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Project Title : **Corrosion mechanism of steel bars in nano-modified cement-based materials**

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Project Team Members : **Dr. Haibing Zheng**

Project Outline :

Recently, nano-scale cement-based materials was reported as the next ground-breaking development for concrete structures. Many kinds of nano materials, nano-silica (NS), nano-alumina (NA), carbon nanotube (CNT), carbon nanofiber (CNF) etc., have been studied for possible application in concrete. These nano-materials with ultra-high specific area might exhibit a) nucleation effect, b) filling effect and c) bridging effect (for CNT and CNF) in concrete. Therefore, these nano materials might serve as effective admixtures in concrete for corrosion inhibition, and the application of nano-materials would also be a potential novel corrosion-prevention method to extend the service life of concrete structures in aggressive environments. However, studies about the influence of nano materials on the corrosion of steel bars in concrete are rather rare.

Four aspects of studies will be conducted, which would offer a systematic knowledge of the corrosion of steel bars in nano-modified cement-based materials. a) corrosion resistance (durability) of nano-modified cement-based materials. b) passivation of steel bars in nano-modified materials. c) determination of chloride threshold value (CTV) of steel bars. d) monitoring of corrosion propagation of steel bars in nano-modified concrete.

Project Progress:

The early-age passivation of carbon steel in the cement paste prepared with and without nano-silica was studied. The aim is to investigate the passivation process, characterize the passive film formed on the traditional carbon steel bar in real concrete environment and then reveal the influence of the SCMs (e.g. nanosilica) on the intrinsic corrosion resistance of the steel bar. The passivation process was studied by electrochemical test methods, including open circuit

potential (OCP), electrochemical impedance spectroscopy (EIS) and potentiodynamic polarization tests. The surface morphology of the steel was analyzed by Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy (EDS) and the passive films formed were characterized by using X-ray Photoelectron Spectroscopy (XPS).

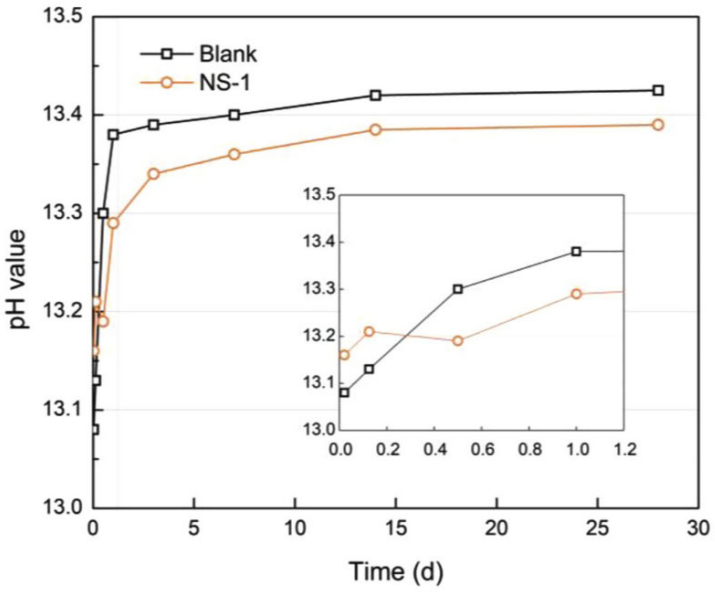

Figure 1 Evolution of pH values of pore solutions in cement pastes with and without nano-silica

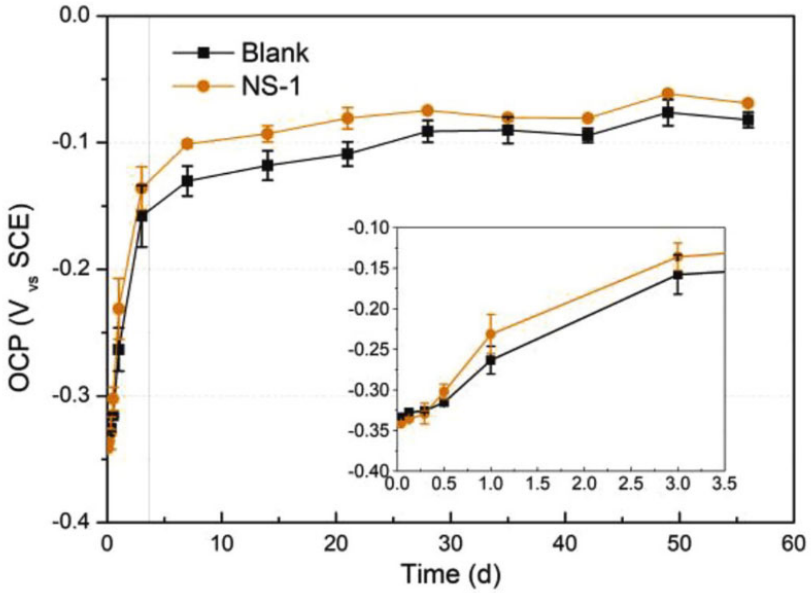

Figure 2 Evolution of open circuit potential of steel bar in cement pastes

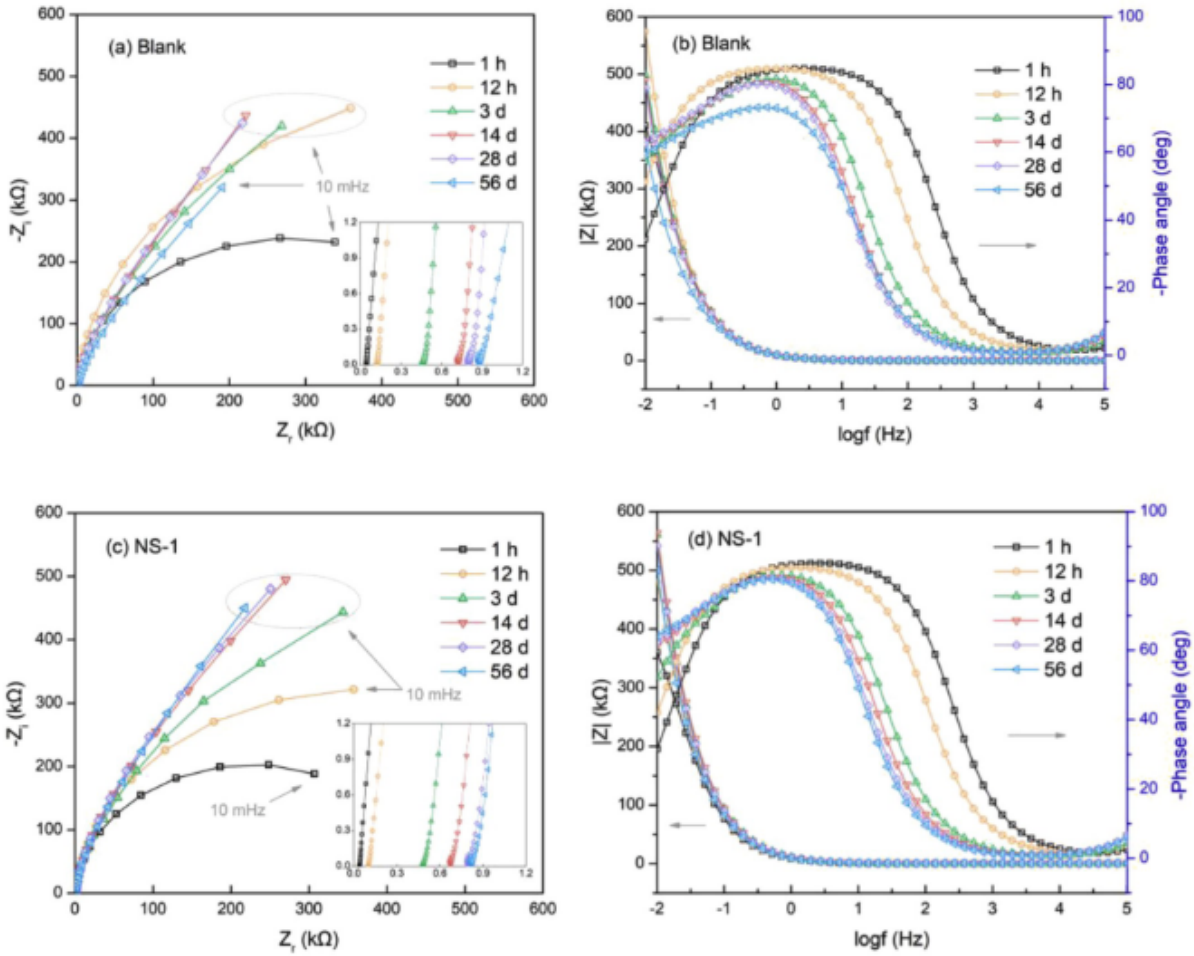

Figure 3 EIS spectra of the steel in cement pastes after different curing times: (a) Nyquist plots and (b) Bode plots of the Blank group specimen; (c) Nyquist plots and (d) Bode plots of the NS-1 group specimen. A representative set of results for each group was selected

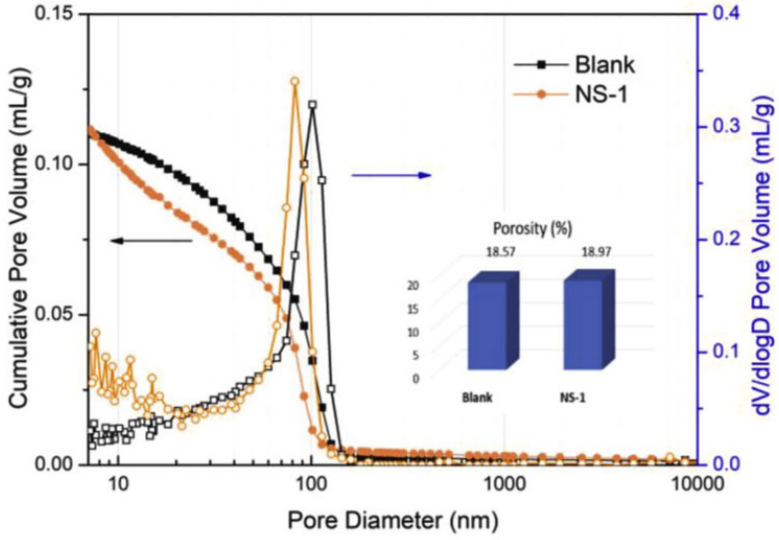

Figure 4 Pore size distributions and porosities of cement pastes prepared with and without nano-silica

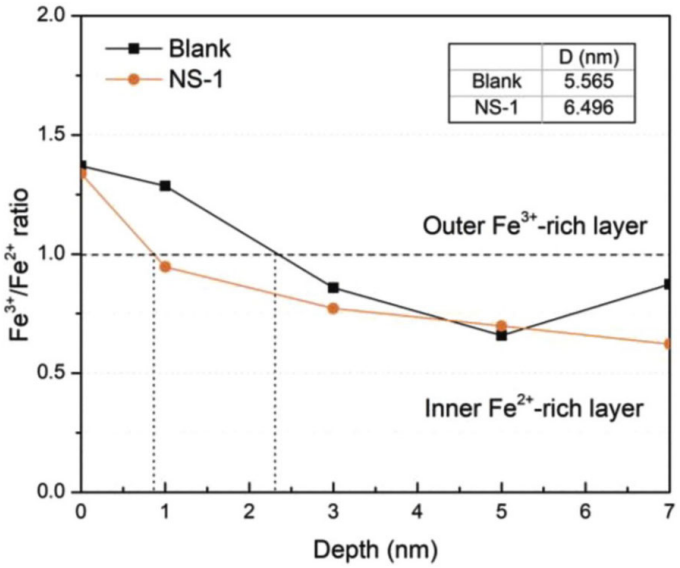

Figure 5 Fe3+/Fe2+ ratio in passive film as a function of sputtered depth

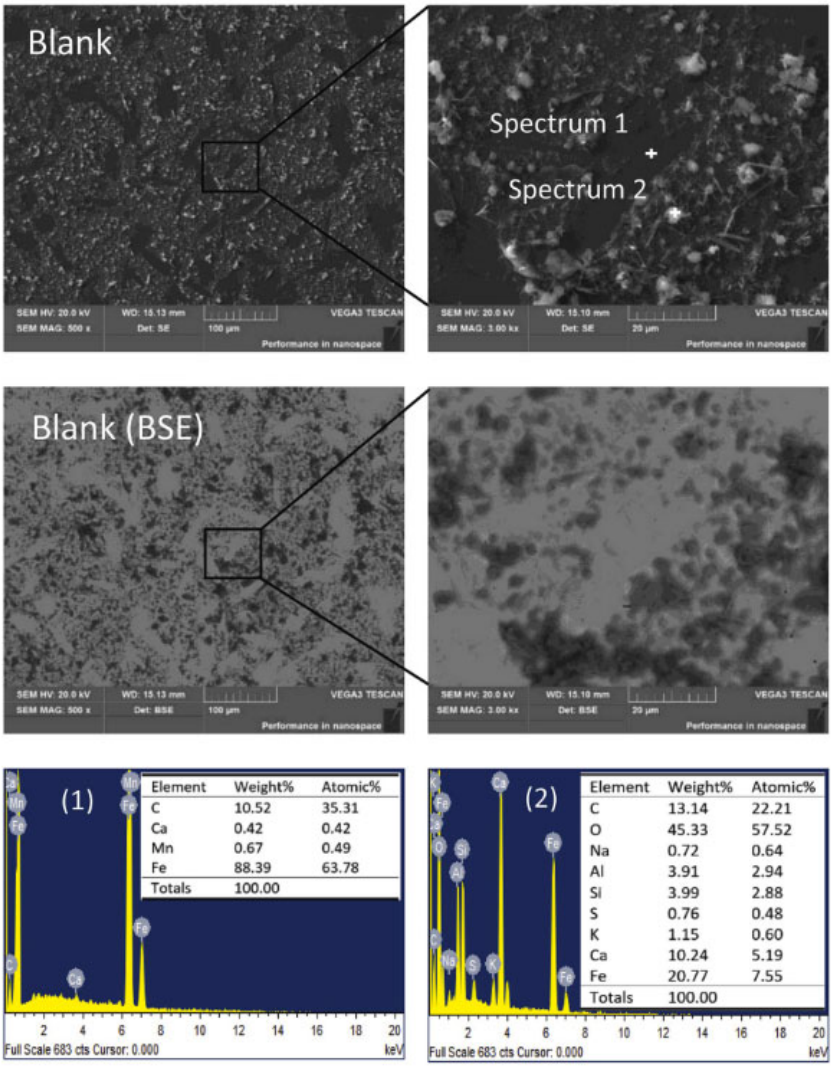

Figure 6 SEM & BSE images and EDS results of steel/paste interface in pure cement paste

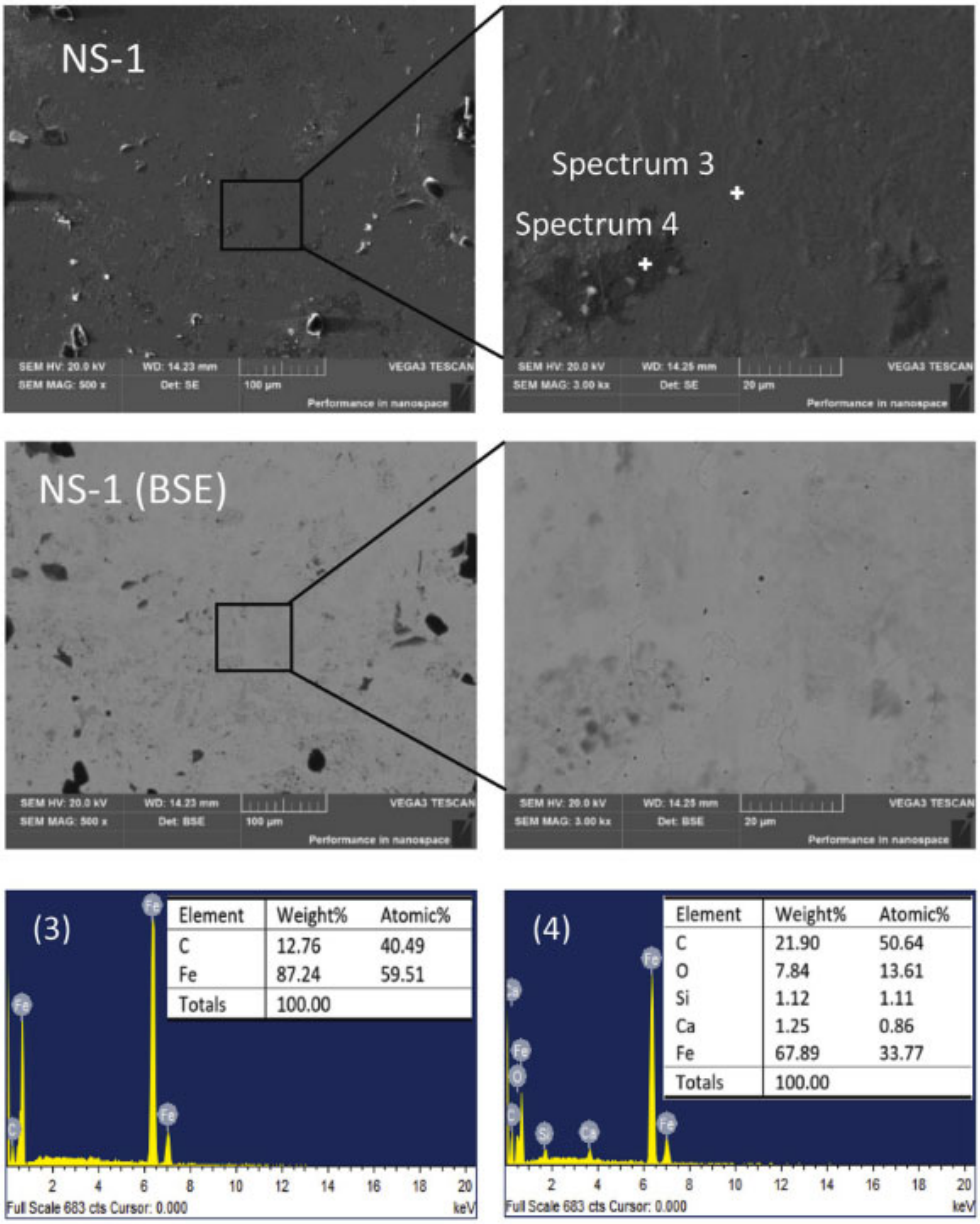

Figure 7 SEM & BSE images and EDS results of steel/paste interface in cement paste prepared with nano-silica

Project Deliverables :

The passivation of steel bar in nano-modified materials

Future Work :

1) Determine the chloride threshold value of steel bar in nano-modified concrete

To determine the CTV of steel bars in nano-modified concrete, accelerated corrosion test (wetting-drying cycles) will be carried out. The electrochemical test methods, including open circuit potential, electrochemical impedance spectroscopy and polarization tests, will be

conducted to monitor the corrosion initiation of steel bars. The chloride ions concentration in the concrete at the depth of steel bars will be measured.

2) monitoring of corrosion propagation of steel bars in nano-modified concrete
Potential will be applied on the steel bars in concrete to accelerate the corrosion process. The corrosion products will be characterized, and the morphology of the steel/concrete interface will be observed. The cracks induced by the corrosion will be analyzed.

Publication List :

1. Haibing Zheng, Chi Sun Poon*, Weihua Li. Mechanistic study on initial passivation and surface chemistry of steel bars in nano-silica cement pastes[J]. Cement & Concrete Composites, 2020: 103661.
2. Haibing Zheng, Jian-Guo Dai, Lei Hou, Guozhe Meng, Chi Sun Poon*, Weihua Li*. Enhanced passivation of galvanized steel bars in nano-silica modified cement mortars[J]. Cement & Concrete Composites, 2020: 103626.
3. Yamei Cai, Haibing Zheng*, Xiang Hu, Jianxin Lu, Chi Sun Poon*, Weihua Li. Comparative studies on passivation and corrosion behaviors of two types of steel bars in simulated concrete pore solution[J]. Construction and Building Materials, 266, 120971.
4. Haibing Zheng, Jian-Guo Dai, Chi Sun Poon*, Weihua Li. Influence of a superplasticizer on initial corrosion of galvanized steel bars in concrete pore solution[J]. Journal of Materials in Civil Engineering. DOI: 10.1061/(ASCE)MT.1943-5533.0003722.