

PERPUSTAKAAN UMP



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EFFECTS OF SQUARE OPENINGS IN REINFORCED CONCRETE DEEP BEAMS

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ABSTRACT

Reinforced concrete (RC) deep beams are usually used in tall buildings' or offshore structures. The presence of web opening in such beams can often be necessary to accommodate crucial services, for instance ventilating as well as air conditioning ducts. This research was conducted to study the effects of opening in RC deep beams with various sizes of openings as a test parameter. The shape of choice is square opening. The square openings were placed at the top of shear span near support. A total six deep beams with same dimensions (100 mm x 500 mm) and the total length of 1200 mm were cast. Three control deep beams and the remaining deep beam with openings with size of 150x150 mm, 200x200 mm and 250x250 mm were studied. The beams were tested to failure under 4-point bending. The results obtained from the test including load-deflection behaviour, and crack pattern. The reinforced concrete deep beams with openings develop shear-diagonal cracks at the openings corner, due to the stress concentration at sharp edges. The crack pattern development varies with opening sizes. The cracking development increased as the size of openings increased. The presence of openings in RC deep beams caused significant reduction in the beam strength. As compared to solid deep beam, the reduction of beam strength falls in the range of 43% - 82%. As for RC deep beams with openings, losses in beam capacity about 43%, 51%, and 82% in beam DBS1, DBS2, and DBS3, respectively were obtained. The size of opening plays a crucial part in this study. The larger the opening size, the more severe crack pattern was observed.

ABSTRAK

Konkrit bertetulang (RC) rasuk dalam biasanya digunakan dalam bangunan tinggi atau struktur luar pesisir. Kehadiran pembukaan web di rasuk itu sering boleh menjadi perlu untuk menampung perkhidmatan penting, misalnya pengalihan udara serta saluran penyaman udara. Kajian ini telah dijalankan untuk mengkaji kesan pembukaan di rasuk dalam RC dengan pelbagai saiz bukaan sebagai parameter ujian. Bentuk pilihan adalah pembukaan persegi. Lubang persegi diletakkan di bahagian atas span ricih berhampiran sokongan. Sebanyak enam rasuk dalam dengan dimensi yang sama (100 mm x 500 mm) dan panjang keseluruhan 1200 mm dibuang. Tiga kawalan rasuk dalam dan rasuk dalam baki dengan bukaan dengan saiz 150x150 mm, 200x200 mm dan 250x250 mm telah dikaji. Rasuk diuji untuk kegagalan di bawah 4-mata lenturan. Keputusan yang diperolehi daripada ujian termasuk tingkah laku beban-pesongan, dan corak retak. Bertetulang rasuk dalam konkrit dengan bukaan membangunkan retak ricih pepenjuru di sudut bukaan, kerana penumpuan tegasan di tepi tajam. Pembangunan corak retak berbeza dengan saiz pembukaan. Pembangunan retak meningkat saiz bukaan meningkat. Kehadiran bukaan di rasuk dalam RC disebabkan pengurangan yang ketara dalam kekuatan rasuk. Berbanding dengan rasuk dalam pepejal, pengurangan kekuatan rasuk jatuh dalam lingkungan 43% - 82%. Bagi RC rasuk dalam dengan bukaan, kerugian dalam kapasiti rasuk kira-kira 43%, 51%, dan 82% pada DBS1 rasuk, DBS2, dan DBS3, masing-masing telah diperolehi. Saiz pembukaan memainkan peranan yang penting dalam kajian ini. Semakin besar saiz pembukaan, corak retak lebih teruk diperhatikan.

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LIST OF SYMBOLS

%	Percentage
MPa	Mega Pascal
mm	Millimeter
m ³	Meter cubes

LIST OF ABBREVIATIONS

DBS1	Deep Beam Square 1
DBS2	Deep Beam Square 2
DBS3	Deep Beam Square 3
RC	Reinforced Concrete
SDB1	Solid Deep Beam 1
SDB2	Solid Deep Beam 2
SDB3	Solid Deep Beam 3
LVDT	Linear Variable Displacement Transducer

CHAPTER 1

INTRODUCTION

1.1 Introduction

These days, deep order design may be actively investigated concerning their necessity being a construction option has grown to be more evident. Reinforced concrete (RC) deep beams frequently used in addition to encountered in several structural as diaphragms, connections, water tanks, precast and to pre-stressed building, foundations, silos, bunkers, and offshore structures. Deep beams defined as beams span to depth “ L/d ” less or add up to 5 with regard to simply supported beams in addition to 2.5 with regard to continuous beams. In each instances, when the shear span on the beam “ a ” will be less or add up to double the depth, it could be processed being a deep beams. The presence of opening inside the web brings advantages with regards to minimizing the price of the creating. Deep beams with world wide web opening goal are with regard to essential services ducts in addition to pipes.

Web openings in a deep beam significantly affect its structural behavior as demonstrated in previous studies (Kong and Sharp 1977; Kong et al. 1978; Mansur and Alwis 1984; Ray 1990; Almeida and Pinto 1999; Ashour and Rishi 2000; Maxwell and Breen 2000; Tan et al. 2003; Yang et al. 2006). A simple structural idealization for predicting the ultimate shear strength of deep beams with web openings was proposed

some thirty years ago based on a series of laboratory testing conducted by Kong and Sharp (1977) and Kong et al. (1978) and extended upon by Tan et al. (2003).

The structural idealization shows the lower and upper paths of load transfer when a web opening is present Yoo et al. (2011). It offers a good indication of the ultimate load-carrying capacity of the beam which is affected by the size and location at which the natural load path is interrupted by an opening (Guan and Doh, 2007). Therefore, these deep beams with opening can help to accumulate the previous data that have been recorded in order to satisfy the need in the world of construction

1.2 Problem Statement

In the construction industry, the uses of RC deep beams with openings are frequently used in tall buildings in both commercial and non-commercial buildings. The actual profile regarding web openings such deep beams is frequently sought to offer accessibility to allow for vital services including ventilating as well as air conditioning ducts. Besides that, it is advantageous in minimizing the cost of the construction in terms of the usage of materials. However, enlargement in openings are required due to architectural or mechanical requirements. Changing in the building's function would reduce the structural strength, thus may result in severe safety hazard. The presence of openings causes reduction in beam strength, beam stiffness, cause excessive cracking and deflection. Therefore, further researches in the area of RC deep beams with openings are required.

1.3 Objectives

The aims of this research are:

1. To determine the load – deflection relationship.
2. To identify the crack pattern of deep beams with and without opening.
3. To determine the effects of opening sizes.

1.4 Scope of Study

In this experimental study, four beams with dimension of 500 mm x 100 mm and a total length of 1200 mm length were prepared. Solid beam without opening named as SDB1 functions as control parameter and remaining beams with square opening of size 150 x 150 mm, 200 x 200 mm and 250 x 250 mm were named as DBS1, DBS2 and DBS3 respectively. The opening section was designed to be located at the top of the shear span near support.

Material such as Ordinary Portland Cements (OPC), sand, coarse aggregates, steel bar and links bar were used. As for the reinforcement, steel bar of size 10mm, 16mm and shear link bar of size 6 mm were chosen. The compression reinforcement bar used for the beam is 2H10 and for tension reinforcement 4H16 bar with link size H6 were placed at 150 mm center to center. These specimens were conducted under 4 points flexural test. All beam samples were compared in terms of load - deflection curve, crack pattern, and effect of sizes.

1.5 Significance of Study

The uses of RC deep beams with openings are frequently used in tall buildings in both commercial and non-commercial buildings. However, enlargement in openings are required due to architectural or mechanical requirements causes reduction in beam strength, beam stiffness, cause excessive cracking and deflection. This study considers square shape of opening (small, medium and large size) as the corners of the opening often subjected to high stress concentration. The opening is also placed at the top of the shear span near support in order to disturb the critical load path. Previous research focuses more on rectangular and circular shape of openings located in shear zone. In this study, the opening was provided at a distance of 100 mm from the support.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Research and study in comparing the behaviors between solid deep beam and deep beams with web openings with the same cross-section and reinforcement had been made before. Some research found that web opening deep beam couldn't resist an extra loadings compared to solid beam which can stand and bear the excess cargo. Thus, this chapter review of the characteristic web opening deep beams and how much the size of opening affects the deep beams. The behavior of the beam was known depending on the opening size on the deep beam and this chapter review the explanations on the square opening deep beams behavior and from those the suggestion and recommendation to increase the concrete square opening deep beams behavior was observed.

This literature covers a vast kind of theories, for that purpose this review are focusing on two major ideas, which mainly focuses on the behavior of RC deep beams with opening including their load – deflection behavior and crack pattern.

2.2 Behavior of Deep Beam Without Opening

Deep beams or non-slender beams are commonly found in reinforcement concrete tall structures. These types of beam are located close to the supports where large loading acting, the shear-span-to depth ratio (a/d) is less than 2.5. Deep beams serviceability performance are quantified by the width and spacing of diagonal cracks that form under the application of service loads. A disturbance in internal stresses is caused by shear action with compression in one direction and tension in the perpendicular direction. This leads to an abrupt shear failure of the beam as the beam depth increases (Yang et al., 2003). The development of crack pattern is much faster than small size deep beams and then leading to sudden failure (Bakir and Boduroglu, 2005).

2.3 Behavior of Deep Beam With Web Opening

Web openings in a deep beam significantly affect its structural behavior as shown in previous studies (Kong and Sharp 1977; Kong et al. 1978; Mansur and Alwis 1984; Ray 1990; Almeida and Pinto 1999; Ashour and Rishi 2000; Maxwell and Breen 2000; Tan et al. 2003; Yang et al. 2006). The provision of openings in RC deep beams is for the passage of utility pipes and ducts to accommodate essential services in buildings. This research would helps the practicing engineers and researchers to better understand the interrelation between the opening position, size, crack pattern, and failure mode of RC deep beams. Figure 2.1 shows a schematic diagram of deep beam with opening.

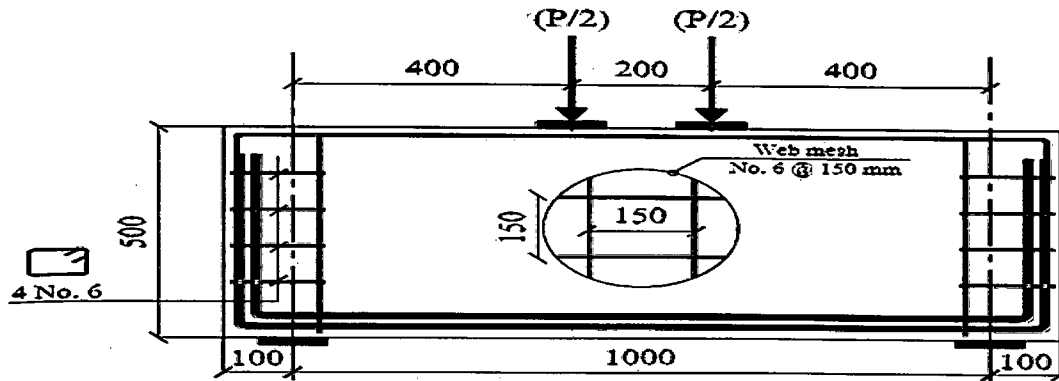


Figure 2.1: Schematic diagram of deep beam with opening.

Sources: Maaddawy and Sherif 2008

2.4 Crack Pattern

Cracks were developed when an opening was present in the structure. According to (Maaddawy and Sherif, 2008) it was stated that as the load was increased, these cracks widened and spread both ways towards the support and loading stages, and the successive application of the load resulted in widening and extension of existing cracks in addition to the introduction of new diagonal cracks through the shear spans.

Two types of diagonal cracks are recognized in reinforced concrete beams: flexure-shear cracks and web-shear cracks (Birrcher et al., 2008). Flexure-shear cracks are formed following or perhaps concurrently with flexural cracks. They expand on the idea of the flexural crack under load. Web-shear cracks occur on their own regarding flexural cracking. They occur when the principal tension stress inside the web of the member exceeds its tensile strength regarding concrete. Throughout in a deep beam, web-shear cracks are usually also known as splitting cracks. This type of crack pattern is when the crack starts to appear at the opening and propagates upward with increasing crack width. As the load increases, the crack propagates half of the beam and

gradually curved towards the loading point. In Figure 2.2 show the types of crack in deep beams.

In addition, the crack propagation that develops on the beam also can determine whether the crack was developed by subjected to bending or shear. According to Behzad et al. (2008), mentioned that when the beam develops cracks at the edge, the beam is not in plane shape anymore after the deformation. This is due to the shear stress near the crack tip, which also leads the warping of the plane section. Thus, any cracks propagate at the sharpness of the beam or at near the rolling support for this study is anticipated to undergo the crack which subjected by the shear stress.

Also, from their research also noted that any cracks propagate at the mid-span of the beam is may subjected by bending stress. Besides, (Yoo et al., 2011) in their research mentioned at 70-90% of the ultimate load, diagonal crack generally develop around the corner of the web opening toward the support and the loading point. And so the cracks are numbered in order of the visual aspects.

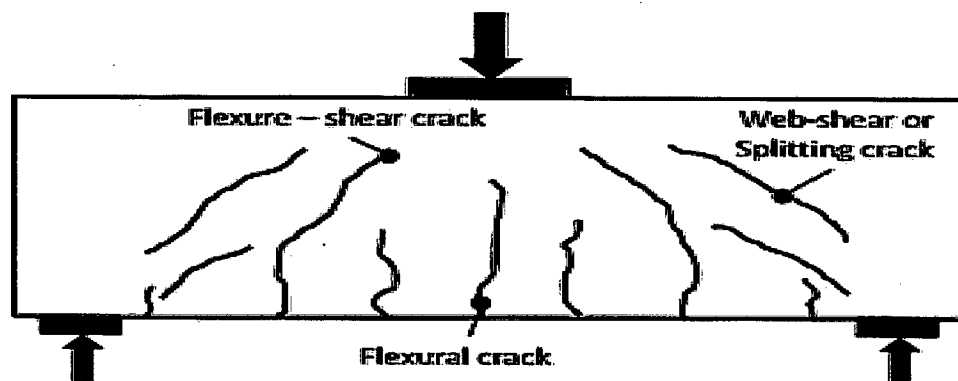


Figure 2.2: Types of cracks in deep beam.

Sources: Birrcher et al. 2008

2.5 Load-Deflection Curve

The presence of opening in deep beam cause geometric discontinuity that affect the strength, which leads to reduce of ultimate strength (Yoo et al., 2010). The opening in the tall structure such as deep beam is required in the nowadays building design for the satisfaction of the requirements due to architectural/mechanical and/or a change in the building's function would reduce the element's shear capacity, thus rendering a severe safety hazard (Maaddawy and Sherif, 2008). Therefore the behavior of the deflection of an opening beam is required to be investigated. According to (Thuc, 2002), the beams' stiffness are mostly depending on the opening locations and the deflection relative to the load in the span created by the opening increased as the opening was closer to the point load. Benitez et al. (1998) made a research about the deflection of the composite beam with web opening. They also describe and come out with the procedures to calculate the deflection of the beam. However, the equation from Benitez et al., (1998) is not included in this literature due to incapability and too conservative.

According to (Maaddawy and Sherif, 2008), that the beam behavior depended primarily on the degree of interruption of the natural load path. As recorded in Figure 2.3, the beam without interrupting the load path exhibit almost a linear relationship up to failure, which is the NS-150-T. Others beams, where the load path have been interrupted by the opening plotted a non-linear graph. According to Benitez et al., (1998) again mentioned that when there has an opening of the beam, the strain compatibility is reduced and there is loss of material to carrying the shear that is effecting on the vertical deflection between the ends of the opening which is subjected to the shear. This review shows that the opening of the beam is affecting the deflection profile of the beam.

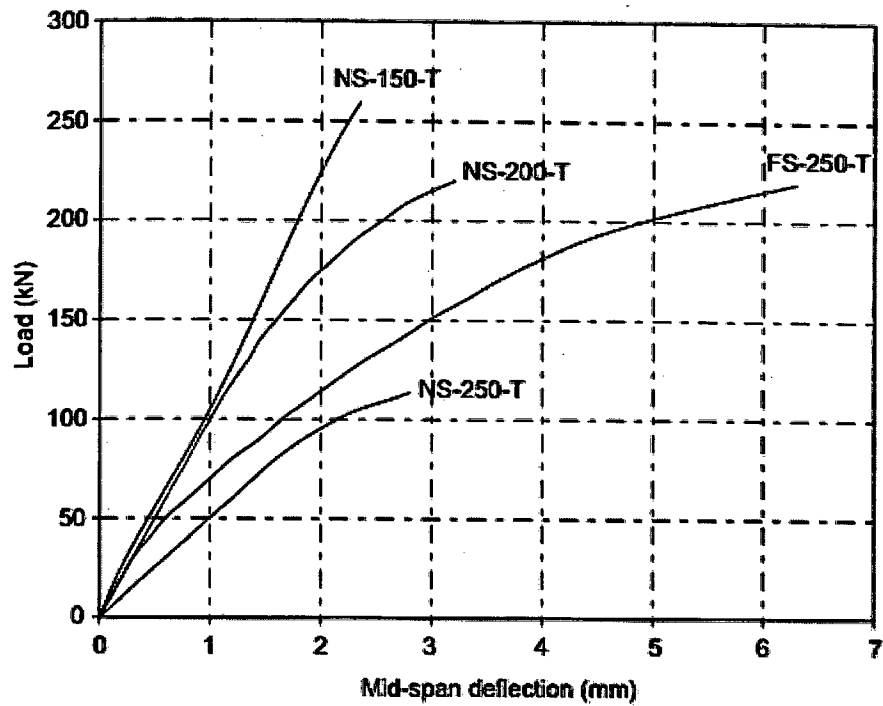


Figure 2.3: Example graph of load deflection curve.

Sources: Maaddawy and Sherif 2008

2.6 Opening Effect

Opening in web of deep beam can affect the structure itself, depending on the size, shape and location of openings. This review shows the sizes of openings in deep beams, shape of opening and location of openings.

2.6.1 Size of Opening

As stated by Mansur, (2006), the openings that are circular, square, or nearly square in shape may be considered as small openings provided that the depth (or diameter) of the opening is in a realistic proportion to the beam size, about less than 40% of the overall beam depth. In such a case, beam action may be assumed to prevail. Therefore, analysis and design of a beam with small openings may follow the similar course of action as that of a solid beam. According (Maaddawy and Sherif, 2008) stated the cracking load decreased as the opening size was increased. For size the opening in this research, we applied three different sizes as follows 150x150 mm, 200x200 mm and 250x250 mm which corresponded to opening height-to-depth (a/h) ratios of 0.3, 0.4, and 0.5, respectively.

2.6.2 Shape of Opening

According to Alsaeq (2013) the use of circular opening has advantages over using square opening regarding the structural strength of the beam. The circular opening was hard to penetrate. The square openings were chosen because the sharp edges in square openings that can easily crack and give a good data to the first objective which is analyzing the crack pattern occur on the deep beams. It too can assist engineers in practicing, when square opening is required in construction.

2.6.3 Location of Opening

Location of the opening can give different impact based on the location. When the opening is reasonably away from the load path, the compression force transfer takes the shortest route from the loading point to the closest support which resembles well to that of the beam without an opening (Guan and Doh, 2007). The strength of the beam increases when the opening is located away from natural load path (Kong, 1978). Location of opening offers a good indication of the ultimate load-carrying capacity of

the beam which is affected by the size and location at which the natural load path is interrupted by an opening (Guan and Doh, 2007). When the opening is located at the mid-depth of the beam, the ultimate load-carrying capacity of the beam is very much affected by the vertical location of the opening (Guan and Doh, 2007). For this research, the location of opening at the top of shear span near to the point load. The location of the opening was to interrupt the natural load path that is the line connecting the bearing plates at the loading and support points. It was also dependent on the extent of the interruption of the load path from the opening.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter explains about the researches that was conducted and explain the study that was carried out. In this chapter also included the explanations about the materials utilized, the research, planning and also the testing have been carried out to find the characteristic of openings concrete deep beams. This section also gives the clear detail of sentiment around the research and clearly demonstrates how the objective of this research can be achieved. At the early stage, the data and the literature review were collected from the previous study.

The source of the study such as books, journals, magazine, research papers, articles, symposium papers and internet. The discussion can be used to improve and gain the knowledge and information regarding the scope of the research. For this study, the materials used are Portland cement, coarse aggregate, and fine aggregate to deep beams with a variety of square openings located at top of shear span near to the point load. After casting and curing part done, the specimens tested by using flexural test (4 point test).

3.2 Flow Chart

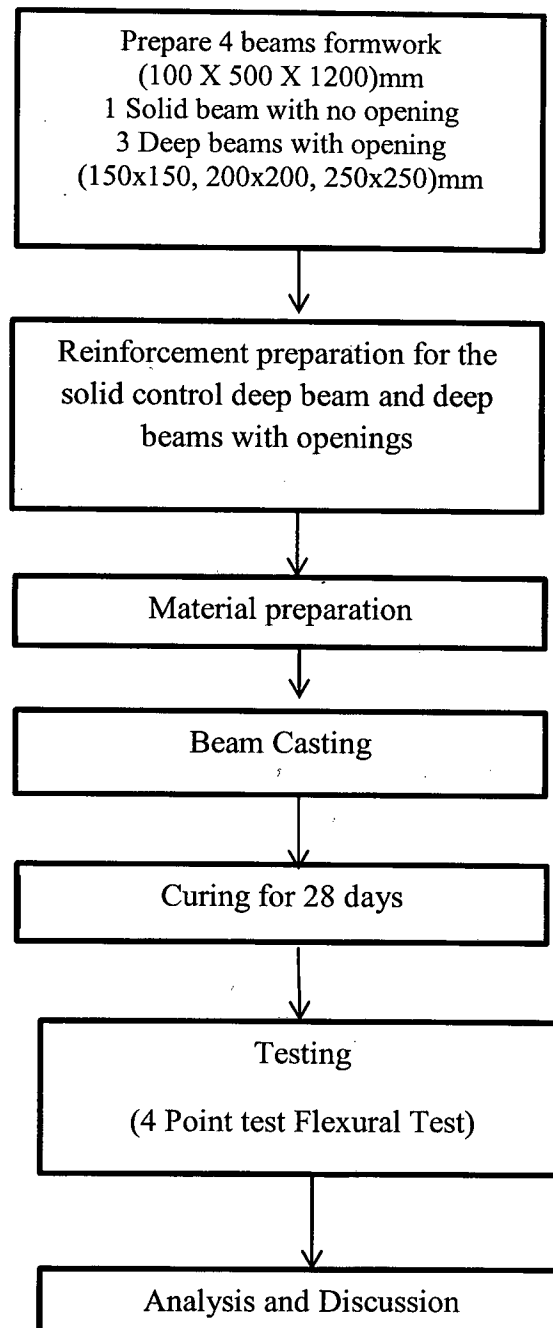


Figure 3.1: Research experimental work flow