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COVER STORY:

Ensuring infrastructure resilience to overcome man-made and natural disasters

PLUS

DESIGN AND ENGINEERING SAFETY: Four Professional Engineers conferred BCA Design and Engineering Safety Award 2020

CIVIL & STRUCTURAL ENGINEERING: The world's first 15-cell caterpillar-shaped cofferdam design for Tuen Mun - Chek Lap Kok Link in Hong Kong

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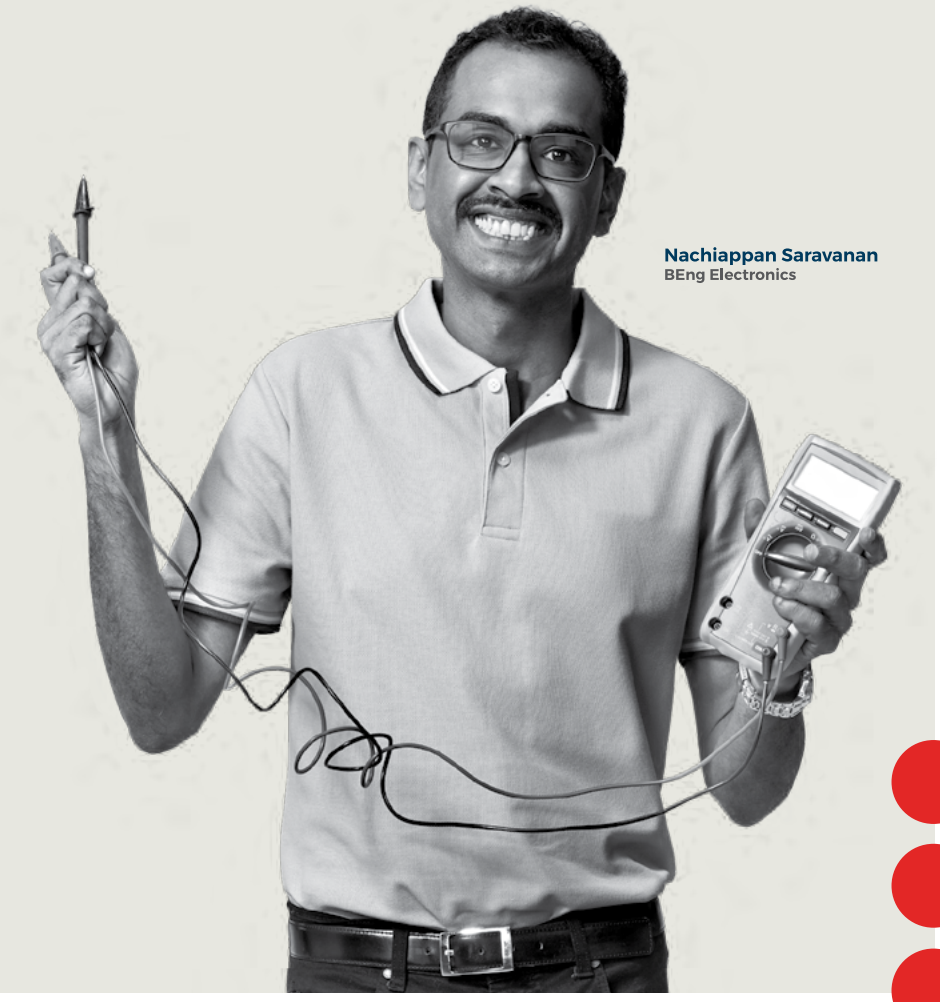

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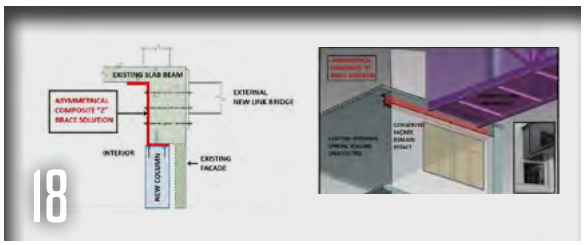

REGULAR SECTIONS

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SURBANA JURONG RANKS 26TH

AMONG TOP 225 INTERNATIONAL DESIGN FIRMS

Surbana Jurong Group, a global multidisciplinary urban, infrastructure and managed services consultancy, has been ranked 26th in the 2020 Engineering News-Record (ENR) Top 225 International Design Firms, moving up from its 2019 ranking (27th). It is the only Singapore-headquartered firm that has made it to the ENR Top 225 list, ranking among the top 30 firms for the last three consecutive years. This is especially significant as the group was formed just five years ago following the merger of Surbana and Jurong International.

As a trusted independent source of news and analysis for the global construction industry, ENR provides industry performance benchmarks through annual surveys and rankings of international companies engaged in engineering, architecture and environmental services, among other specialities. The ENR Top 225 International Design Firms list ranks the 225 largest world design firms, based on design-specific export revenue generated from projects outside each firm's home country.

In 2019, Surbana Jurong Group generated a revenue of USD 700 million from projects outside Singapore, which is more than 60% of its total revenue. The Singapore-headquartered group has a global talent pool of 16,500 employees based in 120 offices across 40 countries. Together with its member companies AETOS, B+H, KTP, Prostruct, Robert Bird Group, SAA, Sino-Sun and SMEC, the group offers a complete suite of multidisciplinary consultancy services that cover the entire project life cycle.

Mr Wong Heang Fine, Group Chief Executive Officer of Surbana Jurong said, "We are honoured to be counted among the world's top design firms, and pleased that Surbana Jurong has achieved an improved ranking. Our strategy to provide an integrated value chain of design and engineering solutions continues to deliver outcomes that matter to our clients and earn us opportunities to change the lives of many, through transforming cities into sustainable and liveable spaces where communities and businesses, present and future, can thrive".

In a publication released in conjunction with the ranking, ENR shows how global design firms are coping with the twin crises of the COVID-19 pandemic and a plunge in oil prices.

Mr Wong shared his perspective on the impact of the COVID-19 pandemic on the global market for design firms.

"We are seeing a dip in large-scale projects, and this could worsen in 2021. Many projects have been shelved, delayed or reduced in scope. But even in these challenging times, we still have clients relying on us", he said.

Mr Wong also shared that there is a growing demand for design firm expertise in planning, designing and engineering for a post-COVID world.

"Governments and organisations are consulting us on retrofitting buildings for care and recovery facilities as well as redesigning spaces for safety, as people return to the workplace and resume activities", he said.

Snowy 2.0, a project undertaken by SMEC, a member of Surbana Jurong Group, received special mention in ENR's Top 225 publication, and was cited as one of the significant hydroelectric power projects. The project is an expansion of the iconic Snowy Mountains Hydroelectric Scheme in Australia. When completed, Snowy 2.0 will be Australia's biggest green energy project and one of the world's biggest pumped storage plants, providing enough energy storage to power the equivalent of half a million homes.

SMEC, a member of Surbana Jurong Group, is involved in Snowy 2.0, the expansion of the Snowy Mountains Hydro-electric Scheme which is recognised as one of the seven civil engineering wonders of the modern world. SMEC contributed to the technical and financial feasibility of the project and has been engaged as the 'Owner's Engineer', providing technical advice and engineering support to help deliver this innovative renewable energy project. The project, which is currently under construction, involves the linking of the two existing reservoirs of Tantangara and Talbingo, through approximately 27 km of underground power waterway tunnels. There will also be a new underground power station with pumping capabilities.

RECOVERING STRONGER FROM COVID-19 THROUGH INNOVATION AND DIGITALISATION

Mr Desmond Lee, Minister for National Development and Minister-in-charge of Social Services Integration, announced a new SGD 20 million Advanced Digital Solutions (ADS) scheme to fund integrated advanced digital solutions to keep worksites and workers safe. He also announced the development of the Intelligent National Productivity and Quality Specifications (iNPQS) platform for the industry. iNPQS is a cloud-based system containing standard templates of project specifications co-created with industry partners.

Mr Lee was speaking at the opening of the International Built Environment Week (IBEW) 2020 on how digitalisation can help as the built environment sector remains vigilant and continues to ensure compliance with work restart requirements. Themed 'Emerging Stronger through Innovation', IBEW 2020 expresses the Built Environment sector's collective aspiration to emerge stronger from COVID-19, to build greater resilience and a smarter and more sustainable built environment sector, through innovation and digitalisation.

Advanced Digital Solutions scheme

The SGD 20 million Advanced Digital Solutions (ADS) scheme funds integrated advanced digital solutions for the construction sector to help firms ensure the safety of their workers. Supported by the Building and Construction Authority (BCA) and the Infocomm Media Digital Authority (IMDA), the ADS solutions for the construction sector will help firms defray up to 80% of the costs of digital equipment such as thermal scanners, facial recognition systems, AI cameras and Bluetooth enabled wearables, and their integration with site management solutions to assist in COVID-Safe worksite management, up to a cap of SGD 20,000 per project.

These digital solutions, when deployed at construction sites, will be able to link up with BCA's newly developed digital platform called the BuildSG-COVIDSafe Platform (CSP). The CSP will facilitate the exchange of data from on-site management platforms and equipment with other government databases to help firms ensure compliance with safe measurement measures. The CSP will also highlight irregularities for early intervention. BCA has completed the pilot testing of the CSP, and is now ready to roll it out for widespread adoption by the industry.

An industry-led project specification platform

To help improve work processes, in order to remain viable in a COVID-19 world, the Singapore Institute of Architects (SIA), the Institution of Engineers, Singapore (IES) and the Association of Consulting Engineers Singapore (ACES) have co-created the iNPQS platform

iNPQS is a cloud-based digital platform that contains standard specifications that can be adapted and customised by firms for their building projects, and has the ability to integrate with Building Information Modelling (BIM) technology. Traditionally, companies prepare their specifications for projects in accordance with the project's requirements - a process which is often time-consuming. The use of iNPQS, which comes with a standard set of base specifications, not only speeds up the drafting process, it also reduces abortive work and minimises conflicting requirements and discrepancies in the specifications.

iNPQS has also garnered support from Government Procuring Entities (GPEs) and various built environment TACs to enrich the base specifications. iNPQS will be ready by November 2020, and will benefit building professionals across the entire built environment value chain.

The Smart FM Challenge

As part of efforts to transform the Facilities Management (FM) industry through digitalisation and adoption of technology, BCA is launching the Smart FM Challenge to enhance productivity and improve service delivery in the FM industry. The challenge aims to bring together service buyers (developers and building owners) and service providers (FM companies and technology providers) to adopt smart FM solutions in the next three years.

The adoption of smart FM solutions and outcome-based performance contracting can help building owners and developers, especially those with a portfolio of buildings, to achieve at least 15% improvement in productivity, cost or manpower savings etc. More than 50 firms, including major developers/building owners, agencies, institutions, FM companies and technology providers, have already come on board.

IBEW

IBEW is jointly presented by BCA and Reed Exhibitions Singapore, and supported by 12 Trade Associations and Chambers (TACs).

The 12 TACs are (i) Association of Property and Facility Managers (ii) Singapore International Facility Management Association (iii) Real Estate Developers' Association of Singapore (iv) Singapore Green Building Council (v) Singapore Institute of Building Limited (vi) Singapore Institute of Surveyors and Valuers (vii) Society of Project Managers (viii) Specialists Trade Alliance of Singapore (ix) Association of Consulting Engineers Singapore (x) Institution of Engineers, Singapore (xi) Singapore Contractors Association Limited and (xii) Singapore Institute of Architects.

This collective spirit across the built environment value chain epitomises the BuildSG movement.

BuildSG is a collaborative effort by industry and government, whose aims are deep capability building, strong collaborations and co-creation of effective solutions for the Built Environment sector.

FACTSHEET ON ADVANCED DIGITAL SOLUTIONS FOR THE CONSTRUCTION SECTOR

The Advanced Digital Solutions (ADS) scheme, available through the Infocomm Media Development Authority's (IMDA) SMEs Go Digital programme, helps enterprises deepen their digital capabilities, strengthen business continuity measures and build longer term resilience. Solutions supported under ADS address common enterprise-level challenges at scale, help enterprises to adopt cutting-edge technologies and enable enterprises to transact more seamlessly within or across sectors.

The types of solutions identified for ADS are those which meet the objectives set out in the Industry Transformation Maps and the Industry Digital Plans that further develop the types of digital solutions that are needed by the industry.

Digitalisation for Safe Re-opening and Resilience

IMDA works with sector lead agencies and industry players to identify relevant integrated digital solutions for their respective sectors, that can be supported under ADS. With regard to the construction sector, IMDA is working with BCA to support construction companies' efforts to safely re-start construction works and accelerate digitalisation to improve productivity. Up to SGD 20 million from ADS will be set aside to provide funding support for enterprises that adopt integrated advanced digital solutions to reduce reliance on manpower, minimise face-to-face contact, enhance productivity and ensure business continuity.

These solutions for the construction sector fall under two categories:

- Category A - Safely Re-open: Digital solutions to meet the COVID-Safe Restart Criteria as defined by BCA (https://www1.bca.gov.sg/docs/default-source/bca-restart/covid-safe-restart-criteria.PDF) (e.g. visitor management with temperature scanning, smart cameras with video analytics and wearables to monitor safe distancing).
- Category B - Build Business Resilience: Digital solutions to digitalise workflows and reduce reliance on manpower (e.g. e-Permit-To-Work, Defect Tracking Management and Quality Inspection). They will be integrated on the BuildSG-COVIDSafe Platform, a single digital platform to facilitate central monitoring and management. Only companies applying for Category A solutions can apply for Category B solutions.

Local construction companies can receive funding for up to 80% of the cost of the integrated digital solutions, subject to a cap of SGD 200,000 per company. Funding caps for Categories A and B also apply:

- Category A: Cap of SGD 20,000 per site, for up to five existing construction sites.
- Category B: Cap of SGD 24,000 per site, for up to the same five existing sites where Category A solutions are implemented.

Eligibility

Companies that wish to adopt the above solutions for the construction sector need to fulfil the following criteria to qualify for ADS funding:

- Be registered and be operating in Singapore.
- Have a minimum of 30% local shareholding.
- Be in a financially viable position to start and complete the project.
- Local construction companies such as developers, main contractors and sub-contractors can apply for the ADS grant support through the project leads of the ADS projects they are interested in. The list of ADS projects and contact information of the respective project leads are available on IMDA's ADS webpage www.imda.gov.sg/advanceddigitalsolutions.
- The duration of solution implementation per construction site must not be longer than 12 months. The digital solutions have to be implemented by 31 December 2021.

OTHER DIGITALISATION SUPPORT MEASURES

IMDA and BCA launched the Construction and Facilities Management Industry Digital Plan (IDP) in March 2020, under the SMEs Go Digital programme. The IDP is a step-by-step guide on useful solutions that SMEs in the Construction and Facilities Management (FM) sectors can adopt at each stage of their growth, and contains information on relevant training schemes for firms to upskill their employees. To make it easy for SMEs to adopt digital solutions, within the IDP, IMDA has provided a list of pre-approved solutions assessed to be market-proven, cost-effective and supported by reliable vendors. SMEs can apply for the Productivity Solutions Grant (PSG) from Enterprise Singapore (ESG) for funding support when they adopt these pre-approved solutions. SMEs that receive funding support from ADS will not be eligible for PSG support for similar solutions and vice versa.

LENDLEASE TO ESTABLISH

PRODUCT DEVELOPMENT CENTRE IN SINGAPORE

International property group Lendlease recently announced that it will set up a SGD 40 million product development centre in Singapore, with the support of the Singapore Economic Development Board (EDB), to accelerate the digital transformation of the property and construction sector.

Slated to open by October this year, the centre will employ 50 technology software application development talents in the first year and will continue to expand the team in the next few years. At least one in five will be aspiring graduates who are keen to be part of the industry's transformation. Lendlease's digital arm will seek out top local tech talents, including Singapore citizens and permanent residents.

The Singapore product development centre is part of the wider Lendlease Digital ecosystem which includes product development centres in Silicon Valley and Sydney. Using a working methodology under the Agile Project Management Framework for teams to iteratively and incrementally complete tasks and projects, Lendlease is creating a scalable supply chain and integrated logistics software platform for property development and construction projects in Singapore and globally.

Tony Lombardo, CEO Asia, Lendlease commented, "We are very excited to have the support of EDB to propel the built environment sector's transition to the digital economy and position Singapore as a global innovation hub that leads the market in automating the creation of tomorrow's smart buildings. We are at a critical inflection point of our industry's development and we are confident that the success of our digitalisation efforts supported by the city state's best-in-class infrastructure will leave a lasting impact on how we shape, construct and future-proof the built world".

Lendlease's new product development centre will introduce a suite of digital products and services leveraging its recently launched digital property lifecycle platform, Lendlease Podium, aimed at simplifying interdependencies in the real estate industry.

Lendlease Podium

Lendlease Podium's streamlined, digitised and interconnected supply chain will unlock efficiencies across the entire design, construction and property supply chain and operating model while achieving the best outcomes for safety and sustainability.

In addition, Lendlease Podium will also be offered as-a-service to the broader industry, to ensure greater clarity and detail as well as smarter investment, bigger savings and improved risk management throughout the entire lifecycle of a project.

Moving towards Industry 4.0

With a long history of innovating and understanding issues faced by the industry, Lendlease is now accelerating towards Industry 4.0, focusing on delivering and enabling transformation through digitalisation.

Dawn Lim, Vice President and Head, Commercial & Professional Services, EDB, said, "The Product Development Centre by Lendlease will add exciting digital capability to the built environment ecosystem. This will create new jobs in the built environment sector, that a wide range of talent, from seasoned professionals to new entrants to the workforce, can aspire towards. We look forward to working with Lendlease and other like-minded companies, to further drive transformation and productivity within the built environment industry".

Harnessing over 60 years of its integrated experience in property development, construction and investment, Lendlease's significant investment underlines its commitment to shaping and growing its digital business by steering the digitalisation of the built environment sector towards autonomous buildings of the future.

For Lendlease, the concept of 'Autonomous Buildings' is more than just unlocking efficiencies. At the heart of it is the adoption of a Design for Manufacturing and Assembly (DfMA) mindset that changes the way construction is viewed, as the move towards industry 4.0 grows stronger and there is a shift from labour-intensive ways to skills-based ways of working. The objective is to achieve urbanisation and place making, with the creation and operation of buildings that bring about the best in safety, health and well-being.

Richard Kuppusamy, Lendlease's Head of Digital Integration commented, "Think of Lendlease Podium as an operating system for real-estate, which allows us to harness the power of data driven insights in everything from creating buildings to improving operational efficiency and sustainability, and provide the best user experiences. Imagine a building that enhances your experience by adapting to your preferences - one that soothes, entertains, improves well-being, and reduces energy consumption with minimal human intervention. This is what we call the 'Autonomous Building'. Lendlease Podium will be the conduit that enables us to achieve this automation in creating the best places for our users".

Inaugural Autonomous Building Summit

In conjunction with the launch of its regional product development centre, Lendlease hosted its inaugural Autonomous Building Summit.

GUOCO TOWER NAMED

A WORLD GOLD WINNER

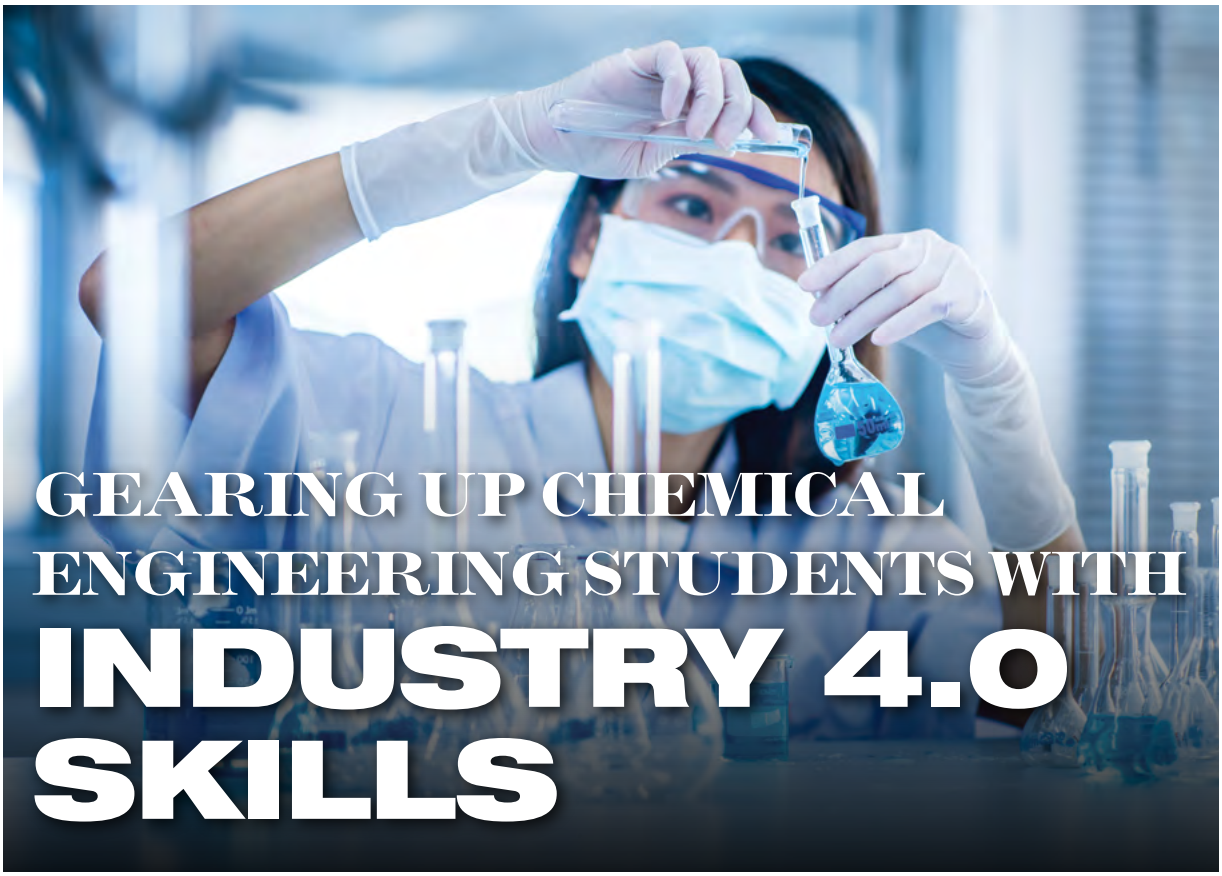
GuocoLand Limited (GuocoLand) recently announced that Guoco Tower, its flagship integrated mixed-use development, has been accorded the title of World Gold Winner in the Mixed-use Development category at the 2020 FIABCI World Prix d'Excellence Awards, making it Singapore's first development to win in this category.

Standing at 290 m, Guoco Tower is Singapore's tallest skyscraper and a catalyst for the transformation of Tanjong Pagar which is located within the Central Business District. The award recognised Guoco Tower as a distinctive, vertically integrated landmark that combines high liveability, connectivity and walkability, coupled with strong community building and place making efforts.

In the lead-up to this victory, Guoco Tower was awarded Gold in the Mixed-use Development category at the 2019 FIABCI Singapore Property Awards organised by FIABCI's local chapter.

Designed by Skidmore, Owings & Merrill LLP, Guoco Tower was completed, in phases, in 2016 and 2017.

Guoco Tower has also received the Leadership in Energy and Environment Design (LEED) CS (core and shell) Platinum certification, the BCA Green Mark Platinum Award, the 2019 Urban Land Institute (ULI) Global Award for Excellence, 2019 ULI Asia Pacific Award for Excellence, 2019 Council on Tall Buildings and Urban Habitat Annual Awards for Urban Habitat Single-Site Scale Award of Excellence, and the 2019 Land Transport Authority Land Transport Excellence Award for Best Design Land Transport Integration.



GEARING UP CHEMICAL ENGINEERING STUDENTS WITH INDUSTRY 4.0 SKILLS

As digital technologies such as artificial intelligence (AI) and automation continue to redefine manufacturing, Singapore's chemical industry is increasingly seeking engineers with Industry 4.0-ready skillsets to support its transformation.

To enable students to ride the waves of opportunities in this field, Singapore Institute of Technology (SIT) is offering a new joint Bachelor of Engineering with Honours in Chemical Engineering degree programme with the Technical University of Munich (TUM).

A degree for a transforming industry

Contributing nearly three per cent of Singapore's GDP in 2015, the energy and chemicals industry sector has been a mainstay of our economy. In 2017, the government launched the Industry Transformation Map (ITM) for this sector, with the aim of increasing its manufacturing value-add to S$12.7 billion and introducing 1,400 new jobs by 2025.

A key component of this ITM is increased adoption of disruptive digital technologies including AI, machine learning, Internet of Things (IoT), blockchain and data analytics to drive new levels of innovation, performance and productivity across the sector.

Recognising this trend, SIT has evolved the Chemical Engineering programme, previously offered solely by TUM, to a joint degree by SIT and TUM, with its first intake in September 2020.

The collaboration encompasses curricula co-development and co-teaching by faculty members of both universities. This exposes students to both global and local knowledge and perspectives – a competitive advantage in the new era of advanced manufacturing.

"We need engineers with forward thinking ideas and solutions to tackle new issues as we progress through the digital era. To support the transformation and manpower demands of the chemical industry, the new joint degree programme in Chemical Engineering will equip students with essential Industry 4.0 skillsets," said Associate Professor Bernard Loo, Programme Director of the SIT-TUM Chemical Engineering programme.

Developing in-demand Industry 4.0 skills

Beyond providing strong fundamentals for aspiring chemical engineers, the programme is the first in Singapore aimed at equipping students with two sought-after Industry 4.0 skillsets – data engineering and additive manufacturing.

In the Data Engineering specialisation track, students will focus on learning the application of data analytics in value chain digital integration, seamless asset lifecycle information from plant design to decommissioning, and business-to-plant production control.

Students specialising in Additive Manufacturing will gain expertise in the design, formulation and engineering principles of new materials for 3D printing industries. They will also cover topics such as polymer engineering, polymer technology, material analysis and failure analysis.

Given the wings to soar

Since its launch in 2011, the Chemical Engineering programme has seen over 300 students graduating, priming them for careers as process, manufacturing, validation and safety engineers; as well as research, data engineering and materials scientists.

Prabu Dev is one such student. After recently obtaining his degree, Prabu is upbeat about his future in the chemical industry.

"SIT and TUM design programmes that meet the needs of the industry. The opportunity to visit TUM's campus in Munich honed my critical thinking skills, enabling me to look at problems from industrial perspectives and develop different solutions," he said.

Armed with a diploma in Medicinal Chemistry from Nanyang Polytechnic, Prabu was initially hesitant about his fit for the course.

However, his concerns proved to be unfounded.

"The study of chemical engineering has never been easy but SIT provided pivotal support to students throughout the course. For example, SIT runs programmes like ChemQuest before the first trimester to gear students up for the course proper. The block teaching is also an effective way of accelerated learning," he said.

Currently, Prabu is furthering his study in industrial chemistry, while also looking forward to his thesis on novel high energy density materials with N-fused heterocycles being published in a scientific journal.

For prospective students, Prabu's advice is to practise good time management, diligently take notes and create a strong support system.

"The journey might test your perseverance as it is tough and fast-paced, but it will be all worthwhile at the end," he said.

Quintessential applied learning

At SIT, learning goes beyond the textbook through its unique applied learning pedagogy. The training places a strong emphasis on preparing students for varied disruptive challenges in the real world, enabling students like Prabu to be industry-ready.

Such a focus is infused into the degree programme, featuring SIT's signature Integrated Work Study Programme (IWSP) and Overseas Immersion Programme (OIP).

In the eight-month IWSP, students will work full-time in a host company related to their specialisation, allowing them to develop deep specialist skills in their chosen field.

The three-week OIP will bring students to TUM's campus in Munich, Germany to widen their global perspectives and experience cross-culture exchanges.

Another unique feature of the programme is block teaching for some modules, an intensive 'boot camp' style of pedagogy comprising lectures, tutorials and examinations on one module within a two-week period.

Such a holistic applied learning experience allows SIT students to transition smoothly to the workforce and embrace emerging opportunities with confidence. ■

Prabu (third from left) formed study groups with his classmates to support each other on their learning journey .
Image credit: Technical University of Munich (TUM) Asia

This sponsored feature on engineering education was brought to you by SIT.

BENTLEY SYSTEMS ANNOUNCES

THE FINALISTS FOR YEAR IN INFRASTRUCTURE 2020 AWARDS

Bentley Systems, Incorporated, a leading global provider of comprehensive software and digital twins services for advancing the design, construction, and operations of infrastructure, has announced the finalists in the Year in Infrastructure 2020 Awards.

The winners will be selected and announced at Bentley's Virtual Year in Infrastructure 2020 Conference, to be held on 20 and 21 October 2020.

The annual awards programme honours the work of Bentley software users advancing infrastructure design, construction, and operations throughout the world. Sixteen independent jury panels selected the 57 finalists from over 400 nominations submitted by more than 330 organisations from more than 60 countries.

The finalists for Year in Infrastructure 2020 Awards for advancements in infrastructure are:

4D DIGITAL CONSTRUCTION

- **DPR Construction** - 2019 LSM DS Tech Upgrade.
- **Mortenson | McCarthy (a Joint Venture)** - Allegiant Stadium
- **Office of the Renovation and Expansion Project of the Beijing-Harbin Expressway Section from Lalin River (Boundary between Jilin Province and Heilongjiang Province) to Harbin, Heilongjiang Construction Technological Innovation & Investment Co Ltd** - Application of 4D Digital Technology in the Management of the Renovation and Expansion Project of the Beijing-Harbin Expressway Section from Lalin River to Harbin

BRIDGES

- **Arup** - Cherrywood Grand Parade Bridge
- **Chongqing Communications Planning, Survey & Design Institute Co Ltd, Guizhou Communications Construction Group Co Ltd, Guizhou Bridge Construction Group Co Ltd** - Digital Design and Construction of Taihong Yangtze River Bridge
- **Sichuan Road & Bridge (Group) Co Ltd** - Chishui River Bridge of Expressway from Jiangjin (Chongqing-Guizhou Border) to Xishui to Gulin (Guizhou-Sichuan Border)

BUILDINGS AND CAMPUSES

- **Beijing General Municipal Engineering Design & Research Institute Co Ltd** - Innovative Application of BIM in Municipal Engineering Design of Ezhou Civil Airport
- **PT Wijaya Karya (Persero) Tbk** - COVID-19 Modular Hospital with NPI Room
- **Voyants Solutions Private Limited** - Bangladesh Regional Waterway Transport Project 1 - Shasanghat (New Dhaka) IWT Terminal

DIGITAL CITIES

- **City of Helsinki** - Digital City Synergy
- **Skanska-Costain-STRABAG Joint Venture** - HS2 Main Works Civils Contract
- **Systematica Srl** - MIND: Testbed of New Mobility Paradigms

GEOTECHNICAL ENGINEERING

- **Golder Associates Hong Kong Ltd** - Tuen Mun-Chek Lap Kok Link Tunnel, Southern Landfall
- **HDR Engineering** - Oroville Dam 3D Seepage and Stability Modeling of the Tallest Earthen Embankment Dam in the US
- **Saidel Engineering SRL** - Nine-story Residential Building above the Subway Tunnels in West Bucharest

LAND SITE AND DEVELOPMENT

- **AAEngineering Group** - Dzhamgyr Mine - Project Implementation in Extreme Conditions
- **Jacobs Engineering India Pvt Ltd** - Master Planning and Engineering for Infrastructure Development at Tumakuru, Karnataka
- **KCI Technologies Inc** - HUB404 Concept Database

MANUFACTURING

- **Citic Heavy Industries Co Ltd** - The Application of BIM Technology in Fujian Ansha's Intelligent Green Cement Production Project with a Daily Output of 4,500 Tons
- **MCC Capital Engineering & Research Incorporation Ltd** - BIM Technology-based Construction of Digital Plant for Iron and Steel Base in Lingang, Laoting of HBIS Group Co Ltd
- **Shenyang Aluminum & Magnesium Engineering & Research Institute Co Ltd** - Guinea Alumina Engineering Digital Twin Application Project of CHALCO Hong Kong Co Ltd

MINING AND OFFSHORE ENGINEERING

- **AAEngineering Group** - Digital Twin of AKSU Plant: from Concept to Startup. A Real Story
- **Sapura Energy Berhad** - Transporting of 3-x-330 Class Barge Loaded with Jacket onboard Semi-submersible Vessel

- **Volgogradnefteproekt, LLC** - Vladimir Filanovsky Offshore Field Modernization and Production Volume Increase

POWER GENERATION

- **PowerChina Hubei Electric Engineering Co Ltd** - Kyrgyzstan Bishkek Thermal Power Plant Reconstruction Project
- **Shanghai Institute of Mechanical and Electrical Engineering Co Ltd** - Shanghai Electric Environmental Protection Group Technology Renovation and Expansion Project for Nantong Thermoelectric Waste Incineration
- **TBEA Xi'an Electric Design Co Ltd** - Application of Digital Technology in the Design of Complex Mountain Wind Farms

PROJECT DELIVERY

- **Aegea Saneamento** - Infra Inteligente Program (Smart Infra Program)
- **Shanghai Water Engineering Design & Research Institute Co Ltd** - The Integrated Delivery and Application of BIM Technology in the Design, Construction, Supervision and Management of Shanghai Water Pump Sluice Project
- **Sweco** - Sweco | Digitalization with BIM

RAIL AND TRANSIT

- **China Railway Electrification Engineering Group Co Ltd, China Railway Engineering Consulting Group Co Ltd, China Academy of Railway Sciences Corporation Limited** - Beijing-Zhangjiakou High-speed Railway
- **Network Rail Wales and Western Region** - Bristol Area Signalling Renewal Enhancements
- **PowerChina Huadong Engineering Corporation Limited** - Innovative Application of Digital Engineering Technology in Shaoxing Rail and Transit Construction

REALITY MODELING

- **AUAV** - Warragamba Water Pipeline Digital Twin
- **Khatib & Alami** - Geo-enabling Reality Model Tips and Tricks
- **Merius Oy** - Merius Smart Mill

ROAD AND RAIL ASSET PERFORMANCE

- **Maryland State Highway** - Maryland One (SUPERLOAD) Violation Tracking & Asset Insight
- **Roads & Transport Authority (RTA)** - Collaborative Information System Implementation - Whole Lifecycle Common Data Environment
- **SMRT Trains Ltd** - Predictive Decision Support System (PDSS)

ROADS AND HIGHWAYS

- **Sichuan Road & Bridge (Group) Co Ltd** - BIM Technology Application on Chengdu-Yibin Expressway
- **Sweco Nederland BV** - Oosterweelverbinding Antwerpen
- **SAI-SYSTRA Group** - Mumbai Coastal Road Project (South) Package-II

STRUCTURAL ENGINEERING

- **CNI Ingenieros Consultores SAS** - Engineering Laboratories and Research Building
- **Indian Railways** - Design & Construction of the World's Tallest Rail Pier Girder Bridge
- **WSP** - WSP overcomes Complex Challenges with Bentley's Technology to Deliver Principal Tower

UTILITIES AND COMMUNICATIONS

- **IOB Technology Sdn Bhd** - BIM for Substation and Electrification Design of Double Rail Track, Johor, Malaysia
- **Qinghai Kexin Electric Power Design Institute Co Ltd** - Dayu 110kV Electrical Transmission and Transformation Project in Hainan Tibetan Autonomous Prefecture, Qinghai Province, China
- **Sterlite Power Transmission Limited** - Sterlite BIM

UTILITIES AND INDUSTRIAL ASSET PERFORMANCE

- **Gazdaş Gaziantep Doğal Gaz Dağitim AŞ & Trakya Bölgesi Doğal Gaz Dağitim AŞ** - Enterprise GIS Project for Natural Gas Utility on SAP/IS-U
- **Glencore** - Implementing Asset Reliability Tool for Copper and Nickel Smelters
- **Shell QGC** - Evolution of Engineering Data, Documents and Information Management

WATER AND WASTEWATER TREATMENT PLANTS

- **AECOM/Wessex Water** - Durleigh WTC Reconstruction
- **Hatch** - Ashbridges Bay Treatment Plant Outfall
- **PowerChina ZhongNan Engineering Corporation Limited** - Research on the Deep Application of BIM and Digital Twin Technology of Water Delivery Project Based on Bentley

WATER, WASTEWATER AND STORMWATER NETWORKS

- **Companhia de Saneamento Básico do Estado de São Paulo** - Operational Restructuring Project of Cursino Water Supply System in São Paulo City
- **DTK Hydronet Solutions** - Digital Water Network Engineering & Asset Management of Dibrugarh Water Supply Project
- **NJS Engineers India P Limited** - JICA Assisted Guwahati Water Supply Project

The finalists, chosen by independent juries of industry experts, will present their projects during a pre-conference showcase beginning 5 October to 16 October 2020.

WORLD'S FIRST INTELLIGENT AERIAL FIREFIGHTING

SOLUTION LAUNCHED

Autonomous aerial vehicle (AAV) technology company, EHang, announced the launch of the world's first large-payload intelligent aerial firefighting solution on 31 July 2020. According to the China-based company, the EHang 216F is specially designed for high-rise firefighting.

With a maximum flight altitude of 600 m, the 216F can carry up to 150 litres of firefighting foam and 6 fire extinguisher bombs in a single trip. It uses a visible light zoom camera to quickly identify the location of the fire before hovering in position to deploy its payload of window breakers, fire extinguishing bombs, and foam.

A laser aiming device is used to direct the payloads to where they are needed.

"We are pleased to introduce the EHang 216F AAV aerial firefighting solution, which solves difficult challenges in high-rise firefighting. The high-rise fire use case highlights the practical application of our passenger-grade AAV platform to different smart city management needs … (and) we will explore and develop more aerial solutions and use cases to empower smart cities," said EHang's founder, chairman and CEO Hu Huazhi.

EHang 216Fs are expected to be deployed in urban fire stations to assist in firefighting within a 5 km radius. Autopilot and centralised management technologies will enable the AAVs to be remotely dispatched for first response before firefighters arrive.

The intelligent firefighting AAV being put through its paces at a demonstration during the launch ceremony in Yunfu, China. Photo: EHang

ST Engineering given approval to perform aircraft inspection using drones

ST Engineering will be using its in-house developed drone solution, DroScan to carry out General Visual Inspection (GVI) at its MRO facilities in Singapore after being granted authorisation by the Civil Aviation Authority of Singapore (CAAS).

The drones will be used to inspect Singapore-registered, approved aircraft models such as the Airbus A320 family.

DroScan leverages automation and smart analytics capabilities to bring about higher efficiency and greater workplace safety during aircraft maintenance work.

For example, it eliminates the need to set up bulky ground equipment such as boom-lifts and work stands for inspectors to climb up and down during manual inspections.

Instead, this can be accomplished using the live video feed and post-flight images captured by the drones. Captured images can be fed through algorithms that detect and classify defects to assist the inspectors in the review process.

Over the past year, ST Engineering demonstrated the solution's capabilities through a number of successful trials with participating airline customers such as Air New Zealand.

In addition to smart analytics capabilities, DroScan is incorporated with safety features that could allow for future operations within Singapore's civil aerodromes.

These features include precise localisation systems to navigate in GPS-denied environment, power-tethered systems for extended flight duration and controlled safety template, multiple sensors for obstacles detection and geo-fencing to prevent the drone from straying out of flight templates.

Moving forward, ST Engineering aims to extend the application of DroScan to more aircraft models, including widebody platforms, as well as develop new robotic solutions for inspections that involve contact-based measurements.

Apart from automation and smart analytics capabilities, the DroScan solution has safety features that could allow for future operations within Singapore's civil aerodromes. Photo: ST Engineering

RAILWAY SYSTEMS HANDBOOK

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ENSURING INFRASTRUCTURE RESILIENCE

TO OVERCOME MAN-MADE AND NATURAL DISASTERS

by Dr Ang Choon Keat, PE (Civil), SPE (Protective Security), Andrew Tan, Senior Consultant (Security & Blast) and Lee Xiong Le, Blast Engineer, Prostruct Consulting (a member of the Surbana Jurong Group)

Dr Ang Choon Keat

Andrew Tan

Lee Xiong Le

Hostile attacks on physical assets and pandemics such as COVID-19 have made safety and security of people and facilities extremely important.

Introduction

When man-made and natural disasters occur, they cause disruption to infrastructures and businesses. Disruptions can be classified into three categories, based on our awareness of their existence and ability to predict their occurrence - known-knowns such as rising sea levels, known-unknowns such as terrorist attacks, and unknown-unknowns such as events that we do not know of nor are we able to predict their occurrence.

The Oklahoma City Bombing occurred on 19 April 1995. The detonation led to the progressive collapse of the Alfred P Murrah Federal Building (Linenthal, 2020) and subsequent cessation of all operations.

The explosion of 2,750 tons of ammonium nitrate at the port of Beirut, Lebanon on 4 August 2020 killed at least 160, wounded 6,000 and displaced 300,000 people from their homes (Reid, 2020). Buildings in a 10 km radius were reported to be damaged (Balkiz, Qiblawi, & Wedeman, 2020).

The COVID-19 pandemic is another example of how disruptions can have significant consequences on individual infrastructures and businesses.

Hence, it is crucial to implement a holistic infrastructure resilience framework to ensure that an infrastructure, a business, or an organisation incorporates the mitigation measures and preparedness, while maintaining the functional objectives of the building.

Literature Review

INFRASTRUCTURE RESILIENCE

In the US, the National Infrastructure Advisory Council (NIAC) conducted the Critical Infrastructure Resilience Study with the objective of recommending methods to integrate resilience and protection into risk-management strategies. It defines Infrastructure Resilience as the ability to reduce the magnitude and/or duration of disruptive events. The effectiveness of a resilient infrastructure or enterprise depends upon its ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event.

Similarly, Resilient Design Institute defines Resilience as the capacity to adapt to changing conditions and to maintain or regain functionality and vitality in the face of stress or disturbance. It is the capacity to bounce back after a disturbance or interruption.

The 'National Infrastructure Protection Plan (NIPP) 2013: Partnering for Critical Infrastructure Security and Resilience' provides further guidance to the critical infrastructure community on building and sustaining critical infrastructure security and resilience, to manage risks.

In the UK, the NHS England Emergency Preparedness, Resilience and Response (EPRR) Framework (2015) outlines the requirements for the National Health Service (NHS) to prepare for emergencies, to have flexible arrangements which can be scalable and adaptable to work in a wide range of scenarios. EPRR aims to ensure that plans are in place to ensure resilience, allowing the community, services, area or infrastructure to detect, prevent, withstand, handle and recover from disruptive challenges (NHS England National EPRR Unit, 2015).

INFRASTRUCTURE RESILIENCE PRINCIPLES

In the US, the National Institute of Building Sciences (NIBS) presented the following four Infrastructure Resilience principles (NIBS, 2018), as determined by NIAC (2009):

Robustness - The ability to maintain critical operations and functions in the face of crisis. The building and its critical and supporting systems can be designed to minimise disruptions.

Redundancy - Backup capabilities are able to provide critical functions when primary sources have failed, reducing the downtime of critical functions and their impact on building operations.

Resourcefulness - The ability to prepare for, respond to, and manage an ongoing crisis or disruption. It includes effective communication of decisions made, business continuity planning, supply chain management, as well as security and resilience management systems. The

contingency measures should prioritise courses of action to control and mitigate damage and should be adaptable to ensure effectiveness in various scenarios.

Recovery - The ability to return to normal operations as quickly and efficiently as possible, after a disruption, through the deployment of the right resources to the right places.

These four principles aim to minimise the disruption to building operations caused by any undesired event and to minimise the time taken to return to 100% operability.

METHODOLOGY

NIPP (2013) provided a comprehensive Critical Infrastructure Risk Management Framework to strengthen critical infrastructure security and resilience. FEMA 452 offers a framework that is similar to that of NIPP. The following methodology was referenced from the Risk Management Framework and FEMA 452:

Set Goals and Objectives of Infrastructure Resilience - Establish objectives and priorities for critical infrastructure, that are tailored and scaled to their available resources, and operational and risk environments.

Identify Critical Assets - Establish and identify the assets, systems and networks, that are essential to the continued operation, considering associated dependencies and interdependencies.

Assess and Analyse Risks - Risk assessments are conducted to facilitate the owner in decision making. Established and mature risk assessment approaches, such as FEMA 452 (FEMA, 2005), are widely available for reference.

Implement Risk Management Activities - Implement measures that minimise disruption to operations and reduce time required to return to normal operations. The implementation of measures in accordance with the Infrastructure Resilience principles is illustrated in this article, under the sections on Physical Security and Bio-Security.

Infrastructure Resilience: Physical Security

Infrastructure Resilience principles will help to frustrate and disrupt an adversary's attack (from planning through to execution of an attack and the recovery of operations after the attack). In addition, the following five layered strategies, referenced from NIAC (2009) and Singapore's Ministry of Home Affairs (MHA) (MHA, 2018), work to provide a robust prevention and protection system:

Deter - Deterrence aims to prevent a potential disruption by turning the infrastructure or facility into an undesirable target. It can be achieved via facility design as well as rules and protocols that prohibit undesired activities or encourage desired practices and awareness.

Detect - Early detection of potential disruption alerts stakeholders, giving them more time to better respond to the disruption.

Delay - This layer aims to slow down the progress of disruption by using obstacles. Stakeholders can use the additional time to better respond to the disruption.

Deny - By creating separate zones within the building, exposure of critical portions of the building to disruption would be reduced.

Defend - This layer focuses on reducing the damage or impact to operations if disruptive incidents occur. It can be achieved by purposeful design of infrastructure and holistic management plans to deal with the crisis.

Figure 2 illustrates the Physical Security measures and technologies which can be utilised to achieve the Physical Security principles. First, deterrence via the various security and protection measures is used to discourage any attempt to attack, by emphasising the likelihood of failure and capture. It is a psychological battle to ensure that some intended criminal activities never start. Effectiveness of security measures can also be amplified through signages and messages.

Entry into the controlled zone would be denied to unauthorised personnel at security checkpoints. Anti-climb fences, vehicle barriers and bollards are installed to deny and delay any attempt to enter the controlled zone.

CCTV systems, intrusion detection systems and electronic access control systems are typical detection systems

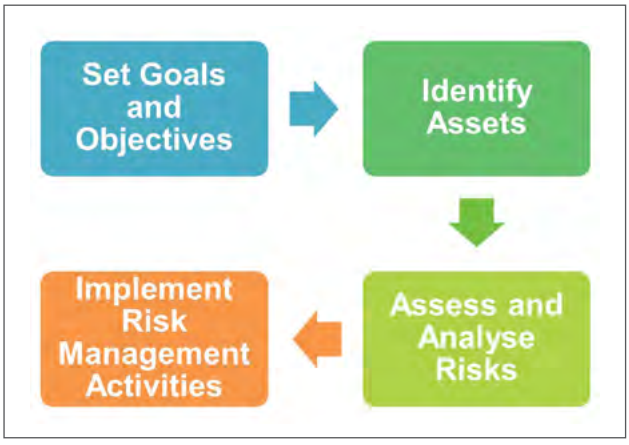

Figure 1: Risk Management process.

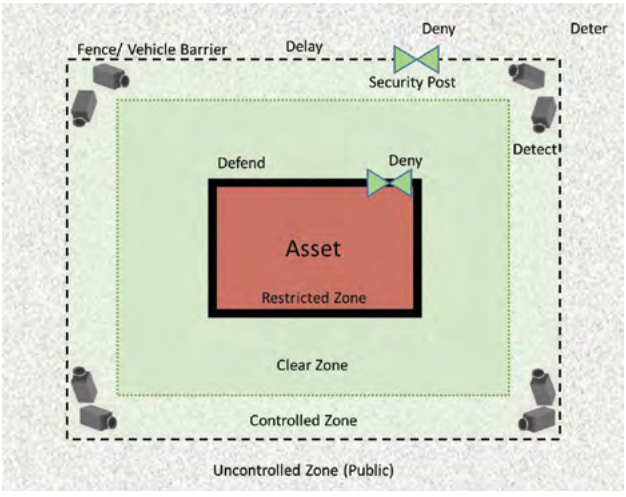

Figure 2: Protection plan.

Figure 3: Security bollards.

that alert security forces on any breach of security. The asset can be further defended by hardening the critical sections of the building. A straightforward method of hardening is to increase the physical size and/or reinforcement details of structural components until they are sufficiently thick and can therefore resist the blast loads. Alternatively, the strength of structural components can also be increased by other means such as external strengthening through Fibre Reinforced Polymer composites or steel jacketing. Openings such as doors, windows, louvres etc can also be hardened by installing blast rated openings.

Even with the implementation of prevention and protection measures, it is still possible that the attack could be successful in damaging the asset, causing disruption to building operations.

With backup assets and resources, single points of failure can be prevented. The contingency plans enacted during peacetime would facilitate the takeover of critical functions within a short time-frame, returning operations to normal levels.

To mitigate the weaknesses of Physical Security measures and design, there is a need to have an adequate number of personnel with the right competencies to ensure effective security & resilience operations during crises and a proper response to crimes and terrorist attacks. Depending on the nature of the threats, additional external responses may be required to mitigate the threats. Resources, standard operating procedures and communication channels should be in place beforehand, such that the response can be initiated immediately.

Infrastructure Resilience: Bio-Security

The recent COVID-19 pandemic is a wake-up call for the world. Organisations have realised their lack of Infrastructure Resilience in the face of similar biological threats. Significant outbreaks of disease / biological threats can threaten lives and cause disruption to infrastructures and businesses. This is true regardless of the origin of the threats which could include the following:

- Natural
  - Pandemic Influenza
  - Emerging infectious diseases
- Man-made
  - Accidental release of biological material from scientific or industrial facilities
  - Deliberate biological attack

The UK Biological Security Strategy (Department for Environment, Food and Rural Affairs et al, 2018) defines four pillars that support the response to biological threats - Understand, Prevent, Detect and Respond. The pillars have been adapted for Infrastructure Resilience, as follows:

Understand - Understand the risks of ongoing or possible future biological threats.

Prevent - Prevent the spread of pathogens through design of the building.

Detect - Ability to identify biological threats or carriers, through the use of detection systems and tests.

Respond - Reduce the impact of biological threats and enable rapid recovery to normal operations.

Regardless of whether they are ongoing or future biological threats, understanding the threats in terms of typical transmission methods, symptoms, signs of contamination etc is crucial for the selection of effective prevention, detection and response methods.

Prevention of the spread of biological threats can be considered during the design phase of the building project. Ventilation systems for various sections of the building can be isolated, to prevent the movement of air-borne pathogens from one part of the building to another. Positive pressure rooms prevent outside air from entering, thereby denying entry of pathogens.

Protective design, with isolation of special-use spaces through layout and ventilation system planning, can further limit the impact of contaminants in vulnerable spaces on the rest of the building, thereby reducing exposure of the bulk of the building occupants to the contaminants (Persily et al, 2007).

Early detection of biological threats can be done via sensing technologies and procedures. Sensors can be deployed at entry points to detect signs of biological threats or symptoms of carriers, thereby preventing possible spread and disruption to operations. Temperature sensors for COVID-19 are examples of sensors that can be implemented quickly during a crisis.

The most critical response during an ongoing biological threat incident is to have effective and proportionate strategies to decontaminate any area that has been contaminated, in order to allow a return to normalcy as soon as possible. Implementation of contingency measures such as staggering of work and meal times, and physical distancing etc at the workplace, combined with the wearing of masks, can aid in delaying the spread of some pathogens.

Besides the impact on occupants, biological threats may impact the operations of the supply chain, leading to disruptions downstream. Buildings that are able to manage supply chain issues during lockdown, by implementing

Figure 4: Temperature screening for COVID-19 at entry points.

business continuity measures and securing alternative sources of supply, would be able to quickly recover from the initial disruption. Appropriate stockpiling of resources and materials during periods of normal activity is crucial to ensuring effective recovery in a wide range of potential adverse scenarios.

Redundancy of personnel can be achieved with split team arrangements as they prevent the spread of pathogens across teams, with each team acting as the respective backup for the other. Telecommuting can be implemented to restore operations in a lockdown, allowing for the rapid recovery to normal operations for certain services and industries.

Conclusion

The Infrastructure Resilience Principles presented here provide building owners, security designers, engineers and architects, with a structured approach to assessing the Infrastructure Resilience against terrorist attacks, biological threats etc. Mitigation measures can then be studied to reduce the risk to assets critical to operation, resulting in the building having greater Infrastructure Resilience.

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Figure 5: Telecommuting (Rawson, 2019).

FOUR PROFESSIONAL ENGINEERS

CONFERRED BCA DESIGN AND ENGINEERING SAFETY AWARD 2020

The award gives recognition to the Qualified Person for Structural Works [QP(ST)] in the selected project, the QP(ST)'s firm, and the project team, for ingenious design processes and solutions in overcoming challenges to ensure safety in design, construction and maintenance, in the implementation of local and overseas building and civil engineering projects.

The Professional Engineers (PEs) who won the BCA Design and Engineering Safety Award 2020 are Er. Aaron Foong from KTP Consultants Pte Ltd (a member of the Surbana Jurong Group), for Maxwell Chambers Suites; Er. Kam Mun Wai from Meinhardt (Singapore) Pte Ltd, for Singapore Management University (SMU) Connexion; Er. Jason Tan Bok Leng from Arup Singapore, for Outram Community Hospital; and Er. Tan Yoong Heng from Arup Singapore, for Thomson-East Coast Line Contract T203 TE2 Woodlands Station.

Winner of BCA Design Engineering and Safety Award 2020 (Commercial Category) Excellence

Maxwell Chambers Suites

Maxwell Chambers Suites

Gazetted as a conservation building in 2007, Maxwell Chambers Suites has a rich heritage and historical significance. Built in 1928, the building was first used as barracks for the police force until it became the Traffic Police headquarters, between the 1930s and 1999. After it was vacated, the building underwent a refurbishment and reopened as the Red Dot Traffic Building, with a signature red façade, in 2005. The extensive restoration of Maxwell Chamber Suites started in 2017, that preserves the building's heritage while repurposing it for its use today as a global dispute resolution centre.

Key challenges

- Sensitive restoration of a century-old heritage building, with stringent conservation requirements, to create new connectivity, improve accessibility and comply with spatial specifications for modern commercial use.
- Intricate structural strengthening to enable the construction of a new overhead link bridge structure connecting the façades of two conserved heritage buildings, without removal of any peripheral façade elements around the connection.
- Strengthening of existing foundations within the confines of a live electrical sub-station in a safe manner.

Solutions

- Rigorous engineering analysis with carefully considered loading scenarios and designing detailed construction sequences ensured a high margin of safety for the structural integrity of the newly integrated structures, while maintaining the key historical features intact at all times.
- Innovative bonded 'Z' steel plate detailing served as an elegant composite strengthening solution to support the new overhead link bridge, without encroaching into the conserved façades of the heritage buildings, and enabling works to be done safely from the inside of the secured buildings.
- Combined foundation strengthening with micro-pile composite foundation cored through the existing shallow foundation achieved a robust integrated foundation and safe working space with zero disruption to the critical electrical substation operations.
- A highly modular and optimised composite structural steel system using a single beam and single column element type was designed for the two newly built Annex blocks.

Preserving heritage through innovation in engineering

One key challenge that Er. Aaron Foong faced was the construction of a 20 m overhead bridge linking the Maxwell Chambers Suites to Maxwell Chambers. In order to support the additional load of the bridge, there was a need to strengthen the existing buildings. However, given that both are conserved buildings, conventional strengthening methods such as adding new independent

columns on the exterior or enlarging existing beams and columns to support the link bridge were not allowed, as these would alter the external façade of the buildings. An additional challenge was having to lay the foundation within the confines of an existing electrical substation that was in operation.

Er. Foong devised an elegant solution, by designing a novel Z-profile steel brace that could support both existing loads from the existing structures and the incremental loads from the new construction. When bonded with the integrated frame on the facade, this allowed the structural strengthening system to support the new overhead link bridge, without any modifications made to the exterior façade of the conserved buildings. This also enabled works to be done safely from the interior of the building.

In addition, Er. Foong implemented an innovative foundation strengthening solution for the live electrical substation, from a tight working space at Maxwell Chambers. This was done by adding new micro-piles under the existing footing foundation. By making this careful modification, it safeguarded the integrity of the existing foundation that supports the weight of the existing building in operation and directed the new incremental loads to be safely transferred to the new micro-piles. This also minimised disruption to existing operations at Maxwell Chambers.

PROJECT CREDITS

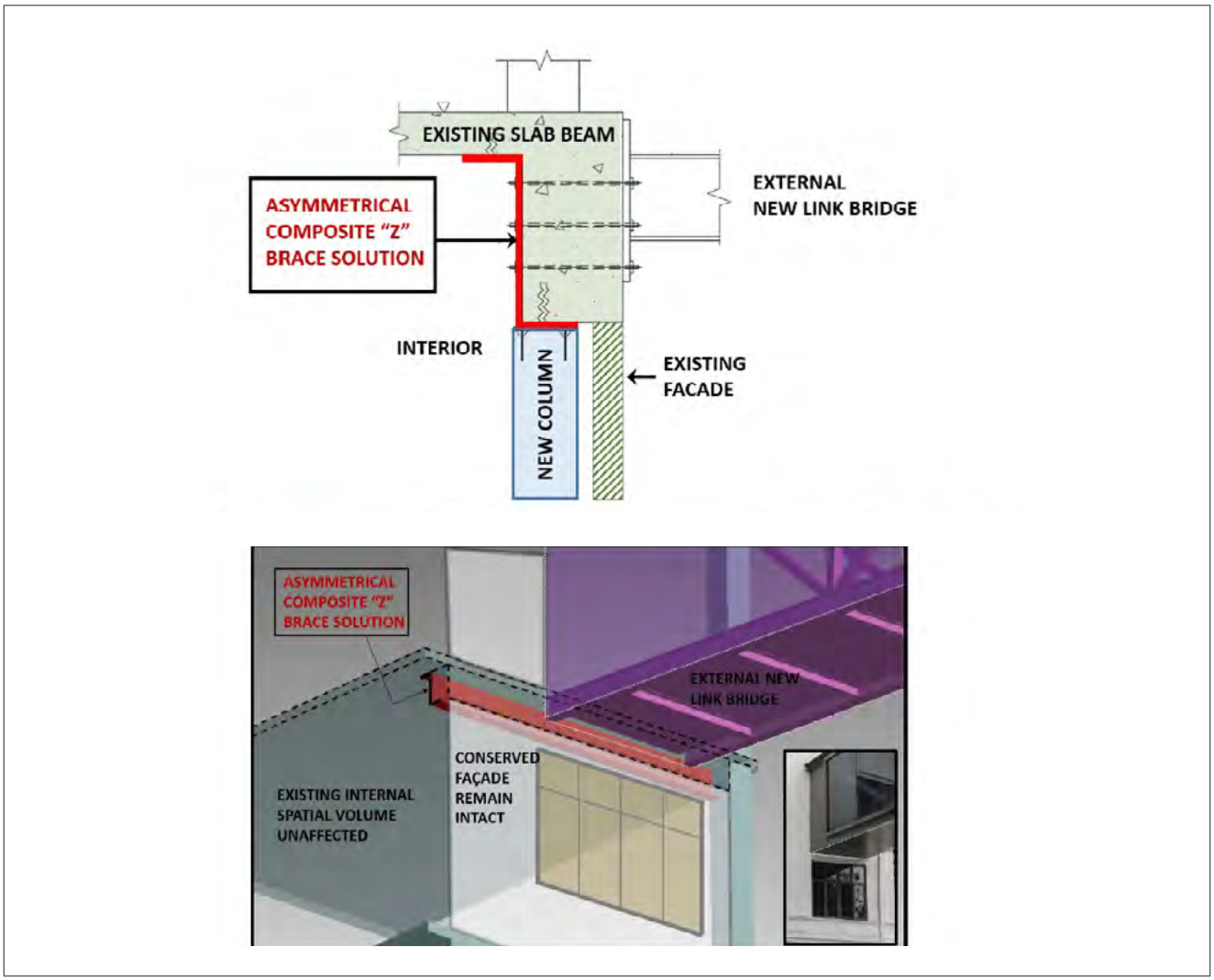
Qualified Person
Er. Aaron Foong Kit Kuen

C&S Consultants
KTP Consultants Pte Ltd

Builder
Guan Ho Construction Co (Pte) Ltd

Developer
Ministry of Law, Singapore

Architectural Consultants
W Architects Pte Ltd



Asymmetrical composite 'Z' brace solution.

Winner of BCA Design Engineering and Safety Award 2020 (Institutional and Industrial Category) Excellence

Singapore Management University (SMU) Connexion

Singapore Management University (SMU) Connexion

Key challenges

- Fast track programme - 15 months construction including piling, main building and ID fitting-out work.
- Construction of a two-storey link building over Fort Canning Link carriageway, to connect to SMU School of Law.
- Extremely tight site and close proximity to sensitive buildings and services.

Solutions

- Innovative hybrid Structural Steel-Cross Laminated Timber (SSCLT) system, adopting extensive off-site fabrication of steel frames and CLT floor slabs for the superstructure. The prefabricated components were erected on site with simple mechanical connections. This system is extremely light-weight, highly buildable and productive. Singapore Management University (SMU) Connexion is the first project in Singapore to adopt this hybrid system.
- Structural design innovation, adopting the light-weight, highly buildable SSCLT system, coupled with a well-strategised sequence, enabled the successful erection of the Link Building structure over Fort Canning Link, within seven days.
- Safeguarding and integration of critical underground infrastructure services into the new building design, to avoid diversion and save time.
- Adoption of Design for Manufacturing and Assembly (DfMA) for other major components like staircases, steel roof, modular M&E and building facade further improved manpower productivity on site.

Successful application of Design for Manufacturing and Assembly (DfMA) techniques

The iconic Singapore Management University (SMU) Connexion is an on-site Net-Zero Energy teaching block in the city. It is also the first building in Singapore to use a hybrid Structural Steel-Cross Laminated Timber (SSCLT) floor system. This innovative solution was chosen for its quick and efficient installation process, in order to mitigate the challenges of onsite space constraints and construction in close proximity to existing occupied buildings.

Er. Kam Mun Wai used prefabricated modular column-beam steel frames for the main building structure. As the frames were designed to be self-supporting, the project team avoided the need for temporary propping during construction. The frames were also of a standard design, allowing faster and safer installation on site. The end result was substantial time savings and reduction of building costs, as there was no need for temporary works. Likewise, the use of CLT panels further reduced construction time as the panels were lightweight, prefabricated to actual dimensions, and easy to install.

Er. Kam and the project team also had to overcome the challenge of constructing a two-storey link building over Fort Canning Link carriageway which had to be temporarily closed for the building works to take place. The project team had to erect the structure quickly and safely, while minimising disruptions around the area. This was accomplished using a similar hybrid SSCLT slab solution. As such, the project team avoided the need to erect temporary support structures over the carriageway. To support the building of the link, a pair of modified Pratt trusses, spanning 27 m across the road, were employed. The lower segments of the trusses were meticulously designed and engineered to support incremental loads from the construction of the upper trusses, floor beams and CLT slab panels. This enabled the concurrent installation of the upper truss segments and CLT flooring. The entire link building structure was completed in a record time of seven days.

PROJECT CREDITS

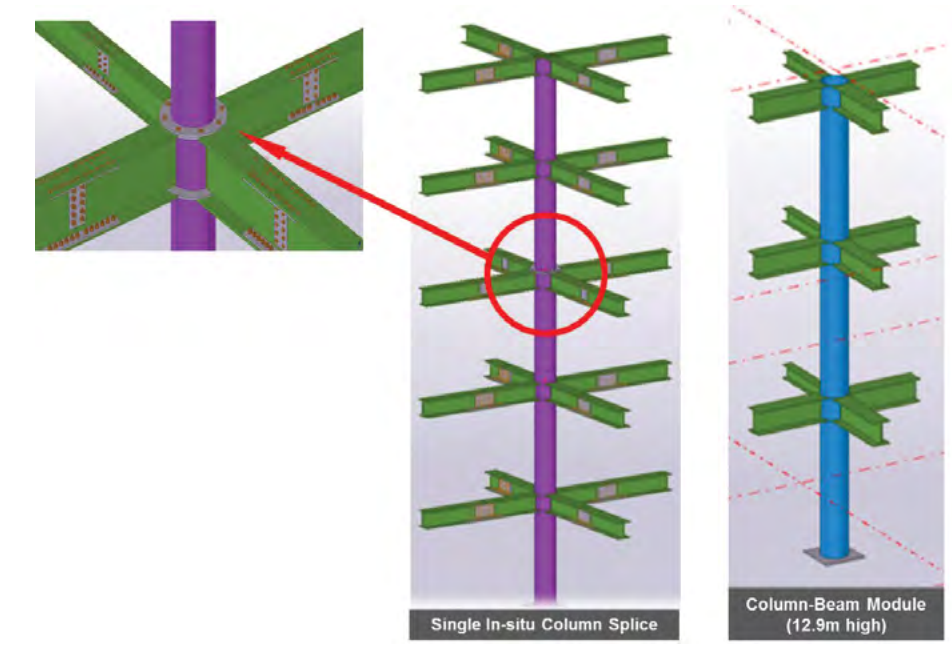
Qualified Person
Er. Kam Mun Wai

C&S Consultants
Meinhardt (Singapore) Pte Ltd

Builder
Lian Ho Lee Construction (Private) Limited

Developer
Singapore Management University

Architectural Consultants
MKPL Architects Pte Ltd



Prefabricated modular column-beam steel frames.

Modified Pratt trusses to support the two-storey link building.

Winner of BCA Design Engineering and Safety Award 2020 (Institutional and Industrial Category) Excellence

Outram Community Hospital

Outram Community Hospital

Key challenges

- The 19-storey building, with four basement levels, had to be built keeping in mind its location next to a live hospital campus and critical roads used by ambulances.
- The site was constrained by railway reserve line restrictions, and the soil strata composed of Jurong Formation made excavation challenging.
- Construction of a 300 m underground tunnel linking Outram Community Hospital's basement to an existing basement meandering under structures such as the 100-year-old Bowyer Block, a National Monument of Singapore at Singapore General Hospital.

Solutions

- A structural steel system was adopted for the superstructure, with steel columns designed in tiers of three floors, reducing craneage requirements, improving productivity, and avoiding site welding and prolonged work at height.
- Pushing boundaries with high-strength Grade 100 concrete-encased steel composite columns, improving productivity, construction speed, and reducing column footprints.
- Earth Retaining Stabilising Structures (ERSS) design, with rigorous site monitoring and numerical analyses, ensured the hospital and MRT operations remained unaffected. A semi top-down method was also adopted for basement construction, primarily to achieve speed of excavation and for the stiffness the ERSS required to limit ground movement.
- Bold designs were also adopted for the 300 m underground tunnel, including excavations under and next to existing roads, skybridge, buildings, tunnels and a historic building, along with carefully considered road diversions, underpinning works and modifications to existing structures.

PROJECT CREDITS

Qualified Person
Er. Jason Tan Bok Leng

C&S Consultants
Arup Singapore Pte Ltd

Builder
Penta-Ocean Construction Co Ltd

Developer
Ministry of Health, Singapore

Architectural Consultants
B+H Architects
CIAP Architects Pte Ltd

Specialist Consultant
WSP Consultancy Pte Ltd

Winner of BCA Design Engineering and Safety Award 2020 (Civil Engineering Category) Excellence

Thomson-East Coast Line Contract T203 TE2 Woodlands Station

Thomson-East Coast Line Contract T203 TE2 Woodlands Station

Key challenges

- TE2 is a two-level underground station with crossover tunnels connected to Woodlands Station NS9 interchange via an elevated transfer link.

  It is also one of the biggest Civil Defence stations in Singapore.

- Constructing the station founded in a mixed-face geology profile and around social and transport infrastructure that are operational.

- Designing around and next to a greenfield earmarked for future development.

Solutions

- Optimising the rail alignment on both ends of TE2 to reduce potential construction risks from the outset, and achieving considerable benefits and conveniences for commuters.

- Placing commuter convenience at the heart of TE2's design, a seamless intermodal transport ambition was achieved with two critical links - an optimised alignment of a slender transfer link bridge between TE2 and NS9, and an underground link from the MRT stations to the bus interchange.

- Considering circular economy principles for the adjacent greenfield, the ERSS wall was designed to be reusable for future excavation and additional knock-out panels were also provided, for future construction.

  This would reduce costs and the carbon footprint for future developers.

- As part of the excavation works, maximum safety during detonation was achieved with a rock blasting simulation and enhanced vibration monitoring at potentially impacted structures.

  A solid protection system was also implemented to prevent and control flying rocks.

PROJECT CREDITS

Qualified Person
Er. Tan Yoong Heng

C&S Consultants
Arup Singapore Pte Ltd

Builder
GS Engineering & Construction Corp

Developer
Land Transport Authority

Architectural Consultants
Aedas Pte Ltd

Singapore companies win Health and Safety Awards

Organisations from Singapore had 80 winning entries at RoSPA Health and Safety Awards 2020.

Every year almost 2,000 entries, representing 7 million employees and 42 countries worldwide, are submitted to the internationally-renowned RoSPA Awards which celebrates high achievement in health and safety, and a commitment to protecting the well-being of staff.

Singaporean companies have this year achieved 61 Gold Awards, 17 Silvers and two Bronzes, while Rotary Engineering Pte Ltd has received the coveted International Sector Award after being Highly Commended in the Construction Engineering Industry Sector.

The International Sector Award, sponsored by Airsweb, is granted to the company with the overall best-performing industry sector entry from outside of the UK. The judges were impressed by Rotary Engineering's clear evidence to support its submission.

Other high-performing organisations from Singapore include Straits Construction Singapore Pte Ltd which was Commended in the Construction, Housebuilding and Property Development Sector; City Developments Limited which received the Order of Distinction for achieving 15 consecutive Gold Awards; and Rotary Electrical & Instrumentation Pte Ltd which received the President's Award for achieving 10 consecutive Gold Awards.

Errol Taylor, RoSPA Chief Executive, said, "The RoSPA Health and Safety Awards are a truly international affair, with organisations from across the globe and from all sectors demonstrating their commitment to employee well-being, and shining a light on best practice to help raise the standard of safety and health globally. With so many high-performing entrants, it is easy to see why Singapore has a safety record to envy. We hope to see more Singaporean entrants in the years to come".

UK-based Royal Society for the Prevention of Accidents (RoSPA) is a 103-year-old safety charity which has Her Majesty The Queen as its Patron, and which has a vision of life, free from serious accidental injury. Its work helps to protect life and limb in occupational environments, as well as in the home, on the road, and in leisure and educational settings.

The RoSPA Awards scheme, which has been running for 64 years, recognises achievement in health and safety management systems, including practices such as leadership and workforce involvement. For the 15th consecutive year, the sponsor of the RoSPA Awards is UK-based National Examination Board in Occupational Safety and Health (NEBOSH).

The RoSPA Awards 2021 opens for registration on 1 October.

THE WORLD'S FIRST 15-CELL CATERPILLAR-SHAPED COFFERDAM DESIGN FOR

TUEN MUN - CHEK LAP KOK LINK IN HONG KONG

The article presents the technical considerations and challenges in both design and construction associated with the innovative caterpillar scheme and its benefits as compared with the conventional approach using straight diaphragm walls.

INTRODUCTION

Tuen Mun - Chek Lap Kok Link (TM-CLKL) is a 5 km sub-sea road link which will provide the most direct route between Hong Kong's Northwest Territories and Hong Kong Island. It forms part of the Hong Kong - Zhuhai - Macau Bridge project which was officially opened in late 2018. The world's longest sea crossing reduces freight and passenger travel time between the three cities to within an hour and plays an important role in promoting the integration of the Greater Bay area.

With an innovative new design and construction approach, the project team successfully overcame the challenges of adverse geology and a tight programme, whilst reducing construction risks and costs.

The uniqueness and challenge of the project was influenced by its large scale. Being constructed in newly reclaimed land added another layer of complexity to the engineering challenge. The key scope of this project was to construct the 630 m long and maximum 33 m wide South Cut-and-Cover Tunnel (SCC) and the Southern Landfall Approach Ramp (SAR) at the southern landfall of the TM-CLKL Northern Connection Sub-sea Tunnel Section site which is a newly reclaimed land with more than 20 m thick marine deposit/alluvium. The maximum excavation depth is around 43 m. Instead of the conventional excavation and lateral support scheme with straight diaphragm walls and steel struts, an innovative idea was developed. The idea was to utilise a 500 m long caterpillar-shaped cofferdam with 15 cells, each of which is formed by perimeter diaphragm wall panels installed in an arc shape and laterally supported by reinforced concrete struts at the locations of specially designed 'Y-panels' - which presents another world first in terms of slurry trench size and complicated reinforcement.

The caterpillar is a sustainable and environment-friendly solution, achieved through substantially reducing the use of steel struts and ground treatment. The success of the project also relied heavily on the combined use of the computer programmes PLAXIS and SAP2000, which enabled the soil structure interaction analysis of the highly complicated ground structure.

Figure 1: Tuen Mun - Chek Lap Kok Link project plan.

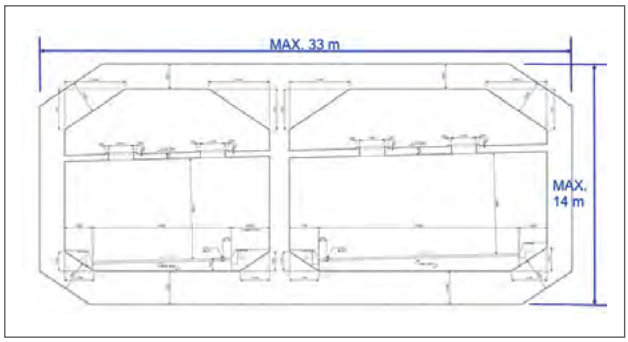


Figure 2: South Cut-and-Cover Tunnel box structure.

The project demonstrates a high level of innovation, engineering excellence and close collaboration between designers and contractors, which have proven to be key to the success of the overall project, adding tremendous social and economic value to Hong Kong and the Greater Bay Area through improved connectivity.

PROJECT BACKGROUND

In August 2013, Dragages-Bouygues Joint Venture (DBJV) was awarded the design and build contract for the TM-CLKL Northern Connection Sub-sea Tunnel Section (Figure 1).

The major works under this contract, which is valued at approximately HKD 18.2 billion, included:

- Reclamation of approximately 16.5 hectares at Tuen Mun Area 40 as the Northern Landfall of the sub-sea tunnel.

Atkins wins award for innovation

Atkins, a member of the SNC-Lavalin Group, has won the 2020 HKIE (Hong Kong Institution of Engineers) Innovation Award for a world-first cofferdam design approach on the Tuen Mun - Chek Lap Kok Link (TM-CLKL) project in Hong Kong.

Due to the complex ground conditions, Atkins, who is supporting Dragages-Bouygues JV on the project, designed the world's longest and largest caterpillar-shaped cofferdam in which TM-CLKL's cut-and-cover tunnel is constructed. At 500 m in length and 43 m in depth, the 15-cell cofferdam design approach could save HKD 500 million to 1 billion and six to 10 months in construction time.

The innovative cofferdam design on TM-CLKL project was also recognised at the 2019 NCE Tunnelling Awards in London. Atkins, alongside Dragages-Bouygues JV, won the Innovation in Design and Delivery Award for the caterpillar-shaped cofferdam for TM-CLKL's cut-and-cover tunnel, and Atkins was also recognised at the 2019 International Tunnel Awards which named TM-CLKL Major Project of the Year with a budget of more than EUR 500 million.

Atkins

Atkins is a design, engineering and project management consultancy, employing over 18,300 people across the UK, North America, Middle East and Africa, Asia Pacific and Europe.

SNC-Lavalin

Founded in 1911, SNC-Lavalin is a fully integrated professional services and project management company with offices around the world.

The 15-cell caterpillar-shaped cofferdam.

- Dual two-lane sub-sea tunnel (two tubes) approximately 5 km long between the Northern Landfall and Southern Landfall, excavated using three slurry-shield Tunnel Boring Machines (TBMs), one of which is the world's largest, with 17.63 m excavation diameter and the other two are identical, with an excavation diameter of 14.00 m.
- Ventilation shafts and buildings, cut-and-cover tunnels and approach ramps at both Northern Landfall and Southern Landfall.

Atkins, a member of the SNC-Lavalin Group, was appointed by DBJV to carry out the design for the Permanent Works (including tunnel structures and its space-proofing, roadworks and drainage) and Temporary Works (mainly the excavation and lateral support) for the Southern Landfall Approach Ramp (SAR) and South Cut-&-Cover Tunnel (SCC), with a total length of about 630 m. The permanent two-cell tunnel box (as shown in Figure 2) is maximum 33 m wide and generally 14 m high, and required maximum 43 m deep excavation within the newly reclaimed land.

STRONG DEMAND FOR AN INNOVATIVE SCHEME

Difficulty with the site geology

The SCC Tunnel is located at the newly reclaimed area at the HZMB Hong Kong Port (HKP). The geological sequence comprises reclamation fill (approximately 15 m thick), marine deposit (approximately 10 m to 15 m thick), then alluvium (approximately 20 m to 30 m thick), and then highly decomposed granite, meta-siltstone or meta-sandstone (with varying thickness) before reaching engineering rockhead. The excavation is maximum 43 m deep and based on the geotechnical interpretation, it would encounter soft clay layers (marine clay and alluvial clay) of around 30 m thick. Figure 3 shows the geological profile along the SCC Tunnel.

The site geology which is particularly variable as regards the continuity of alluvial sand layers, together with the potential impact on nearby sensitive receivers, imposed more difficulties and risks for the conventional scheme, with straight diaphragm wall (D-wall) and steel struts, to work within the project time-frame and budget.

The caterpillar scheme versus the conventional scheme

An initial scheme utilising the conventional straight D-wall was studied (Figure 4).

Up to nine layers of closely-spaced (approximately 4 m vertically and minimum 6 m horizontally) strutting with large steel members are required. Moreover, it would need extensive ground strengthening works below/near the excavation level to strut the D-wall, since the untreated soft ground layers cannot provide sufficient lateral stiffness for the D-wall.

In addition, two TBMs of 14 m diameter had to break through at the northern end of the cofferdam. The space would be extremely tight for the cofferdam, with such close strut spacings.

Also, the risk level in adopting the conventional scheme for deep excavation in soft clay could not be overlooked. Taking into account some past failures, the Designer seriously considered the risk, particularly the uncertainty in the strut design. For instance, the strut/waler connection is designed as 'pinned' but is rigidly connected on site. The rigidity could induce additional bending on the strut when the wall bends.

The idea of the 15-cell caterpillar cofferdam (Figure 5), which counts on the D-wall panels in an arc shape and eliminates the closely spaced steel struts, was developed and implemented.

Instead of the steel struts, reinforced concrete struts with average vertical spacing of 8 m and a minimum horizontal spacing of 25.5 m were used. More details are given elsewhere in the article.

The advantages of the caterpillar cofferdam scheme over the conventional scheme, in terms of safety and economics, are as follows:

- From the environmental point of view, the innovative caterpillar cofferdam has eliminated over 21,000 t of steel and 80,000 m³ of ground treatment. This reduces the carbon footprint generated from the material production and transportation, and enhances the sustainability.
- Site safety was greatly enhanced with no propping works at height and no heavy strut liftings for installation and removal. The risk of site congestion due to strutting was eliminated and excavation plants were able to work in an unrestricted manner.
- The elimination of congested steel struts allows fast-tracking of all related activities, including excavation, retrieval of TBMs and construction of the tunnel box structures. The RC struts for the caterpillar are arranged to provide a clear headroom of 16.5 m above the formation level, which allows using travelling formworks for the permanent structures. Re-propping / box-out, during the construction of the permanent tunnel structures, necessary if using steel struts, was not required. This reduces the number of construction joints (CJ) and subsequently the risk of potential water seepage/leakage through the CJ. Ultimately the maintenance cost could be reduced and sustainability is enhanced considering the whole life cycle.
- In terms of the construction programme, savings of 6 to 10 months was forecast, compared to the conventional scheme.

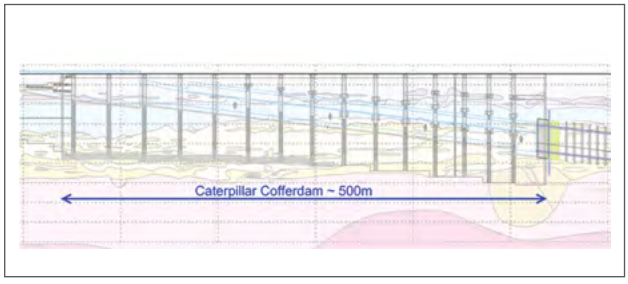


Figure 3: Geological profile along South Cut-and-Cover Tunnel.

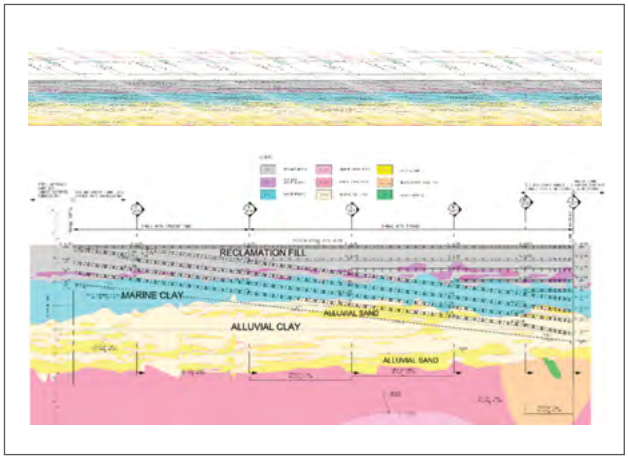


Figure 4: Conventional Excavation and Lateral Support (ELS) Scheme (plan and longitudinal section) with straight D-wall and steel struts.

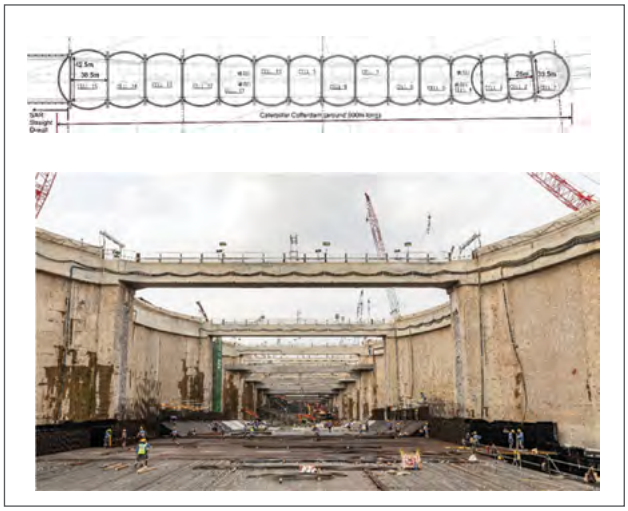


Figure 5: Caterpillar layout.

- Due to the geometric nature of the perimeter arc D-walls for the caterpillar scheme, destabilising pressure at the D-wall toe, from the retained side, is resisted by the hoop action among the arc D-walls and eventually transferred to the Y-panels and cross walls. Hence, the toe stability against kick-out failure was not a concern. The caterpillar D-wall embedding depth and toe grouting could then be substantially reduced as compared with the conventional scheme.

GENERAL ARRANGEMENT OF THE CATERPILLAR

The typical arrangement of the caterpillar cofferdam and the load transfer are shown in Figure 6. The caterpillar consists of 15 cells, each of which is formed by perimeter D-wall (1.2 m or 1.5 m thick) panels arranged in an arc shape, which will resist lateral pressures mainly by means of hoop force. The longitudinal span of the cells varies from 25 m to 36.5 m and the radius of curvature of the arc D-wall varies from 22 m to 28.5 m.

At the interface between cells, the hoop forces induced on the perimeter arc D-walls will be transferred to the 'Y-panels' (Figure 7 shows the geometry) which are hammer-shaped with overall 6.5 m length and maximum 3.6 m width, constructed by 5-bite D-wall trench excavation. More details are given elsewhere in the article.

The Y-panels are laterally supported by the reinforced concrete struts vertically spaced at around 8 m to 11 m centre-to-centre, with maximum three layers at the deepest excavation and a single layer at the shallower section. The RC struts are typically 2 m wide x 2 m deep, but some of the lowest struts are 3.2 m wide x 2.8 m deep. The bottom corners of the lowest struts are chamfered to reduce the Y-panel bending moment. At the strut connection with the Y-panel, the 'wing corbel' (Figure 8) was proposed for strengthening.

Cross walls, in the form of continuous D-wall panels (1.2 m or 1.5 m thick), laterally support the Y-panels below the final excavation level. Above the cut-off levels of the cross wall panels, the excavated trenches were backfilled with lean concrete to provide pre-support to the Y-panels before the RC strut installation, so that the bending moment of the Y-panels could be reduced.

A capping beam, generally 2 m wide x 2 m deep and widened at the location of the Y-panel, is provided on top of the perimeter arc D-walls and Y-panels to enhance the cofferdam integrity. Figure 9 shows the typical ELS section at the Y-panel location.

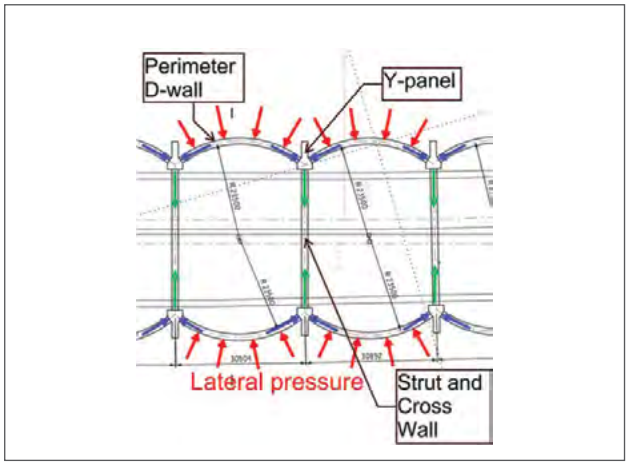


Figure 6: Typical arrangement of caterpillar cells and load transfer.

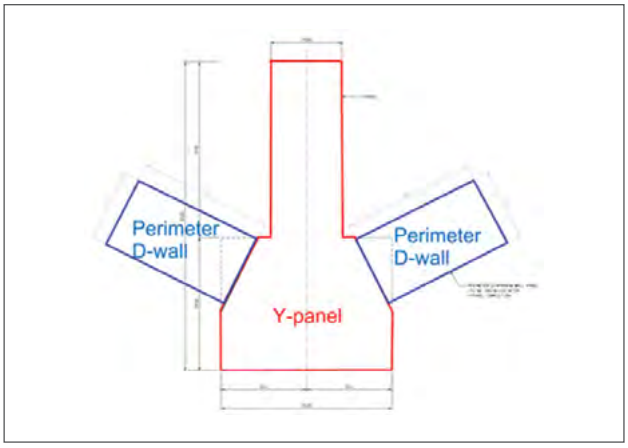
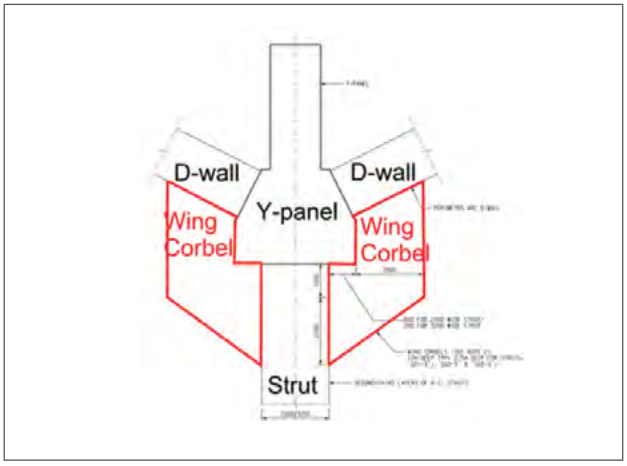


Figure 7: Y-panel geometry.



Figuer 8: Wing corbel for strut.

Figure 9: Typical ELS cross section showing the lateral support.

TECHNICAL CONSIDERATIONS AND CHALLENGES

Axisymmetric analyses, using the computer programme PLAXIS 2D (Figure 10), which take into account the soil-structure interaction, were performed to evaluate the lateral earth pressures, water pressures and ground spring stiffness, which were then input to the structural analysis models. Seepage analyses and staged excavation were considered in the PLAXIS axisymmetric analyses to calculate the lateral earth pressures and pore water distribution inside and outside the excavation, resulting from pumped dewatering below the excavation.

The 'PLAXIS' analyses were conducted for each caterpillar cell with a different excavation depth and design geological profile.

Three-dimensional structural analyses of the caterpillar cofferdam were then performed using the computer programme SAP 2000. The SAP2000 analyses account for the three-dimensional geometry of the caterpillar cells, including the D-wall openings at the TBM breakthrough and the strengthening tympanum. The perimeter arc D-wall, cross walls, struts and Y-panels are represented by a series of thin-shell elements. The ground medium surrounding the perimeter D-wall is represented by a series of area springs perpendicular to the shells. In case of tension, the ground springs are ignored and no reaction is given to the D-wall.

Considering the total length of around 500 m for the 15-cell caterpillar cofferdam, its structural analyses were split into three models, each of which was assigned with the appropriate boundary restraints. PLAXIS 3D analysis, which takes into account the soil-structure interaction, was also used to study the overall behaviour of the caterpillar, in terms of movement and induced forces, and compared with SAP2000 models.

After having presented the general design and analytical approach, the following sub-sections highlight some specific considerations and challenges in terms of both design and construction of the caterpillar.

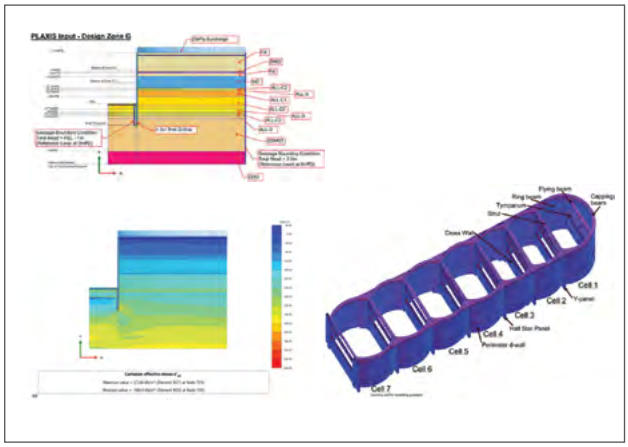


Figure 10: Analysis models for caterpillar.

Longitudinal stability

An arch structure primarily counts on the lateral restraint at its support. Hence, at the early design development stage, it was realised that the longitudinal stability would be crucial for the caterpillar cofferdam which, in principle, counts on the arching effect to resist the lateral loads. To achieve this objective, the arc radius and longitudinal span of each cell had to be calculated in relation to its adjacent cells. From the Contractor's point of view, it would have been preferable to have a larger radius and span (in principle, the shallower the excavation, the larger the cell radius and span could be) so that there would be less excavation volume and also less cross wall/Y-panels. However, the Designer had to optimise these geometric parameters in parallel with the consideration of the structural capacities of the Y-panels and cross walls, as well as minimise the unbalanced load in the longitudinal direction between adjacent cells (Figure 11).

D-wall panel joint in structural modelling and design

The caterpillar cofferdam primarily consists of D-wall panels and hence it is not possible to have rebar continuity across the panel joints. When subjected to the combined effects of hoop (i.e. horizontal) axial force and bending moment, these joints can only act in compression but not in tension. 'Tension cut-off' (i.e. no tensile stress) was assigned to the D-wall elements in the SAP2000 structural analysis to mimic this behaviour.

The perimeter D-wall structural capacity subjected to the hoop forces was checked using the moment-axial force (M-N) interaction diagram, assuming plain concrete, to account for the rebar discontinuity at the panel joints. In the M-N interaction diagram, the governing parameters for the structural capacity are D-wall concrete grade and thickness. For the latter, reduced contact thickness at the D-wall panel joints that resulted from the verticality tolerance was duly considered.

In view of the above design considerations, the verticality control on site is more stringent as

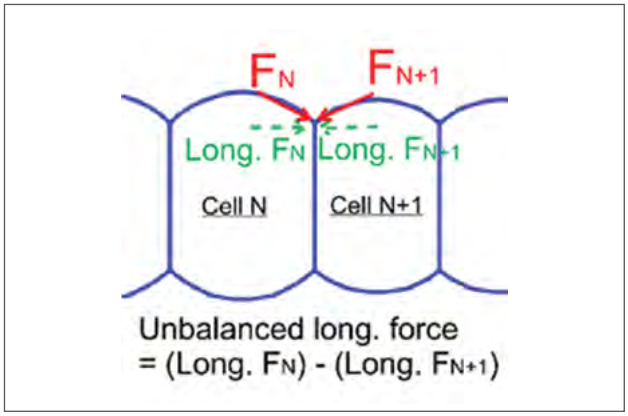


Figure 11: Unbalanced longitudinal load.

compared with the conventional straight D-wall. Generally a maximum 1:200 verticality is specified, whilst for some other panels with less design margin, a maximum 100 mm relative dislocation between adjacent panels is required. And for Y-panels, which are the key structural elements of the caterpillar scheme, the maximum verticality is 1:400.

Y-panels

The Y-panels are key structural elements in the caterpillar scheme as all the perimeter D-walls transfer the loadings to them.

For ease of permanent tunnel structure construction, the levels of the lowest struts were arranged to provide the required clear headroom (around 16.5 m) without any obstacles. The Y-panel cross-section had to be sufficiently large to limit the ultimate shear stress (corresponding to a maximum factored shear force of around 73,000 kN), in accordance with the design standard. The wide front end (3.6 m) provided much more space for the main bars on the excavation face and allowed the stacking of sufficient rebar to take the extreme bending moments (maximum factored is 310,000 kNm). Other than the concern on the structural capacity, the Y-panel geometry had to suit different cell radii and spans, as well as the trench excavation methodology.

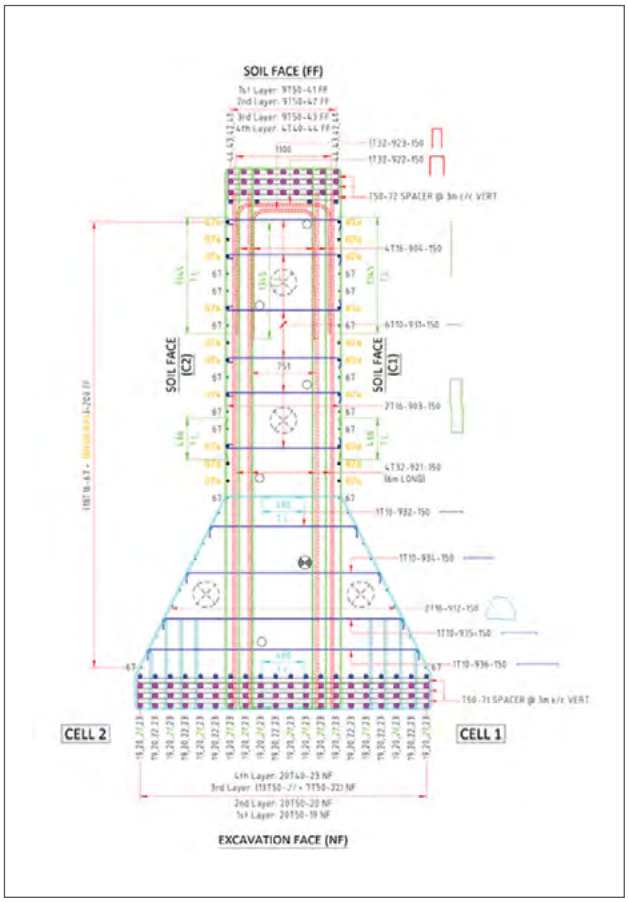


Figure 12: Y-panel cross section.

Subject to the point of action from the perimeter D-walls (similar to a bottom-loaded beam), tension tie bars were required which made the Y-panels more congested, with rebars already required for bending and shear (Figure 12 shows the heavily reinforced Y-panel cross section). The extremely heavy rebar cage (maximum 135 t) made the steel fixing as well as lifting operation on site difficult. A combination of prefabricated rebar cages and in-situ fixed cages were used for one single Y-panel. Large cranes up to 400 t capacity and up to triple lifts were utilised for cage lifting (Figure 13). In terms of rebar detailing, the reinforcement arrangement had to allow for other D-wall installation provisions like grout tubes, sonic tubes and D-wall stop-end, and hence there was high demand for rebar optimisation.

In order to excavate a trench 6.5 m long, 3.6 m wide at its base, and 55.5 m deep for the deepest Y-panel, a 5-bite excavation solution was required (Figure 14). There was no previous experience for such a trench (15.6 m² cross sectional area and 860 m³ volume). Cement-soil mixing (CSM) was adopted around the excavation perimeter as ground strengthening works, in addition to bentonite slurry within the trench excavation.

Figure 13: Y-panel rebar cage lifting operation.

Three-dimensional PLAXIS analysis (Figure 15) was performed to evaluate the trench stability. Trials with the panels were conducted on site, together with instrumentation (ground settlement markers and inclinometers) and monitoring, to verify the trench stability for Y-panel excavation with CSM before fully implementing the ground strengthening works.

SUMMARY AND CONCLUSION

The successful design and construction of the large-scale 15-cell caterpillar-shaped cofferdam on newly reclaimed land is a significant milestone for Hong Kong's construction industry and tunnelling, worldwide. During construction, a stringent instrumentation and monitoring plan was implemented on site, which included the installation of ground settlement markers, D-wall movement markers and inclinometers, piezometers, strain gauges in struts etc. Inclinometers were installed on every Y-panel which was considered as a critical structural element in the caterpillar scheme. Design reviews were conducted at intermediate excavation stages, based on monitoring records.

The caterpillar cofferdam was successfully backfilled without obstruction, in May 2020. With the objectives of completing the strategic project safely, on time, on budget and with the least environmental impact, the challenging and unique project benefitted greatly from the innovative design approach, state-of-the-art design software and close collaboration between stakeholders.

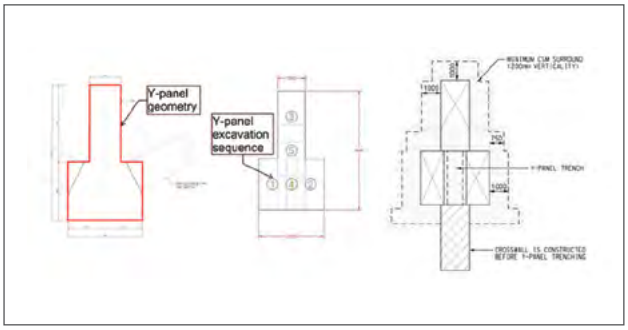


Figure 14: 5-bite trench excavation for Y-panel.

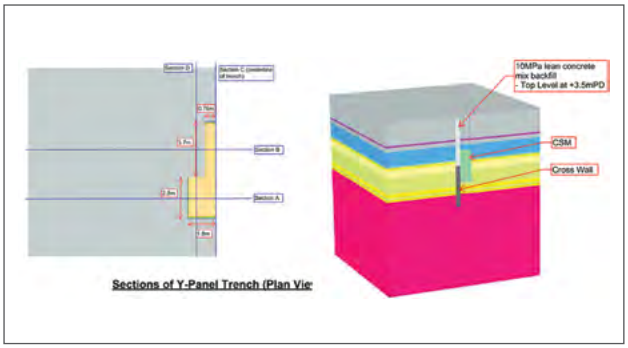


Figure 15: 3D PLAXIS analysis for Y-panel trench stability.

All images by Atkins

Infrastructure leaders predict recovery within 18 months

Atkins recently shared the findings of its independent research which assesses the impact of COVID-19 on the UK infrastructure sector, measures confidence, and explores the roles of government and the private sector during recovery.

The work, which was carried out by the independent market research organisation, Savanta ComRes, on behalf of Atkins, involved a comprehensive survey of senior public and private sector decision-makers across different subsectors within infrastructure, particularly transport, property and utilities.

In total, 398 responses were obtained via an online survey during June and July 2020 and eight in-depth interviews were conducted.

The report, entitled 'Infrastructure Insights: COVID Impact and Recovery', found that while the industry has been impacted by the pandemic, with organisations reporting that 16% of the work they had immediately before COVID-19 had been postponed or cancelled completely, 52% of senior decision-makers were confident that they would see outlooks for the sector return to pre-crisis levels by Q4 of 2021.

In the private sector, almost seven in 10 respondents predicted a return to their organisation's pre-crisis outlook before the end of next year.

The report also reveals that 65% of senior decision-makers would like to see the government provide a clear roadmap to help the sector with the recovery from COVID-19, while 53% want to see increased spending beyond the 2020 budget commitments, and 53% called for better co-ordination between the central and local governments.

There is general agreement that the sector will not emerge from the crisis in the same form, with the vast majority of respondents agreeing that digital innovation will be increasingly important. It is also clear that senior decision-makers want to see digital innovations from the design, engineering and consultancy sector help support their organisations during the COVID-19 crisis and recovery.

Richard Robinson, Atkins UK&E CEO said, "The findings set out in this report represent a compelling and powerful take on the sector and its path forward.

"While it is clear that we need a finalised National Infrastructure Strategy to give us more clarity and confidence, there is an expectation for the private sector to step up the use of technology and data to accelerate the recovery, by building back smarter as well as better", he added.

Atkins' 'Infrastructure Insights: COVID Impact and Recovery' may be downloaded from the company's website.

AWARDS FOR 36 ORGANISATIONS

INVOLVED IN 18 OVERSEAS PROJECTS

Recognition given to developers, consultants and builders.

Singapore's Building and Construction Authority (BCA) has introduced the SGBuilds Awards to recognise the outstanding efforts made by local firms in forming strong partnerships with their local and international partners to venture overseas. Award winners are recognised in the Developer, Consultant and Builder categories, with the pinnacle SGBuilds Star Award category given to exceptional firms.

Success in India for Singapore team

CapitaLand, one of Asia's largest diversified real estate groups, is the first winner in the SGBuilds Star Award (Developer) category for the group's exemplary collaboration with Singapore firm L&W Construction Private Limited (L&W) to develop International Tech Park Pune, Kharadi (ITPP-Kharadi), Block 1, in Pune, India. The park is being developed under CapitaLand's private fund, Ascendas India Growth Programme.

CapitaLand's partnership with L&W began in 2009, when it appointed the joint venture established by two Singapore construction-related companies, Lee Kim Tah Pte Ltd and Woh Hup Holdings Pte Ltd, to develop Zenith building in International Tech Park Chennai, in Chennai, India. The partnership with CapitaLand marked their first foray into India's construction industry. Since then, CapitaLand and L&W have gone from strength to strength, with several CapitaLand International Tech Park developments in major cities across the country. ITPP-Kharadi is the 11th collaboration by the team in India.

Ms Goh Ah Moi, Chief Development Officer, Singapore and International, CapitaLand Group, said, "We are honoured to be the first real estate company to receive the top accolade by winning the SGBuilds Star Award, for ITPP-Kharadi. As a responsible developer, CapitaLand strives to deliver quality developments that enrich people and build communities where we operate. When we expand globally, we work with partners who share our vision, ambition for growth and focus on excellence. Being a Singapore company that has made our mark internationally through our world-class properties, CapitaLand is in a strong position to lend our expertise and local knowledge to help fellow Singapore companies expand overseas. During these challenging times, we continue to stand with our partners to ride through this rough patch together".

Sustainable solutions for the Micronesia archipelago

TW-Asia Consultants Pte Ltd (TW-Asia) is the winner in the SGBuilds Star Award (Consultant) category for its iconic eight-storey resort development at Palau Island, Republic of Palau. Slated for completion in 2021, the resort was the brainchild of a team of creative and sustainability experts which TW-Asia brought together. The team, comprising TW-Asia Consultants Pte Ltd, Park + Associates Pte Ltd, and United Project Consultants Pte Ltd, proved that it was adventurous with a pioneering spirit when it answered the call of opportunity in a less accessible location, Palau, considered to be a 'new frontier' by many in the built environment sector. Adding diversity to the island's vernacular architecture, the team introduced a sleek resort development which allows occupants to enjoy the beauty of nature and the comfort of a modern building envelope, at the same time.

The project proposal took into careful consideration the environmental and societal concerns of the residents as well as the availability of construction materials. The project adopted a holistic solution based on BCA's Green Mark scheme, and incorporated environmental best practices in water conservation, waste management, energy efficiency, the use of renewable energy, drainage systems, and preservation of the surrounding environment and ecosystem.

Ms Maey Leow, Director of TW-Asia said, "The project has won the hearts of locals - this was validated through feedback from a survey done with neighbouring residents. We are delighted with this outcome and it bears testament to the team's vision to create an inclusive and ethical development. It will set the stage for future growth opportunities".

Building expertise and construction solutions for Cambodia

Utracon Overseas Pte Ltd (Utracon) is the winner in the SGBuilds Star Award (Builder) category for securing a project to build an industrial and secured storage building complex for the National Bank of Cambodia. Recognised for its expertise in the post-tensioning specialist trade, Utracon assisted by bringing together architectural, engineering and project management expertise from five other firms. The five companies are Atelier International Management Pte Ltd, IX Architects Pte Ltd, Chee Choon & Associates Pte Ltd, Leng Consultants and VP Engineers. Through their collaboration, they were able to provide a high quality and cost-effective construction method for the client, without compromising on the time-line for the project. As a result of the successful collaboration, Utracon was awarded a third project by the same client.

Explaining, on behalf of the team, how the six Singapore companies banded together, Mr Khoo Jyh Hao, Utracon Overseas Pte Ltd, said, "Finding like-minded and motivated

firms is important particularly for international projects. Being able to venture out internationally is already challenging. On top of that, constructing a sensitive and secured project for a well-established client is something that many would not take on. We were fortunate to have been able to team up with Atelier International Management Pte Ltd with its vast market familiarity in Cambodia and also our other partners for their respective expertise, with the goal of achieving the best project outcome".

Mr Hugh Lim, CEO, BCA, said, "It has been almost three years since we launched the Construction Industry Transformation Map in October 2017. Since then, we have worked towards fulfilling our vision of an advanced and integrated sector; with progressive and collaborative firms offering good jobs for Singaporeans. The SGBuilds award is a good recognition of industry efforts in fulfilling this vision through internationalisation in a collaborative manner. We hope that these awards will inspire other Singapore firms across the entire BE value chain to consider how to pool their capabilities and resources to venture into new markets overseas. We are confident that Singapore firms will have strong solutions that can meet emerging needs of a post-COVID world. With tighter resources, Singapore companies, more than ever, must work together to be ready to pursue opportunities at home and abroad. This must be the hallmark of the SGBuilds spirit, to power us to emerge from COVID-19 stronger, together".

RECIPIENTS OF THE SGBUILDS AWARDS

Developer Category

Building Name	Location	Team	Award
International Tech Park Pune, Kharadi, Block 1	Pune, India	Developer: CapitaLand Limited Builder: L&W Construction Pvt Ltd	SGBuilds Star Award (Developer Category)
Estela Place (Retail) & Estella Heights Phase 2 (Apartment)	Ho Chi Minh City, Vietnam	Developer: Keppel Land Vietnam Architect: DP Architects Pte Ltd	SGBuilds Award (Developer Category)
The View – Riviera Point Phase 2	Ho Chi Minh City, Vietnam	Developer: Keppel Land Vietnam Architect: DP Architects Pte Ltd Local Architect: Atelier Management & Design Consultancy (Vietnam) Co Ltd C&S: Tham & Wong Vietnam Co Ltd Sustainability Consultant: Building System & Diagnostics Pte Ltd	SGBuilds Award (Developer Category)
Velona at Saigon Sports City	Ho Chi Minh City, Vietnam	Developer: Keppel Land Vietnam Architect: DCA Architects Pte Ltd Interior Designer: Index Design Pte Ltd Sustainability Consultant: G-Energy Global Pte Ltd	SGBuilds Award (Developer Category)
Palm City: Palm Heights	Ho Chi Minh City, Vietnam	Developer: Keppel Land Vietnam Architect: Architect 61 Pte Ltd Sustainability Consultant: Building System & Diagnostics Pte Ltd	SGBuilds Award (Developer Category)
Wuxi Park Avenue Heights Phase 3 & 4	Wuxi, China	Developer: Keppel Land China Limited Architect & Landscape Designer: Ong & Ong (Chengdu) Consultants Pte Ltd	SGBuilds Award (Developer Category)
International Water Hub	Nanjing, China	Developer: Sembcorp Development Ltd QS & Cost Consultancy: Surbana (Shanghai) Planning and Design Consultant Co Ltd Lab Design Consultancy: Jurong International Engineering (Suzhou) Co. Ltd End user involvement to co-design the lab and research facility spaces: NUS-Centre for Water Research	SGBuilds Award (Developer Category)
411-421 Smith Street Fitzroy	Melbourne, Australia	Developer: City Developments Limited (CDL) Architect: K2LD Architects Pte Ltd	SGBuilds Award (Developer Category)
Autograph Apartment	Jakarta, Indonesia	Developer: Keppel Land Indonesia Façade Consultant: Meinhardt Façade Technology Interior Design: The ID Dept Pte Ltd	SGBuilds Award (Developer Category)
The Stature	Jakarta, Indonesia	Developer: CapitaLand Limited Builder: Woh Hup Pte Ltd	SGBuilds Award (Developer Category)

INTERNATIONAL TECH PARK PUNE, KHARADI, BLOCK 1

Winner of SGBuilds Star Award (Developer Category)

Located in the prime eastern corridor of Pune, ITPP-Kharadi is a 2.5 million ft² IT/IT Special Economic Zone park comprising two office blocks and an incubation block that provides companies with fully fitted office spaces for immediate occupancy. The IT park's sustainable features include an urban farm, rooftop solar panels to generate renewable energy, double-glazed facades for energy efficiency, and organic waste converters. The park is being developed under CapitaLand's private fund, Ascendas India Growth Programme, in which Singapore's sovereign wealth fund, GIC, is a principal investor. With a built-up area of 1.3 million ft², Block 1 comprises four levels of parking and two wings with 12 and 14 floors of premium office space. The block is estimated to be completed by mid-2021.

Consultant Category

Building Name	Location	Team	Award
Eight-Storey Hotel Development, Palau Island	Palau	C&S: TW-Asia Consultants Pte Ltd Architect: Park + Associates Pte Ltd M&E: United Project Consultants Pte Ltd	SGBuilds Star Award (Consultant Category)
Deira Waterfront Development, Phase 1, Plot 1-2 & 5-10	Dubai, United Arab Emirates	Architect/Lead Consultant: DP Architects Pte Ltd Irrigation Consultant: Netatech Engineering Pte Ltd	SGBuilds Award (Consultant Category)
One Equine	Selangor, Malaysia	Lead Consultant: Surbana Jurong Developer: Beverly Group (subsidiary of Qingdao Investments Pte Ltd)	SGBuilds Award (Consultant Category)
Review of Overall Lusail City Master Plan	Lusail City, Qatar	Infrastructure Planner: Surbana Jurong Master Planner: DP Architects Pte Ltd	SGBuilds Award (Consultant Category)

EIGHT-STOREY HOTEL DEVELOPMENT, PALAU ISLAND

Winner of SGBuilds Star Award (Consultant Category)

The eight-storey hotel development on Palau Island, consists of two mezzanine floors, basement and communal facilities at ground and roof levels. Occupying a site area of 4,027 m², the development comprises 148 units of studios and one-bedroom apartments.

As the island is not easily accessible via flights, the design of the structures is governed mainly by the capabilities of the local builders on the island, and the design is therefore suited to their construction methods. Steel construction is used largely as the main structural frame support for the building. The partner firms hold regular meetings in Singapore to ensure that the project moves forward successfully.

Builder Category

Building Name	Location	Team	Award
Industrial and secured storage building complex for the National Bank of Cambodia (Blk 4)	Cambodia	Post Tensioning: Utracon Overseas Pte Ltd Architect: IX Architects Pte Ltd M&E: Chee Choon & Associates Pte Ltd C&S: Leng Consultants Engineering Design: VP Engineers Project Management: Atelier International Management Pte Ltd	SGBuilds Star Award (Builder Category)
Capgemini Campus	Pune & Mumbai, India	Builder: L&W Construction Pvt Ltd C&S: Buro Engineering Pte Ltd Interior Concept Design: DPD International Pte Ltd Post Tensioning: Utracon Corporation Pte Ltd	SGBuilds Award (Builder Category)
Commercial Development for Havelock City	Colombo, Sri Lanka	Post Tensioning: Utracon Overseas Pte Ltd Architect/Structural Engineer: P&T Consultants Pte Ltd	SGBuilds Award (Builder Category)
Lucky Square Development	Yangon, Myanmar	Developer: Top Global Engineering and Trading Pte Ltd Project Management: Evan Lim & Co Pte Ltd, CKR Holding Pte Ltd Consultants: Struts Building Technology Pte Ltd, PTM Builders Pte Ltd	SGBuilds Award (Builder Category)

INDUSTRIAL AND SECURED STORAGE BUILDING COMPLEX FOR THE NATIONAL BANK OF CAMBODIA (BLK 4)

Winner of SGBuilds Star Award (Builder Category)

The industrial and secured storage building complex for the National Bank of Cambodia (Blk 4) is a six-storey industrial/secured storage facility in pre-stressed concrete, with one basement level. Post-tensioned slabs used for this project enable it to support heavy loading of up to 70 kPa, which is uncommon even for industrial warehouses. The post-tensioned slabs, with a thickness of 525 mm, also allows for column grid spacing of 11.5 m x 8.4 m, which eases arrangement of heavy equipment on the floor slab.

Having delivered the first project successfully, the client is confident of the performance of the project team for this second project. Throughout the project, the firms have worked closely together through regular meetings, both in Singapore and Cambodia, to establish trust and rapport.

RESTORATION AND CONSOLIDATION

OF A 14TH CENTURY CHURCH IN ITALY

Effective and long-lasting products have been used in the restoration and consolidation of a church badly damaged by the passage of time.

Built in the 14th century, the Church of San Paolo Eremita recently underwent structural strengthening and renovation of the masonry.

The Church of San Paolo Eremita (St Paul the Hermit) is one of the most important sites that highlight the cultural heritage of the city of Brindisi in Italy.

The Naples State Archive conserves the most ancient document making reference to the church - a solemn ordinance dating back to 2 March 1284 whereby Charles I of Anjou, King of Naples, granted permission for Franciscan monks to build a monastery and church, which went on to be completed in 1322.

Conservative restoration and consolidation work on the interior and exterior of the church commenced in November 2016 and was completed over a period of two years. The work also included an overhaul of the roof over the aisle, the replacement of the wooden trusses for the apse and the new pitched roof, a thorough cleaning of all the altars, and consolidation of the stone features and elements of the altars.

Winning teamwork on site

The complex work commenced with a preliminary study carried out by Luigi Dell'Atti, a local architect who also guided the team of restorers. Right from the start of the design work, the team was assisted by Mapei Technical Services, with specialists from various product lines also involved. When more significant problems regarding static consolidation arose, Prof Alberto Balsamo from the Federico II University of Naples was also called upon to provide assistance.

This team-synergy approach also included the active participation of the main contractor, Nicolì SpA, which enabled the product systems to be identified and modulated, to overcome the problems that arose regarding the structural strengthening, dehumidification and protection of both the interior and exterior of the church.

Static consolidation of the stone structure

MAPE-ANTIQUE F21 binder was used to consolidate the stone structure and limestone vaulted ceiling of the church. This is a cement-free, salt-resistant product made from lime and Eco-Pozzolan used to make super-fluid, volumetrically stable slurries, and it was injected into the structure by using low-pressure pumps.

For the installation layers and for pointing of the 'natural finish' masonry of the church, on the other hand, the product chosen was MAPE-ANTIQUE ALLETTAMENTO salt-resistant masonry mortar, made from natural hydraulic lime and Eco-Pozzolan, and which is available in seven colours.

Consolidation of the surface of the masonry

The surface of the masonry was consolidated in several steps. The first step was to pre-consolidate the surfaces with PRIMER 3296, an acrylic primer in water dispersion.

The larger cracks in the surface were then stitched with CARBOTUBE C 170/10 (pultruded carbon fibre tubes impregnated with epoxy resin) in combination with INJECTORS Ø23+MAPE-ANTIQUE F21.

Consolidation of the vaulted ceilings

The vaulted ceilings were consolidated by capping them with MAPEANTIQUE STRUTTURALE NHL, a pre-blended, cement-free mortar for transpirant render and masonry work, based on natural hydraulic lime, Eco-Pozzolan, recycled materials, natural sands, micro-fibres, glass fibres and special admixtures.

The use of this product, in combination with MAPENET EM 40 pre-impregnated, alkali-resistant glass fibre mesh (FRP) and MAPENET EM CONNECTOR 7 mm diameter and 200 mm long fibreglass connectors, formed a reinforced layer suitable to consolidate the extrados (exterior curve) of the sandstone vaulted ceilings.

The joints were reinforced with 6 mm diameter MAPEI STEEL BAR 316, ultra high-strength, AISI 304 and AISI 316 stainless steel helical bars, used in combination with MAPE-ANTIQUE ALLETTAMENTO.

MAPE ANTIQUE F21 super-fluid binder was injected through small tubes using low-pressure pumps to consolidate the stone structure.

For the installation layers and for pointing of the 'natural finish' masonry of the church, the product chosen was MAPE-ANTIQUE ALLETTAMENTO salt-resistant masonry mortar, made from natural hydraulic lime and Eco-Pozzolan.

The wooden trusses were consolidated and restored using products from the MAPEWOOD SYSTEM (MAPEWOOD PRIMER 100 and MAPEWOOD PASTE 140).

Consolidation and restoration of the wooden trusses

The wooden trusses were consolidated and restored, using products from the MAPEWOOD SYSTEM. This line of products is made from special epoxy adhesives chemically and physically compatible with wood.

The surface of the wood was initially treated with MAPEWOOD PRIMER 100 - a fluid epoxy primer in water dispersion - and then with MAPEWOOD PASTE 140, a thixotropic epoxy adhesive for repairing wooden beams, trusses and columns.

The dehumidifying system

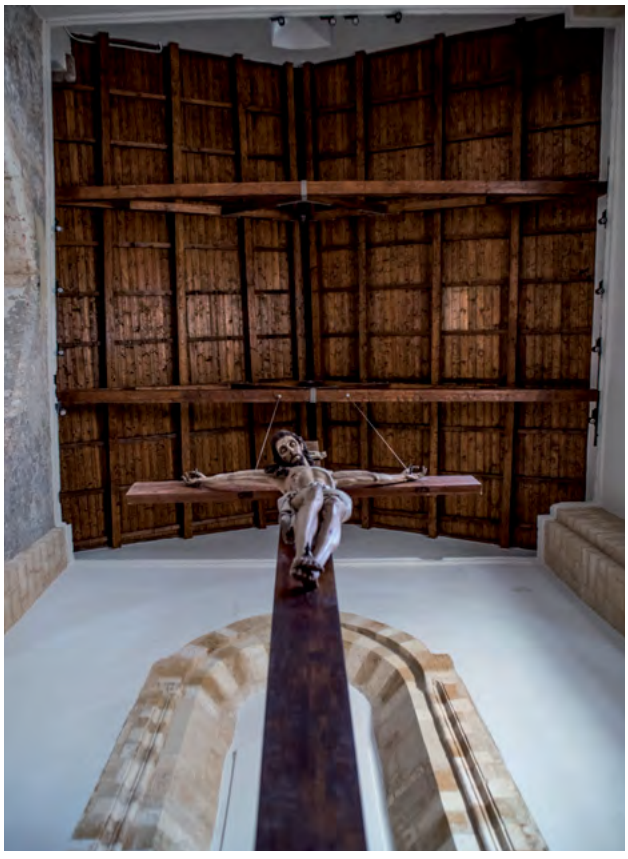
The macro-porous dehumidifying system for the interior masonry of the church consisted of a scratch-coat layer of MAPE-ANTIQUE RINZAFFO cement-free, salt-resistant, transpirant mortar made from lime, Eco-Pozzolan and recycled materials.

This product was followed by a layer of MAPE-ANTIQUE MC, a special salt-resistant, macro-porous, dehumidifying rendering mortar made from lime and Eco-Pozzolan.

Once this layer had cured, the walls were skimmed with MAPE-ANTIQUE FC GROSSO, a salt-resistant, large-grained, transpirant skimming mortar made from lime and Eco-Pozzolan, for a rough finish on renders.

Strengthening the masonry

The masonry was strengthened by applying reinforced render made from MAPEWALL RENDER & STRENGTHEN,



A view of the wooden trusses after completion of the works.

a high strength, fibre-reinforced, natural hydraulic lime-based transpirant rendering and masonry mortar with low VOC (Volatile Organic Compounds) emission levels, for making structural render and even composite reinforced mortar (CRM). The product was used in combination with MAPEGRID B250 primed alkali-resistant basalt fibre mesh which was fixed in place with L-shaped MAPENET EM CONNECTOR L20 glass fibre fasteners anchored with MAPEFIX PE WALL styrene-free chemical anchor.

Protecting the stone surfaces

The stone surfaces of the church were treated to protect them from the action of heavy, driving rain, with ANTIPLUVIOL W, a colourless silane- and siloxane-based water-repellent impregnator in watery emulsion, which also improves the self-cleaning effect of the façade and reduces the capacity of moss and mildew from adhering to the material.

The stone surfaces of the church were protected from the action of rain with ANTIPLUVIOL W water-repellent impregnator.

PROBLEMS AND SOLUTIONS

The intervention ensured the conservative restoration and consolidation of the Church of San Paolo Eremita and the safeguarding of its ancient walls.

By using the MAPE-ANTIQUE line, it was possible to carry out the work without compromising the historical significance of the walls, while the MAPEWOOD line products, which are chemically and physically compatible with the original wood, were used to restore and repair the wooden roof trusses. Lastly, the entire structure was consolidated with the help of products from the Mapei Structural Strengthening line.

PROJECT CREDITS

Project
The Church of San Paolo Eremita, Brindisi, Italy

Client
Brindisi-Ostuni Archdiocese

Year of original construction
1322

Period of the restoration and consolidation work
November 2016 - October 2018

Design
Luigi Dell'Atti
Claudio Riotta
Giacomo Intiglietta

Works Director
Luigi Dell'Atti

Main Contractor
Nicolì SpA

INTERVENTION BY MAPEI

Period of the intervention
2017-2018

Contribution by Mapei
Supply of products for restoring and strengthening the building

Mapei distributor
Nicolì SpA

Mapei products used
Static consolidation of the stone structure - MAPE-ANTIQUE ALLETTAMENTO, MAPE-ANTIQUE F21

Consolidation of the masonry - PRIMER 3296, CARBOTUBE C 170/10, MAPE-ANTIQUE F21

Consolidation of the vaulted ceilings - MAPE-ANTIQUE STRUTTURALE NHL, MAPENET EM 40, MAPENET EM CONNECTORS, MAPEI STEEL BAR 316, MAPE-ANTIQUE ALLETTAMENTO

Consolidation and restoration of the wooden trusses - MAPEWOOD PRIMER 100, MAPEWOOD PASTE 140

Dehumidifying masonry - MAPE-ANTIQUE RINZAFFO, MAPE-ANTIQUE MC, MAPE-ANTIQUE FC GROSSO

Structural strengthening - MAPEWALL RENDER & STRENGTHEN, MAPEGRID B250, MAPENET EM CONNECTOR L20, MAPEFIX PE WALL

Waterproofing external walls - ANTIPLUVIOL W

Website for further information
www.mapei.com

This editorial feature is based on an article from Realtà MAPEI INTERNATIONAL Issue 81. Images by Marco Cerra, Francesco Nicolì.

PROF GEORGE FONG

IES PRESIDENT (1982 – 1984)

Prof George Fong, the 9th President of IES, passed away peacefully at his home in the UK on 28 June 2020, aged 88.

He became involved in the Singapore engineering community in the 80s, sometime after he joined United Engineers Ltd as its Chief Engineer, and later General Manager (Technical).

During that time, he was a member of the planning committee for Nanyang Technological Institute (today known as NTU) and later sat on its Council. Prof Fong also served NTI as an adjunct professor in the Department of Mechanical & Production Engineering.

In pursuance of improving the practice of engineering in Singapore, he was involved closely with the Professional Engineers Board on several aspects during this period. In 1982, he was elected President of IES, and oversaw the decision to move IES from its office space at International Plaza to its current premises at Bukit Tinggi Road, and subsequent fund-raising efforts for the purchase.

Prof Fong also chaired Singapore Polytechnic from 1986 to 1995.

The President, Council and Secretariat are deeply saddened to learn of his passing and offer their sincere condolences to his family.

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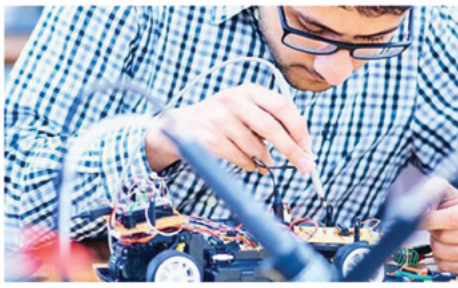

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