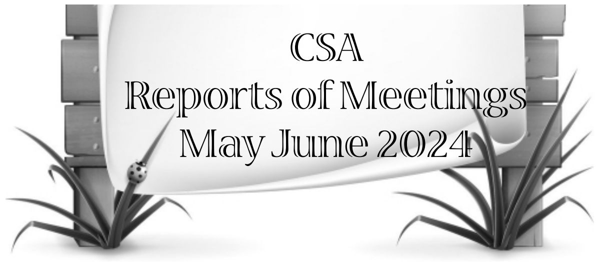


CSA General Meeting and Social

Sunday 2nd June 2024 at 6.30pm
at the Pennant Hills Community Centre
Ramsay Road, Pennant Hills NSW

SPEAKER: Distinguished Professor Buddhima Indraratna AM

TOPIC: Challenges and Advances for Transportation Infrastructure with special reference to Railways

Distinguished Professor Buddhima Indraratna, Director of Transport Research Centre at the University of Technology Sydney (UTS), delivered a presentation on "Challenges and Advances in Transport Infrastructure with Special Reference to Railways" at the CSA General Meeting on 2 June 2024. Prof Indraratna is a Member of the Order of Australia, and he was the first Sri Lankan engineer to be inducted as Fellow of the prestigious Australian Academy of Technological Sciences and Engineering (FTSE).

The following narrative has been written by Shashika Atapattu, a PhD student at UTS, based on Professor Indraratna's presentation:

The development of transport infrastructure involves addressing five key challenges: (i) budget constraints, (ii) safety, comfort and reliability, (iii) circular economy, (iv) emerging technologies, and (v) environmental controls. As the world's economy continues to recover from the COVID-19 pandemic, budgets for high-quality design and construction of transport infrastructure have become tighter. However, the essential requirement for improved safety and comfort in public transportation systems has remained a priority, while encouraging more people to use public transport to ease urban congestion. Moreover, perspectives of circular economy are given greater priority, with an imperative global shift towards building sustainable infrastructure for future generations, including the use of recycled materials and industry byproducts as construction materials. Prof Indraratna explained that environmental controls are also crucial to achieving net-zero emission targets, hence the urgent need for making transport infrastructure more energy-efficient. For example, Australia is committed to reducing its reliance on coal as a major energy source and proactively transitioning towards renewable energy, including solar, wind and tidal power systems. Similarly, Sri Lanka's commitment to UNDP includes reducing greenhouse gas emissions by at least 14% and increasing forest cover by over 30%. In essence, the ultimate aim of transport infrastructure development is to build safe and reliable road and rail systems with low carbon emissions.

In Sri Lanka, as the population still cannot afford electric vehicles and the autonomous or driverless vehicles are currently not feasible, the population needs to prudently consider practical and affordable measures to reduce carbon emissions. Prof Indraratna stressed the need for practical solutions, including greater efficiency of public transport and the emerging bio-engineering solutions such as the growth of trees as green corridors along major roads and railways to stabilise the soil. These green corridors not only help to reduce the excess water in the soil (evaporation from the tree canopy, while the tree roots suck soil moisture), thus strengthening the soil (making it stiffer), but the tree lines also act as noise and wind barriers along the transport corridors, while reducing the carbon dioxide levels in the vicinity. Prof Indraratna vividly explained how the growth of vegetation on either side of railway tracks (green corridor concept) naturally reduces excessive moisture in the low-lying railway lines along the coastal areas, through the evaporation-transpiration cycle – where the moisture evaporates from the leaves, while the tree roots draw the water from the soil continually in the morning and afternoon (process of photosynthesis). A prominent example of the importance of vegetation near roads and railways can be seen in the picture taken by Professor Indraratna during the post-tsunami rail track rehabilitation work in the southern province of Sri Lanka (Photo 1). It is evident from the picture that coconut trees were rarely uprooted by the tsunami waves, while concrete foundations were destroyed. When tree roots intake the soil moisture, this process generates a very high suction pressure that maintains the soil around the roots to be very stiff and strong, and the roots themselves act as soil reinforcements, in the same way that steel reinforcements strengthen concrete slabs.

Photo 1: Challenges in Disaster areas: Post-Tsunami Rail Track Rehabilitation in Sri Lanka (Jan-March 2005.

Identifying common problems related to railway tracks is crucial for developing resilient public transport systems. Some of the common issues include ballast breakage (ballast is the bed of rock particle forming the track foundation), erosion of the foundation materials due to flooding, excessive and irregular settlement along the track, buckling of steel rails, and the soil beneath the track becoming a slurry and pumping upwards under accumulated water pressure in the ground (this phenomenon is called mud pumping). Unacceptable rate of ballast breakage (i.e. when the rock particles supporting the railway track get crushed due to repeated train loads), is a significant concern for railway engineers worldwide. This necessitates the replenishment of ballast regularly to maintain satisfactory strength and to provide minimum confinement to the concrete sleepers (parallel beams) which form the track skeleton. Additionally, flooding can erode the foundation materials including ballast and the soil underneath, compromising the load-bearing strength, stability and safety of the entire track. Differential settlements along the track leading to uneven track alignment also pose further safety risks including derailment. Steel rails are also susceptible to buckling under extreme temperatures especially in the absence of sufficient ballast in the track, thus increasing the risk of potential derailment at increased train speeds. Another major issue of track instability is the softening of the soil below the track due to excessive water and the associated mud pumping when the soil becomes a slurry, and this is mostly caused by poor drainage in the ground, for instance inadequate drainage (blocked culverts and clogging of way-side drains) in low-lying terrains after heavy rainfall. Prof Indraratna explained that when the foundation soil (technical term is subgrade) becomes saturated after heavy rainfall, the strength of the soil rapidly decreases, causing clay and mud particles to fluidize and pump upwards into the ballast layer. If not promptly addressed, these issues can lead to major train derailments, as the clogging of ballast by the pumped soil means that the ballast bed also loses its free-draining capacity, and the load-bearing strength is compromised. Addressing these problems is vital to ensure the safety and reliability of railway transport systems.

In Sri Lanka unfortunately, train derailments are a persistent concern. A major reason for these derailments can be attributed to issues of maintenance of the track and attention to the factors contributing to these incidents (Photo 2). For example, the presence of weeds on the track indicates that the ballast depth (and volume) is insufficient, leading to the accumulation of soil and water in the ballast layer allowing weeds to grow. Moreover, broken concrete and timber sleepers are also indicative of the lack of ballast needed to support these sleepers subjected to impact loads from continual train passage.

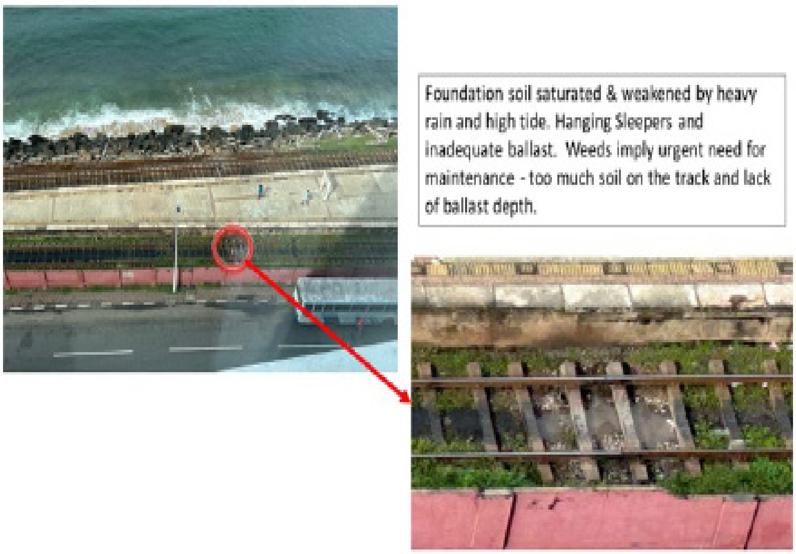


Photo 2: Problems of railway tracks in Sri Lanka

Regular maintenance and the use of good quality rock materials are essential to ensure that ballast depth is checked and replenished when required to provide adequate strength of the track while providing sufficient confinement to railway sleepers. Increasing the amount of ballast volume can provide greater strength and stability to the track.

Solutions for problems related to railway foundations have been introduced through scientific research, with a focus on prioritising the perspectives of a circular economy. In Australia, over 45 million rubber tyres reach the end of their life each year, with only a small portion being recycled. Many rubber tyres around the world are illegally dumped, contributing to environmental issues including breeding grounds for mosquitoes in countries like Sri Lanka. For example, the world's largest tyre landfill site in Kuwait is so vast that it can be seen from space, and occasional spontaneous fires at the dump sites during very hot temperatures release significant carbon emissions (toxic gases too) causing extensive air pollution. This highlights the urgent need for effective research to reduce dumping of recycled tyres and promote more sustainable practices in construction. Sustainability in this context involves not only implementing circular economy principles in the construction industry, but also ensuring that novel engineering solutions perform as well as or better than the acceptable traditional designs approved in conventional technical standards. Rigorous studies involving experimental work, computer modelling, and field monitoring are necessary to validate these innovative solutions for real-world applications.

Prof Indraratna explained innovative railway designs using recycled rubber materials, which have been introduced in various forms. These include rubber crumbs, which are small particles of broken rubber particles (crumbs and shreds) mixed with traditional rock particles to form a blended ballast mixture, under-ballast mats made from waste rubber sheets (from discarded conveyor belts) that are placed beneath the ballast layer to provide additional support and cushioning for the track components, and under-sleeper pads (small pads made from waste rubber that are placed beneath the sleepers) to improve their stability and reduce vibration. Additionally, tyre cell track foundations, which involve assemblies of recycled rubber tyres (infilled with waste materials) to innovatively build an energy-absorbing track foundation, and rubber grids (recycled rubber sheets from factories using conveyor belts, on which holes can be made by water jet cutting), have been used to improve the performance of railway tracks.

The effectiveness of these innovative and patented designs had been tested using advanced testing equipment by Prof Indraratna's team at the UTS transport laboratories, and some of the testing rigs were designed and built in-house specifically for this purpose. Real-size (prototype) testing could also be conducted at the National Facility for Cyclic Testing of High-Speed Rail near Wollongong, a facility that was established by Prof Indraratna. A fully instrumented track was then constructed at Chullora in New South Wales, to investigate real-life performance of the laboratory-proven solutions with actual trains operating on these trial tracks. In Chullora, the world's first tyre cell track foundation was constructed in collaboration with Sydney Trains, c/o Transport for NSW and EcoFlex Australia (Photo 3). Field results of this track indicate that the use of recycled rubber tyre foundation helped to reduce the load transferred to the soft soil beneath the track compared to a standard track, so the track becomes more stable. Therefore, the performance of this innovative sustainable design (tyre cell foundation) is better than the standard track designs. This concept is now an approved Australian Patent by Prof Indraratna together with EcoFlex Australia Ltd.

Photo 3: World's First Rubber Tyre Cell Foundation for Railways at Chullora

In countries where the rainfall is very intense and drainage is poor, particularly in low-lying terrains, mud pumping occurs (photo 4). This is similar to pothole formation in motorways where foundation soil becomes a slurry, causing the asphalt layer to collapse. Prof Indraratna explained this using Crème Brulee as an analogy. Following a mud pumping event, concrete sleepers become unsupported and hang without proper support beneath them. So when a train passes over these unsupported sleepers, there is sudden settlement, increasing the risk of derailment. In Australia alone, a significant portion of the investment is spent on annual track maintenance due to mud pumping. Although this problem is long-standing, it has only gained attention in recent decades due to the rapid increase in heavy freight trains with high axle loads that had intensified mud pumping. Prof Indraratna's research addresses three primary aspects of mud pumping: (i) causes and geotechnical mechanisms, (ii) assessment of mud pumping using laboratory experiments, and (iii) cost-effective solutions to prevent mud pumping. Innovative solutions, such as (i) use of synthetic vertical drains (rolls of drains driven in to the ground like piles to reduce deep water pressures in the natural foundation soil), (ii) geo-textiles (synthetic materials that readily absorb moisture and dissipate excess water pressure) to enhance the drainage capacity of the foundation soil, and (iii) bio-engineering techniques (e.g. growing trees) have been introduced in recent times.

Photo 4: Ballast particles are clogged due to mud pumping

Moving on to port extensions through offshore reclamation, the booming population and associated development in coastal and metropolitan areas have necessitated offshore reclamations. Usually, these extensions are executed by dredging ocean sand with marine mud and pumping it to the development zone within the seawall or breakwater boundaries. The low bearing capacity and high compressibility of this dredged material must be stabilised before commencing construction. The port extension work at the Port of Brisbane in Queensland was achieved using vertical drains driven in to the soft soil foundation with vacuum pressure applied to these drains (i.e. vacuum pumps aiding the extraction of excess moisture) to accelerate the consolidation of the soft materials and strengthen them. Computer modelling techniques were also introduced to accurately predict the stabilisation work in conjunction with an array of field monitoring devices. In contrast, the reclamation work at Port Kembla Outer Harbour in New South Wales used an innovative blend of locally available granular waste by-products, including coal wash (from coal mining) and steel furnace slag (from steel mills), in lieu of the dredged fills from the ocean. Prof Indraratna explained that dredging of ocean sand and marine muds can cause extensive environmental damage to aquatic habitats, while the use of waste materials where possible will significantly reduce environmental damage.

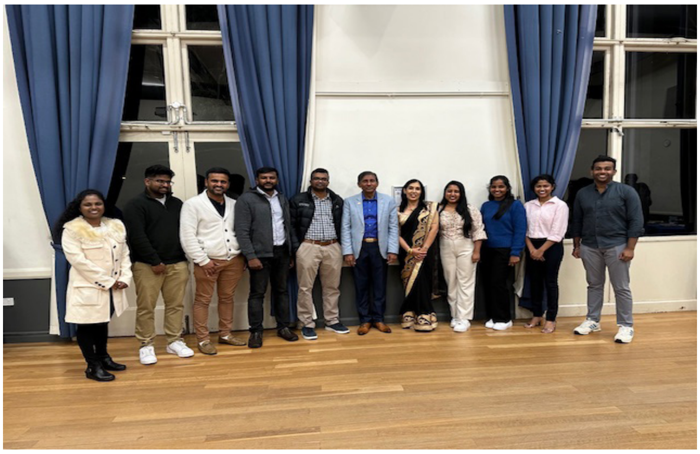
In conclusion, the advancements in transport infrastructure, particularly railway systems, emphasise the importance of innovation, sustainability, and rigorous research. Continued focus on these areas is crucial in meeting future demands and ensuring the development of transport infrastructure that is not only robust and reliable, but also environmentally advantageous.

Prof Indraratna concluded his presentation by acknowledging the efforts of his past and present PhD students and postdoctoral research staff (over 150 to date), whose contributions at various times have also contributed to this presentation.

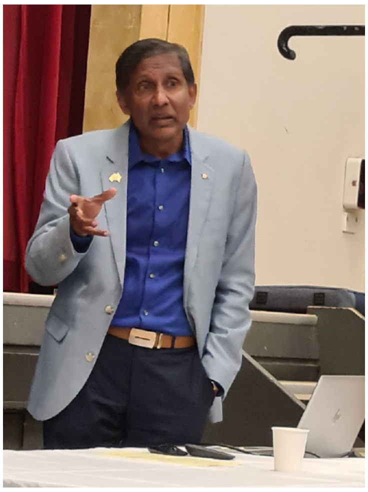
After Professor Indraratna's talk, attendees socialised with him and his PhD students over refreshments, discussing further the innovative work being done by the Professor and his team. A number of the Sri Lankan PhD students as well as young engineers attended the talk, in addition to members of academia. They enjoyed the event, and were interested in talking to President Pauline on the CSA's focus on the historical and cultural heritage of Sri Lanka, and picked up copies of the journal and Membership Application Forms.

Thanks go to Pauline Gunewardene and the CSA Committee for organising a very stimulating, fascinating and successful evening.

SOME PHOTOS FROM THE EVENING



Prof Buddhima Indraratna and his PhD students at the Talk



With CSA President Pauline Gunewardene

Receiving Jose Ibarra 2024 International Civil Engineer Award from Queen of Spain

Section of the audience