CHAPTER 1

INTRODUCTION

1.1 RESEARCH BACKGROUND

In the construction of modern building structures, reinforced concrete (RC) deep beams are often used as primary load transferring elements, such as transfer girders, pile caps and shear wall. Nowadays, the use of deep beams has increased rapidly especially at the lower levels in tall buildings for both residential and commercial purposes due to their convenience and economical efficiency. A deep beam or transfer girder is commonly used when there is a lower column on the exterior façade needed to be removed due to architectural purposes. According to the Building Code Requirements for Structural Concrete (ACI 318-08) published by American Concrete Institute (ACI), deep beam can be defined as a beam in which either clear span is equal to or less than four times the overall member depth or concentrated loads are within a distance equal to or less than two times the depth from the face of support. Large openings through structural members are often required for mechanical and electrical conduits, such utility pipes and ducts are essential to accommodate part of the indispensable services as well as for the means of passageways like doors and hallways in the buildings (ACI Committee 318, 2008). Openings are classified as small or big openings and the best position of the opening is depended on its size (Chin et al, 2011). There is no clear-cut demarcation line or without any definition to classify the size of the opening, whether large or small. However, an opening may be considered as small opening if the depth to diameter of the opening is in realistic proportion to the beam size, about equal to or less than 40% of the overall beam depth. Large openings usually interrupt the natural load path and restrain the load transfer by concrete struts in the deep beams, causing a sharp decrease in strength and serviceability (Mansur, 2006). Normally in practice, the openings are located near the supports where shear is predominant. If the openings are
located between the loading point and the support, the flow of force transfer will be disrupted and the load-carrying capacity of the deep beams will be significantly reduced. Web openings can be found to have various shapes, such as square, circular, rectangular, diamond, triangular, trapezoidal and even irregular shapes. Nevertheless, the circular and square openings are the most general in used practically.

Necessity of strengthening of RC deep beams with large openings is majorly depends on the types of construction of opening in RC deep beam, whether pre-planned or post-planned. Strengthening of RC deep beams with opening is not necessary if the opening is designed as built or pre-planned, since the location and sizes of the opening were specified and sufficient reinforcement is provided during design phase and construction of the deep beam. However, for a post-planned opening in RC deep beam, strengthening of RC deep beam is required to ensure sufficient shear capacity to prevent structural failure. Internal strengthening in deep beam with opening is commonly defined in situation where the upper and lower chords of opening are provided by longitudinal reinforcement whereas surrounding of the opening is strengthened by diagonal reinforcement (Mansur and Tan, 1999). For post-planned opening case, the opening has to be constructed in an existing RC deep beam by hand tool drilling technique. There might be some difficulties during the process of creating service utility pipes and ducts (Tamer and Sherif, 2009). Therefore, it is necessary for the deep beam’s opening to be strengthened externally with the external reinforcing material. Steel plates is the most common external reinforcing material, but fiber reinforced polymer (FRP) system seems to become the favourite in many construction industry currently. The FRP reinforcing system consists of choices of glass fibers, carbon, and aramid, the advantages and disadvantages will be discussed in the nest chapter (Haider, 2014).

Many literature and reports have been done on the effectiveness of CFRP strengthening system in provided external reinforcing to the structural members. The experimental results show that the shear capacity of solid RC beams without web openings is increase significantly. The researchers discovered that the beam’s shear span to depth ratio, internal shear reinforcement ratio, and the total amount of externally bonded CFRP sheets are the factors in effecting the gain in the shear capacity in solid RC beams (Chen and Teng, 2003) (Khalifa and Nanni, 2002). The
results determine a fact that when the internal shear reinforcement ratio increases, the gain in the shear capacity after externally bonded with CFRP will decrease. Improvement and strengthening in shear capacity of RC beam with openings by using externally bonded reinforcement FRP system has become a focus point in the industry (Bousselham and Chaallal, 2006). Previous experimental results provide some precious data and evidences on improvement of weakness of laying a web opening in RC beam by using CFRP strengthening system. There are plenty of researches findings specify the potential of externally CFRP strengthening system in increasing the shear capacity of RC beams with web openings (Abdalla et al, 2003).

In this paper, reinforced concrete deep beams containing large openings are treated separately. Based on the research work reported in the literature, an attempt has been made to give a comprehensive treatment of openings under shear compression, addressing the major issues concerning structural design. It has been shown that the design of beams with large openings can be further simplified by maintaining its rationality and upholding construction economy.

1.2 PROBLEM STATEMENT

Reinforced concrete deep beams are widely used in both commercial and non-commercial buildings. The creation of a web opening in reinforced concrete (RC) deep beams is frequently required to allow accessibility for utility services such as electricity and air conditioning conduits, especially for the post-planned building services. The web openings’ size is categorized as small or large opening, which is differentiate based on the depth-to-diameter of the opening. The behaviour of the RC deep beams in terms of load-deflection and crack patterns would be affected by the characteristics of the openings created on the beam, such as openings’ shapes, sizes and locations on the beams. Creation of large opening would alter the building’s function and thus, the structural strength of the building could reduce as well as resulted in sever safety hazard. From the previous studies, the existence of web opening causes several issues, especially reduction in beam strength, beam stiffness, cracking and deflection. However, the weakness of existence of web opening in RC deep beams can be solved by the externally strengthened method such as carbon fiber reinforced polymer (CFRP). Hence, further studies in the field of strengthening of RC