Indian Institute of Technology Madras

Technologies for Low-Carbon and Lean Construction

NEWSLETTER

November 2023

TLC2 professors with PhD students during TLC2 day

TLC2 day: First ever TLC2 day was conducted on November 4th in IITM Research Park. Our PhD students presented their recent work on various TLC2 themes - Alternative Cementitious Materials, 3D printing, CO_2 mineralization, Recycled materials, Corrosion and Durability, Fiber Reinforced Concrete, Life Cycle Assessment (LCA) and Technology and adoption. Progress of each TLC2 theme was reviewed and future course of action was discussed.

Prof. Ravindra Gettu and Prof. Nikhil Bugalia were the invited speakers in the DRF Lunchtime Clinic at the University of Cambridge organized by Digital Roads of the Future.

Prof. Gettu presented few case studies on Sustainability Assessment of Concrete for Construction.

Prof. Bugalia talked on “Road to Digitalization for Construction Safety Management in India: An Emerging Economy” Perspective.

IN THIS ISSUE

GUEST COLUMN

In conversation with Prof. Sulapha Peethamparan, Professor in the Department of Civil and Environmental Engineering, Clarkson University, USA

NEWS IN BRIEF

- Prof. Ravindra Gettu and Prof. Nikhil Bugalia visited University of Cambridge in November, presented in DRF Lunchtime Clinic organized by Digital Roads of the Future

For more details, please check our LinkedIn page

UPCOMING EVENT

The 3rd International Workshop on Technologies for Low-Carbon and Lean Construction (TLC2) – 2024

January 28th – 31st , 2024

IC&SR Auditorium, IIT MADRAS, Chennai, India

For poster submission and participation in the Young Researchers’ Symposium (YRS) event, please check our website.

GUEST COLUMN

Meet Prof. Sulapha Peethamparan, an alumnus of BTCM division, IIT Madras and our guest and collaborator at CoE on TLC2

Prof. Sulapha Peethamparan is an accomplished researcher and renowned professor in the Department of Civil and Environmental Engineering, Clarkson University, USA. Her research group in Clarkson University primarily works on the understanding of the hydration chemistry, microstructural/nanostructural property development and their influence on the early age and long-term performance of sustainable infrastructural cementitious materials. She came back to her alma mater IIT Madras under the Nehru-Fulbright fellowship and joins TLC2 project as a collaborator.

Please tell us about your career path to date

My career as a researcher date back to my move to Madras to pursue an MS in Building Technology and Construction Management (BTCM) division under the Civil engineering department at IITM. I joined Dr. Ambalavanan's group to study the durability of concrete (1998). After my MS, I joined The National University of Singapore (NUS) to pursue a PhD. The thesis research was on the carbonation of concrete. I earned an MEng degree for that effort because I left after two years. I couldn't turn down an opportunity to join one of the finest civil engineering schools in the USA, Purdue University. The research at Purdue allowed me to delve deeper into the material science of concrete. I want to mention that during my stay in Singapore, I worked as a project engineer in a High-performance concrete research laboratory. At this laboratory, we were conducting fundamental R&D work funded by the Singapore government to develop high-performance concrete for building a large desalination plant. Immediately after graduating with my PhD, I joined Dr. George Scherer's group at Princeton University as a postdoctoral research fellow for one year to study oil well cement. I then joined Clarkson University as an assistant professor, rising through the ranks to become a full professor, the position I hold today. I run the cement and concrete lab with my colleague Dr. Robert Thomas. We currently have 12 graduate and undergraduate students working on projects funded by National Science Foundation, NASA, the Federal Highway Administration, and New York State Pollution and Prevention Control Institute. The privilege of a faculty job is the opportunity to shape young people's lives through teaching and mentoring, to advance knowledge through the pursuit of research and scholarship, and to continue to learn and be intellectually challenged through interactions with amazing colleagues and students. I genuinely enjoy it and am grateful to IITM for serving as a stepping-stone for my career.

Life at IIT Madras, then and now

When I look back at my time at IITM, life was very simple. We only had one women's hostel, Sarayu. I commuted between Sarayu and BTCM on my blue bicycle. Like many students from a different state, Kerala, I had issues transitioning to a new environment, culture, and food. But, once accustomed, life at IITM was beautiful and memorable. Even now, I can recollect the excitement we all shared while waiting for Saturday's dinner special that served Chole Bhatura, then heading out to the Open-Air Theatre (OAT) to watch a Hollywood blockbuster or an Indian local movie. IITM was always a beautiful campus full of greenery and different animal species, from butterflies to birds, monkeys, chitals & blackbucks. With a close-knit family of faculty, graduate students, project associates, and staff, the research life at BTCM was intense but sweet. Although the research infrastructure was minimal then, I am amazed at how much the lab accomplished. At IITM, I learned that the world was much bigger than my home state and that academia was about commitment. My time there also changed my personal life as I met my spouse.

The IITM life still remains wonderful. The changes I see are mostly positive. There is stunning growth in research infrastructure and facilities, which makes IITM comparable to the top universities in the USA. Equally admirable is the growth in the faculty body in terms of both the depth and breadth of their expertise. Unfortunately, I fear that IITM may have been a victim of its own success as the student population has grown, so instead of the calm, serene campus, it is now overcrowded. I also feel like the campus has become hotter and more humid in summer than it used to be. This could be either a change in my perception after living in the cold weather in northern New York for 20 years or the global climate change.

Your Research Interest

My research interest is to advance the knowledge of the fundamental relationship among the chemistry, microstructure, and the performance of various cementitious materials. The goal is to utilize this knowledge for the betterment of society. I am trying to formulate new low-carbon sustainable concrete by inventing novel approaches and utilizing emerging technologies to yield excellent mechanical and durability performance. Currently, I am studying an emerging material called alkali-activated binder. For decades, the

primary strategy for reducing concrete's carbon footprint has been partially replacing portland cement with 30-40% pozzolans (SCMs). As the effect of climate change increases, drastic measures are needed to reduce CO_2 emissions from the concrete industry further. Several alternative types of cement are being developed to reduce the CO_2 footprint. Alkali-activated binders are considered one such sustainable binders. These binders, also called 'geopolymers' sometimes, can be produced by activating an aluminosilicate containing natural minerals or an industrial byproducts with a strong alkali solution. Most of our group's contributions are in understanding the reaction kinetics, microstructure development, and mechanical and durability performance of fly ash and slag-based alkali-activated materials.

At IITM, under the *Nehru-Fulbright fellowship*, we are exploring the feasibility of using agricultural waste streams as the aluminosilicate or precursors to produce so-called one-part or "just add water" alkali-activated material. The difficulty of handling and storing a strong alkali solution in the field is one of the factors preventing the easy adoption of this geopolymer technology. This sparked the idea of developing a geopolymer cement using a solid activator. The scope for factory production and distribution of bagged one-part geopolymer cement can expedite the adoption of the technology. However, the technology heavily depends upon the availability of suitable industrial byproducts. The commonly used precursors, fly ash and slag, are expected to decline globally and are in high demand as SCMs in portland cement concrete. India generates approximately 225 Mtpa of fly ash, 14 Mtpa of red mud ash, 21 Mtpa of sugarcane bagasse ash, and 75 Mtpa Sewage sludge ash as industrial wastes, and all of these materials are potential candidates for the realization of clinker-free geopolymer cement a reality. Even if such cement can find a 10% market in the Indian concrete industry for niche applications, almost 30 million tons of CO_2 emissions to the atmosphere can be prevented annually. I believe our research will provide new insights into the fundamental behaviour of biomass ash-based alkali-activated paste, mortar, and concrete necessary for designing, predicting, and enhancing the performance of such alternative binders.

What / who motivated you to choose concrete and building materials

To be honest, my encounter with concrete and building materials was by chance. I did not get my first-choice option for my MS at IITM and ended up with concrete and building materials as my field of study. For a fresh graduate, it is just another ordinary building material. But when you start investigating, you realize in no time that concrete is one of the most complex heterogeneous composite materials with an enormous length scale effect that determines the performance. The macroscale properties, such as strength, are linked to the micro/nanoscale structure (C-S-H), which in turn depends on several other parameters. I can't name any other materials that can be produced in a liquid form and poured into any shape and form to set, harden, and meet all infrastructure applications at a low cost. The science of concrete, as a field of research, is rich in possibilities and has the potential to impact humanity positively.

Prof. Peethamparan in our MACCEM lab

Your favourite engineer/professor

I have been fortunate to work closely with several well-known researchers who have dedicated their professional lives entirely to the field. I recognized that their commitment helped them to make significant contributions. They include my advisors and professors: Dr. Jan Olek, Dr. Sydney Diamond, Dr. Jason Weiss from Purdue University, Dr. George Scherer from Princeton, and others. Apart from their scholarship and technical contributions, they are great mentors who helped to create a new generation of scientists and engineers. All of them have influenced me immensely.

Your idea about sustainable concrete – US and Indian Context, and way forward

Sustainable concrete development, at a minimum, should yield significant environmental benefits without compromising on its structural and functional performance. Essentially, this means ensuring less CO_2 emission during the whole life span of a structure, counting from the manufacturing of the raw materials to transportation, construction, operation, and dismantling and disposal after the structure's useful life. We have been trying several solutions. For instance, cement producers are constantly striving to reduce the use of fossil fuels by substituting them with industrial wastes or using renewable electricity sources. Likewise, we have been reducing CO_2 emissions during pyroprocessing using various new technologies and using carbon capture technologies at the plants. We have reduced the cement/clinker content in concrete by using SCMs and also optimizing the cement content for effective use of concrete. We have also produced quality-controlled, long-lasting, durable concrete structures that do not need frequent replacement. Recycling demolished concrete in construction is another important method. Likewise, making concrete using locally available materials at the site of application is another promising idea that has been in our discussions for quite some time. Eventually, we need to quantify the potential of CO_2 intake of concrete during its lifespan and methodologies to enhance the uptake. As concrete researchers, we have a significant role in all of these methods. While all of these current solutions have been somewhat uniform globally, I am beginning to recognize that a diverse set of solutions that accommodate location-specific considerations must be developed to make our effort more effective and impactful. Different regions around the world have very diverse resources and needs. Therefore, understanding and addressing them to develop sustainable solutions is critical as we strive to achieve carbon–neutral concrete by 2050, which is why this must be a worldwide collaborative effort.

Life in labs – Clarkson lab, IITM lab, NUS lab

I believe that the life of a researcher in university laboratories around the world is somewhat identical in many respects. Identifying research problems of importance, designing and conducting experiments, meticulously analyzing the results, and disseminating the research findings remain the same. However, there are some differences in the research culture and environment, mainly due to historical and economic reasons. Although Clarkson University is a relatively small university, being a researcher in the USA provides easy access to many resources, including cutting-edge experimental technologies and exposure to a broader research community for potential collaborations. Research rigor in first, second and third-tier universities in the USA is almost the same as we all compete for the same national funding pool. On the other hand, universities like IITM and NUS are blessed with a larger pool of government-funded brilliant students. Personally, working in labs in three different countries, especially in US universities, has given me an excellent opportunity to broaden my understanding of people and perspectives worldwide. It reminds me of the Vedic principle “Vasudhaiva Kutumbakam/The World is One Family” every day. After COVID, we know how to communicate effectively online, and a lot more international collaborative efforts are organically happening because of the internet; hence, any difference is diminishing.

What contribution to your field are you most proud of and why?

I have been lucky to make several contributions to the field, initially as a graduate student or postdoctoral fellow under the guidance of well-known professors and later as a faculty member with the help of many hard-working, brilliant students. My contribution is mainly in understanding the reaction kinetics, microstructure development and mechanical and durability performance of alkali-activated fly ash and slag binders. Eleven articles published on the topic have been cited 100-300 times per article. Our group has also made several contributions to nanomaterials containing concrete, oil well cement hydration at elevated pressure and temperatures, and understanding the natural carbonation in low-carbon concrete. We are currently investigating several nontraditional SCMs as potential substitutes for fly ash and slag through a collaborative effort among Purdue, Penn State, and Clarkson Universities funded by FHWA.

Collaboration with Dr. Piyush Chaunsali and IIT Madras

Dr. Piyush Chaunsali is my Fulbright proposal collaborator. I have known Dr. Piyush Chaunsali since 2009. Piyush was my first graduate (MS) student at Clarkson University, so I have witnessed each step of his growth as a PhD student at UIUC, a postdoc at MIT, and a young faculty member at IITM. My collaboration with Dr. Piyush Chaunsali under the support of TLC2 (Technologies for Carbon and Lean Construction) and IITM aligns with our common goal of developing low-carbon sustainable concrete. The mission of TLC2 is to develop India’s first integrated testbed for evaluating the usage of agricultural, industrial, construction, and demolition waste in concrete for directing practices, policies, and standards for waste reduction in the Indian construction industry. The center's success needs input from material scientists and construction engineers, so BTCM is the ideal host. The specific objectives of our collaborative work under the Fulbright fellowship are to: 1) Explore the viability of producing bagged geopolymer cement using industrial byproducts or biomass wastes and solid alkali activators using one-part alkali activation technology, 2) Correlate the composition, processing, and environmental impact of geopolymer cements with the fresh and hardened properties, and 3) Develop instructional materials for a course titled Alternative Cements.

I also got the opportunity to interact with many highly motivated faculty members and students at IITM. There are many faculty members working on sustainable concrete materials, studying the chemistry, durability, fracture and computational modelling of concrete. Also, there are a few faculty members working in the area of construction management. BTCM group hosts more than 30 graduate research students, postdocs, and project associates. I hope to continue my collaboration with TLC2 beyond the tenure of my Fulbright.

Advice to others interested in Material science

The field of materials science, in general, and building materials, in particular, gives a researcher an excellent opportunity to work on fundamentally challenging problems that can impact the world. The application of concrete is growing exponentially, and research in the field continues to grow with numerous exciting ideas emerging. This includes low-carbon concrete, alternative, concrete 3D printing, lunar regolith concrete, and nanotechnology in concrete. Advances in super-hot technologies such as AI and machine learning are also expected to impact the field of material science as never before. So, understanding the science of materials at a very fundamental level is a need of the hour for these fast-changing areas. I want to conclude by emphasizing that there are many opportunities to conduct computational and experimental work in this field to pursue a rewarding career.

Prof. Sulapha Peethamparan with Prof. Piyush Chaunsali

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