THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

國家鋼結構工程技術研究中心香港分中心
Chinese National Engineering Research Centre
For Steel Construction (Hong Kong Branch)

CNERC NEWSLETTER

APRIL 2022 ISSUE

JAN - APR 2022

FEATURE STORY

CNERC-Steel research work featured on HKIE Journal Cover Story

Our research work on “Effective Use of High Strength S690 to S960 Steel in Construction” was featured on the Cover Story of the Journal of The Hong Kong Institution of Engineers (Vol. 50, May 2022). A comprehensive account on the modern steel construction technology using high strength S690 to S960 steel is presented together with its exemplary innovative engineering application in the Double Arch Steel Bridge of the Cross Bay Link in Tseung Kwan O.

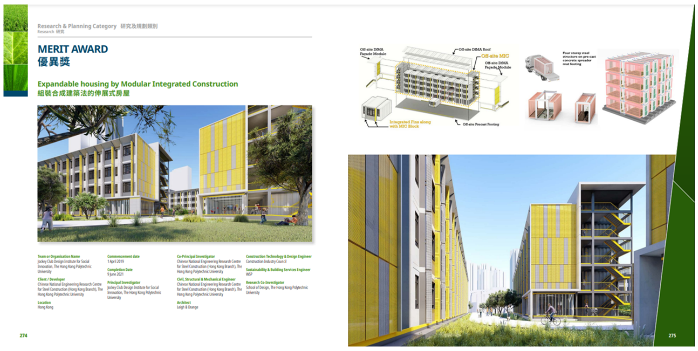
For details of the Cover Story, please refer to: https://www.polyu.edu.hk/cnerc-steel/images/news_events/previous_events/20220508.pdf

Cover Story of “The Journal of The Hong Kong Institution of Engineers” (Vol. 50, May 2022)

NEWS

Green Building Award

CNERC is honoured to receive a Merit Award under Research and Planning Category of the Green Building Award 2021 for research work on "Expandable housing by Modular Integrated Construction" as announced by the Hong Kong Green Building Council at the Virtual Award Presentation Ceremony on 28 April 2022.



Pilot construction projects under DEVB using high strength S690 steel

In January 2022, the CNERC was invited to provide an expert advisory service to the Project Strategy and Governance Office of Development Bureau of the Government of Hong Kong SAR to promote effective use of S690 steel in construction. This is one of the latest initiatives of the Development Bureau to enhance cost-effectiveness of construction projects through adoption of new construction materials and technology through applied research and development. Specific tasks of the CNERC include:

1. To provide assistance in identifying suitable pilot projects with advantages in structural performance and economy after effective adoption of high strength S690 steel.
2. To provide specific requirements and specifications for high strength S690 steel structures.
3. To provide technical information to facilitate design, fabrication and construction for high strength S690 steel in Hong Kong.
4. To upgrade the existing standards for design and construction using high strength S690 steel.

At present, a total of 18 public works projects have been identified, and these include:

- Long span steel roofs with spans typically ranging from 25 to 50 m.
- Heavily loaded noise barriers and enclosures.
- Piled foundations with socketed high strength S690 H-piles.
- Medium span foot bridges of single and multi-spans.

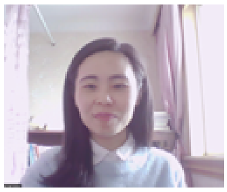
In general, significant savings in steel tonnages in the range of 20 to 37% are readily achieved when S690 steel, instead of S355 steel, is specified. It should be noted that high strength S690 steel are commonly produced in the form of plates rather than sections, and there are well established fabrication practice, in particular, welding and non-destructive tests, to ensure quality fabrication of high strength S690 steel members in China, in particular, in the Greater Bay Area.

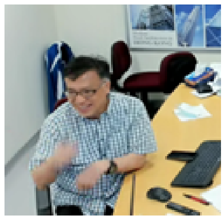
發展局
Development Bureau

NEWS

Research collaboration with Chongqing University Steel Structures Research Institute

The CNERC has been working with Research Institute for Steel Structures at Chongqing University in the past 5 years, and one of the latest research collaboration is to develop an innovative self-centering structural system for piers and beams of composite bridges with simple on-site assembly. In the afternoon of 15 April 2022, an online meeting was jointly hosted by Prof. Xuhong Zhou of CQU, and Prof. K. F. Chung of PolyU to discuss the overall research programme. Prof. Jiepeng Liu, Prof. Ke Ke and Dr. Xuanding Wang from CQU, Mr. Xiaohu Chen of T. Y. Lin International, and Dr. Ligui Yang of Chongqing Jiaotong University, and Dr. Minhui Shen of Shanghai Institute of Technology attended the meeting, and contributed to various technical discussions.





Upgrade of the existing Code of Practice for adoption of high strength S690 steel in building structures

As a response to the need of the construction industry in Hong Kong to exploit the use of high strength S690 steel in building structures, the CNERC proposed a comprehensive revision to the current Code of Practice on the Structural Use of Steel of the Buildings Department in January 2022. The proposed revision was submitted to the respective Technical Committee of the Buildings Department, and various design rules and data consistent to the Code were provided to facilitate designers to use high strength S690 steel effectively in constructing buildings and structures for the private sectors. At present, the proposed revision is under consideration of members of the relevant Technical Committee, and it is expected to be approved in the coming months.

It should be noted that the Code was first published in August 2005, and it became mandatory in August 2007. The design rules for structural steel follow primarily to those given in BS 5950: 2000 and EN 1993-1-1: 2005, and both of them cover Grades S235 to S460 steel. In 2007, EN 1993-1-12 was published which extended conservative design rules given in EN 1993-1-1 to cover high strength steel up to S700. The upcoming prEN 1993-1-1: 2019 allows use of S690 steel in normal design, and hence, no separate design document is needed. The corresponding steel materials specifications, namely, GB 1591: 2018 and EN 10025-6:2019, are also listed as the acceptable standards in the Code of Practice to facilitate adoption of high strength S690 steel in upcoming construction projects.

The CNERC Newsletter incorporates research articles from our researchers in aim to share the latest findings in their research work. Should there be any question or comment in these research work, you may send an email to: cnerc.steel@polyu.edu.hk or contact the researchers directly. The researchers' contact information is available right at the end of each article.

A total of 4 research articles are provided in this issue, namely as follows:

1. Atmospheric Corrosivity of Exposed Structural Steelwork in Hong Kong

2. Corrosion rates monitoring in both external and internal structural steelwork of MiC building - InnoCell at HKSTP and Nam Cheong Street

3. Relocatable Housing by Modular Integrated Construction

4. MiC Innovations

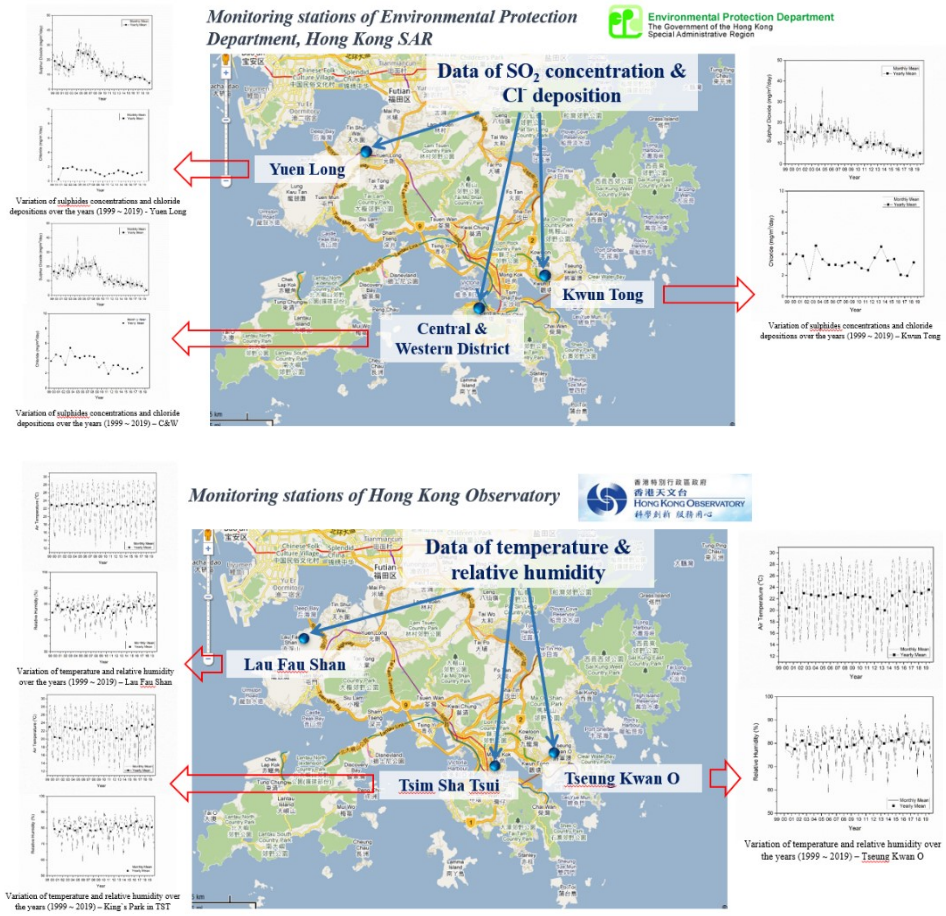
RESEARCH

Atmospheric Corrosivity of Exposed Structural Steelwork in Hong Kong

To confront potential durability problems of the infrastructures in Hong Kong, it is essential to investigate and understand various controlling mechanisms in corrosion in exposed structural steelwork. Hence, it is necessary to examine atmospheric corrosivity of exposed structural steelwork under local environments in Hong Kong. Moreover, it is essential to develop an effective quality control scheme for exposed steel members so that their design service lives will be readily achieved in practice.

- Influential climatic and environmental factors in Hong Kong

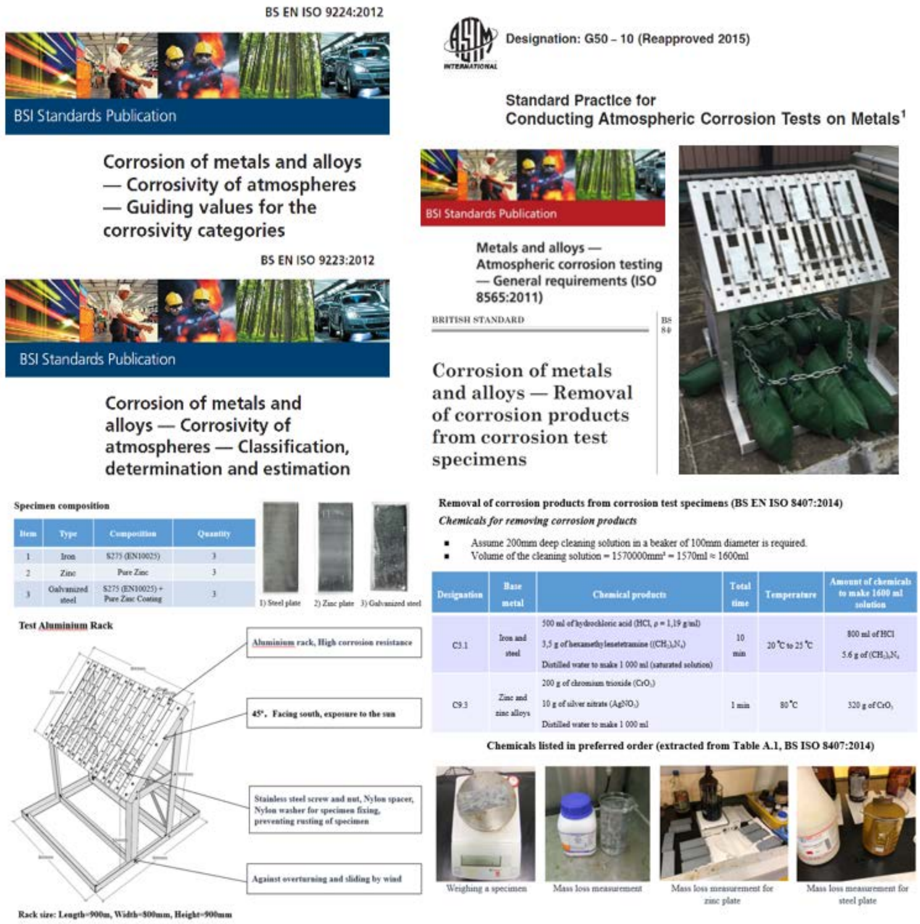
The corrosion rate of steel mainly depends on the atmospheric conditions in various locations, i.e. the combined effect of climatic factors and the composition of the atmosphere. Hence, it is very important to identify the most influential climatic factors affecting the corrosion rate of steels and galvanized coatings under local environments in various locations in Hong Kong. ISO 9223:2012 provides a quantitative method to estimate atmospheric corrosivity from measured atmospheric conditions. It is identified that the major Influential climatic and environmental factors of atmospheric corrosivity are i) air temperature, ii) relative humidity, iii) dry deposition of sulphur dioxide and iv) dry deposition of chlorides. Hence, collaboration with the Hong Kong Observatory, and the Environmental Department of the Government of Hong Kong SAR has been established to obtain these data.



Influential climatic and environmental factors in Hong Kong

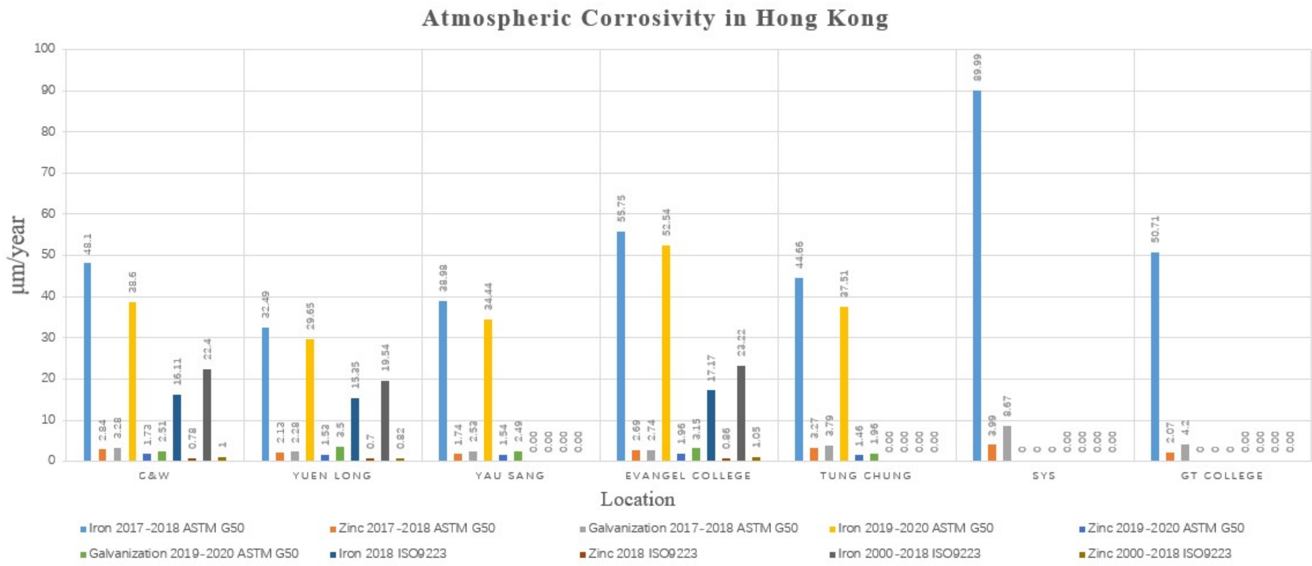
- Atmospheric corrosion rates of steel and galvanized coatings

It is highly desirable to develop an effective design model for atmospheric corrosion for building and civil engineering structures in Greater Bay Area, including Hong Kong and Macau, under local environmental conditions in order to protect buildings, bridges and structures of the community for a service life of 50 to 120 years. In order to obtain measured values of atmospheric corrosivity for calibration against the design equations as specified in BS EN ISO 9223-2012, an atmospheric exposure programme has been conducted in which the mass loss of iron, zinc and hot-dip galvanized steel plates over a period of one year is measured to determine the atmospheric corrosion rates. It should be noted that these specimens are exposed to the atmosphere at seven different sites with different atmospheric conditions in Hong Kong. The tests are carried out in accordance with BS EN ISO 8565:2011 and ASTM G50-10.



Atmospheric corrosion rates of steel and galvanized coatings

Site	Location	Atmospheric condition
A	*Central and Western District*, EPD Air quality monitoring station	Urban
B	*Yuen Long*, EPD Air quality monitoring station	Suburb
C	*Yuen Long*, Yau Sang Factory	Industrial
D	*Tseung Kwan O*, Evangel College	Urban
E	*Tung Chung*, EPD Air quality monitoring station	Urban
F	*Central and Western District*, Sun Yat Sen Memorial Park Sports Centre	Seafront
G	*Tiu Keng Leng*, G.T. (Ellen Yeung) College	Urban



Atmospheric Corrosivity in Hong Kong (2017-2020) accordance with ASTM G50 and ISO 9223

- Design recommendations for corrosion protection design of exposed steelworks using galvanization

Corrosivity evaluation can be made in accordance with BS EN ISO 9223 based on either corrosion rate measurement of standard specimens or environment information. With reference to this important technical document, a generalized equation is adopted for corrosivity design, whilst all coefficients of the key aerosol contents and influential climatic data shall be calibrated with test data.

Researchers: Mr. Hao Jiang and Mr. Eric Yuen (email: eric-k.yuen@polyu.edu.hk)

Corrosion rates monitoring in both external and internal structural steelwork of MiC building - InnoCell at HKSTP and Nam Cheong Street

To confront potential durability problems in Modular Integrated Construction (MiC) buildings in Hong Kong, it is essential to investigate and understand various controlling mechanisms in corrosion of structural steelwork in MiC buildings under both internal and external conditions. Hence, it is necessary to examine atmospheric corrositivity of structural steelwork in MiC buildings under both internal and external conditions through various methods of measurements.

The objective of this project is:

1) To measure corrosion rates in both external and internal structural steelwork in Modular Integrated Construction in Hong Kong.
2) To investigate and quantify levels of atmospheric corrosivity and typical corrosion rates in steel structures in Hong Kong.
3) To develop general corrosion requirements for steel structures in Hong Kong.

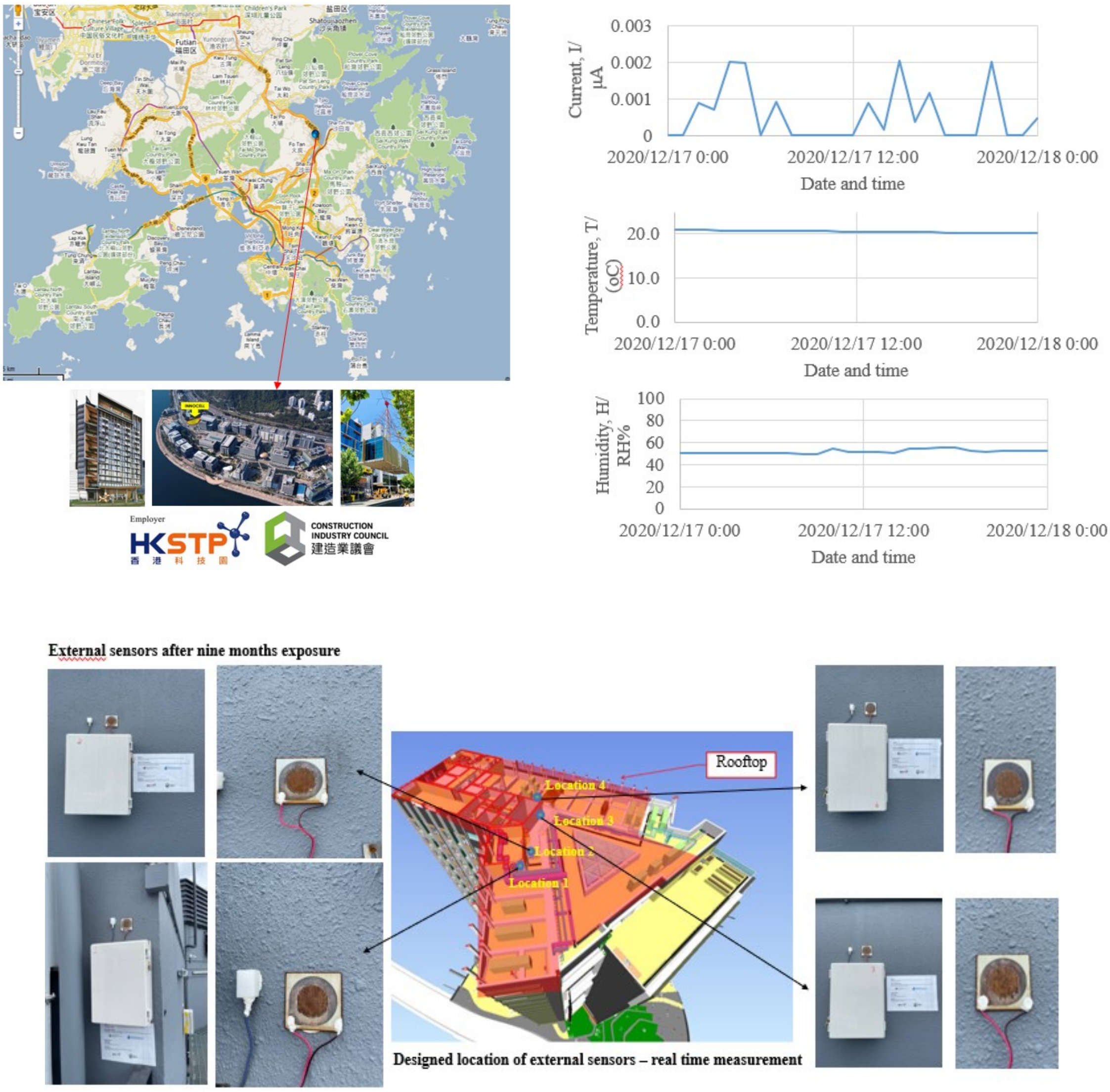
The key deliverable and methodology of this project will be:

1) Collect real time monitoring and direct measurements of corrosion rates of structural steelwork in both internal and external conditions. Real time corrosion rates for different materials (Zinc, Iron and Aluminium) for MiC buildings under both internal and external conditions during 1 year will be obtained.
2) Collect real time measurements of climatic data (temperatures, humidity), and monthly atmospheric chemicals (Cl^- and SO2).
3) Compare with predicted corrosion rates in MiC buildings to ISO/DIS 9223 and 9224 based on one year measured real time climate data and monthly atmospheric chemicals.
4) Exposure atmospheric corrosion test in MiC Buildings will be conducted according to ASTM G50-10, and the measured results for steel plates with different protect systems for 1 year exposure in MiC buildings will be achieved to compare with the calculated corrosion rates according to ISO/DIS 9223 and 9224, and the measured real time corrosion rates.
5) Corrosion resistance and durability of structural steelwork in MiC buildings in Hong Kong will be predicted and the first corrosion mechanism of structural steelwork in MiC buildings in Hong Kong will be built up.

Located in Hong Kong Science Park, InnoCell is a pilot project of using Modular Integrated Construction (MiC) in Hong Kong. It will provide a minimum of 500 bedspaces. Room types include Standard Studio, Sleepbox, Co-living and Family Unit (Recreational and shared living/ working space integrated with the residential units) with supporting ancillary facilities. It will become a smart living and co-creation community for tech talents after the completion of project.

The 17-storey building sits on a 32,000-sq ft. site adjacent to the southeast entrance of Hong Kong Science Park. The building is assembled by 418 modules and provides 5 types of room.

This project are greatly supported by Hong Kong Science Park and Construction Industry Council. 8 sets of corrosion monitoring units in internal positions and 4 sets of corrosion monitoring units in external positions of Innocell building was installed. Meanwhile, 3 Nos. of aluminium racks with different kinds of metal plates were set up on the roof of the building. One year real time monitoring for corrosion rates and exposure test was started in January 2021.

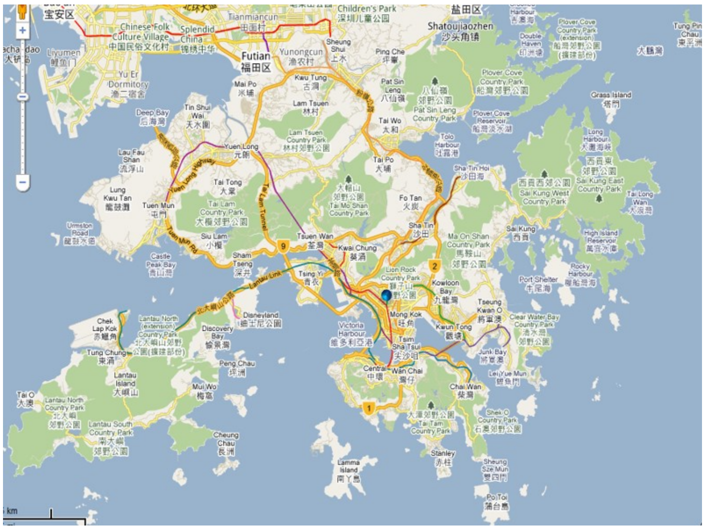


Corrosion rates monitoring in both external and internal structural steelwork of InnoCell at HKSTP

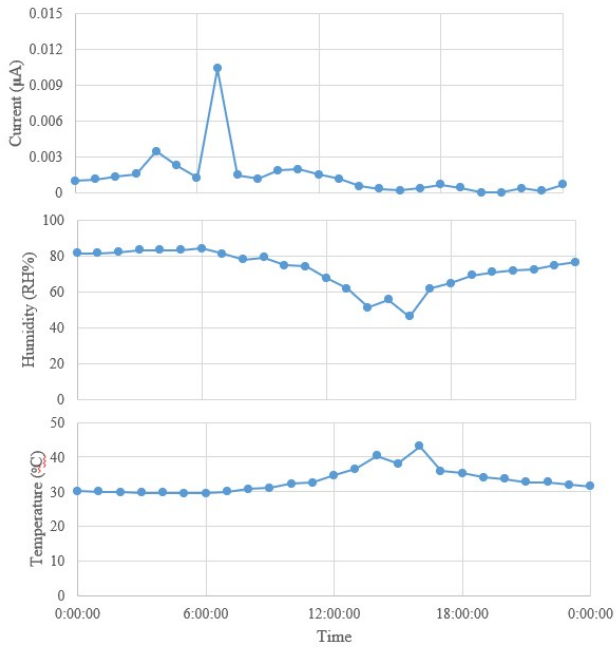
Modular Social Housing Projects adopt modular integrated construction to build transitional social housing in idle land. The Hong Kong Council of Social Service (HKCSS) aims to provide affordable and transitional social housing to families and persons whom queued for the public rental housing and/ or currently live in dismal and inadequate housing conditions so that their living quality can be improved.

Nam cheong street modular social housing project is the first modular social housing project which adopts prefabrication and modular integrated construction (MiC) technology in Hong Kong. The 4-storey "Nam Cheong 220" provides 89 modular housing units of 1 to 3 persons, with unit sizes ranging from 130 to 293 square feet. The project started its assembly at the end of December 2019 and obtained the Occupation Permit in July 2020.

To measure the real time corrosion rates in both external and internal structural steelwork in MiC buildings at Nam Cheong Street, 3 sets of corrosion monitoring units in internal positions and 2 sets of corrosion monitoring units in external positions were installed in Nam cheong street modular social housing project in January 2021. This project is greatly supported by the Hong Kong Council of Social Service.



香港社會服務聯會
The Hong Kong Council of Social Service



Corrosion rates monitoring in both external and internal structural steelwork of Nam cheong street modular social housing project

Researchers: Mr. Hao Jiang and Mr. Eric Yuen (email: eric-k.yuen@polyu.edu.hk)

Relocatable Housing by Modular Integrated Construction

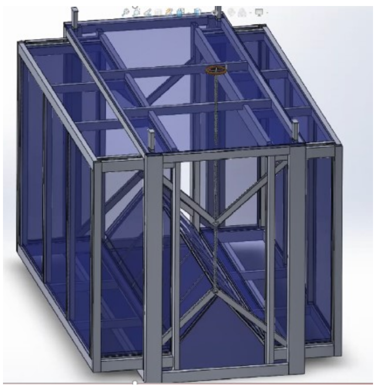
Relocatable housing is in rising demand due to the need for rapid establishment and flexibility in future reuse of transitional housing, work force deployment, disaster relief, etc. The modular integrated construction (MiC) approach adopted recently by the local construction industry was also seen as a logical and viable mean to build this type of relocatable housing. The proposed project aims at developing a design prototype of relocatable housing building system in form of expandable modules and integrated building clusters. For sustainability, light weight and other technical considerations, the prototype was conceived in steel structural frame allowing swift installation and efficient expansion mechanism to overcome transportation limitations. The architectural layout of four standard units was drafted, comprising (1) single person/co-living unit; (2) small family units 3 persons; (3) large family units 4 persons; and (4) accessible units 2-3 persons. Structural analysis and expansion mechanism were also proposed for preliminary assessment. An industry evaluation was also conducted to gather feedback from both the building sector and social organisations, in order to obtain feedback for improvement and assess the potential to proceed to mock up stage.

The first design prototype of the expandable MiC (eMiC) was finalised, including modular unit layout and typical floor/cluster design for a four storey standard building block. Based on the first design prototype, preliminary structural framing scheme and options of expansion mechanism were proposed for technical analysis.

Expansion mechanism

The expandable MiC represents ideal solution for a large variety of places. The capacity of expansion mechanism to multiply two times its net area by symmetrical extension and low installation costs will be considered. Meanwhile, manual mechanisms should be designed to allow expandable MiC to unfold and fold easily and quickly, as well as the electromechanical mechanisms. Moreover, low self-weight and low maintenance cost also plays an important role.
Three different expansion mechanisms have been developed.

M01

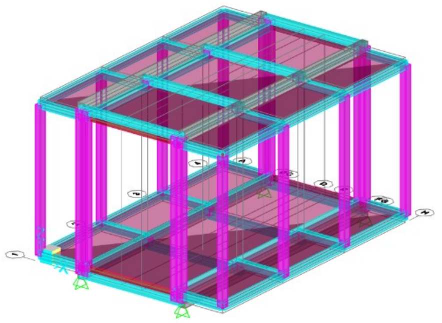


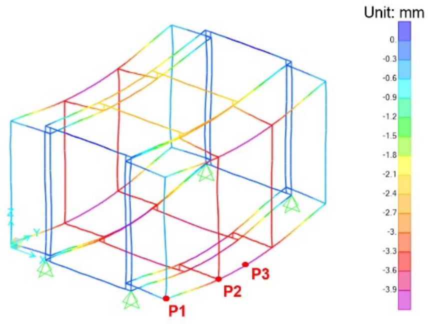
M02

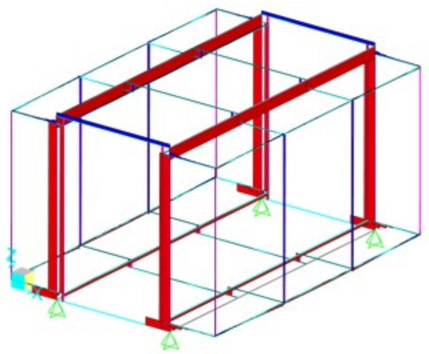
M03

Structural design – steel framing for MiC modules

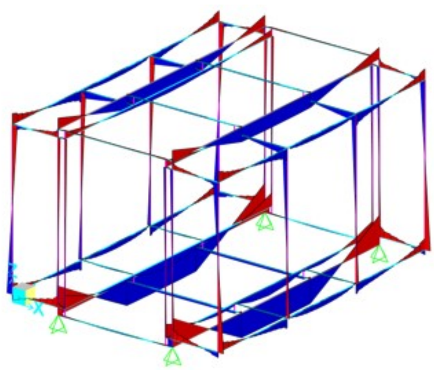
Structural steel of grade S355 has been adopted as the structural frame of the modules and the overall modular building after the modules are stacked on each other. For materials of slabs and ceiling, reinforced concrete Grade C30 has been selected. The overall dimension of a single eMiC unit is 3.5m x 6m x 4.5m with total weight of 34.4 tons. Section designation of all steel members are 120mm x 120mm x 10mm.



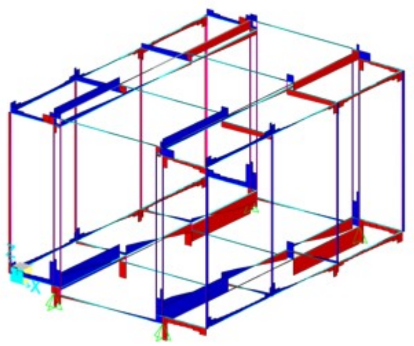




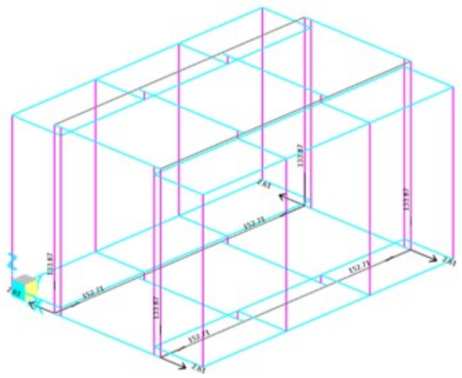
Axial force diagram **Max. Axial Force = 46.41 kN**



Bending moment diagram **Max. Moment = 18.21 kN•m**



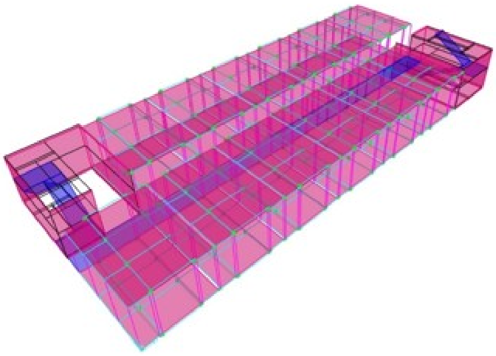
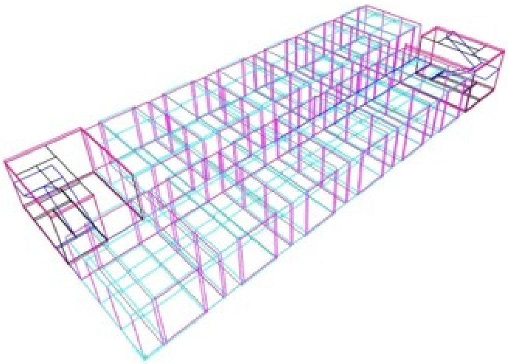
Shear force diagram **Max. Shear Force = 17.33 kN**



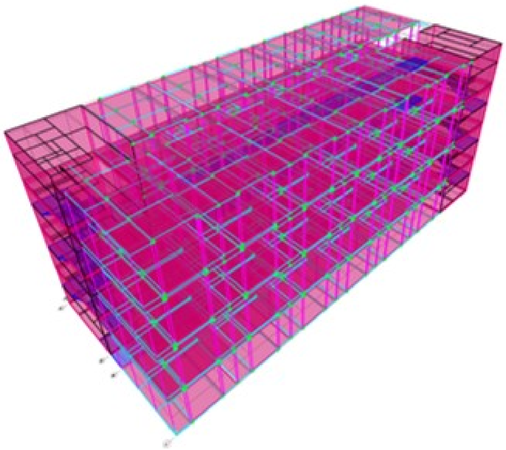
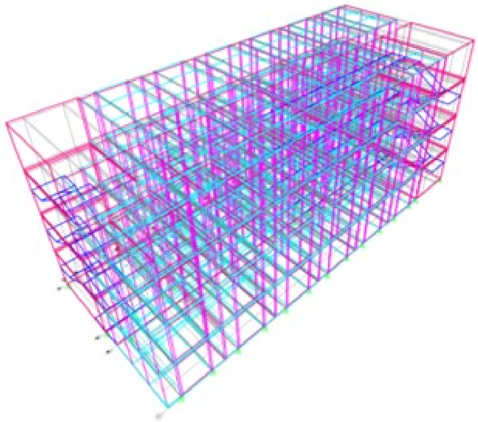
Reaction Force

In terms of connection design, configuration of bolted type with a threaded rod and a shear key is used as the joint between the eMiC units. For vertical connectivity, there are threaded rods that passes through the columns or bolt and nuts. For horizontal connectivity, a shear key, a transfer plate or adjacent plate elements is installed inside the columns.

SAP 2000 model G/F

SAP 2000 model G/F ~ 3/F

The advantages of the structural steel material for the expandable MiC application are:

• Lighter structure and more compacted structural element size by comparing with reinforced concrete structure.
• Fabrication tolerance and accuracy can be controlled to meet a stringent requirement which is essential for the expandable mechanism.
• Fabrication process is relatively faster than that using reinforced concrete structure.
• Bolted connection at the module connection point can be designed and fabricated easily which enable the removal of individual module if required by loosening the connected bolts between modules.
• It is more environmentally friendly than the concrete structure as it can be recycled.

Researchers: Dr. Calvin Luk (email: calvin.luk@polyu.edu.hk)
Ir. Thomas NY Tong, Samule KK Lee, KK Shing,
Ir. Michael Sung, Ir. Hao Jiang, Dr. Aria Yang
(Industry Evaluation: Prof. Ir. Albert PC Chan, Dr. Amos Darko, Dr. Jackie Yang)

MiC Innovations

The Hong Kong Branch in collaboration with the Nano and Advanced Materials Institute Ltd. was granted a 2-year project entitled "Hong Kong Modular Integrated Construction (MiC) Innovations" from the Innovational and Technology Fund, Innovation and Technology Commission of the Government of Hong Kong SAR with a project sum of HK$26M.

The Hong Kong branch will conduct investigations on a) high strength steel materials, b) innovative structural engineering solutions and c) joints and innovation construction and methods.

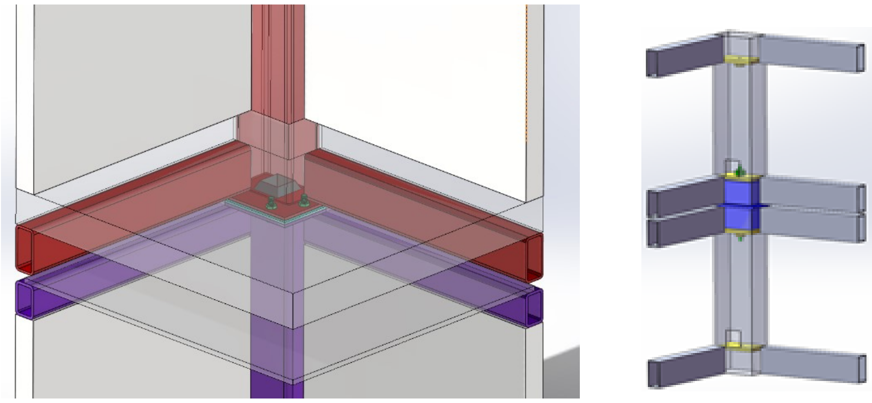
The Hong Kong Construction Industry has delivered civil structures that form an important part of the urban systems which are renowned for their efficiency and reliability. The continuous social growth and development in Hong Kong induces the challenge of continuously improving efficiency and safety of the Construction Industry and of reducing energy and resources consumption associated with civil structures. To achieve these goals, the Modular Integrated Construction (MiC) method by forming the overall structures using the modules fabricated off-site brings the benefits of improved site safety, better quality control, shorter construction period and reduced construction wastes will be more widely applied in the Construction Industry to enhance productivity under the new era of Construction 2.0.

This 2-year project aims to develop innovative MiC hybrid structural systems using high performance concrete and steel materials. With advanced material developments and innovation applications of these high performance materials, specific mechanical and physical properties of these high performance materials will be developed according to prevailing architectural, structural and durability requirements. Through structural engineering design development, innovative MiC building systems with different construction methods and details will be formulated for construction of high-rise buildings. This project has received supports from the following government departments and public body.

CONSTRUCTION INDUSTRY COUNCIL
建造業議會

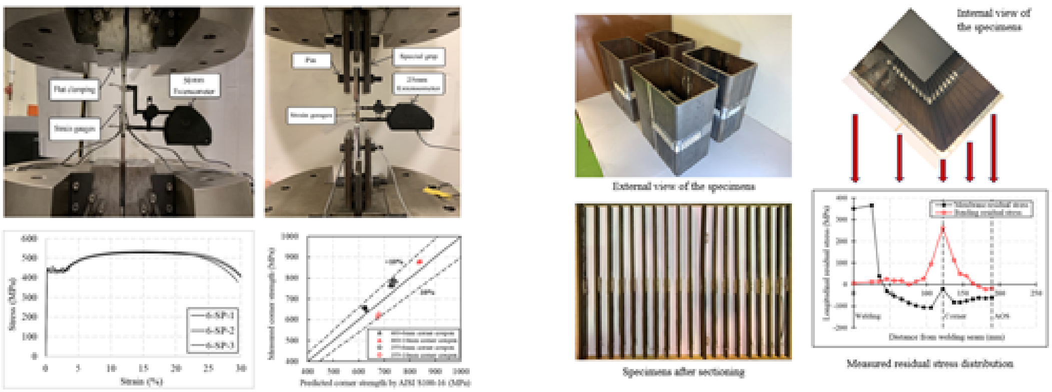
屋宇署
BUILDINGS DEPARTMENT

Through a comprehensive innovative structural engineering design, various design schemes for different storeys buildings were carried out. Moreover, improvements to the connections commonly used in MiC were also be made with enhanced strength and stiffness. As a result, two types of innovative steel joint design have been developed for different storeys MiC buildings. A Hong Kong short term patent and a China utility patent for innovative joint have been granted and application for In-Principle Acceptance of MiC system to HK government is being in process.

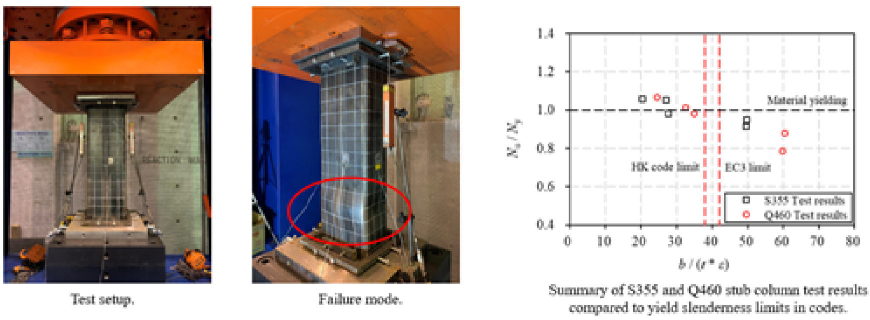


Steel joint design for different storeys MiC buildings

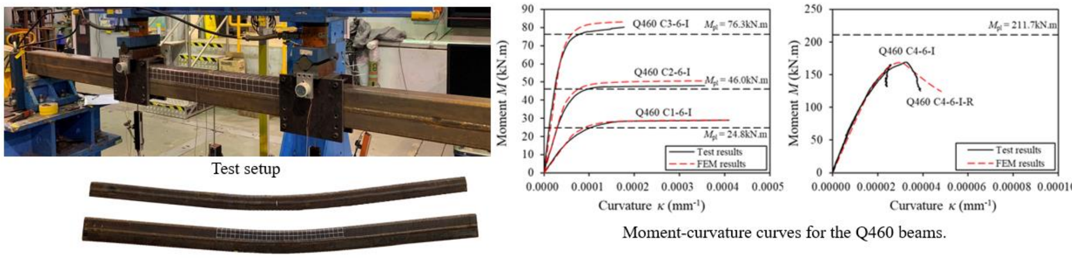
Meanwhile, material tests and residual stress measurements were conducted as well as beam tests and column tests to investigate the material characterization and the structural behaviour of high strength steel members. The outcomes of the tests will provide more local R&D data and definitive guidelines to enable wide adoption of MiC among various professionals in the local construction industry.



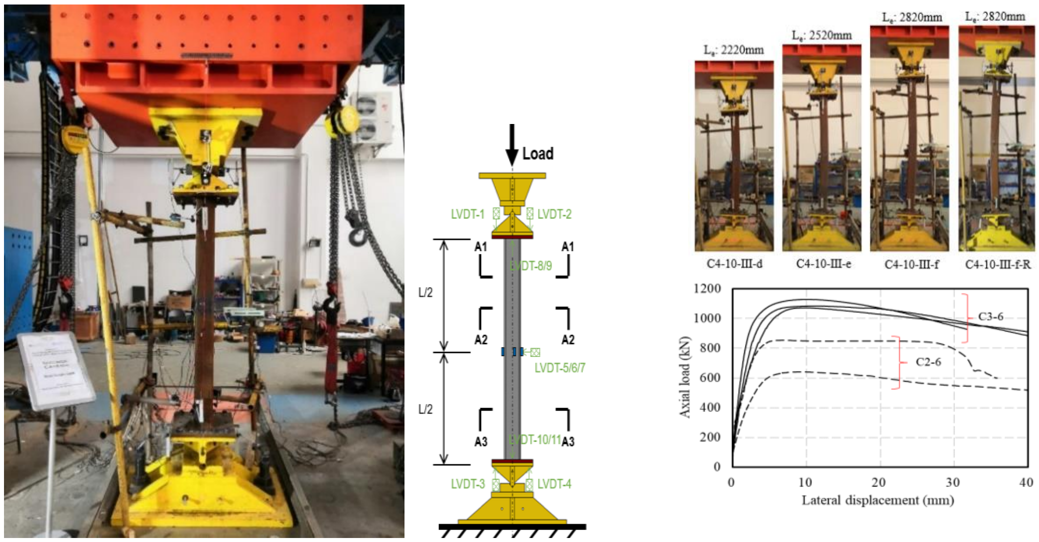
Material tests and residual stress measurements for S460 steel



Stub column tests for S460 columns

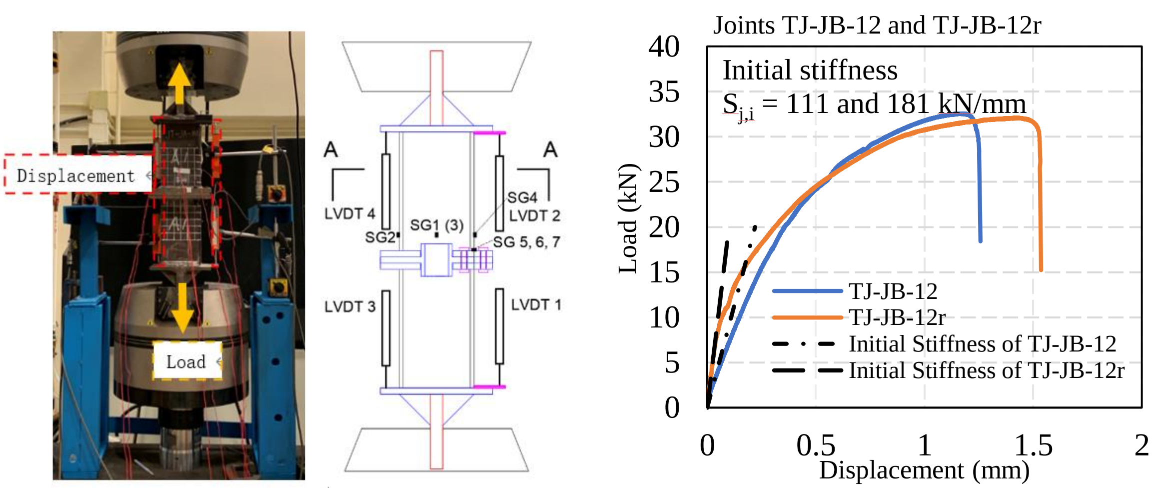


Beam tests for S460 beams

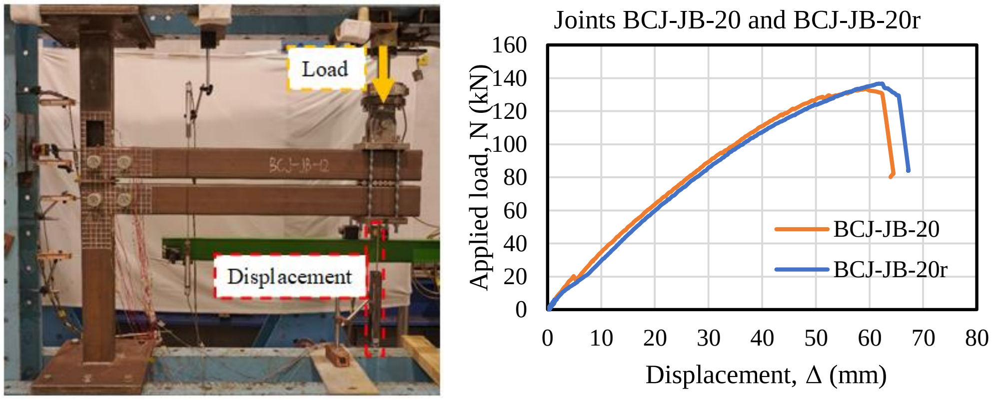


Slender column tests for S460 columns

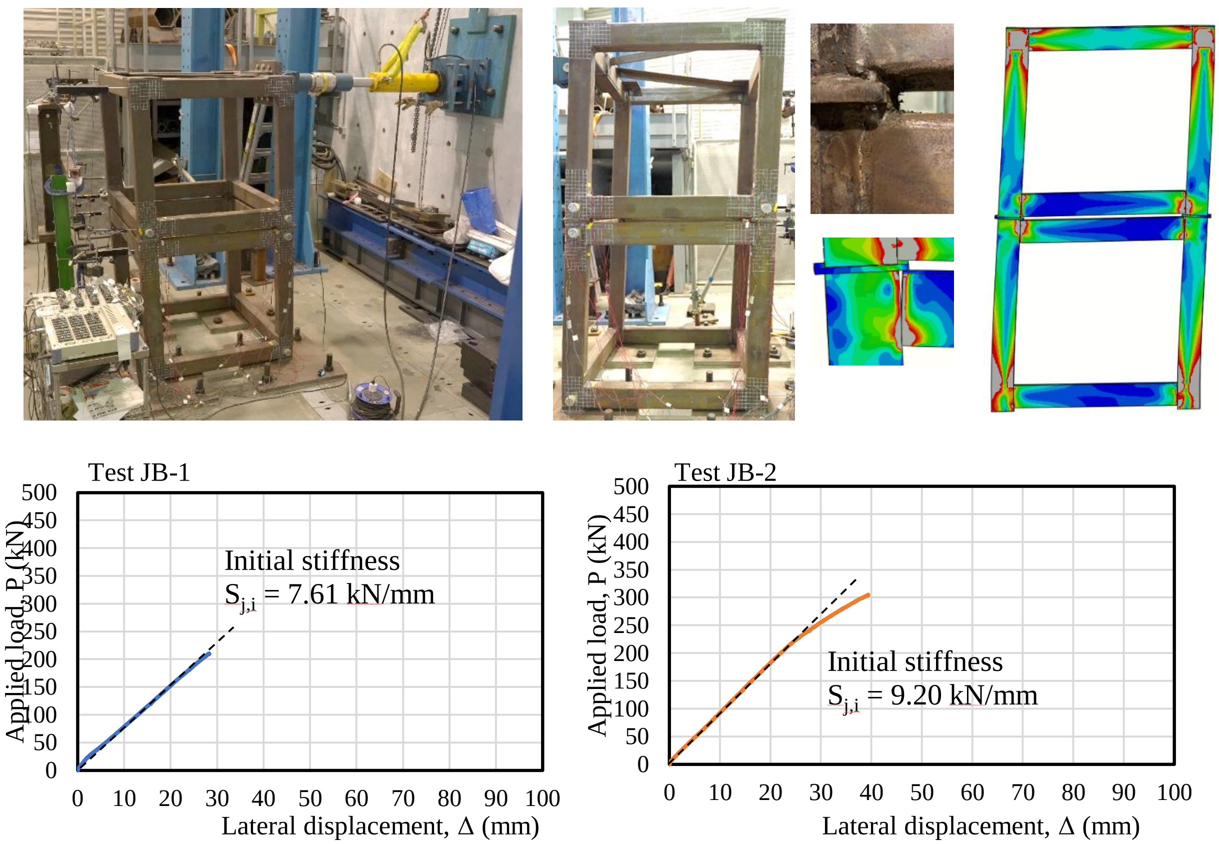
To examine the load transfer mechanism, vertical connection including bolted connections between modules are to be examined. Based on the joint design for different storeys buildings, scaled steel module will be fabricated. Two types of module assembly tests will be conducted.



Effective MiC joint tension test



Effective MiC beam-column joint test



Effective Frame Tests for MiC Modules Assembly

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