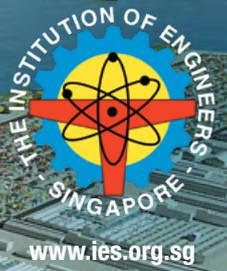


THE MAGAZINE OF THE INSTITUTION OF ENGINEERS, SINGAPORE



THE SINGAPORE ENGINEER

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COVER STORY:
Singapore's next-generation port

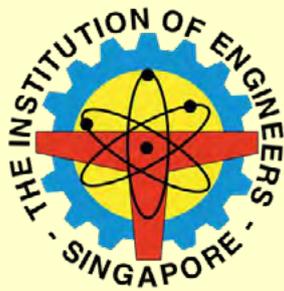


PLUS

CIVIL & STRUCTURAL ENGINEERING: A specialist in pile extraction as well as pre-loading and piling

DESIGN INNOVATION: The new State Courts Towers

PROJECT APPLICATION: The Ferenc Puskás Stadium in Budapest



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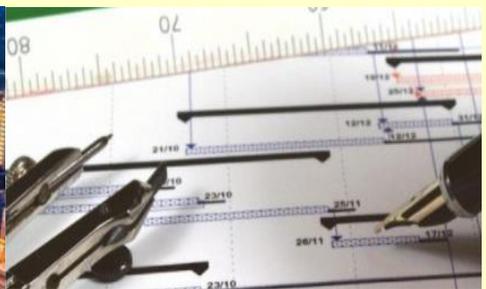


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President
Dr Richard Kwok

Chief Editor
T Bhaskaran
t_b_n8@yahoo.com

Publications Manager
Desmond Teo
desmond@iesnet.org.sg

Snr Publications Executive
Queek Jiayu
jiayu@iesnet.org.sg

Editorial Panel
Dr Chandra Segaran
Prof Er Meng Joo
Dr Ang Keng Been
Mr Gary Chiam
Dr Victor Sim
Mr Syafiq Shahul
Dr Alexander Wiegand

Media Representative
Multimedia Communications
(2000) Pte Ltd
sales@multimediacomms.sg

Design & layout by **2EZ Asia Pte Ltd**

Cover designed by **Irin Kuah**

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PUB RECEIVES TOP INTERNATIONAL HONOURS

AT GLOBAL WATER AWARDS 2021

PUB, Singapore's National Water Agency, has been named 'Resilient Water Agency of the Year' at the Global Water Awards 2021. This is a recognition conferred on PUB, by the international water community, for its robust efforts in ensuring water security for Singapore, even amidst challenges posed by the global COVID-19 pandemic.

In addition, Singapore's newest desalination plant, the Keppel Marina East Desalination Plant (KMEDP) was conferred the 'Desalination Plant of the Year' Award, in recognition of its innovative capability to treat both seawater and freshwater from the surrounding reservoir.

Established by Global Water Intelligence (GWI) in 2006, the annual Global Water Awards recognise the most important achievements in the international water industry and reward initiatives in the water, used water and desalination sectors, that are moving the industry forward through improved operating performance, innovative technology adoption and sustainable financial models.

The 'Resilient Water Agency of the Year' is a new award category to recognise government agencies or water utilities that have offered the most robust or innovative response to the unique challenges of 2020 for the water and used water sector. The three other nominees in this category were Anglian Water in the United Kingdom, Gruppo Hera in Italy, and the Orange County Water District in USA.

The 'Desalination Plant of the Year' Award recognises the most impressive technical or ecological desalination plant commissioned in 2020. The three other nominees were the Al Dur 2 IWPP (Bahrain), Khobar I SWRO (Saudi Arabia) and ZPC Seawater Desalination Project (China).

These awards also mark PUB's fourth consecutive win at the annual Awards. In 2019, the PUB-owned Tuas Desalination Plant was conferred 'Desalination Plant of the Year' while the Ulu Pandan Wastewater Treatment Demonstration Plant was named 'Water/Wastewater Project of the Year' in 2018. Last year, the upgraded Choa Chu Kang Waterworks, home to the world's largest ceramic membrane system, was named the 'Water Project of the Year'. These awards are testament to PUB's commitment towards operational excellence, with continual investments in innovation and technology, in order to become a Smart Utility of the future.

Ensuring water resilience for Singapore

When the COVID-19 pandemic struck early last year, PUB swung into action swiftly and initiated a crisis management plan to ensure all its plants and operations continue to function as usual. As water is an essential service to the whole nation, it is PUB's utmost priority

to keep its staff safe from the virus and to keep the water system ticking along. PUB implemented split-team arrangements, staggered work hours, as well as safe-distancing and sanitation measures at all workplaces, while remote working arrangements were made available for the other half of its 3,500-strong workforce, who were able to telecommute.

PUB also had to respond quickly to manpower challenges and take proactive steps to ensure sufficient stockpile of materials and supplies for its operations, maintenance and construction projects. As a result, Singapore's water system has not missed a beat - taps continue to flow, toilets flush at a push, and drains and reservoirs continue to function as they should.

Forging ahead with key projects to strengthen water resilience

Despite these challenges, PUB pressed on and made headway on three major projects that will strengthen resource resilience and water security for Singapore:

- In June 2020, operations commenced at Singapore's fourth desalination plant. The Keppel Marina East Desalination Plant (KMEDP) is Singapore's first large-scale dual-mode desalination plant. It is capable of producing 137,000 m³ of fresh drinking water per day. The plant is able to treat either seawater or freshwater from the Marina Reservoir. Desalinated water is a weather-resilient water source and the completion of KMEDP is a major boost to Singapore's water security.
- Construction of the floating solar farm on Tengeh Reservoir commenced in August 2020. PUB and Sembcorp began construction of the 60 megawatt-peak (MWp) floating solar photovoltaic system on Tengeh Reservoir, believed to be one of the largest in the world. This is a major step towards harnessing renewable solar energy for water treatment and reducing the carbon footprint. The amount of clean energy generated will be sufficient to power PUB's local water treatment plants, off-setting 7% of PUB's annual energy needs.
- First-phase construction of Tuas Nexus, Singapore's first integrated water and solid waste treatment facility, commenced in September 2020. The greenfield project houses two mega facilities - PUB's Tuas Water Reclamation Plant (Tuas WRP) and NEA's Integrated Waste Management Facility (IWMF) - to harness synergies from used water and solid waste, with the by-product of one facility being used as a resource for the other. These synergies are expected to reduce more than 200,000 tonnes of carbon dioxide (CO₂) annually. This energy self-sufficient nexus is an important step towards maximising Singapore's energy, resource recovery and optimisation of land use.

“As the pandemic grew in 2020, PUB has been focused on achieving two outcomes - keeping our staff and workers safe from the virus and keeping Singapore’s water system running smoothly. Because we have been quick to act, nimble in adjusting, and able to coordinate as one, PUB continues to accomplish our water mission, in spite of a raging pandemic and an uncertain business environment. The commencement of operations at the Keppel Marina East Desalination plant, with its dual-mode capability, has further strengthened Singapore’s water security, adding a weather-resilient source of water in the face of climate change”, said Mr Ng Joo Hee, Chief Executive, PUB.

“The Global Water Awards recognise the most important achievements in the international water industry, and reward those initiatives in the water, wastewater and desalination sectors, that are moving the industry forward. I would like to congratulate PUB, for being named the ‘Resilient Water Agency of the Year’, a new category to honour the tireless and often unseen behind-the-scenes efforts by our water

agencies in ensuring uninterrupted water services during 2020’s COVID-19 challenges. while keeping its staff and customers safe with a comprehensive crisis management plan. I would also like to congratulate Singapore’s Keppel Marina East Desalination Plant, for being named the Desalination Plant of the Year, for setting a new standard for desalination, by optimising energy-efficiency and resource-efficiency with its dual-mode capabilities to treat both seawater and freshwater”, said Mr Christopher Gasson, Publisher of Global Water Intelligence.



Water is an essential service and many of the PUB officers continued to work on-site daily to ensure the smooth running of Singapore’s water systems even during the COVID-19 pandemic. Images: PUB, Singapore’s National Water Agency.



Officially opened by Prime Minister Lee Hsien Loong on 4 February 2021, the Keppel Marina East Desalination Plant is Singapore’s first large-scale dual-mode desalination plant, capable of treating either seawater or freshwater from the Marina Reservoir. Image: Keppel.

MOU SIGNED FOR CLIMATE CHANGE ADAPTATION

STUDIES IN SINGAPORE

CPG Consultants (CPG), a subsidiary of Singapore-based consultancy services, infrastructure, and building management firm CPG Corporation, has signed a Memorandum of Understanding (MoU) with Royal HaskoningDHV, a world-leading consultant in climate change adaptation and flood resilience studies, as part of an initiative to build local expertise in climate adaptation by facilitating knowledge transfer through collaboration with international partners.

CPG will lead a site-specific study along Singapore's City-East Coast, awarded by PUB, Singapore's National Water Agency, via an open tender.

The aim is to develop a climate resilience masterplan and formulate climate adaptation measures for integrated coastal protection to keep the population and critical infrastructure safe from flooding.

Complementing CPG's strengths and experience, Royal HaskoningDHV will provide expertise in water management, coastal protection, and waterfront developments. The parties will work in tandem to collect data and apply key findings in design solutions to supplement the overall masterplan and protect the coastline against rising sea levels and increasingly heavy rainfall.

CPG has been involved in some of Singapore's drainage masterplans - implementing flood mitigation measures for several waterways, and providing engineering consultancy services for major flood mitigation projects like the Stamford Diversion Canal and Stamford Detention Tank, to better protect Orchard Road against floods.

Royal HaskoningDHV has worked on climate adaptation projects internationally, such as a comprehensive urban water strategy in New Jersey, USA, as part of the Hurricane Sandy Task Force's initiative to rebuild affected regions, as well as an integrated coastal development programme for Northern Jakarta and Jakarta Bay, to protect the northern part of Indonesia's capital city against increasing floods.

Commenting on the site-specific study and the inking of the MoU, Mr Yeang Hoong Goon, CEO of CPG Consultants said, "We are honoured to undertake and lead this important study, and thrilled to have the opportunity to combine our extensive knowledge with teams of expert personnel from both CPG and Royal HaskoningDHV to form a world-class collaboration that will push the boundaries in this field and pave the way forward for other opportunities and projects to come. Being able to pioneer solutions for this purpose and to strengthen the country's climate resilience abilities will also allow Singapore to be positioned as a climate



View along the shoreline of East Coast. CPG and Royal HaskoningDHV will undertake a site-specific study along Singapore's City-East Coast. The aim is to develop a climate resilience masterplan and formulate climate adaptation measures for integrated coastal protection. Image: CPG Consultants.

change adaptation solutions hub to serve the region in the long run".

Royal HaskoningDHV's Global Director Water & Digital, Mr Niels Schallenberg, said, "We are proud to work in this partnership with CPG, strengthening Singapore's coastline, protecting millions of people, and safeguarding critical infrastructure, while at the same time enhancing the living environment. We look forward to implementing future-forward solutions together with CPG and PUB".

Besides Royal HaskoningDHV, CPG will also be supported by other local and international specialists, including Royal HaskoningDHV's water management solutions partner Hydroinformatics Institute (H2i), Golder Associates, Ernst & Young Singapore, Professor Koh Lian Pin (National University of Singapore's Centre for Nature-based Climate Solutions), Associate Professor Tan Soon Keat (Nanyang Technological University), and China Communications Construction Water Transportation.

The study is scheduled to take around four years to complete and will cover about 60 km of Singapore's coastline across three areas (Changi, East Coast-Marina stretch, and part of the Greater Southern Waterfront district). It will address the protection of the community as well as important landmarks such as East Coast Park and East Coast Parkway against the adverse effects of sea-level rise.

CPG and its partners aim to develop and nurture a local talent pool of experienced climate change professionals who can protect Singapore in the future through a resilience masterplan with sustainable solutions, and help both Singapore and the region meet the future challenges of rising sea levels.

JLL LAUNCHES TALENT DEVELOPMENT PROGRAMME FOR SINGAPORE'S REAL ESTATE INDUSTRY

Global real estate consultant JLL recently announced the launch of its SGD 2.6 million Future Skills programme aimed at creating a strong local talent pipeline and advancing career opportunities for Singaporeans in an increasingly challenging global environment.

The programme will augment JLL's ongoing efforts to attract, retain and nurture local talent, and put into action the upskilling and reskilling mandates introduced by the National Jobs Council. The opportunities will be available across three pillars:

- Deepening JLL's local talent pipeline of interns, graduates and apprentices, and setting out early career pathways for the industry's workforce.
- Creating employment opportunities for mid-career professionals from adjacent industries, through re-training and skills enhancement initiatives.
- Nurturing JLL's Singaporean employees with the professional skills they need to be future-ready and globally competitive.

Ms Helen Snowball, Head of Human Resources, JLL Asia Pacific, says, "Real estate is an exciting and increasingly tech-enabled field and we see tremendous potential in tapping into Singapore's highly skilled workforce to fuel the growth of our business here. We are proud to have Singapore as our regional headquarters and are supportive and greatly appreciative of the Singapore government's role and partnership in co-investing in the greatest asset we have here - our people".

Pathways for the next generation of industry talent

To set out early careers pathways for the industry's young talent, JLL has designed three programmes for internship, client experience (including a two-month bootcamp for graduates) and functional expertise for graduates. It will partner with local tertiary and vocational institutions to offer internship opportunities and entry-level positions to 122 local undergraduates, graduates and technical associates over the course of three years.

Supporting mid-career transitions

Responding to the National Job Council's call for a whole-of-nation approach to grow job and training opportunities for Singaporeans, JLL aims to expand the industry's workforce by tapping into a cohort of mid-career professionals from adjacent industries. The company aims to retrain local professionals in customer service, technical and engineering roles. The reskilling programme could see technicians from other sectors becoming engineers and facility managers, and guest ambassadors and facilities executives transitioning to more senior roles in facilities management.

"Like us, our clients are excited to attract talent from sectors that have been hit hard by the COVID-19 pandemic, such as hospitality, events and aviation. We look forward to welcoming new employees who will bring fresh perspectives and expertise, and ultimately improve the services we provide - whether it is sales, workplace experience, facilities management or engineering", said Mr Chris Archibold, Country Head, JLL Singapore.

Upskilling local workforce to be 'future fit'

JLL is investing in initiatives to groom its existing local talent through individual programmes. The training focuses on inclusive leadership, resilience and well-being; innovation and human-centred design; sales and business development; and proptech, data and analytics.

Xylem engages students in global youth programme

Xylem, a leading water technology company, is investing in the future of the global water industry with a new dedicated student development programme, Xylem Ignite, targeting high school and university students worldwide. Midway through its inaugural year, Xylem Ignite has already engaged more than 1,700 students in creative water-oriented hackathons and sustainability events, including 650+ participants from 47 countries competing in the Xylem Global Student Innovation Challenge.

"Young leaders are playing such an essential role in our collective ability to solve the global water crisis facing us. We want to encourage them. So we are investing in them with Xylem Ignite. The future of water innovation is coming from many places, including students who are engaging passionately to help address our water challenges", said Mr Patrick Decker, Xylem's Chief Executive Officer.

With access to masterclasses and support from mentors across the water industry, contestants were invited to submit solutions to one of four challenge statements. They included: reducing the water footprint of everyday products, gamifying water quality education, urban flood prediction, and water for life on Mars.

Young innovators developing solutions to various water problems can also apply to be a part of the Xylem Ignite Innovation Incubator. The incubator programme provides up to 12 months' support for participants to scale up their innovations and advance them towards market readiness.

FARO EXPANDS DIGITAL TWIN PRODUCT SUITE THROUGH ACQUISITION OF HOLOBUILDER

US-based FARO Technologies Inc, a global leader of 3D measurement, imaging and realisation solutions for the 3D Metrology, AEC (Architecture, Engineering & Construction), and Public Safety Analytics markets, recently announced the acquisition of HoloBuilder Inc, also from the US.

HoloBuilder brings to FARO its leading photogrammetry-based 3D platform which delivers hardware-agnostic image capture, registration and viewing to the fast-growing digital twin market. With an initial focus on construction management, HoloBuilder's technology platform provides general contractors a solution to efficiently capture and virtually manage construction progress using off-the-shelf 360° cameras.

HoloBuilder's SaaS platform will add fast and easy reality-capture photo documentation and added remote access capability to FARO's accurate, 3D point cloud-based laser scanning to create an end-to-end digital twin solution - all without leaving the FARO ecosystem. The combined solution will provide comprehensive scanning and image management capabilities for the digital twin market, including robotic assembly 3D simulation, construction management, facilities operations and management, and incident pre-planning.

"The high-value that digitalisation brings to the AEC and Operations & Maintenance (O&M) industries creates



FARO Technologies has acquired HoloBuilder.

significant market opportunity for FARO. The addition of HoloBuilder to our offering accelerates the reality of a true end-to-end digital twin solution and advances our strategic objective of increased recurring revenue through market share gains in this large and growing segment", said Mr Michael Burger, President and CEO of FARO.

"HoloBuilder and FARO together furthers our vision of digitising the physical world to enable process automation and workflow optimisation. The powerful combination of high accuracy laser scanning with real-time 360° photo capture and collaboration will empower both companies' customer bases with a comprehensive digital twin solution", said Mr Mostafa Akbari-Hochberg, Founder & President of HoloBuilder.

Lendlease Global Commercial Trust Management appoints new Chairman

Lendlease Global Commercial Trust Management Pte Ltd, as the Manager of Lendlease Global Commercial REIT (the Manager), announced the appointment of Ms Ng Hsueh Ling as its new Chairman, with effect from 1 June 2021.

She took over the position from Mr Anthony Peter Lombardo who assumed the role of Group Chief Executive Officer and Managing Director of Lendlease. Mr Lombardo will remain on the board as a Non-Executive and Non-Independent Director of the Manager.

Ms Ng is the Managing Director, Singapore, and Chief Investment Officer, Asia, at Lendlease, a post she has held since August 2017. She is also the key Executive Officer of Lendlease Retail Pte Ltd. In these roles, she is instrumental in driving the growth of Lendlease's Asia Investment Management business platform, where she manages the growth strategy for Lendlease's investment management portfolio in Asia which includes creating

access and pathways into new funds, REITs and assets.

Ms Ng brings with her over 29 years of real estate experience across Asia, in strategic sourcing, investments and divestments, asset and portfolio management, as well as in the development of assets.



Ms Ng Hsueh Ling

She also has extensive fund management experience in the areas of real estate fund product creation, deal origination, distribution and structuring of real estate-based financial products.

Ms Ng holds a Bachelor of Science degree in Estate Management from the National University of Singapore and has an Appraiser's Licence from the Inland Revenue Authority of Singapore.

VEOLIA WATER TECHNOLOGIES

STRENGTHENS ITS DISTRIBUTION NETWORK

Veolia Water Technologies, a leading solutions provider for water and wastewater treatment, has recently signed new agreements with multiple partners to deliver water solutions in countries across Asia Pacific.

A total of 24 new partners have entered into agreements with Veolia Water Technologies in Asia Pacific to market, sell, and deliver specific Veolia products - enabling the company to strengthen its local customer support and product offering in the region. These new contracts cover numerous territories including China, Indonesia, Malaysia, Thailand, Vietnam as well as Bangladesh, Sri Lanka and New Zealand.

“We are delighted to work with these water solution companies across the region. These partnerships align well with our growth strategy in Asia Pacific and allow

our customers greater accessibility to Veolia’s sustainable water solutions”, said Mr Mathieu Le Noir, Asia Pacific Distribution Director, Veolia Water Technologies.

These partners, with years of practical experience in their respective locations, will provide a tailored offering to their markets, bolstered by access to Veolia’s expertise and proven water treatment technologies.

Suzhou ANFENG Environmental Technology Co Ltd is one of the new partners for China.

“Veolia is a well-established, trusted brand, and we anticipate that this alliance will take the development of our business to the next level”, said Mr Jazz Wang, Marketing Director at Suzhou ANFENG, who is also responsible for the Veolia line of products.

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BENTLEY SYSTEMS ANNOUNCES SEEQUENT'S ACQUISITION OF AARHUS GEOSOFTWARE

Bentley Systems Incorporated, the infrastructure engineering software company, recently announced that its Sequent business unit has acquired Danish company Aarhus GeoSoftware (AGS), a developer of geophysical software. The acquisition extends Sequent's solutions for operational ground water management, and for sustainability projects involving exploration, contaminants, and infrastructure resilience.

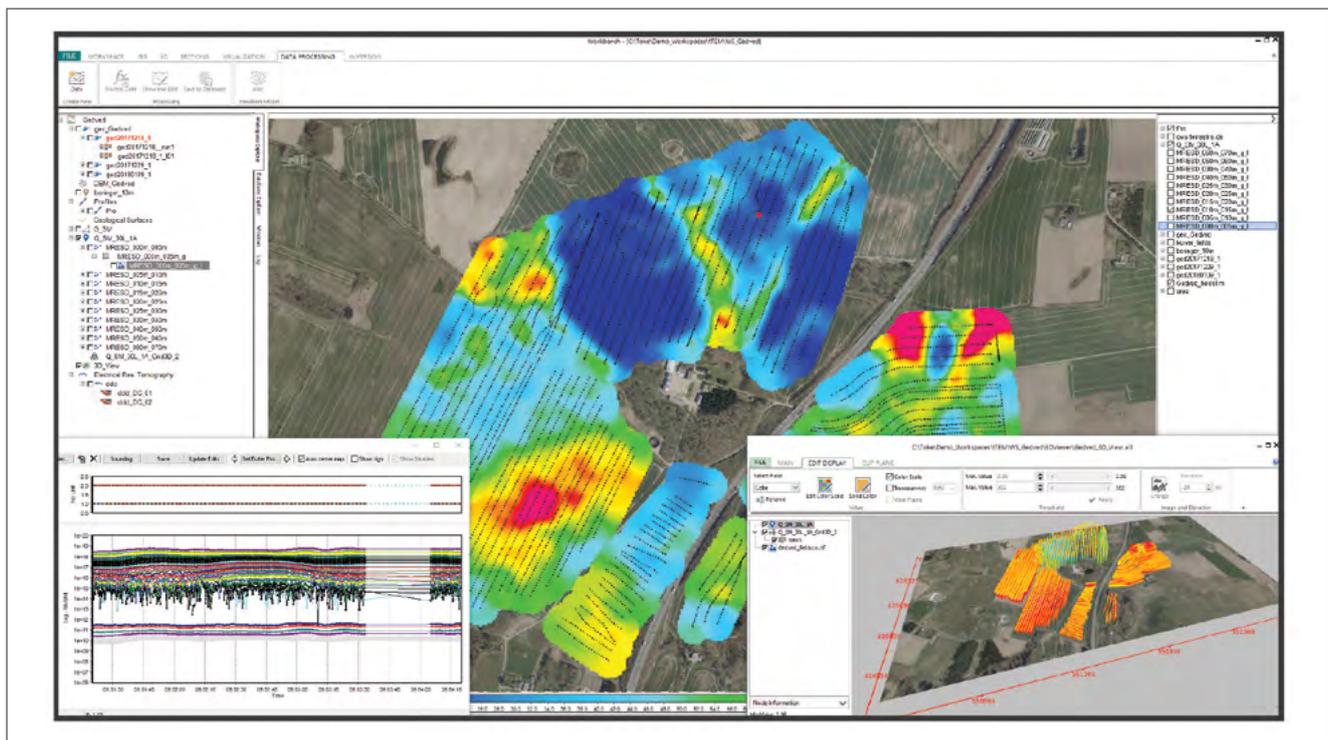
Aarhus GeoSoftware, a spinoff company from Aarhus University in Denmark, develops the software packages AGS Workbench, SPIA, Res2DInv and Res3DInv, for the processing, inversion, and visualisation of geophysical data from ground-based and airborne electromagnetic (AEM) remote sensing, electrical resistivity tomography (ERT) remote sensing, and other sources. AGS software enables users to create 2D and 3D images of subsurface electrical resistivity. The outputs of the software can be used to distinguish and differentiate subsurface materials and can subsequently be modelled in Sequent's Leapfrog to aid in various subsurface investigations.

The software uses electric field measurements, collected at ground level or with airborne sensors, to map the subsurface distribution of certain materials. Electrical resistivity allows a better understanding of the distribution of materials such as water, mineral

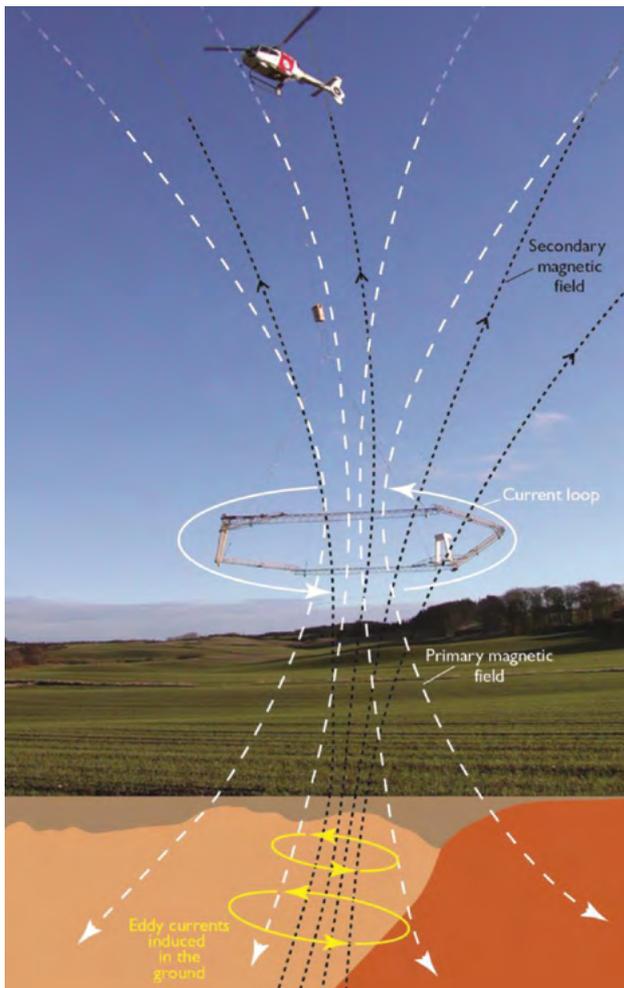
deposits and clays, and when the water contains other compounds such as salt, researchers and industry professionals can infer the distribution.

Airborne Electromagnetic (AEM) remote sensing uses electromagnetic induction to collect extensive volumes of data from an aircraft. It is a fast and cost-effective way of subsurface mapping, can cover large areas (up to thousands of square kilometres) in a few days, requires no new drilling or ground access and, using 3D modelling and visualisation software, has a quick turnaround for mapping the subsurface. The technique involves a helicopter or a small airplane towing a sensor loop approximately 100 ft (30 m) above the ground. This generates an electromagnetic signal transmitted into the earth based on the subsurface properties, thereby creating a secondary field which is measured at the aircraft. The data is then processed to estimate subsurface electrical properties. The returned signal, which depends on the resistivity or conductivity, helps geoscientists establish the nature of the subsurface.

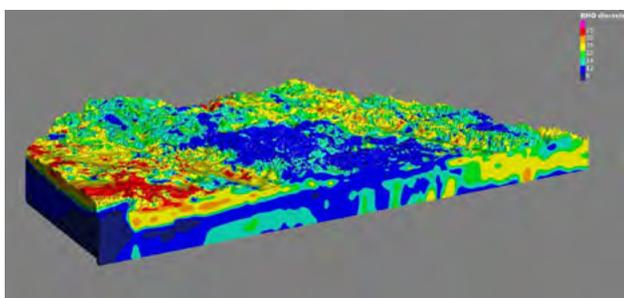
The genesis of AGS software was to ensure clean drinking water for future generations, by mapping groundwater across Denmark. It now has many applications, including locating subsurface faults and cavities to mitigate construction risk; investigating orebodies and waste rock and tailing processes, in mining; monitoring



AGS Workbench is a comprehensive software package for processing, inversion, and visualisation of geophysical and geological data. The AGS Workbench package is based on a GIS interface and includes dedicated data processing modules for various geophysical data types. The package integrates all workflow steps from processing the raw data to the final visualisation and interpretation of the inversion models.



Airborne Electromagnetic (AEM) remote sensing is used to collect extensive volumes of data from an aircraft. A sensor loop below a helicopter or small plane transmits an electromagnetic signal to the earth. Based on the subsurface properties, a secondary field is created and measured at the aircraft. The data is then processed to estimate subsurface electrical properties. The AGS Workbench software is used for processing, inversion, and visualisation of the data collected by AEM and other geophysical methods.



Sensing data processed and inverted in AGS Workbench software can be combined in Seequent's Leapfrog Works to create a 3D model that gives a detailed overview of resources. Shown in the image is a hydrogeological map of the subsurface of the Principal Aquifer (and parts of the Ogallala Aquifer) in Nebraska, USA. AEM remote sensing was used to capture data from the 4,000-square-mile study area. The colour-coded volumes represent eight resistivity categories. Higher resistivity values are represented as yellow to red (sand and gravel), lower resistivity values are represented as blue to green (clay and silt), and brown represents bedrock.

movements of groundwater and contaminants to help understand environmental impacts; modelling dam and tunnel stability; and assessing the risk of a landslide to gauge asset resilience or construction plan impacts. Seequent will continue its tradition of collaborating with universities and research organisations worldwide through ongoing engagement with Aarhus University for the development of AGS geophysical solutions.

Graham Grant, Chief Executive Officer of Seequent, said, "The acquisition will add new geophysical data processing capabilities to our workflows, to help advance subsurface investigation and modelling. AGS software, coupled with Seequent's advanced geologic modelling and analysis software, creates a key tool in helping understand and manage groundwater and assessing risk in infrastructure such as dams and canals. We are excited about the new possibilities this opens up for our collective users worldwide, improving life-time digital twins".

Toke Højbjerg Søltoft, Chief Executive Officer of Aarhus GeoSoftware, said, "Seequent's global reach will allow AGS software to positively impact more projects worldwide. As we continue to develop solutions, our users will benefit from our tools being in Seequent's ecosystem and workflow. We are excited to join Seequent and to work together on our shared vision of helping organisations make more informed and sustainable decisions through a better understanding of the subsurface".

Bentley iTwin platform to integrate with NVIDIA Omniverse

Bentley Systems recently announced that it is developing applications using the NVIDIA Omniverse platform for photorealistic, real-time visualisation and simulation of digital twins of massive-scale industrial and civil infrastructure projects.

The company has extended the Bentley iTwin platform to integrate with NVIDIA Omniverse to provide a graphics pipeline for AI-enhanced, real-time visualisation and simulation of infrastructure digital twins. This integration allows engineering-grade, millimetre-accurate digital content to be visualised with photorealistic lighting and environmental effects on multiple devices including web browsers, workstations, tablets, and virtual reality and augmented reality headsets, from anywhere in the world.

Bentley iTwin is an open, scalable cloud platform that enables engineering firms and owner-operators to create, visualise, and analyse digital twins of infrastructure assets. Digital information managers use it to incorporate engineering data created by diverse design tools into a living digital twin and align it with reality data, IoT data and other associated data, without disrupting their current tools or processes.

MAPEI AND ELETTRONDATA ANNOUNCE STRATEGIC PARTNERSHIP

Mapei, a leading company in supplying chemical products and solutions for the building industry, and Elettrondata, a leader in automation systems for the management, production and control of ready-mix concrete plants, have signed a multi-year partnership agreement to offer equipment and services for quality control, production and transport of ready-mix concrete.

The combination of Elettrondata's process automation technology and Mapei's concrete technology, will be an alliance that will provide the entire concrete industry with the added value resulting from the implementation of the Total Quality process and will support the industry's quest towards CO₂ neutrality.

A change towards a circular economy is crucial for value creation, economic growth as well as resource management and waste management. Through Mapei Concrete Industry Solutions, this partnership will integrate raw materials, concrete admixtures, fibres and digital solutions in a circular process that will ensure quality and sustainability. Focusing on the total life cycle of a structure, it will increase the value and reduce the carbon footprint through high-end products and process automation.

In addition, thanks to the new EDSM II system, which was created as a result of this partnership, the concrete delivery phase is now part of the quality process.

Mr Marco Squinzi, CEO of Mapei, said, "Mapei focuses on a sustainable concrete industry. The partnership with Elettrondata is a winning combination for our customers, allowing the successful mix of proven, robust, and user-friendly hardware and software with our chemical products and solutions. As the world-leading supplier of admixtures and fibre technology for concrete, we have developed a full range of ancillary products to support all the steps of concrete production and use. Offering the EDSM II is part of this Total Quality and Sustainability thinking, focusing on concrete production, from raw materials, mix design, production, transport, casting & curing and recycling".

Mr Leonardo Nigro, CEO of Elettrondata, said, "The partnership with Mapei is for us a source of pride and an incentive to continue to innovate. For over 15 years, we have been studying and implementing the SM system for the control of the delivered concrete. Today we have more than 3,000 SM systems installed on as many truck mixers. Thanks to the collaboration with Mapei, EDSM II was born, the new system for the control of the concrete during its delivery that integrates the SM system and is improved with further functions, in order to provide the concrete producer with all the data in real-time".



Mapei and Elettrondata have signed a partnership agreement. Seen in the picture are Mr Marco Squinzi, CEO of Mapei (left) and Mr Leonardo Nigro, CEO of Elettrondata (right).

Aurecon invests in Malaysia

Leading international engineering, design and advisory company Aurecon recently announced that it had made an investment in Malaysia's GCU Consultants Sdn Bhd (GCU), a move that will strengthen the company's regional presence and expertise.

Mr William Cox, Chief Executive Officer at Aurecon, says the investment in GCU is an important step in the company's growth ambitions and creates a direct presence in one of Southeast Asia's most important economies.

"There is strong alignment between our companies and when we first looked at GCU, we were impressed with its technical excellence, professionalism and success", he said.

GCU was established in 1998 and has a strong reputation for its market-leading geotechnical consultancy. The company also offers expert consultancy in civil and structural, and mechanical and electrical engineering disciplines.

Ir. E G Balakrishnan, Managing Director of GCU, says joining with Aurecon will give GCU the opportunity to secure bigger, more innovative projects.

"We are very excited to be joining the Aurecon group. There is much to look forward to in Malaysia's engineering sector and being part of Aurecon will allow us to offer additional resources and digital engineering tools that will enable us to take on larger and more challenging projects. We look forward to helping even more clients in Malaysia to bring their ideas to life", he said.

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SINGAPORE'S

NEXT-GENERATION PORT

Tuas Port will be a resilient and sustainable marine transportation hub.



Artist's impression of Tuas Port, Singapore's next generation port.

INTRODUCTION

In order to maintain Singapore's position as a global hub port and an international maritime centre, Singapore has been investing in its port capacity and capabilities ahead of demand. Over the years, the port capacity has expanded from the first container terminal at Tanjong Pagar to also include Keppel Terminal, Brani Terminal and Pasir Panjang Terminal.

First announced in 2012, Singapore's plan is to consolidate container port operations from the current terminals to a single location at Tuas at the western end of the country. The vision is to build a smart, next-generation port that increases productivity, optimises land use, improves safety and security, and enhances sustainability.

When fully completed in the 2040s, Tuas Port will be capable of handling up to 65 million Twenty-foot Equivalent Units (TEUs) annually. Consolidating all container-handling facilities at Tuas will significantly reduce inter-terminal haulage operations and greenhouse gas (GHG) emissions while achieving greater economies of scale.



Aerial view of the Tuas Port site as at early January 2021.

The Maritime and Port Authority of Singapore (MPA) has planned the development of Tuas Port in four phases. The land reclamation work under Phase 1 commenced in March 2015 and MPA is on track to complete Phase 1 land reclamation works by the end of 2021. Phase 2 reclamation works for Tuas Port are ongoing as scheduled.



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The master planning for Tuas Port includes the planning of the port layout, water depth, navigation channel and anchorages to serve the port and the port eco-system and other objectives. The reclamation work in Phases 1 and 2 of the Tuas Port project involves the creation of 681 hectares (ha) of reclaimed land, fabrication of 448 caissons and the dredging of the Temasek Fairway and Tuas Basins to a depth of -23 m at Chart Datum (CD). Finger-piers with caisson quay walls were adopted to maximise limited land and sea space. Coupled with long linear berths and a design depth of -23 m at CD, Tuas Port will be able to accommodate mega container ships exceeding 450 m in length.

Sustainability

Sustainability is at the heart of the planning, design, construction and operations of Tuas Port. It will be a green port, which is economically and environmentally sustainable with energy-efficient processes and a safe and clean environment. Many environmentally friendly initiatives were considered in developing Tuas Port. To adapt to rising sea levels, Tuas Port will be built at least 5 m above mean sea level to future-proof it against sea level rise in the coming decades.

More than 50% of the total fill materials for Phases 1 and 2 are dredged and excavated material from local construction projects. Reusing such material, which would otherwise be disposed of, reduces the reliance on sand for reclamation and saves more than SGD 2 billion in fill material costs, apart for constructing Tuas Port in a sustainable manner.

Environmental impact assessments were carried out before reclamation works, which resulted in preventive and mitigation actions such as implementing a SGD 6 million programme to relocate and monitor corals that may be affected during Tuas Port development. The community was encouraged to be guardians of the ecological environment in the waters off Tuas Port. Corals in proximity to the port development were relocated with the help of nature volunteers, and environmental monitoring of the relocated corals was carried out by established academics in the National University of Singapore (NUS). These efforts have helped to raise public awareness and promote community participation in protecting the environment. Strict Environmental Quality Objectives for compliance during the reclamation works were also established to protect marine habitats and sensitive commercial water intakes under the on-going Environmental Monitoring and Management Programme (EMMP).

Digitalisation

Beyond the physical port, Tuas Port will use automated technology, boasting features such as automated wharf and yard functions and fully electric automated guided vehicles.

Tuas Port will be highly digitalised, with the use of a state-of-the-art vessel traffic information system, an active anchorage management system and digitalPORT@SG™ to efficiently manage the shipping traffic. The digitalPORT@SG™ is a one-stop portal for port clearanc-

MPA receives accolade at World Ports Sustainability Awards

At the International Association of Ports and Harbors' (IAPH) World Ports Sustainability Awards 2020, Tuas Port won the award in the 'Port Development and License to Operate' Focus Area, under the 'Community Outreach & Port City Dialogue' category.

The accolade recognises the efforts of the Maritime and Port Authority of Singapore (MPA) in 'aligning and integrating port and community objectives for the betterment of both'. These efforts include developing community engagement programmes and managing the externalities of port expansion in urban environments.

Er Tham Wai Wah, MPA's Chief Engineer and Senior Director (Engineering and Project Management), said, "Tuas Port represents a bold vision for Singapore. As a responsible hub port, this award affirms our commitment to balance environmental protection with port development. It is our ambition for Tuas Port to become a beacon for sustainability, safety and efficiency".

es and other regulatory transactions as well as Just-In-Time services to enhance efficiency of port operations and improve the turnaround time of ships.

digitalPORT@SG™ will also be integrated with port and marine service providers to facilitate a marketplace for seamless access to services for customers and port users. The digital port ensures sustainability in terms of eco-efficiency, by endeavouring to minimise vessel and land vehicle movements, reduce idling time and streamline maritime processes. Consequently, the operational efficiencies gained would reduce emissions at the port, its surrounding eco-system and beyond our port waters.

In addition, Tuas Port will utilise advanced communication networks to support IoT, automation and digitalisation, and deploy innovative technologies such as data analytics and artificial intelligence in decision-making.

Tuas Port will also be at the heart of a larger eco-system in the industrial hinterland. This will create greater port-industry synergies that will strengthen the link between the port and businesses, and will reduce the logistics costs. Under the larger Tuas eco-system, MPA, together with other agencies, has developed measures to be implemented in tandem with the ramping up of port operations at Tuas to ensure the accessibility of Tuas Port for its workers. Clustering synergistic industries in a port-centric eco-system around Tuas Port offers carbon footprint savings through shortened supply chains, shared facilities, and resource optimisation.

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Maritime and Port Authority of Singapore

The Maritime and Port Authority of Singapore (MPA) was established on 2 February 1996, with the mission to develop Singapore as a premier global hub port and international maritime centre (IMC), and to advance and safeguard Singapore's strategic maritime interests. MPA is the driving force behind Singapore's port and maritime development, taking on the roles of Port Authority, Port Regulator, Port Planner, IMC Champion, and National Maritime Representative. MPA partners the industry and other agencies to enhance safety, security and environmental protection in our port waters, facilitate port operations and growth, expand the cluster of maritime ancillary services, and promote maritime R&D and manpower development.

TUAS PORT PHASE 1 CONSTRUCTION

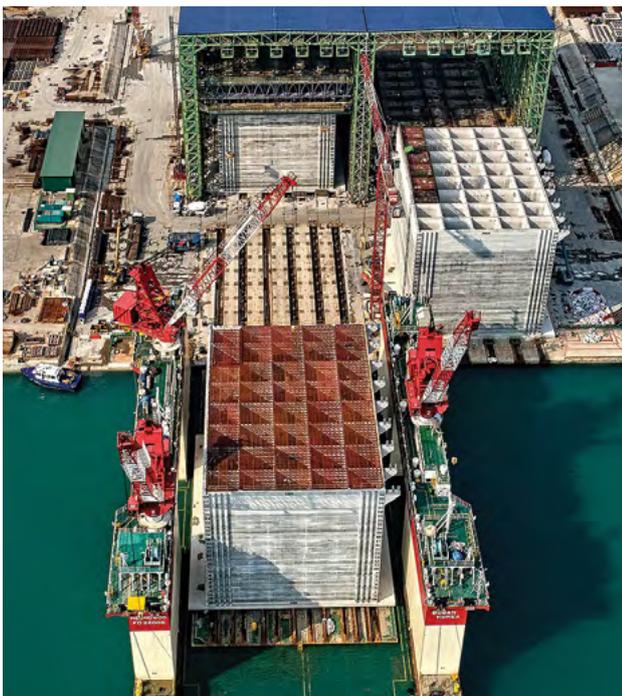
Tuas Port Phase 1 construction commenced in end-April 2016, with the launch of the first caisson.

In February 2015, MPA appointed the DIAP-Daelim Joint Venture to carry out the land reclamation and related works for Tuas Port Phase 1 development. The works include reclaiming 294 hectares of land, dredging the Tuas basin and Temasek Fairway, as well as constructing the wharf structure.

Innovative engineering solutions

The scale and complexity of the project presented opportunities for the team of MPA and local as well as international engineers to challenge themselves and find innovative solutions to overcome resource constraints.

One such challenge was the construction of the wharf structure, which saw the engineering teams use an innovative caisson design with the caissons prefabricated on site.



Overview of a typical caisson.



Grab dredgers are used to dredge the seabed and the dredged materials are used as reclamation fill.



From left: Filling of dredged materials into the final caisson with an e-crane to lock its position and celebratory water cannons from tugboats to mark the last caisson installation in Tuas Port Phase 1.



The reclaimer is a specialised equipment that is used to fill the soft dredged materials above the water surface, such as filling across the caisson wharf line.



Soil improvement using pre-fabricated vertical drains (PVDs) with sand surcharge has been adopted to improve the recycled fill materials which are soft clayey soils and the existing soft clayey seabed materials.

The use of caissons is a more efficient method of construction than other methods such as piling, and affords site personnel a safer work environment. In addition, as the caissons are of standard sizes and prefabricated in a factory-like environment on-site, productivity and the quality of the wharf structure are also improved. The caissons used for Tuas Port's construction are one of the largest in the world. Pre-fabricated onsite, each caisson weighs 15,000 tonnes and measures 40 m in length, 28 m in width and 28 m in height.

The DIAP-Daelim Joint Venture has also used cutting-edge equipment and techniques to maximise efficiency. It mobilised the world's largest grab dredger and one of the world's most powerful cutter suction dredgers, along with a wide range of other dredging and reclamation equipment. In addition, the use of soil improvement techniques allowed the dredged materials from the deepening of basins and nearby fairway, as well as excavated earth obtained from other land construction projects, to be reused as reclamation fill materials for the project. Re-using such materials, which would otherwise be disposed of, reduces

the quantity of sand fill required for reclamation, resulting in fill material cost savings.

A total of 221 caissons form the permanent wharf structure. The final caisson for Tuas Port Phase 1 reclamation was installed in late April 2019.

MPA, together with their partners DIAP-Daelim Joint Venture, Surbana Jurong, YJP surveyors and Xjera also adopted other innovative solutions, ranging from the pre-installation of geotextiles on caissons on land instead of at sea and test-bedding the use of video analytics with artificial intelligence for site safety, to the use of drones with Lidar capabilities for site survey and progress monitoring.

In addition, there are two innovations that have pushed the frontiers of engineering:

- The deployment of TEMAROCK, a next-generation, all-in-one rock mound construction vessel: The conventional process of rock mound construction requires multiple vessels for rock laying and compaction, one survey vessel to facilitate operation, and support by



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divers. TEMAROCK automates these tasks, eliminating the need for multiple vessels or assistance from divers. This enhances efficiency and safety.

- The use of the Automatic Rebar Machine Systems (ARMS) which employs robotics: ARMS automates the bending and cutting of reinforcement steel bars (rebars), which are used to strengthen concrete, to the desired design, and then transfers them to the stacking area. The conventional practice requires workers to handle the rebar manually, which exposes them to mechanical hazards when they operate the rebar cutting and bar bending machines.

With the completion of Phase 1 reclamation works in 2021, PSA, the operator of the port, expects to commence operations of the first set of berths by the end of this year.

TUAS PORT PHASE 2

The reclamation work for Tuas Port Phase 2 commenced in early July 2019, with the installation of the first caisson. When fully operational, Tuas Port Phase 2 will add a capacity of 21 million twenty-foot equivalent units (TEUs).

MPA appointed Penta-Ocean Construction Co. Ltd/Hyundai Engineering & Construction Co Ltd/Boskalis International BV (PHB) Joint Venture to carry out land reclamation and related works for Tuas Port Phase 2 development in February 2018. At 387 hectares, this is the largest of the four phases to be reclaimed. The 8.6 km wharf structure will be constructed with 227 caissons that will be fabricated on site.

The use of innovative and modern construction methods

The Tuas Port Phase 2 project team is using innovative construction methods to boost safety and improve productivity. For example, the project team is using a slip form jack monitoring system and rebar modularisation, for the fabrication of the caissons. The slip form jack monitoring system provides an unobstructed view of the hydraulic system. This feature enhances the safety of workers through prompt rectifications of the hydraulic system. The process of rebar modularisation allows for

the pre-fabrication of steel bars that form part of the base slab. This significantly improves the safety of those working under the steel bars. The project team is also adopting modern construction technology such as an automated curing system which is a water circulation system that helps to control the quality of the base slab. In addition, there is one innovation that has enhanced construction safety:

- The deployment of the unmanned silane sprayer, Silane Apache, for the application of silane on internal concrete walls of the caisson and Silane Alpinist, for the application on external concrete walls: The conventional process required workers to use a single hand nozzle sprayer while working at height in a suspended man cage or boom lift basket. Silane Apache and Silane Alpinist automated these tasks, eliminating the risk of accidents from working at height and reducing the exposure of workers to toxic fumes. This enhances productivity and safety.

Furthermore, the project team is using modelling and simulation techniques to simulate numerous construction activities at the reclamation sites to assess congestion hotspots for trucks on land and vessels in the sea, which could be potential risk areas for accidents. This allows the Contractor to better plan, schedule and allocate resources to move construction and reclamation fill materials around safely and efficiently on site.

Innovation Initiatives and Research and Development (R&D) Efforts

Currently, there is no existing knowledge on the performance of reclaimed port land with large-scale use of dredged and excavated materials to support automated container terminal operations. Together with a team of NUS researchers, engineers from MPA and PSA Corporation are developing a digital twin of the Tuas Port reclaimed land (DigitaLand@Tuas) using fundamentals of soil mechanics and machine learning optimisation techniques. DigitaLand@Tuas could help to identify susceptible areas within the container terminal where and when stringent allowable ground settlement may be reached, and automated operations could be affected.



Installation of the first caisson for Tuas Port Phase 2.

With this predictive ability, PSA's engineers can plan preventive maintenance early to repair a potential area of excessive settlement and reinstate the port pavement to its required level, if necessary. If this R&D is successful, this innovation would help the port operator to better predict long-term settlement behaviour and mitigate the risks of hampering productivity of terminal operations due to frequent closure of yards and berths for repair and maintenance works over the long term.

MPA is also partnering a team of Nanyang Technological University (NTU) researchers to study the use of controlled modulus columns (CMC) as a foundation to support heavy container stacks in storage yards. Upon demolition, CMCs are easier to remove than conventional steel reinforced concrete piles. If the R&D pilot trial of CMC is successful, CMC could be a better alternative for constructing foundations for container yards to future proof the port.

In addition, MPA is also working with NTU and DHI Singapore to deploy video analytics for silt plume detection in coastal waters around Tuas Port. Drones with hyperspectral and multispectral cameras will carry out remote sensing to monitor turbidity concentrations in the waters. Using Artificial Intelligence with Convolutional Neural Networks imaging analysis, the software will be able to put together a contour map of turbidity concentration of the silt plume. This R&D project complements the on-going EMMP which uses real-time sensors to monitor the impact of dredging and reclamation works on the marine environment. If successful, this project will help to digitalise environmental monitoring operations in Singapore waters and gives near real-time information to optimise allowable spill budgets for reclamation work.

All images by Maritime and Port Authority of Singapore

PROJECT CREDITS (EARLY STAGE DEVELOPMENT)

DEVELOPER

MARITIME AND PORT AUTHORITY OF SINGAPORE (MPA)

SITE INVESTIGATION WORKS

KISO JIBAN CONSULTANTS CO LTD

ENVIRONMENTAL IMPACT ASSESSMENT AND CORALS RELOCATION WORKS

DHI WATER & ENVIRONMENT (SINGAPORE) PTE LTD

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SPACE INTENSIFICATION STUDIES

SURBANA JURONG CONSULTANTS PTE LTD

MARINE RISK ASSESSMENT

SIMPLUS PTE LTD

PROJECT CREDITS (CONSTRUCTION STAGE)

DEVELOPER

MARITIME AND PORT AUTHORITY OF SINGAPORE (MPA)

TPP1 MAIN -CONTRACTOR

DIAP-DAELIM JOINT VENTURE - MAIN CONTRACTOR (PHASE 1)

TPP2 MAIN -CONTRACTOR

PENTA-OCEAN CONSTRUCTION CO LTD./ HYUNDAI ENGINEERING & CONSTRUCTION/ROYAL BOSKALIS WESTMINSTER N.V. JOINT VENTURE (PHBJV) - MAIN CONTRACTOR (PHASE 2)

TPP1 AND TPP2 SUPERVISION CONSULTANT

SURBANA JURONG CONSULTANTS PTE LTD

TPP1 AND TPP2 CONSULTANTS AND CONTRACTORS

TY. LIN INTERNATIONAL PTE LTD
KISO-JIBAN CONSULTANTS CO LTD
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A SPECIALIST IN PILE EXTRACTION

AS WELL AS PRE-LOADING AND PILING

by Nobuo Oi, Managing Director,
Fukuichi Oi, Project Manager and
Hlaing Su Su, Civil Engineer, Taiyo
Asia (E&C) Pte Ltd

The company has introduced new,
innovative methods.



Mr Nobuo Oi



Mr Fukuichi Oi



Ms Hlaing Su Su

INTRODUCTION

Taiyo Jack Leasing & Trading has been involved in civil engineering work since it was established in 1993.

The company has been providing ERSS (Earth Retaining and Stabilising Structures) strutting works and pre-loading works in Singapore.

It has successfully completed LTA projects and other commercial projects.

Following a period of growth, year after year, the decision was taken to establish Taiyo Asia (E&C) Pte Ltd (Taiyo Asia) in 2011, in order to focus the company's business on pile extraction works in Singapore. Taiyo Asia uses its innovative pile extraction method to extract H-Piles, Timber Piles, Soldier Piles and Bored Piles.

The company also specialises in pre-loading and piling.

PILE REMOVAL

Taiyo Asia has successfully extracted piles with an average length of 18 m to 38 m, in various projects.

The company's pile extraction method has been developed through modification of and improvements to existing methods.

Taiyo Asia uses the jacking method to extract H-Piles and Soldier Piles.

As a result, noise and vibration are less than when using other machines.

PRE-LOAD JACK-UP

When excavating the ground, a force equivalent to the force of the ground to be excavated is introduced to the strut to push back the earth retaining wall.

The introductory pre-load axial force must be set in consideration of the ground conditions, the rigidity of the girder, the condition of the retaining wall and the condition of the adjacent buildings.

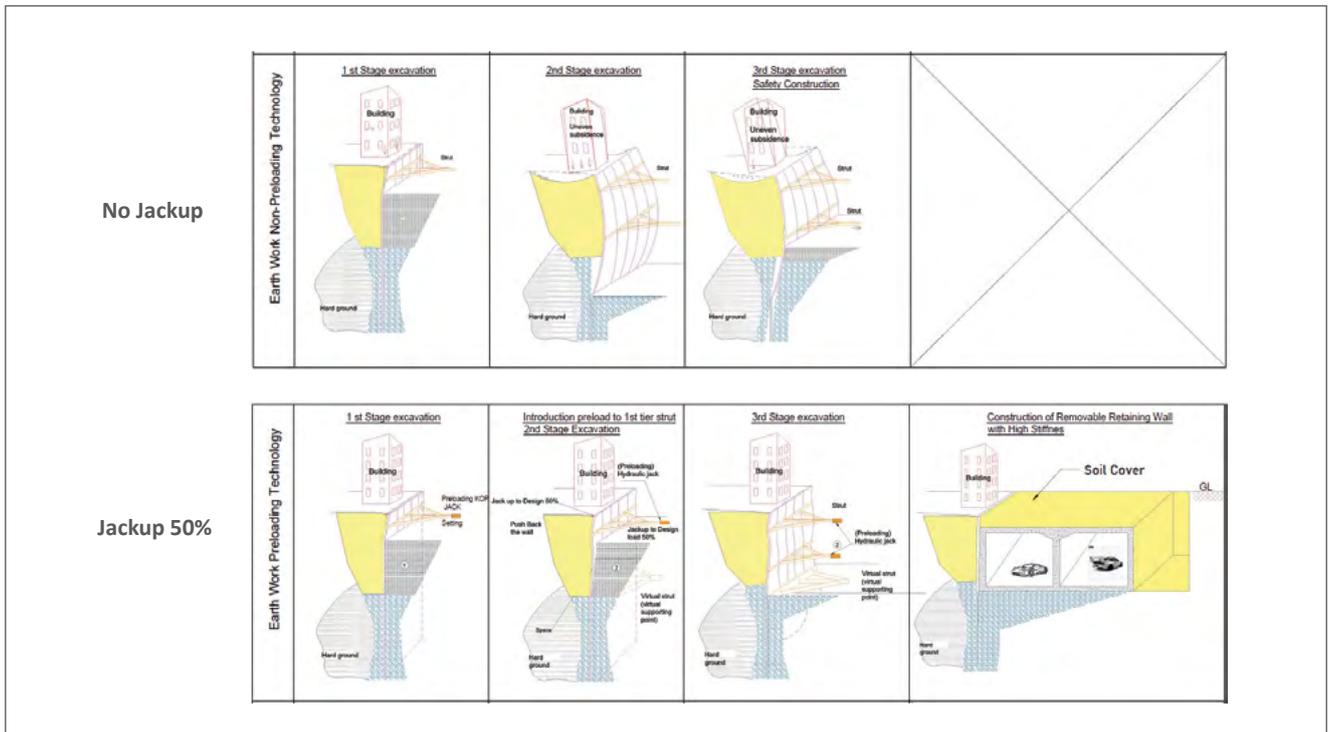
Many standards state that the plan should be in the range of 50% to 80% of the design load.



Pile removal.



Pile removal machines.



Comparison between earthworks technology without pre-loading (image on top) and earthworks technology with pre-loading (image below).



Introduction of the pre-load axial force.



Pre-loading with the help of pressure from the hydraulic jack.

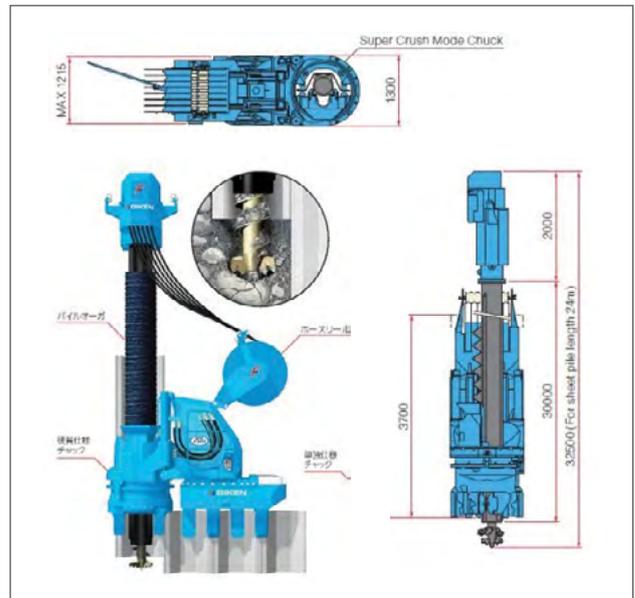
PILING
HYDRAULIC PRESS-IN METHOD

Silent Piler

The Hydraulic Press-in Method is a method that is used to drive a sheet pile into the ground statically, by taking advantage of the resistant force from the driven sheet piles. This method is usually required in urban areas where low vibration and low noise construction are required, and also where the construction space is limited or narrow.

Silent Piler in Crush Mode

One of the innovative solutions is the Hard Ground Press-in Method (Silent Piler in Crush Mode for Hat Type Sheet Pile). With this technology, it is possible to install sheet piles into hard soil layers such as gravelly soil and cobble- or boulder-mixed soil, without losing the advantages of the Press-in Method. For the Press-in Method with Pile Auger, pre-augering of soil and installation of Hat Type Sheet Pile can be done simultaneously. This would improve the efficiency of piling works, in terms of time and cost savings, as there is no additional setting up for the pre-augering machine. There will be minimal soil disturbance, as well.



Features of Silent Piler in Crush Mode. Images: GIKEN SEISAKUSHO ASIA PTE LTD.

JACKING PRESS-IN METHOD

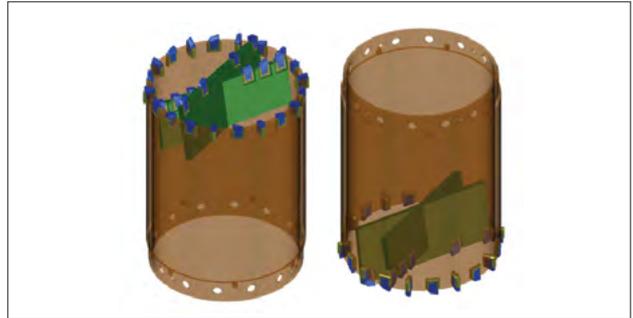
For the Jacking Press-in Method for the Hat Type Sheet Pile with H-beam combined pile, the machine capacity is 200 t for installation and extraction of piles. From a field test conducted in March 2019, it was proven that the Jacking Press-in Method is suitable for installation of the Hat Type Sheet Pile with H-beam combined pile, with low noise generation and little vibration.

ROTARY CASING METHOD (PRE-BORING METHOD)

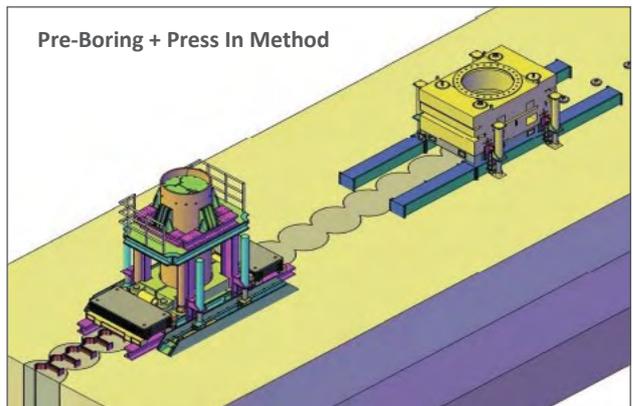
For a soil condition with SPT-N Value > 100 and rock layers, pre-boring using the Rotary Casing Method is recommended, followed by use of the Press-in Method. For example, for the installation of piles in rock layers in the city area, pre-boring with casing rotator with casing should be used. A hammer grab can be used to dig up the hard soil layer, followed by sand filling and removal of the casing. Lastly, the pile can be installed (Hat Type Sheet Pile with H-beam) by using the Jacking Press-in Method.



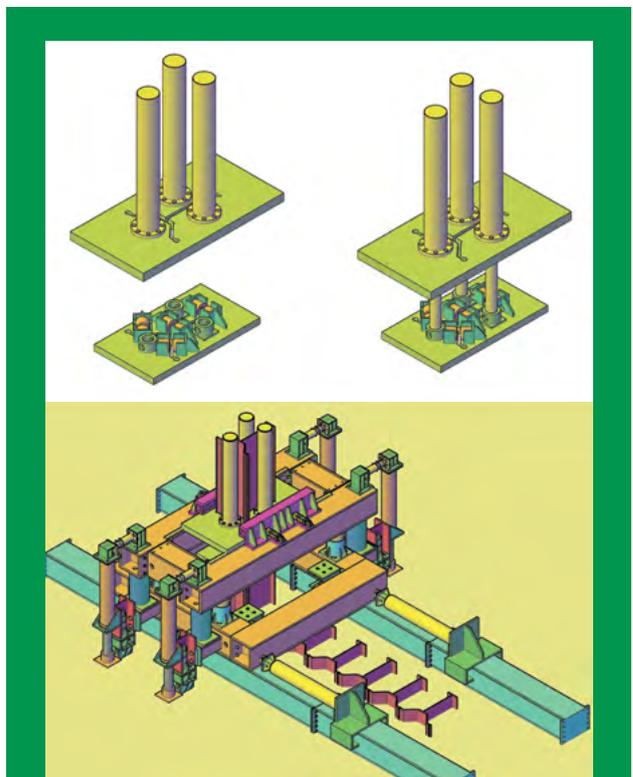
Application of the Jacking Press-in Method.



Features of the Rotary Casing System.



Rotary Casing Method (on right) with the Press in Method (on left).



More information may be obtained from:
 Taiyo Asia (E&C) Pte Ltd
 32 Tuas Avenue 11, Singapore 639109
 Email: admin@taiyojack.com. Tel: 6365 5093

REBAR COUPLER SYSTEMS

FOR SINGAPORE INFRASTRUCTURE PROJECTS

by Richard Goodman, Technical Manager, Dextra, UK



Mr Richard Goodman

Their advantages are explained.

1 INTRODUCTION

Reinforced concrete design and construction practice has historically focused on the use of lap splicing as a method of transferring load between reinforcement bars. This relies on the load being transferred from one rebar, through the surrounding concrete and into the adjacent lapped rebar. However, the lapping of reinforcement is not always the most appropriate splicing method and there are many situations where the use of mechanical rebar couplers is more desirable from a design perspective or more convenient from a construction perspective, or both.

Rebar coupler systems, sometimes also known as mechanical splices, are used as an alternative to traditional lap splices in concrete. They transmit the rebar load directly from one rebar to another without relying on the rebar-concrete bond, concrete strength, or the condition of the concrete surrounding the rebar and coupler.

2 ADVANTAGES

There are many well documented advantages to using rebar coupler systems. These include:

2.1 REBAR CONTINUITY

Reinforced concrete design codes of practice, including Eurocode 2, assume that the detailing, quality of materials and workmanship are such that the transmission of forces from one rebar to the other is assured [1]. However, if the bond between the concrete and the rebar is lost, as a result of concrete cracking, deterioration, poor on-site workmanship, rebar corrosion and subse-

quent spalling etc, then the rebar splice may fail. Rebar couplers do not rely on the rebar-concrete bond and therefore they create more reliable rebar continuity.

2.2 AVOIDANCE OF TRANSVERSE SPLITTING FORCES

Many structural concrete codes of practice recommend the use of rebar couplers as an alternative to lapping, particularly for large rebar diameters where splitting and dowel action forces can be significant. Eurocode 2 states “Generally large diameter bars should not be lapped. Exceptions include sections with a minimum dimension 1.0 m or where the stress is not greater than 80% of the design ultimate strength” and “Splitting forces are higher and dowel action is greater with the use of large diameter bars” [2].

2.3 REDUCTION OF REBAR CONGESTION

Lapping rebar in heavily reinforced sections can cause significant congestion, resulting in problems fixing the steel and insufficient room for the proper placement and compaction of the concrete. The use of rebar couplers will significantly reduce congestion, making the placement and compaction of the concrete easier, leading to less risk of concrete segregation due to over-vibration and, as a result, an increase in the concrete quality.

2.4 SAFETY

On-site safety during construction is paramount and the use of rebar couplers can contribute to enhancing site safety. In particular:

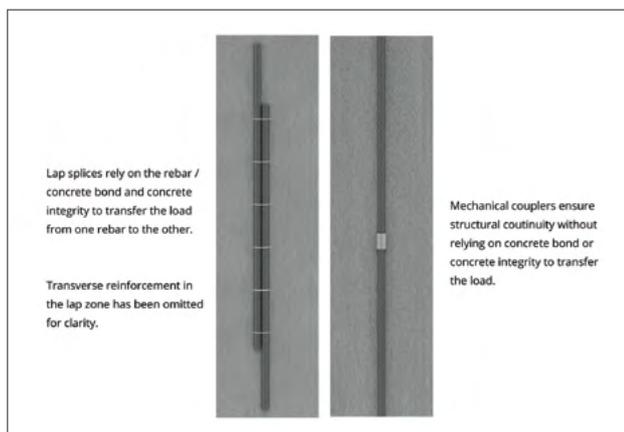


Figure 1. Lap splice and the equivalent rebar coupler system.



Figure 2. The use of rebar couplers can reduce rebar congestion as it eliminates the requirement to lap rebar.

- Rebar protruding through shuttering, which can be hazardous, can be eliminated by using couplers butted up against the shuttering or formwork, allowing the connection of the adjoining rebar after the shuttering or formwork is removed.
- On-site welding of rebar can be eliminated, by joining prefabricated cages with rebar couplers.

As well as contributing to construction site safety, rebar couplers are often seen as a safer alternative to lapping, as they do not rely on the rebar-concrete bond and therefore they create more reliable rebar continuity - as explained in Section 2.1.

2.5 EASE OF CONSTRUCTION

The safety advantages of rebar couplers do not come at the expense of constructability. In fact, the use of rebar couplers can make on-site or off-site construction easier and faster as well as safer.

- Prefabricated rebar cages can be easily connected on site, making on-site welding of rebar unnecessary.
- Individual concrete elements can be joined and construction joints can be created, without the need to drill through shuttering.
- The use of couplers allows for the face of the concrete elements to remain smooth during construction, making construction easier and faster.

2.6 REDUCTION IN STEEL USE

The use of rebar couplers reduces steel consumption and can therefore be an environment-friendly and more sustainable option than lapping. The rebar steel saving is equivalent to the lap length.

2.7 SEISMIC USE

The scope of Eurocode 8 is to protect human lives, limit damage and ensure that structures important for civil protection remain operational, but it also recognises that “The random nature of the seismic events and the limited resources available to counter their effects are such as to make the attainment of these goals only partially possible and only measurable in probabilistic terms” (Clause 1.1.1) [3].

Severe cracking and the degradation of concrete elements are therefore possible. In such cases, the bond between the rebar and the concrete may be compromised and this, in turn, will compromise the ability of a lap splice to transfer load from one bar to another, and thus compromise the ability of the element to carry load. Mechanical rebar couplers do not rely on the rebar-concrete bond in order to transfer the load from one bar to the other and are therefore seen as a safer option to lap splicing in seismically designed structures, provided they are a full capacity ‘bar break’ system.

If conventional lap splicing is employed, the seismic design of reinforced concrete structures will often exacerbate reinforcement congestion problems. In addition, the significant increase in lap lengths and other codified de-

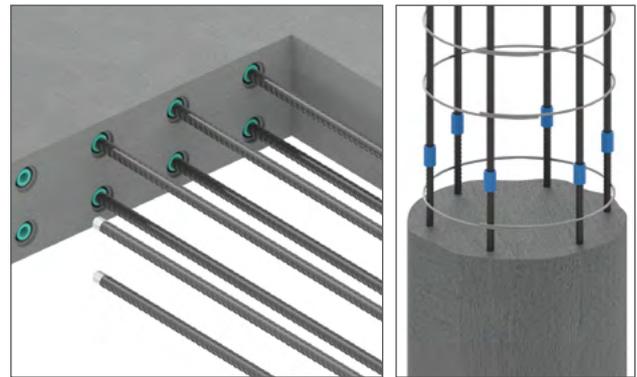


Figure 3: The use of couplers at concrete faces means that concrete elements can be joined without the need to drill through formwork (left). Couplers can be used to join prefabricated cages on site, making on-site welding unnecessary (right).

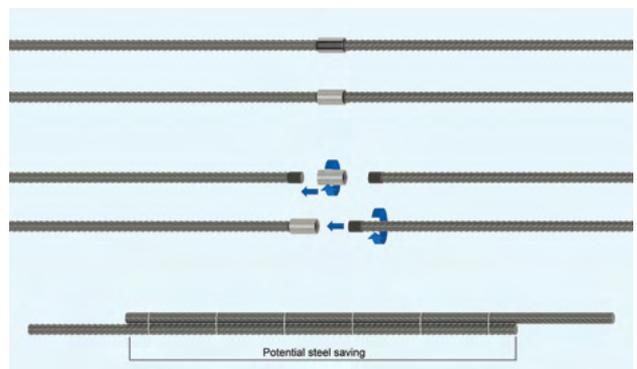


Figure 4: The use of rebar couplers allows for the effective use of material and a reduction in the quantity of steel used.

tailoring requirements can lead to over-reinforced concrete and a potential for non-ductile, brittle behaviour at the lap splice region, due to the concentration of stresses at both ends of the lap, inadvertently altering the element’s deformation capacity. In such cases, the use of mechanical rebar couplers is seen as a distinct advantage.

The ductility of reinforcement is of significant importance in seismic design, with the reinforcement ductility requirements increasing as the requirement for energy dissipation increases as a result of greater seismic loading.

Eurocode 8 clause 5.2.3.4 states that “The steel used in critical regions of primary seismic elements should have high uniform plastic elongation”.

Eurocode 8 clause 5.6.3 states that “There may be splicing by mechanical couplers in columns and walls, if these devices are covered by appropriate testing under conditions compatible with the selected ductility class”. It must be noted that, in this context, the ductility class is that associated with the structure, as defined by Eurocode 8, i.e. DCL, DCM or DCH.

The only way to retain the full ductility of the rebar, and therefore remain compatible, when connected with a mechanical coupler, is to ensure that it retains the ability to be taken to its ultimate tensile stress and its capacity is not reduced as a result of a stress raiser or loss of rebar cross-section at the mechanical rebar coupler. In

other words, the coupler needs to be what is commonly known as a bar break system, that is, a system which exceeds the ultimate tensile strength of the actual rebar it is connected to, ultimately forcing a tensile failure to occur in the rebar away from the influence of the coupler splice.

Thus, only full capacity, bar break systems should be used in seismically designed reinforced concrete structures, as these are the only types of systems where the ductility of the connecting rebar is not compromised.

2.8 SUMMARY OF ADVANTAGES

Mechanical rebar couplers create a continuity of reinforcement, which is not reliant on the quality or integrity of the concrete. Their use creates less rebar congestion, and more convenient and often safer site practice, as well as reduces the amount of steel used. Their use is not just allowed by Eurocodes but is also recommended under certain circumstances. While different performance levels exist for rebar couplers, the use of a guaranteed bar break coupler means there will ultimately be no brittle failure in a 'beyond design' event and the full ductility of the rebar will be maintained - a feature which is recommended in safety-critical applications or if the structure could be subject to impact damage or a seismic event.

3 TYPES OF COUPLER SYSTEMS

Clause 8.7.1 of Eurocode 2 allows the forces to be transmitted from one rebar to another by the lapping or welding of rebar as well as the use of "mechanical devices assuring load transfer in tension-compression or in compression only". However, compression only couplers are not used or certified for use in Singapore.

Tension-compression couplers can broadly be categorised as follows:

- (a) Couplers requiring rebar end preparation such as threading or the extrusion of sleeves onto the ends of the rebar.
- (b) Repair couplers requiring no rebar end preparation.
- (c) Grouted couplers, requiring one or both adjoining rebars to be grouted into the coupler.

In addition, some coupler systems have in-built quality control features whereby each and every connection is automatically and systematically proof loaded by the processing machinery as part of a quality control procedure.

Different types of rebar coupler systems are shown in Figure 3-1 of the Singapore Building and Construction Authority (BCA) design guide for the use of Grade B600 rebar [4]. However, the Singapore Land Transport Authority's (LTA) materials and workmanship specification states that "Only straight metric threaded and swaged couplers shall be used. The couplers shall be a type which are simple to install and can be verified to be installed correctly by visual inspection" (Clause 11.18.4.1) [5]. Both of these types of rebar coupler systems fit into category (a) above, are discussed further in Section 3.1,



Figure 5: Straight metric threads. The ends of the rebar are cold forged to increase their diameter, prior to threading.

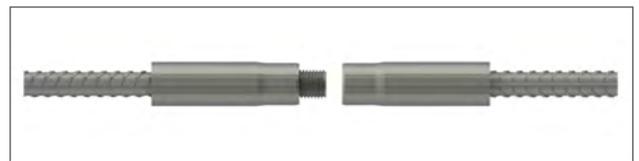


Figure 6: Swaged (extruded) sleeve system. Male and female sleeves are swaged/extruded onto the rebar ends.

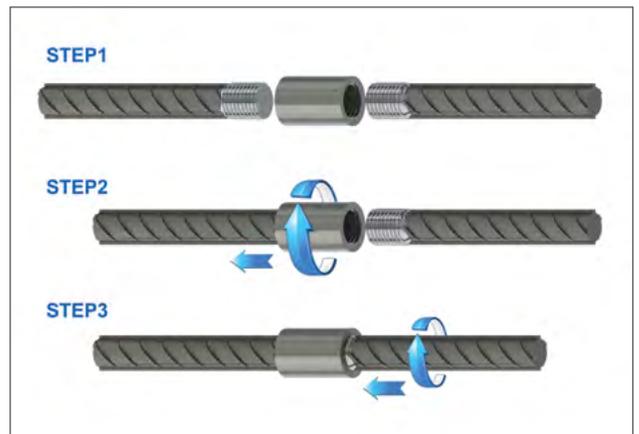


Figure 7: Typical standard coupler splice configuration.

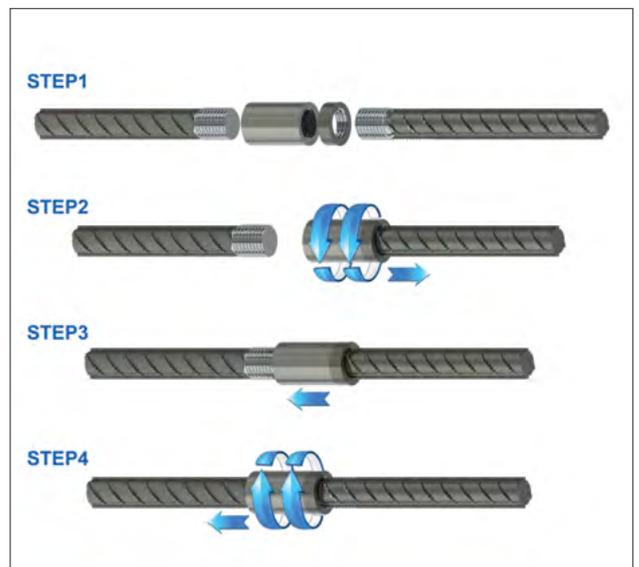


Figure 8: Typical positional coupler splice configuration.

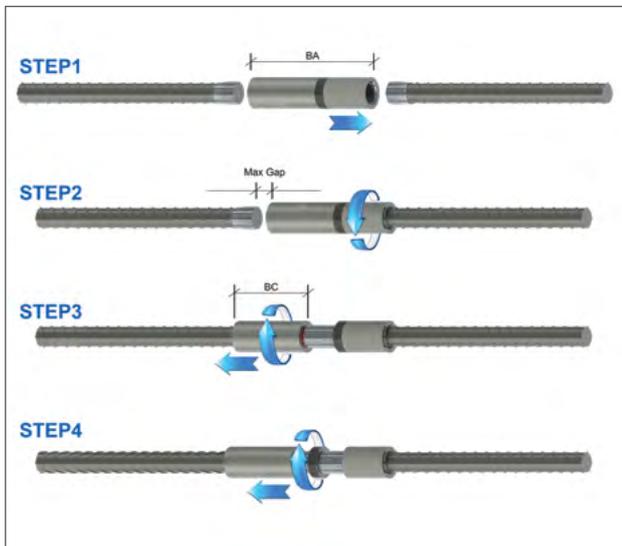


Figure 9: Typical bridging coupler splice configuration.

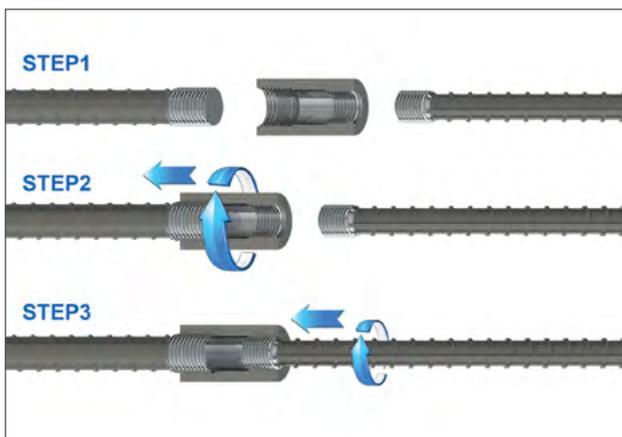


Figure 10: Typical transition coupler splice configuration.

and are illustrated in Figure 5 and Figure 6.

It should be noted that the couplers shown in Figure 5 and Figure 6 are both simple to install and their correct installation can be verified by visual inspection, as the achievement of the appropriate level of male-to-female thread engagement can be clearly seen. When using other types of couplers, it is more difficult, and often impossible, to visually verify that they are installed correctly.

Some types of coupler systems require to be torqued to a specific minimum value, in order to achieve the correct level of performance. It is advisable that these types of couplers are marked in some way after the torquing operation has been completed, in order to give a visual indication that the correct procedures have been followed.

3.1 COUPLERS REQUIRING REBAR END PREPARATION

Coupler systems requiring rebar end preparation are usually the most cost-effective, but their use needs to be pre-planned, as the bar end processing usually occurs at the rebar cut-and-bend depot and the appro-

priate rebar is supplied to the site. These cut-and-bend fabricators would usually hold a stock of couplers and have the machinery to process the rebar ends to suit the coupler system.

Each system is typically available in a number of different configurations. These are:

- Standard: Standard couplers require the adjoining rebar to be rotated to form the connection.
- Positional: Positional coupler systems do not require the rotation of the adjoining rebar.
- Bridging: Bridging coupler systems will allow the adjoining rebar to be connected without rotation while also bridging a gap.
- Transition: Transition couplers allow connection between rebars of different diameters.

3.1.1 Standard couplers

A standard coupler configuration requires the rotation of the adjoining rebar to make the connection.

3.1.2 Positional couplers

A typical positional coupler configuration has an extended length of thread onto the ribs of one rebar, allowing the coupler unit to be fully screwed onto one bar, before being screwed back onto the adjoining rebar. This type of system is often supplied with a locknut in order to lock the assembly into position without rotating the rebars.

3.1.3 Bridging couplers

Where the ends of the connecting rebar cannot be brought together, a bridging coupler system can be used, in order to bridge a small gap between the ends of the rebar.

3.1.4 Transition couplers

Transition coupler systems are designed to connect rebars with two different diameters. Sometimes this can be done by applying a smaller thread on the larger diameter bar and, at other times, by using a transitional coupler, as shown in Figure 10. ISO 15835-1 states that if couplers are used to connect rebars of different diameters, the strength and ductility requirements shall be based on the smaller of the two rebar diameters used [6].

4 REBAR COUPLER REQUIREMENTS FOR INFRASTRUCTURE PROJECTS IN SINGAPORE

For infrastructure projects in Singapore, the LTA Materials & Workmanship Specification for Civil & Structural Works is applicable. This document covers the applicable performance, test requirements, production control and quality assurance tests required. In addition, the rebar coupler supplier is required to hold ISO 9001 quality assurance certification or equivalent.

4.1 PERFORMANCE REQUIREMENTS

Rebar couplers are required to comply with the requirements of ISO 15835-1. This sets out performance requirements for strength, permanent elongation (commonly called slip), and ductility. However, it should be noted that the LTA requirements are based on the 2009

version of ISO 15835, rather than the more up-to-date 2018 version.

The LTA specification document also requires all thread-
ed rebar coupler systems to undergo systematic proof
loading, prior to being released from the cut-and-bend
fabricators, with a requirement to mark the rebar to
indicate that this has been done. The proof load should
be between 75% and 100% of the characteristic yield
strength of the rebar.

4.1.1 Tensile strength

The LTA rebar coupler specification document requires
that the strength of the assembly be equal to or greater
than the required SS 560: 2016 characteristic tensile
strength of the rebar used as part of the assembly [7].
For example, when a coupler system is used with grade
500B rebar, the minimum assembly breaking load should
equates to a load which produces a stress in the adjoining
rebar equal to or greater than $500 \times 1.08 = 540$ Mpa.
1.08 is the applicable minimum tensile strength/yield
strength ratio specified in SS 560.

The standard goes on to say that “failure of the cou-
pled bar assembly shall occur in the bar outside the
coupler or testing machine grips”. It should be noted
that this is different to failure outside of the mechanical
splice length, i.e. outside the influence of the coupler,
connection or processed bar material, as defined in ISO
15835-1: 2018. For additional safety, and to ensure the
adjoining rebar is capable of achieving its full A_{gt} duc-
tility (percentage total elongation at maximum force),
as described in Section 4.4, it is recommended that
the rebar coupler system is capable of achieving a full
bar break level of performance, i.e. a failure location
outside the length of mechanical splice, as defined in
ISO 15835-1: 2018.

4.1.2 Permanent elongation/slip

The LTA requirement for permanent elongation, com-
monly known as slip, after unloading from 60% of the

characteristic yield strength, is for the value to be not
greater than 0.1 mm. The testing procedure for this is
the ISO 15835-1: 2018 Option 2 test.

4.1.3 Ductility

Ductility is measured in terms of A_{gt} for the adjoining re-
bar. The LTA requirement is in line with ISO 15835-1: 2018,
with the requirement for recorded values to be greater
than 70% of the value for the parent (reference) bar.

4.2 TESTING AND QUALITY CONTROL REQUIREMENTS

Prior to acceptance of use, the contractor is required to
prepare samples for initial qualification testing. Testing is
also required during production, for the project in ques-
tion. One assembly is tested during the production of
the first 10 sets of couplers, and one assembly is tested
per 200 units produced thereafter. One control bar is
also required with each coupler assembly. These samples
are taken during the processing stage (bar end forging,
threading, swaging etc), which would normally take place
at the rebar cut-and-bend factory.

Finally, the contractor is required to submit a method
statement for assembly, installation and post-installation
inspection.

4.3 STRENGTH AND DUCTILITY DISCUSSION

The tensile strength requirements within the LTA
rebar specification are expressed in terms of rebar
stress, with the tensile strength/yield strength ratios
taken from the rebar product standard SS 560: 2016.
Therefore, the coupler assembly strength requirement
depends on the rebar grade and on the rebar ductility
class being used.

The LTA rebar coupler specification gives no strength
performance categories. Given that the ultimate tensile
strength of B500 and B600 rebar can vary dramatically

Grade & Ductility Class	Rebar ^a			Coupler Assembly
	Yield Strength, R_e (Mpa)	Tensile strength/ yield strength ratio, R_m/R_e	Total elongation at max. force, A_{gt} (%)	Minimum stress in rebar required for coupler assembly failure (Mpa)
B500A	500	1.05	2.5	525
B500B	500	1.08	5.0	540
B500C	500	$\geq 1.15 < 1.35$	7.5	575
B600A	600	1.05	2.5	630
B600B	600	1.08	5.0	648
B600C	600	$\geq 1.15 < 1.35$	7.5	690

^a Characteristic rebar properties as per SS 560: 2016

Table 1: Comparison between rebar strength and rebar coupler assembly strength.

(for example, SS 560 allows for the ultimate tensile strength of B500C rebar to vary between 575 Mpa and 897 Mpa), this means that there can be a variety of tensile strength performance characteristics of rebar couplers approved for use with the B500 or B600 rebar. If a higher tensile performance level/greater factor of safety is required, then a bar break coupler system should be specified, which requires a tensile failure to occur in the rebar away from the influence of the connection or bar-end processing. This failure mode is defined in ISO 15835-1: 2018 and the failure mode is recorded on laboratory test certificates, as defined in ISO 15835-2: 2018.

The percentage elongation at maximum force (A_{gt}) is the principal measure of SS 560 rebar ductility, and it should be noted that if the rebar coupler system fails before the rebar, the rebar will not reach its maximum force and will therefore exhibit a reduction in A_{gt} ductility. The only way to maintain the full A_{gt} of the rebar system is to have a bar break rebar coupler system.

5 REFERENCES

[1] EN 1992-1-1 Eurocode 2: Design of concrete structures. Part 1-1: General rules and rules for buildings.
 [2] EN 1992-1-1 defines large diameter rebar as that having a diameter greater than 32 mm. National Annexes may differ.
 [3] EN 1998-1 Eurocode 8: Design of structures for earthquake resistance. Part 1: General rules, seismic actions and rules for buildings.
 [4] BC 5: 2019 Design Guide for the Use of Grade B600 High Strength Reinforcement in Reinforced Concrete Structures. Building and Construction Authority.
 [5] Materials & Workmanship Specification for Civil & Structural Works. Land Transport Authority Engineering Group Document. E/GD/09/104/A2(a).
 [6] ISO 15835-1: 2018 Steels for the reinforcement of concrete - Reinforcement couplers for mechanical splices of bars - Part 1: Requirements. International Organization for Standardization.
 [7] SS 560: 2016 Singapore Standard, Specification of steel for the reinforcement of concrete - Weldable reinforcement steel - Bar, coil and decoiled product.

Colossal bridge in the Philippines nears completion

The Cebu-Cordova Link Expressway (CCLEX) is one of the biggest infrastructure projects being undertaken in the Philippines. The project features a combination of a causeway, a gigantic cable-stayed bridge that will cross the navigable zone of the Cebu Strait, two viaducts and four low height bridges, as well as roadways and pedestrian walkways.

CCLEX is a project undertaken by Cebu Cordova Link Expressway Corporation (CCLEC), in partnership with the local government units of Cebu City and the Municipality of Cordova. CCLEC is a wholly owned subsidiary of MPTC, the toll road arm of Metro Pacific Investments Corporation (MPIC), a publicly listed infrastructure holding company and a member of the MVP Group of Companies.

The CCLEX project aims to provide better transport facilities, while reducing traffic congestion in the region, as well as improving connectivity within Cebu City. It will also support Cordova’s economic growth, as the expressway will position the city as the gateway for island tourism.

After its completion, CCLEX will link Cebu mainland and Mactan Island through Cordova town. The 8.5 km-long toll bridge will feature two lanes that will serve up to 40,000 vehicles a day.

The main bridge will be built with a 400 m cable-stayed main span, with a 60 m navigation clearance, allowing ships to easily navigate through the expressway. The main bridge of the expressway



The Cebu-Cordova Link Expressway is expected to be open to motorists in the first quarter of 2022. Image: Cebu Cordova Link Expressway Corporation.

will connect Guadalupe River to the Shell Island in Cordova, while its colossal viaducts will link it to the causeway and road networks to Mactan.

The design and the construction of this megaproject is undertaken by the Cebu Link Joint Venture (CLJV). The CLJV is a joint-venture partnership between Spain-based Acciona Construccion S A and the Philippines-based First Balfour Inc and D M Consunji Inc.

For the reinforcement of the colossal expressway’s foundations, the contractor chose Dexra’s rebar splicing solutions, including Standard, Bridging as well as Transition splices.

The official ground-breaking of the toll bridge was performed in 2017. It is targeted to be substantially completed by the end of 2021 and open to motorists in the first quarter of 2022.

THE NEW

STATE COURTS TOWERS

Unlike typical courtroom complexes, the new building is a high-rise development with an open architecture.

Nearly two years after the topping-out ceremony officiated by Honourable Chief Justice Sundaresh Menon, Singapore's new State Courts Towers is now fully operational.

Located at 1 Havelock Square, the new State Courts Towers, which stands 178 m high, is said to be the tallest government building in Singapore to-date. It is also one of the world's tallest courthouses.

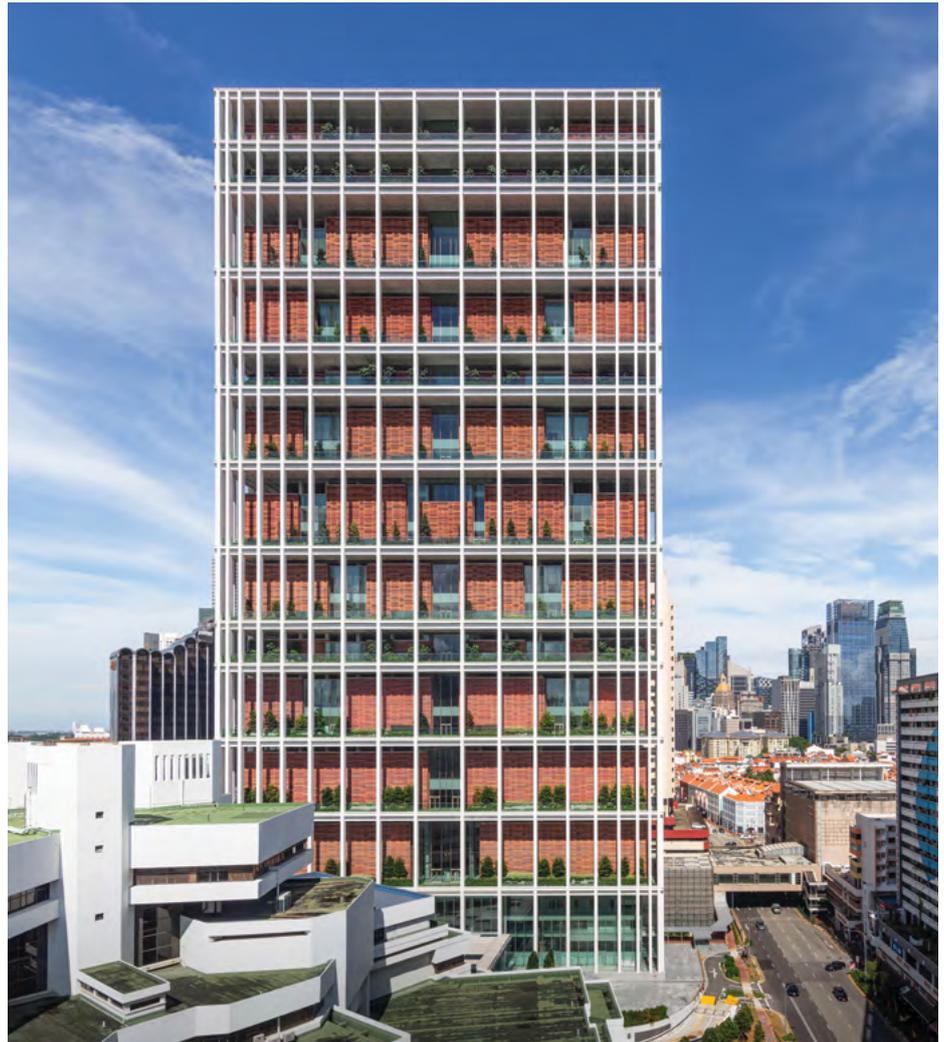
The new State Courts Towers was designed by Serie + Multiply Consultants Pte Ltd, winner of a public, two-stage, Open Design Competition organised by the State Courts in 2011. The project was developed and completed in collaboration with CPG Consultants Pte Ltd who was the Principal Consultant and Architect.

Courtroom complexes are typically designed in a conservative manner, partly due to circulation requirements to separate the movement of judges, persons-in-custody, and the public.

In contrast, the new, 35-storey State Courts Towers has been designed to be highly open and visible to the public. This was achieved with two architectural strategies.

The first strategy in the design of the State Court Towers was the creation of two slender towers, the Court Tower and the Office Tower. The towers are connected by 39 link bridges. The Court Tower accommodates the courtrooms while the Office Tower accommodates the judges' chambers and staff offices. This architectural concept not only brings light deep into the building but also helps to separate the movement of the various groups of people.

The second strategy was to place the courtroom boxes onto large open 'court trays'. These trays are not only of different heights to fit courtrooms of different sizes, but are also completely open - there is no glazed facade



The new State Courts Towers is said to be the tallest government building in Singapore. Image: Finbarr Fallon.

around the tower. Instead, each tray accommodates a lushly planted garden terrace that filters the tropical sun and allows views out over the city. As a result, the Court Tower appears light, open and welcoming.

The courtrooms themselves are clad in tall, pigmented precast concrete panels measuring 5 m to 12 m in height, inspired by the colours and textures of the tiled roofs on the adjacent, historic Chinatown shophouses. The intention is to bring together two typical forms of architecture from the immediate area, namely those for high-rise buildings and shophouses, into a single frame, so that the new building is at once familiar and yet excitingly new.



The building comprises two slender towers that are connected by link bridges. Image: Finbarr Fallon.



The interior of a courtroom. Image: Khoogj.

The Office Tower, which houses working spaces, is expressed as a thin and elegant slab tower. The facade features an expanding and contracting grid. Vertically, the grid contracts where the service core is located and expands in the middle, where light and views are required. The modulation of the horizontal grids draws the eye across the facade and towards the sky, giving a clean and absolute form and a sense of playful rhythm.

An Entrance Canopy was built for the new State Courts Towers, which opens up the site to the surrounding context and creates two entrances - the entrance from Havelock Square and that from Upper Cross Street.

The site for the new State Courts Towers is also smaller, which meant that vertical court towers, as compared to a more common, horizontal layout, had to be planned. This posed a challenge, as careful planning and stacking of the 53 courtrooms and 54 hearing chambers was necessary to ensure that court operations will not be hindered in any way. One of the successful outcomes was the simplicity in

the vertical stacking of the programmes and circulation, which makes wayfinding easy for the public.

As a modern and IT-enabled courthouse, the complex also incorporates various smart building features like facial recognition technology and automation of various building management processes related to security and mechanical & electrical systems. Other IT or web-enabled services introduced include video-conferencing facilities and interactive self-service kiosks. In addition, as a modern courthouse, a universal design approach was adopted to ensure that it is user-friendly for the judges, persons-in-custody, and the public. For example, court attendees are provided with Assistive Listening Systems in all the courtrooms, digital wayfinding options through the use of apps, and child-minding facilities.

The State Courts Towers is also an environmentally sustainable building, with innovative green building features incorporated in its design, such as solar panels and condensate water recovery systems. It was awarded the BCA Green Mark Platinum Award in 2018.

Explaining the approach taken for the design of the State Court Towers, Mr Christopher Lee, Principal at Serie Architects, UK, said, "The relationship between the city and its civic buildings was our primary interest for this project. The new State Courts Towers should be a building that is symbolically open and accessible to the public. Its design language is drawn from the architecture typical of the city and hence is both familiar and surprisingly new to its citizens".

Commenting on the intricacies of court planning, Mr Colin Wu, Lead Architect and Senior Vice President of CPG Consultants said, "CPG has historically designed and constructed many of Singapore's present court buildings, such as the Supreme Court and Family Justice Courts. Our familiarity in Court Complex Design and Planning in Singapore helped us in designing the programmatic spaces, operations, and security requirements for this first, high-rise court complex. Our aim in this project is to ensure there is clear segregation in the programming of the three primary user groups - the judges, persons-in-custody and the public".

KEY DESIGN CONCEPTS

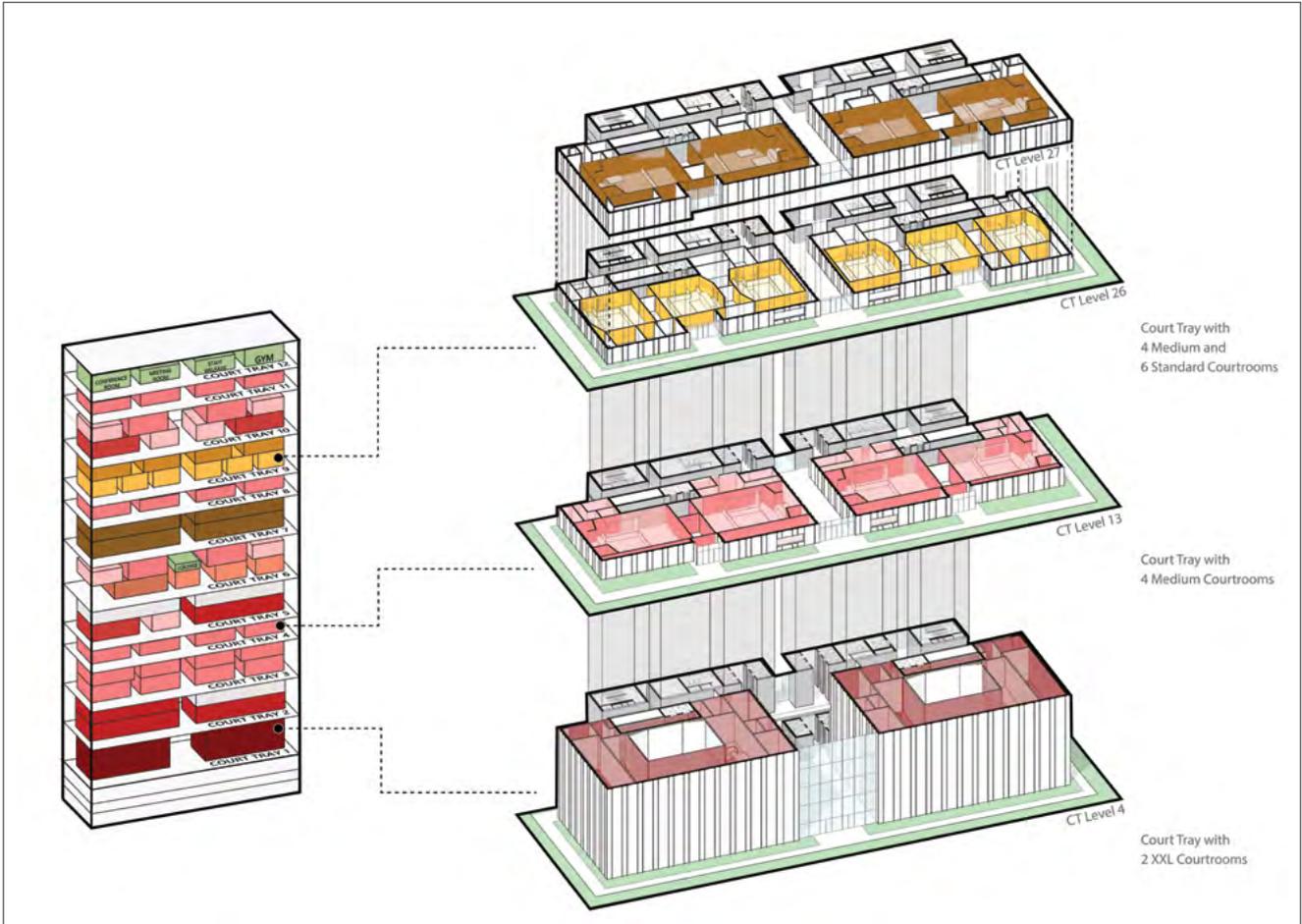
VERTICAL STACKING AND CIRCULATION

Stacking of programmes

The simplicity of the design of the two towers provides a clear organisational diagram. All the primary court functions are placed in the Court Tower - courtrooms, witnesses' rooms, holding rooms, court officers' rooms, exhibit rooms and public waiting areas. The supporting programme, including the judge's chambers, is placed in the Office Tower.

Various court tray types

There are different numbers of courtroom boxes on each court tray. The court trays are either single volume or double volume in size. The landscape design of the sky terraces is varied as a result of these two factors. There is no external glazed facade.



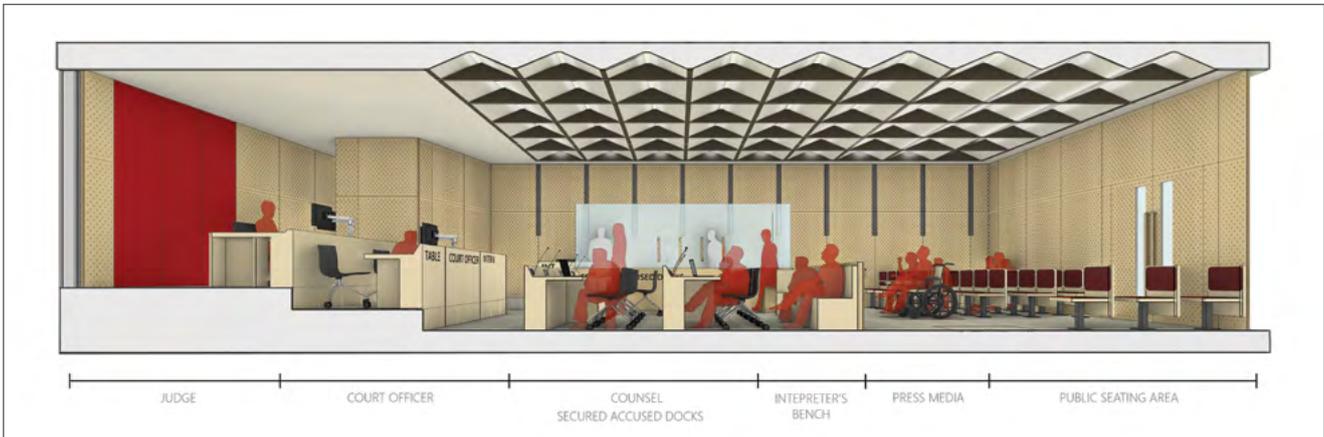
Different sizes of courtrooms are placed on each court tray. Image: CPG Consultants.



Courtrooms are clad with pigmented, precast concrete panels. Image: Khoogj.



The selection of the precast concrete panels was inspired by the colours and textures of the terracotta roofs of shophouses in Chinatown, adjacent to the new State Courts Towers. Image: Finbarr Fallon.



The courtrooms are characterised by a functional layout, contemporary interior design and smart technology. Image: CPG Consultants.

AN ARTICULATION OF TERRACOTTA TILES

A contemporary approach was adopted in the design of the courtrooms, which was also inspired by the delicate undulation and colours of the terracotta roofs crowning the surrounding shophouses in Chinatown. Accordingly, the courtrooms are clad in pigmented, precast concrete panels measuring 5 m to 12 m in height.

MODERN COURTROOM DESIGN PLANNING

The new States Courts Towers sets a high standard for modern courtrooms, with its functional layout, a contemporary interior design concept and smart technology.

- A functional and typical courtroom layout needs to cater for the public, judges, court officers, counsel, persons-in-custody docks, media and transcribers.
- The courtroom layout includes the zoning of the three main users (judges, persons-in-custody and the public), whilst also being mindful of the three separated basic circulations.

PROJECT DATA

Project

State Courts Towers

Location

1 Havelock Square, Singapore

Building Type

Judiciary / Courthouse

Client

State Courts, Singapore

Year of Completion

2019

Operation Start Date

2019

Gross Floor Area

113,000 m²

PROJECT CREDITS

Principal Consultant and Architect

CPG Consultants Pte Ltd

Design Consultant

Serie+Multiply Consultants Pte Ltd

Environmental Sustainability Design Consultant

Surbana International Consultants Pte Ltd

Civil & Structural Engineer

CPG Consultants Pte Ltd

Mechanical & Electrical Engineer

CPG Consultants Pte Ltd

Quantity Surveyor

CPG Consultants Pte Ltd

Landscape Architect

Plantwerkz Pte Ltd

ID Consultant

SCA Design Pte Ltd (Ong & Ong Pte Ltd)

Lighting Designer

Ong & Ong Pte Ltd

Other Consultants / Specialists

PM Link Pte Ltd (Project Management)

HCCH Consulting Pte Ltd, BFG (Facade Consultants)

Square Peg Design Asia Pte Ltd

(Signage & Wayfinding)

Alpha Acoustics Engineering Pte Ltd

(Acoustic & AV Systems)

Certis Cisco Consulting Services Pte Ltd

(Security & Blast)

Builder

Samsung C&T Corporation

Landscape Contractor

Nature Landscapes Pte Ltd

CRANES DEPLOYED TO LIFT

AND INSTALL BRIDGE SPANS

A pedestrian and bicycle bridge was constructed within a narrow time frame.

Constructing a three-span pedestrian and bicycle bridge seems a straightforward task. But if it is going over the third-busiest set of railroad tracks in the US, with an estimated traffic of 100 trains per day, it would be necessary to work closely with the railroad to get the critical work-clearance time that is needed to set spans. And it is likely to be scheduled in extremely brief, single-hour increments. That would take a combination of planning, materials, people and cranes to get the job done.

That was the scenario as a new hiking and biking bridge was constructed in Cleveland's Wendy Park as part of an expansion of the Ohio & Erie Canal Towpath Trail. The 100-mile path connects Cleveland to the Cuyahoga Valley National Park and cities to its south.

ALL Crane provided several pieces of equipment for the job site, including various aerial lifts and a forklift, but the main machines were the two cranes used to set bridge spans and the final arch that topped off the structure. The ALL family of companies is the largest privately

held crane rental and sales operation in North America.

The cranes were a 450 t capacity Liebherr LTM 1450-8.1 and a 250 t capacity Liebherr LTM 1250-6.1. Often, the units worked independently of each other in setting 38 m spans that weighed 38.5 t. But, for one critical window, they came together to help set the two halves of the arch and hold them in position so that Youngstown Bridge's ironworkers could execute a mid-air splice.

Narrow time frame

Plans for the lift were submitted months in advance to Norfolk Southern Railway, owner of the tracks and ALL specified the cranes. Once the plan was submitted, no changes could be made to the lifting programme. And, when the approved work time finally came, the team on the ground would likely have just an hour to complete the placement of the arch. That is usually the maximum amount of time a railway operator can halt train traffic for lifting work to be performed.



The LTM 1450-8.1 from ALL Crane placed the left half of the new bridge span, while The LTM 1250-6.1 from ALL Crane placed the right half of the bridge span.

In the days leading up to the lifting day, the project supervisor for Youngstown Bridge had his team perform several pre-lift tests to make sure they would be ready to make the most of their time. This gave the ironworkers the opportunity to fine-tune the rigging of each arch section, incorporating the actual crane configurations that would be used on the lifting day. This was important, given the time constraints. The team could know, well before the lift, that the two arches would be within a degree or two of each other at the splice point. For these practice runs, zones on the arch were assigned to each of the ironworkers so that they would know exactly where to focus their efforts and what tasks to perform during the actual splicing.

The railway window was suddenly moved up by three days, compared to the original schedule. The flexibility of ALL Crane ensured that they would quickly be able, on short notice, to mobilise the 250 t capacity LTM 1250-6.1 and to have it assembled and be ready for the lift. When the pre-determined hour finally arrived to set the two arch sections, nearly eight months of planning came down to 60 minutes. The LTM 1450-8.1 was configured with 48 m main boom at a 15 m radius and the maximum of 134 t of counterweight. The LTM 1250-6.1 had 40 m of main boom at a 10 m radius.

Successful teamwork

In the preceding days, both cranes had already been quite busy. The two 38 m bridge spans were set on their respective abutments and temporary structures towards the middle, and a 75 m centre span rested on temporary structures. By installing the arch, which would assume the bulk of structural support duties for the entire bridge, the temporary structures below could be removed and the bridge would be essentially complete.

With the clock running, crane operators held each arch piece in position as a dozen ironworkers, six in man lifts and six on the ground, worked to install scores of bolts at critical splice points. There was a minimum number of bolts that had to be installed for the structure to support its own weight, and this became a crucial milestone. It meant that, should the work window start to close, the bridge would be stable enough to stand on its own.

Otherwise, if the milestone was not met, ironworkers would have to reverse course and disassemble the arch so they could try again on another day. Given the difficulty in scheduling work windows, this was not desirable.

At the 35-minute mark, the threshold was reached. Just 23 minutes later, the work was completed. There was, therefore, no need to schedule a second work window. The new hiking and biking bridge had become a reality.



Tandem hoisting was used to place the huge bridge span over the railroad tracks.

THE FERENC PUSKÁS STADIUM

IN BUDAPEST

Waterproofing materials, resin floors and building solutions were provided for one of Hungary's largest sports stadiums.



The Ferenc Puskás stadium was rebuilt and completed in 2019 and can now host 67,000 spectators.

The new stadium in Budapest, dedicated to the footballer Ferenc Puskás, is a monumental structure worthy of the legendary status of this Hungarian superstar. Rebuilding work on the remains of the old stadium, which started in 2017 and was completed in 2019, was one of the largest ever investments in Hungary for a sports complex - 190 billion Forints (around EUR 610 million) to build a stadium which has a capacity of 67,000 and which was used to host some of the 2020 UEFA championship matches.

The stadium is made up of a structure with 38 forty-metre high, steel and reinforced concrete pylons. Two cement mixing units were installed directly on site to actually construct the load-bearing structure. Each cement mixing unit had a maximum daily output of 1,200 m³ of concrete. Every day, the site had a workforce of 1,500 and 21 cranes - all working at the same time.

Waterproofing at 360°

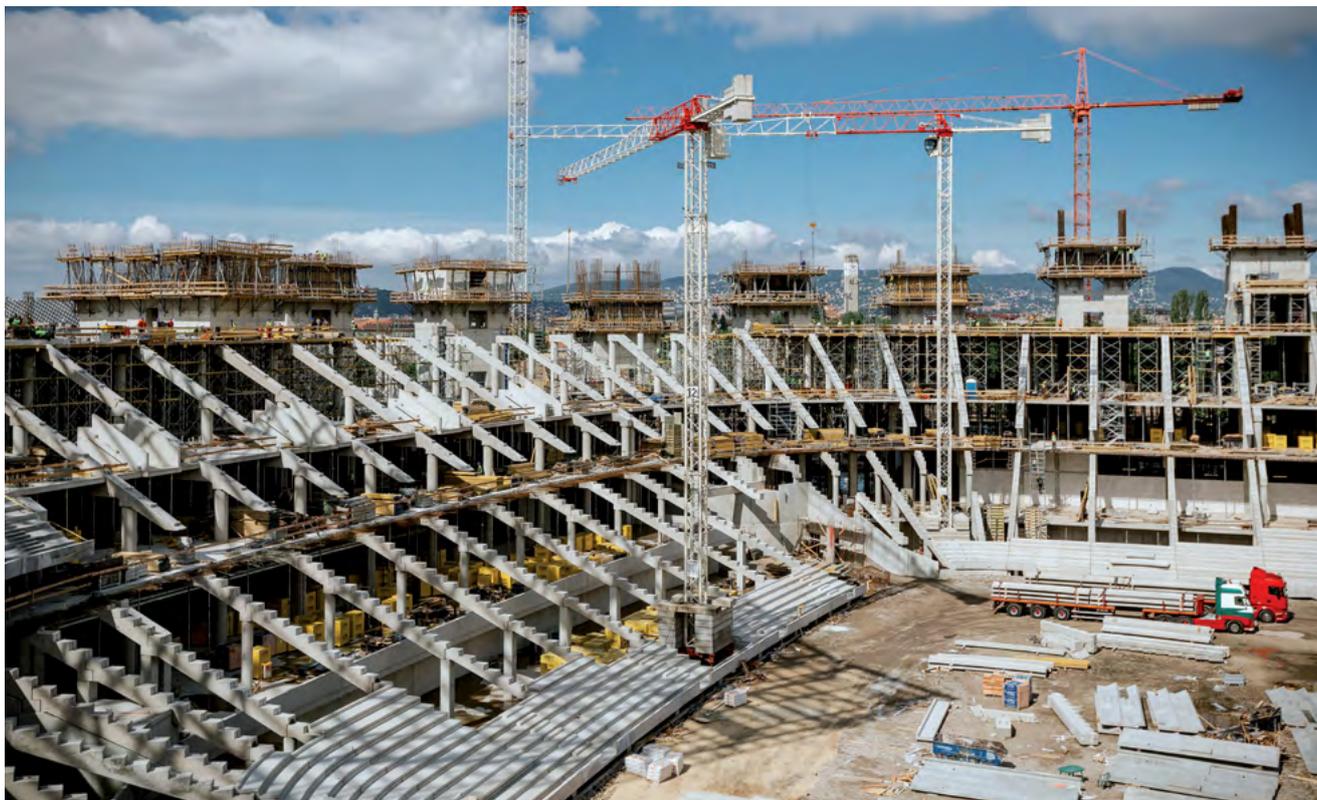
Mapei played a key role in the construction of the new stadium, supplying products for various areas and applications. The products included MAPEFILL MF 610,

an expansive grout which was used to anchor the large pylons of the load-bearing structure.

But it was in all the waterproofing applications that Mapei really made its contribution, by proposing specific solutions for each of the problem areas.

For example, for the surfaces below ground level, that were exposed to water under pressure from the subsoil, and for the surfaces on the ground floor exposed to moisture from the ground, technology had to be employed that would guarantee good water-tightness, while forming a tough bond with the substrates. For this reason, for this part of the work, 10,000 m² of surfaces were sprayed with PLASTIMUL 2K SUPER and PLASTIMUL 1K SUPER PLUS, two-component, solvent-free, highly flexible, low-shrinkage, thixotropic bituminous emulsions.

For the reinforced concrete masonry below ground level, on the other hand, the preference was for PLANISEAL 88, a one-component, osmotic mortar, with good adhesion to the substrate, for complete waterproofing, even in the presence of negative pressure.



To build the structure, a workforce of 1,500 and 21 cranes worked together every day on-site, along with two cement mixing units to produce the concrete.

For the water storage tanks and the bathrooms, the product employed was MAPELASTIC FOUNDATION, a two-component, flexible, cementitious mortar that is ideal for waterproofing concrete surfaces subjected to positive and negative water pressure. The possibility of applying the product either manually or by spray using a rendering machine, was a deciding factor in its choice.

For the plant service rooms, a quick, effective and reliable waterproofing solution was needed - one that could guarantee good tensile strength, tear resistance and elongation capacity, as well as long-term resistance to leakage between the various levels of the structure, even if there are cracks in the piping. Accordingly, the PURTOP SYSTEM was used, which consisted of the application of a coat of PRIMER SN, a two-component, epoxy primer, on the substrate, broadcasting of quartz sand over the primer and then application of PURTOP 400 M, a two-component, hybrid polyurea membrane. The surfaces were then treated with PRIMER P3, a two-component polyurethane primer and covered with two coats of MAPECOAT TC aliphatic polyurethane finish.

For the installation of ceramic tiles on around 42,000 m² of substrates in the bathrooms, showers, kitchens and changing rooms, the surfaces were first waterproofed with MAPELASTIC AQUADEFENSE membrane and MAPEBAND rubber tape, after treating them with PRIMER G and levelling them off with ULTRAPLAN RENOVATION.



The emulsions PLASTIMUL 2K SUPER and PLASTIMUL 1K SUPER PLUS were used to waterproof the structures below ground level, that are exposed to ground water under pressure, and to waterproof the surfaces on the ground floor, exposed to moisture coming from the ground.

The ultra-quick-drying properties of MAPELASTIC AQUADEFENSE were a crucial factor in opting for this product, because it made application much easier, even when the surrounding temperature was particularly low.

Installation of ceramic wall coverings and resin floors

Ceramic tiles were installed in various areas of the stadium (bathrooms, changing rooms and kitchens), using the adhesives, KERAFLEX LIGHT S1, distributed on the Hungarian market by Mapei Kft, and ADESILEX P9.



Application of MAPEFLOOR PU 410, using a rake. MAPEFLOOR PU 410 is one of the components of the MAPEFLOOR PARKING SYSTEM HE which was used to create resin flooring in the stands and on the external (north and south) ramps constructed to provide access to the stadium.

The joints were grouted with KERACOLOR FF FLEX (a mortar distributed on the Hungarian market by Mapei Kft), while the expansion joints were sealed with MAPESIL AC.

MAPEFLOOR PARKING SYSTEM HE, a multi-layered polyurethane system with good physical and mechanical characteristics, that provides surfaces with long-lasting protection, was used for the floors in the VIP stand and in the business and press boxes, as well as on the external ramps (north and south) that provide access to the stadium. The system consisted of the application of a coat of PRIMER SN, followed by the polyurethane binders, MAPEFLOOR PU 400 LV and MAPEFLOOR PU 410, and to finish, the two-component, aliphatic, topcoat, MAPEFLOOR FINISH 451. Between each layer of the system, the surfaces were broadcast with various grades of quartz sand, according to the type of material applied and their particular function within the layered system.

Concrete repair in the museum

The only part of the old structure left standing in the new stadium was a tower which was then converted into a museum dedicated to sport. Specific restoration products had to be used on the tower, to repair the old concrete, such as MAPEFER 1K, an anticorrosion mortar for the reinforcement rods; MAPEGROUT 430 thixotropic mortar, to repair the surfaces of damaged concrete; PRIMER 3296, to consolidate the screeds; and PLANITOP 550 mortar, which is distributed on the Hungarian market by Mapei Kft, to create a tough, even surface, on the old stairs.

This editorial feature is based on an article from *Realtà MAPEI INTERNATIONAL* Issue 86. Images by Mapei.

PROJECT DATA

Project

Ferenc Puskás Stadium, Budapest, Hungary

Owner

Hungarian Football Federation

Design

György Skardelli

Period of Construction

2017-2019

Main contractors

Magyar Építő PLC–Záév PLC Consortium
Épkar PLC
WHB LLC

Resin flooring contractor

SpecTech LLC

Waterproofing contractor

Akvaszig LLC

Concrete repair contractor

TípoX Betontechnika LLC

Contractor for the installation of ceramic tiles

Stukkó LLC
Ratskó-Bau LLC
Dominó LLC

INTERVENTION BY MAPEI

Period of the intervention

2017-2019

Contribution by Mapei

Supply of products for waterproofing, anchoring, installing ceramic tiles, laying resin floors and repairing concrete

Mapei distributor

BNF Department Store

Mapei products used

Waterproofing - PURTOP 400 M, PLANISEAL 88, PLASTIMUL C, PLASTIMUL 1K SUPER PLUS, PLASTIMUL 2K SUPER, MAPELASTIC FOUNDATION, MAPELASTIC AQUADEFENSE, MAPEBAND, MAPENET 150

Laying resin floors - PRIMER SN, QUARTZ 0.5, QUARTZ 0.9, QUARTZ 1.2, MAPEFLOOR PU 400 LV, MAPEFLOOR PU 410

Concrete repair - MAPEFILL MF 610, MAPEFILL, MAPEGROUT 430, MAPEFER 1K, PLANITOP 550

Preparing substrates - PRIMER 3296, ULTRAPLAN RENOVATION, PRIMER SN, PRIMER P3

Installing ceramic tiles - KERAFLEX LIGHT S1, KERACOLOR FF FLEX, MAPESIL AC, ADESILEX P9

Anchoring - MAPEFILL MF 610

Website for further information

www.mapei.com
www.mapei.hu

NEW BATTERY-POWERED ELECTRIC VEHICLE

FROM CATERPILLAR

The new Cat R1700 XE LHD, with its 15-tonne payload and 24,190-kg lift and tilt breakout, features a battery-powered electric design that delivers superior productivity, particularly in underground applications, with the benefits of no engine heat or exhaust emissions. It offers an 18 km/h top speed.

The new Cat LHD offers 100% battery electric propulsion. An Autodig function optimises loading and traction control to extend tyre life. Liquid cooling allows the batteries to be cooled while the machine is put back in operation, increasing machine uptime availability.

To maximise run-time, batteries stay on the machine. Using the portable Cat MEC500 Mobile Equipment Charger, the R1700 XE can be fully charged in less than 30 minutes using a single charger or in less than 20 minutes using two chargers.

There is a need for a clean and safe working environment underground, which currently requires installation and maintenance of complex and expensive ventilation systems for clearing exhaust emissions.

With less emissions from machines like the new Cat R1700 XE, there will be less dependence on these ventilation systems. The new R1700 XE LHD is a key part of the vision of an all-electric mining operation. It is the first battery-powered/zero emissions equipment in the underground hard rock mining LHD (Load Haul Dump) product line and offers remote control operation capability.

MEC500 mobile equipment charger

A first-of-its-kind in the industry, the new Cat MEC500 Mobile Equipment Charger is designed to charge quickly and safely wherever it is needed. Unlike static charging stations, the 1600-kg portable charger can be moved to where it is needed via towing, fork truck, or the R1700 XE. It eliminates the need for regular battery handling and swapping, allowing for more efficient charging and production.

Its 500 kW capability delivers an impressive range of 300 Volts to 1,000 Volts and up to 700 Amps. This fast charger can be used as a single unit to deliver a full



The new Cat R1700 XE LHD, with its 15-tonne payload and 24,190-kg lift and tilt breakout, features a battery-powered electric design.



The new Cat MEC500 Mobile Equipment Charger is designed to charge quickly and safely wherever it is needed.

charge to the R1700 XE in less than 30 minutes or in parallel to charge the LHD in less than 20 minutes. Its adjustable output voltage and current can trickle charge the battery, maintaining optimal performance for the R1700 XE.

The charger is built rugged, meeting ISO2867 rockfall protection and IP66 rating for water and dust protection. Key components are isolation-mounted against vibration or seismic activity. It is sealed against humidity with enclosed air conditioning.

YOUNG ENGINEERS COMMITTEE HOLDS WEBINAR ON TRANSPORTATION INFRASTRUCTURE ENGINEERING

The IES Young Engineers Committee (IES-YEC) held its first webinar for 2021, split over 2 sessions that took place on 31 May and 14 June.

Revolving around the topic of transportation infrastructure engineering design and construction in Singapore, the webinar attracted more than 260 participants in total, who hailed from Singapore, as well as other countries in the region such as Malaysia, the Philippines, Myanmar, India, and Bangladesh.

This success was the result of good teamwork amongst the Program and Training and People and Engagement sub-committee.

The speaker was Er. David Ng, co-founder of One Smart and IES Council Member. Er. Ng is a veteran engineer with more than 20 years of experience in management, planning, design, and construction of major infrastructure and transportation projects in Singapore, Malaysia, and India. He has also been involved in the publication of more than 70 technical papers in the field of geotechnical and environmental engineering.

The main objective of the webinar was to create more awareness and appreciation of the beauty of Transportation Engineering and to attract more young engineers to specialise in this area.

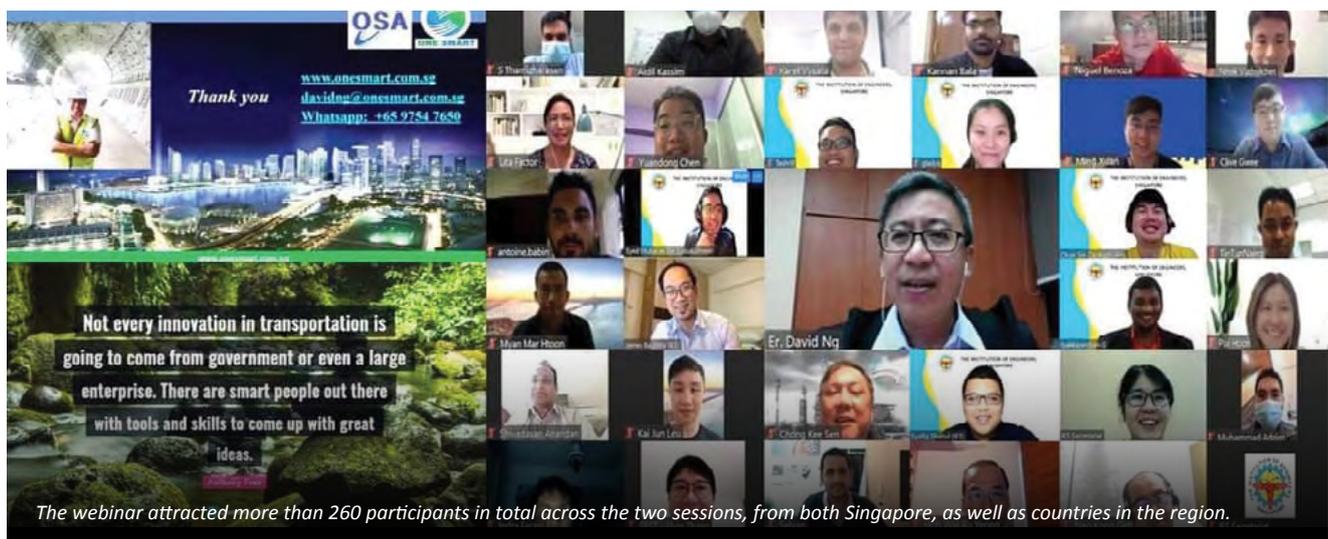
Er. Ng introduced to participants the various types of transportation infrastructure, from underground bored tunneling to above-ground viaduct structures, and shared some design principles and their challenges.

He also shared some insights and observations on current and upcoming transportation infrastructure projects, such as the Thomson-East Coast Line, Cross Island Line, the North-South Corridor highway, and the Rail Transit System (RTS) between Singapore and Johor.

Er. Ng ended his presentation with a poignant quote from Mr Anthony Foxx, the former US Secretary of Transportation: “Not every innovation in transportation is going to come from government or even a large enterprise. There are smart people out there with tools and skills to come up with a great idea.”

This is reflective of the important role engineers play in the success of transport infrastructure within the nation. Innovation in this area complements the available resources, thus helping to secure a technological advantage that would benefit all.

It was an informative session for all the young engineers who attended.



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- Join our Social Events

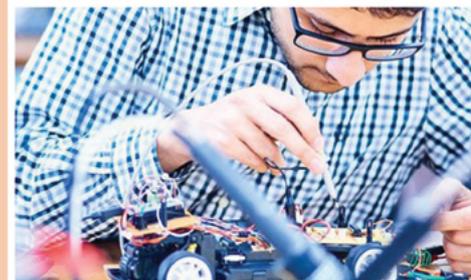


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