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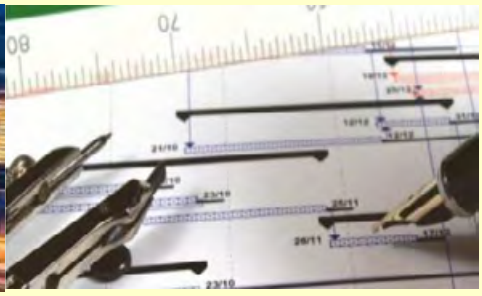

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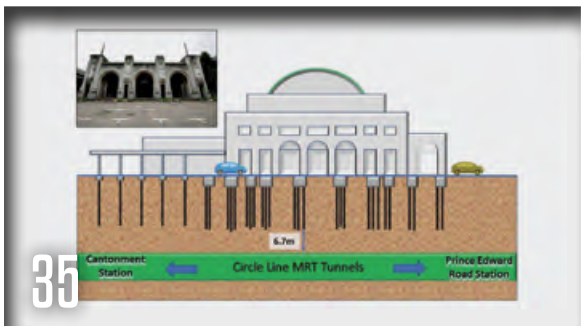

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Pan-United and Shell join forces to explore decarbonisation solutions

Pan-United Corporation Ltd (Pan-United) and Shell Eastern Petroleum (Pte) Ltd (Shell) recently signed a Memorandum of Understanding (MoU) to explore various decarbonisation solutions in the construction and urban development sector. The collaboration is expected to create benefits in terms of decarbonisation in the built environment, through the creation of possible new business models and market opportunities.

The MoU outlines the joint effort to identify opportunities in areas such as low-carbon and renewable energy products, electric mobility solutions, circular use of materials, and other digitalisation-enabled solutions.

The three-year MoU is the first of its kind between Pan-United and Shell.

The collaboration is expected to advance both companies' emission reduction efforts en route to achieving net-zero emissions and is also in line with Pan-United's sustainability targets to offer only low-carbon concrete by 2030 and offer carbon-neutral concrete products by 2040. Additionally, it will help to bring Pan-United closer to its ambition of becoming a carbon-neutral, ready-mix concrete company by 2050.

In particular, Pan-United and Shell will explore repurposing used industrial materials and carbon dioxide from Shell's local facilities such as the Shell Energy and Chemicals Park Singapore on Pulau Bukom, and Shell Jurong Island, as alternative raw materials in the production of low-carbon concrete. This will significantly reduce energy consumption and environmental impacts during the production of construction materials.

Leveraging Pan-United's expertise in innovative sustainable concrete solutions, Shell can explore the possible utilisation of Pan-United's low-carbon and carbon-dioxide-mineralised concrete products and solutions in Shell's existing and new development projects in Singapore. Shell will also have access to Pan-United's sustainability consultancy in terms of low-carbon concrete solutions and technical expertise at the design stage of new development projects, with a view to reduce the level of embodied carbon in the development.

Pan-United's Chief Operating Officer Mr Ken Loh (right) with Mr Tan Yew Chong, General Manager, Commercial Fuels East at Shell (left), at the MoU signing ceremony held at Shell Singapore. Ms Aw Kah Peng, Chairman of Shell Companies in Singapore (centre), officiated the MoU signing.

On the renewable energy front, Pan-United can tap Shell as the partner of choice for the decarbonisation of its and its customers' projects, by exploring the procurement of renewable energy and onsite energy generation, as well as other energy solutions such as downstream natural gas supply, battery energy storage and carbon offset solutions.

In addition, Pan-United will work with Shell to accelerate the transition of its trucking fleet to electric and hydrogen options, through electric-vehicle smart-charging solutions and hydrogen for mobility. In the meantime, Pan-United will make use of Shell's low-carbon fuels and biofuels, as well as its carbon offsets, to drive carbon-neutrality. Pan-United and Shell will explore the viability of deploying Shell's advanced renewable power generation technologies, such as high-efficiency solar, to meet Pan-United's power needs. Concurrently, both companies will seek to explore digitisation opportunities while protecting the environment and reducing carbon emissions effectively.

Ms Aw Kah Peng, Chairman of Shell Companies in Singapore, said, "In Shell's approach to net zero, we believe it is vital to work with our customers. This is just as important as reducing our own emissions. With a long-standing partner like Pan-United, I am confident that the solutions we develop together will have the potential to advance decarbonisation for the construction and real estate sector".

Ms May Ng, Pan-United's Chief Executive Officer, said, "We are excited to work with a well-established and like-minded partner in Shell, as we forge ahead in the new year with our efforts to promote the transition towards net-zero emissions within the Singapore built environment. The collaboration is in line with our circular economy approach to reduce input by minimising waste and using sustainable raw materials. We look forward to tapping Shell's deep know-how in providing clean energy solutions to accelerate the construction sector's progress towards achieving net-zero emissions".

Surbana Jurong spearheads Infrastructure Sustainability Assessment in Singapore

At the Surbana Jurong ISAPs Conferment Ceremony are, from left to right, Mr Jason Reeve, Executive Associate, Sustainability and Resiliency Office; Mr Wong Heang Fine, Group CEO, Surbana Jurong; Miss Ainsley Simpson, CEO, Infrastructure Sustainability Council (onscreen via VC); Mr Eugene Seah, Senior Director, Special Projects; and Mr Martin Lim, Principal Project Manager, Sustainability and Resiliency Office.

Three professionals in Surbana Jurong have become the first Infrastructure Sustainability Accredited Professionals (ISAPs) in Singapore.

They are Mr Eugene Seah, Senior Director, Special Projects; Mr Jason Reeve, Executive Associate, Sustainability and Resiliency Office; and Mr Martin Lim, Principal Project Manager, Sustainability and Resiliency Office. The three professionals are qualified to evaluate infrastructure assets, ranging from roads and transport to utilities and waste management, across the planning, design, construction and operational phases.

The accreditation was conferred by the Infrastructure Sustainability Council (IS Council), an industry body operating in Australia and New Zealand, to enable sustainability outcomes in infrastructure. With the accreditation, Surbana Jurong will be able to measure and assess the economic, environmental, social and governance (ESG) impact of critical infrastructure in Singapore, including roads, bridges, rail networks and utility structures, in a more rigorous and structured manner, using the Infrastructure Sustainability (IS) rating scheme.

Singapore is at the region's forefront, in setting sustainability benchmarks for buildings but there is currently no over-arching methodology for the assessment of the ESG impacts of critical infrastructure assets including transport infrastructure, bridges, cabling and signalling systems, and water and waste management systems. These assets are typically built over many years and require massive amounts of raw materials to build. The potential impact of these materials on the environment and the communities around which they are built needs to be measured, monitored and mitigated.

"There is a lot of untapped opportunity to measure and set targets for sustainable infrastructure, to help infrastructure developers and operators manage their carbon footprint", said Mr Wong Heang Fine, CEO, Surbana Jurong Group.

The IS rating scheme is meticulous and comprehensive in that it uses a quadruple bottom line assessment framework comprising economic as well as ESG aspects, to evaluate the overall sustainability performance of infrastructure assets. Its holistic approach sets and quantifies sustainability goals for the design and operation stages, and covers a range of subjects, from water and waste management to energy consumption, and the adoption of sustainable procurement as well as the usage of low carbon building materials. It is also aligned with the UN Sustainable Development Goals.

The IS Council administers the framework in Australia and New Zealand, to assess the sustainability of the planning, design, construction and operation phases of over AUD 200 billion of infrastructure programmes, projects, networks and assets.

As a leading urban and infrastructure development consultant with a global footprint, Surbana Jurong saw the need to train its practitioners in the IS rating scheme.

SMEC, a member company of Surbana Jurong Group, has applied the IS rating scheme to several of its projects in Australia, including Sydney Metro's Crows Nest Station, the Hells Gate Dam Feasibility Study, and the Fitzroy to Gladstone pipeline project.

In the case of the Crows Nest Station upgrade, SMEC's Sustainability and Climate Resilience team, which includes accredited professionals, facilitated the station's Green Star rating (six-star design rating) and worked with designers to incorporate climate risk mitigation measures into the final design.

Surbana Jurong will be working with the IS Council to introduce and implement the international version of the IS rating scheme in Singapore and across Asia.

"The knowledge that Surbana Jurong Group has gained from our professionals completing the accredited training will boost our ability to design, build and operate sustainable infrastructure with resiliency in mind. This will also enable us to grow our sustainability advisory business. We will look at how this can be used to value-add projects in Singapore and Southeast Asia, especially where there is a need for sustainable financing and some form of platform to measure sustainability for infrastructure. Our clients will stand to benefit from our ability to educate, innovate and apply this effective methodology to our designs", said Mr Wong.

While the IS rating scheme is still new to Asia, adhering to its standards could unlock new value propositions. It will enable Surbana Jurong to help its clients to access green funds for project financing at more competitive rates, through compliance with sustainability processes in design, construction and life cycle management. Additionally, it will lead to projects that have a lower carbon footprint and optimally utilised materials. Post-construction, these projects would also have reduced operational and maintenance costs.

"Sustainable infrastructure protects and preserves the ecological processes required to maintain human health, equity and diversity. With infrastructure sustainability gaining momentum across Asia, we need to stay ahead and have our people acquire the expertise that our clients need for maintaining the sustainability of their assets", he added.

The three newly accredited professionals in Singapore bring the total number of accredited practitioners to 13 across the Surbana Jurong Group, including those in SMEC who have already received their accreditation.

Surbana Jurong joins hands with Nippon Koei and DHI to build resilient cities

Surbana Jurong has signed a Memorandum of Understanding (MoU) with Japan-headquartered engineering consultant, Nippon Koei, and DHI Water & Environment (S) Pte Ltd, a Danish water and environment consulting company, to help clients build safer and more resilient cities and townships, across the globe.

The three parties are looking to set up a Centre of Excellence leveraging the unique strengths of each, to help clients set climate change targets and measure their performance as well as secure financing to fund sustainability projects.

Nippon Koei has deep expertise in disaster prevention and renewable energy, having participated in major public-private partnerships in urban development programmes.

DHI is consultant to 140 countries in the conservation, re-distribution, quality control and flow management of water environments, spanning rivers, reservoirs, oceans, coastlines, cities and factories. It actively collaborates in joint projects with the World Health Organization and the United Nations.

Mr Wong Heang Fine, Group CEO, Surbana Jurong said, "The recent COP26 meeting underscored the complexities surrounding the transition to net zero. Surbana Jurong, Nippon Koei and DHI's partnership is a timely response to these challenges, particularly in the area of R&D innovation, financing and innovative engineering, to enhance the resiliency of urban infrastructure against the threat of rising sea levels and rising temperatures".

At the MoU signing ceremony, held online, are, from left to right, Mr Wong Heang Fine, Group CEO, Surbana Jurong; Ms Mette Vestergaard, CEO, DHI; and Mr Hiroaki Shinya, President and CEO, Nippon Koei.

Industry projections estimate that enhancing the resiliency of infrastructure could save USD 4.2 trillion from climate change damages globally.

The signing of the MoU has its roots in earlier collaborations that Surbana Jurong entered into, with Nippon Koei in 2020 and with DHI for the last 13 years.

Mr Hiroaki Shinya, President and CEO, Nippon Koei said, "Through collaboration between the three companies, we will promote projects on a global scale, mainly in Asia, where the formation of sustainable development projects through public-private partnerships is expected, and contribute to the achievement of sustainable development, by using comprehensive technological capabilities.

Ms Mette Vestergaard, CEO, DHI said, "The history, heritage, culture, and complementary skills and experience of our organisations position us well to offer exceptional and impactful solutions to our clients who require us to help them adapt and thrive in an uncertain world".

Mott MacDonald appoints new leads in ASEAN and East Asia

Mr David Boyland

Er. You FookHin

Mott MacDonald, a leading engineering, management and development consultancy, has appointed two new leads. Mr David Boyland will become the Unit General Manager for ASEAN and East Asia, and Er. You FookHin will become Deputy General Manager.

Mr Boyland joined Mott MacDonald in 1998 as a graduate and has had a long international project and senior management career spanning multiple continents around the world. He has been one of the key architects responsible for establishing and growing Mott MacDonald's global renewable energy business.

Before being appointed Unit General Manager, he was responsible for leading and delivering Mott MacDonald's Asia Pacific energy business, encompassing project and advisory work, primarily in decarbonised energy infrastructure such as hydropower, renewable energy, battery and energy storage systems and hydrogen. He devised and implemented a regional strategy development to position Mott MacDonald at the forefront of energy transition services in Asia Pacific.

Based in Singapore and moving forward in his new role, he will have accountability for leading and delivering Mott MacDonald's ASEAN and East Asia business operations within the infrastructural development and engineering sectors, including but not limited to, transport, water, energy and built environment infrastructure.

Er. You has extensive experience in advanced structural projects. He has been a member of Mott MacDonald, since 1989. He was, previously, Managing Director for the Singapore Office and, prior to this, he had performed Project Director roles within the consultancy.

His recent positions include being Project Director and Qualified Person on architectural and engineering consultancy services for the Eastern Region Line (ERL) MRT stations and Project Director on the North-South Line Extension Contract 156 Marina South station.

Er. You holds an MSc in Civil Engineering from the National University of Singapore. He is a Professional Engineer (PE) and a Senior Member of the Institution of Engineers, Singapore (IES). He was a winner of the Building and Construction Authority's Design & Engineering Safety Excellence Award 2009 and the same award for 2016, and was awarded the Ministry of Transport Minister's Innovation Award – Distinguished, for 2015, for his contribution to Singapore's First Underground Bicycle Park design.

Mr Boyland said, "Mott MacDonald has a long and proud heritage of infrastructural development in the ASEAN and East Asia region, stretching back more than 120 years. It is an honour to be given the responsibility of leading our business forward within the region and to continue our journey at the forefront of delivering some of the region's most critical infrastructure. I am especially committed to influencing and contributing to a vision that helps shape the low carbon future and deliver greater social outcomes".

Er. You said, "I am honoured to be appointed to this new role and look forward to working closely with our colleagues in ASEAN and East Asia, as well as Australia, New Zealand and Greater China, to grow the business further".

Mott MacDonald appointed lead consultant

Mott MacDonald has been appointed to deliver the Asian Development Bank's (ADB) Southeast Asia Facility for Resilient Cities (SFRC). The facility aims for provide technical assistance to project preparation for investment programmes in the urban development and water sectors, in developing member countries (DMCs) in Southeast Asia. Mott MacDonald will support the operations of ADB's Southeast Asia Regional Department (SERD) to catalyse climate resilient investments of up to USD 2.2 billion over the next five years.

ADB's SFRC aims to unlock transformative benefits from the long-term partnerships with cities and countries to address key urban issues such as declining water security, poor access to sanitation, inadequate flood management, poor municipal solid waste management, diminishing liveability, and faltering social inclusiveness.

Mott MacDonald will deliver holistic solutions and assist in generating knowledge on scalable and replicable interventions across the region.

Mott MacDonald's Director for the Southeast Asia Facility for Resilient Cities, Ms Stephanie Tseng, said, "In partnership with ADB, we are committed to working for the benefit of DMCs and help them achieve the incremental changes necessary to transform their cities into prosperous, inclusive, resilient, and sustainable places".

Lendlease appoints new Managing Director in Malaysia

Ms Yong Su-Lin

International real estate group, Lendlease, recently announced the appointment of Ms Yong Su-Lin as Managing Director, Malaysia. She joins the Asia Leadership Team, reporting directly to Mr Justin Gabbani, Chief Executive Officer, Asia.

Based in Kuala Lumpur, Ms Yong will assume leadership of the business in Malaysia, driving the strategy, growth and operations across Lendlease's Development, Investments and Construction businesses in the country.

The appointment follows incumbent Mr Stuart Mendel's return to Australia after seven years in Malaysia. Ms Yong commences her role on 1 March 2022.

Ms Yong has more than 25 years of corporate banking and real estate experience including project financing and consultancy. She was most recently CEO of Sentral REIT, a role she assumed in 2015. Part of the core team since 2006, Ms Yong was involved in the operations of Sentral REIT and led the investment and investor relations function.

"I would like to congratulate Su-Lin and welcome her to Lendlease. Malaysia is a key market for the Asia business and home to our largest integrated development – The Exchange TRX. Su-Lin's expertise and experience will add further perspective to the Asia Leadership Team. In collaboration with Dinesh Nambiar, who continues in his role as Chairman of Lendlease Malaysia, I look forward to further advancing our growth strategy and to continue to deliver long-term sustainable value", said Mr Gabbani.

Japanese researcher wins prestigious Lee Kuan Yew Water Prize 2020

When Professor Kazuo Yamamoto first shared his idea of submerging membranes in used water to improve the efficiency and quality of used water treatment in the mid-1980s, it was met with much scepticism from the membrane community as it went against the conventional scientific thinking of the time. Many regarded the concept as ridiculous and dismissed it as a 'crazy idea'.

Not one to concede defeat easily, Professor Yamamoto held fast to his convictions and persevered in his research to successfully develop the world's first operationally viable submerged Membrane Bioreactor (MBR) prototype in 1988. For his pioneering invention that has since benefitted millions worldwide with enhanced public health and water security, 67-year-old Professor Kazuo Yamamoto was awarded the Lee Kuan Yew Water Prize 2020.

The Lee Kuan Yew Water Prize, sponsored by Temasek Foundation, awards the winning recipient a SGD 300,000 cash prize, a certificate and a gold medallion.

"It is a great privilege to be bestowed the distinguished Lee Kuan Yew Water Prize. This award nurtures the spearheading soul and innovative outlook needed to inspire future generations of water leaders to persevere and continue our objective of benefitting communities around the world in the areas of sanitation and water reuse", said Professor Yamamoto.

Professor Yamamoto, who is the 9th recipient of this award, is currently Emeritus Professor at the University of Tokyo, in Japan, and an Audit & Supervisory Board Member of IDEA Consultants Inc, an environmental and infrastructure consultancy firm based in Tokyo, Japan.

Overcoming challenges to strengthen water sustainability

Although MBRs for used water treatment had existed prior to Professor Yamamoto's prototype, earlier designs could not be adopted on a large scale, due to their massive energy requirement and a propensity for the membranes to foul easily. Professor Yamamoto then engineered a design that uses hollow fibre membranes that are submerged into the biological treatment tank and the filtration is done intermittently, instead of continuously – the process is called intermittent filtration. This circumvents both the energy-intensive recirculation loop and membrane fouling issues found in earlier MBR designs and was a breakthrough in the field of used water treatment and water reuse.

From left, Mr Ryan Yuen, Managing Director, Singapore International Water Week; Mr Ng Joo Hee, Chief Executive, PUB; Professor Kazuo Yamamoto, Lee Kuan Yew Water Prize 2020 Laureate; Mr Harry Seah, Deputy Chief Executive (Operations), PUB; and Dr Pang Chee Meng, Chief Engineering & Technology Officer, PUB.

Although he was the first person to present the submerged MBR concept at the International Association on Water Quality Conference in 1988, Professor Yamamoto chose not to claim patent rights for his invention. His decision allowed for extensive research & development, and commercialisation efforts to be carried out, which accelerated the adoption of submerged MBR technology for used water treatment, thus benefitting the water sector and humanity at large. Professor Yamamoto also continued to contribute to the advancement of the technology through further research and close partnerships with membrane companies in Japan and abroad, that facilitated the commercialisation and implementation of the technology globally.

Today, submerged MBR technology is widely recognised by experts as an effective technology to achieve effluent quality standards beneficial for water reuse, which also reduces the environmental impact of used water discharge. The technology has paved the way for governments and water solutions providers across the world to develop higher standards of public health. It has reduced the impact of used water discharges to the environment and enabled savings on infrastructural cost, facilitated by shorter outfall pipelines, thanks to the high-quality effluent suited for potable reuse. It is also a sustainable treatment option for fast growing communities, as it can be quickly retrofitted into existing plants.

Widespread application for greater impact

Over the last few decades, there has been an exponential increase in the number and in the scale of MBR plants commissioned for municipal used water treatment, based on Professor Yamamoto's design. Since 2010, the total capacity

Process unit (digester) at Changi Water Reclamation Plant.

of the MBR system has more than doubled from around 4.1 million m³/d to over 8.3 million m³/d by 2014. Since the early 2000s, MBR has become almost on par with tertiary treatment systems, with approximately 45% of large-scale used water installations globally being MBR systems. This is a sign that there is a shift in the technology's application, from niche areas in smaller installations to larger projects, particularly in the municipal sector.

Singapore has adopted MBR technology in its used water treatment processes since 2006. They are currently implemented in three water reclamation plants (WRPs) – Changi, Ulu Pandan and Jurong. MBR technology, with a smaller footprint, has helped reap significant benefits for land-scarce Singapore. The higher quality effluent produced greatly facilitates water reuse and NEWater production which is a key pillar of Singapore's water sustainability strategy. Tuas WRP, currently under construction, will similarly adopt MBR technology to treat used water.

"We in Singapore have benefitted tremendously from Yamamoto's work. His creation lets us build very compact water reclamation plants, freeing up land for other uses. Tuas WRP – currently under construction and the world's largest MBR plant when it becomes operational in 2026 – occupies only half the usual footprint because of his discovery. The high quality of effluent that will come out of Tuas, again because of submerged MBRs first invented by Yamamoto, will enhance NEWater production and further advance the circularity of Singapore's water economy", said Mr Ng Joo Hee, Chief Executive, PUB, Singapore's National Water Agency.

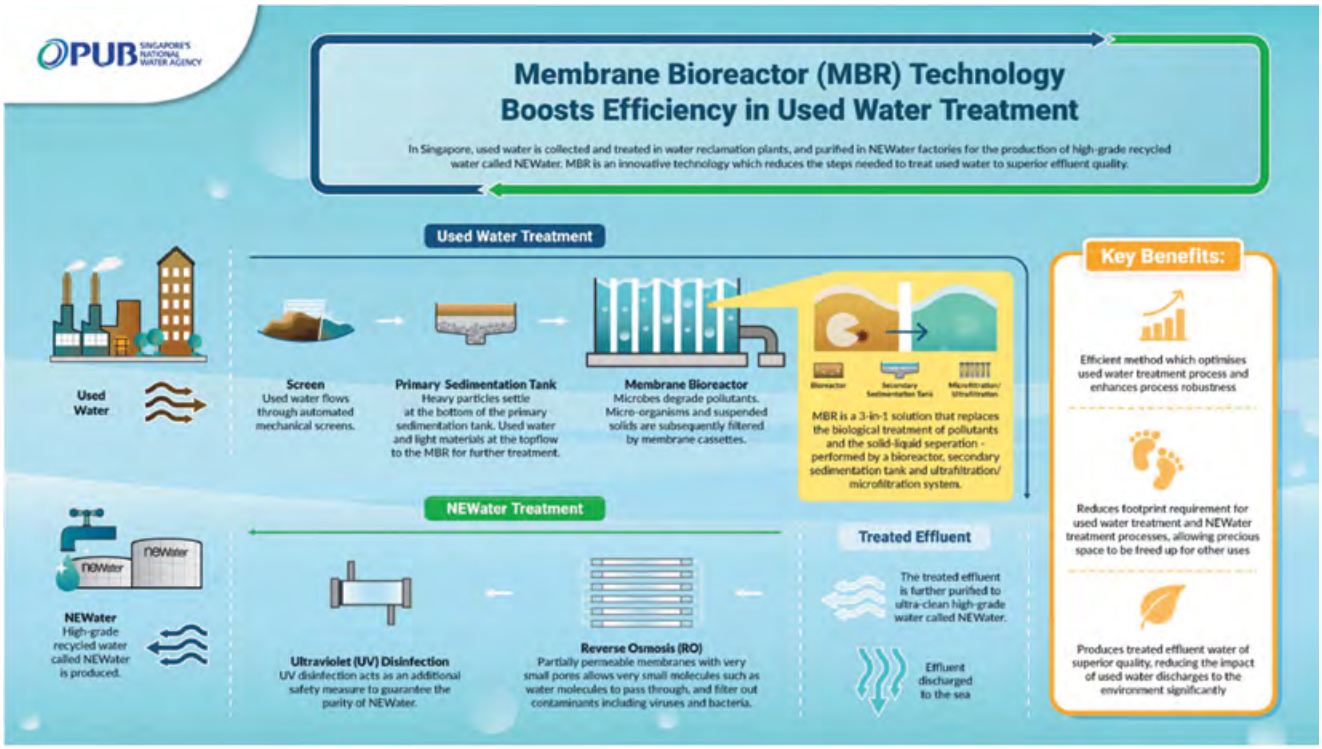
Professor Yamamoto has also advised on national used water treatment projects around the world, since 2007, such as for a low-energy demo wastewater treatment plant (WWTP) for industrial used water reuse in Saudi Arabia, and for Myanmar's first MBR-based WWTP. In 2011, he chaired the Sewage Technical Meeting on Membrane Technology to develop guidelines for introducing membrane technology in sewage works.

"The Lee Kuan Yew Water Prize recognises outstanding individuals or organisations for their efforts directed towards solving the world's water challenges and whose work will benefit millions or even billions, globally. We are proud to have Professor Yamamoto join our distinguished list of laureates. We look forward to welcoming global water leaders, like Professor Yamamoto, in-person, to share and exchange innovative solutions to solve emerging urban water challenges, at Singapore International Water Week 2022 in April", said Mr Ryan Yuen, Managing Director, Singapore International Water Week (SIWW).

Professor Yamamoto will receive the Lee Kuan Yew Water Prize 2020 medallion from Mdm Halimah Yacob, President of the Republic of Singapore, at an award ceremony to be held on 18 April 2022, during the 9th edition of SIWW. This event, which will be held from 17 to 21 April 2022, will feature a range of flagship programmes, such as the Water Leaders Summit, the Water Convention and the Water Expo, for thought leaders and stakeholders from the global water industry to share best practices and solutions, harness business opportunities and co-create innovative water solutions.

Lee Kuan Yew Water Prize

Named after Singapore's first Prime Minister, whose foresight, and leadership enabled Singapore to attain a sustainable water supply, the Lee Kuan Yew Water Prize was launched in 2008, to honour outstanding contributions by individuals or organisations towards solving the world's water problems, by developing or applying innovative technologies or implementing policies and programmes that benefit humanity.



APPLICATION OF MEMBRANE BIOREACTOR TECHNOLOGY IN SINGAPORE'S WATER RECLAMATION

Since 2006, PUB has been adopting the Membrane Bioreactor (MBR) technology for water reclamation in Singapore. The application of MBR technology is a 3-in-1 solution that combines conventional bioreactors, secondary sedimentation tanks and microfiltration / ultrafiltration in one single step. MBR can be applied for the production of Industrial Water or combined with Reverse Osmosis to produce NEWater.

In the private sector, large manufacturing companies use MBR technology to recycle industrial wastewater for re-use as cooling tower makeup. The availability of reliable technologies such as MBR enables the industry to play a major role in the conservation of precious water resources.

Following the successful trial at Ulu Pandan Water Reclamation Plant (WRP), MBR was implemented at full-scale for one of the treatment trains at Jurong WRP to produce Industrial Water. Subsequently, Changi WRP also retrofitted four of the existing 24 bioreactor basins into MBR facilities, increasing the plant's treatment capacity by 26 million gallons per day (mgd). Over the years, as PUB expanded its application of MBR technology, its engineers optimised the treatment process further and harnessed significant energy savings. Optimisation measures included improved equipment design and the modification of key operating parameters, which systematically brought down the MBR process energy consumption by 80% over a 15-year period of R&D.

Currently, PUB's total MBR treatment capacity is about 13% of Singapore's used water treatment capacity. This will increase to about 22% when Changi WRP Phase 2 expansion is completed, and to 54% when Tuas WRP – the world's largest MBR facility – is commissioned.

There are several benefits realised through the application of MBR technology at PUB plants.

Firstly, it takes up less space than conventional systems. MBR is used after larger particles are removed, in the secondary stage of used water treatment. It uses naturally occurring bacteria which break down waste products in used water, after which microfiltration / ultrafiltration membranes filter the remaining impurities. It offers a more efficient method of used water treatment as it optimises the used water treatment process, enabling used water to be treated using fewer steps and less space compared to conventional systems. The implementation of MBR can reduce the total treatment footprint by up to half, as compared with conventional WRPs with a single stack sedimentation tanks.

Secondly, it produces treated used water that is cleaner than what the conventional treatment process produces.

Thirdly, the product water quality is highly consistent, and can be applied to produce industrial water or combined with Reverse Osmosis to produce NEWater, boosting water reuse in Singapore.

WRPs in Singapore

Singapore is currently served by four large Water Reclamation Plants (WRPs), namely, Kranji, Jurong, Ulu Pandan and Changi WRPs.

Changi WRP, commissioned in 2008, is the largest of the four WRPs, treating more than half of Singapore's used water.

Used water from households and industries is conveyed to Changi WRP through a network of sewers and the Deep Tunnel Sewerage System (DTSS).

Pumps in two 70 m deep pumping stations lift the used water up to the treatment modules where particles are removed, and pollutants and organic matter are broken down.

The treated used water undergoes further purification at the two NEWater factories on the roofs of Changi WRP to produce ultra-clean, high-grade reclaimed water used primarily by industries that require ultra-pure water for production processes.

World's largest MBR facility at Tuas WRP

An advanced water reclamation plant located in Tuas will be commissioned in 2026. Slated to be the world's largest MBR facility, Tuas WRP will treat used water conveyed from the western half of Singapore.

It will be equipped to receive both domestic and industrial used water streams from two separate deep tunnels for treatment. The plant will also be capable of treating industrial used water to a sufficiently high standard for industrial use – a first for Singapore.

A NEWater factory will also be built on the roof of the plant. This factory will significantly boost PUB's NEWater production capability and help ensure a resilient water supply.

Tuas WRP will form part of Tuas Nexus, Singapore's first integrated water and solid waste treatment facility, forging a more sustainable Singapore by optimising land use and maximising energy and resource recovery.

Alstom named one of Singapore's Top Employers 2022

Alstom, a leader in smart, sustainable mobility, has obtained the Top Employer 2022 certification in Singapore for the second consecutive year. The company has also received the recognition in Australia, China, Hong Kong and India, in the Asia Pacific region.

Alstom has been responding to the growing demand for greener, more modern metro and light rail fleets and equipment, with optimised capacity in Singapore for over 20 years. While delivering a reliable and safe rail service to Singapore commuters, the company is equally dedicated to maintaining a happy, healthy and motivated workforce.

"At Alstom, the people agenda is central to the business. It is all about keeping people engaged with us, and ensuring that they feel empowered and supported in their career aspirations. As a result, our team has continued to deliver outstanding performance even while working remotely during the pandemic. On top of being the largest rail system supplier, this recognition, as the only Top Employer in Singapore's mobility industry, is further testament to our commitment to making Alstom one of the best work environments here", said Mr Jayaram Naidu, Managing Director for Alstom in Singapore and Malaysia.

Today, Alstom's solutions are implemented on all existing MRT lines and the Bukit Panjang LRT.

Even before the start of the pandemic, employee wellbeing had been a key employer focus for Alstom. With the company's profile in Singapore, which combines qualified teams and diverse product portfolios, efforts are afoot to strengthen not only the health, but also the resilience of its expanded, localised workforce.

Some of the actions taken at Alstom to enhance employee well-being include providing flexible and safe work arrangements, as well as an Employee Assistance Programme with a 24/7 helpline to support employees with personal problems. Virtual classes are also organised with the aim of helping employees balance various facets of life, as well as continuously grow and improve themselves. At the same time, interns and new joiners are assimilated into the organisation through a structured digital onboarding programme.

Top Employer certification

The Top Employer certification recognises a company's commitment to creating a better working environment and the excellence of its HR policies and practices. The Top Employers Institute certifies organisations based on the results of its HR Best Practices Survey.

Alstom

Headquartered in France, Alstom is now present in 70 countries and employs more than 70,000 people.

Boarding a train at a station along the Circle Line MRT in Singapore. Image: Alstom / A Fevrier.

Singapore International Water Week 2022 to be held in April

Singapore International Water Week (SIWW) 2022 will take place, from 17 to 21 April 2022, at the Sands Expo and Convention Centre, Marina Bay Sands, alongside CleanEnviro Summit Singapore 2022.

Into its 9th edition, SIWW 2022 will be one of the first international water shows to be held in-person in the Asia-Pacific region, since the pandemic. It will also feature an online, on-demand component that allows global attendees to watch recordings of all sessions delivered at the event.

This year's event carries great significance for a few reasons. First, it marks the resumption of face-to-face business meetings and interactions, after a hiatus.

More importantly, building on the momentum generated by the 2021 United Nations Climate Change Conference (COP26) held in Glasgow, in November 2021, SIWW 2022 seeks to present solutions and innovations to spur collective action by the water sector to build resilience against climate change impacts and create a sustainable water future.

Key thematic areas presented during SIWW 2022 will revolve around climate mitigation and adaptation efforts by utilities, cities, and industries, including net zero, decarbonisation, nexus and circularity, digital water and sustainability. To achieve this, SIWW 2022 will invite leaders, experts and practitioners from governments, utilities, international organisations, industry and academia, to share best practices, co-create innovative urban water solutions, and generate new business opportunities.

SIWW is organised by Singapore International Water Week Pte Ltd, a company set up by Singapore's Ministry of Sustainability and the Environment and PUB, Singapore's National Water Agency.

Flagship programmes and platforms that will be delivered at SIWW2022 include:

- The Water Leaders Summit which brings global water leaders together to share strategies, policy insights and solutions, to tackle urban water challenges. The summit will focus on climate impacts and look to the future of global water megatrends.
- The Water Convention, a platform for professionals and technology providers from around the world to share their knowledge, practical experiences, and novel technologies for addressing the current and emerging water challenges.

  Comprising an opening plenary, six hot issues workshops, 49 oral sessions, one poster session and a closing plenary, the Water Convention will present over 300 high quality papers spanning six themes – Delivering Water from Source to Tap (Network), Delivering Water from Source to Tap (Treatment), Effective and Efficient Wastewater Management (Treatment & Conveyance), Cities of the Future, Water Quality and Health, and Nexus and Circularity.
- The Lee Kuan Yew Water Prize 2020 which will awarded at SIWW 2022, to recognise the achievements of a water expert for the expert's outstanding contributions in tackling the world's water problems.
- The Water Expo which is melting pot of products and services. Featuring 350 international exhibitors with 14 dedicated country and regional pavilions, the expo provides a one-stop marketplace for buyers looking for innovative urban water solutions.
- Thematic Forums that provide deep dives on thematic areas, offering case studies and applied solutions to address specific urban water challenges. Business Forums share critical information on emerging trends, business opportunities and challenges in today's water sector to improve delegates' understanding of the market and provide insights into specific project opportunities.
- TechXchange, a forum connecting innovators with investors, partners, and buyers to share innovative technologies, promote interactive debate and generate networking opportunities.
- Technical Site Visits to some of PUB's water facilities and installations, exemplifying the best of sustainable urban and water solutions.

SIWW 2022 is strongly supported by 12 founding sponsors, one platinum sponsor, eight gold sponsors, one knowledge partner sponsor, five corporate sponsors and six strategic partners.

A view of Singapore International Water Week 2018. Image: Singapore International Water Week.

CleanEnviro Summit Singapore 2022 to address sustainability and urban environmental challenges

The fifth edition of CleanEnviro Summit Singapore (CESG) will be held, from 17 to 21 April 2022, at the Sands Expo and Convention Centre, Marina Bay Sands. The event will address the theme 'Towards Sustainable and Climate-Resilient Cities'.

CESG is a global networking platform for thought leaders, regulators, policy makers, and industry captains to discuss pressing and pertinent issues, such as promoting circular economy frameworks, adopting climate resilient policies and safeguarding public hygiene standards.

The five focus areas are Waste as Resource, Enhanced Hygiene Standards, Effective Pest Management, Sustainable Energy, and Pollution Control.

Bringing leaders together

A hallmark feature at every CESG is the Environmental & Water Leaders Forum, jointly organised with Singapore International Water Week (SIWW). This year's forum will feature industry leaders and senior government officials from around the world, including Ms Michele Blom, Netherlands' Vice-Minister of Infrastructure and Water Management; and Mr Paul Bulcke, Chairman, Nestle.

The forum will tackle issues contributing to climate change, such as urbanisation and population growth, finite resources, and the need for clean water, sanitation and public hygiene. Leaders at the forum will share their views on how nations and organisations can capitalise on the sustainability challenges and transform them into opportunities.

Environmental leaders will connect and forge new partnerships at the Clean Environment Leaders Summit (CELS) to advance their sustainability agenda. Speakers at the plenary sessions of CELS include Ms Grace Fu, Minister for Sustainability and the Environment, Singapore; Mr Rajeev Menon, Board Member of the US-ASEAN Business Council and President, Marriott International Inc for Asia Pacific excluding Greater China (APEC); and Dr Amy Khor, Senior Minister of State for Sustainability and the Environment, Singapore.

Another highlight of CESG is the Clean Environment Convention (CEC), where industry professionals and technical experts will get to network and exchange ideas about the latest solutions and best practices to meet environmental needs and challenges. The convention will comprise four tracks – Sustainable Energy and Energy Efficiency; Resource Sustainability; Advancing Public Hygiene (Environmental Cleaning); Disinfection & Pest Management in an Urban Environment; and Innovations & Technology in Climate Change Defence (held in collaboration with the Asia Climate Forum).

The concurrent Environment Expo will feature innovative solutions and the latest technologies in cleaning, pest management, waste and resource management, pollution control and sustainable energy. Innovative solutions to build resilience and address extreme weather and climate change will also be presented at the Asia Climate Forum Exhibit.

Lastly, CESG 2022 will feature a Youth Environment Leaders Immersion Programme for the first time. The programme will provide opportunities for a group of youth leaders to network and exchange ideas with their peers, as well as learn from accomplished environment leaders and industry captains in the environmental sustainability space.

"We look forward to the return of the CleanEnviro Summit Singapore (CESG) after a three-year hiatus. This is an important platform for industry leaders, regulators and policy makers to reconnect and renew commitments to address sustainability and climate-related issues that are challenging all of us. Showcasing at CESG are novel technologies and solutions that can help turn waste into resources, improve public hygiene standards and monitor pollution. We hope that CESG can be the landmark platform for the region's key players to explore innovative solutions and forge new partnerships towards creating a more sustainable and climate-resilient world", said Mr Dalson Chung, Managing Director, CESG.

A presentation at CleanEnviro Summit Singapore 2018. Image: National Environment Agency.

Singapore projects among winners of Structural Awards 2021

Apple Marina Bay Sands and Jewel Changi Airport are included within the diverse range of structures recognised.

Apple Marina Bay Sands. Image: Ian Langham.

In early November 2021, the Institution of Structural Engineers (IStructE) announced the winners of the Structural Awards 2021. Now in its 54th year, the awards celebrate the best work of the global structural engineering community.

Apple Marina Bay Sands won in 'The Award for Construction Innovation' category while Jewel Changi Airport won in 'The Award for Long Span Structures' category.

The coveted Supreme Award for Structural Engineering Excellence, presented to the year's most outstanding example of structural engineering design, was jointly won by Christchurch Town Hall, New Zealand (which also received 'The Award for Structural Heritage') and

Jewel Changi Airport. Image: Safdie Architects.

Lille Langebro, Denmark (which also received 'The Award for Pedestrian Bridges').

The winners were chosen from a list of 53 pioneering projects across 13 categories and judged according to their creativity, quality and sustainability as well as the ingenuity of the engineering team behind them.

The entries underline how structural engineers around the world are responding to emerging issues in construction, particularly the climate challenge. Many of the shortlisted and winning projects showcase adapted approaches, designed to deliver the same exceptional work in a more eco-friendly way.

Commenting on this year's programme, Professor Tim Ibell, Chairman of the Judging Panel and former IStructE President, said, "Massive congratulations to all the winners and thanks to all those who entered. What this year's submissions demonstrated is how there has been a shift in attitudes towards green building. No doubt we will see sustainability become a non-negotiable project requirement, as important as structural integrity, safety and comfort".

"It will also influence the way these awards are judged, going forward, becoming an essential part of the application process. It will help demonstrate how our profession is playing a key role in reducing waste and protecting the environment", he added.

The Structural Awards

The Structural Awards celebrate the achievements of structural engineers as innovative, creative design professionals and the guardians of public safety.

For over 50 years, the Structural Awards have showcased the world's most cutting edge engineering achievements.

All entries are reviewed by a panel of world renowned judges who are truly passionate about structural engineers' contribution to society as design professionals.

Christchurch Town Hall. Image: Holmes Consulting LP.

Lille Langebro. Image: Buro Happold.

The Institution of Structural Engineers

The Institution of Structural Engineers (IStructE) is the world's largest membership organisation dedicated to the art and science of structural engineering. IStructE has over 28,000 members working in 105 countries around the world.

WINNERS OF STRUCTURAL AWARDS 2021

THE SUPREME AWARD FOR STRUCTURAL ENGINEERING EXCELLENCE (& THE AWARD FOR STRUCTURAL HERITAGE)

Winner: Christchurch Town Hall

Location: Christchurch, New Zealand

Structural Designer: Holmes Consulting

Client: Christchurch City Council

In the project to repair and strengthen a town hall following devastating earthquakes, significant portions of the structure were upgraded, repaired and restored. Other areas underwent a complete rebuild. High-end analysis minimised the strengthening work required for the superstructure. On completion, the town hall achieved a 100% New Building Standard rating.

THE SUPREME AWARD FOR STRUCTURAL ENGINEERING EXCELLENCE (& THE AWARD FOR PEDESTRIAN BRIDGES)

Winner: Lille Langebro

Location: Copenhagen, Denmark

Structural Designer: Buro Happold

Client: Realdania By & Byg

The Lille Langebro is the latest moveable bridge to be built across Copenhagen harbour. Its elegant design was the result of an international competition and incorporates a complex geometry

that has demanded excellence in structural design and detailing. In order to maintain a slender profile in elevation, an innovative moment connection has been designed to connect the moving parts together at midspan. The four bridge sections were prefabricated off-site and delivered to site by sea.

THE AWARD FOR CONSTRUCTION INNOVATION

Winner: Apple Marina Bay Sands

Location: Singapore

Structural Designer: Eckersley O'Callaghan and Foster + Partners

Client: Apple

Apple Marina Bay Sands in Singapore is the largest structure in the world to use glass as the primary bracing system and, as a consequence, it has a very slender steel frame, the simplicity of which belies its engineering complexity. Its design is the culmination of nearly 20 years of Eckersley O'Callaghan's research, development and practical experience of working with structural glass. Every aspect of the design of this project was considered and meticulously detailed. At each stage, the engineers have worked closely to push the boundaries of engineering design – from the technique used to bend the glass and the bespoke scripting written to analyse the structure, to the connection design and prefabrication for construction.

THE AWARD FOR CONSTRUCTION INNOVATION

Commendation: King's Scholars Pond Sewer Rehabilitation

Location: Westminster, London, UK

Structural Designer: Transport for London

Client: Transport for London

The project rehabilitated the 170-year-old KSP Bazelgette sewer buried beneath one of London's busiest intersections and above one of London Underground's live tunnels at Baker Street, without either rail or road closure. The project boasts impressive savings of GBP 23 million and 26,443 t CO_2 against the client's original business plan. With a design life of 120 years, it also eliminates catastrophic failure of the asset and associated disruptions and risk to the public.

King's Scholars Pond Sewer Rehabilitation. Image: Roozbeh Shirandami.

THE AWARD FOR LONG SPAN STRUCTURES

Winner: Jewel Changi Airport

Location: Singapore

Structural Designer: Buro Happold

Client: Jewel Changi Airport Trustee Pte Ltd

The new mixed-use complex at Jewel Changi Airport in Singapore delivers an exceptional experience for the 85 million passengers estimated to pass through it every year. Occupying a site of approximately 1.4 million ft², this lifestyle destination, combines shopping, hotel and dining facilities as well as a tropical forest valley within a global air travel hub. At the apex of Jewel's glass roof is an oculus that showers approximately 10,000 gallons of rainwater a minute down through this spectacular central garden space.

THE AWARD FOR LONG SPAN STRUCTURES

Commendation: Shijiazhuang International Convention and Exhibition Center

Location: Shijiazhuang, Hebei Province, China

Structural Designer: Architecture Design & Research Institute of Tsinghua University

Client: China Construction Haoyun Co Ltd

Shijiazhuang International Convention and Exhibition Center is located in Hebei Province, China. The project includes four groups of large exhibition halls which were realised by two-way cable structure. The longest span of the cable reaches 108 m, and the area covered by the bidirectional cable roof reaches 288 m x 105 m, making it one of the largest structures of this type in the world. The project combines the natural arc of the cable with the sloping roof of a classical Chinese building to create a traditional and architecturally graceful external appearance, and a large and clear interior space.

THE AWARD FOR MINIMAL STRUCTURAL INTERVENTION

Winner: Elizabeth Line OLE Gantry Rigorous Assesments

Location: UK

Structural Designer: Buro Happold

Client: Network Rail

The new Elizabeth Line includes existing above-ground sections between Stratford and Maidenhead where new overhead line equipment (OLE) has been installed. This equipment is supported by gantries

of different types that are up to 70 years old. Initial assessment, based on traditional codified approaches, showed that replacement would be necessary. However, rigorous non-linear structural analysis was developed that led to the majority of the structures being safely retained. The project is noteworthy for significant programme/cost savings achieved using sophisticated engineering analysis. It is also remarkable from a sustainability point of view as a vast amount of infrastructure has been reused.

THE AWARD FOR PEDESTRIAN BRIDGES

Commendation: Swing Bridge to Dinosaur Island

Location: Crystal Palace Park, London, UK

Structural Designer: Arup

Client: Friends of Crystal Palace Dinosaurs

Swing Bridge to Dinosaur Island is a moving pedestrian footbridge offering secure access to the Grade 1-listed Dinosaur Sculptures located within a waterway in Crystal Palace Park, London. The team's unique approach to the design allowed for a simple and robust solution to be sought, that elegantly balanced the needs of the client. The bridge featured a number of innovative solutions that allowed for efficient fabrication and erection and, importantly, came to define the character of the bridge. The bridge was made possible through generous donations and pro-bono time. Working to a tight budget required the design to be materially efficient and therefore more sustainable, and the project acted as a catalyst to draw the local community together.

THE AWARD FOR SMALL PROJECTS (OF UNDER GBP 3 MILLION)

Winner: The Viper Elevated Walkway at the Newt in Somerset

Location: Castle Cary, UK

Structural Designer: Henry Fagan & Partners

Client: Mr Koos Bekker, The Newt in Somerset

Shijiazhuang International Convention and Exhibition Center. Image: Architecture Design & Research Institute of Tsinghua University.

Elizabeth Line OLE Gantry Rigorous Assesments. Image: Buro Happold.

Swing Bridge to Dinosaur Island. Image: Stuart Chambers.

The Viper Elevated Walkway at the Newt in Somerset. Henry Fagan & Partners.

The Viper is an elegant and elevated woodland walkway. The design took a sensitive approach to the environment, ensuring minimal impact on the natural forest floor. To achieve this, columns are supported on tripods on steel piles and manufactured to individual bespoke dimensions. Its winding layout is designed to avoid all the trees in the forest canopy.

THE AWARD FOR SMALL PROJECTS (OF UNDER GBP 3 MILLION)

Commendation: Stroud Christian Community Chapel

Location: Gloucestershire, UK

Structural Designer: Corbett & Tasker

Client: The Christian Community

The new Christian Community Chapel in Stroud is a low carbon, original and innovative development of 'folded plate' or origami structures, realised using Cross Laminated Timber panels to form a complex polyhedral form, reminiscent of traditional vaulted cathedrals. The structural panels are honestly expressed internally to create a subtle planar form, with otherwise visually distracting stiffening glulam ribs screwed to the panels externally. The 3D form is derived from sacred geometry and forms an efficient and elegant structure where in-plane forces dominate, creating an acoustically sealed 'sound box' where spoken word and music naturally resonate within the chapel structure. Advanced finite element analytical techniques were developed to justify the unique rib stiffened structural shell which makes up the roof and walls, taking into account the orthotropic nature of the panels.

Stroud Christian Community Chapel. Image: Tom Bignell.

Taiyuan Botanical Garden Domes. Image: Lucas Epp.

THE AWARD FOR STRUCTURAL ARTISTRY (BUILDING STRUCTURES)

Winner: Taiyuan Botanical Garden Domes

Location: Taiyuan, China

Structural Designer: Arcplus Institute of Shanghai Architectural Design & Research (Co Ltd) and StructureCraft

Client: Taiyuan Botanical Garden

The three domes, with spans of up to 89.5 m are constructed through a new structural system which combines timber beams overlapped in two directions and stainless steel cables, making it the largest span of its kind in world. The adoption of new overlapping joints and splicing joints presents the architectural effect of the whole timber structure exposed outside and integrated into the exterior topography. The greenhouses are located on the already existing coal mining pit. The project concept is based on land restoration. The choice of materials follows the subject-matter, using natural elements to create the atmosphere.

THE AWARD FOR STRUCTURAL ARTISTRY (NON-BUILDING STRUCTURES)

Winner: Future Tree

Location: Esslingen, Switzerland

Structural Designer: Basler & Hofmann AG

Client: Basler & Hofmann AG

The Future Tree is an eye-catching canopy. The digitally fabricated crown is made of 380 timber elements. The frame's geometry plays with the opening of the reciprocal knots to achieve a higher stiffness in the cantilevering part. For the reinforced concrete column, a 3D printed formwork was combined with a fast-hardening concrete. The project demonstrates the potential of digital technologies to develop a new design language, optimise functionalities and reduce construction waste.

Future Tree. Image: Tanja Coray

THE AWARD FOR STRUCTURAL HERITAGE

Commendation: Repair and Rehabilitation of Daly's (Shakey) Bridge

Location: Cork, Ireland

Structural Designer: RPS Consulting Engineers Ltd

Client: Cork City Council

The rehabilitation of Daly's (Shakey) bridge project has seen one of Cork's most iconic structures faithfully restored for future generations to enjoy. The suspension bridge is a well-known, local landmark and its colloquial name, 'Shakey bridge', derives from the lively movement of the deck under footfall. The David Rowell design remains the only suspension bridge in Cork City and is the only surviving bridge of its type in Ireland. The timely execution of the structural repairs ultimately prevented the introduction of load restrictions and eventual closure of the bridge. RPS used analytical structural models and physical accelerometer measurements to record and monitor the natural frequency and vibration response of the structure prior to, and following, repair works, to ensure the signature shake was retained. The successful delivery ensures continued safe use of the bridge and protects a significant contributor to the built heritage of the city.

Repair and Rehabilitation of Daly's (Shakey) Bridge. Image: Michael Minehane.

THE AWARD FOR STRUCTURAL TRANSFORMATION

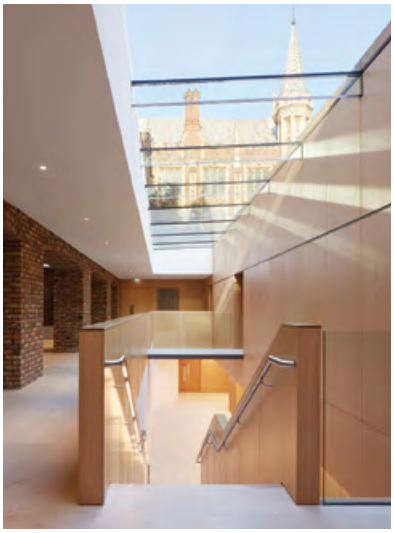
Winner: Ashworth Centre and Library Extension - Lincoln's Inn Fields

Location: London, United Kingdom

Structural Designer: Eckersley O'Callaghan

Client: The Honourable Society of Lincoln's Inn Fields

A major, recent refurbishment included a 3,000 ft² extension to the existing library building, separated by a glass link, and the addition of two cavernous basement spaces totalling 20,000 ft² and linked directly to the historic building via new subterranean apertures. Obtaining planning permission for such an intervention on this iconic site required a thoroughly measured approach with contention across the council committee, client and tenants. This sprawling project presented challenges across a range of materials and scale, and included safeguarding the historic building and the subtleties required for a sympathetic response to the reconfigured architecture. Numerous junctions with the existing buildings were carefully detailed to allow the two to freely articulate without visual disruption.



Ashworth Centre and Library Extension - Lincoln's Inn Fields. Image: Duncan Walsh.

THE AWARD FOR STRUCTURES IN EXTREME CONDITIONS

Winner: Atrio North Tower

Location: Bogotá, Colombia

Structural Designer: Arup and PYD (Engineer of Record)

Client: Grupo A, QBO

The Atrio project has a scale and ambition which is unprecedented in Colombia. Rising over 200 m, and set against the ridges of the Andes, the striking architecture of North Tower is symbolic of a brighter future for Colombia whilst also being a remarkable integrated engineering solution that responds to a challenging and highly seismic site. The structural design resolves complex technical challenges which have required both research and construction collaboration to realise an architecturally expressed, and highly efficient, composite braced frame. At 46 storeys, and with a total development area of 120,667 m², it is the tallest office building in Colombia.

THE AWARD FOR TALL OR SLENDER STRUCTURES

Winner: Tianjin CTF Finance Centre

Location: Tianjin, China

Structural Designer: Skidmore, Owings & Merrill and ECADI

Client: New World China Land Limited Project Management Department

A dramatic, undulating profile distinguishes this 530 m-tall tower, as a new landmark in the growing Tianjin Economic-Technological Development Area (TEDA). The tower's design is a synthesis of architectural, structural, and functional requirements. The primary structural innovation for the tower was the use of a system of 'soft-braces' consisting of variable sloped columns that were configured to simultaneously optimise the structural performance for both the frequent and the rare seismic events.

Atrio North Tower. Image: Tom Clewlow.

Tianjin CTF Finance Centre. Image: Seth Powers.

THE AWARD FOR VEHICLE BRIDGES

Winner: Rose Fitzgerald Kennedy Bridge over the River Barrow

Location: Wexford and Kilkenny, Ireland

Structural Designer: Arup and Carlos Fernandez Casado S L

Client: Transport Infrastructure Ireland

The Rose Fitzgerald Kennedy Bridge is one of the most iconic structures in Ireland. This nine-span, three-tower extradosed bridge comprises a single central plane of cables supporting four traffic lanes. At 887 m between expansion joints, the bridge is considered the longest in Ireland, while the two main spans of 230 m each are the longest post-tensioned extradosed concrete spans in the world.

THE AWARD FOR ZERO-CARBON AMBITION

Winner: York House

Location: King's Cross, London, UK

Structural Designer: Webb Yates Engineers

Client: The Office Group

Situated in the heart of Kings Cross, York House is an eight-storey refurbishment and extension scheme providing flexible co-working space for The Office Group.

The existing building was one of the earliest office blocks built on Pentonville Road. Although it stands in a prominent location with a triple aspect outlook, the building was not in use due to the deterioration of the façade and dimly lit, poorly ventilated internal spaces.

The existing building was refurbished across all floors, providing meeting rooms, open plan areas, reception, café, bike storage and changing facilities. A new lightwell was added at the front of the building, to make the existing basement usable as office space. At the front, a new CLT extension was added, and the existing structure at roof level was extended with a CLT structure, providing flexible working spaces.

THE AWARD FOR ZERO-CARBON AMBITION

Commendation: Oregon Forest Science Complex

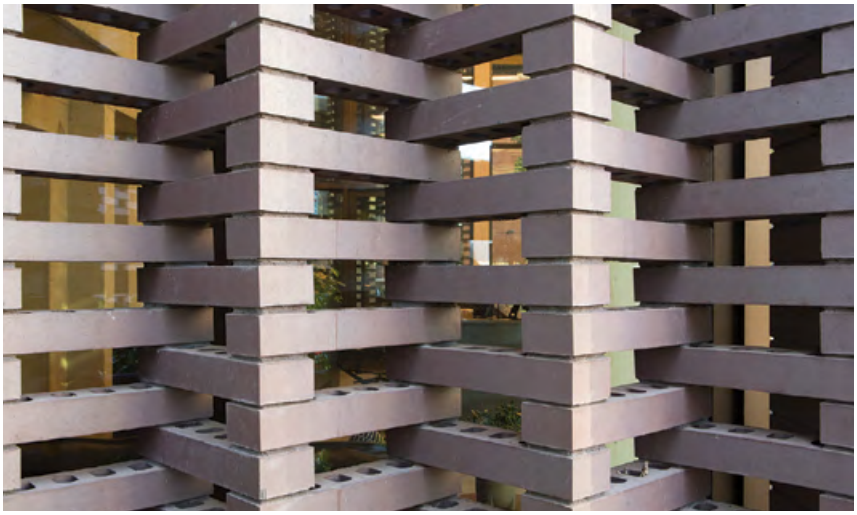
Location: Corvallis, Oregon, USA

Structural Designer: Equilibrium Consulting Inc.

Client: Oregon State University

The Oregon Forest Science Complex comprises two new faculty buildings for Oregon State University, and includes an extensive variety of classrooms, laboratories, and gathering places. The building structure sets a new bar for contemporary timber construction founded on state-of-the-art components, including the first use of self-centring post-tensioned CLT shear-walls in North America, as well as large timber-concrete composite spans substantiated by significant research, analysis and on-site vibration testing. The complex is living proof that mass timber has earned its rightful place among high-tech construction materials for institutional buildings, offering a viable alternative to traditional high-performance construction systems, at a competitive cost, and with a fraction of the embodied carbon.

Rose Fitzgerald Kennedy Bridge over the River Barrow. Image: insta_mavic.



York House. Image: Agnese Sanvito.

Oregon Forest Science Complex. Image: Daniel Dowek.

Continuing a legacy of achievement

Er. Yeang Hoong Goon. Image: CPG Consultants.

With the first office for public works established in Singapore, in 1833, CPG Corporation, as the corporatised entity of the former Public Works Department of Singapore, boasts a 188-year legacy. The corporation recently commemorated this milestone and its journey in the Built Environment industry, through the publication of a book titled 'CPG 188'.

Er. Yeang Hoong Goon, Chief Executive Officer, CPG Consultants Pte Ltd, a subsidiary of CPG Corporation, speaks to 'The Singapore Engineer' on developments in the Built Environment industry, and specifically on some of the technically demanding projects undertaken by CPG.

The Singapore Engineer (TSE): What are the main challenges today for the Built Environment industry and what are the approaches that you would suggest to deal with them?

Er. Yeang Hoong Goon (YHG): I think significant challenges in today's Built Environment industry tend to surface from three major areas – technology, sustainability and talent resources.

As technology advances rapidly, building designs and construction methods have to keep pace with the changes. The drive for Integrated Digital Delivery (IDD) is speeding up the adoption of digital technologies to integrate work processes and connect stakeholders working on the same project, throughout the construction cycle and building life-cycle. IDD includes design, fabrication and assembly on-site, and the operation and maintenance of buildings.

Because the emerging technologies improve the Built Environment industry by expanding its efficiencies and opportunities across the life-cycle of buildings and infrastructure, we have to acquire knowledge of these technologies and to use them quickly. Technologies such as Building Information Modelling (BIM), Virtual Design and Construction (VDC), 3D printing to create structural walls etc, are some examples of what have been quickly adopted and implemented in many projects over the past few years.

While the advancement of technology is not unique to the Built Environment industry, we feel the challenge more in this industry, because the rate at which we have to adopt the technologies is faster, as demanded and required by environmental changes and societal expectations.

Sustainability consists of economic, environmental and social pillars that are closely linked to the Built Environment industry. What we build and how we build impacts the harmony with our natural environment. In particular, environmental sustainability relating to climate change is a challenge. In Singapore, for example, rising sea levels are a current concern. The consequences of coastal flooding on the Built Environment industry and industrial infrastructure are intricate and multi-pronged in their impact, and will affect all areas, including technical, socio-economic, health and environmental aspects.

As professionals in the Built Environment industry, we must take ownership of the resilience required to define better adaptive approaches and planning of buildings and amenities that can withstand climate change. As an engineer, I view this challenge seriously, since engineering is key to better defining adaptive approaches. Climate change is a real threat and our contributions are critical and significant.

Achieving a delicate balance between conservation and development is also a challenging feat. Sustainability is a core philosophy that we have to base our Built Environment decisions on, in today's world. How we use resources such as energy, land and water, in the Built Environment, determines if resource utilisation can be made sustainable and if there will be sufficient resources for future generations.

To achieve decarbonisation of the Built Environment, the approaches to engineering, in particular, will need to be reconsidered for new buildings and existing ones. Engineers will have to think and adopt technologies that would help them decarbonise the power supplies to building systems and infrastructures.

The Built Environment also has a significant role in reducing biodiversity loss. In recent years, the Built Environment has increasingly adopted biophilic practices, such as providing green urban spaces, green roofs, and natural spaces and ecosystems, that contribute to conservation of urban biodiversity.

Lastly, the issue of human resources has always been a constant challenge for the Built Environment industry. In Singapore, the workforce is quite sophisticated, and people have many options when choosing occupations. It is challenging to find skilled labour in the construction sector which currently relies heavily on foreign workers. As a result of the restrictions imposed, in dealing with the COVID-19 pandemic, many projects faced delays due to the inability to bring in foreign workers, and also due to supply chain problems.

In response to the manpower issues, there has been a greater emphasis on nurturing local talents

in the Built Environment industry. As a business that recognises the importance of maintaining a steady stream of talents for the industry, we are actively working on providing opportunities to our young employees to upgrade their skills through courses and mentoring them through actual project exposure.

TSE: Specifically for CPG, from the recent past, what have been some of the technically challenging projects and the solutions successfully developed and implemented?

YHG: One of the more exciting transportation infrastructure projects was the Marina Coastal Expressway (MCE) project. The MCE is a dual five-lane expressway planned by the Singapore Land Transport Authority (LTA) along the city-state's southern coast. It is a vital transportation link between the new downtown, Marina Bay, and the rest of the island. Although just 5 km long, over two-thirds of it was constructed below ground, including a portion designed by CPG, that runs through a stretch of land reclaimed just for it.

The challenge was to reclaim land from the sea, consisting of soft upper marine clay, from a depth of up to 32 m. Instead of the traditional method of installing individual caissons in the sea, used in the Tuas Mega Port project, which would mean having to excavate much marine clay from a site that was way too deep, the CPG transportation infrastructure team came up with an innovative solution. We designed a cellular pipe-box seawall – a construction method similar to building structures over oceans, to create a rigid seawall. This innovative approach simplified the construction process and resulted in substantial time and cost savings, without compromising quality.

The State Courts Singapore is another challenging and interesting project, from an engineering aspect. The Government had plans to develop a new State Courts building as the 'engine room' of Singapore's judiciary system. The former State Courts, built in the 1970s, was fast running out of space. The

The Marina Coastal Expressway is a dual five-lane expressway along Singapore's southern coast. Image: Purple Light Visuals.

The new 35-storey State Courts Towers comprises the Court Tower and a slender Office Tower. Image: Khoogj.

new 35-storey State Courts Towers comprises the Court Tower and a slender Office Tower. In constructing the challenging slender Office Tower, 39 link bridges span the Office Tower's circulation space to the stockier Court Tower. These link bridges, in turn, provide lateral stability to the Office Tower. Each link bridge was prefabricated and delivered to the site as one unit, before being hoisted and placed on temporary supporting corbels. Final connections were then made safely. Construction within a constrained space was thus possible and working at height was minimised, thereby improving safety on site.

In addition, the slender Office Tower needed a structural design that could withstand high wind speeds. We conducted a wind tunnel study of the building model to analyse the forces acting on the towers and the link bridges. These forces were applied on 3D structural models, and the building was designed to ensure that its sway is within acceptable limits and does not affect human comfort.

Another major challenge was the difficulty of the deep basement construction. The site is close to a conserved building, an underground MRT station and a gazetted national monument. It was critical to construct three basement levels for the State Courts without adversely affecting the neighbouring buildings. To achieve this, we adopted a robust earth-retaining structure, comprising diaphragm walls and a semi top-down construction method for basement construction to minimise wall deflection, ground movement and water drawdown.

These innovative design processes and solutions that we adopted to overcome the project challenges won our engineers the BCA Design and Engineering Safety 'Excellence' Award in 2021.

TSE: Could you comment on some of the current projects that are particularly interesting, from an engineering point of view?

YHG: We are currently working with Leighton Contractors (Asia) Limited – Singapore Branch to deliver Contract T-09 of the Deep Tunnel Sewerage System (DTSS) Phase 2 Project.

First conceived, more than two decades ago, as part of efforts to enhance Singapore's water resilience, DTSS uses deep tunnel sewers to convey used water by gravity to centralised water reclamation plants in Singapore's coastal areas. While the 108 km long Phase 1 of the DTSS, completed in 2008, serves the eastern part of Singapore, Phase 2 of the project will cross 100 km of the western part of the island, covering the downtown area and supporting upcoming developments such as Tengah and the Jurong Lake District.

CPG Consultants has been appointed Qualified Person (Design & Supervision). One of the main tasks, within our scope of work, is to design and model six hydraulic vortex drop structures, with drop heights ranging from 10 m to 30 m, to convey water at flow rate of up to 14 m^3 per second, by the year 2100.

Due to the complex nature of the hydraulics associated with flow through drop structures, the DTSS project requires an in-depth understanding of flow dynamics and hydraulics engineering. The used water can be effectively conveyed 30 m down to the South Tunnel without damaging the structures and causing air entrainment. We used Computational Fluid Dynamics (CFD) modelling to evaluate the performance of the hydraulic structures and recommend their optimised design. The tunnelling work involves constructing a deep shaft of 60 m near the Jurong Formation (a sedimentary rock formation covering the southwest portion of the island of Singapore). The sewer tunnel has a large diameter of around 6 m. We use a Slurry Tunnel Boring Machine (TBM) instead of the Earth Pressure Balance (EPB) tunnelling machine for this work. When completed, the DTSS will collect and transport water from the whole of Singapore to three water reclamation plants, in Changi, Kranji and Tuas, for treatment.

We are honoured to be involved in this national water reclamation project, which will help boost Singapore's water sustainability and harness and recycle water, for the benefit of future generations.

Another project is Singapore's Southeast Coast study. As I mentioned previously, one of the challenges that the Built Environment industry faces is climate change and the consequential possibility of coastal flooding. CPG will lead a site-specific study of Singapore's Southeast Coast, awarded by PUB, Singapore's National Water Agency, via an open tender.

The study is scheduled to take around four years to complete. It will cover about 60 km of the coastline, across three areas – Changi, the East Coast-Marina stretch, and part of the Greater Southern Waterfront district. It is interesting

The Deep Tunnel Sewerage System (DTSS) Phase 2 Project will cover 100 km of the western part of the island. Image: CPG Consultants.

because it is the first extensive and in-depth site-specific study to develop coastal protection measures along the Southeast Coast.

In addition to achieving the primary objective of flood protection, the proposed measures will have to complement land use visions of the respective areas. We will have to think and develop coastal adaptation pathways and measures that will complement the land use plan for the Southeast Coast, with co-location of amenities/recreational spaces for the community to enhance our living environment. Examples of potential measures include sea walls, earth bunds, empoldering and nature-based enhancements such as mangroves.

The project is also engaging because we can use this opportunity to develop and nurture a local talent pool of experienced climate change professionals. Having a local workforce in the long run, that can conceptualise resilience masterplans with sustainable solutions, will help both Singapore and the region to meet future challenges of rising sea levels.

TSE: What are your thoughts on the role of education in creating a strong talent pool for the Built Environment industry?

YHG: Personally, I find that part of the solution to achieving resilience is to build up sufficient professional talent resources in Singapore. This is so that we will always have a ready workforce in the Built Environment industry, that is equipped with knowledge to face any sudden challenges.

The STEM education in Singapore is an excellent way to nurture talents and build up local human resources in the long run. STEM education has a curriculum that focuses on teaching students in the disciplines of science, technology, engineering and mathematics. Unlike other countries that teach STEM with a conventional approach, STEM education in Singapore integrates the four disciplines into one cohesive learning model that focuses on real-world examples.

Having an option to access such an educational paradigm would allow our young to develop relevant STEM skills to keep catching up with innovations brought about by rapid technological advancements. As such an educational approach becomes more common, and there are increasing options for our future generations, more and more people can find opportunities to go into the science and technology field and the Built Environment industry.

TSE: Related to the above are the important issues of continuing education, re-skilling and upskilling, in order to ensure meaningful and attractive careers in the Built Environment industry. How does CPG Consultants, as a multidisciplinary enterprise, view these issues?

YHG: At CPG Consultants, we invest in talent capital because our people are the reason for our success. As such, we believe that continuous education is fundamental and we are constantly encouraging and providing platforms for our people to pursue knowledge and keep up with the times. For instance, we encourage young talents from CPG to actively participate in programmes such as the Young Leaders Programme initiated by the Building and Construction Authority of Singapore.

As a multidisciplinary enterprise, we can provide our talents with opportunities to experience the Built Environment from a macro and eco-system level, and straddling the entire value chain. We encourage our talents to break out of siloed thinking and consider our work in the greater scheme of things. For example, we are not just designing structures to fulfil deadlines. Instead, we design to provide value, resolve challenges and overcome constraints of the physical world through applying engineering principles, and provide service excellence to all around us.

It is also critical and beneficial to the training of engineers and professionals in our company that we always attempt to do the work ourselves rather than outsource it. By tapping into resources within our company, we solve issues by streamlining processes and ensuring that projects are on track, through the coordination among our departments, which is precisely the advantage a multidisciplinary consultancy like CPG enjoys. We meet and work with a variety of stakeholders and can discuss the pros and cons of different types of project implementation with colleagues and external stakeholders alike.

Aerial view of East Coast to the Greater Southern Waterfront. Image: CPG Consultants.

A theatre in Italy reopens after 22 years of closure

The restoration works in the interior and exterior areas of the Giorgio Gaber Theatre in Milan, involved structural strengthening and the application of special construction chemicals.

Inaugurated in 1796 and originally named Teatro Della Cannobiana, the building hosting this theatre was designed by Giuseppe Piermarini in 1776. The original structure (with four rows of boxes, a gallery and two upper circles) was later modified, following restoration work in 1893 and 1932, and especially after the fire that partially destroyed the theatre in 1938. When it was rebuilt by the architects Cassi and Ramelli, following the fire, the boxes were eliminated.

The theatre, which is now called the Teatro Lirico Giorgio Gaber, reopened its doors to the public in December 2021 after being closed for 22 years. Following the rebuild-

The Giorgio Gaber Theatre in Milan, Italy, reopened its doors in December 2021.

ing work to bring the theatre back to its previous condition, after the bombardments in 1943, it is now much the same as it was back in 1940, apart from the second overhanging central gallery.

Renovation of the interior and exterior

The conservative restoration project, funded entirely by Milan City Council, included renovation work on both the interior and exterior of the structure.

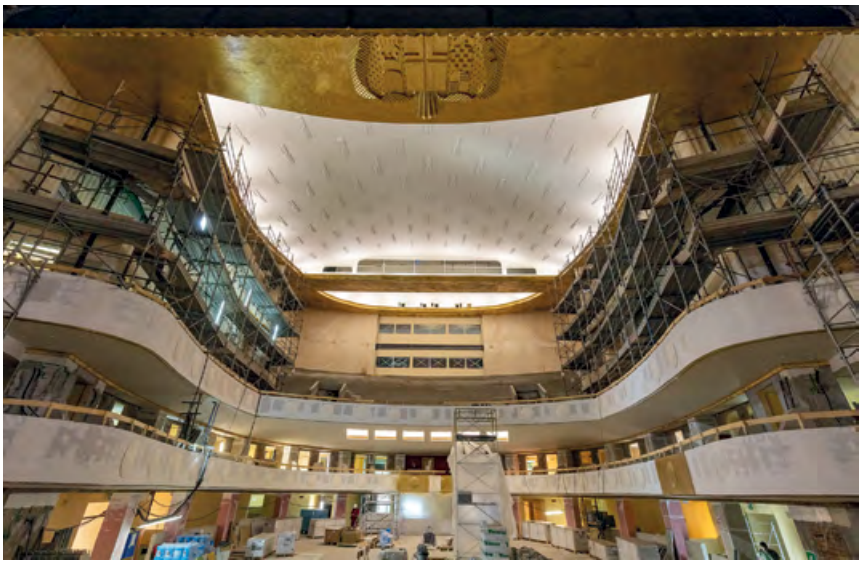
Inside the building, theatregoers can now find new gilding on the large, shell-shaped vaulted ceilings and other decorative features; herring-bone oak parquet flooring in the stalls; and red, black and white marble in the foyer. The walls are covered with pink granite and marmorino plaster while the ceilings are adorned with decorative features in gypsum which were recently restored.

Outside the theatre, works included restoring and reintegrating the render in the same colour as the original. This involved the application of both mineral-based coatings on the neoclassic façade in front of Via Larga and coloured paste plasters on the remaining external areas. Restoration also involved a thorough cleaning and treatment of the parts in pink granite and ornamental stone to ensure water repellence. The conservative restoration works also included the large porch, the fly tower and the dressing rooms/service unit, and rehearsals rooms.

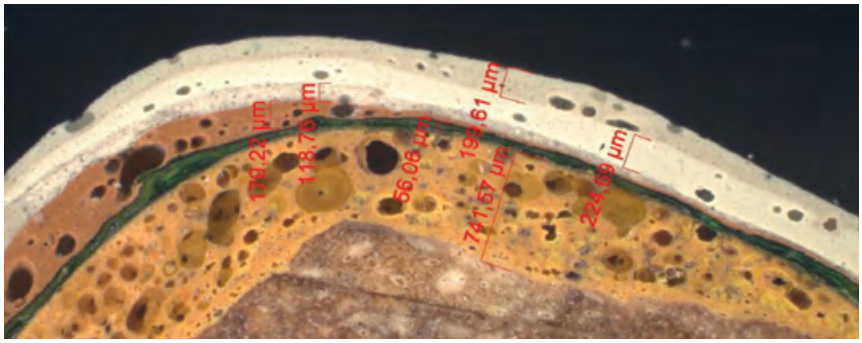
The biggest chunk of work, however, is hidden from view and includes structural strengthening work on several sections of the building, the removal of asbestos, anti-seismic upgrading of the structure, and an upgrade of the services equipment and acoustics.

Working in collaboration

As Technical Sponsor from the start of the project in 2016, Mapei participated in the conservative restoration work and in the upgrading of the structure by supplying products and providing on-site support. The solutions supplied for the project were defined after carrying out in-depth chemical and physical analyses, and testing and sampling procedures approved by Milan City Council and the designers. The analyses were all carried out in the Mapei Research and Development laboratories and accurately identified the problems that caused the deterioration phenomena; the composition of the mortars and finishes originally used; and the different restoration works carried out previously, that had overlapped one another.



The interior of the theatre during the restoration. The gold leafing on the vaulted ceiling was also restored.



A view of the layers of paint that were found on the golden finish of the vaults.

In the case of the conch vaulted ceiling, for example, the analysis carried out proved to be indispensable in showing the Works Director that, underneath a good five layers of white paint, there was a finish similar to a gold leaf. This meant that the original décor could be conserved and today may be viewed in its entirety. Testing and sampling were carried out on each and every system and technology employed, to verify what had been proposed and to receive the approval of the Works Director from Milan City Council and all the designers involved.

Numerous Mapei products and systems were used in the various stages of the work, including the following:

- CONSOLIDANTE ETS WR was used to consolidate the surface of weak, crumbling substrates. The product is used for the conservative restoration and consolidation of porous stone, brick, terracotta and renders. Beside consolidating substrates, it also has high water-repellent properties, therefore it can be used on surfaces that might come in contact with rainwater. PRIMER 3296 was also used on most masonry substrates

before applying renders and skim coats. This is an acrylic polymer-based water dispersion primer, with high penetration characteristics, even on surfaces with low porosity.

- SILANCOLOR CLEANER PLUS mould- and algae-resistant solution was used to provide a 'hygienising' treatment for the damaged render on the brick, stone and tuff masonry.
- To strengthen the extrados of the floor slabs with steel joists, the connection of the joists to the walls was improved by anchoring the ends in the walls around the floors with MAPEFIX VE SF and applying a coat of EPORIP resin and PRIMER 3296 along each steel joist.
- An FRP strengthening system was proposed to strengthen the reinforced concrete beams. After protecting the reinforcing rods with MAPEFER 1K and integrating their surface with PLANITOP SMOOTH & REPAIR R, the concrete beams were strengthened by applying a coat of MAPEWRAP PRIMER 1 on the surface of the intrados of the beams followed by a layer of MAPEWRAP 11.

  The next step was to apply CARBOPLATE plates on the intrados of the beams. To increase the shear strength of the beams, and, at the same time, minimise the potential 'debonding' effect in the longitudinal carbon-fibre strengthening, MAPEWRAP C UNI-AX unidirectional, high-strength carbon fibre fabric was applied around the supports.
- The extrados of the masonry vaulted ceilings was strengthened by applying MAPE-ANTIQUE STRUTTURALE NHL natural hydraulic lime- and Eco-Pozzolan-based mortar which is physically and mechanically compatible with the substrates, and applying MAPEGRID G 220 glass fibre mesh along the extrados of the areas to be strengthened.
- Restoration of damaged and deteriorated render was carried out by firstly applying MAPE-WALL INTONACO BASE natural, hydraulic lime-based base render. Then, after skimming the surfaces with PLANITOP 510 fine-graded, lime-cement based skimming compound, the surfaces were painted with SILEXCOLOR BASE COAT and SILEXCOLOR PAINT in the colour shade chosen by the Works Direction.

Before applying the render and skim coat, the masonry was consolidated by applying a coat of PRIMER 3296.

PLANITOP 510 fine-textured, lime-cement skimming mortar was applied on the external surfaces before painting them. When the render was made of lime, the product chosen was MAPE-ANTIQUE NHL ECO RASANTE CIVILE fine-grained, breathable, smoothing and levelling mortar.

- Restoration of damaged and deteriorated render was carried out by applying MAPE-ANTIQUE INTONACO NHL cement-free, natural hydraulic lime-based breathable base render. MAPE-ANTIQUE FC CIVILE salt-resistant, fine-grained lime and Eco-Pozzolan based transpirant skimming mortar was then used to skim the surface, followed by SILEXCOLOR BASE COAT and SILEXCOLOR PAINT to paint the surfaces in the colour shade chosen by the Works Direction.
- The concrete was repaired using various products – MAPEGROUT 430 thixotropic mortar, MAPEGROUT HI-FLOW mortar and MAPEGROUT T40 thixotropic mortar – all mixed with MAPECURE SRA.
- The joints in the new marble floors in the corridors and foyer were grouted with ULTRACOLOR PLUS grout chosen in different shades, in order to match the colour of the existing joints.

The walls in all the corridors, stair wells and stalls were finished off with SILEXCOLOR MARMORINO.

- The restoration of the finishes on the steps of the staircases was carried out by applying ULTRATOP LOFT SYSTEM. Firstly, the substrate was mechanically prepared, with the consequent removal of the dust, and primed with PRIMER SN which was fully blinded, while still fresh, with QUARTZ 0.5 quartz sand. After the hardening of the primer and the elimination of the excess quartz, ULTRATOP LOFT W, one-component, fine-textured cementitious paste, was applied with a flat metal trowel, to create (up to 2 mm thick) decorative floor and wall coatings with a trowelled or mottled finish.

  After its hardening, the surface was sanded and dust was removed before applying PRIMER LT, one-component, acrylic adhesion promoter, diluted with water in a ratio of 1:1 by weight. After the complete hardening of PRIMER LT, the second coat of ULTRATOP LOFT W was applied with a flat metal trowel. The surfaces were then sanded and vacuumed before applying ULTRATOP BASE COAT, one-component acrylic formulation in water dispersion. The final finish was created by using a mohair roller to apply a coat of transparent MAPEFLOOR FINISH 58 W, two-component, aliphatic, matte polyurethane finish in water dispersion.

- The external render was restored by applying MAPE-ANTIQUE STRUTTURALE NHL natural hydraulic lime-based mortar with high ductility and MAPEGRID G 220 glass fibre structural mesh around the extrados of the span of the vault requiring strengthening. The render was then finished off by applying two coats of MAPE-ANTIQUE FC GROSSO cement-free, large-grained, lime-based skimming mortar, followed by a coat of SILEXCOLOR BASE COAT and then two applications of SILEXCOLOR TONACHINO textured silicate coating paste with high breathability, for internal and external surfaces, in the same colour as the original.

- Conservative restoration of the neoclassic façade in Via Larga was carried out by removing the deteriorated render, reintegrating it with MAPE-ANTIQUE INTONACO NHL, applying a coat of SILEXCOLOR BASE COAT to even out the substrate, and then applying SILEXCOLOR PAINT silicate-based paint in the same colour as the original.

- Conservative restoration of the finishes in the main vault and in the foyer included applying MALECH base coat and COLORITE PERFORMANCE protective acrylic paint with high resistance to UV rays, in the same colour as the original finishes.

- The conservative restoration of the finishes on the walls in the corridors, in the stair wells and the auditorium with a 'plaster-effect' finish included the removal of the plastic coating, the application of PRIMER 3296 to even out the absorption of the substrate, PLANITOP 560 lime-cement mortar to smooth over the surfaces, SILEXCOLOR PRIMER to even out the substrate, and SILEXCOLOR MARMORINO silicate-based plaster in the same colour as the original.

PROJECT DATA

Project
Giorgio Gaber Theatre, Milan, Italy

Original design
Giuseppe Piermarini

Period of construction
1776 to 1796

Period of the restoration intervention
2015 to 2021

Owner
Milan City Council

INTERVENTION BY MAPEI

Contribution by Mapei
Providing technical support on site and supplying products for structural strengthening, restoring and rebuilding renders, restoring existing coatings and applying new coatings.

Website for further information
www.mapei.com

This editorial feature is based on an article from Realtà MAPEI INTERNATIONAL Issue 90. Images by Mapei.

An introduction to cathodic corrosion protection

by Asokan P Pillai, Principal Consulting Engineer, Pipeline Integrity Consulting Engineers Pte Ltd

Mr Asokan P Pillai

Basic information on this important, but often neglected, subject is presented.

It is estimated that the global cost of corrosion is around USD 2.5 trillion. This is almost equivalent to 3.4% of the global Gross Domestic Product (GDP), for 2013. Of this, a good 15% to 35% savings can be realised by the application of already available corrosion control techniques [1]. Although the industry is aware of these cost benefits, it is still behind the curve in its implementation. This is basically due to the lack of knowledge of, and difficulty in measuring, the substantial cost savings in operating expenditure (OPEX) resulting from capital expenditure (CAPEX) in corrosion control. In many instances, the industry and the regulators tend to react only after the occurrence of a catastrophic event like pipeline explosions, tank leakage, environmental degradation, and loss of life.

THE ELECTROCHEMISTRY OF CORROSION

Corrosion is a natural process and may be defined as the destruction or deterioration of a material due to its reaction with the environment. It is an electrochemical process involving the flow of electrons and ions and requires four components – an anode, a cathode, an electrolyte for the flow of ions, and a metallic path for the flow of electrons.

There are generally four main corrosion control techniques. They are as follows:

- The application of protective coatings, linings, and wrappings.
- The application of cathodic and anodic protection.
- The application of inhibitors and chemical treatment.
- Appropriate design and materials selection.

This article focuses on the application of the cathodic protection method.

CATHODIC PROTECTION

Cathodic protection is an electrochemical technique where the corrosion of a metal is reduced virtually to zero, by the attachment of the metal to a much more electronegative metal, also known as a sacrificial or galvanic anode, which is usually magnesium, aluminium or zinc, or by making the metal a cathode by means of an externally applied direct current, also known

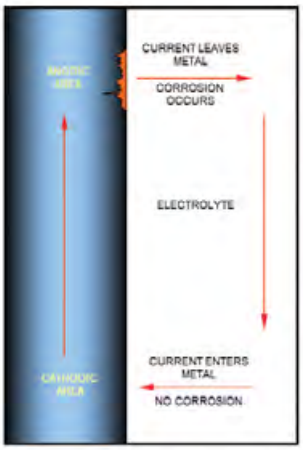


Figure 1: The corrosion cell.

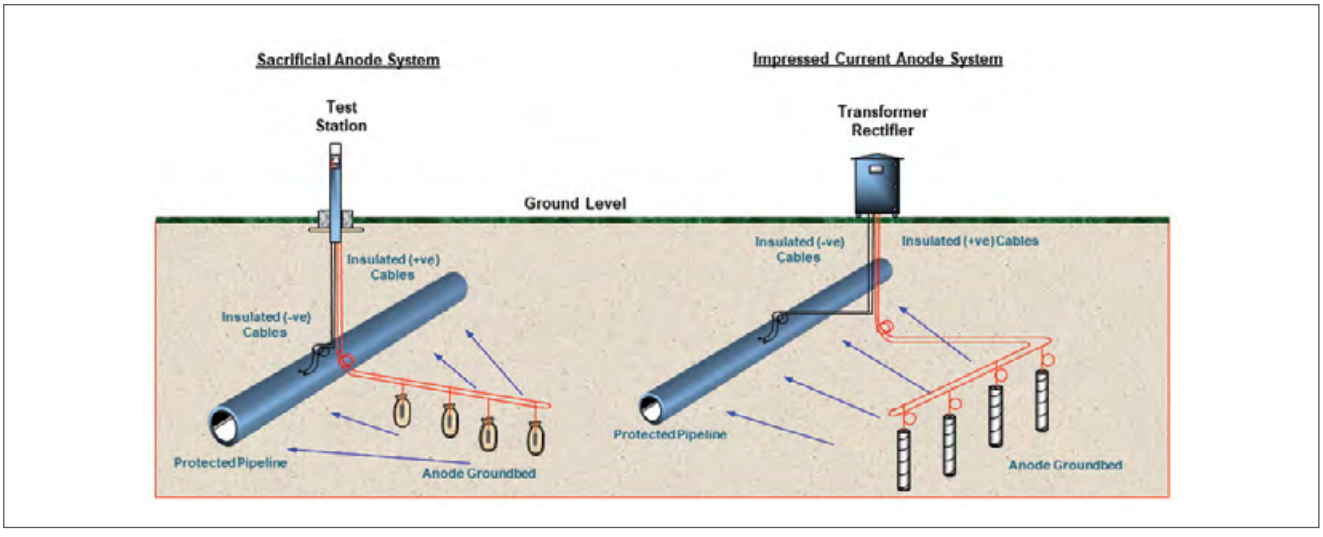


Figure 2: Typical sacrificial and impressed current anode system configurations.

as impressed current. Thus, there are two types of cathodic protection systems:

- Sacrificial/galvanic anode system
- Impressed current anode system

It is imperative to note that cathodic protection can be applied effectively only to the buried, immersed, or embedded sections of the metallic structure, as the presence of the common electrolyte component is mandatory.

SACRIFICIAL/GALVANIC ANODE SYSTEM

A sacrificial anode cathodic protection system involves electrically connecting a sacrificial anode, usually magnesium, aluminium or zinc, of sufficient mass and size, to the corroding structure in the same electrolyte environment, to provide the necessary cathodic protection current. The buried, immersed, or embedded corroding structure is thereby protected against corrosion by the simultaneous consumption of the sacrificial anode by electrochemical dissolution, for the design period.

IMPRESSED CURRENT ANODE SYSTEM

An impressed current anode system entails the connection of an external direct current power supply via inert anodes like mixed metal oxide, titanium, high silicon iron or graphite, which show a relatively low consumption rate compared to the corroding structure, in the same electrolyte environment, to provide the necessary cathodic protection current. The buried, immersed, or embedded corroding structure is thereby protected against corrosion by the simultaneous consumption of the anode, for the design period.

DIFFERENCES BETWEEN SACRIFICIAL ANODE AND IMPRESSED CURRENT ANODE SYSTEMS

The main differences between a sacrificial anode and an impressed current anode cathodic protection system are shown in Table 1.

A commonly asked question in the industry is "If a buried or immersed structure is already coated with a protective coating system, does it still need a cathodic protection system?"

The reality is that a perfect coating system is never feasible. Pin holes, holidays and coating damage can occur during the installation of the structure and corrosion normally concentrates at such imperfections. Thus, the application of a cathodic protection system to complement the protective coating system is the most pragmatic, cost-effective and holistic corrosion mitigation solution.

Typical structures where cathodic protection is applied include onshore pipelines, offshore pipelines, water pipelines, above-ground storage tanks, underground storage tanks, mounted storage vessels, process plant equipment internal

No	Sacrificial Anode System	Impressed Current Anode System
1.	Independent of external power source	Requires external power source
2.	Limited current output and design life	Wide range of current output with extended design life
3.	Insignificant influence on nearby foreign structures	May influence nearby foreign structures
4.	May be impractical due to environmental conditions	Less restrictions on application
5.	Nominal maintenance	Routine maintenance

Table 1: Differences between the two types of cathodic protection systems.

surfaces, power plant equipment, water intake facilities, marine jetty piles, offshore platform legs, marine concrete decks/piles, concrete tunnels, lamp posts, transmission tower legs and numerous other structures.

ENGINEERING STANDARDS AND CRITERIA

The most referred to global cathodic protection engineering standards in the industry are the following:

- International Organization for Standardization (ISO) Standards
- National Association of Corrosion Engineers (NACE) Standards (SP)
- British Standards Institution (BSI EN) Standards
- Australian Standards (AS)
- Det Norske Veritas (DNV) Recommended Practices (which are mostly for marine applications)

For cathodic protection of carbon steel, the general acceptance criterion is a structure to electrolyte potential at which the corrosion rate is reduced to less than 0.01 mm per year. This translates to a protection potential of -0.85 V with respect to CSE (copper/copper sulphate reference electrode), eliminating the voltage drop at the boundaries in soil and water.

Thus, the acceptance criteria are as follows:

- A negative (cathodic) potential of at least -0.85 V with respect to CSE with the cathodic protection applied and the voltage drop, other than those across the structure-to-electrolyte boundary, considered, or
- A negative polarised potential of at least -0.85 V with respect to CSE, or
- A minimum of 100 mV shift of cathodic polarisation between the structure surface and a stable reference electrode contacting the electrolyte.

Other criteria that have been applied in the industry include:

- Structure/electrolyte current direction
- E log I
- -300 mV potential shift

It is important to appreciate that different acceptance criteria are applicable for different materials in different environments.

COMPONENTS OF A TYPICAL CATHODIC PROTECTION SYSTEM

Cathodic protection system components vary according to their specific design configurations and applications. Table 2 provides an overview of the most used components.

PRE-REQUISITES FOR CATHODIC PROTECTION APPLICATION

Electrical continuity - It is absolutely necessary that the buried, immersed or embedded sections of the structure have perfect electrical continuity, in order to be cathodically protected. Cast iron/ductile pipes, with ball and spigot joints or joints with rubber seals and mechanical couplings, must be coupled with continuity bonding cables, to provide adequate electrical continuity.

Electrical isolation – Electrical insulation/isolation from adjoining foreign structures is an absolute necessity for achieving a satisfactory level of cathodic protection within the intended buried sections. Any foreign structure which is able to act as earth, such as power lines, metal pipes, reinforcing steel rebars in concrete works, insulating sheathing or screening, should be electrically isolated from the intended buried structure which requires cathodic protection, to avoid unwarranted cathodic current drainage.

Shielding effects – An electrical shield, either metallic or non-metallic, can be an effective barrier, that will prevent the cathodic current from flowing to the structure that it is protecting, or divert it away from the structure. Electrical shields include insulating barriers, shorted cased crossings, reinforced wire in weighted concrete coatings, and shielding in congested areas.

Stray current interference - Leakage of returning current from an electrical system like rail tractions or an impressed current anode system can cause electrical interference to neighbouring buried structures in their sphere of influence. It has been known to cause substantial corrosion of nearby structures.

Bacterial corrosion - Anaerobic corrosion is a manifestation of the

No	Components	Sacrificial Anode System	Impressed Current System
1.	Power Sources	-	Transformer Rectifiers, Solar Power Units etc.
2.	Anodes	Magnesium, Zinc and Aluminium	Mixed Metal Oxide, Platinized Titanium, High Silicon Iron, Graphite etc
3.	Junction Boxes	Optional	Anode, Cathode, Inter-bonding etc
4.	Test Stations	Many Configurations	
5.	Circuit Cables	XLPE/PVC, PVC/PVC, PVC, HMWPE, KYNAR/HMWPE, HALAR/HMWPE etc.	
6.	Reference Electrodes	Copper/Copper Sulphate, Silver/Silver Chloride, Zinc etc	
7.	Polarization Coupons	DC Coupons, AC Coupons etc	
3.	Isolation Joints	Insulating Flange Kits, Monolithic Joints, etc	
9.	Surge Arresters	Spark Gaps, Polarization Cells, DC Decouplers etc	
10.	Cable Connections	Exothermic Welds, Pin Brazing, Stud Welding etc	

Table 2: Overview of the most used components.

effect of corrosion by soil bacteria commonly known as Desulfrobrio Desulfuricans. This is commonly noted at poor drainage locations and under stagnant, water-logged conditions.

CATHODIC PROTECTION SYSTEM DESIGN PARAMETERS

Cathodic protection system designs can vary substantially, depending on the design parameters embraced and the design concept proposed. For ease of appreciation, it is important that the following basic design information is clearly defined:

- Type of system
- Design life
- Structure dimensions
- Protective coating status
- Electrolyte corrosivity and resistivity
- Current density
- Structure operating temperature
- Availability of power source
- Presence of other related structures
- Stray current / interference issues
- Operations and maintenance preferences
- Cost implications
- Other information

OPERATIONS AND MAINTENANCE OF CATHODIC PROTECTION SYSTEMS

Monitoring, inspection and regular maintenance of a cathodic protection system should be carried out at regular intervals to ascertain that

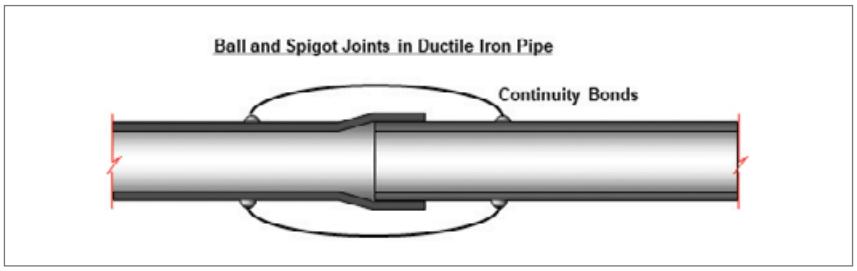


Figure 3: Electrical continuity bonding.

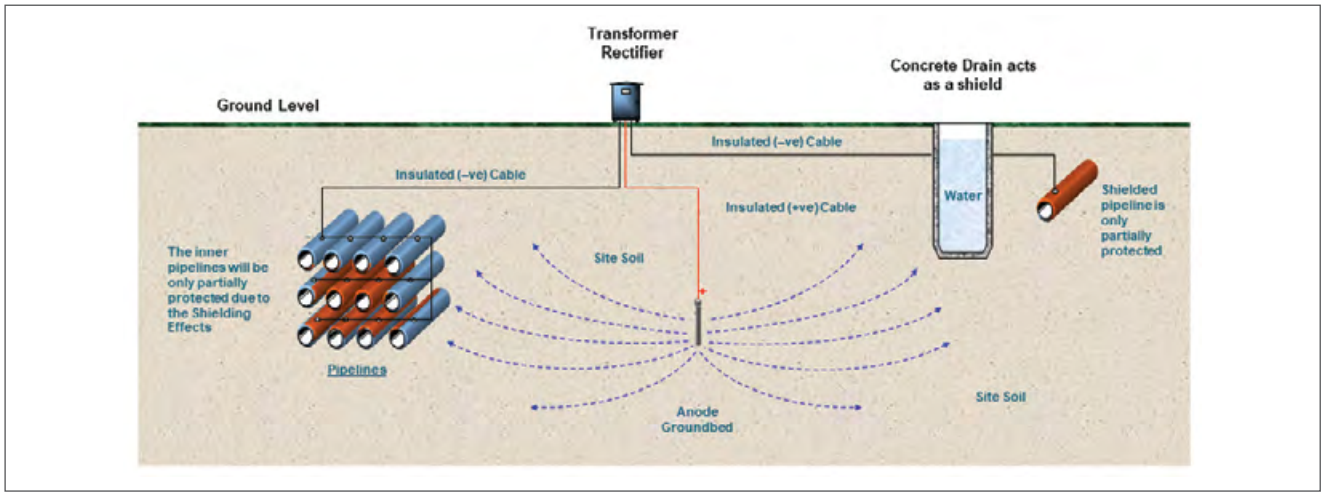


Figure 4: Shielding effects.

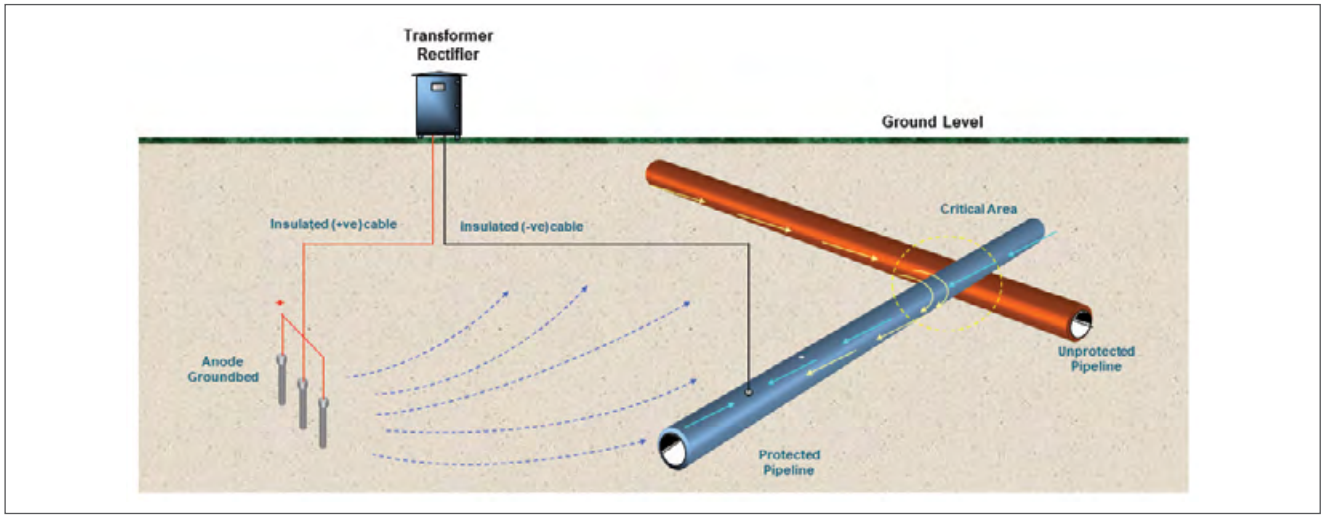


Figure 5: Interference effects caused by an impressed current system on a foreign pipeline.

the system is providing the necessary level of corrosion protection and meeting the acceptance criteria. Where deficiencies are noted, they should be rectified promptly, to avoid unwarranted further deterioration resulting in a system shut down.

Table 3 details the recommended routine inspection checks that are normally required for typical cathodic protection system components.

ANODIC PROTECTION

Anodic corrosion protection is the reverse of cathodic protection and is defined as an electrochemical technique to control corrosion, based on the formation of a protective passive film on a metal surface due to an externally applied anodic current. Developed by Edeleanu in 1954, this method is normally applied to metals that exhibit active to passive transition in environments where the current density in the freely corroding state is significantly higher than the current density in the passive state, over a specific range of potentials.

CONCLUSION

Cathodic protection is generally credited to Sir Humphrey Davy. It is an established and field-proven science. Appropriately designed and supplemented with a good protective coating system, cathodic protection systems should provide excellent corrosion mitigation for buried, immersed, and embedded metallic structures. It is a very cost-effective solution for preventing metallic corrosion in soil, water, and concrete. In most developed countries it is mandated by legislation and regulated in some states to ascertain its correct application, in order to avoid unwarranted interferences to neighbouring structures.

REFERENCES

[1] NACE International: 'International Measures of Prevention, Application and Economics of Corrosion Technology (IMPACT)' Study (2016).

No	Cathodic Protection System Components	Inspection Requirements	Periodicity
1.	Transformer Rectifiers	Visual inspection and recording of output voltage and current	Once every two to three months
		Comprehensive inspection including functional tests of related panel meters, control instruments, insulating oil condition etc	Once a year
2.	Sacrificial Anodes	Anode potential measurements and visual inspection of anode dissolution where feasible	Once a year
3.	Junction Boxes	Visual inspection and measurement of anode current output, resistance etc	Once a year
4.	Test Stations	Visual inspection and measurement of structure to electrolyte 'ON' potential	Once every three to six months
		Visual inspection and measurement of structure to electrolyte 'Instant OFF' potential	Once a year
5.	Permanent Reference Electrodes	Calibration with a portable master reference electrode	Once every six months
6.	Polarization Coupons	Measurement of 'ON' and 'Instant OFF' coupon to electrolyte potentials	Once a year
7.	Polarization Cells, DC Decouplers and Surge Arresters	Measurement of resistance, potentials etc	Once a year
8.	Close Interval Pipe to Soil Potential Survey (CIPS) for Pipelines	Measurement of pipe to soil potentials at close intervals	Once every three to five years
9.	Direct Current Voltage Gradient (DCVG) Coating Defects or Alternating Current Voltage Gradient (ACVG) Survey for Pipelines	Measurement of voltage gradient along pipeline	Once every three to five years
10.	Other Specialist Assessments include Guided Wave, In-Line Inspection etc.	Metal Loss, Remaining Strength, Fitness for Purpose Assessment etc	As per corporate and code requirements

Table 3: Recommended routine inspection checks for typical cathodic protection system components.

Circle Line 6 tunnelling works completed

Work had to be carried out, carefully, beneath heritage buildings and close to commercial buildings and road infrastructure.

Tunnelling works for Circle Line 6 (CCL6) which consists of three new stations – Keppel, Cantonment and Prince Edward Road – started in August 2019. Three tunnel boring machines (TBMs) were used to construct the three stretches of twin tunnels linking the new stations to the rest of the Circle Line. The first stretch of tunnelling works from Keppel Station towards HarbourFront Station was completed in August 2020. The TBMs were then re-launched to mine between Keppel Station and Cantonment station. Works for this leg were completed in July 2021.

The completion of the final stretch of works, which includes the boring of 2 km-long twin tunnels from Prince Edward Road Station to Cantonment Station, marked the completion of CCL6 tunnelling works. With this, the progress for CCL6's civil construction works is about 55% per cent complete.

Moving forward, works will commence to build the structural connections between the bored tunnels and stations. This will be carried out in tandem with the rest of the structural works for the three new underground stations for CCL6.

Separately, structural works for the underground Kim Chuan Depot extension are also progressing well. The expanded depot will have increased capacity to house new Circle Line trains.

Upon completion of the basic civil structural works, the installation of track-related equipment as well as electrical & mechanical services and systems will commence, followed by systems testing and commissioning.

The CCL6 is on schedule to open in 2026, closing the Circle Line loop by connecting HarbourFront Station to Marina Bay Station. This will provide commuters in Telok Blangah a more direct, faster and more convenient route to the Marina Bay area, cutting travelling time by up to 10 minutes. Commuters travelling from Paya Lebar and Mountbatten will enjoy faster access to the retail and office centres in the HarbourFront area, and those in the west, such as Pasir Panjang and Kent Ridge, can also have a direct route to the Central Business District.

Overcoming tunnelling challenges

The CCL6 tunnelling works had to be planned and undertaken carefully, as they were carried out beneath heritage buildings and close to the foundations of many existing commercial buildings and road infrastructure in the densely built-up Central Business District. At the sections which interface with the existing HarbourFront Station and Marina Bay Station, precautions were also taken to avoid affecting daily train operations.

One example is the tunnels between Prince Edward Road Station and Cantonment Station, which cross under the former Tanjong Pagar Railway Station - a gazetted National Monument. As the works would be carried out just 6.7 m below the building's piles, additional protection measures were implemented before tunnelling commenced. Extensive foundation investigations were carried out to ensure that the building's piles were not within the tunnel alignment, while protective structures were installed to reinforce and stabilise the former Tanjong Pagar Railway Station's interior and exterior elements. In addition, over 600 monitoring instruments were installed and observed round-the-clock, to detect any movements of the building during the tunnelling works.

Another challenge was the tunnels between Cantonment Station and Keppel Station, which run under the existing Keppel Viaduct. New micro piles were installed to underpin the viaduct structure, replacing three bored piles which had to be cut away to accommodate the new rail tunnels. To ensure structural integrity and safety of road users, close to 100 instruments were installed to monitor the road viaduct during the underpinning and tunnelling works.

The Circle Line

The completed Circle Line will comprise 33 stations over 40 km, including 12 interchange stations with other MRT lines, providing better connectivity and greater time savings for commuters. Commuters will enjoy a direct route between areas in the west, such as Pasir Panjang and Kent Ridge, as well as areas such as the Central Business District and Marina Bay, to Paya Lebar and Mountbatten.

Underground Tunneling Equipment Market Research Report 2022 – 2026

The Underground Tunneling Equipment market research report, recently published by Kingpin Market Research, gives a detailed analysis of the most recent trends, market drivers, development imperatives and the forces that are adding to the development of the business.

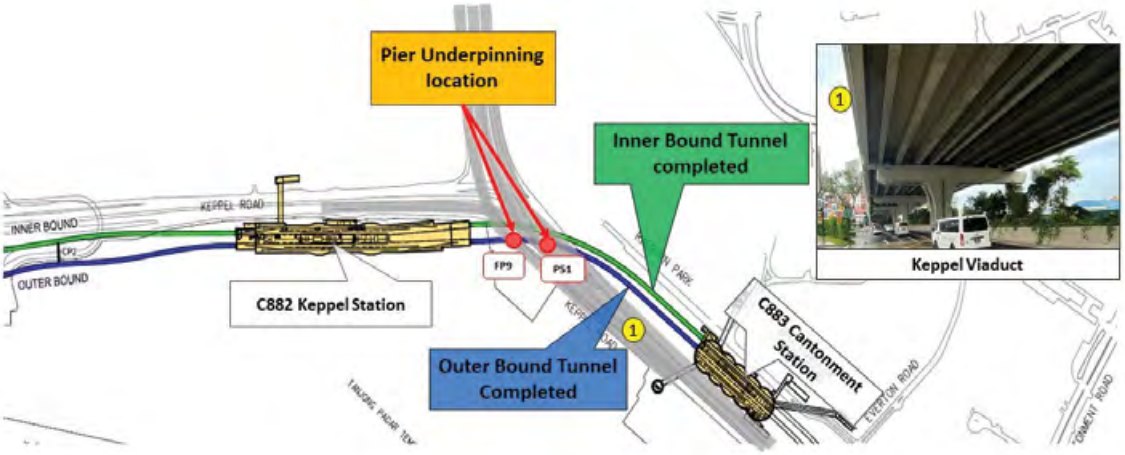
The report evaluates the production processes, significant issues and solutions to reduce risk. The driving and restraining forces in the market and their effects are also presented.

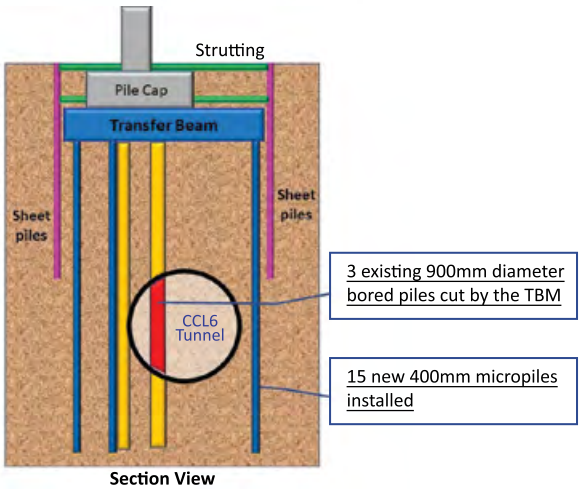
The report also gives the methodologies that are being adopted by leading organisations, as well as possibilities for the future.

Exterior protection works

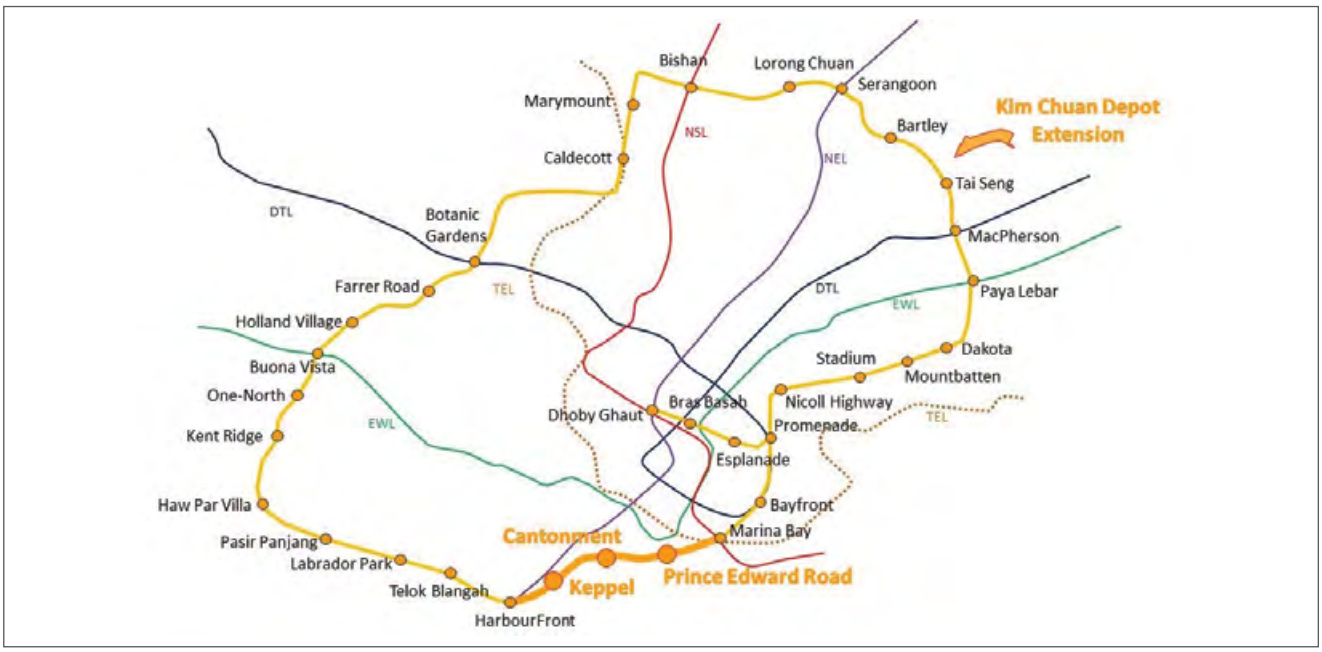
Interior protection works

Additional measures were implemented during the construction of the tunnel between Prince Edward Road Station and Cantonment Station, to protect the former Tanjong Pagar Railway Station - a gazetted National Monument.





New micro piles were installed to underpin the Keppel Viaduct structure, replacing three bored piles which had to be cut away to accommodate the new rail tunnels.



The completed Circle Line will comprise 33 stations.

LTA Awards civil contract for design and construction of Pasir Ris East Station

The Land Transport Authority (LTA) has awarded the civil contract for the design and construction of Pasir Ris East station, under the first phase of the Cross Island Line (CRL1), to Singapore Engineering & Construction Pte Ltd - Sinohydro Corporation Limited (Singapore Branch) Joint Venture. This contract is valued at around SGD 363 million.

Singapore Engineering & Construction is one of Singapore's most established civil engineering and construction specialists. The company's previous projects include the construction of Tai Seng Facility Building which serves the Downtown Line and the widening of Keppel Viaduct.

Sinohydro Corporation Limited is a hydropower engineering and construction company which has been involved in a wide range of infrastructure works locally and abroad. The company is currently constructing Napier Station and Marina South Station for the Thomson-East Coast Line.

Construction works for the CRL1 Pasir Ris East Station are expected to start in the second quarter of this year, with passenger service expected to commence in 2030.

Engineering highlights

CRL1 Pasir Ris East station is located along the busy roads of Pasir Ris Drive 1, in the vicinity of residential blocks and community amenities. To mitigate the impact to residents and motorists, staggered stages of traffic and utilities diversions will have to be implemented to facilitate the construction works. Safety measures will be taken when carrying out Earth Retaining and Stabilising Structure works and excavation works, which are expected to be approximately 25 m deep, to ensure stability of the ground and surrounding structures. LTA and the contractor will closely monitor the works to ensure that they are carried out safely with minimal impact to nearby stakeholders.

Cross Island Line

The Cross Island Line (CRL) is Singapore's eighth MRT line. It will serve existing and future developments in the eastern, north-eastern and western corridors, linking major hubs such as Jurong Lake District, Punggol Digital District and Changi region. The CRL will have almost half of its stations as interchanges with other rail lines, making it easier and more convenient for commuters to travel across the rail network.

CRL1 is 29 km long and comprises 12 stations from Aviation Park Station to Bright Hill Station (all station names are working names). This will serve residential and industrial areas in Loyang, Tampines, Pasir Ris, Defu, Hougang, Serangoon North and Ang Mo Kio, and benefit more than 100,000 households. With CRL1, recreational spaces such as Changi Beach Park and Bishan-Ang Mo Kio Park will be more accessible by public transport. Studies on subsequent CRL phases are ongoing.

IES COMMEMORATES WORLD ENGINEERING DAY 2022 BY SHARING KNOWLEDGE AND TELLING THE SINGAPORE ENGINEERING STORY

The World Engineering Day for Sustainable Development (WED), an official International day, was proclaimed in 2019 by the United Nations Educational, Scientific and Cultural Organization (UNESCO). This was based on a proposal from the World Federation of Engineering Organizations (WFEO).

On every 4th March of each year, WED celebrates engineering and the contribution of the world's engineers for a better, sustainable world.

To commemorate this important occasion, IES organised the Charles Rudd Distinguished Public Lectures 2022 and participated in WFEO's 24-hour live broadcast to share knowledge with and tell the Singapore engineering story to the world.

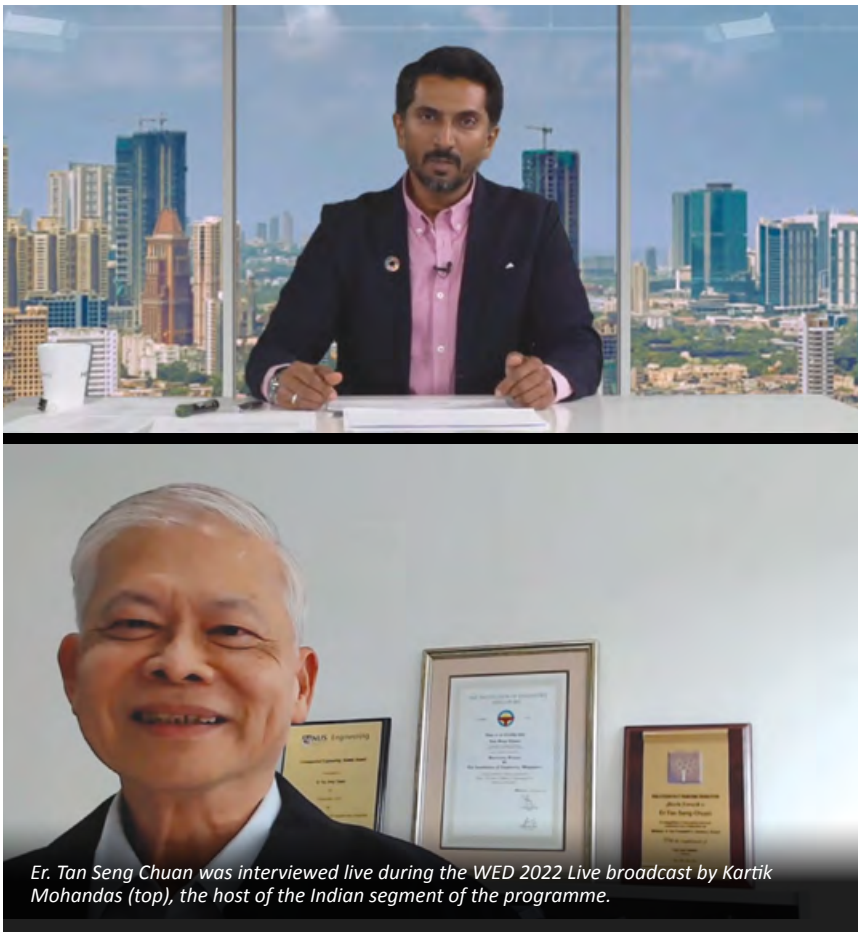
The Lecture took place on 17 February 2022 at the Stephen Riady Auditorium @ NTUC. Some 2,500 participants and invited guests attended the hybrid event, which was themed around the circular and digital economies.

Her Excellency Ms Iwona Piórko, European Union Ambassador to Singapore, was the Distinguished Speaker. In her opening address, she spoke about the increased efforts by the EU to tackle climate change, recognising the potential of the digital revolution in accelerating the paradigm shift in line with the European Green Deal, and the common priority shared by the Singapore Green Plan 2030 and the European Green Deal to shift from linear to circular economic growth.

Three thought-provoking lectures were delivered by Ms Sheila Remes, Vice President for Environmental Sustainability at Boeing, Dr Darian McBain, Chief Sustainability Officer at the Monetary Authority of Singapore, and Prof Cheong Koon Hean, Chairman for the Centre for Liveable Cities (MND) and the Lee Kuan Yew Centre for Innovative Cities (SUTD). These thought leaders shared their insights on sustainable flight, green financing, and climate-compatible developments respectively.

Ms Iwona Piórko, the EU Ambassador to Singapore, was the Distinguished Speaker for this year's Charles Rudd Distinguished Public Lectures.

Ms Susanna Kass joined the discussion panel virtually from California. On stage, from left to right, were: Mr Jonathan Kua, Prof Cheong Koon Hean, Prof Seeram, Dr Darian McBain, and Ms Sheila Remes.



Er. Tan Seng Chuan was interviewed live during the WED 2022 Live broadcast by Kartik Mohandas (top), the host of the Indian segment of the programme.

They were joined by Ms Susanna Kass, Data Centre Advisor for the UNSDG programme and Energy Fellow at Stanford University, as well as Mr Jonathan Kua, Senior Vice President and Head, Group Sustainability at ST Engineering for a discussion panel about the various presentations and how the various industry sectors were, or could, work towards achieving their sustainability goals.

The panel was moderated by Prof Seeram Ramakrishna, FREng, FIES, Chairman of the NUS Circular Economy Taskforce and IES Sustainable Manufacturing Technical Committee.

On World Engineering Day itself, WFEO pioneered a 24-hour live broadcast through its dedicated website and YouTube. Starting from 9.00am (Singapore time), WFEO members from around the world put up videos, messages, and presentations that showcased the work and achievements of engineers in their country.

IES participated with a three-video presentation on Singapore's efforts in sustainable development and the contributions of engineers.

The first video, produced by the Ministry of Sustainability and the Environment for the Singapore Green Plan 2030, offers insights into Singapore's advancement of the national agenda on sustainable development through the Singapore Green Plan 2030. The Plan helps strengthen Singapore's commitments under the UN 2030 Sustainable Development Agenda and Paris Agreement to achieve long-term net zero emissions aspiration as soon as viable.

Exclusively produced by IES for this event, the second video captured highlights in Singapore's sustainability journey since the 1970s, underpinned by the accomplishments of engineers from different disciplines.

The transformation of the Marina Bay Area, development of Changi International Airport, building of Jurong Island, the creation of the four national (water) taps and the development of smart housing projects like Punggol Northshore were amongst the success stories cited.

This video also illustrates how IES, as the national society of engineers in Singapore, has been leading the engineering community to forge a sustainable future for Singapore through initiatives such as the World Engineers Summit and the Charles Rudd Distinguished Public Lectures.

The third video focuses on collaborations between IES and Science Centre Singapore to nurture the young into Singapore's next generation of engineers to drive sustainable development into the future.

Besides the videos, IES Emeritus President Er. Tan Seng Chuan was also interviewed live to highlight the importance of engineering contributions in sustainable development and emerging trends in shaping the future of engineering.

The replay of the live broadcast can be viewed at **https://worldengineeringday.net**. IES' presentations and Er. Tan's interview takes place during the India segment.

Flying the Singapore flag high

During the WFEO General Assembly on 10 March 2022, Er. Tan Seng Chuan was elected to the position of Executive Vice President for a two-year term ending October 2023. He was previously its Treasurer.

The Executive Vice President, of which there are two, sits on the WFEO Executive Council, the highest decision-making body of the Organization. Working under the auspices of UNESCO, WFEO brings together engineering institutions from some 100 nations and represents more than 30 million engineers.

New Classic Line pavers from Vögele

Vögele has introduced two new pavers for small to medium-sized projects on a tight schedule. The SUPER 1300 and SUPER 1303 Compact Class pavers are ideal both for rehabilitating a wide variety of traffic areas and for economically and efficiently completing projects in inner cities and on major roads to a high standard. Both pavers belong to Vögele's Classic Line and are therefore aimed at customers who give a high priority to robust and reliable engineering, but whose construction projects do not require the full functionality of the company's Premium Line.

The new compact pavers provide all the basic paving functions and feature the clear, easy-to-learn ErgoBasic operating concept as well as the optional Niveltronic Basic System for Automated Grade and Slope Control. Their compact design, 74.4 kW diesel engine and laydown rates of up to 350 t/h make these pavers powerful, robust and versatile.

Both machines comply with European emission standard Stage 3a and US standard EPA Tier 3. In combination with the AB 340 Extending Screed and the compacting systems comprising tamper (T), vibrators (V) or a combination (TV), these machines facilitate pave widths from 1.8 m to 3.4 m. Cut-off shoes furthermore allow a minimum pave width of 0.75 m, whilst additional bolt-on extensions enable a maximum pave width of up to 5 m to be achieved.

The new SUPER 1300 and SUPER 1303 Classic Line pavers.

Simple operation with ErgoBasic

The ErgoBasic operating concept was developed on the basis of the proven ErgoPlus 3 operating system and tailored specifically to meet the needs and requirements of Classic Line users. Equipped with ErgoBasic, the SUPER 1300 and SUPER 1303 are just as fast, precise and intuitive to operate as the Premium Line machines, though ErgoBasic is limited to the basic functions required.

These include clear function and status displays, control of various modes, glare-free backlighting for working at night and simple steering involving either a rotary controller or, in the case of the wheeled model, a steering wheel. Both the ErgoBasic and the ErgoPlus 3 operating systems are based on the same concept and the same system of symbols, making it straightforward for users to switch between Classic Line and Premium Line pavers.

Niveltronic Basic System

To go with the ErgoBasic operating concept, Vögele is also supplying the Niveltronic Basic System for Automated Grade and Slope Control on its Classic Line pavers. It is completely integrated in the machine control system and precisely tailored to the paver model concerned.

The system for Automated Grade and Slope Control can be controlled separately for each side of the screed using a compact, sturdy remote-control unit. It is straightforward and intuitive to operate, ensuring paving true to line and level on any terrain. Niveltronic Basic can furthermore be combined with a wide variety of Vögele sensors, ranging from a variable mechanical grade sensor to non-contacting sonic sensors or a laser receiver.

THE HEART & VOICE OF ENGINEERS

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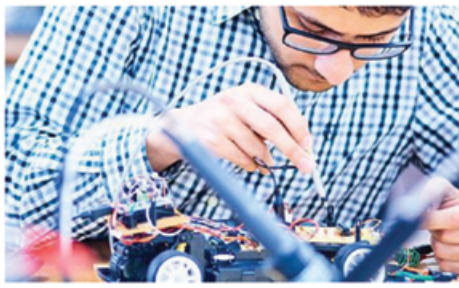

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