THE EFFECT OF LOCATION OF POST DRILLED WEB OPENING ON THE STRENGTH OF REINFORCED CONCRETE BEAM

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DEDICATION

Specially dedicated to my father and mother

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ABSTRACT

The construction of modern buildings requires many pipes and ducts in order to accommodate essential services such as electricity, air conditioning, telephone, and network cables. Web openings in Reinforced Concrete (RC) beams enable the installation of these services under lower floor to floor height without compromising any architectural headroom. However, the requirement of opening often reaches the engineers and contractors after the beam has been constructed. As such, there is a need to reassess the new strength of the beam with the newly added opening without the placement of trimmer reinforcement bar. Methods to assess the reduced strength of the RC beams due to post drilling these opening are often complicated. To overcome this, a research has been carried out with the aim to provide simple guidance to engineers to access the new strength of the RC beams due to small post drilled transverse circular web openings at different location of the beam. RC beams with a series of opening at different location were analysed using LUSAS, by conducting nonlinear analysis to determine the new strength of the RC beam. A graph of relative load bearing capacity of an RC beam with respect to location of post drilled web opening is proposed to aid design engineers to assess the beam capacity without a need for detail calculation.

ABSTRAK

Pembinaan bangunan moden memerlukan banyak paip dan saluran untuk menampung perkhidmatan asas seperti elektrik, penghawa dingin, telefon, dan kabel rangkaian. Bukaan web dalam rasuk concrete bertetulang (RC) membolehkan pemasangan perkhidmatan ini di bawah lantai yang lebih rendah ke lantai yang lebih tinggi tanpa menjejaskan mana-mana ketinggian lantai bangunan. Walau bagaimanapun, keperluan untuk menebuk lubang sering sampai kepada jurutera dan kontraktor selepas rasuk telah dibina. Oleh itu, terdapat keperluan untuk menilai semula kekuatan baru rasuk dengan lubang yang baru ditambah tanpa dipasang tetulang trimmer tetulan. Kaedah untuk menilai kekuatan baru rasuk RC selepas penggerudian lubang ini sering rumit. Untuk mengatasi masalah ini, satu kajian telah dijalankan dengan tujuan untuk memberi panduan mudah untuk jurutera untuk mengakses kekuatan baru rasuk RC selepas ia digerudi untuk membuat lubang kecil pada web di lokasi yang berbeza. Rasuk RC dengan lubang yang ditebuka di lokasi yang berbeza dianalisis menggunakan LUSAS, iaitu dengan menjalankan analisis tidak lelurus untuk menentukan kekuatan baru rasuk tersebut. Graf pengurangan keupayaan galas beban rasuk RC lawan lokasi lubang pada web telah dicadangkan untuk membantu jurutera reka bentuk untuk menilai kapasiti rasuk tanpa perlu membuat kengiraan yang baru yang sukar.

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INTRODUCTION

In modern building construction, transverse openings in reinforced concrete beams are often required for the passage of utility ducts and pipes due to high requirement of Mechanical, Electrical and Plumbing (MEP) services. These ducts and pipes are usually placed underneath the soffit of the beam and are often covered by a suspended ceiling for aesthetic purposes, thus creating an unused space (waste of space). This results in additional overall height or reduced headroom of a building as these unused space accumulate in each floor respectively. The significant of extra overall height depends on the depth of space required for MEP services. Alternatively by providing web openings will enable engineers to reduce the overall height of the structure. The reduced overall floor to floor height becomes significant especially in tall building construction, which will result in a more economical design. Thus, installation of mechanical and electrical services prompt structural engineers to provide solutions by providing opening at primary and secondary beam of a building.

1.1 Problem Statement

As mentioned above, installation of mechanical and electrical services prompt structural engineers to provide solutions by providing opening at primary and secondary beam of a building. In a building refurbishment project, installation of new mechanical and electrical services are often required, which leads to requirement of transverse opening on a constructed beam. These beams were usually constructed

without the provision of these openings, with no pipe sleeve or trimmer bar installed. As such, structural engineers are required to assess the effect of the opening on these beams, including the reduction of beam capacity, requirement of beam strengthening, and beam strengthening method. Dealing with a project on a fast track basis, engineers need a simple method of assessment to provide fast and accurate decision and judgement.

A simple formulated assessment method, or guidance to carry out preliminary assessment on the effect of opening on beams is often absent in design standard available locally, such as British Standard, Eurocode, Australian Standard or American Standard. Description given in these codes are brief, as show in Table 1.1.

Table 1.1 : Codes and Clauses

Code and Standard	**Description in code**
AS 3600-2009(+A2) Concrete Structure <Clause 8.6.4>	*Crack control at openings and discontinuities* Reinforcement shall be provided for crack control at openings and discontinuities in a beam.
ACI318R-08 <Clause 11.1.1.1>	Openings in the web of a member can reduce its shear strength. The effects of openings are discussed in Section 4.7 of Reference 11.1 and in References 11.4 and 11.5. In determining Vn, the effect of any openings in members shall be considered.
BS 8110-1-1997	No detail information
BS EN 1992-1-1:2004	No detail information

To assess the above stated problem, engineers are required to seek from another source of information such as reference books, research journals of similar works or advice from experience engineers. Without a simple formulated assessment method, engineers are required to carry out advance analysis involving complicated analysis method such as nonlinear finite element analysis or tedious hand calculations.

For example, the presence of transverse openings will transform a simple beam behaviour into a more complex behaviour such as a strut tie behaviour which

assessment involve complicated formulas and mathematical equations, provided in a book by Mansur (1999). These methods of analysis are often too complicated and only to be carry out by experience engineer or a specialist. Even so, the process is often time consuming and prompt to human error, which eventually jeopardise the progress of a project.

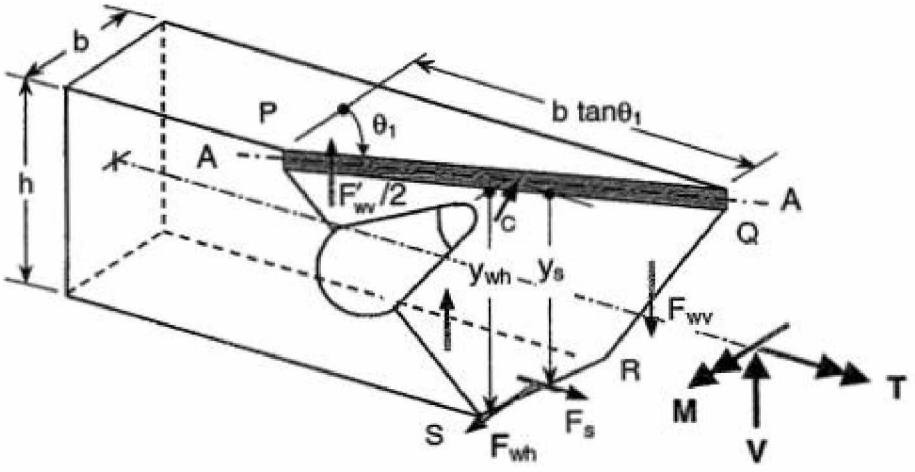

Figure 1.1 Free Body Diagram of Beam with Opening under Torsion (Mansor 1998)

Thus, a research to investigate the effect of post drilled circular small web opening at different location on a beams on the load bearing capacity of beams is carried out, using numerical modelling with Finite Element Method (LUSAS).

1.2 Aim

The aim of this study is to provide a simple guidance to design engineers to evaluate the effect of post drilled circular small web opening at different location on a reinforced concrete beam on the load bearing capacity of the beam.

1.3 Objectives

The objective of this research is to produce a chart for engineers to evaluate the effect of post drilled opening at different location on a reinforced concrete beam on the load bearing capacity of the beam

1.4 Scope of Work

The scope of work includes specification of reinforced concrete beam, dimension of opening, location of opening, loading, steel reinforcement layout and arrangement, and model verifications. Detail is as follows.

1.4.1 Reinforced Concrete Beam - Normal Beam

Beam investigated is a normal beam with dimension of beam to be investigated shall be 6m (length) x 600mm (depth) x 300mm (width). The dimension investigated comply with EUROCODE (BS EN 1992-1-1:2004+A1:2014, 2014) clause 5.3.1 (3). The beam is modelled with concrete grade of 40MPa and reinforced with steel rebar of grade 500MPa.

1.4.2 Dimension of Opening

Opening studied in this research is a small transverse circular opening with dimension of 150mm diameter. The dimension comply with the definition of small opening according to recommendation by Mansur and Tan (1999).

1.4.3 Location of Opening

Location of opening studied is at the centroid of the beam cross section, along the length of the beam at a 300mm interval, 450mm, 750mm, 1050mm, 1350mm, 1650mm, 1950mm, 2250mm, 2550mm and 2850mm

1.4.4 Loading

Type of loading studied are uniformly distributed load and two point load at 1/3 of span of beam respectively, loaded to failure of the beam.

1.4.5 Steel Reinforcement Layout and Arrangement

The steel reinforcement consist normal beam reinforcement with no trimmer bar around the opening, details as follows.

Bottom Reinforcement	: 2% Reinforcement
Top Reinforcement	: 2H12
Shear Reinforcement	: 2H12 at 300mm centre to centre spacing

1.5 Model verification

The accuracy of the model is verified by comparing crack pattern of the beam the model with existing research.

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