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

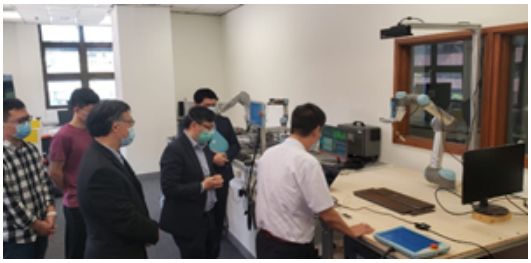
NEWSLETTER

AUGUST 2020 ISSUE
MAY - AUGUST 2020

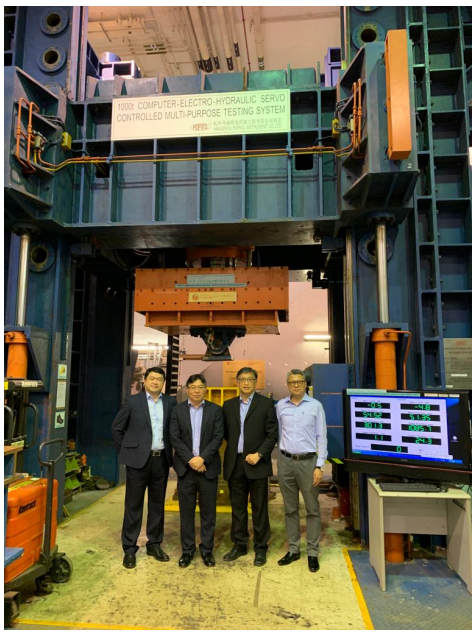
FEATURE STORY

Visit by Development Bureau

Ir Sai Hung LAM, Permanent Secretary for Development (Works), and Ir John Ka Sing KWONG, Head of Project Strategy and Governance Office of Development Bureau, Government of HKSAR visited the CNERC on 19 June 2020.



Ir S. H. Lam and Ir John Kwong visited the Robotic Development Laboratory of the Industrial Centre.



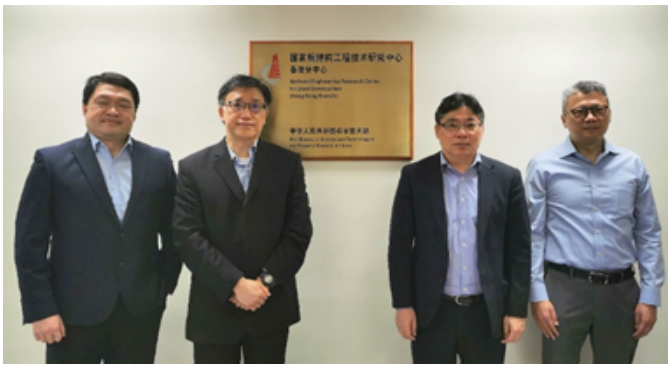
From left: Ir John Kwong, Ir S. H. Lam, Prof. K. F. Chung, and Prof. Michael Yam at the Structural Engineering Research Laboratory of Department of Civil and Environmental Engineering.

A demonstration on real time interactive manipulation on robotic movement was conducted by Ir Victor Wu, Senior Project Fellow of CNERC. Both Ir S. H. Lam and Ir John Kwong were very impressed to these newly developed technique, and they were interested to explore potential applications of these technique in construction.

Both Ir S. H. Lam and Ir John Kwong had also visited the Structural Engineering Research Laboratory, and they were able to appreciate various capabilities of these large scale testing systems, and also the efforts needed in their frequent and reliable operations.

Prof. K. F. Chung gave a brief presentation on various research activities and recent development of CNERC, in particular:

1. **structural performance of high strength S690 welded sections, and their design development to European Structural Steel Design Code EN 1993-1**
2. **welding technology on high strength S690 steels and applications in construction**
3. **research and development needs for high-rise MiC against structural adequacy and progressive collapse.**



From left: Ir John Kwong, Prof. K. F. Chung, Ir S. H. Lam and Prof. Michael Yam.

CNERC Annual Technical Symposium 2020

The first CNERC Annual Technical Symposium was held on 12 June 2020, and it was completed fruitfully with the support of all its participating research personnel.

The CNERC Annual Technical Symposium 2020 is the first technical symposium organized by the CNERC to promote technological development and exchanges among researchers of CNERC projects. Principal investigators of all the CNERC research projects are invited to share and exchange technical information of their projects. As of today, there are more than 20 research projects funded by the CNERC with over 50 research personnel affiliated to the CNERC.

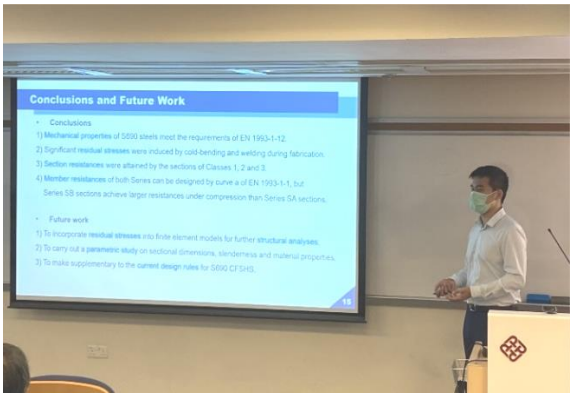
In order to encourage young researchers' participation, a Young Researchers Competition was held to reward outstanding young researchers of the projects.

It is our pleasure to have Ir Prof. Ben Young, the Vice President (Student and International Affairs), The Hong Kong Polytechnic University, as the Officiating Guest, and Ir Dr. Richard Pang, Director of Industry Development, Construction Industry Council as the Honorable Judge for our Symposium.

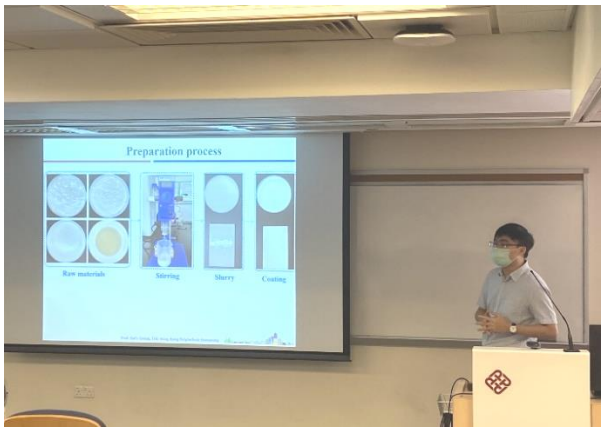
From left: Dr. T. M. Chan, Ir Prof. Ben Young, Ir Prof. K. F. Chung, Ir Dr. Richard Pang

Among the 20+ research projects and over 50 affiliated research personnel funded by the CNERC in 2019/20, an overwhelming response on nominations were received. Out of 24 nominations, 12 presenters have been shortlisted for presentation at the Symposium. It is evident that many of the presenters are well prepared, and their presentations are well organized to convey key findings of the research projects.

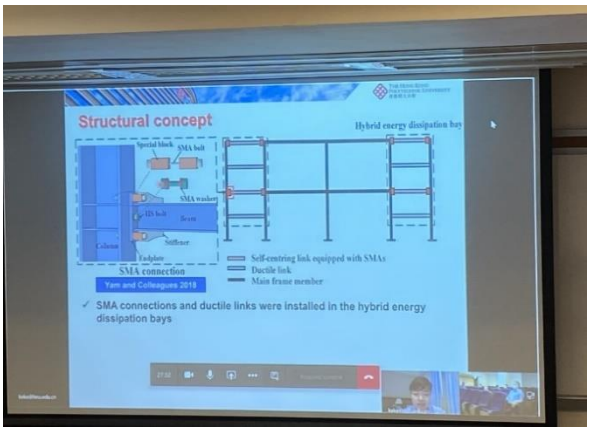
Mr. Junbo CHEN, Research Associate (CEE) gave a presentation on “Experimental investigation into stub column behaviour of high strength steel octagonal hollow sections”.



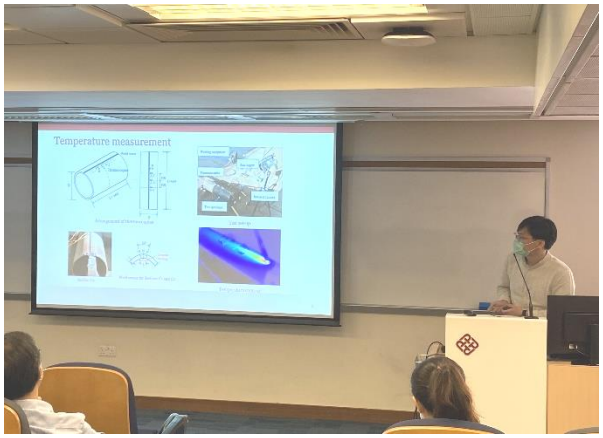
Mr. Meng XIAO, Research Associate (CEE) gave a presentation on “Experimental-numerical investigation into S690 cold-formed square hollow sections”.



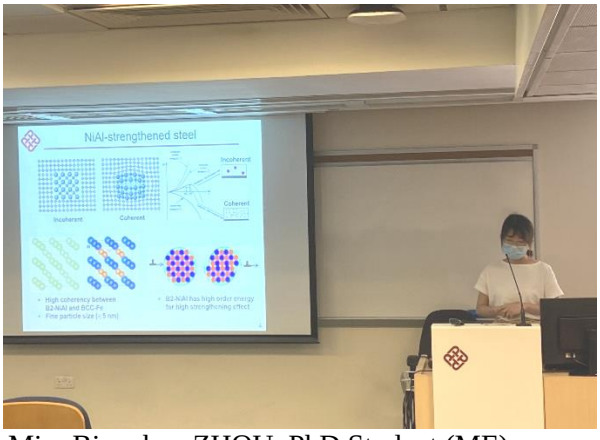
Dr. Xiao XUE, Research Fellow (CEE) gave a presentation on “Reduced graphene oxide-geopolymer coating for enhancement of corrosion resistance”.



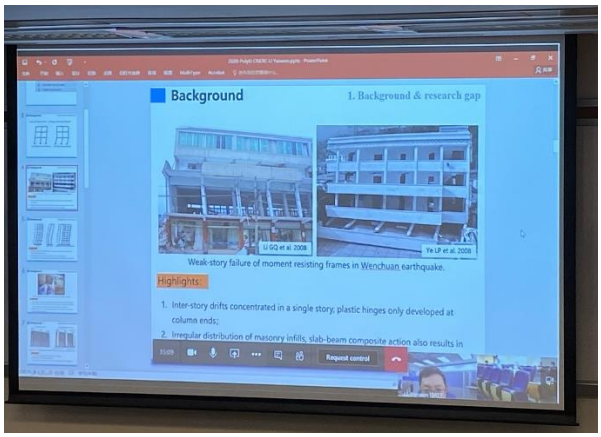
Dr. Ke KE, Postdoctoral Fellow (BRE) gave a presentation on “Partially self-centring steel frames equipped with SMA connections and ductile links subjected to near-field earthquake motions: A spectral energy factor model”.



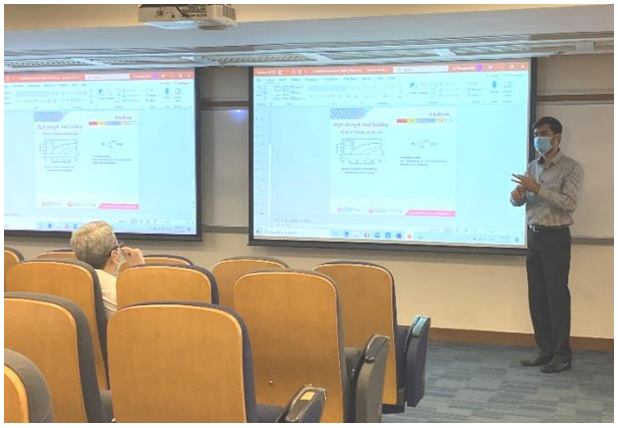
Dr. Yifei HU, Postdoctoral Fellow (CEE) gave a presentation on “Residual stresses in high strength S690 steel cold-formed circular hollow sections”.



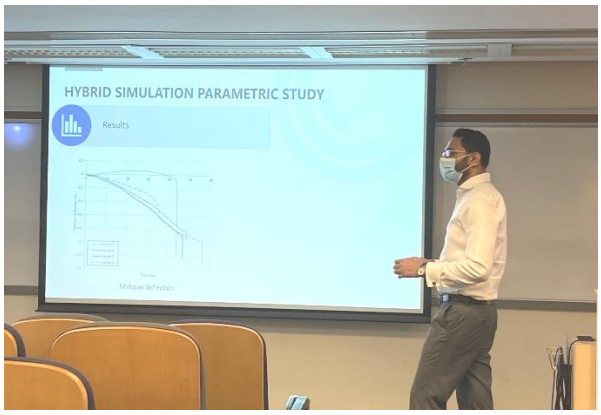
Miss Bingchen ZHOU, PhD Student (ME) gave a presentation on “Effects of Cu on the nanostructure and mechanical properties of high strength steels”.



Dr. Yanwen LI, Postdoctoral Fellow (BRE) gave a presentation on “A study of energy-dissipative rocking columns with nitinol shape memory alloy tension brace subject to cyclic loading”.



Mr. Ghazanfar Ali ANWAR, PhD Student (CEE) gave a presentation on “Seismic performance and resilience of steel buildings by using high strength steel”.



Dr. Mustesin Ali KHAN, Research Assistant Professor (BSE) gave a presentation on “Hybrid simulation of structures exposed to fire”.

Dr. Xuanding WANG, Postdoctoral Fellow (CEE) gave a presentation on “Study on prefabricated composite bridge girder using high strength steel”.

Mr. Dong WANG, PhD Student (BRE) gave a presentation on “A comprehensive study on crane selection and site location models for MiC”.

After a rigorous discussion among members of the Judging Panel including Ir Dr. Richard Pang, the following were selected as winners of the Young Researchers Competition:

CNERC Outstanding Young Researcher Awards 2020
Dr. Ke KE, Department of Building and Real Estate
Dr. Mustesin Ali KHAN, Department of Building Services Engineering

CNERC Young Researcher Awards
Mr. Junbo CHEN, Department of Civil and Environmental Engineering
Dr. Yifei HU, Department of Civil and Environmental Engineering
Mr. Meng XIAO, Department of Civil and Environmental Engineering
Miss Bingchen ZHOU, Department of Mechanical Engineering

RESEARCH

Starting from this issue, the CNERC Newsletter will incorporate research articles from our researchers in sharing 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 as follows:

1. ***"Advanced Instantaneous Area Method for Determination of True Stress Strain Characteristics of High Strength S690 Steels"*, Dr. H. C. Ho**

2. **"Net Section Resistances of Bolted Connections of High Strength S690 and S960 Steels", Ms. X. M. Lin**

3. **"Development of a Constitutive Model with Ductile Fracture for High Strength S960 Steels", Dr. C. Chen**

4. ***"High-performance shear connection systems in prefabricated composite bridges"*, Dr. X. D. Wang**

Advanced Instantaneous Area Method for
Determination of True Stress Strain Characteristics of High Strength S690 Steels

In order to enable accurate analysis and prediction on structural behaviour of high strength S690 steel members and connections at large deformations, an integrated experimental, theoretical and numerical investigation to formulate a full range constitutive model was conducted from 2016 to 2019. It is well known that standard tensile tests are effective means to obtain key mechanical properties of steel coupons for deformations up to an on-set of necking. However, owing to non-uniform cross-sectional distributions in both stresses and strains within the necking regions of the coupons, it is important to allow for these effects when analysing measured forces and extensions to give true stresses and strains of the coupons for accurate predictions beyond necking.

An instantaneous area method has been developed and calibrated against test results of a total of 30 standard tensile tests on S690 cylindrical coupons, and it is formulated with key mechanical properties of engineering stress-strain curves which are readily obtained from standard tensile tests. High resolution digital images of the deformed coupons are captured and analysed to obtain instantaneous dimensions of the necking areas. Through theoretical formulation, true stress-strain curves of the coupons after on-set of necking are derived, and modified with numerical correction factors through successive approximations. After normalization on all the corrected true stress-strain curves, a set of formulae to describe the full-range constitutive model for the high strength S690 steels is proposed. Consequently, the proposed model is readily applicable to both analytical and numerical analyses of the high strength S690 steels and their structural members undergoing both small and large deformations up to fracture.

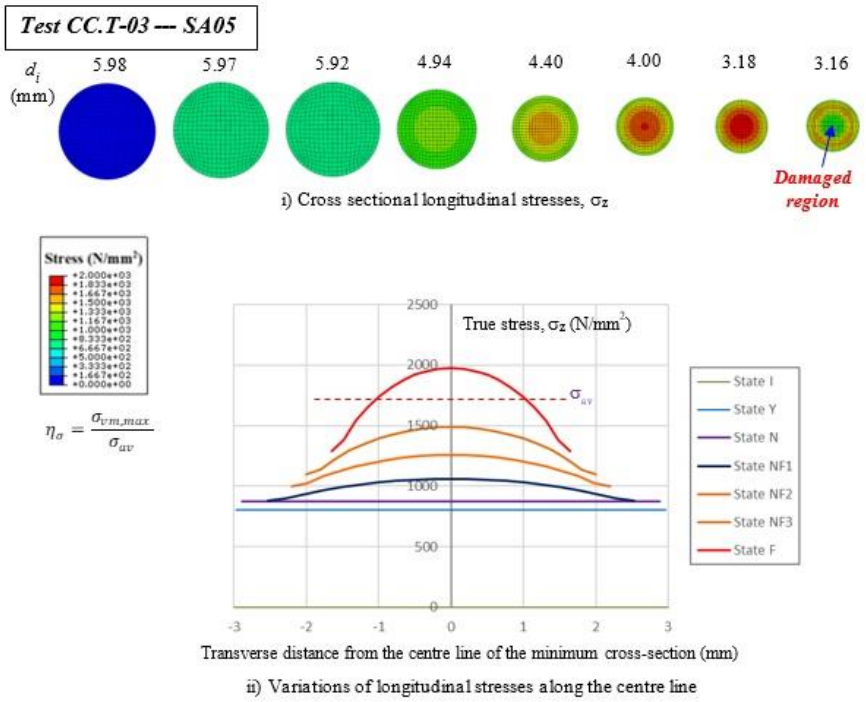


Figure 1 True stress distributions of the critical cross-section at various deformation states: Test CC.T-03

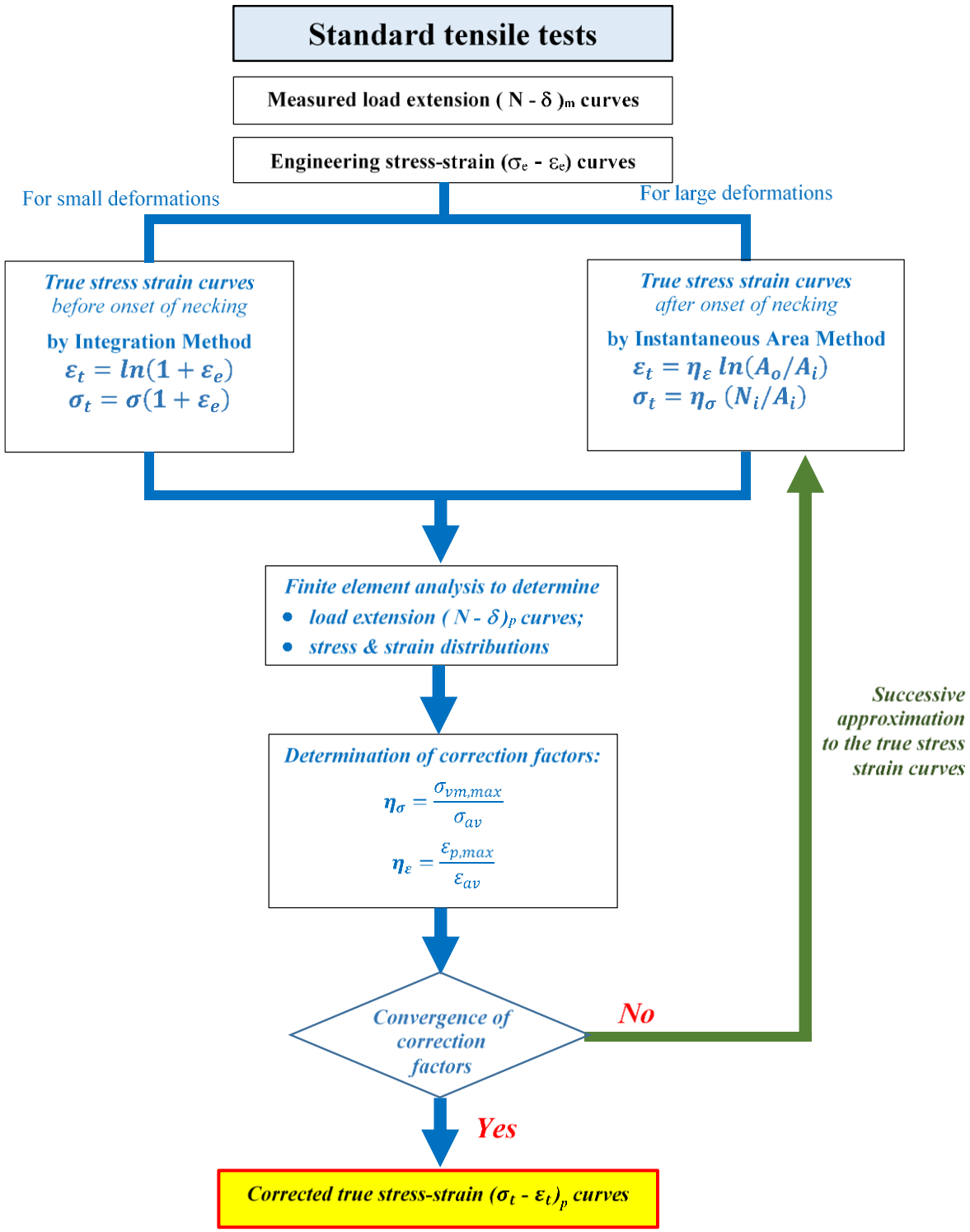


Figure 2 Flow chart of Instantaneous Area Method with numerical correction factors through successive approximations

Researchers: Dr. H. C. Ho (Email: hc.ho@polyu.edu.hk) and

Prof. K. F. Chung (Email: kwok-fai.chung@polyu.edu.hk)

Net Section Resistances of Bolted Connections of High Strength S690 and S960 Steels

In order to verify applicability of the current design equation of net section resistances in EN 1993 to high strength Q690 and Q960 steel (HSS) connections, the net section resistances of HSS bolted connections subject to double shear were investigated experimentally and numerically. A total of 22 HSS bolted connections were tested to net section fracture together with a total of 11 Q345 steel bolted connections.

The main achievements of the experimental investigation are summarised as follows:

a) In general, the HSS connections were able to mobilize their net section resistances even though the HSS have a relatively low ductility and a small tensile-to-yield strength ratio (f_u/f_y), when compared with those of the Q345 steels.

b) The effects of ductility and the ratio f_u/f_y onto the structural behaviour of the HSS bolted connections were further studied with finite element method. It was found that full attainment of the net section resistances of the HSS bolted connections were mainly due to:
   - despite of a relatively low ductility, when compared with Q345 steels, the HSS were able to allow an efficient stress redistribution across the net section, and
   - the tensile resistances of the perforated steel plates were enhanced due to the presence of bi-axial stresses in the vicinity of the bolt holes.

c) Reliability analysis was carried out to re-examine the partial safety factor adopted in the design equation in EN 1993-1-8 for predicting the net section resistances of bolted connections. It was found that the current design equation for net section resistances of HSS (S460~S700) in EN 1993-1-12 with a partial safety factor of 1.25 always provided conservative predictions of the HSS bolted connections.

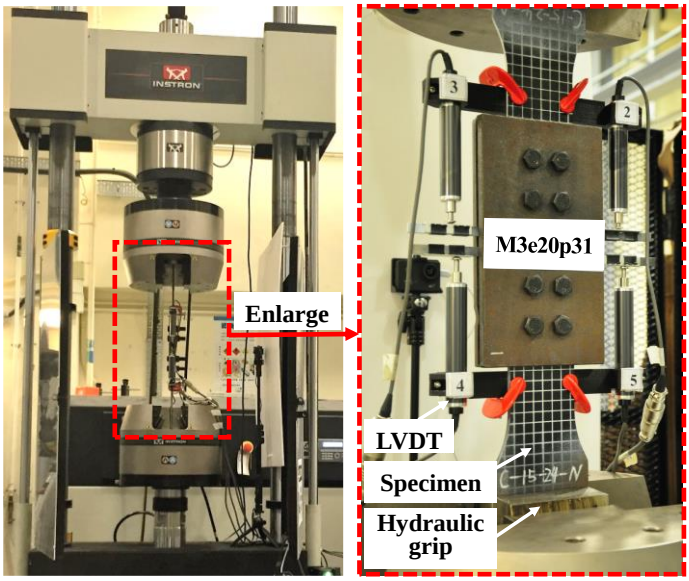
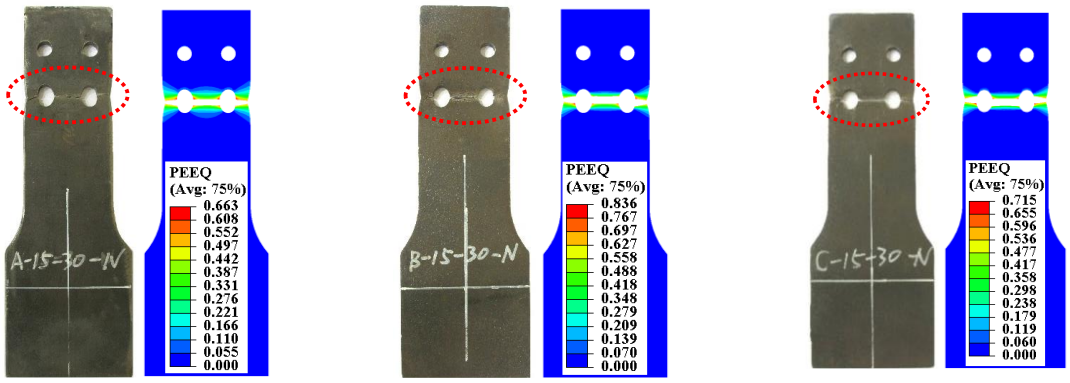


Figure 1 – Test set-up



a) Connection M1e20p39 Q345 steel

b) Connection M2e20p39 Q690 steel

c) Connection M3e20p39 Q960 steel

Figure 2 – Typical failure modes in bolted connections with various steels

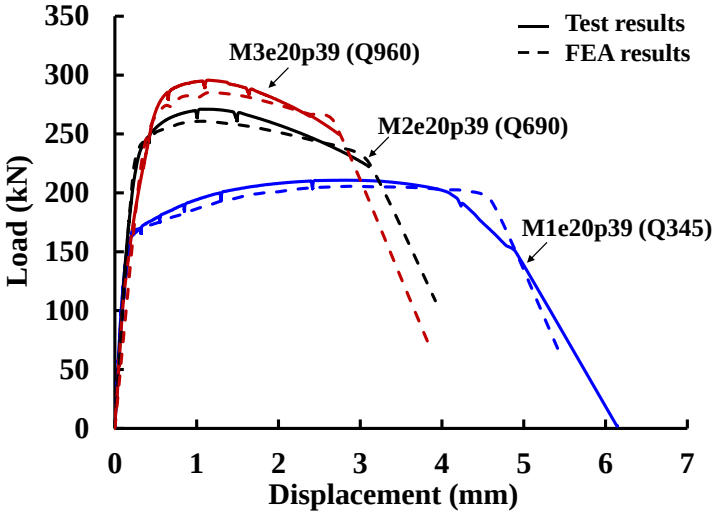


Figure 3 – Load-displacement curves of various bolted connections

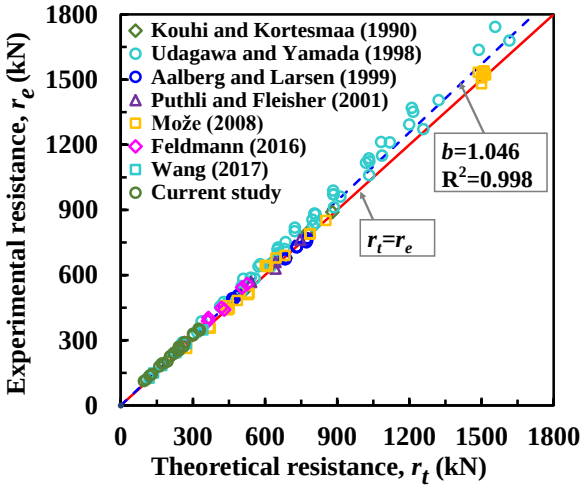


Figure 4 – Statistic evaluation of design model $A_{net}f_u$

Researchers: Ms. X. M. Lin (Email: xm.lin@connect.polyu.hk);

Prof. Michael Yam (Email: michael.yam@polyu.edu.hk) and

Prof. K. F. Chung (Email: kwok-fai.chung@polyu.edu.hk)

Development of a Constitutive Model with Ductile Fracture for High Strength S960 Steels

High strength steels enable significant savings in both materials and time in construction owing to their high strength-to-self-weight ratios. It is essential to develop a constitutive models of high strength S960 steels suitable for a wide range of engineering applications.

In this project, an experimental and numerical investigation into the structural behaviour of specially designed coupons of high strength S960 steels with different degrees of triaxiality was conducted systematically as follows:

a) standard tensile tests of 12 coupons with circular cross-sections with i) a gauge length of 5 do, ii) a gauge length of 1 do, and iii) a gauge length of 0.5 do.

b) finite element modelling on all the tested coupons to predict their deformation characteristics undergoing large deformations as well as at fracture.

c) design development for the true stress-strain curve through the use of the Bridgman's method, and to derive a ductile fracture criterion based on the measured stress triaxiality of various notched coupons at appropriately selected crack initiation strains.

Consequently, a constitutive model with ductile fracture parameters are proposed to facilitate accurate prediction of the deformation characteristics of the high strength S960 steels after onset of necking, and to simulate fracture successfully.

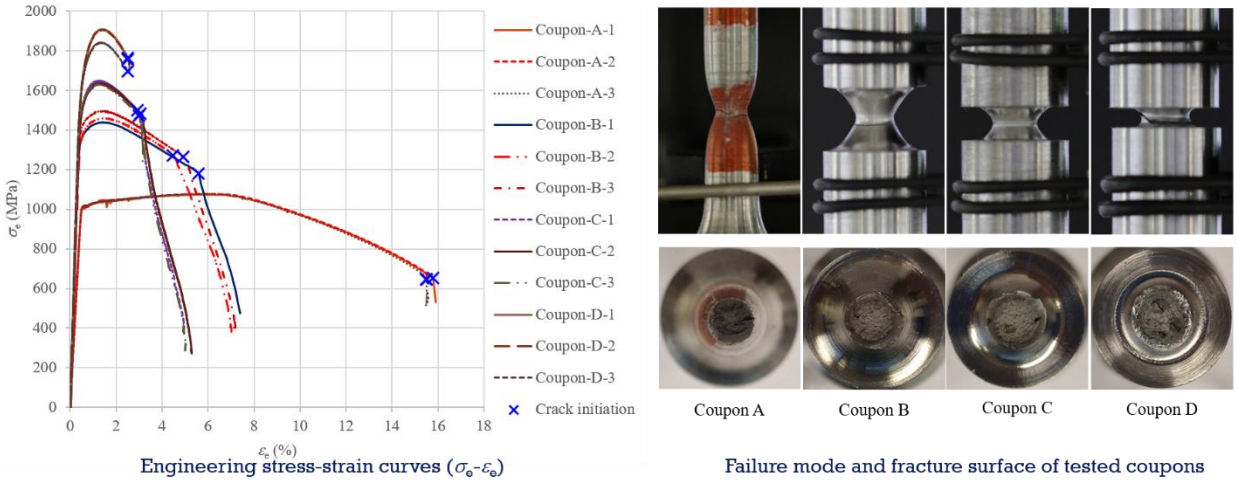
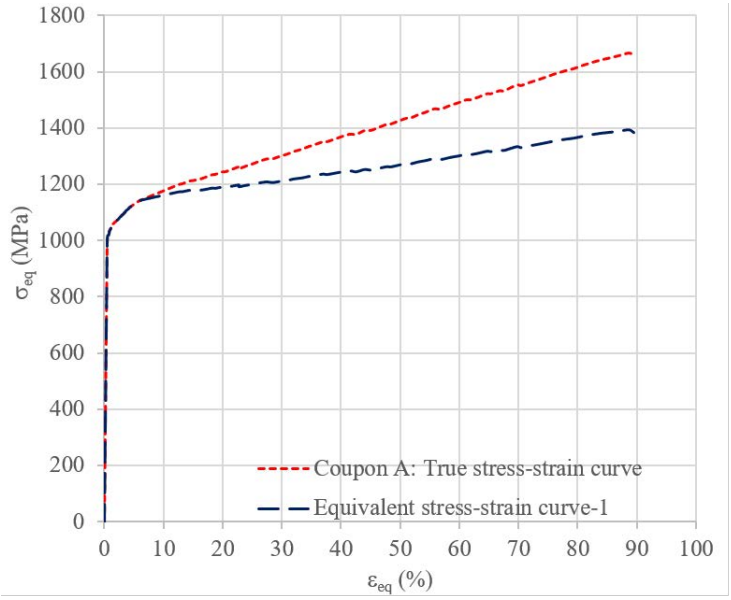
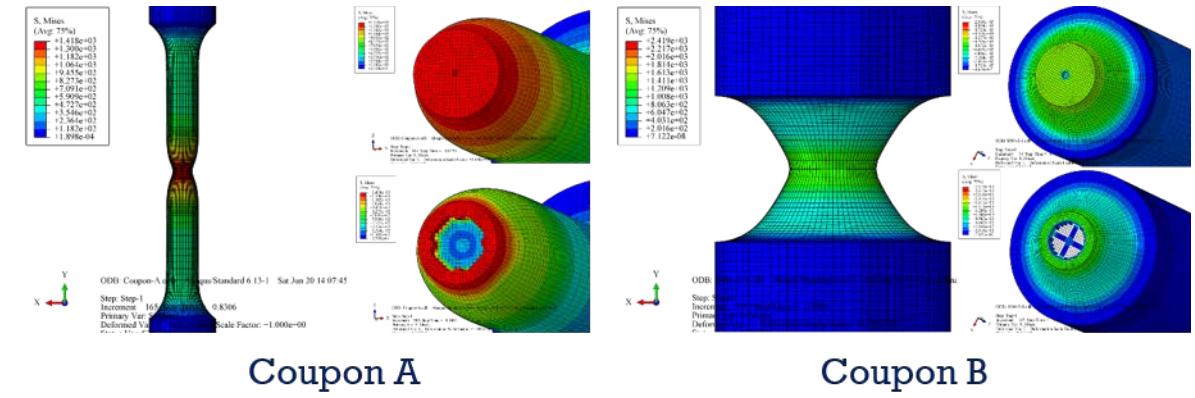


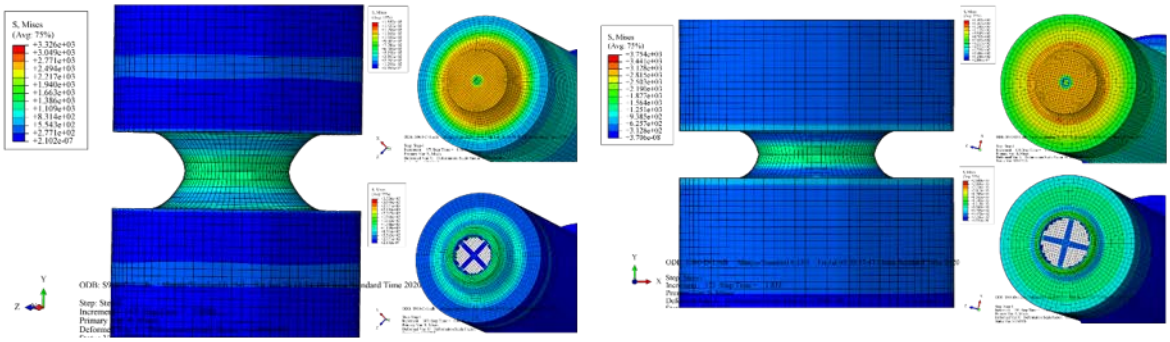
Figure 1 Tensile test results of cylindrical and notched coupons



Equivalent stress-strain curve of S960 HSS



Coupon A Coupon B



Coupon C Coupon D

Numerical simulation of tested coupons

Figure 2 Numerical verification of constitutive model with ductile fracture for S960 HSS

Researchers: Dr. C. Chen (Email: cheng20.chen@polyu.edu.hk) and

Prof. K. F. Chung (Email: kwok-fai.chung@polyu.edu.hk)

High-performance shear connection systems in prefabricated composite bridges

Shear connection systems with multiple shear studs are widely used in pre-fabricated composite bridges. Owing to the demand of large shear resistances in practical conditions, the use of typical shear studs with a diameter of 19 mm is not effective as many of them are often needed. Physical arrangements of these shear studs may cause detailing problems: spacings, end distances, and overlapping resistance zones.

In order to reduce adverse effects of shear pockets on fabrication and installation of pre-cast concrete decks, it is proposed to develop an innovative high-performance shear connection system with i) a steel block connector with double webs, ii) multiple large diameter shear studs, iiii) ultra high performance concrete (UHPC) mortars, and iv) steel and polymer fibers. Systematic push-out tests on the proposed shear connection system with various connection configurations and material grades are carried out. It should be noted that an innovative loading device is specifically designed for these tests, and the confinement effect onto the UHPC mortars provided by surrounding concrete is readily simulated.

In recent trial tests on the proposed shear connection system using bolt connectors with a diameter of 30 mm, a high shear resistance was successfully achieved, and typical failure mode was found to be shear fracture of the bolt connectors. The proposed shear connection system is expected to transfer high shear forces in composite bridges with high strength S690 steel girders.

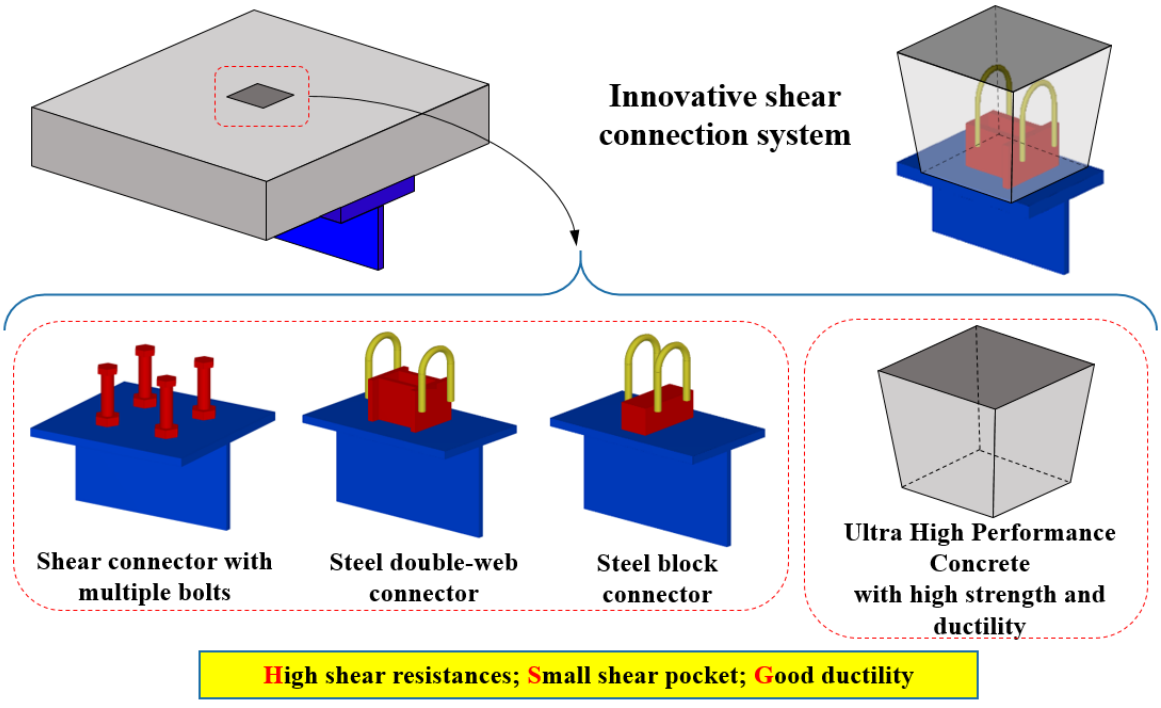


Figure 1 High-performance shear connection systems in pre-fabricated composite bridges

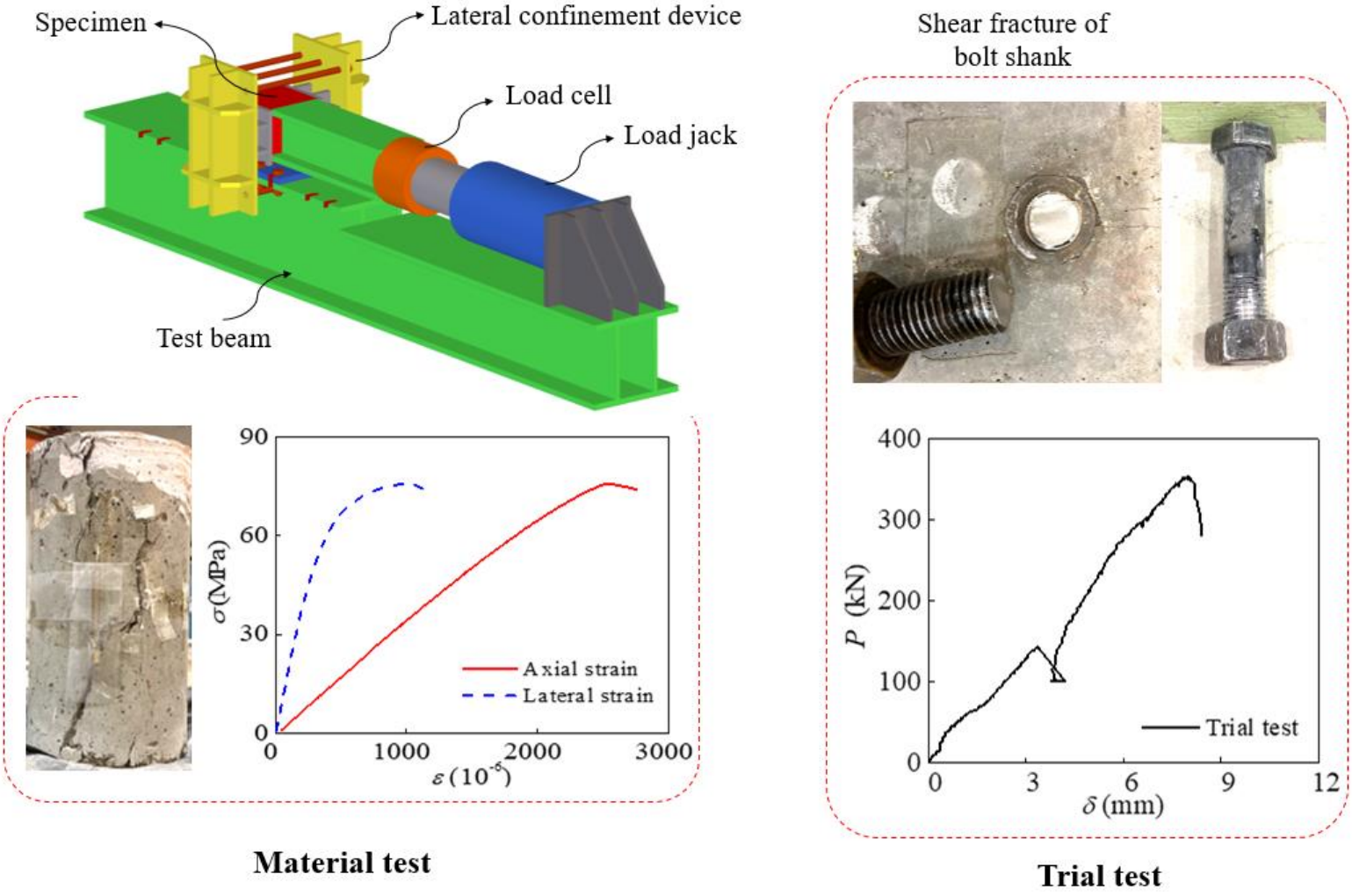


Figure 2 Push-out test of the proposed shear connection system

Researchers: Dr. X. D. Wang (Email: xuanding.wang@polyu.edu.hk) and
Prof. K. F. Chung (Email: kwok-fai.chung@polyu.edu.hk)

UPCOMING EVENTS

For details of the CNERC's upcoming events, please check out our website at:
https://www.polyu.edu.hk/cnerc-steel/en/news-events/upcoming-events

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