CHAPTER 1

INTRODUCTION

1.1 Introduction

Due to deterioration, many reinforced concrete structures all over the world need to be repaired and maintained throughout their service life. In addition, sometimes there is a need to upgrade the capacity of the structures due to some changes in the loading condition. In this respect the use of bonded metallic plates to strengthen and rehabilitate existing reinforced concrete structures have been in the construction industry for quite some time. The wide acceptance of this method of upgrading or repairing using epoxy–bonded external plates can be attributed to the development of high quality, reliability and durability of epoxy adhesive system, the rapid method of construction, together with the negligible changes to the overall dimensions of the structure and minimum disruption to its use when the additional construction work is in progress. Steel plates have been widely used in the rehabilitation work using plate-bonding system, but Fibre Reinforced Polymer (FRP), made of either carbon, glass or aramid fibre embedded in polymeric matrix system, is being considered as a contender to replace steel. Fibre Reinforced Polymer materials not only have higher tensile strength compared to steel but are also lighter and more durable than steel. To strengthen or upgrade the deteriorated reinforced concrete member using FRP is more cost-effective than steel. The ease of handling of FRP compared to steel will reduce the labour cost during installation of the system. However, in spite of these advantages offered by the FRP

bonded system, Malaysians engineers have little experience of the materials system and the structural implications of the use of these materials for long-term performance.

1.2 Background of the Problem

At present, corrosion of steel reinforcement in reinforced concrete structures is one of the main problems faced by the construction industry. Thus maintenance and repair of the deteriorated reinforced concrete structures are becoming important in order to prolong their service life. There are many techniques available in the market that can be used in the process of rehabilitation and repair work. One of the techniques is by strengthening the deteriorated member using steel plate bonding system. Steel plate bonding system has been used for quite some time in the construction industry. However, the exposed steel plates may tend to corrode upon exposure to harsh environment. In addition, the handling of steel plates during installation requires heavy machinery. Nowadays, there is a new material called Fibre Reinforced Polymer (FRP) in the form of plates and fabric system that has a potential application as strengthening material to replace steel plate. The FRP plates and fabric system offer many technical and economic advantages over steel plates when they are used to strengthen and upgrade concrete structures, such as high tensile strength and modulus to weight ratios, corrosion resistance, high durability and cost effectiveness. The lightweight of FRP composites has also resulted in the ease of handling on site. However, studies on the long-term performance of the FRP plate system, epoxy adhesive system and FRP plate bonded to concrete being exposed to tropical climate are very limited. In the tropical climate weather conditions, the structural materials are normally exposed to sunshine, heavy rain and also to high moisture. The response of those materials system exposed to aggressive environmental conditions such as to highly chemical polluted and marine areas is not yet established [1]. Thus, in order to use the material in great confidence, the long-term bond integrity performance needs to be investigated further, focusing especially on the bond interfaces between FRP-adhesive and adhesive-concrete.

In this study, Carbon Fibre Reinforced Polymer (CFRP) plate is chosen due to its higher tensile strength, higher modulus of elasticity and it is more durable to most aggressive environments compared to other FRP composites made of glass or aramid fibre system. Apart from that, a two-part structural epoxy system formulated to suit with CFRP composites and concrete is also investigated on its performances under tropical climatic conditions. In addition to that, the research will provide data and results on the performance of CFRP plate bonded system under tropical environment in which at present there are very limited data available. The finding is vital and will be used as a reference in future studies and projects.

1.3 Statement of the Problem

Will the CFRP plate-bonded system applied to concrete perform satisfactorily under tropical climate exposure environment?

1.4 The Objectives

The main aim of this research is to study the performance of adhesive bonding of the CFRP plate-concrete bonded system exposed to tropical climate environment. In order to achieve the purpose, the following sub-programme objectives are as follows;

i. To design and fabricate rigs for specimen preparation, experimentation and load test that are able to perform and produce reliable results.
ii. To study the tensile properties and failure mode of CFRP plates exposed to tropical environmental conditions.
iii. To study the in-plane shear properties of brittle structural epoxy exposed to tropical environmental conditions using Arcan Test Method.
iv. To study the effects of tropical environment conditions on the local bond stress characteristics of CFRP plate-concrete bonded system.

1.5 Scope of Research

In order to achieve the programme objectives, the overall studies are divided into five main chapters (i.e. Chapters 2,3,4,5 and 6) and each of them comes with its own scope of works. The scopes for the named chapter are described as follows;

i. In Chapter 2, the work was focuses on the review of various sources from established journals, books, thesis, websites that related to the overall programme objectives.

ii. In Chapter 3, the study focuses on the design, development and fabrication of mechanical rigs and fixtures used to fulfil the research programme needs. The study starts with the design of mould fixtures for specimen preparation and experimental test rigs.

iii. In Chapters 4, 5 and 6, the study focuses on the durability aspects of CFRP plate composite, epoxy adhesive and CFRP plate-epoxy-concrete prisms under the exposure of four different environmental conditions, i.e. laboratory, plain water, salt water and outdoor conditions. The research work involves the preparation of test samples and experimental works. The experimental study on bonding performance between CFRP plate-concrete prisms bond samples (stressed and unstressed) is carried out to investigate the integrity of the CFRP plate, the CFRP plate-adhesive and the adhesive-concrete interfaces when subjected to tropical environment conditions. The test data for all these three materials system are analysed and discussed in the forms of graphs and tables, supported by visual observations to conclude the research findings.

1.6 The Arrangement of Chapters

The thesis is structured according to the overall programme methodology by taking into consideration the most prioritised research works. The arrangement of the overall thesis presentation framework is briefly described as follows;

i. In Chapter 2, the work focuses on reviewing the technical aspects of the reinforced concrete structure strengthening applications, studying tropical weathering characteristics, Fibre Reinforced Polymer (FRP) composites technology and applications, adhesive bonding technology and finally studying the development of test rigs by previous researchers.

ii. In Chapter 3, the discussion focuses on the rigs used for specimen preparation, experimentations and final load tests. The most important part of this chapter is the discussion on the design, assembly and performance test of sustainable stressed rig used to sustain the load on the CFRP plate-concrete bonded specimen.

iii. In Chapter 4, the discussion focuses on the outcomes of tensile test on the experimentation specimens of Carbon Fibre Reinforced Polymer (i.e. CFRP with vinyl ester matrix) composite plate exposed to tropical environmental conditions. The discussion focuses on the mechanical and physical characteristics relationship between exposed specimens and the control ones.

iv. In Chapter 5, the discussion focuses on the outcomes of shear test on the experimentation specimens of brittle type Selfix Carbofibe epoxy system exposed to tropical environmental conditions. The discussion focuses on the in-plane shear properties and physical characteristics (i.e. from microstructure analysis) relationship between exposed specimens and the control ones.

v. In Chapter 6, the discussion focuses on the results obtained from pull-out test of CFRP plate-concrete bonded specimens being exposed to designated exposure conditions reflecting the tropical environment. The discussion on the bond failure loads, CFRP plate local strains, and bond slips are the main focus in order to correlate the outcomes between test specimens and exposure conditions ones.

vi. In Chapter 7, the overall research programme findings concludes by focusing on the effects of exposure conditions on the test samples. From the research programme experience, a few suggestions have been made to conduct and explore more studies on the bonding performances especially on the durability of FRP in concrete bonded system due to tropical climatic conditions.