ANALYSIS OF STEEL BEAM-COLUMN ASSEMBLIES UNDER COLUMN REMOVAL SCENARIO WITH WEB OPENING BEAM

NUR AIN ITHNIN BINTI ALIAS

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Faculty of Civil Engineering and Earth Resources
Universiti Malaysia Pahang

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ABSTRACT

This paper present and discuss the finite element method as an alternative method to investigate and analyze the steel beam-column with web opening assemblies under a column removal scenario. In this paper, analytical models produced in LUSAS Modeler for defining the deflections and stress due to vertically applied load. The steel structures assemblies are selected and analyzed for linear deflection and stress pattern when the column is removed. Four steel model assemblies were used. Two models were assembled by solid steel structure while the other two were with assembled with web opening beam structures. For both assemblies, the results taken before and after the column removed. The model with and without web opening were compared due to their strength and behaviour using Linear Finite Element Analysis. It was found that the model assemblies with web opening have lower results in terms of strength. The maximum load that it can withstand is the lowest of all assemblies especially when the center column is removed. The results of this study shows that the presence of web opening in structure may weakened the assembly of the structures itself.

ABSTRAK

Kertas kerja ini membentangkan dan membincangkan kaedah unsur terhingga sebagai satu kaedah kaedah alternatif untuk menyiasat dan menganalisa pemasangan struktur keluli rasuk-tiang dengan rasuk yang mempunyai bukaan di bawah keadaan tiang yang di singkirkan. Dalam kertas ini, model analisis yang dihasilkan dalam Pemodel LUSAS untuk menentukan pesongan dan tekanan akibat daripada beban menegak yang dikenakan. Gabungan struktur keluli dipilih dan dianalisis untuk mendapatkan pesongan dan tekanan linear akibat beban menegak dikenakan. Empat pemasangan model keluli telah digunakan. Dua model telah dipasasang dengan struktur keluli tanpa bukaan. Dua model yang lain pula dipasang dengan struktur keluli yang mempunyai bukaan pada rasuknya. Bagi kedua-dua pemasangan, keputusan yang diambil berdasarkan keadaan sebelum dan selepas tiang tengah disingkirkan dari pemasangan. Model dengan bukaan dan tanpa bukaan pada rasuk dibandingkan berdasarkan kekuatan dan sifat mereka dengan menggunkan linear analysis unsur terhingga. Didapati bahawa model dengan bukaan pada rasuk mempunyai nilai kekuatan yang rendah. Beban maksima yang boleh ditanggung oleh pemasangan dengan bukaan pada rasuk adalah lebih kecil jika dibandingkan dengan pemasangan lain. Keputusan kajian ini menunjukkan bahawa kehadiran bukaan pada rasuk dalam struktur boleh melemahkan pemasangan struktur itu sendiri.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Progressive collapse due to unexpected disaster became a subject of interest for structural design Engineers starting with the partial collapse of a tower block from Ronan Point, London (May 16, 1968) continuing with the collapse of the World Trade Centre (WTC) in America (September 11, 2001). All these tragedies were reported as the lost of column structure. Since then, many experts in the structural field were concerned with the design of the structural members and most of them tried to take into account this phenomenon with the column removal behavior.

Since the column received loads from beam, it is important to know the type of connections that will be used to connect beam to column. End plate connections were generally had the most satisfactory behavior and have provided greater economy than could be achieved by other connections. The typical end plate connection consists of a plate that is shop-welded to the end of a beam which is then bolted to the supporting member in the field.

In recent years, there is a growing trend of using beam with web opening in the structures. The use of beam with web opening is to allow services to run through it. The introduction of an opening in the web of the beam alters the stress distribution within the member and also influences its collapse behavior. Thus, the efficient design of beams with web openings has become one of the important considerations in modern structures.

1.2 Problem Statement

1.2.1 Column Removal

There had been numerous reports detailing the cause of the World Trade Center Tower (WTC) collapse on September 11, 2001 (Eager and Musso, 2001). One of the main reasons for the collapse of WTC was removal of the several columns in the perimeter wall due to the crashed of large passenger jetliners with the building structure.

Though the number of columns damage on the initial impact was not large and the loads were shifted to remaining columns in this highly redundant structure, but when multiple members fail, the shifting loads eventually overstress the adjacent members and the collapse occurs like a row of dominoes falling down. Therefore it is important to study the column removal scenario to analyze the deformation behavior associated with the transfer of the forces in such scenario.

1.2.2 Beam-Column Connection

Beam-column joint connections are a common structural weakness in dealing with seismic effect. Prior to the introduction of modern seismic codes in early 1970s, beam-column connections were typically non-engineered or designed.

Hence, if the beam is not supported in the lateral direction, the beam will fail in buckling when it is subjected to an increase flexural load to a critical limit. Failure of beam-column joint connections can typically lead to a sudden collapse of a structure.

1.2.3 Web Opening

Web opening can be designed in several shapes and sizes. It also can be designed not only single, but double, triple and more on a span of beam.

However, the presence of web opening may have a severe penalty on the load carrying capacities of structural members. If the beam members fail to carry the loads, the beam will experience the excessive buckling that will lead to structural collapse.

1.3 Objective of Study

The objectives of the study are to investigate and analyses the steel beam-column with web opening assemblies under a column removal scenario. Therefore, in order to achieve the above aim, the following objectives have been identified:

i) To analyze the strength of beam-column assemblies under column removal scenario in term of stress and deflection.

ii) To study the behaviour of the beam-column assemblies with web opening under column removal scenario.

1.4 Scope of Study

The proposed study aims at providing a better understanding of the beam-column with web opening assemblies under a column removal scenario for steel structures. Besides, this study will provide the analysis of the structures using Finite Element Analysis (FEA) and modeling.

1.4.1 Structures Assemblies

The structures used for the assemblies are steel beam and steel column with I-shaped. All the structures are in ungraded mild steel condition.

1.4.2 Connection

As for the connection, bolted end-plate connections are used with one-side extended.

1.4.3 Analysis

In term of analysis, LUSAS (London University Stress Analysis System) Software is used to analyze the strength and behaviour of the assemblies in terms of stress and deflection. The analysis conducted with linear finite element analysis.

1.5 Significant of Study

Research significance to be obtained from this study will be the results and analysis of the strength and behaviour of beam-column when the column is removed from the assemblies. This comparison will be used to analyze the strength and behaviour for beam with web opening and beam without web opening for both before and after column removal.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This study is influenced by previous research study, testing and analysis of steel beam with web opening for beam-column assemblies under a column removal scenario from Sadek et. al, (2011). From the previous testing and analysis conducted by Sadek et. al, the laboratories testing and the analysis with Finite Element analysis (FEA) were used. The feasibility study of Finite Element analysis (FEA) using finite beam element to approximate the behavior of the beam with web opening in this research will justify its result accuracy and hence the generality of FEA in practical analysis.

2.2 Finite Element

The Finite Element Analysis (FEA) is a very powerful and modern computational tool. This method has been used successfully to solve very complex structural engineering problems. "Numerical solutions to even very complicated stress problems can now be obtained regularly using FEA" (Roylance, 2001). FEA has also been widely used in other fields such as thermal analysis, fluid mechanics, and electromagnetic fields. Since the method involves a large number of computations, therefore it requires computer to solve a problem.

Finite Element Analysis (FEA) was first developed in 1943 by Courant, who utilized the Ritz method of numerical analysis and minimization of variational calculus to obtain approximate solutions to vibration systems. Shortly thereafter, a paper published to establish a broader definition of numerical analysis (Turner et. al, 1956). The paper centered on the 'stiffness and deflection of complex structures' (Swatantra et. al, 2011).

2.2.1 Finite Element Method of Analysis

Finite Element Analysis was accepted by industry soon after its introduction, for reasons by foregoing two applications. Finite Elements can represent structures of arbitrary complex geometry.

According to See, (2010), "Finite Element Analysis is a method for numerical solution of field problem requires that we determine the spatial distribution of one or more dependent variables. Thus we may seek the distribution of displacements and stresses of a beam or other type structural members. Mathematically, a field problem is described by differential equations or by integral expression. Either description may be used to formulate Finite Element (FE) formulations, in ready-to-use form."

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

2.2.2 Types of Finite Element Analysis

There are generally two types of analysis that are used in industry which are 2 Dimension (2-D) modeling and 3 Dimension (3-D) modeling. "2-D modeling keep simplicity and allows the analysis to be run on a relatively normal computer, it produced less accurate results while 3-D modeling produces more accurate results" (Faizul, 2009).

"Within each of these modeling schemes, the programmer can insert numerous algorithms (functions) which may make the system behave linearly or non-linearly" (Widas, 97). Linear systems are far less complex and generally do not take into account plastic deformation. Non-linear systems do account for plastic deformation, and many also are capable of testing a material all the way to fracture.

The feasibility study of Finite Element analysis (FEA) using surface element to approximate the behaviour of the beam with web opening in this research will justify its result accuracy and hence the generality of FEA in practical analysis.

2.3 Steel Structure

Structural steel can be defined as steel construction material, a profile, formed with a specific shape or cross section and certain standards of chemical composition and mechanical properties. Structural steel shape, size, composition, strength and storage are regulated in most industrialized countries.

In this study, steel beam and steel column are used to form the assemblies. The shape of structure used for beam and column is I-shape.

2.3.1 Steel I-Beam

I-Beams are widely used in the construction industry and are available in a variety of standard sizes.

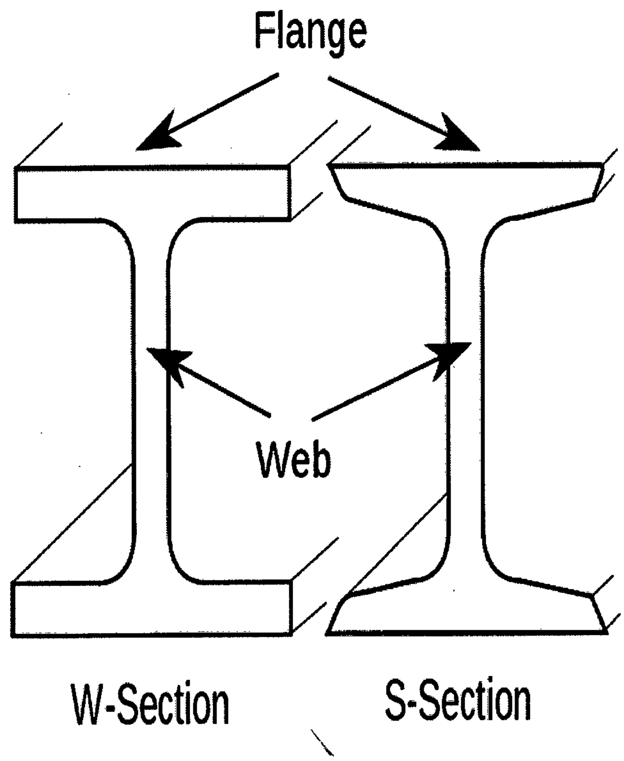

Figure 2.1: Typical Cross-Section of I-Beam

Structural steel members as well as I-beams, have high second moments of area, which allow them to be very stiff in respect to their cross-sectional area.

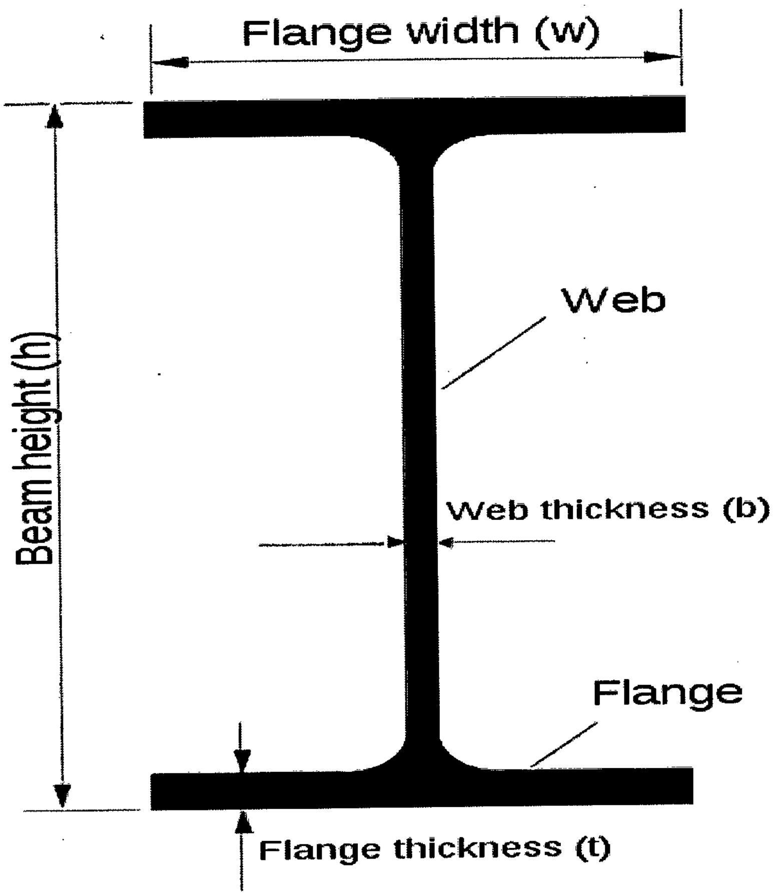

Figure 2.2: Section of Wide Flange I-Beam

The horizontal elements are flanges, while the vertical element is the web. The web resists shear forces while the flanges resist most of the bending moment experienced by the beam. Beam theory shows that the I-shape sections is a very efficient form for carrying both bending and shear loads in the plane of the web. On the other hand, the cross-section has a reduced capacity in the transverse direction, and is also inefficient in carrying torsion, for which hollow structural sections are often preferred.