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PLUS

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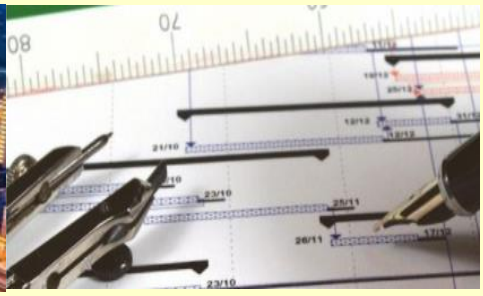

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BENTLEY SYSTEMS ANNOUNCES

NEW EDUCATION PROGRAMME

Bentley Systems, Incorporated, the infrastructure engineering software company, recently announced the Bentley Education Program, which encourages the development of future infrastructure professionals for careers in engineering, design, and architecture.

The Bentley Education Program is initially available in the UK, Australia, Singapore, Ireland, and Lithuania, with plans to expand it to the US, Canada, Mexico, Latin America, and India, by mid-summer.

The programme's student and educator entitlements allow no-cost learning licences for Bentley infrastructure engineering applications and proven learnings through the new Bentley Education portal.

Students and educators from around the globe can register on the Bentley Education portal and connect to infrastructure organisations and resources to prepare for and to recruit for infrastructure engineering careers.

Bentley also announced the Future Infrastructure Star Challenge 2021.

The Bentley Education portal provides a single source of on-demand, frictionless and fun experience for students as they build and enhance their digital design skills. Students and educators have access to comprehensive resources, including:

- Insights from leading Architecture, Engineering, and Construction (AEC) professionals on what the industry has to offer students and what skills are in high demand.
- The latest news and emerging trends in AEC.
- A first-hand perspective of current engineering students, mentors, and women in infrastructure engineering.

The programme offers full access to learning licences of over 40 of Bentley's most popular applications used by infrastructure professionals around the globe, including ContextCapture, MicroStation, OpenRoads Designer, STAAD.Pro, and SYNCHRO.

The Bentley Education Program is open to students and educators at community colleges, technical institutes, polytechnics, universities, secondary schools, and home-schooled students. The programme is designed to create world-class talent that can rise to the challenge of improving the quality of life and positively changing the world, using Bentley infrastructure engineering software, applications, and proven learnings.

The Bentley Education Program will also help students develop digital skills which are critical for a qualified talent pipeline to support infrastructure growth and resilience worldwide.

The Bentley Education Program helps students develop digital skills which are critical for a qualified talent pipeline to support infrastructure growth and resilience worldwide.

The Bentley Education Program uses a role-based learning approach, allowing future infrastructure professionals to focus on specific capabilities needed for specific professions. Students can go beyond mere product proficiency and develop a comprehensive understanding of skillsets required to excel in various roles in infrastructure engineering.

"With many nations and institutions committing to infrastructure and digital education initiatives as top priorities for a post-pandemic world, we are excited to launch this much-requested and responsive programme now. We want to inspire and encourage students to learn about infrastructure engineering as a possible career path, and to introduce these young minds to the vast opportunities that lie ahead, with infrastructure going digital", said Katriona Lord-Levins, Chief Success Officer, Bentley Systems.

Future Infrastructure Star Challenge 2021

The Bentley Education portal also serves as a gateway for individual students or teams of two to submit their innovative concepts for Bentley's Future Infrastructure Star Challenge 2021. The global competition is open to students from community colleges, polytechnics and universities.

Students advancing in the global competition, based on their ideas that improve quality of life, will work on modelling, simulation, and visualisation, to develop a design model. The winner of the Future Infrastructure Star Challenge will be announced during the Going Digital Awards at the Year in Infrastructure 2021 Conference.

The inaugural Future Infrastructure Star Challenge is divided into Stage 1 (Conceptualization), and Stage 2 (Design and Visualization).

In Stage 1 (Conceptualization), students are invited to submit their ideas for 'a next big infrastructure project' in any of the following categories - road and rail, building and facilities, water and wastewater, cities and mapping, and power generation. While conceptualising their idea, students should focus on an environmental challenge that affects or is affected by infrastructure development, consider applying the Internet of Things, and emphasise the project's contribution to the world's health and welfare.

The top 20 judged projects from Stage 1 (Conceptualization) will each win USD 500, with the top 10 projects moving on to Stage 2 (Design and Visualization). Here, each such entry may take advantage of opportunities to work with infrastructure professionals, and/or to attend masterclasses with Bentley experts, to bring their ideas to life using Bentley applications.

The winner of the Future Infrastructure Star Challenge 2021 will be honoured at the Year in Infrastructure 2021 Conference. The winner will also receive a cash prize of USD 5,000 and recognition in Bentley's 2021 Infrastructure Yearbook.

Vinayak Trivedi, Vice President of Bentley Education, said, "We want to make the Bentley Education portal the place where students can go to learn about and become inspired to make infrastructure engineering their career choice. The goal of the programme is to help students who are passionate about infrastructure to get a jump-start on a fulfilling career. The Future Infrastructure Star Challenge 2021 provides an opportunity for them to be creative and innovative in project designs for improving the quality of life and positively changing the world".

More information on the Bentley Education program, including on how to register students and educational organisations, can be obtained from https://education.bentley.com.

BENTLEY SYSTEMS ANNOUNCES ACQUISITION OF MOBILITY SIMULATION LEADER INRO

Bentley Systems recently announced the acquisition of INRO Software, a global leader in multimodal transportation planning, traffic simulation, and mobility visualisation software. The acquisition expands Bentley's capabilities in the important growth area of mobility digital twins, just as countries including the US are poised to make a generational investment in infrastructure, and as transportation systems must evolve faster to accommodate both urbanisation and carbon reduction goals, and the transition to electric and autonomous vehicles.

INRO, based in Montreal, Quebec, Canada, has for more than 40 years contributed to the advancement of mobility simulation and modelling for metropolitan, regional, and national transport and transit operators and planning agencies. Users of its multimodal simulation offerings include some of the world's busiest transit systems and metros, such as Transport for London, Transport for New South Wales, the Washington State Department of Transportation, the Swedish Transport Administration Trafikverket, and the public transport system of São Paulo in Brazil.

INRO's products include Emme, a multimodal transportation planning system for urban, regional, and national transportation forecasting; Dynameq, a vehicle-based traffic simulation platform for city-wide traffic planning; and CityPhi, a mobility visualisation solution providing data visualisation and visual analytics of large-scale mobility and geospatial datasets.

Combining the capabilities of INRO's advanced traffic and vehicle simulation with Bentley's passenger and pedestrian simulation and civil design software, including CUBE, Streetlytics, LEGION, and OpenRoads, places Bentley in a strong position to deliver comprehensive mobility digital twins of multimodal transportation systems on an urban, metropolitan, regional, and national scale.

ADVANCING SMART CONSTRUCTION TECHNOLOGIES

AND FACILITATING PARTNERSHIPS IN TECHNOLOGY TRANSFER

The Housing & Development Board (HDB) and Agency for Science, Technology and Research (A*STAR) have inked two collaboration initiatives to develop and adopt 5G-enabled smart construction technologies, as well as to facilitate partnerships and commercialisation of the research outcomes developed by agencies under the Ministry of National Development (MND) for operational use.

The initiatives, announced at the Urban Sustainability R&D e-Symposia 2021 Opening Webinar recently, aim to transform the Built Environment sector by developing more productive ways to design, build, and maintain the city.

The two collaboration initiatives are:

- A Research Collaboration Agreement (RCA) between HDB and A*STAR's Institute for Infocomm Research (I²R) to enable smarter construction, by developing and adopting 5G-enabled robotic, drone and Artificial Intelligence (AI) technologies that can help raise productivity and improve safety at construction sites.
- A Memorandum of Understanding (MoU) between HDB and A*STAR to bring together the research community, agencies and industry partners to facilitate partnerships in technology transfer and translate R&D outcomes into commercially ready products.

"As the master developer of public housing in Singapore, HDB constantly seeks to leverage innovative technologies and smart solutions that can help us deliver quality homes for Singaporeans. Through relentless research and innovation over the years, we have built up a wealth of knowledge in urban solutions for the built environment. We will continue to work closely with industry partners to accelerate technology transfer, so that the built environment sector can benefit from of our R&D outcomes", said Mr Tan Meng Dui, Chief Executive Officer, HDB.

"A*STAR is increasing our support of the Urban Solutions and Sustainability (USS) domain under Research-Innovation-Enterprise (RIE) 2025. A*STAR is collaborating closely with HDB on introducing innovative technologies into the built environment sector, and catalysing more public sector collaboration with industry. We also aim to work with HDB to translate public sector R&D into positive impact on our society and economy, through such collaborations", said Mr Frederick Chew, Chief Executive Officer, A*STAR.

DEVELOPING SMARTER CONSTRUCTION TECHNOLOGIES

The COVID-19 pandemic has affected the supply of building materials and manpower within the construction industry. This has put unprecedented pressure on the construction timelines of building projects across both the public and private sectors. There is thus a strong impetus for the industry to accelerate the adoption of advanced technologies and digitalisation, to be able to build faster, safer and more efficiently. With the impending roll-out of the 5G network in Singapore, there is an opportunity for greater use of automation and robotics in the construction sector, leveraging on 5G technology, to enhance productivity and reduce labour dependency.

The collaboration between HDB and A*STAR's I²R seeks to research and develop a system which will capture videos, images and data through the use of sensors on robots (legged and wheeled) and drones. Examples of how such information can be used to improve productivity include:

- Scanning and mapping of the construction environment to develop an up-to-date as-built model (i.e. exact rendering of the construction project as it is built) using light detection and ranging (LiDAR) technology. LiDAR is a remote sensing technology that uses light in the form of a pulsed laser to measure distances to a target.
- Enhancing safety of the construction site through real-time video-streaming and surveillance of construction activities.

Scanning and mapping of the construction environment

HDB will study the possibility of employing drone fleets and robotic systems equipped with LiDAR laser scanning technology, to automate the scanning of actual physical built environments into a 3D as-built site model. Currently, the development of as-built models in the construction industry, which typically takes place when construction is nearing completion, is manual and labour-intensive. By deploying a fleet of drones and robotic systems that can intelligently monitor various aspects of a construction site, the entire process can be automated to enable onsite scanning and mapping of the construction site into a 3D as-built model. This will bring about savings in manpower and time.

To allow the drones and robots to function smoothly, HDB will leverage 5G technology for its high data transmission rate and increased network capacity. A*STAR will develop a 5G modem prototype module with low latency and a robust communication link, to enable onsite scanning and mapping of the site as the project is built, and real-time monitoring of activities at construction sites. Latency refers to the time lag or delay before a response is generated.

By using drone fleets and robotic systems equipped with LiDAR laser scanning technology, a 3D model of the construction site can be built up as the work progresses.

Real-time video streaming and surveillance of construction activities

Today, most construction sites employ static CCTV systems to assist with site monitoring. As construction sites cover a large area, there may be spots which are not covered by the scope of the CCTVs. Tapping on 5G technology, HDB will explore the deployment of multiple drones or robotic systems simultaneously, to make monitoring over a larger surface area more efficient.

Through cameras mounted on the drones and robotic systems, high-definition real-time videos of the site environment can be captured wirelessly. AI and Machine Learning technologies will be applied to the live video feeds, so that the system can automatically identify safety lapses and detect potentially unsafe behaviours and conditions at HDB construction sites in real-time. When such lapses are detected, alerts can be immediately sent to the relevant personnel, so swift action can be taken to rectify the situation and resolve the issue. These technologies are thus deployed to function as a mobile monitoring system to augment the manual supervision by safety officers on site.

To ascertain the performance of the system, trials will be conducted at a selected HDB construction site that has ready 5G coverage. The research study is expected to span 2.5 years. If the trials prove successful, HDB will consider extending the system to more construction sites.

FACILITATING PARTNERSHIPS IN TECHNOLOGY TRANSFER

Over the years, HDB has pioneered new and innovative solutions to provide residents with a quality living environment, and has filed over 30 patents for the innovations developed in-house. Examples of such solutions include the Prefabricated Extensive Green (PEG) Roof Tray System and the Floating Solar System (FSS).

AI and Machine Learning technologies will be applied to video feeds captured on drones and robotic systems, to automatically identify safety lapses in real-time.

PEG Roof Tray System

The PEG Roof Tray System was developed to intensify HDB's greening efforts on rooftops. Besides deploying the system in its housing projects, HDB tied up with local firms, Eng Seng Tech Pte Ltd and Plantwerkz Pte Ltd, to commercialise the product in countries and cities, such as China, Malaysia and Hong Kong.

The PEG Roof Tray System helps to green the rooftops of buildings, thereby addressing the environmental concerns of many cities with limited green spaces.

Floating Solar System

In its push to generate more clean energy and accelerate solar adoption in Singapore, HDB invented the Floating Solar System (FSS) which supports solar panels on water bodies, to harness solar energy. The FSS was adapted from a modular floating system known as the Floating Wetland System that was earlier patented by HDB for cultivating wetland plants. Following the successful test-bedding of the FSS in Tengeh Reservoir in Tuas, HDB collaborated with a local company, ISO Landscape Pte Ltd, to deploy a 5 MegaWatt-peak (MWp) FSS off the coast of Woodlands.

Forging closer partnerships to create impactful solutions

Building on the R&D efforts, the MoU between HDB and A*STAR seeks to forge closer partnerships among the research community, government agencies and industry partners, over the next three years, to facilitate technology transfer and translate R&D outcomes into impactful solutions for Singapore, and potentially for cities around the world.

With its prior experience in intellectual property (IP) management, HDB has been appointed the lead agency for IP management and technology transfer, for the agencies under the Ministry of National Development. The MoU will tap on A*STAR's expertise and connection with the industries and the local science and technology ecosystem, to facilitate collaborations to commercialise

The FSS holds solar panels on water bodies to harvest solar energy.

MND R&D outcomes and IPs. Over the years, A*STAR has accumulated proficiency in dealing with numerous research collaborations and licensing agreements with the industry, and will be able to facilitate business matching opportunities between the agencies and industry partners. This includes facilitating knowledge-sharing and organising joint events to build up a network of industry partners for MND agencies. Where needed, A*STAR will also help to further develop MND IPs into commercial solutions or products that are useful for the industry.

All images by HDB

CUNDALL TO OFFER

STRUCTURAL ENGINEERING SERVICES IN SINGAPORE

International multi-disciplinary engineering consultancy, Cundall, has expanded its services in Singapore to include structural engineering, with the appointment of Ms Chaoming Yu as Associate Director.

Ms Chaoming Yu

As a Chartered Engineer, Chaoming brings a wealth of experience to Cundall. Her projects include Hong Kong International Airport Terminal 2 Expansion, Hong Kong West Kowloon Terminus, Morpheus Hotel in Macau, and Sentosa Vessels and Founders' Memorial (shortlisted design), both in Singapore.

Prior to joining Cundall, Chaoming spent many years with Buro Happold in the UK and Hong Kong, followed by AECOM in Hong Kong before joining Passage Projects in Singapore.

Commenting on her new role, Chaoming said, "I am so thrilled to join the Cundall team. Cundall has a reputation for delivering quality multi-disciplinary services to its clients worldwide, and the culture to push boundaries with sustainable and innovative design is very exciting".

Cundall's international practice has been delivering structural design for over 40 years.

Marcus Eckersley, Director, Cundall Singapore said, "Having been in Singapore for 10 years and where we have built a solid reputation as MEP engineers, we feel the time is right to bring Chaoming in to lead the structural team in Singapore".

INNOVATIVE DESIGN AND MATERIALS

FOR AN INSTITUTIONAL BUILDING

Singapore Management University (SMU) Connexion received the BCA Design and Engineering Safety Award 2020 as well as the IES Prestigious Engineering Achievement Award 2020.

Overview of the completed SMU Connexion.

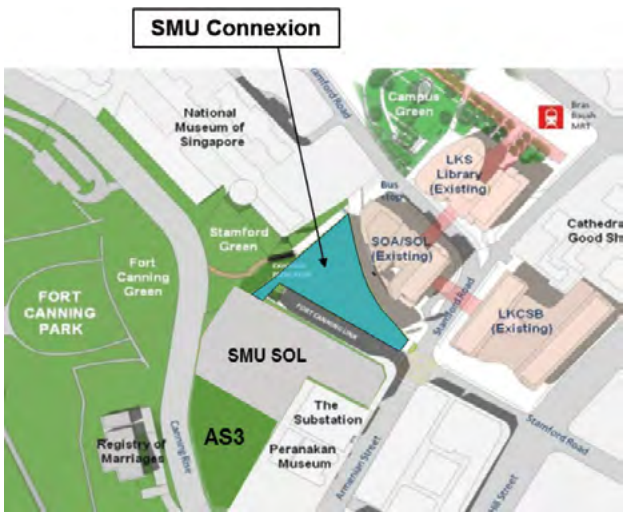
INTRODUCTION

SMU Connexion (SMUC) is an institutional development comprising a five-storey teaching block and a two-storey link building. It is a new addition to the Singapore Management University (SMU) City Campus, that supports experiential learning through real-world projects and cultivates innovation and entrepreneurship. The project sets out to fulfil four key design goals, namely encourage experimentation, enable 24/7 learning, engage the city, and embrace new sustainability initiatives.

The development sits on a tight site of only about 3,544 m², with no direct vehicular entrance nor access. The site was partly occupied by the old National Library which had since been demolished.

The new building will also provide direct connectivity and linkage to the existing SMU School of Accountancy and School of Law, over Fort Canning Link.

The 8565.94 m² GFA (Gross Floor Area) space includes active learning classrooms, brainstorming hubs, collaborative zones, integrated learning studios, makerspace, student lounges, cafeteria and incubation spaces for start-ups. For maximum flexibility, the building has open floor plates, with minimal fixed walls that can be adapted



Location plan.

to accommodate new learning modalities in the future. Learning spaces will be defined through creative use of furniture to achieve a sense of openness and transparency.

SMUC is designed to meet the Building and Construction Authority (BCA) Green Mark Platinum certification and the international WELL Building Standard. It also holds the distinction of being the city centre's first large-scale Mass Engineered Timber (MET) development and an on-site net zero energy building, with its own power generated from a photovoltaic system. Other Green features and technologies include advanced passive displacement cooling, smart LED lighting and predictive smart building control systems.

The project was tendered out in a single package with a contract completion period of only 15 months. This included the installation of foundation piles, the main building works, the construction of the Link Building over the busy 3-lane Fort Canning Link and the Additions and Alteration works to the School of Accountancy.

The project is acknowledged as an example for the industry, showcasing the adoption of DfMA principles and the use of innovative structural systems, advanced construction materials (Cross Laminated Timber), modular M&E systems design and a prefabricated facade, for fast-track construction, buildability and productivity improvement. It has also incorporated several green and energy-efficient technologies to become an on-site net zero energy building.

STRUCTURAL DESIGN PROCESSES AND SOLUTIONS EMPHASISING SAFETY

The main technical challenges in the design and construction of SMUC were:

- Creation of an iconic new teaching block with connectivity to the SMU School of Law and School of Accountancy.
- Close proximity to surrounding buildings and services.
- Construction of the Link Building over the existing Fort Canning Link.
- Low floor-to-floor height due to tight AMSL (Above Mean Sea Level) control.
- Fast-track construction programme of only 15 months.
- Presence of critical 'live' underground services below and adjacent to the site, whose diversion was not a feasible option due to their importance, site constraints and time.
- Fire safety authority compliances and product testing challenges, as this is a newly-adopted methodology in the local context.
- Construction in a dense city centre.
- Extremely constrained site and limited access.

Construction safety and risk management were key considerations during the design process. In addition to the inherent challenges, the development was also designed to be SMU's first on-site net zero energy building, being self-sustainable with its own power generated from a photovoltaic system located within the same premises.

Given the challenges, the design had to be highly buildable, taking into consideration the access and logistical constraints on site and the fast-track programme to complete the building.

The concepts and basic principles of Design for Manufacturing and Assembly (DfMA) were adopted and implemented for all trades where possible - Architectural, Structural and M&E.

Innovative structural system

The superstructure comprises an innovative hybrid Steel-Cross Laminated Timber (CLT) slab system. The frames of the building are erected in structural steel, while the slab is in CLT. The adoption of this hybrid system is a first-of-its-kind in Singapore.

The structural system adopted offered the following advantages:

- Structural steel frames offer greater flexibility especially for long span structures.
- CLT slabs provide an alternative to composite steel decking but without the need for any concrete topping.
- A hybrid of steel and CLT offers a super lightweight structure, resulting in savings to foundations of between 20% to 40%, compared to composite steel and conventional concrete systems.
- Prefabrication of frames and slabs can be done fully off-site, for better quality control and workmanship.
- Substantial reduction of overall site concreting.
- Better adaptability for future-proofing.
- High speed of construction and ease of erection and fixing into position.
- Reduction in on-site labour.
- Improvement in productivity and buildability.
- Shorter construction period.
- Pleasing aesthetics with the integration of the structural system and the M&E services expressed as part of the architecture and interior design.

One of the key benefits with this hybrid system was the substantial reduction of in-situ concreting. As the site was very small, being adjacent to a busy road junction and without any permanent vehicular access, the adoption of this system ensured minimum disruption to both pedestrian and vehicular traffic.

The structural steel frames comprise circular tubes for the columns and universal beams for the floor elements. As the steel frames would mainly be exposed and expressed architecturally, the sizes, shapes, configuration and connection details had to be worked out closely with the Architect, to achieve their design intent. To further enhance productivity and buildability, the steel members were prefabricated into modular frames off-site. The whole length of the column was divided and fabricated in two segments - from L1 to L4 and from L4 to the roof.

The connecting beams at every floor level were welded to the column in the factory, as short stubs, to form a modular frame.

The column frames were erected from the 1st storey. Guy wires were used to stabilise the columns temporarily during setting out and alignment checks. Once the frames were stabilised with the installation of the 2nd storey floor beams to form a bay, the guy wires were released. The frames were designed to be self-supporting, thereby avoiding the need for temporary props or falsework during installation and enabling an uninterrupted and smooth erection sequence. This fabrication and erection strategy was repeated for all the building columns and beams. The dimensions of the frames were also engineered to facilitate easy transportation, storage and erection. The end result was the achievement of standardised and repetitive steel frames that facilitated simple and swift erection on site. The remaining parts of the beams were then connected on-site to the frames, using bolted connections, as the floors were progressively erected. The benefits of using bolted connections are as follows:

- The process is easy and simple.
- It enables faster erection and construction, compared to welding which requires a more elaborate set of QA/QC and testing of weld quality.
- It facilitates the use of engineered timber.

The CLT slab was designed to perform two functions:

- To support gravity loads and transfer these to the supporting beams.
- To act as a horizontal diaphragm that transfers lateral wind and notional loads to the core and shear walls.

The typical CLT slab consists of seven lamellas glued together to make up a total thickness of 220 mm. A polyurethane adhesive was specified as it is formaldehyde-free and more sustainable in the long term. The 3rd storey of the Link Building was constructed with a thinner floor system made from 140 mm thick CLT panels.

The CLT panels were typically connected to each other and to the top flanges of the supporting beams by wood screws. Special connections to the cores and shear walls were detailed as these were required to transmit wind and notional forces. The CLT slab was designed for a fire rating of 1 hour. Fire protection of the slab is achieved through the charring depth of the CLT. The design of the CLT slab took into consideration the effects of charring during a fire. Likewise, anchor bolts and fixtures to suspend services from the underside of the CLT slab had also considered the charring depth in the design of the embedment depth. Fire protection of the steel structure is typically achieved by intumescent paint.

Prefabricated structural steel beam-column frames erected on site.

Innovative Steel - CLT floor system erection.

Large, flexible and aesthetically-pleasing spaces were created through innovative integration of structural and MEP systems.

The top of the CLT slab was protected with a waterproofing membrane. An acoustic membrane was laid over and finished off with 70 mm of floor screeding. The screeding serves to protect the two membranes and also conceal the floor trunking and service outlet boxes laid over the slab.

CLT was adopted only for the sheltered and dry areas within the building. The slabs for wet areas, like toilets and MEP plant rooms, are made of composite steel decking. The cores and shear walls were constructed in conventional reinforced concrete. The 1st storey adopted a highly buildable flat plate system. The roof is a lightweight steel structure and roofing sheets, designed to support the weight of the PV solar panels and enable access for maintenance, have been used.

The new building is supported on bored piles installed into the Fort Canning boulder bed.

Link Building design and construction

The Link Building connects the new educational block to the existing SMU School of Law, and had to be built over Fort Canning Link. The building comprises essentially two storeys and extends from the 3rd and 4th storeys of the main building, with a roof over it. It measures approximately 19 m x 27 m on plan and is supported on four columns. Its design and construction was one of the key challenges in the project.

In order to bridge over the carriageway below and not affect its continued operation as a major artery that serves traffic coming from the east via Marina Coastal Expressway, East Coast Parkway and Nicol Highway, the Link Building is supported from the new building and by two new columns erected from the side table of SMU School of Law. There is also a requirement to maintain as high a headroom over the road as possible, so that motorists can see the Fort Canning Tunnel clearly as they approach it from Stamford Road.

Erection of the Link Building was a critical consideration in the design. Early consultation and extensive brain-storming sessions were conducted internally and with the Land Transport Authority (LTA). Several options, with their pros and cons, were considered, and the number of options eventually narrowed down to two:

- Option 1: Closing of Fort Canning Link for seven days to enable 24/7 construction. Motorists could temporarily use an alternative route to bypass Fort Canning Link.
- Option 2: Construction of the Link Building only during non-peak hours, from 8 pm to 5.30 am, with partial road closure for 45 days.

Fort Canning Link is a major arterial road (with a three-lane carriageway) that provides direct connection from Stamford Road to Orchard Road.

Option 1 would enable the Builder to erect the basic building structure and key services over the carriageway within seven days.

Option 2 would entail the erection of the Link Building in smaller segments within a confined operational period. Temporary staging would be required to prop the erection and the whole construction would take up the planned duration of 45 days.

LTA accepted Option 1. The challenge for the project team was then to work together with LTA to erect the building within this short time-period.

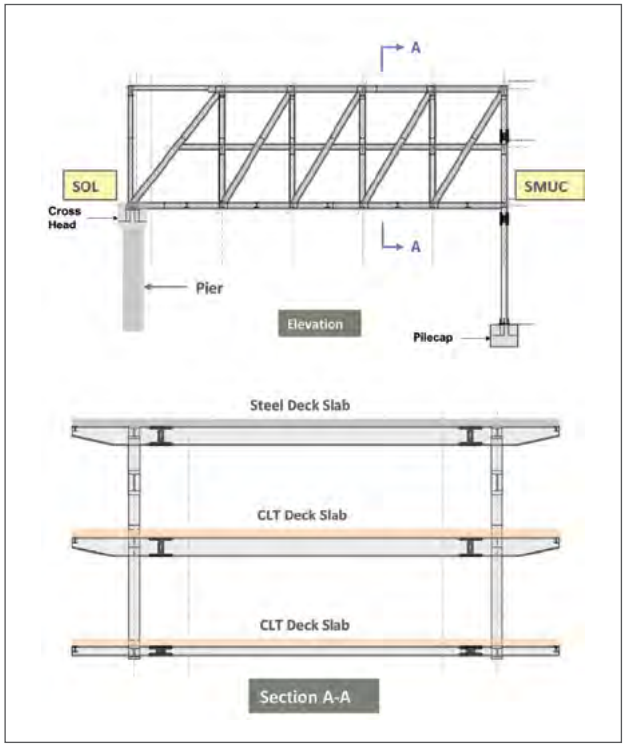
Two 'modified' Pratt Trusses were designed to span 27 m across the carriageway to support the building. The trusses are integrated into the building design and are expressed architecturally within the interior spaces. The depth of these trusses spans over two floors, from the 3rd storey to the roof. This maximises the potential of the truss depth and enables optimisation of the element design. It has resulted in shallower chord and beam depths, thus achieving a high headroom over the carriageway, of about 7.5 m. The trusses are supported on two steel columns at the main building side. Two new columns supported on micropiles were constructed with a cross head to support the truss on the SMU School of Law side.

The hybrid steel-CLT slab system has also been adopted for the Link Building, for ease of construction. Secondary beams spanning across the two trusses were designed to support the CLT panels. As the trusses are set back from the façade edge, the secondary beams were extended and cantilevered beyond the trusses with moment connections. The roof and landscape areas were designed in composite steel with concrete topping, instead of CLT panels. These areas are protected with a waterproofing membrane system since they are exposed directly to the weather.

Each of the two trusses was divided into two segments, horizontally, for hoisting, using 500 ton and 350 ton cranes. The lower segments of the trusses were erected first. Nominal temporary ties and bracings were provided at the supports to stabilise the truss segments. The 3rd storey floor beams were progressively lifted and bolted to the trusses. The remaining two segments of the upper trusses were then erected over the lower segments. The joints of the trusses were welded on site. This was then followed by the installation of the 4th storey and roof beams.

During the whole process of installation, the truss segments were not propped nor supported temporarily from the road below. To facilitate the installation process and avoid unnecessary erection of falsework or temporary work over the carriageway, the lower segments of the trusses were engineered and designed to support the upper trusses and installation of the floor beams and CLT slab panels during erection. This enabled concurrent welding of the truss segments and erection of the other structural elements to expedite site work. The last activity, to complete the Link Building erection, was the concreting of the topping for the composite steel decking. This was carried out only after the two trusses were fully assembled and welded.

The whole building structure was constructed within seven days, as planned, in spite of interruptions due to heavy downpours during this period. Fort Canning Link was reopened on time, as planned.



'Modified' Pratt Truss elevation and section.

Installation of lower truss segments.

Installation of CLT panels and upper truss segment.

Welding of truss segments and installation of CLT panels.

SMU SOL

The Link Building.

Fort Canning Tunnel

Safeguarding existing services

There are many services running below and adjacent to the site, which affected the design and construction. Some of these were either diverted, abandoned or safeguarded. The critical services that required safeguarding and integration with the new design or need to co-exist with the new design are:

- The 10 m wide Stamford Canal sandwiched between SMU School of Accountancy and the site. The canal was constructed as an open channel about 40 years ago and was subsequently slabbed over.
- Critical Singtel cables and draw pit running across the site, which cannot be diverted.
- Critical SMU data fibre optic cables and service sumps serving existing SMU schools.

The Singtel cables serve critical facilities. Similarly, the fibre optic cables that serve existing SMU premises are also considered as critical infrastructure. Given the importance of the services and potential time delays, diversion and relocation of these services was not a consideration. There was also practically no space outside the site for the diversion or relocation of the services.

The decision was taken, early, to integrate these critical services, thereby ensuring their co-existence within the overall building design. Structures were designed to bridge over and protect the services while, at the same time, enabling maintenance, repair or replacement, if required in the long term. The services were also safeguarded and monitored during pilecap and detention tank construction, to prevent damage.

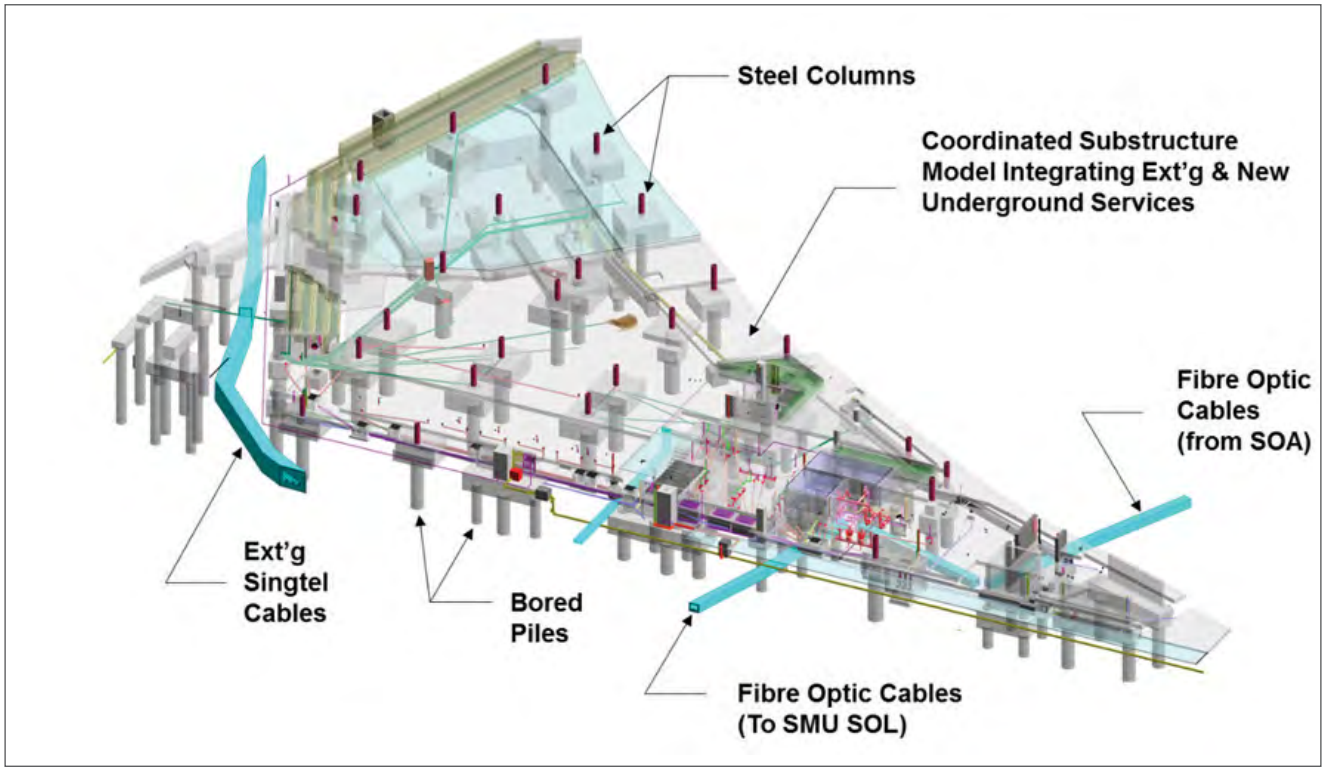
The SMU fibre optic cables were buried under Fort Canning Link and this affected the installation of the micropiles for the Link Building on the SMU School of Law side. The micropiles and columns were adjusted to avoid the cables, based on on-site measurements. As a result, a cantilevered cross-head was introduced to support the two trusses.

There were also existing drains within the site, that served Fort Canning Park. These were relatively simpler to divert and manage, to make way for the new building and a new permanent drainage system that flows into the adjacent Stamford Canal.

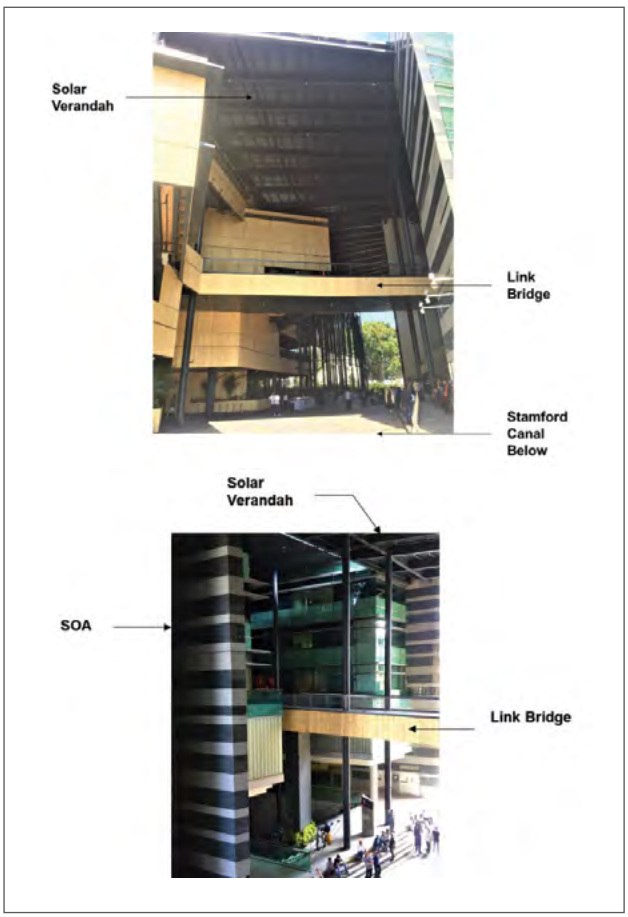
Solar verandah and link bridge connection to SMU School of Accountancy

As part of the project requirements to achieve the on-site net zero energy building status, solar panels were installed over the roof to collect and harness the energy. A solar verandah was also created to bridge the roof of the new building to the School of Accountancy across Stamford Canal. The solar verandah serves two purposes - to provide an additional platform to harvest solar energy as well as to offer an all-weather shelter for pedestrians at the 1st storey. It creates a large covered plaza extending between the new building and the School of Accountancy, which allows campus activities and programmes to be carried out within it. A link bridge was also constructed on the 3rd storey, to connect the new building to the School of Accountancy.

Part of the new structures are supported from the School of Accountancy structures at the roof and Basement 1.



Integration of the existing ground services into the new building design.



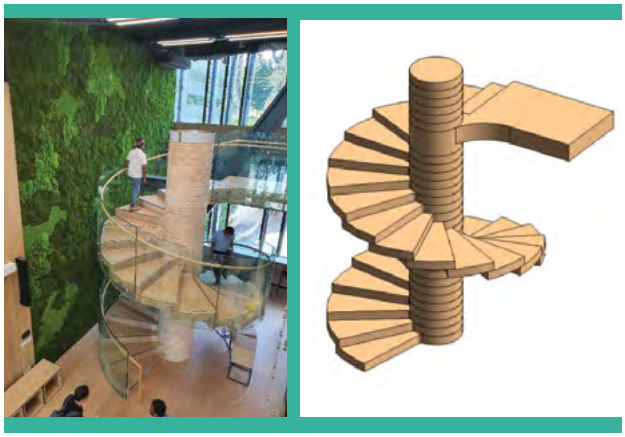
Solar verandah and link bridge to the School of Accountancy.

Both the verandah and link bridge were designed using structural steel, primarily to reduce the additional loads of the new build on the existing structures, as well as to facilitate construction. Steel members were essentially prefabricated off-site and delivered for on-site installation. The existing structures were analysed and checked in detail for the loadings from the new build. Several framing options were investigated, to minimise structural modification and overstressing of existing elements. The foundations and vertical structural elements were generally found to be adequate to support the new loads. Part of the 1st storey and basement beams were also checked and some were found to be inadequate to support the additional loads, despite the effort to redistribute them. These beams were strengthened using Carbon Fibre Reinforced Polymer (CFRP), before the new structures were erected.

Architectural staircases

There are two staircases in the building, that are designed as architectural icons. One is at the Central Plaza, from the 1st storey to the 3rd storey, and the other is within the Link Building, from the 3rd storey to the 4th storey, which serves the Business Incubator space. Both are spiral stairs.

The stairs at the plaza was designed using structural steel. The curved stringers are framed using plates. The treads and risers were formed using thin folded plates. These folded plates serve two functions - to provide



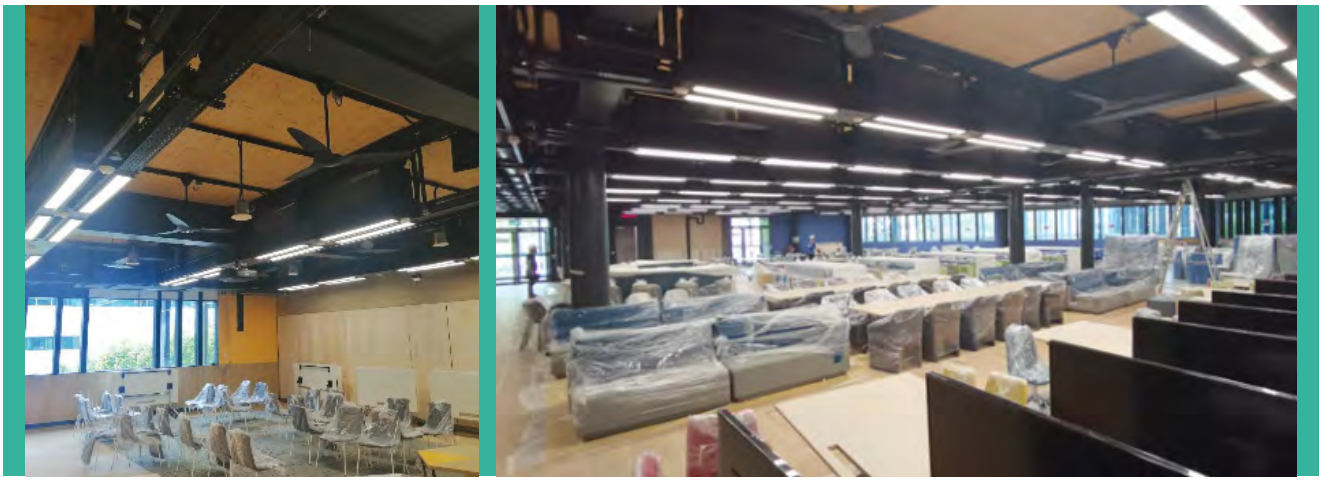
Spiral CLT stairs in the Link Building.

restraint to the stringer plates against lateral torsional buckling, and to also provide overall lateral stability to the stairs. Besides strength checks, vibration control was also a critical consideration in the design, as vibration can cause discomfort to people using the stairs. The stair components were mainly fabricated in the yard and delivered to site for erection. However, due to the need for full structural continuity of the stringers, welding was required on site to connect these members and the folded plates together.

The stairs in the Link Building was constructed entirely in CLT. The design concept innovatively embraced the basic principles of physics and the theory of equilibrium. The design consists of a single column, with the steps radiating from it, from the 3rd storey to the 4th storey. The interesting feature is that the CLT stairs was fabricated entirely off site, with every piece having the same dimensions (except the final topping piece). These pieces are, in turn, stacked vertically to form the spiral. Each piece of the CLT panel came with the column and step fabricated together and cut to the exact size.

Pre-formed holes in the CLT allowed steel rods to pass through to tie these pieces together as they were being stacked. The tie rods were then locked off and secured onto the floor slab and the top of the column. The self-weight of the stairs (column in compression) and the steel rods (within the column) provide the basic resistance to bending moments from the cantilevered steps. The staircase is lightweight and was erected expeditiously with minimal effort. It was a simple engineering idea which resulted in an iconic expression for all to appreciate.

The other staircases were erected also predominantly in structural steel, with simple bolted connections on site. This avoided in-situ concreting and expedited the provision of vertical access to the floors for commencement of subsequent trades. The whole concept of DfMA was applied to the design and installation of the staircases, to enable off-site fabrication, better quality control and use of lighter and more sustainable materials and forms of construction, as well as to enhance productivity and buildability. This ultimately created a safer and cleaner work environment on site.



Modular M&E services.

Modular M&E systems

DfMA was adopted for C&S work and also extensively for M&E and architectural works.

The main and secondary routing of M&E services were integrated into standardised and repetitive modules, to enable off-site fabrication. The routes and layout were coordinated early, through BIM, and mock ups were carried out on site to verify the design and feasibility. The modules are suspended from the soffit of the CLT slabs. As the services are integrated into modules, the loading consideration is different from that for a conventional design. The concentrated loads from the modules can be much higher than uniform loads that are typically assumed. The design of the CLT slab had taken into consideration these point loads as well as its char depth, in order to embed the fixings required for the suspension of the M&E modules.

There is, generally, no ceiling provided for the learning spaces. The steel structure, CLT slab and the M&E services were carefully organised and expressed. Penetrations for services were created through the steel structures, to maximise the available floor height.

DfMA facade

The iconic building facade is a lightweight modular system which was also designed by adopting the principles of DfMA. The primary façade components comprising the window frames, sun shades, fire-rated boards and acetylated timber were fabricated and assembled off-site in modular panel sizes. These were then delivered, installed and finished off with waterproofing and fire sealant, on site. The secondary aluminum fins of the façade were installed on site, after the primary panels were in place.

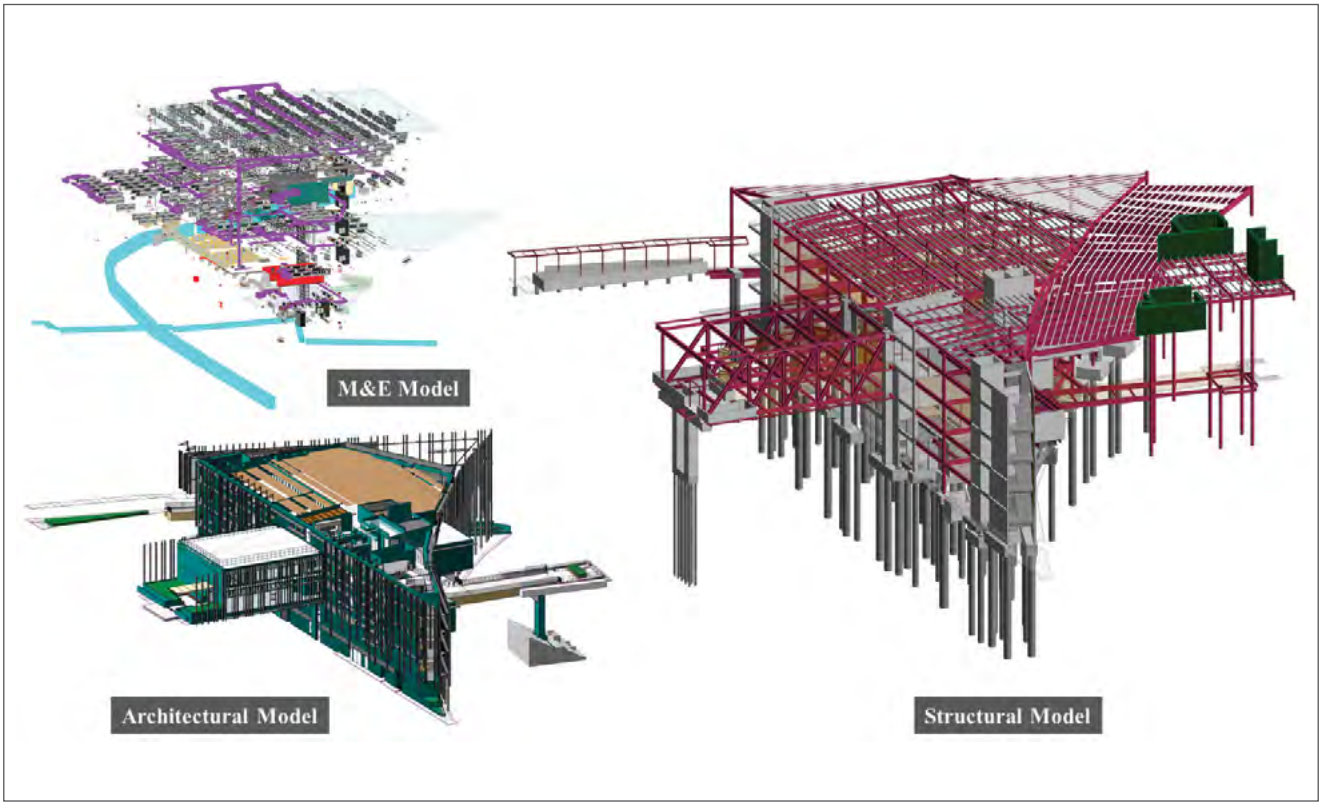
The modularisation of the façade further improved site productivity and buildability. Many of the façade panels are supported from the CLT slab, while the rest are either hung from the RC stairwalls or concrete slabs. The CLT slabs are generally cantilevered from the perimeter beams and were checked for these additional loads from the façade. The façade panels were connected to the CLT slab using aluminum floor brackets and wood screws. The stresses on the CLT slabs were also checked locally to ensure there would be no crushing due to the façade connections.

Installation of the DfMA façade.

The extensive connection of the external façade to CLT slabs in this project was a first-of-its-kind in Singapore. While the design demonstrated structural adequacy of the proposed detail, an actual scale model of a typical connection was made to verify its load-carrying capacity. Due to multiple load cases on the façade, the connection was subjected to different directional loads to ascertain its performance. The test results were satisfactory.

Collaboration among Project Team members

The design and coordination process was fully implemented by adopting the Virtual Design and Construction (VDC) management approach. Intensive coordination was carried out during design, by the team, and together with the Builder, after the award of the construction



Architectural, structural and M&E models.

contract. The DfMA process demands the confirmation of design early, so that preparation and approval of shop drawings can be completed ahead of the procurement of structural steel and CLT panels. This process was required to be completed within three months after the main contract award. It is substantially different from conventional design where less intensive design coordination and approval is required so early.

The design process was coordinated with Building Information Modelling (BIM). VDC sessions were conducted on a weekly basis to discuss and coordinate the design. Updating of the BIM models by the individual Consultants was carried out regularly. These models were uploaded and shared weekly for continued coordination and reviews. The BIM model prepared by the Consultants was issued with the main tender as a reference and as information for the bidders.

After being awarded the contract, the Builder took over, to lead the main coordination of the works, jointly with the Consultants. It was an important process and a key part of the collaboration, to enable the on-time procurement, fabrication and erection of the steelwork, CLT slabs, modular M&E systems and DfMA façade, on site. This led to successful and timely completion of the project.

A QUALITY APPROACH

A collaborative approach was adopted for the design and construction, and accompanying specifications, involving the Client, Team of Consultants and Builder. Close design co-ordination and detailing ensured that there were no structural transfer elements in the new building, and safety considerations were incorporated into the design, from construction to maintenance.

The design, detailing and specifications for the hybrid structural steel CLT slab system were documented to high standards, in line with the design requirements and quality expectations. As the system was relatively new in Singapore, extensive research and consultations with specialists, in particular on CLT, were carried out.

The technical specifications for the CLT slabs were crafted to suit the project requirements and local conditions. Working closely with the Builder and with an open mind, the specifications and requirements were implemented on site to ensure the basic functions, testing regime, code compliance and performance standards, were met. The project was supervised on site with one Resident Engineer and two Resident Technical Officers.

The incorporation of highly buildable features into the design, including modular M&E systems and the DfMA façade, improved constructability and overall site safety. The minimum Buildable Score required is 79 points. The Buildable Score achieved by the design is 87 points. The Concrete Usage Index (CUI) was approximately 0.26, which is much lower than the 0.35 m^3/m^2 required to achieve maximum points for the Green Mark Platinum Award. The Builder also adopted highly productive

construction technologies and systems. A Constructability Score of 73 points was achieved compared to the minimum requirement of 50.

CONSTRUCTION QUALITY & SAFETY

The unique structural system eliminated the need for any falsework or propping on site, to erect the floors. Construction and erection of the superstructure were made simple and safe. The critical site activity was the initial setting out and erection of the columns from the 1st storey. This had to be correct, to ensure smooth erection of the subsequent structural elements, due to the tight tolerance and precision required of the hybrid system. Once this was verified, the installation of the beams and CLT panels for the various floors was readily facilitated and undertaken expeditiously.

Regular checks on the quality of the structural steel was carried out by periodic visits of the Qualified Site Supervisors (QSS) to the fabrication yard. An independent Testing Agency was also appointed to provide full time inspection and testing of the work, both in the yard and on site. The quality of the CLT panels was also a key consideration and requirement of the project, as these had to be expressed visually. The panels were cut and fabricated to the exact size in Austria. Close coordination among the project team members was needed upfront to finalise all shop drawings, setting out, dimensions, vertical penetrations, recesses, etc, in order to confirm the CLT order and production. Once the CLT panels are fabricated and transported, it would not be easy to modify them. Early design confirmation by all stakeholders was therefore essential.

A visit to the fabrication yard in Ybbs, Austria, was carried out to witness the production and testing of one of the CLT batches. The objective of the visit was to understand and appreciate the CLT manufacturing process. The Quality Assurance and Quality Control in the production process and the associated verification tests for compliance and acceptance of the batch were also discussed and witnessed.

In addition to ensuring that the production process was in order and in compliance with the requirements of the European Technical Assessment (ETA), two full-scale CLT slab tests were conducted in Singapore. In the tests, 140 mm thick and 220 mm thick panels were test-loaded to failure. These were verified and found to be consistent with the design output. The test results were satisfactory. Similarly, a fire test on a CLT sample was carried out in Italy and the results were verified by an accredited laboratory for performance compliance under the fire safety design codes.

Connection of the CLT slabs, between adjacent panels, to the steel beams and other supporting elements like walls and brackets was effected through the use of wood screws. The wood screw was therefore a critical structural component for the overall integrity of the building structure. Load tests were also conducted on samples of the screws to ensure conformity.

INSPECTION AND TESTING PROGRAMME

Thorough and comprehensive risk analysis studies were carried out regularly for every stage of the construction process to identify the key risk issues and to control and mitigate the situation with preventive measures. A comprehensive instrumentation regime was put in place and monitored closely.

Supervision of works was carried out progressively to ensure safety, quality and performance, in terms of meeting the progress targets set. Regular site meetings were held with the Builder to review and eliminate safety issues prior to the work activities. Inspection, testing and monitoring were carried out through quality checklists.

Approved shop drawings were circulated to all relevant parties prior to construction, and inspection was carried out based only on approved drawings. The QP and the resident site team conducted regular site meetings and walks to ensure QA/QC.

DESIGN FOR SAFE INSPECTION AND MAINTENANCE

The safe inspection and maintenance of the building after completion was a key consideration at the outset of the project. Reference was made to BCA's Design for Maintainability checklist. As the structural elements are generally exposed and expressed architecturally, the inspection of the structural elements can be carried out easily, at any time, and especially during the mandatory inspection every five years. Similarly, since most of the M&E services and fixtures at every floor are well organised (arranged in standardised and repetitive modules) and exposed without a ceiling, the inspection, maintenance and replacement of any fixture can be carried out readily. The major MEP equipment are also generally located near the lift. Therefore, replacement of a whole equipment or parts of it can be carried out in future, without difficulty, whenever required.

The inspection and maintenance of the building façade can be carried out by several means. For low-rise areas, lifts, scissor lifts and/or cherry pickers can be used. For the maintenance of high volume spaces and along the building edges, a building maintenance unit that can move along a monorail was installed to facilitate cleaning, inspection and servicing.

The solar panels installed over the main roof and the verandah can, likewise, be readily maintained and serviced over the building life. Access to all these areas has been detailed and provided, with safety railings and life lines. The roof structure was designed, taking into consideration also the loads from the placement of the solar panels and access for maintenance.

Besides the general requirements for maintenance of any building, there is also a need to establish a maintenance regime and guidelines for the CLT slabs. The Builder and the CLT specialist supplier formulated an Operation and Maintenance Manual for the Owner,

upon completion. The manual basically outlines the common causes of damage to CLT, maintenance guidelines, management of CLT slabs and visual inspection. Reference was also made to BCA's Design for Manufacturing and Assembly (DfMA) of Mass Engineered Timber Guide Book.

CONCLUSION

SMU Connexion was successfully completed safely and on time, with no public safety incident or adverse feedback throughout the construction. By adopting holistic DfMA technologies, manpower savings of approximately 26% was achieved. The corresponding productivity improvement was 35%.

The project achieved the initial design objective to be a sustainable and green building, meeting both BCA's Green Mark Platinum and the international WELL Building Standards. The project has also achieved a high-quality standard expected of a new building for a top university.

All images by SMU

PROJECT CREDITS

Project
SMU Connexion (A-South 2)

Location
40 Stamford Road, Singapore 178908

Developer
Singapore Management University (SMU)

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MKPL Architects Pte Ltd

Civil & Structural Engineer
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Mechanical & Electrical Engineer
Meinhardt (Singapore) Pte Ltd

Quantity Surveyor
Rider Levett Bucknall LLP

Builder
Singapore Engineering & Construction Pte Ltd

SMU Connexion is an architecturally elegant, green building.

ADVANCED HAT SOLUTIONS FOR MANPOWER REDUCTION AND COST-EFFECTIVE CONSTRUCTION OF EARTH RETAINING AND STABILISING STRUCTURES

by Kazutaka Otsushi, Senior Manager, Nippon Steel Southeast Asia, Singapore; Kelly Lim Swee Chin, Senior Civil Engineer, Nippon Steel Southeast Asia, Singapore; and Zac Chen, Marketing, Nippon Steel Southeast Asia, Singapore

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In Singapore, steel sheet pile/soldier pile walls are generally constructed where there is need for temporary retaining walls. For this, the Hat Sheet Pile with 900 mm was described in the BCA design guide (BC1:2012) as JIS A 5523 grade, in Year 2012. Since then, it has further developed into Advanced Hat Solutions with the Hat Soldier Pile (non-welding type) and Hat + H Pile (combined by welding type). The Hat + H type has been adopted by LTA, for the construction of retaining walls in MRT projects.

This article will explain the different technical aspects of Advanced Hat Solutions, their features, applications in construction to improve construction productivity, and innovative methods for pilling works in hard soil layers.

INTRODUCTION

The Hat type with H-beam solutions have strong track records in many countries, including in ASEAN countries (Singapore, Philippines and Indonesia) as well as in the US, China, India and other countries, in applications such as the construction of wharves/ river revetments, underground temporary walls, retaining walls, water cofferdams etc.

For Advanced Hat Solutions, which are used in excavations of more than 10 m in depth, there are two main types - one is the Hat Soldier Pile (Hat with H-beam without welding) and Hat+H Pile (Hat with H-beam combined with welding).

SERIES OF HAT TYPE SHEET PILE SOLUTIONS

Based on the required stiffness, the most suitable solutions can be selected with Hat sheet pile technology. The Hat type has four sizes, namely, 10H, 25H, 45H and 50H. If a higher wall stiffness is required in the design of Earth Retaining and Stabilising Structures (ERSS), Advanced Hat Solutions (Hat type with H-beam solutions) are recommended (Figure 1).

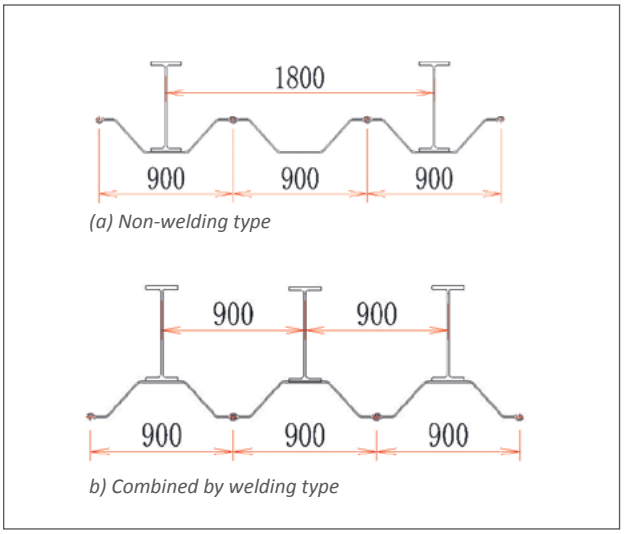


Figure 1: Hat with H-beam solutions

HAT Soldier Pile (non-welded type)

The Hat with H-beam (non-welded type), namely the Hat Soldier Pile, is the same system as the conventional Soldier Pile but with a different sheet pile as lagging. For this, the

use of the Hat type is recommended. The reason is because the Hat type 10H or 25H can be applied up to the required pile length so that the construction budget can be reduced in terms of the total wall weight and piling length (Table 1).

HAT + H Pile (combined by welding type)

The Hat with H-beam (combined by welding type), named Hat+H Pile, has higher stiffness than the Hat Soldier Pile system, because the Hat type and H-beam are integrated. Thus, even when the excavation depth is around 15 m, the Hat+H Pile can be applied and the H-beam size can be adjusted to a suitable stiffness. Moreover, total piling length can be shortened as it is a combined pile (Table 2).

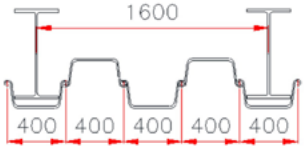
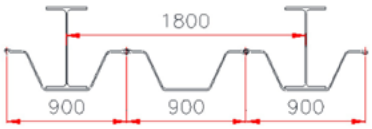
TYPE	U TYPE + SOLDIER PILE (NON-WELDED TYPE)	HAT TYPE + SOLDIER PILE (NON-WELDED TYPE)
Section		
Specification (example)	FSP IV + UB914x305x253 at 1.6m pitch	Hat 10H + UB914x305x289 at 1.8m pitch
Unit Weight	348.6 kg/m2 (1.00)	256.6 kg/m2 (0.74)
Stiffness	572,250 kNm2/m	588,000 kNm2/m
Installation	2 Piles Installation (Installed U-type and soldier pile separately)	2 Piles Installation (Installed Hat-type and soldier pile separately)
Applicability	For Temporary Works	For Temporary Works

Table 1: Comparison between Hat Soldier Pile with the conventional Soldier Pile.

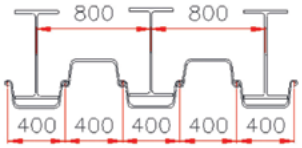
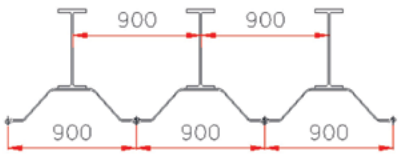
TYPE	U TYPE + SOLDIER PILE (NON-WELDED TYPE)	HAT + H COMBINED PILE (WELDED TYPE, 40% to 60% fillet welding)
Section		
Specification (example)	FSP IV + UB914x305x253 at 0.8m pitch	Hat 10H + HY900x250x14x19 at 0.9m pitch
Unit Weight	551.6 kg/m2 (1.0)	286.0 kg/m2 (0.52)
Stiffness	1,144,500 kNm2/m	1,182,930 kNm2/m
Installation	2 Piles Installation (Installed U-type and soldier pile separately)	1 Pile Installation (Installed Hat and H at the same time)
Applicability	For Temporary Works	For Temporary and Permanent Works

Table 2: Comparison between the Hat + H Pile and the conventional Soldier Pile.

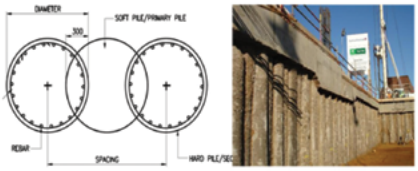
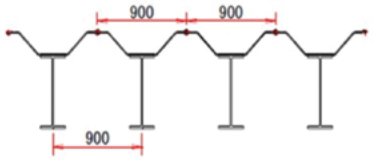
TYPE	SECANT BORED PILE	HAT + H COMBINED PILE
Outline		
Specification (example)	Φ=1000mm, c/c – 1200mm	HAT+H: 10H+HY750x250x12x22
Flexural Stiffness, EI	**8.02E+05 kNm²/m** (E_c = 2.8 x 10^7 kN/m²)	**8.47E+05 kNm²/m** (E_S = 2.1 x 10^8 kN/m²)
Installation	**Around 1 SBP per day** (concrete pile needs curing period)	▪ **3 to 4 piles per day by Jacking Press-in Method** (around 3m to 4m elongation) ▪ **7 to 8 piles per day by Vibratory Hammer Method**, if pile length is around 20m-24m (around 7m to 8m elongation)
Extraction	**Not possible** (but can be cut-off at least 2m-3m for future development)	**Possible** after construction (future development will not be affected)

Table 3: Reference for higher stiffness wall in Singapore.

CONSTRUCTION PRODUCTIVITY

In view of the COVID-19 situation, methods that can save manpower and construction time will have priority in Singapore. Thus, the Hat with H-beam solutions can contribute their advantages and can also help to reduce construction budgets. This is beneficial for owners as well as contractors.

As Hat solutions are methods using steel, the steel can be extracted after construction and used for future developments, without having to cut it near the surface along the length of the wall, as in the case of concrete (Figure 2). This can also contribute to shortening the work period.

HAT+H PILE WITH THE JACK-IN PRESS-IN METHOD

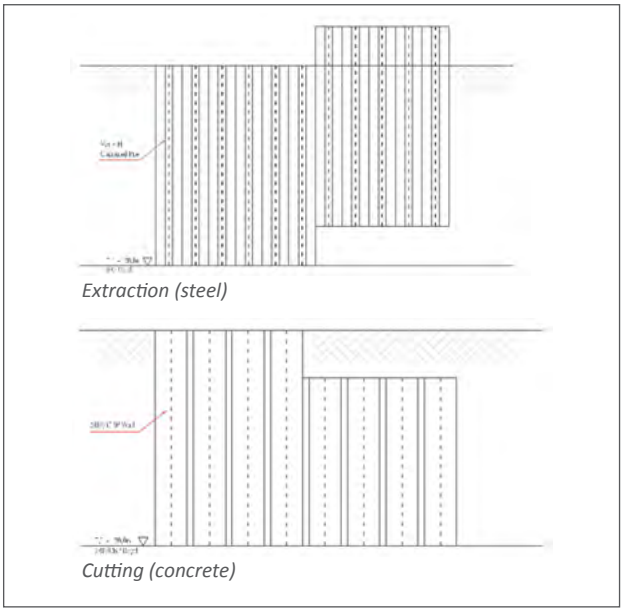
The Hat+H Pile can be installed using the jack-in press-in method, as it can satisfy the requirement of low noise and low vibration (Figure 3). This method was evaluated through an installation test conducted in Singapore.

APPLICATION OF ADVANCED HAT TYPE SOLUTIONS

Hat type with H-beam solutions are suitable for many types of applications, such as the following:

Entrance portion of an MRT station

For an underground MRT station, a diaphragm wall is usually used as the permanent main wall (Figure 4). Hat type with H-beam solutions are suitable for temporary walls, especially in areas where it is required to extract



Extraction (steel)

Cutting (concrete)

Figure 2: Procedure after temporary works.

them after construction, for future developments. The Hat+H combined pile has been installed in an MRT station portion, as a temporary wall, and then it was extracted after around three years (Picture 1).

Underground ERSS (temporary wall)

For an underground ERSS wall, like on a highway, the Hat series can be applied according to the required

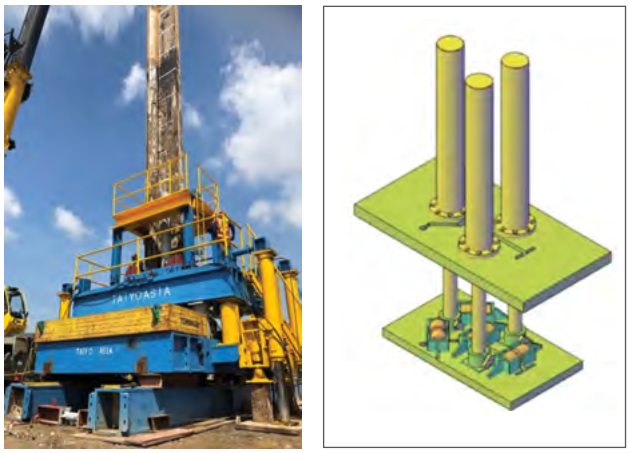


Figure 3: Installation of Hat+H piles using the jack-in press-in method.

stiffness. The most suitable solutions are the Hat type, in the shallow range, the Hat soldier pile in the middle deep range, and the Hat+H pile is in the deeper range (Figure 5).

Basement wall of a building

In some cases, Hat solutions can serve as the underground permanent ERSS wall (Picture 2).

Retaining wall

Hat solutions are also used as permanent retaining walls, thereby eliminating the need for temporary works (Figure 6 and Picture 3).

In this way, construction budgets can be optimised, as the Hat solutions can be used for both temporary and permanent structures.

SOLUTION FOR HARD SOIL LAYERS

For hard soil layers, before installing Hat type solutions, the pre-augering method can be used to loosen the soil, without digging. In Singapore, the common diameter for pre augering holes, using an excavator, is 400 mm to 500 mm, and if using a base machine, it is 600 mm to 800 mm (Picture 4).

CONCLUSION

Based on the required stiffness, it can be said that the use of Advanced Hat Solutions is the most suitable method in actual site conditions. They will satisfy the requirements through reducing wall weight and total piling length. As a result, there will be savings in the construction budget, especially in terms of manpower and construction time - which are very important considering the current COVID-19 situation. Thus, it can be concluded that Advanced Hat Solutions can improve construction productivity in Singapore.

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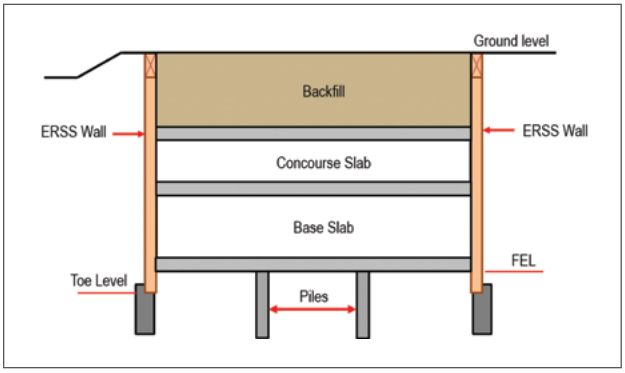


Figure 4: The entrance portion of the MRT station.

Picture 1: The Hat+H combined pile has been installed in an MRT station portion, as a temporary wall, and then it was extracted after around three years.

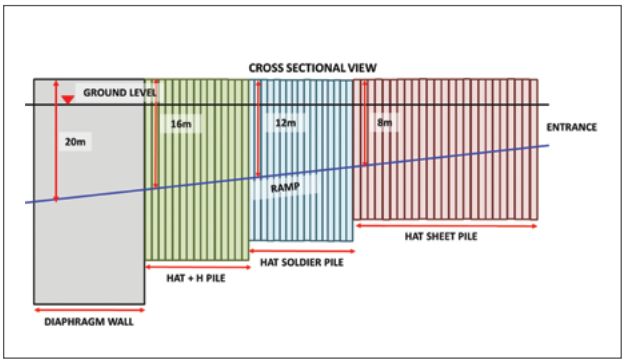


Figure 5: The Hat series can be can be used for an underground ERSS (temporary wall).

Picture 2: Application of Hat solutions as an underground permanent wall. Image: Giken ASIA.

(a) Conventional method

(b) Hat type solutions

Figure 6: Hat solutions can be used as permanent retaining wall.

Picture 3: Actual application of Hat solutions as permanent retaining wall.

Picture 4: Pre-augering in hard soil layers.

PUB BEGINS WORK ON DEVELOPING

A COASTAL-INLAND FLOOD MODEL

Supporting the efforts to address the challenges of extreme sea levels and inland floods.

PUB, Singapore's National Water Agency, has begun work on a state-of-the-art modelling system that is capable of simulating and evaluating both inland and coastal flood risks in tandem. This Coastal-Inland Flood Model will enable PUB to better assess the impact of climate change on Singapore's coastal areas. A consortium led by the National University of Singapore (NUS), with water management solutions provider Hydroinformatics Institute (H2i) as a partner, has been appointed to develop the model to support PUB's coastal protection efforts.

The purpose-built model will be developed based on Singapore's densely built-up and urbanised environment, and will enable holistic flood risk assessment by estimating the combined effects of extreme sea levels and inland floods caused by intense rainfall. It will comprise two independent models - a coastal model and an inland model - that can run separately or together to carry out flood risk analysis for different scenarios.

The model will aid PUB in the planning of coastal adaptation measures, evaluating the effectiveness of proposed coastal protection infrastructure, as well as in operations management. Development will take about four years and it will be continually updated and improved along with new climate data and developments in climate science. In the near term, the model will also be able to support the upcoming site-specific studies, starting with the City-East Coast and Jurong Island.

The coastal model will be equipped to simulate potential changes in nearshore waves and storm surge activities within the region under different climate change scenarios, while the inland model will be capable of simulating urban flooding caused by different sources, including heavy rainfall, and their interactions with sea levels. Advanced modelling techniques will be used to enhance the accuracy and speed in simulating rainfall-induced flows within Singapore's densely built-up water catchments.

PUB officers will work closely with the team from NUS and H2i during the entire project duration, to share their experience with existing modelling systems. This will also allow PUB to build new expertise in-house, to develop, test and validate coastal protection technologies and concepts. When completed, PUB will be equipped to operate the model and make future enhancements to it when needed.

The project team will be led by Professor Philip Liu, Distinguished Professor, Department of Civil and Environmental Engineering, NUS. Professor Liu, who is internationally recognised for his work on coastal engineering and wave modelling, has been instrumental in developing tsunami and coastal disaster resilience technology in Taiwan and the South China Sea region. H2i will bring to the table its rich expertise in hydrological and inland flow modelling and model development, having worked with PUB previously on its rainfall monitoring and predicting system which uses X-band radar technology.

Ms Hazel Khoo, Director of PUB's Coastal Protection Department, said, "As a small coastal city with many low-lying areas, Singapore is particularly susceptible to rising sea levels. Coupled with the upward trend of average annual rainfall and frequency of heavy rainfall that we have observed in recent years, the development of this model is timely as we embark on the monumental task of building coastal defences for Singapore. Through this project, we aim to enhance capabilities and deepen our expertise in modelling to support coastal protection efforts from now and into the future. Given the uncertainties in climate science, protecting our coastlines will always be a work-in-progress, but we aim to stay ahead of the curve. We are pleased to have both NUS and H2i on board and look forward to working with them on this important project".

Professor Liu added, "NUS is excited to be leading this consortium. I am confident that the synergistic pool of talent and resources from NUS, H2i and PUB will catalyse a collaborative advancement of Singapore's efforts to bolster coastal protection. In anticipating continued climate changes, the development of a Coastal-Inland Flood Model is timely and will help to safeguard both our coastlines and our collective future against severe weather and rising sea levels".

H2i's Director, Mr Martin Lechner, said, "H2i has, through our various projects, developed a depth and breadth of understanding of the impact that climate change could have on both lives and livelihoods in Singapore. We have already deployed our capabilities in areas like coastal monitoring and modelling and flood-risk management, and the development of the Coastal-Inland Flood Model builds on this. The combined expertise of our team, which includes renowned industry leaders like hydraulics specialist Professor Guus Stelling, will mean faster, more accurate and more visual water management insights. This will allow Singapore to better plan for climate change, and secure its own future".

PUB COMMENCES COASTAL PROTECTION

STUDY AT CITY-EAST COAST

First site-specific study is key to developing a flood resilient master plan to protect Singapore's south-eastern coastlines from sea-level rise.

PUB, Singapore's National Water Agency, will commence a site-specific study along Singapore's City-East Coast, looking into possible solutions to protect it from the threat of rising seas caused by climate change. This is the first of a series of planned studies for different parts of Singapore's coastline, which will be progressively carried out over the next few years and are a key plank in Singapore's long-term coastal protection plans.

The study covers 57.8 km of the coastline, across three areas - Changi, the East Coast-Marina stretch and part of the Greater Southern Waterfront district. This section of the coastline had been identified to be more vulnerable and critical, based on factors such as the potential impact of a flood event, criticality of assets (e.g. airports, economic and industrial districts) and opportunities to dovetail with upcoming developments.

The study will take around four years to complete, and will include work such as literature reviews to glean international best practices, collecting site data to support design works, formulating adaptation measures and pathways, and developing the designs of solutions to mitigate flood risks.

Ms Hazel Khoo, Director of PUB's Coastal Protection Department, said, "When PUB was appointed national coastal protection agency in April 2020, this study was earmarked as a significant milestone in our mission to prepare Singapore for the impacts of sea-level rise. But this is just the beginning - the real challenge is to develop solutions that are flexible and adaptive to climate change uncertainties, to safeguard our island and people from flooding risks while ensuring our coastlines remain liveable".

"This is also an opportunity for us to explore a combination of both engineering and nature-based solutions, with innovative designs, to better integrate with local development and land-use plans. This will allow us to potentially enhance the living environment and create new recreational spaces with multi-functional uses for the community like what was done at Marina Reservoir", she added.

Having divided Singapore's coastline into different segments, PUB will adopt a phased approach to progressively roll out studies and develop protection measures for the respective segments of the coastline. Studies to protect Jurong Island and the North-West coast, comprising Sungei Kadut and Lim Chu Kang, will commence later this year and in 2022, respectively.

The City-East Coast study will be undertaken by CPG Consultants Pte Ltd, a subsidiary of Singapore-based consultancy services, infrastructure and building management firm CPG Corporation. CPG was appointed, following an open tender exercise in 2020.

To augment its knowledge and capabilities in coastal protection and computer modelling, CPG will be partnering with Royal HaskoningDHV, a consultancy firm headquartered in the Netherlands, that specialises in coastal engineering, as well as with water management solutions provider Hydroinformatics Institute (H2i).

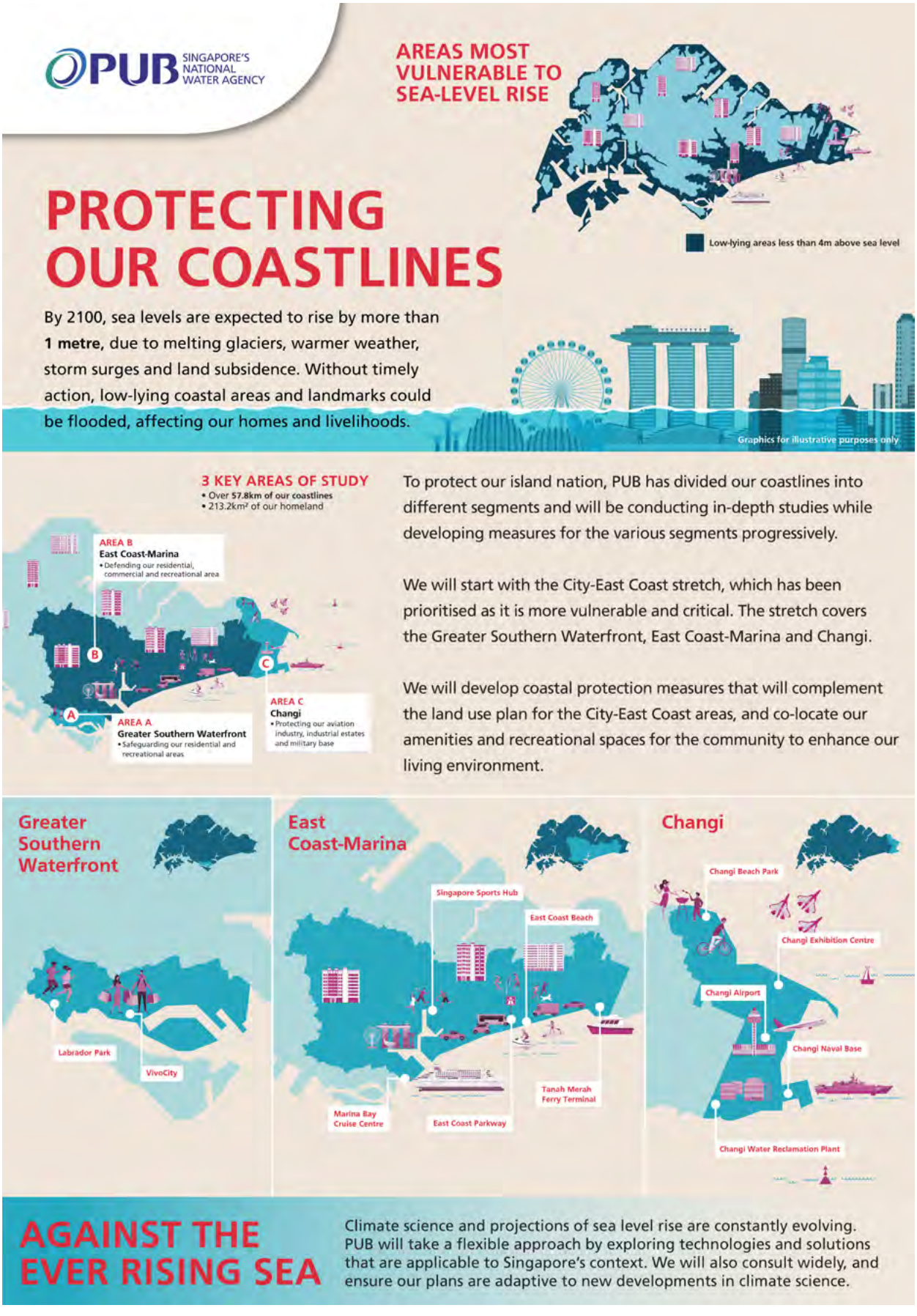
Building local expertise and engaging with stakeholders

To enhance its knowledge and expertise in coastal engineering, PUB has formed a Coastal Protection Expert Panel, comprising both local and international experts in the relevant fields. The panel will share international best practices and planning considerations, and will provide advice that will allow PUB to build new capabilities and aid in its overall planning efforts.

The panel is chaired by Professor Chan Eng Soon, Chief Executive Officer of the Technology Centre for Offshore and Marine, Singapore (TCOMS). Panel members include coastal engineering experts such as Professor Marcel Stive from the Netherlands, Professor Robert Dalrymple from the US, as well as Professor Robert Nicholls and Professor David Balmforth, both from the UK.

Said Prof Chan, "I am glad to have the opportunity to work with a team of eminent colleagues in this field - especially in guiding PUB as it embarks on the monumental task of protecting Singapore from flooding due to intense rainfall and rising sea levels. Our aim is to function as an independent advisory body to PUB's coastal protection efforts".

Besides consulting experts, PUB also intends to adopt a collaborative approach as it develops the strategies and solutions to protect Singapore's coastlines. The agency will work closely with the community and relevant stakeholders, including nature groups and businesses, to seek their feedback on the proposed coastal protection measures and explore opportunities to create a vibrant living environment in harmony with nature.



Scope of site-specific studies at Singapore's City-East Coast. Infographic: PUB, Singapore's National Water Agency.

A REDUCTION IN

OVERALL WASTE GENERATION IN 2020

Less waste sent to Semakau Landfill.

The National Environment Agency's (NEA) 2020 waste and recycling statistics have revealed that in 2020, waste generation and recyclables collection were impacted by the COVID-19 pandemic. Waste generated at office, commercial and industrial premises fell in tandem with the pause in non-essential economic activities during the Circuit Breaker as well as the reduction in the demand for goods and the restriction in the movement of people last year. There was also less waste recycled by the non-domestic sector. The aggregate recycling volumes were therefore lower.

About 5.88 million tonnes of solid waste were generated, which was 19% less than the 7.23 million tonnes generated in 2019. Waste generation is made up of the total waste disposed and the total waste recycled.

Of the waste amount generated in 2020, 3.04 million tonnes was recycled. Waste generation by the non-domestic and domestic sectors both saw a reduction in 2020 - from 5.37 million tonnes and 1.87 million tonnes, respectively, in 2019, to 4.12 million tonnes and 1.76 million tonnes, respectively, in 2020.

Non-domestic waste is waste collected from industries and commercial premises.

Domestic waste is waste collected from households and trade premises (e.g. shophouses, educational institutions, petrol stations, hawker centres and places of worship).

The recycling rate in the non-domestic sector fell to 68% in 2020 from 73% in 2019, while that in the domestic sector fell to 13%, from 17%. Overall, the recycling rate fell to 52% in 2020 from 59% in 2019.

The recycling rate is derived from the amount of waste recycled divided by the total of the amount of waste recycled and waste disposed of.

KEY FINDINGS AND OBSERVATIONS

In 2020, overall waste generated decreased for a fourth consecutive year, since 2017, resulting in less waste being sent to Semakau Landfill. The amount of waste recycled and disposed of, in 2020, fell by 28% and 5%, respectively, compared to 2019.

Households disposed of more packaging waste, as online shopping and home-delivered food gained market share during the Circuit Breaker. However, recyclables collections from the domestic sector were put on hold at the peak of the pandemic, in 2020, and restarted only gradually, from 3Q 2020. As the impact of COVID-19 gradually eases, the waste generation and recycling patterns of 2020 are unlikely to be repeated in 2021.

A DROP IN THE OVERALL RECYCLING RATE

The overall recycling rate decreased from 59% in 2019 to 52% in 2020. The recycling rates for each of the 14 waste streams were either consistent with those of 2019 or better, except for Paper/Cardboard waste. The drop in the overall recycling rate in 2020 is largely due to the substantially smaller amounts of Ferrous Metal scrap and Construction & Demolition (C&D) waste generated and recycled.

C&D waste and ferrous metal/non-ferrous metal together typically accounts for 60% of waste generated and waste recycled quantities.

Both of these waste streams have traditionally high recycling rates. C&D waste has been one of the largest waste streams in the last decade. The smaller amount of C&D waste generated in 2020 was due to the slowdown of the construction industry and particularly the halt in construction activities during the Circuit Breaker period.

Ferrous metals, another major waste stream, saw large falls in both the amount of waste generated and recycled. This was mainly due to the slowdown in industrial activities due to COVID-19 measures.

While the recycling rates for these two waste streams did not change and remained high, a drop in the quantities of these waste streams affected the overall recycling rates because they made up a significant portion of the waste mix.

A DROP IN WASTE GENERATION FOR PLASTIC AND FOOD WASTE

Plastic waste

Compared to 2019, the overall amount of plastic waste generated fell by about 7%. The overall recycling rate of plastic waste was 4% in 2020, similar to 2019.

The plastic waste generated in 2020 in the non-domestic sector fell to 463,000 tonnes compared to 504,000 tonnes in 2019. Less plastic waste was disposed of by industry due to the slowdown in activities during the Circuit Breaker.

For the domestic and trade sector, the amount of plastic waste generated fell from 426,000 tonnes in 2019 to 405,000 tonnes in 2020. Less plastic waste was disposed of at shophouses, places of worship and hawker centres. The amount of plastic recyclables collected under the National Recycling Programme (NRP) in 2020 was 2,300 tonnes compared to 2,800 tonnes in 2019. The Cash-for-Trash scheme and door-to-door activities were halted during the Circuit Breaker, which led to a drop in the collection of plastic recyclables.

Food waste
The overall amount of food waste generated in 2020 was 665,000 tonnes, which was 11% less than the 744,000 tonnes in 2019. There was a slight increase in the recycling rate for food waste from 18% in 2019 to 19% in 2020.

The amount of food waste generated in the non-domestic sector in 2020 was 223,000 tonnes compared to 258,000 tonnes in 2019. In the domestic sector, the amount of food waste generated in 2020 fell to 442,000 tonnes from 486,000 tonnes in 2019.

PAPER/CARDBOARD WASTE AS THE LARGEST WASTE STREAM

The amount of paper/cardboard waste generated increased by 13% from 1.01 million tonnes in 2019 to 1.14 million tonnes in 2020. Paper/cardboard waste was the largest waste stream in 2020. The overall recycling rate of paper/cardboard fell from 44% in 2019 to 38% in 2020. The drop in the recycling rate of paper also contributed to the lower overall recycling rate. Less paper recyclables were collected during the Circuit Breaker period when the Cash-for-Trash scheme, ad-hoc collection drives by schools and Residents' Committee centres and door-to-door recyclables collection programmes by the Public Waste Collectors (PWCs) were halted. The continued low overseas demand for paper recyclables and COVID-19-related trade restrictions also contributed to the low recycling rate of paper. More packaging waste from online shopping and home-delivered food being disposed of by households also led to higher paper/cardboard waste generation.

ACHIEVING THE NATIONAL GOALS

While the COVID-19 situation has disrupted 3R (Reduce, Reuse and Recycle) efforts, environmental sustainability remains important. Singapore's national goals are to achieve a 70% overall recycling rate and to reduce the amount of waste sent to Semakau Landfill by 30% per capita per day by 2030. Under the Singapore Green Plan 2030, this is being frontloaded to achieve a 20% reduction in waste-to-landfill per capita per day by 2026.

It will take a whole-of-nation effort to achieve Singapore's vision of a Zero Waste Nation. To this end, NEA will continue to engage businesses and consumers to be more sustainable. This will be achieved through the various campaigns and engagements, and waste reduction efforts to close the waste loop This is a long-term effort that requires the people as well as the private and public sectors to work together.

IMPROVING RESIDENTIAL RECYCLING IN THE US

Significant federal and corporate investment could improve the US curbside recycling rate to nearly 70% and deliver more than USD 30 billion in economic benefits and nearly 200,000 new jobs within 10 years, according to a new report released by The Recycling Partnership.

The report titled 'Paying it Forward: Investment in Recycling Will Pay Dividends' calls for a USD 17 billion investment over five years to completely transform the US residential recycling system, maximise its potential, and make it as accessible to all households as trash service. The investment, which would be applied to proven recycling solutions, will have an immediate positive impact including an economic benefit of USD 30.8 billion over 10 years (including wages, taxes, landfill savings, and the value of recyclables).

"Levelling up the current US residential recycling system will require collective collaboration from all parts of industry, all levels of government, investors, brands, and people. Now is time to take action. Corporations, federal, state, and local politicians are at the table and ready to deliver tangible change. People and the planet are demanding packaging that is both recyclable and has the means to be recycled, the US government is setting aggressive sustainability and greenhouse gas goals, and companies are making bold commitments around recycling and the circularity of packaging", said Mr Keefe Harrison, CEO, The Recycling Partnership.

The report's findings come at a pivotal time as corporations make aggressive commitments to use more recycled content, federal and state policy-makers signal increased recycling expectations, and the American people call on businesses and government alike for more sustainable choice.

For more than seven years, The Recycling Partnership has been working with communities to transform local recycling programmes.

According to The Recycling Partnership, while recycling has been a part of the American ethos for nearly 50 years, nearly half of the people still lack convenient, equitable access to recycling. The current system is not only fractured and underperforming, but it also fails to capture and return the volume of recycled materials required to truly support a circular economy, which is an economic system aimed at eliminating waste and reducing the use of natural resources.

The report calls for three one-time investments:

- USD 4 billion investment to accomplish equitable recycling for every U S household.
- USD 3 billion investment on new or upgraded material recovery facilities that would support domestic manufacturing.
- USD 4 billion investment to create residential recycling solutions for film and flexible plastics.

Furthermore, the report calls for an annual USD 1.2 billion investment for continual education and outreach strategies.

HELPING TO ACQUIRE SKILLS AS

PART OF LIFE-LONG LEARNING

US-based Project Management Institute (PMI) is said to be the world's leading professional association for a growing global community comprising millions of project professionals and change-makers worldwide.

Mr Ben Breen, Global Head of Construction and Managing Director, Asia Pacific, PMI, provides an overview of PMI's activities that are of significance to Singapore, in an interview with 'The Singapore Engineer'.

Mr Ben Breen

The Singapore Engineer' (TSE): Could you describe the objectives, activities and structure of PMI?

Mr Ben Breen (BB): As a leading authority on project management, PMI empowers people to make ideas a reality. Through global advocacy, networking, collaboration, research, and education, PMI prepares organisations and individuals at every stage of their career journey to work smarter, so they can drive success in a world of change.

There are more than 700,000 PMI members in over 200 countries and territories, in six continents.

At least one independently run chapter in each country represents PMI in that country. The chapters are not-for-profit entities and are governed by PMI's charter agreement.

In terms of composition of the membership, globally, our biggest vertical is the IT sector. This is followed by others like manufacturing, consulting, construction, oil & gas and so on. However, the PMI is essentially industry-agnostic and so it is quite broad in its overall outreach and includes members involved in any kind of project management activity, whether from the government or from any type of industry.

The Singapore Chapter has over 2,000 members, and most of them are also from the IT sector. We also have another 8,000 members from PMI Global in Singapore, and even more who are PMI-certified but are not active members.

TSE: How would you define 'project management'?

BB: I would say it is the implementation of a defined scope of work, over a defined period of time, to deliver a defined outcome.

TSE: What can project management skills bring in terms of optimising timelines, budgets etc?

BB: Overall, it is about improving the efficiency, reducing wastage, improving communications, and adopting technology, to achieve a better project outcome.

In terms of efficiency, McKinsey & Company has said that USD 3.7 trillion will need to be invested globally per year on projects to keep pace with projected GDP growth. Let us say we can have an impact of about 1% on efficiency in construction, then that is USD 37 billion a year saved.

Specifically for the construction industry, what we found was that for every USD 1 billion spent, USD 127 million is wasted. A 1% improvement sounds humble but it is a very big goal that we are trying to achieve, but we think with our global partners and our reach, we could definitely have a significant impact. So that is the aim.

TSE: Could you elaborate on PMI's educational programmes and their relevance to a post-pandemic 'new normal'?

BB: We have programmes that try to respond to changing situations and suit all levels of capabilities.

We have seen how the pandemic is creating a demand for new skills, when more are working from home. While we are working remotely, a lot of us are dealing with people from all around the world. The technical skills are always important, but now we are witnessing what we call 'power skills' that will stay with us for a long time as well. These are essentially 'soft skills', but we think the word 'soft' does not do justice to the impact that these skills have on delivering projects.

Power skills relate more to communication abilities as well as collaboration abilities and empathy for colleagues and customers, amongst other things. They are about improving one's listening skills and actually taking the time to understand another person's point of view.

With regard to upgrading capability levels, I wish to mention the example of the many 'accidental' project managers there are today. While they are not formally trained as project managers, they are running projects for their companies and we have had a lot of companies reaching out to us, especially from the start-up space, because their project managers do not have any formal training. These companies would like PMI to provide their employees with entry-level knowledge and help them create a suitable programme to map out the career progression of employees and improve their knowledge of project management, and ultimately, successfully deliver projects.

TSE: What are some of the PMI programmes and certifications?

BB: PMI programmes are designed to address the need for life-long learning, especially for mid-career executives, and the acquisition of transferrable skills. Also, as I mentioned earlier, we try to have programmes that suit all levels of capabilities. We have PM Ready which is a very basic introduction to project management to help professionals understand the stakeholders, understand how to do a clear communication plan, and how to achieve defined outcomes. Without any real background in project management, you can do a PM Ready course.

Or, if you have just come out of university, from a related field of study like engineering, then you have the Certified Associate in Project Management (CAPM) certification. This is an entry-level certification for new graduates that are joining the industrial world and it gives them a strong foundation, based on PMI's Project Management Body of Knowledge (PMBOK). They will start to learn the basics of project management and it is a stepping stone to the next PMI certification.

And we have the PMP (Project Management Professional) certification which is our most popular certification. It covers all industries. We now have about 1.7 million people who have been certified as PMPs.

The CAPM and the PMP are both registered in Singapore and persons signing up for the relevant courses conducted by authorised training partners are eligible for government subsidies through SkillsFuture.

All our certifications originate from US but we have a Global Accreditation Center which is a globally recognised and independent academic accreditation body that certifies the programmes we run. So I would say that our course offerings are designed based on a set of robust criteria.

TSE: Coming specifically to the construction industry, what is PMI's approach?

BB: We are now focusing more on engineering and construction, and one thing that we found was that while PMP is a great foundation, and we do have the construction extension to the PMBOK, our members have asked if we can create something specific to construction. Therefore we have formed an expert panel, with companies like Jacobs Engineering Group, BHP and Saudi Aramco, to develop a course specific to construction.

Also, we surveyed around 40,000 holders of PMP certification who are in construction, to find out what was crucial to them. The pain points were things like projects finishing late or over-budget, or the problems due to the changes that had to be made to the original design - all the typical things when you run a project.

Communication was the 'Number One' cause for a lot of problems down the line, so that was the first course we started developing to cover things like setting up an effective communication plan, understanding the stakeholders, active listening, and acquiring other power skills.

This is part of the seven different courses we are creating. It may grow later on but this year, we are doing these seven, and at the end of that you can be certified to show that you have acquired the skills related to the construction industry. That is the new initiative that we will be launching soon.

TSE: Any other information that you would like to provide?

BB: A key challenge for project management is the general lack of consistent standards around the world, across different geographies and industries. For project managers to be fully effective, they need to speak the 'same language', by following a similar set of processes and systems. That is why PMI has pushed for project management to become a ubiquitous function, worldwide, and will continue to do so.

Project Management Institute

Building on a proud legacy dating back to 1969, PMI is a 'for-purpose' organisation working in nearly every country around the world to advance careers, strengthen organisational success, and enable change-makers with new skills and ways of working to maximise their impact. PMI offerings include globally recognised standards, certifications, online courses, thought leadership, tools, digital publications, and communities.

Top 50 most influential projects of the last 50 years

In early October 2019, Project Management Institute (PMI) announced the top 50 notable and influential projects of the past 50 years in its list of Most Influential Projects. This is a first-of-its-kind ranking for PMI.

The top ranked project is the creation of the World Wide Web. Other honorees include iconic achievements such as the Apollo 11 mission, the Boeing 747 airplane, and the Human Genome Project, as well as under-the-radar triumphs like the Svalbard Global Seed Vault in Norway and China's Tengger Desert Solar Park.

The honorees were chosen from among more than 1,000 high-impact projects identified by 400 leaders in the global project management community, including PMI chapter leaders and members, as well as academics and industry experts. The final selections, made by PMI's thought-leadership team, provide an inspirational reflection on what project work has enabled and the central role it has played in creating our present.

PROTECTING IMPORTANT INFRASTRUCTURE

IN BOSNIA-HERZEGOVINA

High quality waterproofing membranes were installed.

The Babina Rijeka viaduct, located in Zenica, Bosnia-Herzegovina.

Polyglass SpA, a part of the Mapei Group, has been operating in the Bosnian market for more than 15 years. The company's modified polymer-based bituminous waterproofing membranes are being specified by the country's installation companies and professionals working in the waterproofing sector.

Several road decks have been protected over the last few years with Polyglass membranes, particularly POLYBOND HP.

Strategic infrastructures for the country's growth

The 5C Pan-European Corridor is a strategic project for the entire Eastern Europe and, once completed, it will link Budapest to the Croatian port of Ploče on the Adriatic coast, passing through the whole of Bosnia-Herzegovina and the Bosnian capital, Sarajevo, along the way. The new highway (Autoput A1 – E73) is of primary importance for a country characterised by mountain ranges, narrow valleys, numerous rivers and small villages dotted all around the country, and still not very well connected to one another. Modern communications infrastructure, therefore, is an important driver behind the economic and social growth of this country. The bypass around Zenica, approximately 60 km from Sarajevo, was one of the most challenging stretches from an engineering and construction point of view. Along just 8 km of road, two tunnels, four viaducts and a bridge had to be built.

The Babina Reijka viaduct, which was constructed on the Donja Gračanica-Drivuša section / Klopče-Donja Gračanica sub-section of the motorway, crosses the Babina valley and is the highest deck ever built until now along the 5C Corridor - it is 120 m above the River Babina.

The viaduct is made up of two parallel buildings. The left building is 389.2 m long and the right building is 380.74 m long. Each building has three spans supported by one pillar at each end and two central pillars. The height of the two central pillars range between 60 m and 80 m, with a central span of around 165 m. The pillars are anchored in 18 m-deep, circular, reinforced concrete wells measuring 12 m in diameter at the base,

Waterproofing the road surfaces with Polyglass solutions.

while their top ends are elastically constrained to the superstructure. The superstructure is made up of a 6.5 m wide reinforced concrete caisson, prestressed in a longitudinal direction, with a box-like section that can be varied in height. The width of the upper part of the deck is 13.76 m.

The Pehare viaduct was also built along the same stretch of motorway and is also made up of two separate structures. The building on the left is 429.95 m long and the one on the right is 420 m long. The size and position of the pillars were dictated by the geological characteristics of the soil and the local road network. In fact, a part of the geological landscape coincides with a particularly unstable area subject to landslides, while the other part does not suffer from any stability problems. The width of the upper part of the deck is 11.70 m, not including the concrete safety barrier.

A membrane designed for bridges and viaducts

Polyglass SpA took part in the construction of this important infrastructure, by supplying the 5 mm plastomeric bituminous membrane POLYBOND HP, a product specifically designed for bridges and viaducts and compliant with EN 14695 Standard (Reinforced bitumen sheets for waterproofing of concrete bridge decks and other trafficked areas of concrete).

The concrete deck was initially treated with MAPEFLOOR I 914, a two-component, epoxy protective coating for concrete, that was broadcast with quartz sand. The product is manufactured and was supplied by Mapei. The next step was to apply the membrane using the traditional torching technique. The special bituminous compound formulation, combined with the optimum mechanical parameters offered by the internal reinforcement consisting of spun-bonded stabilised polyester, make the product suitable for hot asphalt application using pavers and rollers.

POLYBOND HP and MAPEFLOOR I 914, were approved by the Italian Federal Ministry of Spatial Planning (document number: UPI/03-19-2-75/20) before the installation.

During the application, several pullout tests were carried out on site with good results regarding the adhesion of the product on the concrete load-bearing structure.

This editorial feature is based on an article from Realtà MAPEI INTERNATIONAL Issue 85

PROJECT DATA

Babina Rijeka and Pehare viaducts, Zenica (Bosnia Herzegovina)

Period of construction
2016 to 2020

Client
JP Autoceste FBiH

Main contractors
Euro-asfalt and Strabag AG JV

Supervision
JV Egis International
Ipsa Institut d.o.o.

INTERVENTION BY POLYGLASS

Period of the intervention
July to September 2020

Contribution by Polyglass
Supply of waterproofing membranes

Polyglass distributor
KIMEEL d.o.o.

Polyglass products used
Waterproofing membrane - POLYBOND HP P

Mapei products used
Treating the concrete deck - MAPEFLOOR I-914

Waterproofing contractor
Bersia d.o.o.

Website for further information
www.polyglass.com
www.mapei.com

KUWAIT'S FIRST IN-SITU

CANTILEVER BRIDGE

An all-in-one formwork solution was provided for the project.

Nawaseeb Road is an important element of Kuwait's transport infrastructure. The bridge project is a special case for two reasons: Not only is it currently Kuwait's first cantilever bridge project, but it is also the first time a bridge is cast in-situ.

The Nawaseeb Road in Kuwait forms an important part of the country's national infrastructure, providing a strategic, logistical corridor to neighbouring Saudi Arabia.

In delivering a solution for the highway bridge section, Doka has helped provide Kuwait with a landmark achievement - its first, in-situ cantilever bridge. Doka is a world leader in providing innovative formwork, solutions and services in all areas of construction. The company supplied an all-in-one solution, which included 3D planning, Cantilever Forming Travellers (CFTs), and formwork instructors' support to ensure a smooth, fast and cost-effective process.

Section RA217 of Nawaseeb Road, also known as Route 40, is one of Kuwait's most important infrastructure and transport projects and is part of the Kuwait Development Plan 2015-2020. Covering a stretch of 37 km, the development includes the reconstruction and expansion of the highway into a six-lane dual carriageway (three in each direction) with nine interchanges and three bridges, with the ultimate aim of improving access and safety on the roads, by eliminating U-turns and replacing them with roundabouts at all interchanges.

Doka was required to find a casting solution for the two main bridges, including pier-to-pier spans, which at their longest measures 110 m each and has a total combined length of 940 m, as well as one ramp bridge with a maximum span of 95 m between piers and measuring 893 m in length. A total of 300 casting sections, weighing up to 250 tons, were required for the project.

The Doka Cantilever Forming Traveller offers formwork and shoring from a single source. The ideal balance between support structure and formwork enables the construction of 470 m of the main bridge.

All-in-one solution

Doka used its internal, digital planning tools to design the right solution for the project, which included detailed designs that helped accelerate the planning process, while providing the client with an overall visual representation of the project. In addition, a 3D model was developed with DokaCAD for Revit to give more precise visualisation of the CFT system.

In total, six Doka CFTs, supplemented with approximately 2,000 m² of Large-area formwork Top 50 were used on both the main bridges and ramp bridge at Interchange

five. In total, approximately 825 tons of Doka material were used during this process.

Using 3D modelling techniques, Doka provided an accurate rendering of the CFT in action, prior to erection on site.

Minimal parts kept erection times to a minimum

Using Doka's CFT, the client was reassured by its precision and how its modular components enabled it to adapt flexibly and quickly to the bridges' varying geometrics. Thanks to the system's ergonomics and a small number of separate parts, the construction process was optimised, meaning a shorter construction schedule and reduced cost.

Adjustments made easy with hydraulic cylinder

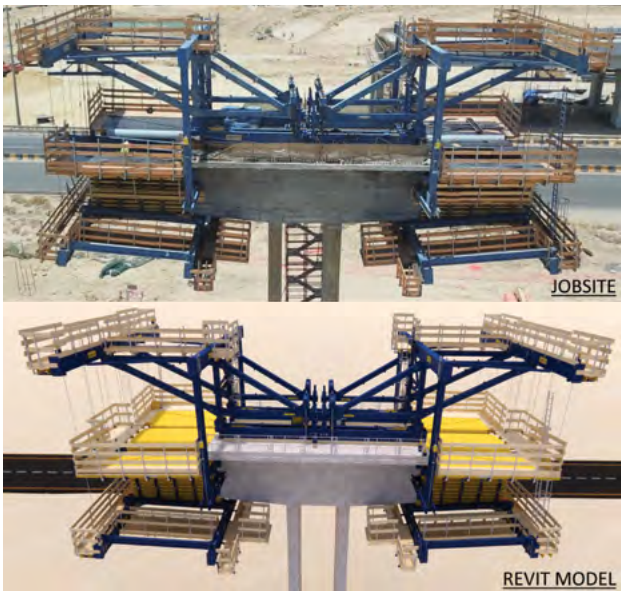
Due to the limited space available on-site, hydraulic cylinders were used to strip the inner wall formwork. As the bridge deck geometry was required to be reduced at every casting step, as part of the agreed planning process, the formwork and components of the CFT had to be continuously adjusted. Various hydraulic cylinders and other integrated functions allowed for an easy adjustment process without using chain hoists or additional workforce.

Safety first through slide bearings

The CFT uses special slide bearings to allow safe and controllable shunting while preventing unwanted movement along its longitudinal gradients. Thanks to this feature, the construction team's safety was ensured in every phase of the project through fully-enclosed working platforms and an integrated ladder system at all levels.

Formwork for pier heads and temporary supporting towers

Doka also provided the formwork for the pier heads, which measured up to 20 m in height, 12 m in length, and was erected onto Load-bearing towers d3 with Large-area formwork Top 50.



Using 3D modelling techniques, Doka provided an accurate rendering of the CFT in action, prior to erection on site.

Due to the restrictions imposed by existing gas pipelines, the piers' location was pre-defined, resulting in different spans, which led to an imbalance in construction delivery. To support the bridge deck during this phase, Doka UniKit towers were used to safely transfer up to a maximum force of 3,800 kN, to restore balance to the process and ensure the safe delivery of the piers.

Doka Formwork Instructors supported on-site delivery by ensuring that the formwork was used effectively and that the operations ran smoothly from start to finish.

All images by Doka

PROJECT DATA

Project
RA217 Nawaseeb Road

Location
Kuwait City, Kuwait

Building type
In-situ concrete bridge project using the cantilever method

Length of the main bridge
470 m

Span of the main bridge
110 m

Number of casting steps
84

Length of the ramp bridge
893 m

Span of the ramp bridge
95 m

Number of casting steps
132

Client
Ministry of Public Works (MPW)

Main Contractor
Freysinnet

Start of formwork operation
January 2020

End of formwork operation
February 2021

Contribution by Doka

Products provided
Cantilever Formwork Travellers (CFTs)
Large-area formwork Top 50
Load-bearing tower d3
Load-bearing system Doka UniKit

Services provided
3D planning with DokaCAD for Revit
Technical project support
Formwork instructors

FULLY REDESIGNED

MRT ROTATING TELEHANDLERS FROM MANITOU

To bring clarity to its range of rotating telehandlers, the Manitou Group has decided to give its two ranges new names - VISION and VISION+.

Also, two new machines, the MRT 1645 and MRT 1845 models, have been added to the VISION range.

With 500 kg (1,100 lbs) of additional load capacity compared to their predecessors, these two products offer a lifting height of 16 m (52 ft 5 in) and 18 m (59 ft 1 in), respectively, for a load of 4.5 tons (9,900 lbs). They are also equipped with a new Stage V engine, producing power of 75 hp and 116 hp, respectively.

The VISION range offers a wide selection of 14 models with heights ranging from 16 m (52 ft 5 in) to 25 m (82 ft), for a load capacity of up to 4.5 tons (9,900 lbs).

The MRT 2260 is a new model within the VISION+ range of rotating telehandlers from Manitou.

The highest capacities are grouped together in the VISION+ range, which features 12 new models. The range has been completely revamped with six new products - MRT 2260, MRT 2660, MRT 3570 (also available in an electronic suspension version), MRT 2570 and MRT 3060.

This high-capacity equipment range meets the requirements of customers who want higher performance on construction sites.

With models offering a lifting height of 22 m (72 ft 9 in) to 35 m (114 ft 8 in) and a much improved capacity of up to 7 tons (15,400 lbs), this range is ideal for the installation of structural steelwork, renovation of buildings and even demolition.

These two ranges are connected as standard, in order to optimise maintenance, increase the machine's operating hours and therefore reduce the total cost of ownership for the user.

The VISION and VISION+ ranges are now available worldwide and will be delivered to the dealer network, to rentals and to key accounts by September 2021.

MRT-specific attachments

New attachments, designed by the Manitou Attachment Competence Center (ACC) based in Italy, accompany the launch of these two ranges. Two CAF 1030 (6 tons / 13,200 lbs and 7 tons / 15,400 lbs) and CAF 1080 (7 tons / 15,400 lbs) floating fork carriages will benefit users who need to handle pallets or big-bags with optimum visibility. They are lighter and more robust, and are fitted with a fork locking system.

The performance of winches, jibs and cranes is enhanced with a winch equipped with a new hydraulic motor suited to the new MRTs. With a capacity ranging from 600 kg (1,300 lbs) to 2 tons (4,400 lbs), they meet the requirements of the new MRT range. A new 100% aluminum platform is now available across the whole VISION+ range. Weighing just 180 kg (396 lbs), for a loading capacity of 365 kg (805 lbs), the PSE 4200/365 is lighter than the previous range, allowing a greater outreach. It also features easy opening. These new attachments have been designed based on feedback from customers, in order to help them optimise their operations.

Innovative equipment for increased productivity

The VISION name was also chosen to convey the idea of in-cab visibility. To further increase visibility, a reinforced gridless roof, certified to ROPS/FOPS level 2, is available as an option, for closely monitoring loading operations at height. Present on all VISION and VISION+ models, the pressurised cab guarantees a healthy working environment for the operator, and additional sound insulation for greater comfort.

Another innovation presented by the group is a new optional driving remote control for controlling the machine from the basket or when the operator is outside the machine. As a result, it is possible to move it safely without having to return to the driver's cab, saving precious time on site.

ADVANCED TECHNOLOGY AND NEW DESIGNS

FOR THE CAT 815 SOIL COMPACTOR

The new Cat 815 Soil Compactor features technology upgrades to help increase productivity and efficiency, so more area is compacted in less time on large earthworks projects. New machine designs and revised service groupings combine to cut maintenance costs. With all components relocated from the cab roof to lower overall transport height, the redesigned operator's cab upgrades the steering and climate controls to elevate comfort.

The Cat 815 is built for high-speed, high quality soil compaction with its four 39 in (991 mm) wide steel drums. Drum design boasts a chevron pattern to the tamping tips, delivering high ground pressure and compaction, good traction and a smooth ride. A symmetrical tip pattern offers equal compaction effort in both forward and reverse, and the special tamper design reduces material fluffing. Adjustable cleaner bars eliminate material carryover regardless of rolling direction to maximise compaction efficiency.

Technology increases productivity

With the new 815 Soil Compactor, Cat Compact GPS mapping is now offered from the factory to provide visibility to compacted areas as well as cut and fill data. These new technologies allow companies to meet compaction targets quickly, uniformly and in fewer passes, with the 815, saving on fuel and the costs associated with rework.

Operators are kept informed of compaction progress with Cat Compaction Control with Machine Drive Power (MDP). This energy-based measurement system correlates compaction with rolling resistance to indicate soil stiffness, improving compaction efficiency. Real-time machine performance and operating data captured by the Vital Information Management System (VIMS) are conveniently monitored on the large, in-cab 3G touchscreen display. Accessed online via the VisionLink interface, Cat Link technology captures operating data such as machine location, hours, fuel consumption, idle time, events and diagnostic codes, to improve fleet management efficiency.

Advancing operator productivity

The compactor's redesigned cab delivers greater comfort and easier control for higher operator productivity. Upgrades to the single Cat STIC system allow for shorter, faster cycles to reduce operator fatigue and increase efficiency. The STIC system combines steering, gear selection and other functions into a single lever. Only small side-to-side inputs are required to steer the new 815, and gear changes are effortlessly fingertip-controlled.

The cab sits on isolation mounts and features a new Premium Plus seat with leather finish, forced air heating and cooling, two-way thigh adjustment, power lumbar and back bolster adjustment, and dynamic end

The new Cat 815 Soil Compactor is built for high speed, high quality soil compaction.

dampening, for total comfort throughout the workday. A flip-up armrest affords easier ingress/egress to the cab.

Pressurised to keep debris out, the cab features an automatic climate control system that maintains the operator's preferred temperature settings. Its sealed design lowers interior sound levels to improve operator comfort. The standard rearview camera is conveniently visible on the in-cab display to improve operator visibility when compacting in reverse.

Lower maintenance costs

The new 815 soil compactor features improved airflow technology to reduce cleaning and maintenance. A new radial air filter delivers three times the life of the previous design, and operators are alerted to airflow blockages, by an electronic air inlet restriction indicator.

The compactor's electronics bay is located inside the updated cab to improve servicing ease in a climate-controlled environment. Sight gauges for the coolant, transmission oil and hydraulic system provide quick inspection with reduced contamination risk. Grouped hydraulic oil, fuel cooler and condenser service points, along with centralised grease points, help to further minimise maintenance time. Access to emergency shutdown, battery disconnect and jump start are quickly and conveniently obtained from ground level.

Heavy-duty main structures are built to be rebuilt, offering multiple life cycles to lower total cost of ownership for the new 815. Heat-treated and direct-hardened, the adjustable cleaner bar tips deliver increased wear life with lower operating costs. The durable tamping tips deliver a long life and are replaceable.

Smooth power

The new Cat 815 Soil Compactor is powered by the field-proven Cat C7.1 engine designed for maximum fuel economy, reliable performance and increased power density.

SUSTAINABILITY THE KEY DRIVER OF CONVERSATIONS

AT IES CHARLES RUDD DISTINGUISHED PUBLIC LECTURES 2021

On 14 May 2021, the IES Charles Rudd Distinguished Public Lecture was held at the Singapore University of Technology and Design (SUTD) Auditorium. A hybrid event, it was attended by some 50 guests physically, and viewed online by more than 1,700 participants from Singapore and around the world.

Jointly organised with SUTD, the Lecture focused on sustainability and its impact on our future lives. Its aim was to drive greater understanding and action in building a green and liveable home, and highlight the challenges and opportunities in engineering – a key enabler of a sustainable future.

The Lecture was also held in commemoration of the UNESCO World Engineering Day for Sustainable Development.

Relating to the theme, Minister for Sustainability and the Environment Grace Fu spoke about the effect of climate change on Singapore, the tradeoffs and issues the nation faces in its decarbonisation journey, as well as the solutions Singapore is pursuing to overcome these challenges, in her keynote address.

Mr Manohar Khiatani from CapitaLand Group speaks to participants about driving sustainability in the built environment.

She noted that engineers would play an important role in the journey to achieve the targets set under the Singapore Green Plan 2030.

The invited speakers then took the podium to share their insight on sustainability in the local and global context. Each an eminent engineering expert and thought leader in their fields, the speakers were: Prof Lui Pao Chuen, Temasek Defence Professor; Dr Bicky Bhangu, President, South East Asia, Pacific & South

Prof Seeram (third from left) leads the rest of the speakers and panellists during the panel discussion. The rest of the panel include (left to right): Mr Benedict Chia, Dr Bicky Bhangu, Prof Lui Pao Chuen, Mr Calvin Chung, and Er. Goh Chee Tiong.

Korea, Rolls-Royce; Mr Benedict Chia, Director (Strategic Issues), National Climate Change Secretariat, Strategy Group, Prime Minister's Office; Mr Manohar Khiatani, Senior Executive Director, CapitaLand Group; and Prof Seeram Ramakrishna, Chairman of both the NUS Circular Economy Taskforce and the IES Sustainable Manufacturing Technical Committee.

Joining the speakers for the panel discussion on sustainability driving the future of engineering, jobs, economy and life were: Mr Calvin Chung, Chief Environmental Officer, JTC Corporation; and Er. Goh Chee Tiong, Chief Engineer/ Deputy Director, Carbon Mitigation Division, NEA.

They outlined the progress made in areas such as increasing food production, enhancing energy efficiency, and developing greener transportation, and discussed potential growth areas for individuals, companies, and nations alike.

The four-hour webinar concluded with a lively discussion between the panellists and the online audience, whose questions were picked out by Prof Seeram, who moderated the discussion.

IES offers its deepest appreciation to SUTD for co-organising the Lecture, as well as to all sponsors and supporting partners for their assistance in ensuring the event was held in a safe, smooth, and sustainable manner.

Wong Yui Cheong conferred the IES Lifetime Engineering Achievement Award 2021

At the Lecture, Ms Grace Fu, who was also the guest-of-honour, presented the IES Lifetime Engineering Achievement Award 2021 to Mr Wong Yui Cheong.

The award is the highest honour accorded to an engineering leader in recognition of lifetime accomplishments that have made profound impact on the engineering discipline, industry and community and for bringing international honours to Singapore.

In an illustrious career spanning over 40 years, Mr Wong has made distinctive contributions to the local built environment as an exceptional design engineer, project manager, consulting engineer, real estate developer and educator.

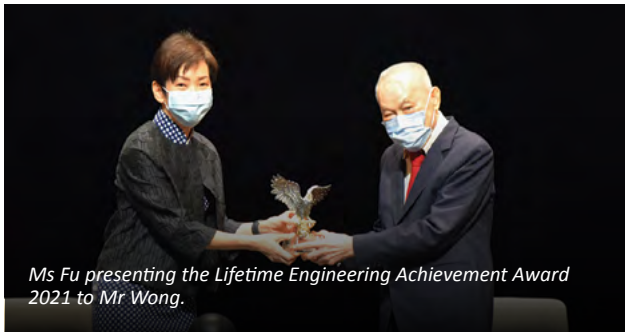
He was involved in several iconic and important buildings in Singapore, such as the DBS Building, Plaza Singapura, Pandan Valley Condominium, and Raffles City complex. He also left his mark on design engineering internationally, through notable projects such as the waterfront landmark structures in Merseyside, England and Malayan Flour Mill in Lumut, Malaysia.

After retiring from business in 1999, he took up an adjunct professor role in construction project management, contract administration and risk management for the Master of Science (International Construction Management) programme at NTU.

He also made a generous SGD 1 million donation to IES that led to the setting up of the IES-YC Wong Project Management Scholarship Fund to support post-graduate students in carrying out research in project management.

Furthermore, he provided engineering consultancy services to the structural design of the original IES building for a token fee of one dollar, and donated SGD 20,000 to the new IES Green Building fund. Mr Wong has also made valuable contributions to IES as a Council Member and Chairman of the Civil and Structural Engineering Technical Committee.

"I am very honoured to receive this award. As we move into a new era, global concerns such as climate change and future pandemics are critical issues that will require engineers to solve. It is my hope that the younger generation will join the ranks of engineers to push the boundaries of engineering and create an even greater future for Singapore," said Mr Wong.



Ms Fu presenting the Lifetime Engineering Achievement Award 2021 to Mr Wong.

(From left) IES President Dr Richard Kwok, Ms Fu, Mr Wong, Immediate Past President and Awards Committee Chairman Prof Yeoh Lean Weng, and Deputy President Dalson Chung take a group photo on stage.

ER. ONG SEE HO

FORMER IES VICE PRESIDENT AND COUNCIL MEMBER

Er. Ong See Ho FIES, FIStructE, who was Vice President of IES from 2011 to 2014 and from 2016 to 2020, passed away peacefully on 10 May 2021. He was 68.

A member of IES since 1978, Er. Ong was instrumental in forming the Engineering Accreditation Board (EAB) in 2002, as well as getting it admitted as a full signatory of the Washington Accord in 2006. The EAB, which he chaired until 2018, represents IES as a body to accredit undergraduate engineering degree programmes that are delivered and awarded in Singapore. This allows engineering degrees awarded here to be recognised by other Washington Accord signatories.

Er. Ong also helped set up the Chartered Engineer programme in 2013 to provide professional recognition to engineers across all sectors, as a validation of competence and expertise, especially in disciplines that do not require registration as Professional Engineers. He chaired its Board from 2015 to 2020.

Apart from these initiatives, Er. Ong helped guide the activities of the various committees that he held leadership positions in. These include the APEC Engineer/IntPE Monitoring Committee, Engineering Expert Panel, IES-ACES Joint Registry Monitoring Committee, Qualification & Membership Committee, and the Smart Nation Cluster.

For his significant efforts towards developing the engineering community, he was conferred fellowship in IES and IStructE. He also received the Public Administration Medal (Silver) in 2004 for his contributions to the Building and Construction Authority, and was similarly honoured with the NUS

Distinguished Alumni Award in 2012 and Honorary Fellowship in the ASEAN Federation of Engineering Organisations in 2015.

His tireless efforts and exemplary service at IES are an inspiration to all.

The President, Council and Secretariat are deeply saddened by this news and express their sincere condolences to his family.

THE HEART & VOICE OF ENGINEERS

IES Membership

1) Professional Development

- Eligible for Chartered Engineers Certification Application (subject to registration criteria and conditions)
- Enjoy preferential rates for IES conferences, seminars and workshops
- Enjoy 10% to 15% discount for IES Academy Courses (T&Cs apply)

2) International Affiliations

- Interaction with overseas engineering institutions in joint programmes

3) Networking

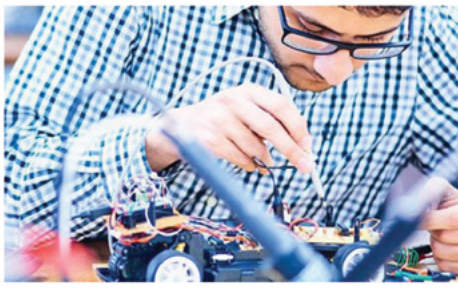
- Exclusive FREE Members' Night (T&Cs apply)
- Enjoy preferential rates for networking activities
- Join our Sports Interest Groups
- Join our Social Events

4) Communication

- Enjoy free subscription of IES weekly e-Newsletter
- Free monthly e-zine – The Singapore Engineer
- Free Annual IES Directory containing the business contacts of all members
- Get the latest updates on government regulations and the activities of allied institutions

5) Others

- Enjoy special rate for IES professional Indemnity Insurance Schemes
- Enjoy exclusive merchant benefits
- Free parking in IES premises
- Get a 5% discount off your membership subscription when you pay by GIRO (T&Cs apply)



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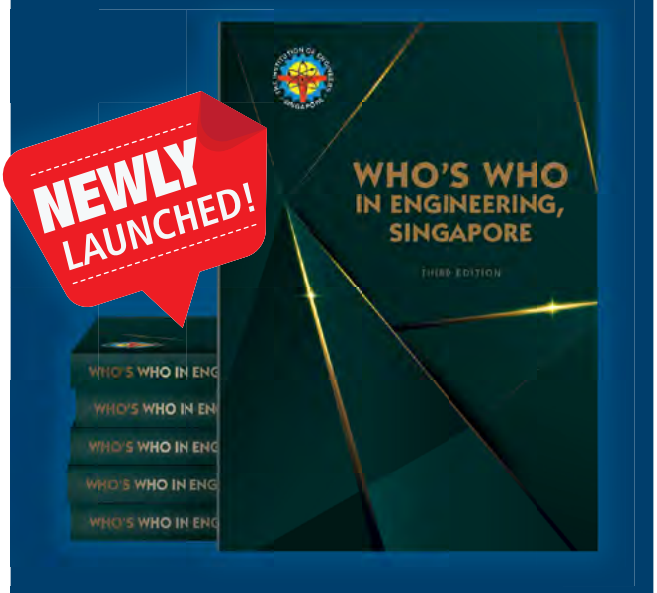

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