UNIVERSITI TEKNOLOGI MARA

EFFECTS OF CHLORIDE TRANSPORT PROPERTIES IN NANO METACLAYED ULTRA-HIGH PERFORMANCE CONCRETE TOWARDS CORROSION CHARACTERISTICS OF EMBEDDED STEEL

MOHD FAIZAL BIN MD JAAFAR

Thesis submitted in fulfillment
of the requirements for the degree of
Doctor of Philosophy

Faculty of Civil Engineering

May 2019

ABSTRACT

The major concern on the deterioration of reinforced concrete structure is due to the corrosion of steel reinforcement from the aggressive environment such as chloride penetration. Ultra-high performance concrete (UHPC) is an advanced concrete material having ultra-high strength with excellent durability properties. Inclusion of nano metaclay in UHPC is expected to overcome the chloride penetration resulting corrosion of steel embedded in UHPC by providing nano filler effect. In this study, chloride penetration resistance characteristics of concrete and corrosion steel embedded in concrete specimens were investigated. Four (4) types of concrete were cast namely normal performance concrete (NPC), high performance concrete (HPC), ultra-high performance concrete (UHPC) and a series of nano metaclayed-UHPC. The raw nano clay underwent the calcination process to produce nano metaclay and its chemical composition and morphology properties were determined by using X-Ray Diffraction (XRD) and Scanning Electron Microscope (SEM), respectively. The nano metaclayed-UHPC mixes were designed based on 1%, 3% and 5% levels of replacement of nano metaclay to Ordinary Portland Cement (OPC). The hardened concrete properties were examined in terms of compressive strength and chloride resistance characteristics. For chloride resistance characteristics, three (3) assessments were conducted which are chloride content, chloride depth and rapid chloride permeability. HACH spectrometer and colorimetric spray method were carried out to evaluate chloride content and chloride depth inside the immersed concrete specimens, respectively. Meanwhile, rapid chloride permeability test (RCPT) was carried out to determine the Coulombs charge passed through the concrete specimens. For corrosion monitoring, the steel embedded in concrete specimens were assessed by using half-cell potential and Fibre Bragg Grating (FBG) strain sensor. Finally, the change in pH of reinforced concrete and weight loss of corroded steel were examined. All the concrete specimens were immersed in 3% NaCl solution up to 365 days and the tests conducted were performed at 3, 7, 28, 56, 91, 182 and 365 days. It was found that UHPC1 which is inclusion of 1% nano metaclay in UHPC enhanced the compressive strength up to 10% corresponding to the plain UHPC. The results exhibited that UHPC1 demonstrated a superior performance in term of chloride penetration resistance. It is also noticeably that the corrosion potential of embedded steel in concrete recorded by half-cell potential can be explained by the variations in strain changes recorded by FBG sensor. It is demonstrated that inclusion of 1% nano metaclay significantly and positively affect corrosion resistant for embedded steel in concrete and these can be detected using both techniques. Moreover, Response Surface Method (RSM) was performed to determine the relationship. Based on RSM analysis, inclusion of nano metaclay in UHPC have strong relationship towards the strength, chloride resistance characteristics and corrosion resistance for its embedded steel reinforcement. Considering all these test results, it was attained that 1% of nano metaclay in UHPC exhibits excellent compressive strength and adequate durability performance in terms of chloride penetration resistance and delayed the embedded steel in concrete to corrode.

ACKNOWLEDGEMENT

In the name of Allah S.W.T. the most gracious and most merciful, Lord of the Universe, with His permission Alhamdulillah the study has been completed. Praise to Prophet Muhammad S.A.W., His companions and to those on the path as what He preached upon, might Allah Almighty keep us His blessing and tenders.

I wish to express my gratitude to my supervisor, Professor Dr. Hjh. Hamidah Mohd Saman for her supervision, valuable guidance, advices, reviewing my thesis and suggestions, support and encouragement that enable me to complete my thesis report. I also wish to express deepest gratitude to my co-supervisor, Professor Dr. Azmi Ibrahim for technical advice, sharing ideas and information with me. This study would not have been possible without their utmost capability and intelligence. Heartfelt thanks also to Ministry of Higher Education (MOHE) and Universiti Malaysia Pahang (UMP) for providing scholarship.

A millions of thanks to the staffs, technicians and parties from Faculty of Civil Engineering, Universiti Teknologi MARA (UITM), Shah Alam those involved directly or indirectly for their advice and assistance towards this study success. Special appreciation to all technicians at Concrete, Heavy Structure, Non-Destructive Test and Environmental Laboratories at Faculty of Civil Engineering, UITM Shah Alam. Also thanks to all technicians at Heat Treatment Laboratory, Faculty of Mechanical, UITM Shah Alam. The knowledgeable and unreplaceable memories will be embedded forever.

I owe tremendous appreciation to my family, especially to my beloved parents, Md Jaafar Kolan and [redacted] whose great understanding and their generous support in every way. Last but not least, my gratitude also goes to my colleagues who helped me to maintain my faith in humanity and encourage me especially to Dr. Muhd Norhasri Muhd Sidek for the support and motivation during the tough time throughout the duration of this study.

Thank you so much and may Allah S.W.T the Almighty be with us all the time. Only Allah S.W.T could repay for the kindness and supports given. *Amin Ya Rabbal Alamin*.

TABLE OF CONTENT