the work particularly on the spire, did you have to go up however many stories it is and be at that peak?

Roma Agrawal
So, for somebody that scared of heights that will very quickly cure you, make you or break you, I guess. We do so much work before anything is actually even made. I spent months looking at the forces, so we worked with wind tunnel engineers, so that we could study what the effects of the different wind forces were on this tower.

Sue Nelson
That's right, because some, some buildings do sway?

Roma Agrawal
All buildings sway.

Sue Nelson
Oh, all of them? I didn’t realise that.

Roma Agrawal
All buildings sway because there is going to be natural movement. And the trick for us as engineers is to make sure that that movement isn't too much, and that it isn't perceivable. Those are the two things that we're really aiming for. So, we do wind tunnel testing, especially for towers of the height of the Shard, and to understand what the forces are and how they interact with the materials that we put in. So that was a big part that we worked on. And then the other thing is, you know, yes, we would love for our towers just to appear in place and just be there. But, of course, it's a staged construction sequence. So, we have to think about the logistics, you know, how are we going to actually bring pieces of steel to the site in the middle of Central London? How are we going to get it up to that height, two to 300 metres up in the air? That's the highest anyone's ever built in the UK. How are we going to do that safely? And then how are we going to actually connect all these different bits of steel together to make sure that it can be done quickly and safely as possible? So, in that, the structural engineers, and me, we worked with the steel manufacturers, you know, the people that were actually pouring the steel sections together. And we also worked with the contractors that were coming up with the crane logistics, you know, how heavy were the pieces of steel that needed to be lifted by the crane? Where could the crane sit? So, it is absolutely fascinating to get involved in something like that.

Sue Nelson
And it sounds as if you worked with a huge array of different people who are experts in their particular field?

Roma Agrawal
Yes. And I think that's one thing about engineering that I didn't fully appreciate when I was studying it at university, was exactly how collaborative it had to be, and especially between different disciplines as you mentioned. So, at university at least, you know, kind of 15 years ago when I was doing the course, and things have changed, I was just doing projects with other structural engineers. But nowadays, a lot of universities are doing group projects that are cross discipline. So, you have structural engineers, mechanical engineers, public health engineers, and architects even, coming together to do these projects. Because what you quickly realise is that you can have all the technical skills in the world. But if you can't explain those complex principles to somebody who's not a structural engineer, in a way that's accessible and understandable to them, then it you know, it makes for a much harder project.

Sue Nelson
You mentioned building materials, how have building materials changed over the centuries?

Roma Agrawal
In some ways, they haven't changed at all. And I always find it really interesting that you know, the brick, which in its most rudimentary form is a 10,000-year-old technology, is something that we still use today. And steel has been around for a long time. I would say steel manufacture to the mass manufacture to the extent that we use it today really happened during the Industrial Revolution, so, more than 100 years ago. And concrete, of course, has been around for thousands of years, the Romans had an amazing recipe that they used more than 2000 years ago. So, in those senses, the base materials that we use haven't actually changed. I think what's changed is the process and the industrialization and the scale at which we can manufacture these things. And perhaps, to some extent, our understanding of how these materials work.

Sue Nelson
I mentioned in the introduction that you know, that describing the building, for those of you who have not seen it, this elongated sort of stretch tall pyramid. Did it feel like you were making the modern-day equivalent of the pyramids at the time?

Roma Agrawal
They are so incredibly different. So, absolutely, I agree with you that the shape could be described as an elongated pyramid, but the way that they work are actually complete different. So, there are two main forms of frames, I guess, that you can give a building. So, that's how a building takes gravity and how it distributes the forces of gravity through its own body and down to the foundations. What the pyramids did was basically to stack up a huge amount of material so that the weight of the material just goes straight down. Whereas the Shard was more like a frame or a skeleton. So, if you think about our human bodies, when we stand up, our weight is being channelled through all our different bones and it's getting split at our hips, and then it's going down our two legs. And the way the shard works with its steel and concrete columns is much more similar to this kind of skeletal system compared to this pure gravity system that the pyramids used.

Sue Nelson
That's really interesting. How would you define a successful building?

Roma Agrawal
For me, from the point of view of a structural engineer, a successful building is one that has the minimal amount of material that's required. So, it's very easy to shove a lot of material into building to make it safe. And then we know that it will work and that it will stand up, it'll be stable, it'll be safe. But the sophistication and the skill of a structural engineer is in minimising the amount of material, which reduces the weight, which gives a

lot more flexibility in the spaces that we're creating so that we don't have these big chunky bits of structure, interfering with big open plan offices, for example. And of course, it makes it a lot more eco-friendly and sustainable to reduce the amount of material we're using. So that's my first definition of a successful building. And then of course, what happens later on is that human beings start interacting with the structures you've created. And then for me, you know, when I see people, for example, taking photographs in front of the Shard or standing on the footbridge that are worked on in my career. Just seeing people enjoying the structure and being happy in it and being productive in it is of course a huge mark of success.

Sue Nelson
That's right, because there's a lot of emotion attached to people's either love or dislike of certain structures. It's funny the way they can really divide people.

Roma Agrawal
They can. And I think we forget, you know, what percentage of our day we spend interacting with structures, because we're at home, or we're at work, we're in a school, you know, we could be anywhere. And for a large proportion of our day, we are inside a structure, you know, especially now in today's kind of, situation where a lot of us are spending a lot of time at home. We're suddenly noticing our home in different ways, I think. So I was talking to somebody the other day that "Oh, we're clearing out our cupboards we're looking at our bookshelves and thinking about what we actually want on there", but I think it, it kind of defines that relationship a bit more strongly when you when you realise that, "Oh, I'm going to be in this area, this space for a really long time, what are the things about it that I haven't noticed before?" And I think that's a really huge motivation for me in my other work, which is trying to promote engineering, and to just make people a bit more conscious and excited by the structures around them.

Sue Nelson
Well one of the things that you did in order to, you know, promote engineering was write your book, 'Built', which was hugely successful. And you also went into sort of engineering failures there, as well. I thought that was really interesting, particularly in terms of what led to the collapse of the World Trade Centre, the two towers. For people who have not yet read your book, how would you sum up what those building failures were?

Roma Agrawal
I think building failures occur for a few different types of reasons. And unfortunately, a lot of that is human error. Because at the end of the day, you know, people make mistakes. And sometimes we're pushing boundaries, we're trying things that we haven't tried before. And sometimes they don't work. Sometimes those failures can be, you know, not life threatening. So, for example, the wobbly bridge, the Millennium Bridge in London, which was swaying a lot when it first opened. Or it can be quite catastrophic and, and really tragic in the sense of the World Trade Centres. Sometimes things change, so the World Trade centres were built more than 50 years ago, about 70 years ago, perhaps. And it had actually been designed for a plane impact but the size of the planes that they actually designed that impact for was smaller than the size of the plane that actually hit it in the end in 2001.

Sue Nelson
They were of their time effectively.

Roma Agrawal
Exactly. So, you know, we also need to think about the longevity of our buildings. So, if our buildings are going to be there for 70 years, 100 years, then trying to anticipate the changes that can happen. And then one more area that failure sometimes happen in is during construction. So, where I was talking about before that

construction is a staged process, the building could be absolutely safe in its final configuration, but while you're building it, the way the forces are interacting with your structure are different. So it is down to the engineers and the contractors who are building it to deeply think about what those stages are, what the forces are, and how that might affect that same beam or column in a very different way, in that temporary stage compared to the final stage and making sure it's strong enough.

Sue Nelson
Now you did a degree in physics and a master's in engineering, what produced that change, change of gear? Because obviously there's a big overlap with the maths.

Roma Agrawal
There is. So, I didn't know what I wanted to do with my life and career when I was 16-17 years old applying for university. I loved maths and physics, so decided to pursue that university and quite rightly felt that with a physics degree, I could do quite a big range of different careers once I graduated. I was then working a summer job to earn some money for about three months and I had a particularly boring project that I had to do, which was to go and record where all the fire safety equipment, important but boring job, was in the physics department at Oxford. And so, I was doing this job but luckily, I was surrounded by engineers. And every so often, they would sort of throw me a little titbit and say, “Oh, you know, I need to design this whole different lens, which is going to get cooled down to minus 70 degrees” or “here's this little piece of equipment that we need to design a vibration stand for so that we can transport it easily”. And I suddenly just thought, this is so incredibly interesting. These people are using maths and physics to solve every day real problems. So that was, I guess, the lightbulb moment for me where I saw I could use my physics and math skills to, you know, make stuff.

Sue Nelson
Yeah. And were you one of those kids that like a lot of engineers completely into LEGO buildings?

Roma Agrawal
Yes, I loved LEGO. We also had this amazing crane set, which, you know, so we used to build cranes nearly every weekend, or towers or, I think that kind of that curiosity in making stuff is innate in so many children, if not, you know, all children. And I was lucky to kind of rediscover that later on.

Sue Nelson
I have noticed that bit like in the medical profession, quite a lot of engineers have got engineers and the family. Do you have engineers and the family?

Roma Agrawal
My dad is an engineer. He's an electrical engineer. And the thing is that he stopped working as an electrical engineer when I was very young and had to take over our family business in India due to a kind of family situation. So, in some senses, I wasn't exposed to what an everyday career in engineering would look like. And my mum did maths and science at university and was a computer programmer. So, I think what happened with my parents is that, you know, that STEM background kind of filtered through to me and my sister and resulted in them encouraging us to play with blocks at the weekend and so on. So, while I wasn't necessarily exposed to what the day to day working life of an engineer might be like, I think that impacted the way you think, and so on, and did really filter through.

Sue Nelson

Now you mentioned India there, and you've had quite an interesting background in terms of where you've lived. London, where you are now, New York, and Mumbai. How did that sort of spread of locations affect your attitude or maybe your approach to your work?

Roma Agrawal
That's a really interesting question. So, I was in the US when I was really quite young. But I do have these quite vivid memories of wandering around the streets of New York, which, you know, I used to live in a really small town in northern New York State. So, it was a huge contrast. And then going to Bombay was a huge contrast again. So, we went from living in this kind of large wooden house in the countryside, to living in a seven-storey concrete tower. Then I moved to London and I lived in a house with an aunt and uncle for a few years, went to university and then that was all different again. So, I think in some ways, I've just lived in very, very contrasting places. I think probably one of the biggest influences would have been living in Bombay because, I think over there, it was very obvious what the benefits of engineering were. So, it's a developing city. There were new roads being constructed all the time. And you could see that traffic would ease in a particular area, and then they would build a bridge and then that would help again and we used to experience power cuts and cuts to our water. So, I think we understood that, you know, these fundamental pieces of infrastructure are so important and what the effect is when they don't work very well. So, I think engineering is a lot more in people's consciousness.

Sue Nelson
It's given the respect it deserves effectively, that people really do rate engineers very highly.

Roma Agrawal
I completely agree. And I think, I always had this vague understanding that engineering as a profession exists. I didn't understand the day to day workings of it. But I understood that it made a difference to people and to society and so on. So, I did find it quite strange when I came to the UK and people just had no idea what it is that engineers do. And it used to be that right? We had the golden age of engineering in the industrial era, but in some way that has, I guess, faded into the background in the UK. So I think having that really international background has meant that engineering and the effect it has on society is quite, you know, it's very present in my thinking.

Sue Nelson
Is the attitude towards women engineers as high in India as it is for the engineering profession as a whole?

Roma Agrawal
Yes, in some ways it's a complicated question to answer. So, there are a lot of young women that aspire to be engineers. So that's brilliant. I think there are some other different societal challenges that women face in India that could prevent them from going into the workforce. But again, things are sort of progressing and changing. But I do feel that, you know, a lot of young women aspire to be engineers, and that's often software related, computing related, but it's definitely something that young women think about. So, in some ways, I found the gender divide different. There is a still a gender divide in India, but it's different in the UK, where I was sort of surprised to see that young girls are often just told that this is not for them, or they think that it's not for them. That's a very different issue than I saw in India.

Sue Nelson
Do you think the UK could learn from India in this respect in terms of their SciComm effectively? It should be EngComm shouldn't it?

Roma Agrawal
I would say, Asia in general. So, looking to South Korea, to Taiwan, even to Malaysia, Singapore, you know, countries like that seem to do really well with female representation in engineering compared to the west. But even if we look closer to home, Eastern Europe has a lot more women engineers than the UK does. The UK is actually the lowest in the whole of Europe.

Sue Nelson
It's astonishing really, isn't it? Every time I hear that, I can't quite believe it.

Roma Agrawal
And I do think it really comes down to how respected engineering is as a profession in society.

Sue Nelson
So, if it's given more kudos more respect, a higher profile, then everyone will see it as something worth going for.

Roma Agrawal
Exactly, and I think another thing that's a bit different between, you know, the US and the UK compared to the eastern countries that I've mentioned, is the emphasis on mathematical education and scientific education. We're sort of told that, oh, if you want to get a high paying secure, good job, then study science, study maths, you know, these are the subjects you should be studying. And that's often to the detriment of English and history. And in the West, you know, the UK and the US, it seems to be quite different, where people aspire more to be lawyers or to study English. And so again, there's this kind of cultural divide in what the aspirations are. So, you know, I think students in the UK should be studying maths, and, you know, at least one science for longer than we currently are.

Sue Nelson
You do an awful lot of SciComm. You were awarded the Rooke award for promotion of engineering, public promotion of engineering by the Royal Academy of Engineering. You've talked to schools, you've done TED Talks, and I even saw that a school in Birmingham named a building after you? I mean that's, what an honour!

Roma Agrawal
I know that one really did make me cry because they got the students to actually vote for which role model, they wanted to name their building after. So, the headmistress selected a few different people and that they had to go and do research about all of us. And they picked me and that was just so lovely.

Sue Nelson
It is lovely, isn't it?

Roma Agrawal
It's so lovely. And I think what was particularly touching for me was that, that school, it's an academy. It's got a lot of low-income students there in the middle of Birmingham. And the vast majority of the students there are from BAME backgrounds as well. So, it felt particularly really lovely to me that, you know, I could just be a face of something that they may not have thought about that was possible for them.

Sue Nelson
And you're also the face of a Marks and Spencer campaign?

Roma Agrawal
That's going back about five years now.

Sue Nelson
But I had quite an impact.

Roma Agrawal
It was one of those really odd experiences in my life I never thought I would have. I got this email about it and I just thought it was a hoax. You know, I didn't really take it very seriously. But it did happen. And the reason I decided to do it was because it was a campaign called The Leading Ladies campaign. So, they had women from lots of different fields involved. And there were varying levels of famousness, I guess. There was me, who was this kind of structural engineer and then there was Emma Thompson, you know, so there was a huge range of how well known we were.

Sue Nelson
I saw a picture of you, standing there looking glorious in a dress and they're in the foreground with sort of Rita Ora.

Roma Agrawal
Yes, exactly. But I think the reason I was keen to do that was because, you know, again, I felt that if people saw my name and saw me and then saw my profession, which they said they would also talk about, so they said structural engineer. It might just make people think twice and say, “Oh, I didn't realise young women, young Indian women, wearing these glamorous dresses could be structural engineers”. So, you know, hopefully, I just made a few people think a bit more deeply about what structural engineers actually look like.

Sue Nelson
Now, I mentioned at the start that you are something called a framework manager for Aecom. I must confess, I have no idea what a framework manager is. I know you're on sabbatical at the moment, but before we discuss that, what is framework manager?

Roma Agrawal
Of course, I worked as quite, you know, a full structural engineer for most of my career, but for the last two years or so, I've been branching out a little bit and I think it's important talk about the fact that, you know, as an engineer, you can kind of go off into all different directions. So, what I now look at is the front end of the project. So, before I would get a project on my desk, and then I would start to make that project to reality. But before that even happens, a lot needs to be done. So, I now work with clients, you know, with people that want to build housing, that want to commission work to improve air quality in their local borough, for example, in London. And so, what I'm doing is, I understand and work with my whole company to think about all the different types of engineering services that we offer. I then look at clients who are generally local councils in London or local government in London, to see what their targets are. So, all local councils, they want to improve air quality, they want to build housing, they’ve got all these different things they're thinking about, and I try and match those two things together, and then actually start working on the contracts. And think about how we're going to deliver these things. So, once all of that's done and the contracts are signed, I now pass that project on to an engineer, which, you know, used to be me once upon a time. But now, you know, a team of engineers kind of takes it away. So, I find that front end of projects really quite fascinating, which is actually you know, what project is needed in the first place and how can we make that happen?

Sue Nelson

That's something that quite a few engineers go into isn't it is project manager. And it's usually as a result of having to deal with very big projects that help you understand exactly what's involved, how many areas involved, because after you worked on the Shard, you also worked on Crystal Palace station. I'm assuming because that has underground areas as well is that you've got to take loads of the surrounding infrastructure into account?

Roma Agrawal
Yeah, I think that's true for pretty much any type of project that you do in London and I think most of my projects apart from one, have been in London. So, it is it is really fascinating when you have to manage all these different interfaces. So, I worked on an apartment block, which had interfaces with Network Rail trains, and with the Docklands Light Railway trains, which are two separate companies if you're not familiar with London. And then it also had interfaces with private land and public land. And we, you know, we're trying to build apartments. So, you know, designing the steel and concrete in some ways is the easy part. But I had to work with all these different rail authorities and water authorities to ensure that they were happy that our project was safe for them. So that's how you slowly, kind of transition to this project management type of roles that you're talking about. And you also find out what your skills are and I, you know, I love talking to people as we've discovered, so when an engineer can effectively engage with clients and explain things to clients and to train operators and water operators about how the engineering is going to work, then that becomes a very valuable skill. And that's one that I've been trying to pursue for the last couple of years in my career.

Sue Nelson
So, what are you doing at the moment? You have a sabbatical? I know you've got a young child? Are you writing another book as well?

Roma Agrawal
My maternity leave officially finished just a few days ago. And then I did request that I get a sabbatical. So, I'm taking a year off. And I sadly can't quite tell you what I'm doing at the moment, but I'll leave it to your imagination. In general, the projects are around communication again. And I did work on a podcast as well. So, there's three episodes of a little mini-series I did called 'Building Stories' which is free to download, so you know, I'd love for listeners to have a listen to that as well.

Sue Nelson
Well, good luck with the rest of your career, I'm sure actually listening to you will make a lot of people interested in structural engineering.

Roma Agrawal
Thank you so much for having me.

Sue Nelson
Well, that's it for Create the Future. Thanks to my guest structural engineer Roma Agrawal. Do join me next month for another insight into the world of engineering in our Create the Future podcast.