CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

It is very common to see beams with openings. These openings in beams allow pathway for the pipes, air-conditioning ducting and internet cables so that engineers can have a more adequate building design (Aykac *et al.*, 2013). However, due to openings present in the beams, the original strength intended is no longer the same. The existence of openings in reinforced concrete (RC) beam reduces its bearing capacity and have negative effect on the overall structure.

In the attempt to regain the lost strength due to openings, bamboo fibre plate reinforced with polyester and vinyl ester are used to strengthen around the openings. Bamboo fiber is a natural fiber from plants that has gained popularity due to green technology. Products which are bio-degradable gained from natural resources are long-lasting and environmental friendly that can be a new competitor to current market populated by petroleum-based products (Abdul Khalil *et al.*, 2012). Bamboo has some significant characteristics over other plant fibers such as higher mechanical strength, lightweight and lower cost to prepare. All these advantages make bamboo fibers an ideal material as a natural fiber to do strengthening works.

The bamboo fiber is reinforced with resin using polyester or vinyl ester. This bamboo fiber plate is then bonded to the concrete beam surface for external strengthening. The bamboo fiber reinforced with resin composites is being experimented by various groups. Research found that the tensile strength of bamboo fiber reinforced composite plate (BFRCP) performed better than glass fiber reinforced composite (Chen *et al.*, 2009). Some of the research and studies have been done on RC beams with openings using ANSYS software. One of the research investigated was to determine the

behaviour of RC beams using finite element analysis (Hawileh *et al.*, 2012). However, research using finite element analysis to determine the effects of bamboo fiber in strengthening beams with openings is still lacking. The finite element software, ABAQUS is also not commonly used among the finite element modelling research.

1.2 PROBLEM STATEMENT

RC beam with openings possesses reduced compressive strength, thus, it has lower load bearing capacity than its counterpart without openings. The size of the openings varies depending on the intended functions for the opening to be there. The bigger the openings, there will be a bigger loss of strength and may susceptible to cracks when loaded. Most of the openings are of square shape or circular shape. However, circular opening is considered in this thesis because the shape can allow most of the services to pass through compared to square opening. This is because the services such as electrical wiring and piping are round shape. Furthermore, less stress concentration was traced around the circular opening compared to square shape of opening. Hence, Fiber Reinforced Polymer (FRP) has been commonly used to strengthen around the reinforced concrete beam in order to regain its lost strength. As of today's trend, natural fibers have been opted as a new trend as sustainable and lower cost replacement to synthetic fibres such as glass and carbon (Jain *et al.*, 1992). This is because synthetic fiber is costly in production and the world is moving towards a greener and more economical approach. Thus, researchers now shifting their attention to natural fiber, which is more abundant and easier to obtain with reduced cost. Bamboo fiber is one of the targeted natural fiber to be implement as a replacement to synthetic fiber. This is because bamboo fiber exhibits high tensile strength itself (Okubo *et al.*, 2004). Therefore, various research had been done to review its potential as a substitution of synthetic fiber. The target of this study is to obtain data on the effect of using Bamboo Fiber Reinforced Composite Plate (BFRCP) in strengthening the bending and shear zones of the RC beams. To achieve this target, finite element analysis is used to analyse its effects and load-deflection curve and crack pattern are generated. The reason of using finite element analysis is to validate results with the laboratory testing. Lab tests have some disadvantages such as time consuming, costly materials and tedious procedure to obtain the data. Finite element analysis can be used to predict the outcomes using various

conditions without going through the laboratory testing, which save a lot of time and labour cost.

1.3 OBJECTIVES OF STUDY

The objectives of the study are as follows:

i) To determine the behaviour of RC beam (solid) and RC beam with opening in terms of load-deflection and crack pattern in finite element analysis.
ii) To determine the effect of strengthening using bamboo fiber plate reinforced with polyester and vinyl ester in bending and shear zone in finite element analysis.
iii) To validate the experimental results and finite element results.

1.4 SCOPE OF STUDY

In this study, the analysis was carried out using a commercial finite element analysis software, ABAQUS 6.14. This particular software was used to run numerous numerical analysis of finite element involving stresses, strains, load-deflection and crack pattern as well as provide solutions to the problems. The behaviour of RC beams with and without openings were analysed as well as the beam behaviour after strengthening using BFRCP. There were a total of six types of beams to be analysed to verify the results. The first one was the RC beam without any opening, which acted as a control beam while other two beams were strengthened at flexural zone using BFRCP with polyester and vinyl ester respectively. Another RC beam with openings will also acted as a control beam while another two beams with openings were strengthened at shear zone using BFRCP with polyester and vinyl ester, respectively. All the beams were modelled accordingly and tested by applying four-points loading method. The load-deflection curve and crack pattern were identified as well. The stress-strain diagram was then obtained and the results from modelling analysis were compared with laboratory experimental results for validation. The dimension of the RC beams used for this study were 120 mm x 300 mm for the cross section of width and height and length of 1500 mm. There were two circular openings on the beam in which the size of circular opening at the shear zone was 120 mm in diameter. The distance from the end of the beam to the centre of the circular opening was 310 mm. The steel reinforcement used for the RC beams were two steel bars with 10 mm diameter for both tension and compression region.