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FACULTY OF ENGINEERING
Structural Engineering

Assessment and Restoration of Bond Strength for Fire-Damaged Reinforced Concrete Elements

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by

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Statement

This thesis is submitted as a partial fulfillment of Master of Science in Civil Engineering (Structural Engineering), Faculty of Engineering, Ain shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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ABSTRACT

Reinforced concrete structures are vulnerable to high temperature conditions such as those during exposure to fire. At elevated temperatures, the mechanical properties of concrete and reinforcing steel as well as the bond between steel rebars and concrete may significantly deteriorate. The decrease in the bond strength may influence the moment capacity of the reinforced concrete elements. The assessment of bond strength degradation is required for structural design of fire safety and structural post-fire repair. Therefore, there is a need to investigate the bond behavior between concrete and steel rebars after fire exposure and to study the most suitable repairing techniques and materials to restore the bond strength between concrete and reinforcing steel after fire exposure.

This thesis contains an experimental and analytical investigation on the residual bond strength between concrete and steel rebars after fire exposure and normal cooling to room temperature. Also, it discusses the effectiveness of using different repairing techniques and materials to restore the bond strength between concrete and steel rebars. The bond tests were carried out using beam end specimens. The test parameters considered in the current research include: exposure condition, concrete class, rebar type, rebar size, rebar location, repairing technique and repairing material. Two different exposure conditions were applied to the specimens, namely fire exposure and ambient exposure. In the fire condition, all the fire damaged specimens were subjected to a heating regime before testing in bond while in the ambient condition, the specimens weren't exposed to any heating regimes before testing. Concrete strengths included are 20 and 40 MPa. The different types of

rebars considered are ribbed and plain rebars. Rebar sizes considered are 22, 16 and 8 mm. The rebar locations considered are outside and inside with respect to the transverse bars.

Two different repairing techniques were conducted in this study. The first technique was deep repair where the deteriorated concrete layer was removed by breaking off at least 25 mm behind the tested rebar then replaced with the repairing material. The second technique was shallow repair in which the deteriorated concrete up to the center line of the tested rebar was removed. Four different repairing materials were used in the study namely; concrete, polypropylene Fiber reinforced concrete, polymer modified cement mortar and commercially available fiber reinforced polymer modified cement mortar.

The experimental test results showed a significant loss up to 70 % in the bond strength between concrete and steel rebars after fire exposure with a dramatic change in the bond stress-slippage behavior. Considering the repair of fire damaged specimens, the shallow and the deep repair techniques using the polymer modified cement mortar, for the specimens involving plain rebars restored 77% and 93%, respectively of the original bond strength whereas for the specimens involving ribbed rebars, the highest observed restoration was 48.7% and 65%, respectively of the original bond strength. The specimens repaired with deep repair using the concrete restored up to 83% of the original strength, whereas fiber reinforced concrete and fiber reinforced polymer modified cement mortar restored about 86% and 96% respectively of the original bond strength.

Based on the experimental results, an analytical expression was proposed to predict the bond stress-slippage relationship and for computation of the residual bond strength between concrete and steel

rebars after fire exposure. Also, a heat transfer analysis was carried out using FEM to obtain the temperature distribution within the cross section of the fire exposed specimens.

Keywords: Residual bond strength, Bond behavior, Fire damage, Repair, Restoration, Assessment

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TABLE OF CONTENTS

ABSTRACT	Page i
ACKNOWLEDGEMENT	iii
TABLE OF CONTENTS	iv
LIST OF FIGURES	vii
LIST OF TABLES	ix
NOTATION	x
CHAPTER (1):INTRODUCTION	1
1.1 Background	1
1.2 Research Objectives	2
1.3 Scope	2
1.4 Thesis Outline	3
CHAPTER (2): LITERATURE REVIEW	5
2.1 Introduction	5
2.2 Bond Behavior at Ambient Temperature	5
2.3 Effect of Elevated Temperature on Concrete Properties	16
2.3.1 Concrete Compressive Strength	16
2.3.1.1 Effect of Cooling Regime on the Compressive Strength	24
2.3.1.2 Expressions for Residual Compressive Strength of Fire Damaged Concrete	24
2.3.2 Effect of Temperature on the Concrete Tensile strength	27
2.3.3 Effect of Temperature on the Strength of Steel Rebars	27
2.3.4 Bond Behavior after Cooling for Post-Fired Elements	29
2.3.5 Bond Behavior at Elevated Temperature	36
2.4 Assessment of Fire Damaged Concrete Structures	38
2.4.1 Assessment of Damage	38
2.4.1.1 Method I	38
2.4.1.2 Method II	42
2.5 Repairing Techniques of Fire Damaged Concrete Elements	45
2.5.1 Fiber Reinforced Polymer (FRP)	45
2.5.2 Partial Removal and Replacement of Concrete and Rebars	47
2.5.2.1 Removal of Concrete	48
2.5.2.2 Partial Replacement of Rebars	48
2.5.2.3 Partial Replacement of Concrete	49
2.5.3 Concrete Jacketing	49
2.6 Bond Testing	50

2.6.1 Pullout Test	50
2.6.2 Beam Anchorage Test	51
2.6.3 Beam End Test	52
2.7 Needed Research	54
CHAPTER (3): RESEARCH PLAN, CONSTRUCTION, AND TESTING PROCEDURES	55
3.1 Introduction	55
3.2 Research Plan	55
3.2.1 Objective	55
3.3 Experimental Work	56
3.3.1 Test Specimens	56
3.3.1.1 Geometry	56
3.3.1.2 Fabrication	57
3.3.2 Test Matrix	60
3.3.3 Material Characteristics	62
3.3.3.1 Coarse and Fine Aggregates	62
3.3.3.2 Cement	62
3.3.3.3 Super plasticizer	63
3.3.3.4 Concrete	63
3.3.3.5 Concrete Test Results	63
3.3.3.6 Steel Reinforcement	64
3.3.3.7 Repairing Materials	64
3.3.4 Repairing Techniques	65
3.3.5 Heating Regime	66
3.3.6 Repairing Procedures	67
3.3.7 Test Setup and Instrumentation	69
CHAPTER (4): TEST RESULTS & DISCUSSIONS AND ANALYTICAL STUDY	72
4.1 Introduction	72
4.2 Specimens Exposed to Ambient Temperature	72
4.2.1 General	72
4.2.2 Failure Modes	72
4.2.3 Bond Stress-Slippage Curves	73
4.3 Specimens Exposed to Fire	76
4.3.1 General	76
4.3.2 Fire Damage Assessment	76
4.3.3 Failure Modes	77
4.3.4 Bond Stress-Slippage Curves	78
4.4 Specimens Repaired using Shallow	80
4.4.1 General	80
4.4.2 Failure Modes	80

4.4.3 Bond Stress-Slippage Curves	81
4.5 Specimens Repaired using Deep Technique	84
4.5.1 General	84
4.5.2 Failure Modes	84
4.5.3 Bond Stress-Slippage Curves	85
4.6 Discussion of Test Result	87
4.6.1 Fire Damage Assessment	87
4.6.2 Failure Modes	88
4.6.3 Analysis of Test Results	89
4.6.4 Effect of Fire Exposure	90
4.6.5 Effect of Rebar Type	94
4.6.6 Effect of Rebar Size	94
4.6.7 Effect of Rebar Location	95
4.6.8 Effect of Concrete Compressive Strength	95
4.6.9 Effect of Repairing Technique and Material	96
CHAPTER (5): ANALYTICAL STUDY	103
5.1 Introduction	103
5.2 Bond Strength Predictions	103
5.2.1 Bond Strength Predictions using Available Expressions in Literature	103
5.2.2 Comparison between Experimental Results and Predictions of Bond Strength	105
5.2.3 Proposed Equation for Residual Bond Strength after Fire Exposure	106
5.3 Bond Stress-Slippage Relationship	108
5.4 Thermal Analysis	114
5.4.1 Model Description	114
5.4.2 Elements and Meshing	114
5.4.3 Material Modeling	115
5.4.4 Heating Modeling	116
5.4.5 Validation of the Model	117
5.4.6 Heating Transfer Analysis	119
CHAPTER (6): SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS	119
6.1 Introduction	119
6.2 Summary and Conclusions	120
6.3 Recommendations for Further Studies	122
REFERENCES	124

LIST OF FIGURES

	Page
Fig.(1.1) Spalling of Fire Exposed Reinforced Concrete Slab	1
Fig.(2.1) Local Bond-Stress Law [Tepfers <i>et al.</i> (2000)]	5
Fig.(2.2) Bond Forces Balanced against Tensile Stress Rigs	6
Fig. (2.3) Effect of Bonded Length on the Bond Behavior	8
Fig. (2.4) Effect of the Concrete Strength on the Bond Behavior	8
Fig. (2.5) Effect of the Rebar Type on the Bond Behavior	9
Fig. (2.6) Effect of the Loading Rate on the Bond Behavior	9
Fig. (2.7) Pull out Specimen for [Walker <i>et al.</i> (1997)]	10
Fig. (2.8) Relationship of Bond Stress Ratio and Rebar	11
Fig. (2.9) Double Pull out Specimen for [Kankam (2003)]	11
Fig. (2.10) Influence of the Concrete Strength on the Bond	12
Fig. (2.11) Influence of the Rebar Size on the Average Bond	12
Fig. (2.12) Influence of the Rebar Type [Kankam (2003)]	13
Fig. (2.13) Test Specimen for [Rehm (1968)]	14
Fig.(2.14) Load Behavior of Normal Strength Concrete at	17
Fig.(2.15) Load Behavior of High Strength Concrete at Elevated	17
Fig.(2.16) Stress Strain Relationships of Normal Strength	18
Fig.(2.17) Stress Strain Relationships of High Strength Concrete	18
Fig.(2.18) Stress Strain Relationships of Normal and High	19
Fig.(2.19) Stress Strain Relationships for 42 MPa Concrete	19
Fig.(2.20) Residual Stress Strain Curve of 72 MPa Concrete	20
Fig.(2.21) Residual Stress Strain Curves of 95 MPa Concrete	20
Fig.(2.22) Residual Strength of Heated Un-Stressed Dense	21
Fig.(2.23) Residual Strength of Heated Stressed Dense	22
Fig.(2.24) Residual Compressive Strength of Concrete after	22
Fig.(2.25) Yield Strength of Steel Tested at Elevated	27
Fig.(2.26) Yield Strength of Steel Tested at Room Temperature	27
Fig.(2.27) Test Set up [Morley and Royles (1983a)]	29
Fig.(2.28) Comparison between Bond Strength Reduction and	31

Fig.(2.29)	Bond Strengths between C20 Concrete and Steel	32
Fig.(2.30)	Bond Strengths between C35 Concrete and Steel Bars	32
Fig.(2.31)	Test setup [Xiao <i>et al.</i> (2014)]	33
Fig.(2.32)	Development of Peak Free End Slippage with	33
Fig.(2.33)	Degradation of Bond Strength and Compressive	34
Fig.(2.34)	Test Set up [Diederichs and Schneider (1982)]	35
Fig.(2.35)	Color Changes in Concrete [Tucker (1981)]	39
Fig.(2.36)	Fire Damage Factors for Columns, Beams and Slabs	41
Fig.(2.37)	Strengthening of Beam using FRP Plate [Zaman, H.	45
Fig.(2.38)	Strengthening of Beam using FRP Sheet	46
Fig.(2.39)	Strengthening of Column using FRP Sheet	46
Fig.(2.40)	Hydro Blasting for Concrete Removal	47
Fig.(2.41)	Shotcrete to Replace Removed Damaged Concrete	48
Fig. (2.42)	Concrete Jacketing before Applying the New	49
Fig.(2.43)	Schematic of the Pullout Test	50
Fig. (2.44)	Bond Beam Test – National Bureau of Standard	51
Fig. (2.45)	Bond beam test- University of Texas	51
Fig. (2.46)	Schematic of the Beam End Test	52
Fig. (2.47)	Specimen Geometry and Reinforcement	53
Fig.(3.1)	Configuration of the Test Specimens	57
Fig.(3.2a)	Steel Molds	58
Fig.(3.2b)	Prepared Cage of Reinforcement	58
Fig.(3.3)	Placement of Reinforcement in Molds	58
Fig.(3.4)	Debonding Region Preparation	59
Fig.(3.5)	Leveling of Concrete	59
Fig.(3.6)	Curing of Specimens	59
Fig.(3.7)	Insulation of Extended Reinforcing Rebars with	60
Fig.(3.8)	Indirect Tension Test	65
Fig.(3.9)	Repairing Techniques	65
Fig.(3.10)	Beam and Cube Specimens in the Gas Furnace	66
Fig.(3.11)	Time - Temperature Curve for Fire Regime	66

Fig.(3.12)	Surface Breaking off	67
Fig.(3.13)	Depth of Breaking off for Deep Repair	68
Fig.(3.14)	Depth of Breaking Off for Shallow Repair	68
Fig.(3.15)	Primary Coat of Bonding Agent	68
Fig.(3.16)	Filling of Repairing Material	69
Fig.(3.17a)	Schematic Drawing of Test Setup	70
Fig.(3.17b)	Actual Test Setup	70
Fig.(3.18)	Wheatstone Bridge Electrical Circuit	71
Fig.(3.19)	Fabricated Load Cell	71
Fig.(4.1)	Typical Failure Modes for Specimens Exposed to	73
Fig.(4.2)	Bond Stress - Slippage Curve for	74
Fig.(4.3)	Bond Stress - Slippage Curve for	74
Fig.(4.4)	Bond Stress - Slippage Curve for C40-16RO-A	74
Fig.(4.5)	Bond Stress - Slippage Curve for C20-22RO-A	74
Fig.(4.6)	Surface Cracks on Cubes after Heating	76
Fig.(4.7)	Surface Cracks on Beam End Specimens after Heating	77
Fig.(4.8)	Extracted Core Sample from Damaged Specimens	77
Fig.(4.9)	Typical Splitting Failure Mode for Fire Exposed	78
Fig.(4.10)	Bond Stress - Slippage Curve for C20-16RO-F	78
Fig.(4.11)	Bond Stress - Slippage Curve for C20-16RI-F	79
Fig.(4.12)	Bond Stress - Slippage Curve for C40-16RO-F	79
Fig.(4.13)	Bond Stress - Slippage Curve for C20-22RO-F	80
Fig.(4.14)	Typical Splitting Failure Mode for Specimens Repaired	81
Fig.(4.15)	Bond Stress - Slippage Curve for C20-16RO-F-SM	82
Fig.(4.16)	Bond Stress - Slippage Curve for C20-16RI-F-SM	82
Fig.(4.17)	Bond Stress - Slippage Curve for C40-16RO-F-SM	83
Fig.(4.18)	Bond Stress - Slippage Curve for C20-22RO-F-SM	83
Fig.(4.19)	Typical Splitting Failure Mode for Specimens Repaired	84
Fig.(4.20)	Bond Stress - Slippage Curve for C20-16RO-F-DM	85
Fig.(4.21)	Bond Stress - Slippage Curve for C20-16RI-F-DM	86
Fig.(4.22)	Bond Stress - Slippage Curve for C40-16RO-F-DM	86

Fig.(4.23) Bond Stress - Slippage Curve for C20-22RO-F-DM	87
Fig.(4.24) Typical Splitting Failure Mode for Specimens Repaired	87
Fig.(4.25) Bond Stress - Slippage Curve for C20-16RO-F-DCM	88
Fig.(4.26) Bond Stress - Slippage Curve for C20-22RO-F-DCM	88
Fig.(4.27) Typical Splitting Failure Mode for Specimen Repaired	89
Fig.(4.28) The Bond Stress – Slippage Curve	91
Fig. (4.29) Normalized Bond Strength for Specimens Exposed to Ambient and Fire Conditions	93
Fig. (4.30) Normalized Compressive Strength for Specimens	94
Fig. (4.31) Normalized Slippage at Ultimate Bond Strength for Specimens Exposed to Ambient and Fire Conditions	94
Fig. (4.32) Normalized Slope of Ascending Branch for	95
Fig. (4.33) Normalized Bond Strength for Specimens Repaired	99
Fig. (4.34) Normalized Slippage at Ultimate Bond Strength for Specimens Repaired using Different Techniques with	99
Fig. (4.35) Normalized Slope of Ascending Branch for	100
Fig.(4.36) Bond Stress - Slippage Curves for C20-16RO	102
Fig.(4.37) Bond Stress - Slippage Curves for C20-16RI	103
Fig.(4.38) Bond Stress - Slippage Curves for C40-16RO	103
Fig.(4.39) Bond Stress - Slippage Curves for C20-22RO	104
Fig.(4.40) Bond Stress-Slippage Curves for C20-16RO	104
Fig.(5.1) Correlation between the Degradation Coefficients of the Bond Strength and Compressive Strength	108
Fig.(5.2) Comparison of Predicated Vs Measured Bond Strength	110
Fig.(5.3) Analytical versus Experimental Bond Stress-Slippage	112
Fig.(5.4) Analytical versus Experimental Bond Stress-Slippage	112
Fig.(5.5) Analytical versus Experimental Bond Stress-Slippage	113
Fig.(5.6) Analytical versus Experimental Bond Stress-Slippage	113
Fig.(5.7) Analytical versus Experimental Bond Stress-Slippage	114
Fig.(5.8) Analytical versus Experimental Bond Stress-Slippage	114
Fig.(5.9) Analytical versus Experimental Bond Stress-Slippage	115
Fig.(5.10) Typical Finite Element Mesh for the Beam End	117

Fig.(5.11)	Temperature Distribution Over the Beam Cross Section without Modeling Steel Rebars	119
Fig.(5.12)	Temperature Distribution Over the Beam Cross Section with Modeling Steel Rebars	120