PLASTIC ANALYSIS OF STEEL FRAME WITH RIGID AND SEMI RIGID CONNECTION

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To my beloved family and friends

To my respected supervisor

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ABSTRACT

Fully plastic condition is defined as one at which a sufficient number of plastic hinges are formed to transform the structure into a mechanism,then the structure is geometrically unstable. On the other hand the actual behavior of beam to column connections in steel frames is seldom fully rigid or fully pinned. But in actual, the connection is behaved most likely between these two conditions. The connection is called semi-rigid. This paper presents rigid and semi rigid steel frame under nonlinear plastic analysis. One of the important issues in the study of steel frames is to find the ultimate load due to lateral load and besides a suitable formulation for semi-rigid connections. This study is focused on plastic analysis of steel frame structure in three steps. Firstly, elastic analysis of rigid frame based on the stiffness method was developed using software called MATLAB to simulate the behaviour of steel frame under rigid connection. The most important thing in this step was to reach a fully plastic condition with increasing the applied load until yielding occure according to yield locus. Secondly plastic analysis of steel frame under rigid connection and then semi rigid connections considerations. From the result of this study, it is found that by increasing the applied lateral load in elastic step we can find the ultimate load to reach to plastic condition. This is based on yield locus diagram. In addition this study clearly shows the comparison of displacement between rigid and semi rigid connection.

ABSTRAK

Keadaan plastik sepenuhnya ditakrifkan sebagai salah satu keadaan di mana bilangan engsel plastik yang mencukupi dibentuk untuk mengubah struktur kepada mekanisme, dengan ini struktur geometri adalah tidak stabil. Sebaliknya kelakuan sebenar sambungan rasuk tiang dalam kerangka keluli adalah samada tegar sepenuhnya atau disemat sepenuhnya. Tetapi dalam keadaan sebenar kelakuan sambungan kemungkinan besar antara kedua-dua sambungan. Sambungan ini dipanggil separa tegar. Kertas kerja ini membentangkan kerangka keluli tegar dan separa tegar di bawah analisis plastic tak linear. Salah satu daripada isu penting dalam kajian kerangka keluli adalah untuk mencari beban muktamad kerangka keluli akibat beban sisi selain formulasi yang sesuai untuk sambungan separa tegar. Kajian ini memberi tumpuan kepada analisis plastik struktur kerangka keluli dalam tiga langkah. Pertama, analisis anjal kerangka tegar dijalangaa berdasarkan kaedah kekukuhan yang dibangunkan dengan menggunakan perisian yang dipanggil MATLAB untuk menganggar tingkah laku sambungan tegar. Perkara yang paling penting dalam langkah ini adalah untuk mencapai keadaan plastik sepenuhnya dengan peningkatan beban yang dikenakan sehingga menghasilkan alhan menggunakan lokus alah. Kedua analisis plastic kerangka kelulj dengan anggapan sambungan tegar dan sambungan separuh tegar dijalankan. Dari hasil kajian ini, didapati bahawa dengan meningkatkan beban sisi dalam tahap anjal kita boleh mencari beban muktamad untuk mencapai keadaan plastik. Ini adalah berdasarkan kepada gambarajah lokus alah. Di samping itu kajian ini jelas menunjukkan perbandingan anjakan antara sambungan tegar dan separa tegar.

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LIST OF SYMBOLS

A	-	Area of the section
I	-	Moment of inertia
L	-	Length
E	-	Modulus of elasticity
P	-	Vertical load
H	-	Horizontal load
Φ	-	Angle
k_e	-	Local linear elastic stiffness matrix
K_e	-	Global linear elastic stiffness matrix
T	-	Transformation matrix
K	-	The assembled stiffness matrix
U	-	Member displacement
F	-	Member force
k_m	-	Plastic reduction matrix
P_y	-	Squash load
M_y	-	Plastic moment
σ_y	-	Stress
G	-	Gradient
$C_{\theta j}$	-	Spring coefficient
$C_{\theta k}$	-	Spring coefficient
M_{if}	-	Flexural moment
M_{kf}	-	Flexural moment
ϕ_j	-	Rotation
ϕ_k	-	Rotation
R_j	-	Rigidity index
R_k	-	Rigidity index
ϕ_{jyr}	-	Rotal rotation
ϕ_{kyr}	-	Rotal rotation

K_{yr}^{t}	-	Stiffness matrix relating rigidity index
K_{s1}	-	Stiffness matrix of a semi-rigid column element
K_{s2}	-	Stiffness matrix of a semi-rigid beam element
Δ	-	Lateral displacement
α_r	-	Proportion coefficient
Ze	-	Elastic section modulus
T_e	-	Force in elastic stage
T_p	-	Force in plastic stage
M_e	-	Moment in elastic stage
M_p	-	Moment in plastic stage
Z_p	-	Plastic section modulus
ε_e	-	Elastic strain
ε_p	-	Plastic strain
$d\Delta_e$	-	Elastic displacement vector
$d\Delta_p$	-	Plastic displacement vector
$d\Delta$	-	Total displacement vector
$M - \theta$	-	Moment rotation

CHAPTER 1

INTRODUCTION

1.1 Introduction

The structural frame system mainly consist components of beams, columns and connections. Among these three components, the connection between beam to column play important role to the effect of load distribution, strength, stability and constructability of the structure. It also well known that the connections show a variation of behavior in term of strength and stiffness. Usually in conventional method of analysis, the connection behaves either as a pin transferring only nominal moment or they are function as a rigid and maintain full moment continuity.

The two common assumptions as to the behavior of a building frame are that its beams are free to rotate at their connections or that its members are so connected that the angles they make with each other do not change under load .

Generally, the frame analysis assumes that beam-to-column connections are rigid or pinned. Rigid connections, where no relative rotations occur between the connected members, transfer not only a significant amount of bending moments, but also shear and axial forces. On the other extreme, pinned connections are characterized by almost free rotation movement between the connected elements that prevent the bending moment transmission. Despite these facts, it is largely recognized that great majority of joints do not exhibit such idealized behavior. These connections are called semi-rigid, and their analysis should be performed according to their actual structural behavior.

In addition, in the simple plastic hinge method, the element stiffness matrix is modified to account for the presence of plastic hinges developed suddenly from an elastic state to a fully plastic state. After a hinge has formed in a member, the section id replaced by a real hinge with a constant moment, Mp, and the incremental equations are adjusted to reflect the change in the member stiffness. Thus, the simple plastic hinge method may over predict the real limit loads of steel frames due to neglecting the effect of partial yield in members. A modified stiffness method is proposed which can take into account the effect of partial plasticity in members. The limit loads and load-deflection responses can be predicted reasonably by the proposed method.

1.2 Problem Statement

Conventional or traditional analysis of frames basically based on assumption that the connections are either fully rigid or ideally pinned (simple connections). Fully rigid assumption makes it clear that no relative rotation of the connection occurs and the end moment of the beam is completely transfer to the adjacent column. On the other hand, pinned connection implies that no restraint for connection exists and the end moment at the connection is assumed zero (Chen *et al.*, 1996). However, the actual behavior of the connections used in current practice posseses some stiffness that fall between the two extreme cases of fully rigid and ideally pinned.

On the other hand, although there are numerous research reported about the method and advantages of semi-rigid connection, but there is still no orderly absorption by structural designer due to lack of confident about its behaviour, Burns (2002). According to Ahmed (1996), the semi-rigid nature of the connection effects the frame behavior in that the distribution of internal forces and moments in the beams and columns are different from those of the standardized curves. Needless to say, frame analysis neglecting the true behavior of the connection will result in unreliable prediction of frame response.

In addition, to compared with the static analysis, the research on plastic analysis of rigid and semi-rigid jointed frames is relatively limited. Although the analysis of frames has been the subject of research for several decades, it was not until recently that investigators started including the effects of the partial rigidity of connections in their analyses. This recent trend in analysis acknowledges the fact that most connections used in steel constructions are neither fully rigid nor completely flexible.

Besides a linear analysis is more prefer as compare to non linear analysis in structural design. This is because it can be simplify by design, time and cost saving, and at the same time it does not require the use of computer software for non linear case. Furthermore, a non linear analysis is more complicated than linear analysis in structural problem solving.

1.3 Objectives

The main objective of this study can be described as follow:

1. Reaching a fully plastic condition by increasing the applied load until yielding according to yield locus.
2. To find the first hinge according to ultimate load.
3. To study the plastic behavior of rigid connection.
4. The foremost objective of this research is to plastic analysis of semi-rigid frames.
5. To investigate the stiffness matrix of semi-rigid connection in 3 steps.

1.4 Research Scope

The behavior of frame structures is highly influenced by the connections. The analysis of such frames, whether elastic or plastic, can only be performed with accuracy if the correct joint behavior is incorporated in the analysis. A computer program (MATLAB) was developed to analyze frames by taking into account the effect of internal and external rotations of the connection based on the stiffness method analysis.

This study was limited to the use of linear analysis and non-linear analysis by considering different stiffnesses in each stage of analysis.

1.5 Significant of the Study

Typically, the behavior of semi-rigid connections relates to the performance on sub-assemblage frame of beam-to-column connection. In semi-continuous construction design, semi-rigid connection developed an end restrain leading to reduction on beam moment which resulted to lighter beam in many cases. The amount of restrain developed from the semi-rigid connections depends on the stiffness of the connection. The term stiffness in each connection nodes can be either modeled as pinned, rigid or semi-rigid case. This leads to the simplicity and effectiveness of the structural analysis.

The use of semi-rigid connections in building construction has reduced material usage leading to more effective and quicker construction. Studies conducted on semi-rigid connections have proven the savings in material usage while achieving required strength.

On the other hand, in the simple plastic hinge method, the element stiffness matrix is modified to account for the presence of plastic hinges developed suddenly from an elastic state to a fully plastic state.

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