STUDY ON THE PERFORMANCE OF CFRP STRENGTHENED CORRODED STEEL MEMBERS

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Degree of Master of Philosophy

Department of Civil Engineering

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Thesis submitted in partial fulfilment of the requirements for the degree Master of Philosophy

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DECLARATION

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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The above candidate has carried out research for the MPhil thesis under my supervision.

Signature of the supervisor: Date: 05.27.2020

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ABSTRACT

Most of the metallic structures such as offshore platforms and railway bridges are now in the need of retrofitting due to corrosion. One of the efficient ways of strengthening these structures is by using (Carbon Fibre Reinforced Polymer) CFRP materials. Since the weakest link in this system is the bond between the adherends, the effect of pre-corrosion level of the steel elements on the bond characteristics and durability performance of the strengthened units should be properly evaluated. Even though there are many research studies on bond durability none of them has used corroded steel plates for bond strength evaluation and considered the inherent surface characteristics of the corroded steel surfaces. Therefore, this study aimed at investigating the bond performance of CFRP bonded corroded steel plates which are subjected to different ageing conditions and surface roughness characteristics.

A total of one hundred and twenty-eight conditioned and non-conditioned double strap joint specimens were tested. Both corroded and non-corroded steel plates and two different surface preparation methods were used to witness the importance of the surface texture properties. Scanning Electronic Microscopic (SEM) analysis was carried out to determine the surface characteristic properties of the corroded/non-corroded steel plates. The short-term bond performance was evaluated along with different bonding configurations. In the long-term analysis, six different environmental exposures; seawater, wet/dry cycles, open tropical environment, and distilled water at three different temperature levels, 25 ^{o}C -30 ^{o}C, 40 ^{o}C and 3 ^{o}C were considered for conditioning. Residual bond strengths of the conditioned test specimens were evaluated after 6- and 12-month exposure periods at ambient temperature. A numerical model was developed to estimate the stress-strain variation of CFRP/steel specimens along the bond line. Bond-slip curves were evaluated to estimate the interfacial fracture energy of CFRP/steel composites. Moreover, experimental results were compared with the analytical results obtained from Hart-Smith model and a theoretical relationship between the failure modes was derived.

Test results indicated a major influence of surface roughness on the long-term performance of CFRP/steel joints. CFRP strengthened corroded steel joints showed a residual bond capacity of about 90% in seawater immersion and 111% in tropical environmental condition suggesting its suitability to adopt CFRP technique in these exposures. After 12 months of exposure duration, a similar bond degradation was observed of about 31% in distilled water immersed specimens at ambient temperature and about 60% in dry/wet cyclic condition irrespective of the pre-corrosion level. During an exposure period of 12 months, the rate of bond degradation was found to be less than 20% for cold water immersed specimens with non-corroded steel plates. The interfacial fracture energy of CFRP/steel composites exposed to hot humid environments indicated a significant reduction of 78% compared to control test specimens.

Keywords: *CFRP/Steel, Double strap joints, Corroded steel, Bond performance, Environmental durability*

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LIST OF ABBREVIATIONS

Abbreviation	Description
ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
CFRP	Carbon Fibre Reinforced Polymer
CL(A)	Corrosion Level (A)
CL(B)	Corrosion Level (A)
CL(C)	Corrosion Level (A)
CL(D)	Corrosion Level (A)
DM1	Deteriorated steel surface prepared with M-01
DM2	Deteriorated steel surface prepared with M-02
DW	Distilled water immersion at ambient temperature
DW-CW	Distilled water immersion at cold weather
DW-HW	Distilled water immersion at hot weather
FE	Finite Element
FEA	Finite Element Analysis
FEM	Finite Element Modelling
FRP	Fibre Reinforced Polymer
GFRP	Glass Fibre Reinforced Polymer
HDT	Heat Distortion Temperature
HM	High Modulus
LEFM	Linear Elastic Fracture Mechanics
LM	Low Modulus
LVDT	Linear Variable Differential Transformers
NDM1	Non-deteriorated steel surface prepared with M-01
NDM2	Non-deteriorated steel surface prepared with M-01
NM	Normal Modulus
UHM	Ultra-High Modulus
SEM	Scanning Electronic Microscope
SERR	Strain Energy Release Rate
SET	Surface Exposure Time