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)

FEATURE STORY

Visit by Mr. Alfred Sit Wing-hang, JP Secretary for Innovation and Technology, the Government of Hong Kong SAR

Mr. Alfred Sit Wing-hang, Secretary for Innovation and Technology, the Government of Hong Kong SAR led a Delegation Team to visit CNERC in the afternoon of Thursday 20 May 2021. The Delegation Team was warmly received by Prof. J. G. Teng, President of PolyU, and Prof. K. F. Chung, Director of CNERC together with all office bearers. The Delegation Team consisted of:

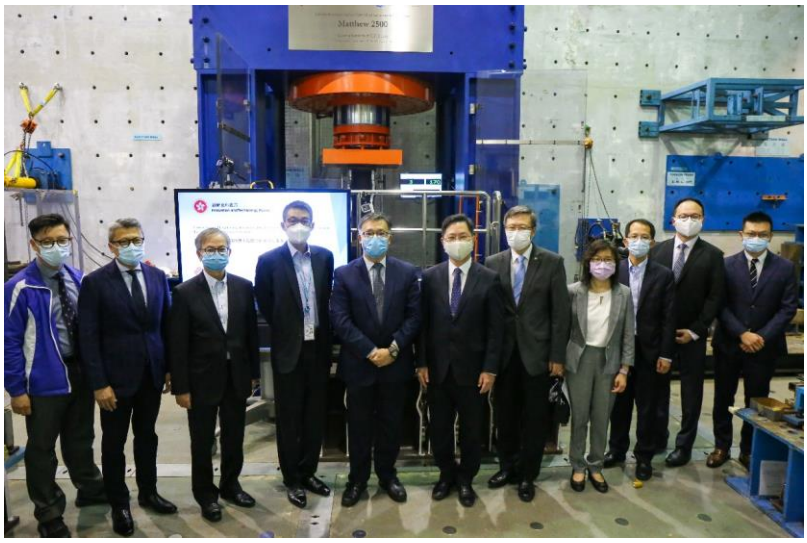
- Mr. Alfred Sit, Secretary for Innovation and Technology
- Dr. David Chung, Under-Secretary for Innovation and Technology
- Ms. Rebecca Pun, Commissioner for Innovation and Technology
- Mr. Arthur Au, Deputy Commissioner for Innovation and Technology
- Ms. Fiona Au, Assistant Commissioner for Innovation and Technology
- Mr. Jeffrey Chim, Administrative Assistant to Secretary for Innovation and Technology
- Ms. Jessie Wong, Press Secretary to Secretary for Innovation and Technology
- Ms. Lillian Cheong, Political Assistant to Secretary for Innovation and Technology
- Mr. Sammy Chan, Researcher
- Ms. Eva Shum, Researcher

The following Senior Engineers from the Government were also invited to join the visit:

- Ir John Kwong, Head of Project Strategy and Governance Office, Development Bureau
- Ir Michael Leung, Project Manager, East Development Office, Civil Engineering and Development Department
- Ir Tommy Cheung, Assistant Secretary of Project Strategy and Governance Office, Development Bureau

Prof. Chung led a technical guide for the Delegation Team to visit the Structural Engineering Research Laboratory, Laboratory Y001, of the PolyU, and inspected large scale testing facilities on structural members and joints. Prof. Chung also introduced to the Delegation Team a number of research and development projects on high strength S690 and S960 welded members and sections under both monotonic and cyclic actions.

From left: Mr. Alfred Sit, Prof. J. G. Teng, Prof. K. F. Chung



From left: Dr. H. C. Ho, Prof. Michael Yam, Dr. David Chung, Ir Michael Leung, Prof. K. F. Chung, Mr. Alfred Sit, Prof. J. G. Teng, Ms. Rebecca Pun, Mr. Arthur Au, Dr. T. M. Chan, and Dr. Andy Leung.

A group photo of Mr. Alfred Sit, Prof. J. G. Teng, and Prof. K. F. Chung with research personnel of CNERC.

From left: Ir John Kwong, Prof. J. G. Teng, Mr. Alfred Sit, Prof. K. F. Chung, Ms. Rebecca Pun, Mr. Arthur Au, Ir Michael Leung, and Dr. David Chung.

Prof. K. F. Chung reported to Mr. Sit and the Delegation Team the latest research activities and achievements of CNERC, in particular:

- effective use of high strength S690 steels in construction, and welding technology
- strength and ductility, member buckling and joint resistances
- design development and codification, and compilation of technical guides
- application of high strength S690 steels in construction projects:
    i. Steel Bridge “Eternity Arch” of Cross Bay Link, Tseung Kwan O, East Kowloon, Hong Kong SAR, and
    ii. The Fourth Macau-Taipa Bridge, Macau SAR.

Potential applications of high strength S690 steels in construction include steel piles, noise barriers, and foot bridges.

Visit of Civil Engineering and Development Department of The Government of Hong Kong SAR

Following up the visit of Civil Engineering and Development Department(CEDD) to our Centre in mid-March 2021, Dr. Julian Kwan, AssistantDirector (Technical) of CEDD led a team of 10 senior engineers to visit CNERC on 16 June 2021 to carry out technical exchange about the latestresearch and development of S690 steels. The delegation team consisted of:

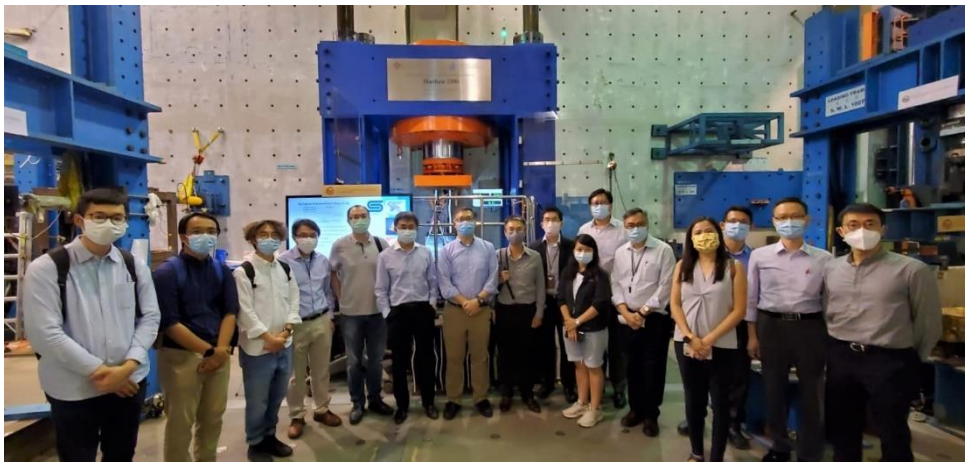
- Dr. Julian Kwan, Assistant Director (Technical)
- Ir Peter P. C. Mok, Deputy Head of Civil Engineering Office (Project & Environmental Management)
- Ir Henry C. K. Chu, Deputy Project Manager (East), East Development Office
- Ir Kenneth K. S. Ho, Deputy Head of Geotechnical Engineering Office (Landslip Preventive Measures)
- Ir Gabriel Woo, Project Team Leader, Civil Engineering Office
- Ir Jason Hung, Senior Engineer
- Ir Hung Cheung Wai, Senior Engineer
- Ir Tam Siu Ming, Senior Engineer
- Ir Alice Leung, Senior Engineer
- Ir Patrick Lam, Geotechnical Engineer
- Ir Charles Ho, Engineer
- Ir Yip On Yee, Engineer

Moreover, Prof. K. F. Chung, Director of CNERC, has invited the following senior personnel of Pristine Structural Steel Fabrication in Dongguan to join the visit:

- Mr. Chi Fat Chan, General Manager, Construction Services Division
- Mr. Martin Man, Engineer
- Mr. Alan Yuen, Engineer

Being a subsidiary of Gammon Construction Ltd., Pristine is a technical collaborator of CNERC on fabrication of S690 steels since 2013.

The Delegation Team visited the Structural Engineering Research Laboratory, Laboratory Y001, of the PolyU, and inspected various research and testing capabilities for large scale structural tests. The Delegation Team was also introduced on a number of research and development projects on high strength S690 and S960 steels.



Prof. K. F. Chung reported the latest research activities and achievements of the CNERC, in particular:

- Effective use of high strength S690 steels in construction, and their welding technology;
- Application of high strength S690 steels in construction projects.

Mr. Chan from Pristine spared his experiences on steelwork fabrication and welding practice commonly adopted in the industry, and he had also addressed the following issues:

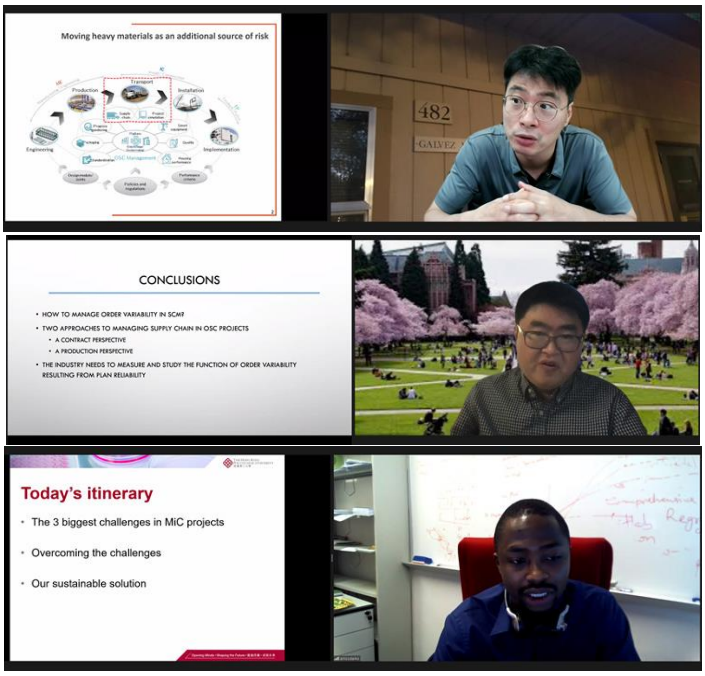
- fabrication of box sections, and pre-heating temperatures;
- selection of welding electrodes; and
- good practice in site welding.

NEWS

CNERC and Korea Institute of Construction Engineering and Management jointly organized The First ICCEPM International Seminar on Modular Integrated and Off-site Construction (MiC) on 12 August 2021, and the seminar is initiated and supported by the International Consortium of Construction Engineering and Project Management, with 210 participants from 21 countries including HK, Mainland China, South Korea, United States and Australia.

The seminar was hosted by four speakers from Hong Kong, South Korea, and the U.S.A. who shared their state-of-the-art studies in supply chain management, logistics planning, structural engineering and sustainability for MiC and OSC. This seminar provided valuable opportunities for both researchers and practitioners to learn and share various approaches to tackle managerial, technical and engineering issues for MiC and OSC.

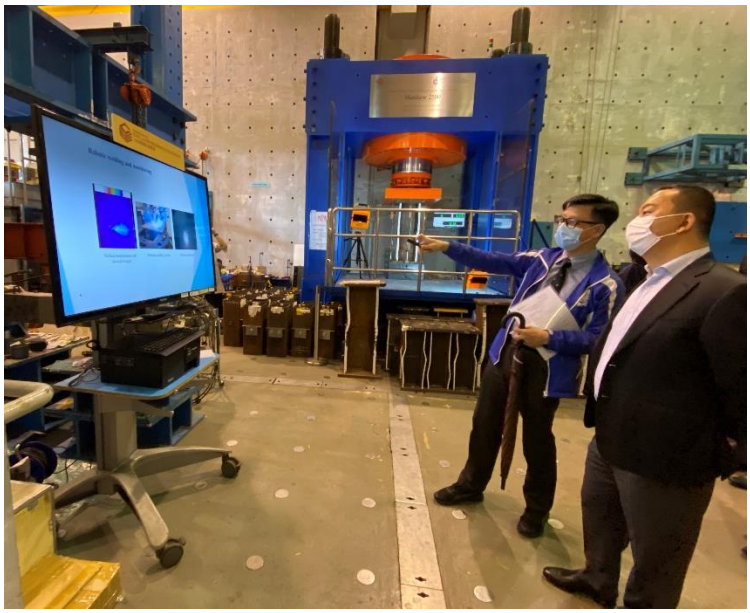
Dr. T. M. Chan, Deputy Executive Secretary of CNERC was one of the speakers of the ICCEPM International Seminar.



Speakers of the ICCEPM International Seminar.

NEWS

Mr. Sun Feng Quan, Chairman and CEO of Hong Kong Aerospace Technology Group Co, Ltd., and Mr. Liu Zhi Ming, representative of MOST HK visited the Structural Engineering Research Laboratory of PolyU on 19 August 2021, and Dr. H. C. Ho, Deputy Executive Secretary of CNERC introduced the recent research achievements of CNERC to the visitors.



CNERC RESEARCH

The CNERC Newsletter incorporates research articles from our researchers 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.

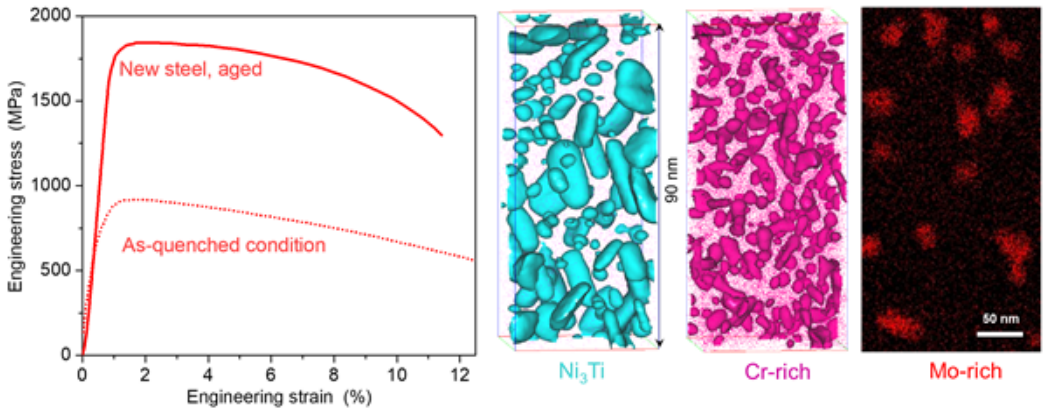
A total of 3 research articles are provided in this issue as follows:

1. Design of Ultrahigh-strength Steels Strengthened by Multiple Precipitates
2. Incorporating Machine Learning in Estimating Steel Properties
3. Self-cleaning Eco-friendly Advanced Coating for Steel Corrosion Prevention in Marine Infrastructures

RESEARCH

Design of Ultrahigh-strength Steels Strengthened by Multiple Precipitates

Ultrahigh-strengthsteels are critical in the automotive, aerospace, shipbuilding, and energy industries due to their high potential for light-weight design, cost reduction, and energy saving. Maraging steels represent an important class of high-alloyed and almost carbon-free ultrahigh-strengthsteels, the hardening of which occurs in aging of the carbon-free martensite as the result of precipitation of dispersed intermetallic nanoparticles. However, conventional maraging steels contain high levels of expensive alloying additions, including Ni and Co, which results in a dramatically increase of the steel cost, making these materials too expensive for general use and application. In this work, we developed a new class of ultrahigh-strengthsteels that achieves balanced mechanical properties and cost effectiveness. Our strategy is to partially replace the high-costalloying elements Ni and Co with inexpensive Cr while optimizing the Ti and Mo contents,which allows for the development of new maraging steels with comparable mechanical properties but substantially reduced cost as compared with conventional maraging steels. Moreover, the Cr addition to maraging steels improves their corrosion and oxidation resistance, making them potentially applicable in harsh environments, such as elevated-temperatureconditions. With the cooperative strengthening of Ni3Ti, Mo-enriched, and Cr-rich co-precipitates,the newly developed steels exhibit a yield strength of 1.8 GPa at the room temperatureand over 1.1 GPa at 500 °C, demonstratinga high strength over a wide temperature range.



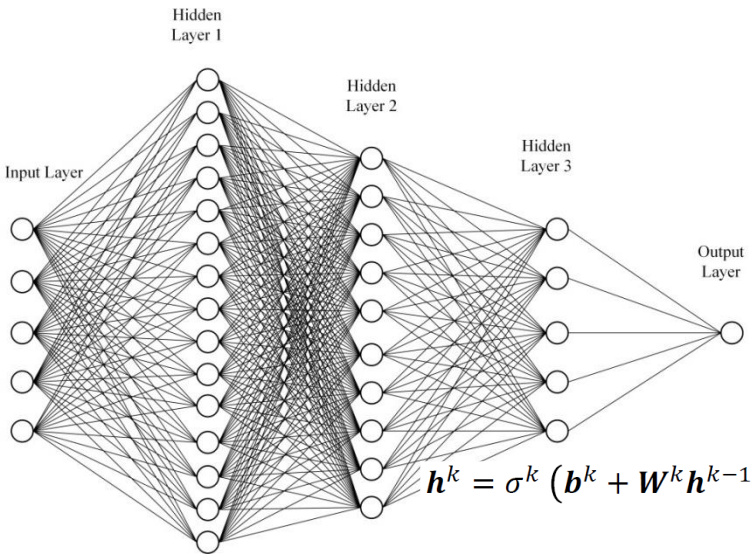
Mechanical properties and precipitate microstructure of the newly developed steel

Researcher: Dr. Z. B. Jiao, ME (email: zb.jiao@polyu.edu.hk)

Incorporating Machine Learning in Estimating Steel Properties

In the steel production process, various substances are used to alloy with the steel, with compositions tailored to achieve different characteristics of the material. These substances may include manganese, silicon, phosphorus or sulphur in various forms. When added in different amounts and at different stages of the production, they can significant affect the physical and mechanical properties of the material such as the strength, ductility and weldability, etc. While our knowledge in metallurgy and material sciences have advanced, the complex relationships among the material composition, production process and various properties of the end product still involve much uncertainty. There may be 'hidden' correlations that are not yet well understood, but can be uncovered by harnessing large volume of production data through advanced data analytics such as machine learning techniques. This enables quantification of the rich experience in the past, for enhanced understanding of material properties and improved quality assurance for future production.

To facilitate better understanding of these issues and their implications to civil engineering applications involving high performance steel, this study investigates various machine learning and deep learning techniques in the characterization of construction material properties, and to develop tailor-made models suitable for prediction of steel properties based on the components and manufacture process. These data analytics techniques include deep neural networks (DNN), ensemble methods (e.g., random forest, XGBoost), support vector machine, ridge and lasso regression, etc.



Activation Function	Formula
sigmoid	$s(x) = \frac{1}{1+e^{-x}}$
tanh	$\tanh(x) = \frac{e^x - e^{-x}}{e^x + e^{-x}}$
relu	$y(x) = \max(0, x)$
leaky-relu	$y(x) = \max(\alpha x, x) : 0 < \alpha \ll 1$
linear	$y(x) = x$

Activation function σ

Figure 1 Sample structure of DNN, using mineral compositions and parameters in manufacture process as input, and obtaining steel strength as output.

A trial database of steel properties was then established containing 2000 entries of yield strength and various contributing factors including compositions of elements (C, Si, Mg, P and S), and the identities of manufacturers and adopted procedure standards in the manufacturing process. With the limited dataset in the trial database, XGBoost appear to be more suitable for prediction of steel strength from the manufacture process. As machine learning methods generally improve with the number of data points and the number of attributes considered (information on raw material, mineral composition and other details of the manufacturing process), the performance is expected to improve further with an expanded database. Besides, further discussions and interpretations on the significance of features by model interpreters would discover deeper understanding of the matter.

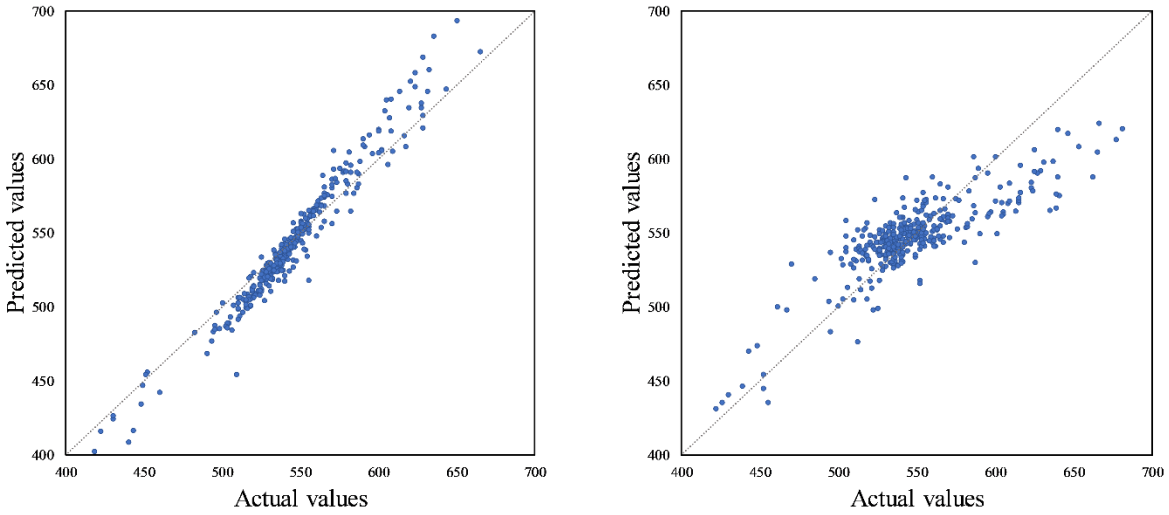


Figure 2 Predicted versus actual steel yield strength by (a) XGBoost and (b) DNN

Researchers: Dr. Andy Leung, CEE (email: andy.yf.leung@polyu.edu.hk);
Mr. Vahid Asghari, CEE (email: vahid.asghari@connect.polyu.hk);
Dr. Mark Hsu, CEE (email: mark.hsu@polyu.edu.hk)

Self-cleaning Eco-friendly Advanced Coating for Steel Corrosion Prevention in Marine Infrastructures

Corrosion is a serious problem for steel structures exposed to marine environments. To improve the corrosion resistance of steel structures, an environmentally friendly water-based geopolymer coating has been developed to protect steel from corrosion. The geopolymer was made through akali activiation of metakaolin and two-dimensional graphene nanosheets were used as functional fillers to modify the micro-structures of geopolymer (Fig.1). The self-cleaning properties was also entitled to the coating by a simple process. The geopolymer is consisted of silicon oxygen tetrahedra and aluminum oxygen tetrahedra linked by oxygen bridges. Due to the high energy of silicon oxygen bond and aluminum oxygen bond, the geopolymer has many excellent properties, including high mechanical strength, good durability in terms of the acid and alkali resistance, and good impermeability, which made it an excellent coating material. Graphene nanosheets can be filled into the coating defects and form a physical barrier layer, reducing the surface energy of the coating, making the coating more hydrophobic (Fig.2). The nanosheets are dispersed and stacked in the coating, using the labyrinth effect to effectively prevent the migration of corrosive substances to the steel substrate. The electrochemical test results showed that, due to the high chemical stability and dense structure of the geopolymer and the labyrinth effect of the in-situ reduced graphene oxide nanosheets, the anti-corrosion resistance of steel is improved by more than two orders of magnitude when the added amount is 0.1 wt% only.

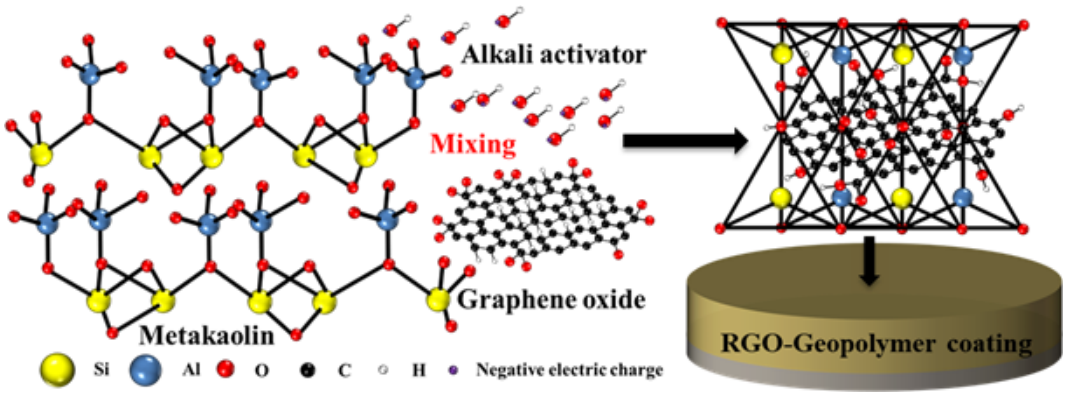


Figure 1 Schematic illustration of preparation process for RGO-modified geopolymer coating

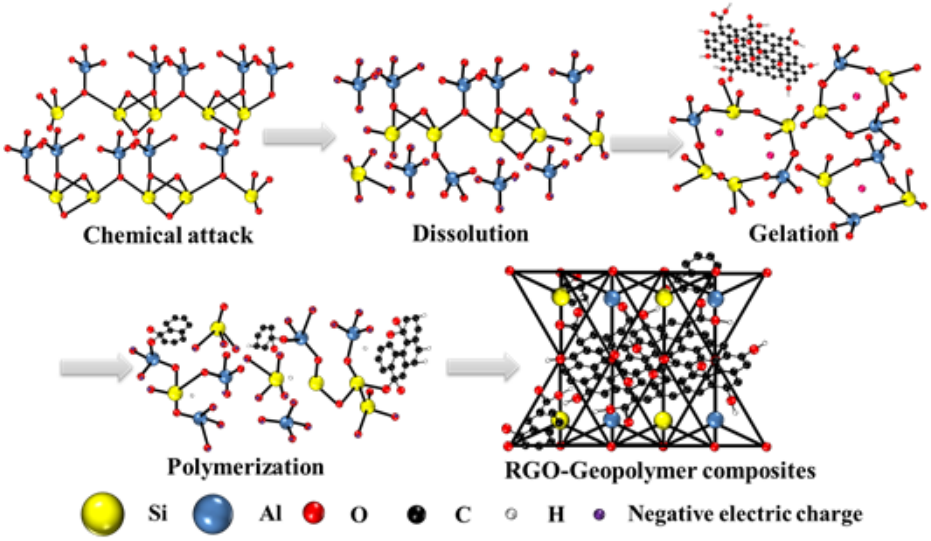


Figure 2 Schematic illustrations of the chemical structural transformation of RGO-modified geopolymer

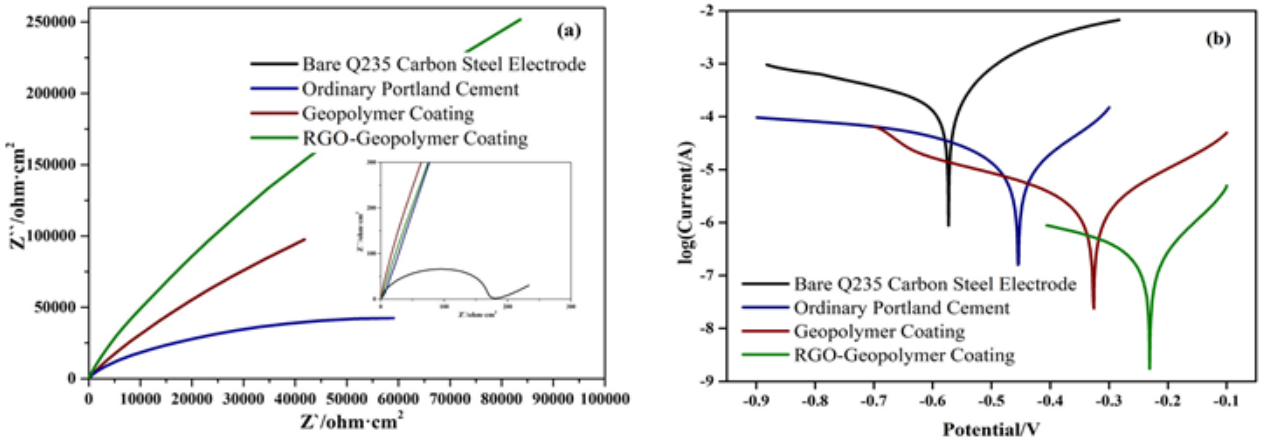


Figure 3 Nyquist plots (a) and Tafel plots (b) of the bare steel and steel protected by different types of coating

Researcher: Prof. J. G. Dai, CEE (email: jian-guo.dai@polyu.edu.hk)

UPCOMING EVENTS

CNERC is going to organize the second Annual Technical Symposium (ATS) on 9 September 2021. The first ATS was held last June among researchers of CNERC, and favorable responses from Project Investigators with over 20 nominations were received with a total of 12 presentations were made during the one-day event.

Details of the upcoming ATS:-

Date: 9 September 2021 (Thursday)
Time: 9:00 a.m. – 5:30 p.m.
Venue: Z206, The Hong Kong Polytechnic University

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/

CONTACT US

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