CERAMIC TECH CHAT

Episode 63

Title – "Cement solutions for sustainable construction: Juan Pablo Gevaudan"

INTRO

McDonald: "I'm Lisa McDonald, and this is Ceramic Tech Chat.

> Many of us have fallen into the trap that working longer hours leads to more results. But prioritizing your physical and mental wellbeing through proper sleep schedules and taking small breaks throughout the day can give you the energy and focus necessary to make the truly big discoveries."

Gevaudan: "During my first year of graduate school, I at first wanted to do permeable concrete because permeable concrete is a fantastic way to replenish local watersheds and aquifers. My advisor asked me, 'Okay, great, how are you going to make that better?' And I spent weeks diving deep into the literature thinking about different ways that we could make it better. And one night, I must have been reading so much about different methods, but I remember like in my dream just thinking, 'Change the cement.' And I woke up thinking, 'Oh my god, I should change the cement.' And I had just been reading about alkali-activated materials, so I said, 'What if we do an alkali-activated cement permeable concrete?' And that's what really kicked off my Ph.D."

McDonald: "That's Juan Pablo Gevaudan, assistant professor of architectural engineering at The Pennsylvania State University. As head of the D/Carb Group at Penn State, JP works with students on developing solutions to reduce carbon emissions in the cement and concrete industry by taking a whole lifecycle approach to the challenge.

> In today's episode, JP will talk about how his childhood desire to protect the environment led to his eventual work in cement, describe some of the research taking place in the cement industry to reduce carbon emissions, and share how his identity as a Latino and Hispanic scientist plays a role in his approach to learning and teaching."
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> (music)

SECTION 1

Gevaudan: "I'm from Venezuela, and seeing beautiful nature around me as a kid, and I always wanted to do something to preserve it. And through all my life, I've been very fortunate to live in different places. I lived in Mexico, and one of the things that I started noticing is that there was this contrast, this juxtaposition between development—growing as a society, growing cities and so forth—and then the conflict with nature.

I remember vividly when I was going up to Monterrey in Mexico, I would go with my family, and we would do these picnics up in the Chipinque Park that overlooks the whole city of Monterrey. It's like a really beautiful park. But then something that really like blew my mind was that when I was in the city, I saw everything clear, right? Like there wasn't any smog that I would see because I was in it. But then when I was up in the mountains, in the Chipinque Park, I could see the smog. And that really blew my mind as a kid because I said, 'Wow, I was just down there and I had no idea that I was breathing in this contaminated air.' And I think that really started to make me think about this tension between development and preserving the natural environment around us.

So, it wasn't until later on that I started to think about what can I really do about changing this contrast, this juxtaposition between development and the natural world that we live in. So, I think with that idea, I really said, 'I want to be an environmental engineer,' because you have the environmental aspect and you have the engineering aspect of doing something for the environment.

And that pathway really started to shape around ceramics until my second research experience during undergraduate. I did my undergrad at UT Austin [The University of Texas at Austin] in civil engineering. So, I had the opportunity to really focus on environmental engineering, but turns out I was also really interested in buildings because we spend 90% of our lives in buildings. So, I remember walking into the cement chemistry lab of Maria Juenger, and I just remember being part of Dexter's Laboratory. It was a '90s cartoon, and I just felt like Dexter in the laboratory, and I was immediately just jazzed about the opportunity to use beakers and glassware and, you know, make new materials, make new sustainable cements, and study them and analyze them and get this material out.

And I think that, all of that, we have to preface with the fact that concrete is the most utilized material in the world. So, remember I wanted that impact, so this is a material that is number one used material in the world, and cement, which is just the glue that binds together your gravel and sand, cement itself accounts between 4 and 6% of CO_2 emissions globally. So, that did it for me. I was like, 'Oh my god. Not only is concrete the most utilized material in the world, cement, just one component of it, accounts for a large part of our global CO_2 emissions annually and is the material that we use to construct our cities. So, if we can make this material carbon negative or if we can make it better, even if it's just 1% better, it's going to have such a global impact into the environmental sustainability of our world.'"

McDonald: "Your passion really comes through with how you really found the solution to the question that you had. You want to make an impact, how can you do that, and cement and concrete really was the answer that you were seeking. So, once this piece of the puzzle really fell into place for you in undergrad, where did you go next?"

Gevaudan: "So, I graduated from UT Austin with my civil engineering, focus on environmental engineering. I also did a minor in architecture because, as I was saying earlier, I have this really big interest in seeing how we design buildings and how can we incorporate

materials into the design of buildings that can lead to regenerative functions of the local ecology. So, with that in mind, I went to the University of Colorado Boulder, where I did my master's and Ph.D. in architectural engineering. And I thought that architectural engineering was bringing in that architectural design aspect that I looked in my minor but also the material science aspects of how do we actually make concrete sustainable and how do we implement that into sustainable building design.

So, my whole Ph.D. was really on answering just one very specific issue with concrete sewers, where they were degrading at an alarming pace because we are, as we should, we're conserving water, which is fantastic. But as we implement water conservation measures across many cities in the U.S., that also exacerbates the biogenic sulfuric acid attack that happens within sewers, and particularly when we have concrete sewers, those degrade more rapidly. So, my whole Ph.D. was trying to not only create a more durable type of cement that we can use to create those concrete sewers but a cement that we can produce from clays, which are the most abundant material that we have across the whole world and also reduce the carbon footprint of that cement by 90%. So, it was really cool, we were able to get some really interesting results through a technology that we call alkali activation.

After my Ph.D., I did a Marie Curie fellowship in the U.K. at the University of Leeds with Susan Bernal, who is an expert in alkaline activation. So I brought in my understanding of alkali activation, and in that fellowship, I focused on the big, big problem of corrosion of embedded carbon steel reinforcement. So, way different problem, but what is beautiful about the science I think is that there is always this connection to a dissolution of precipitation reaction in cements, whether we're thinking about how they are forming in the early stages, but also in later stages, how they are degrading. There is a dissolution precipitation reaction, whether you're talking about acids in sewers or you're talking about electrochemical corrosion. Really, there is this aspect of the solution precipitation that I fell in love with.

So, yeah, so that's my whole story. And then after my fellowship, I was fortunate enough to come to join the architectural engineering department at Penn State, where I now lead the D/Carb Group, which is focused on how do we understand not only new types of sustainable cements and concrete technologies, but how do we actually move the needle forward in how we are manufacturing cements, and how do we do that in a way that we can actually valorize emissions. Instead of seeing emissions as something that is harmful, how can we see those emissions as valuable reagents that we can use in the production of more cements and more concrete materials."

(music)

SECTION 2

McDonald: "There really are just so many aspects to account for when approaching this problem of a material that is kind of all around us that we don't often think about every day."

Gevaudan: “Totally, yes.”

McDonald: “And I think that also brings us to a great point, is what would you summarize as kind of the main challenges overall among all these different aspects that we’re trying to address right now with cement research?”

Gevaudan: “It’s a great question. I think that the biggest challenge we have right now is that we need to decarbonize industrial sectors by 2050, and we’re not on track. Specifically, the cement sector, we’re not on track to really meet those 2050 decarbonization goals. The reason for that is multilayered, but one of the first things that we need to consider is that we need to actually reduce the amount of cement in concrete. That’s what we really need to do right now.

And there’s a lot of really great research right now trying to do that, but it presents a problem, right? Because cement, as we were talking about before, is what allows your coarse and fine aggregate to bind together and make up concrete and it gives it that compressive strength that we rely on. So, if we’re using less cement in the concrete, then of course our compressive strength is not going to be as high as maybe we need it to be in certain structural functions. So, one of the things that we also need to think about is how do we reduce cement while not compromising the mechanical performance or the durability performance of concrete.

Right now, main strategy that we have had since the 1940s, really, has been to use cement replacements. Maybe fly ash or landfilled and ponded ash, as well as slag, blast furnace slag, that has been utilized. The problem with that is that since 2022, we’ve seen shortages of these cement replacements throughout the U.S. So, with these shortages, really what they’re pointing to is a supply chain issue and a logistics issue really in getting cement replacements to projects across the U.S.

So, one of the things that we’re trying to do in our group at Penn State is trying to think about how do we actually manufacture those cement replacements across the U.S. so that we are producing cement replacements near where they’re going to be needed from local geological resources that are abundant in the U.S., such as basalt, an igneous rock that is particularly great chemistry for us to create a cement replacement but requires a technology to actually make that chemistry work as a cement replacement. So, we spend a lot of time thinking about that and actually doing a lot of research and developing some technologies to do that. Our main goal is that our technology can not only create a cement replacement from these basalts or similar geological resources, but that during that production, we can actually use CO_2 as that valuable reagent, so that instead of just emitting CO_2 into the atmosphere, we can use it in our process and lock it away.”

McDonald: “That’s really useful to be able to take it out of the atmosphere and trap it in such a way that it’s not contributing to our climate change problem.”

Gevaudan: “Right, right. So, that’s one of the main goals. And another thing that is really important here to consider is that it is not until we start seeing emissions as a resource that

we can start to open up possibilities and opportunities that make, in my opinion, research very exciting. So, just to give you a quick illustrative example. Over the past couple of years, we have actually closed down cement plants in the U.S. And that is a big deal because if we're not producing cement in the U.S., it means that now we're relying on more expensive alternatives being imported from different places. So, it's a big issue, and the reason why they're being closed down is because we have particulate matter emission policies, regulations that are controlling this pollution that we often call dust pollution from cement plants. And we should absolutely have regulation on that dust or particulate matter emissions because they have significant health consequences, particularly to the disadvantaged communities that don't have anywhere else to live but near that cement plant. So, we should be caring about the health of the people around the cement plants or where cement is being produced. However, we also do need cement, right? We need cement to create concrete.

So, it becomes a real tension, particularly if we are seeing, again, emissions as something that is harmful, not good, not beneficial. If we start seeing them as something that's beneficial, something that we can do something with them, then new research opportunities open up. And what I mean by that is that turns out that this particulate matter emissions, this dust, a large proportion of this dust is Portland cement. And that is super exciting because it means that if we can collect it, if we can actually instead of just emitting it, if we can actually collect it and use it in a technology such as the one that we have developed at Penn State, where we can make those basalt cement replacements, it means that we can actually improve the efficiency of that CO_2 sequestration, that CO_2 storage that we talked about. And the reason for that is because cement in our technology dissolves, it increases the pH of that slurry that we're creating to make those cement replacements, and that high pH allows CO_2 to really efficiently convert from a gas into a solid, and those carbonates get incorporated into that cement replacement, and we can not only sell that cement replacement, we can also sell this CO_2 sequestration in terms of carbon credits."

McDonald: "I think this really shows a significant shift from the original Industrial Revolution. We've always really thought of industry and consumption as a linear process: Once it reaches the end, we just discard it. But we're really coming to realize that just because it's been discarded doesn't mean it's useless. Being able to look at our waste, reevaluate it, and how we can cycle it back in and reuse it just makes this whole way that we consume much more circular and less of an endpoint that just pollutes into the environment."

Gevaudan: "Absolutely, yes. In the 1800s, we thought development equals pollution. For our country to grow its GDP [gross domestic product], it needs to pollute, right? That was the 1800s motto. But nowadays, we're seeing that that's not true anymore. Specifically with the advances in renewable energy technologies, we're seeing that we can decouple GDP growth from pollution or contamination. And we hope that we can find solutions that are the best and right fit for a project. Sustainability is not a global problem; it's a regional problem. What I mean by that is that the most sustainable option is going to be what makes sense for a project in the local context, of what is available in terms of materials or

what that climate looks like, of what the skills are available for the construction of that project. So, that's what I mean by that.

What I try to do at Penn State with the D/Carb Group is really think about thinking locally to identify how sustainability metrics and goals and even definitions may change from project to project. So, I teach lifecycle assessment of buildings, particularly in how we think about sustainable building design. And then in the research, what we try to do is think about sustainability from a whole lifecycle perspective because we need to make sure that through our whole lifecycle, for example, the technologies that I described with the basalt cement replacements, that we're not actually contributing to worsening global climate change by actually emitting more CO_2 due to the operational energy that it requires [for] us to run that process. So, we need to think about it holistically, the whole lifecycle, so that we are really ensuring that we are contributing to the solution rather than contributing to worsening the problem."

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BREAK

McDonald: "The American Ceramic Society's Cements Division is involved with the research, development, manufacture, and sale of cements, limes, and plasters. This Division organizes the Advances in Cement-Based Materials meeting each summer. Learn more about this Division at www.ceramics.org/cementsdivision."

SECTION 3

McDonald: "So I know we talked about that what really drove you to become a cement chemist was your childhood experiences seeing the environment around you, really getting to kind of learn about the dichotomy between nature and the built environment. But we also know childhood experiences are very formative in how you go about pursuing your professional career as a researcher. And coming from Venezuela, you have backgrounds as both a Latino and a Hispanic scientist. How would you say that those kinds of experiences and those identities that you hold have shaped your career path?"

Gevaudan: "So, you know, there is, there's a lot, where do I start. So, I think coming from a Latino perspective and experience, I think that both my parents didn't graduate high school or college, and I think that coming from a Latino perspective, there is this emphasis in making it and getting a job, starting your life, starting producing money, like getting out there and, you know, working. And I think because I was so interested in and fascinated about changing the world by bringing in harmony between a natural and built environment from a very young age, I had to push back a little bit and say, 'No, I am going to do research because this is fascinating and I think I can see this impact and I want to make sure that I'm learning different skills and I'm learning about cement chemistry.' So that aspect, I think, hopefully some of the listeners can relate to, where you have to do a lot of advocation for yourself because perhaps the family around you may not really understand what is it that you're doing. Then they may ask you like, 'Why are you taking more

classes? Like why? Why don't you just graduate?' That was the main question that I would get: Why don't you just graduate? And definitely going into master's and Ph.D. program, I think because my family hadn't done that, they didn't really understand. And I think from a Latino perspective, I think like that may, not sure how general that is, but that was my experience.

And then from the Hispanic perspective, I moved to the U.S. to do high school in Montana. I didn't know much English, and I think that was difficult because I remember missing a lot of assignments and the best advice that I got was that smile and nod, right? And I think that it definitely pushed me outside my comfort zone in terms of I need to figure out what is going on and I need to learn English as fast as possible, I need to be fluent as fast as possible. But then from a different perspective, I think you always have as an English second language speaker, you always have that challenge in the back of your mind, 'Am I really understanding what I'm reading?' And until now, I do have to read and reread sections, papers, paragraphs. So, I'm a very slow reader, and I think that it's important to recognize that there are challenges with that. And, of course, benefits because I think it really makes you scrappy, it makes you really figure out different modes of learning.

Something that I would recommend, because I'm getting on my soap box here, is really engaging multiple modes of learning. There is research out there that is conflicting on this, but it really is helpful, at least from my experience, to see materials in different ways. So, if it's a video, it's a diagram, it's just a lecture where you're just speaking about it, engaging in different modes of learning, in my perspective and in my opinion, do make for a more diverse and more inclusive learning opportunities. So, that's my soapbox because I do think that that inclusivity is very important.

McDonald: "As we've said before, there are so many aspects to this challenge with concrete and cement, we need as many perspectives and communities working on it as possible. So, making the research area accessible to as many different perspectives and backgrounds as possible is important."

Gevaudan: "Yeah, absolutely, absolutely. This is why I like ACerS so much."

McDonald: "Of course, exactly. And that is why you're here on our podcast is you are one of our members in The American Ceramic Society. So, how is it along your journey that you came to know about us and join the Society?"

Gevaudan: "It was my first year in graduate school, and my advisor comes to me and says, 'There is this conference, it's really cool, it's in Manhattan.' And I was excited. I was, 'Oh my god, I'm going to go to the Big Apple in my first year of graduate school.' Like, I made it, right? Like, this is awesome. And of course, he followed that with 'Kansas.' So, Manhattan, Kansas. Which is actually lovely. And I was very excited. That was The American Ceramic Society Cements Division conference. It was one of the best experiences, and I'm so grateful that I had it in my first year of my graduate career because ACerS Cements Division is one of the most insightful meetings and conferences

that we have, particularly because we focus on talking about the science of what we're doing in the U.S. about cements, and the community is small enough that we can all really get to know each other.

It's really cool to be with other people that are passionate about cements and that want to not only talk about it but mentor each other. And I received so much mentoring as a student, as a graduate student, and that mentoring is what I look forward to providing the most when I go to ACerS Cements Division conferences now. And I am now the ACerS Cements secretary, and it's really amazing because I've always wanted to be involved in putting this meeting together and the leadership of this immense Division. So, I am just happy to be part of it.

And we put a lot of care and dedication into not only the opportunities but even the events that we put together. So, last year, I was the diversity, equity, and inclusion chair of the Division, and we had two really successful events. One of them was at the Boulder Museum [the Museum of Boulder], where we looked at regional black history and the historical context around challenges and racial issues that were affecting not only Boulder but Colorado as well. And in the other event, we really wanted to open it up to be more of a community development event where we were not just learning, we were learning about each other. And that, of course, we did a hike up the Flatirons, and we broke up into little groups as we were walking this beautiful mountain in Colorado. So, it was fantastic. But, of course, I'm biased because, you know, I was part of the team organizing that."

McDonald: "It probably just hearkens back to some of those good childhood memories. Like you said, you were hiking in Mexico, too, so hiking's always been a thing that you've done, really connecting with nature."

Gevaudan: "Really, yeah. The connection with nature is fantastic. And also gaining perspective, that elevation, like physical perspective, I think also gives you an opportunity to gain perspective on your own life and think about how far you have come."

(music)

CONCLUSION

McDonald: "With so many different aspects and layers to the cements challenge, it will take a community—one that you could join!—to address them all.

I'm Lisa McDonald, and this is Ceramic Tech Chat."

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"Visit our website at ceramics.org for this episode's show notes and to learn more about JP, his research, and ACerS Cements Division. Ceramic Tech Chat is produced by Lisa McDonald and copyrighted by The American Ceramic Society.

Until next time, I’m Lisa McDonald, and thank you for joining us.”