

# LIST OF CONTENTS

<b>CONTENTS</b>	<b>Page.</b>
<b>ACKNOWLEDGEMENTS</b>	<b>i</b>
<b>ABSTRACT</b>	<b>ii</b>
<b>LIST OF CONTENTS</b>	<b>iv</b>
<b>LIST OF TABLES</b>	<b>vii</b>
<b>LIST OF FIGURES</b>	<b>viii</b>
<b>LIST OF ABBREVIATION</b>	<b>xii</b>
<b>CHAPTER (1) INTRODUCTION</b>	<b>1</b>
<b>1-1 General</b>	<b>1</b>
<b>1-2 Problem statement</b>	<b>2</b>
<b>1-3 Research Objectives</b>	<b>2</b>
<b>1-4 Research Program</b>	<b>3</b>
<b>1-5 Thesis Layout</b>	<b>3</b>
 <b>CHAPTER (2) LITERATURE REVIEW</b>	 <b>5</b>
<b>2-1 Background</b>	<b>5</b>
<b>2-2 Application And Problem Of FRP</b>	<b>6</b>
<b>2-2-1 The advantages of FRP properties</b>	<b>6</b>
<b>2-2-2 FRP Problems of application</b>	<b>7</b>
<b>2-2-3 Durability concerns for FRP composite</b>	<b>7</b>
<b>2-3 Strengthening of RC beams with FRP system</b>	<b>7</b>
<b>2-3-1 Flexural strengthening using FRP sheets and strip</b>	<b>8</b>
<b>2-3-2 shear strengthening using FRP</b>	<b>10</b>
<b>2-4 Fire attack</b>	<b>12</b>
<b>2-4-1 Fire growth</b>	<b>12</b>
<b>2-4-2 Heat</b>	<b>12</b>
<b>2-4-3 Smoke</b>	<b>12</b>
<b>2-4-4 Specific heat</b>	<b>13</b>
<b>2-4-5 Thermal diffusivity</b>	<b>13</b>
<b>2-4-6 Thermal expansion</b>	<b>14</b>
<b>2-4-7 Thermal resistance</b>	<b>14</b>
<b>2-4-8 Heat transfer analysis</b>	<b>15</b>
<b>2-5 Effect of fire and elevated temperature on reinforced concrete and (FRP) materials in construction</b>	<b>15</b>
<b>2-5-1 Thermo-mechanical properties of concrete</b>	<b>15</b>
<b>2-5-2 Thermo-mechanical properties of steel</b>	<b>18</b>
<b>2-5-3 Effect of fire and high temperature on FRP system</b>	<b>19</b>
<b>2-5-3-1 Thermo-mechanical properties of the fiber</b>	<b>19</b>
<b>2-5-3-2 Thermo-mechanical properties of the matrix</b>	<b>20</b>
<b>2-5-3-3 Thermo-mechanical properties of the composite elements</b>	<b>23</b>
<b>2-5-4 Interfacial bond between FRP concrete at elevated temperature</b>	<b>29</b>
<b>2-6 Effect of high temperature on FRP strengthened concrete beam strength</b>	<b>29</b>

<b>CONTENTS</b>	<b>Page.</b>
<b>2-7 Coating materials for insulation against fire</b>	<b>31</b>
<b>CHAPTER (3) EXPERIMENTAL PROGRAM</b>	<b>40</b>
<b>3-1 Introduction</b>	<b>40</b>
<b>3-2 Experimental program.</b>	<b>40</b>
<b>3-3 Properties of incorporated materials</b>	<b>43</b>
<b>3-3-1 Aggregates</b>	<b>43</b>
<b>3-3-2 Cement</b>	<b>45</b>
<b>3-3-3 Steel Reinforcement and Ties</b>	<b>45</b>
<b>3-3-4 Mixing water</b>	<b>46</b>
<b>3-3-5 FRP Laminates</b>	<b>46</b>
<b>3-3-6 Perlite</b>	<b>47</b>
<b>3-3-7 Vermiculite</b>	<b>48</b>
<b>3-3-8 Ordinary Portland cement</b>	<b>50</b>
<b>3-3-9 Red Aswan clay</b>	<b>50</b>
<b>3-3-10 Ceramic fiber</b>	<b>52</b>
<b>3-3-11 Glass fiber admixture</b>	<b>54</b>
<b>3-3-12 Air entraining admixture</b>	<b>54</b>
<b>3-3-13 Thermocouple</b>	<b>54</b>
<b>3-4 Preparation of test specimens</b>	<b>54</b>
<b>3-4-1 Concrete mix</b>	<b>55</b>
<b>3-4-2 Reinforcement of tested beams</b>	<b>55</b>
<b>3-4-3 Casting of specimens</b>	<b>56</b>
<b>3-4-4 Application of FRP laminate for beams.</b>	<b>56</b>
<b>3-4-5 Application of thermal protecting coating material on cubes and beams</b>	<b>59</b>
<b>3-5 Testing of specimens</b>	<b>63</b>
<b>3-5-1 Phase 1 (testing of cubes)</b>	<b>63</b>
3-5-1-1 The testing of the first Group of cubes	<b>64</b>
3-5-1-2 The testing of the second Group of cubes	<b>65</b>
3-5-1-3 The testing of the third Group of cubes	<b>67</b>
<b>3-5-2 Phase 2 (testing of beam specimens)</b>	<b>67</b>
3-5-2-1 The testing of the first Group of beams	<b>68</b>
3-5-2-2 The testing of the second Group of beams	<b>69</b>
3-5-2-3 The testing of the Third Group of beams	<b>70</b>
<b>3-6 Test set-up</b>	<b>71</b>
<b>3-6-1 Test set-up for phase 1 of the experimental program</b>	<b>71</b>
<b>3-6-2 Test set-up for phase 2 of the experimental program</b>	<b>71</b>
<b>3-7 Instrumentation</b>	<b>72</b>
<b>3-8 Furnace Manufacture</b>	<b>74</b>
<b>3-9 Specimen Installation in the furnace.</b>	<b>75</b>
<b>CHAPTER (4) EXPERIMENTAL RESULTS</b>	<b>76</b>
<b>4-1 Introduction</b>	<b>76</b>
<b>4-2 Experimental Results for phase 1 ( testing cubes)</b>	<b>76</b>
<b>4-2-1 First group (control)</b>	<b>76</b>

<b>CONTENTS</b>	<b>Page.</b>
4-2-2 Second group	79
4-2-2-1 Second group with protective coating of different types at 400°C at (400°C)	80
4-2-2-2 Second group with protective coating of different types at 400°C at (500°C)	86
4-2-2-3 Second group with protective coating of different types at 400°C at (600°C)	92
4-2-3 Third group	97
4-3 Experimental Results for phase 2 (testing beams)	102
4-3-1 First group (control)	102
4-3-2 Second group	108
4-3-3 Third group	114
<b>CHAPTER (5) ANALYSIS OF EXPERIMENTAL RESULTS</b>	<b>120</b>
<b>5-1 Introduction</b>	<b>120</b>
<b>5-2 Analysis of Experimental Results for phase 1 (testing cubes)</b>	<b>120</b>
5-2-1 First Group (control group-unprotected)	120
5-2-2 Second Group(protected concrete cubes exposed to various temperatures)	121
5-2-2-1 Protected concrete cubes subjected to 400°C	121
5-2-2-2 Protected concrete cubes subjected to 500°C	125
5-2-2-3 Protected concrete cubes subjected to 600°C	128
5-2-3 Third Group at 600°C	131
<b>5-3 Analysis of Experimental Results for phase 2 (testing beams)</b>	<b>134</b>
5-3-1 First Group (control)	134
5-3-2 Second Group at 600°C	136
5-3-3 Third Group at 600°C	140
<b>CHAPTER (6) CONCLUSIONS, RECOMMENDATION AND FURTHER RESEARCH</b>	<b>143</b>
6-1 CONCLUSIONS	143
6-2 Recommendation	144
6-3 suggestions for further research	145
<b>REFERENCE</b>	<b>146</b>