CORROSION ASSESSMENT IN REBARS OF REINFORCED CONCRETE STRUCTURES USING EQUIVALENT PARAMETERS EXTRACTED FROM PIEZO-PATCHES

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by

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CERTIFICATE

This is to certify that the thesis entitled, “CORROSION ASSESSMENT IN REBARS OF REINFORCED CONCRETE STRUCTURES USING EQUIVALENT PARAMETERS EXTRACTED FROM PIEZO-PATCHES” submitted by Ms. Talakokula Visalakshi to Indian Institute of Technology Delhi, for the award of the degree of the Doctor of Philosophy is a record of bonafide research work carried out by her. She worked under our supervision for the submission of this thesis, which to the best of our knowledge has reached the requisite standard.

The research reports and the results presented in this thesis have not been submitted in parts or in full to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

Reinforced concrete (RC) is an economical, versatile and successful construction material as it can be moulded to a variety of shapes and finishes. In most cases, it is durable and strong, performing well throughout its service life. However, in some cases, it does not perform adequately due to various reasons, one of which is the corrosion of the embedded steel bars used as reinforcement. Concrete provides an almost ideal environment for protecting the embedded steel from corrosion due to the passive film surrounding the steel rebars. However, the breakdown of this passive film, either due to chloride attack or due to carbonation, results in the corrosion of rebars. Thus rebar corrosion is one of the main causes of damage and premature failure of the RC structures worldwide, causing enormous costs for inspection, maintenance, restoration and replacement. Therefore, early detection of corrosion and timely remedial action on the affected portion can facilitate an optimum utilization of the structure, imparting longevity to it.

A large number of investigations have been conducted on the problems related to the deterioration of RC structures due to the corrosion of steel rebars. Usually, the condition of the structure is monitored by visual inspection and remedial measures are resorted to only when the condition becomes very serious. In order to prevent the deterioration levels reaching severe dimensions, it is desirable to monitor the condition of strategic structures right from the construction stage using structural health monitoring (SHM) techniques. The recent advent of the electro-mechanical impedance (EMI) technique for SHM has provided a new paradigm to the maintenance engineers to diagnose the onset of the damage at the incipient stage itself. The EMI technique utilizes the piezoelectric ceramic patches as collocated actuators-sensors and employ ultrasonic vibrations (typically in 30-400 kHz...
range) to acquire the characteristic ‘signature’ of the structure, which contains vital
information governing the phenomenological nature of the structure, and can signal the onset
of structural damages.

Although the EMI technique is well established for damage detection and quantification of
various civil and aerospace structures, limited studies have been reported for its application
in corrosion detection. This thesis presents a new corrosion assessment models based on the
equivalent parameters extracted from the impedance spectrum of concrete-rebar system using
the EMI technique via the PZT sensors. The corrosion assessment models are developed
based on an accelerated corrosion study carried out on RC specimens covering both chloride
and carbonation induced corrosion using PZT sensors that are surface bonded on rebars as
well as using piezo-composite concrete vibration sensor (CVS) embedded in concrete near
rebar. This is the first ever research reporting such extensive studies on the application of the
equivalent parameters for corrosion assessment of rebars embedded in concrete.

Proof-of-concept experiments were performed extending up to 120 days to detect chloride
induced corrosion using surface bonded PZT patches as well as CVS. Accelerated corrosion
tests were performed in order to obtain the data in a reasonable time frame for a laboratory-
based study. Firstly, the equivalent structural parameters were extracted from the admittance
spectra of the PZT patches surface bonded to bare rebars for chloride induced corrosion and
an empirical model was developed for correlating the actual mass and stiffness with the
equivalent mass and stiffness identified by the PZT sensor. Further, the empirical model was
extended to the RC specimens to determine the corrosion rates and identify various phrases
of corrosion using the PZT patches both surface bonded to rebar as well as CVS embedded
near rebar. The experimental results indicate that the equivalent parameters and the
developed model are effective in detecting and quantifying the rebar corrosion in a realistic manner.

The research was further extended to the second type of corrosion i.e., carbonation induced corrosion through accelerated carbonation tests conducted on RC cylinders (with rebars surface bonded with PZT patches) in a carbonation chamber for a period of 250 days. The carbonation corrosion assessment models developed were correlated with the progress of depth of carbonation. Imaging techniques such as scanning electron microscopic images and Raman spectroscopy were also used to further establish the onset of carbonation corrosion and correlate with the signal provided by the PZT patches.

Finally, to enhance the efficiency of the proposed model in real life application, the empirical model developed for chloride induced corrosion under accelerated tests was validated by comparing the corrosion rates of RC specimens exposed to natural environment for a period of 420 days. In addition, the influence of mineral admixture, namely fly ash, on the corrosion performance of steel is also investigated non-destructively using the developed model.

The corrosion assessment models developed are empirical and non-destructive in nature. The stiffness model is used to determine the severity of corrosion damage during various phases and the mass model for determining the corrosion rates for both chloride induced and carbonation induced corrosion. These models can be used for non-destructive corrosion monitoring of RC structures in real life with no “a-prior” information regarding the structure and with no modelling required. It is expected that this research will provide a new alternative experimental technique to the researchers and diagnostic engineers working in the field of rebar corrosion.
TABLE OF CONTENTS

CERTIFICATE ............................................................................................................................... i
ACKNOWLEDGEMENTS ........................................................................................................... ii
ABSTRACT ..................................................................................................................................... iii
TABLE OF CONTENTS .............................................................................................................. vi
LIST OF FIGURES ...................................................................................................................... x
LIST OF TABLES ........................................................................................................................ xv
LIST OF ACRONYMNS ............................................................................................................. xvi
LIST OF SYMBOLS .................................................................................................................. xviii

CHAPTER 1 : INTRODUCTION ................................................................................................. 1
  1.1 Background ......................................................................................................................... 1
  1.2 Research Hypothesis .......................................................................................................... 3
  1.3 Research Objectives and Scope ....................................................................................... 3
  1.4 Research Significance ...................................................................................................... 5
  1.5 Outline of Thesis ............................................................................................................. 6

CHAPTER 2 : LITERATURE REVIEW ....................................................................................... 8
  2.1 Introduction ........................................................................................................................ 8
  2.2 The Corrosion Process ..................................................................................................... 9
  2.3 Rebar Corrosion in Reinforced Concrete Structures ................................................... 10
      2.3.1 Chloride Induced Corrosion in Concrete ........................................................... 11
      2.3.2 Carbonation Induced Corrosion in Concrete ..................................................... 13
  2.4 Techniques for Corrosion Detection ............................................................................. 14
      2.4.1 Electro-Chemical Techniques ............................................................................ 15
          2.4.1.1 Potential Measurement Technique ...................................................... 15
          2.4.1.2 Linear Polarization Resistance Technique .......................................... 21
          2.4.1.3 Alternating current Impedance Spectroscopy Technique ................... 24
      2.4.2 Gravimetric Measurement Technique ............................................................... 24
2.4.3 Corrosion Monitoring Using Sensors .................................................................25
2.5 Impedance Based Structural Health Monitoring ......................................................27
2.5.1 Piezoelectric Materials .......................................................................................27
2.5.2 Geometric Details of PZT patches .....................................................................29
2.5.3 Diverse Applications of Piezoelectric Materials .................................................29
2.6 Electro-Mechanical Impedance Technique Using PZT patches ..............................30
2.6.1 Physical Principles .............................................................................................30
2.6.2 Frequency Range Selection ................................................................................34
2.6.3 Effect of Temperature ........................................................................................35
2.6.4 Sensing Range and Optimal Placement of PZT Patches .................................36
2.6.5 Excitation Voltage and Signature Acquisition ...................................................36
2.6.6 Instrumentation and Other Considerations .......................................................36
2.7 Major Research in Electro-Mechanical Impedance Technique Since 1990’s ...........37
2.8 Limitations in Application of PZT patches for Structural Health Monitoring ........41
2.9 Summary: Critical Points of Review .....................................................................42
2.10 Research Objectives ..............................................................................................44

CHAPTER 3 : DIAGNOSIS OF CHLORIDE INDUCED CORROSION IN BARE STEEL REBARS .................................................................47
3.1 Introduction .............................................................................................................47
3.2 Mechanical Impedance of Structures .....................................................................47
3.3 Mechanical Impedance of PZT patches ..................................................................50
3.4 Details of Accelerated Corrosion Study ..................................................................51
3.5 Damage Quantification .........................................................................................56
3.5.1 Root Mean Square Deviation ............................................................................56
3.5.2 Signature Assurance Criteria ............................................................................57
3.5.3 Waveform Chain Code Technique ...................................................................57
3.5.4 Adaptive Template Matching ...........................................................................58
3.6 Analysis of Structural Mechanical Impedance Extracted From Admittance Signature ...60
3.7 Concluding Remarks .............................................................................................73
CHAPTER 4: DEVELOPMENT OF CORROSION ASSESSMENT MODEL FOR REBARS EMBEDDED IN REINFORCED CONCRETE STRUCTURES ..............................................74

4.1 Introduction ........................................................................................................................74
4.2 Rebar Corrosion in Reinforced Concrete Structures ........................................................74
4.3 Specimen Preparation .......................................................................................................77
4.4 Accelerated Corrosion Exposure on Conductance Signatures ......................................78
4.5 Analysis Based on Equivalent Structural Parameters .......................................................85
4.6 Calibration of Extracted Equivalent Parameters ...............................................................90
  4.6.1 Development of Equivalent stiffness model ..............................................................90
  4.6.2 Development of Equivalent Mass Model for Corrosion Rates ...............................94
4.7 Concluding Remarks ........................................................................................................97

CHAPTER 5: COMPARISON OF CORROSION ASSESSMENT CAPABILITY OF SURFACE BONDED AND EMBEDDED PIEZO SENSORS .................................................99

5.1 Introduction ....................................................................................................................99
5.2 Advantages of Embedded Sensors ..................................................................................100
5.3 Configuration and Application of Embedded PZT Sensors ......................................98
5.4 Experimental Details and Results ...............................................................................102
  5.4.1 Comparison of Conductance Signatures .................................................................103
  5.4.2 Comparison of Root Mean Square Deviation Index ............................................105
  5.4.3 Comparison of Equivalent Stiffness Parameters ......................................................106
5.5 Concluding Remarks ........................................................................................................111

CHAPTER 6: MONITORING AND ASSESSMENT OF CARBONATION INDUCED CORROSION IN REINFORCED CONCRETE STRUCTURES ........................................113

6.1 Introduction .....................................................................................................................113
6.2 Accelerated Carbonation Study: Experimental Procedure ..........................................114
6.3 Analysis of Results .........................................................................................................118
6.4 Correlation With Microscopic Image Analysis and Raman Analysis ............................123
6.5 Validation of Corrosion Rate Prediction Model .............................................................128

6.5 Concluding Remarks ......................................................................................................129
CHAPTER 7 : APPLICATIONS OF THE PROPOSED CORROSION ASSESSMENT MODEL ON FLY ASH BLENDED CONCRETE AND ON NATURALLY CORRODED SPECIMENS

7.1 Introduction

7.2 Proof-of-Concept Validation 1: Corrosion Assessment in Fly Ash Blended Concrete
   7.2.1 Details of Fly Ash utilized
   7.2.2 Experimental Details (Concrete and Fly Ash)
   7.2.3 Microstructural Analysis
   7.2.4 Corrosion Assessment in Fly Ash Blended Concrete Using the Derived Model

7.3 Proof-of-Concept Validation 2: Corrosion Assessment in Naturally Corroded Specimens

7.4 Concluding Remarks

CHAPTER 8 : CONCLUSIONS AND RECOMMENDATIONS

8.1 Introduction
8.2 Research Conclusions and Contributions
8.3 Limitations
8.4 Recommendations for Future

PUBLICATIONS BASED ON THIS RESEARCH

REFERENCES

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