CHAPTER 7

CONCLUSIONS AND SUGGESTION FOR FUTURE STUDY

7.1 Conclusions

The FRP plate bonding system, either using FRP plate bonded or FRP wet laminate system, is seen to be applicable as a rehabilitation technique. However, several areas of structural implications due to durability factors need to be seriously looked into before it can be placed into service. In addition, the bond durability behaviour of FRP plate-bonded system under the influence of tropical climate exposure must be technically understood, especially materials system characteristics such as brittleness and proneness to moisture ingression. From the overall study programme, the following conclusions can be drawn:

i. In this study programme, there were three mechanical fixtures and two load test rigs that have successfully been developed for specimen preparation and final load test respectively. The design and fabrication development process of the rigs were part of the works in this study programme that led to research project finding.

ii. The first and most outstanding load sustainability experimentation test rig was produced successfully. The rig was successful in creating and transferring the stresses onto the specimen and sustained the load without any maintenance during experimentation period even when exposed to outdoor, plain water and salt water conditions.

iii. The experimentation results have provided some interesting information regarding the durability aspects of CFRP plate specimens. From load test and visual observation, it was noticed that the moisture diffusion was the main factor leading to specimen interlaminar shear out. The failure mode was dominated by those specimens exposed to plain and salt water conditions.

iv. The Arcan test method and the modified fixture were reliable as the specimen shear stress and strain relationship was linearly propagated. The main factors that influenced the test results were porosity, moisture diffusion and oxidation. Apart from that, the shear strength and shear modulus for all test specimens showed a significant effect influenced by exposure conditions.

v. Both BOLTUS and BOLTALS50 group of specimens showed that the bond force transfer from the CFRP plate to concrete at low load level was fairly linear and occurred at a uniform rate. At higher and near to failure loads level, the bond force distribution became non-uniform and non-linear. This caused the formation of macro-debonding at bond interfaces, which in turn led to progressive propagation bond failure from the most stressed region toward the free end.

vi. Higher strain data showed by BOLTUS-OD, PW and SW together with BOLTALS50-PW and SW lead to the conclusion that their respected exposure conditions produced less effective bond performances at their respected weak bond interface.

vii. Local bond stress distribution was influenced by crack history, where the debonding of the CFRP plate-epoxy due to micro-cracking or adhesive-concrete interface failure has caused progressive growth of bond transfer length at failure load level. Most of the specimen bond failure was dominated by concrete shearing influenced by low tensile and shear strength properties of concrete as compared to CFRP plate and epoxy adhesive.

viii. At low load level, the maximum local bond stress occurred within the region of the most stressed end for all test specimens. The force transfer length was relatively short at low and medium load levels and progressively increased at near to failure load. Bond interface failure between adhesive-concrete near stressed end region has shifted to the adjacent region and further towards free end with the increment of applied load together with the formation of bond interface debonding when the stress exceeded the material shear strength.

ix. Bond slips and time to failure were the parameters that provided significant indications in measuring the level of durability effect on exposed specimens. In addition, through visual inspection, it showed that the six months exposure period managed to provide some sign on the bond durability failure behaviour on the specimens.

7.2 Suggestion for Future Study

During the implementation of the project, a few problems have been faced. These obstacles might have slightly affected the outcomes of the programme study. Therefore, some suggestions are listed for further study improvements.

i. Enhancing the mechanical and geometrical parametric study by varying CFRP plate geometry, plate properties, concrete strength, bond width and adhesive thickness, through dedicated developed numerical formulation. In addition, an improvement technique onto concrete bond surface by introducing filler (i.e. to enhance concrete bond strength) and the application of thermoplastic FRP must be highlighted in future study of bond behaviour under tropical climate exposure condition.

ii. Increase the exposure duration to appropriate time limit to be able to produce more comprehensive results. This has been done by a research group from the University of Sheffield, United Kingdom to study the long-term performance on bond durability of steel plate-concrete bonded system (under mechanical stressed) exposed to aggressive condition (i.e. polluted industrialised area).

iii. The experimentation test results can be further enhanced by improving the existing analytical model developed by using a fairly simple elastic theory or non-linear fracture energy model. The bond mechanism analysis can be more useful by varying bond parameters such as material properties, material geometries, adhesive thickness, bond length and introducing appropriate boundary conditions, by taking into account the durability effects parameters. The mathematical model is very useful in predicting interfacial shear stress that is difficult to measure by standard instrumentations.