NON-LINEAR BEHAVIOUR OF ONE-BAY STEEL FRAMES WITH SEMI-RIGID CONNECTIONS

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ABSTRACT

This project studies the static non-linear behaviour of plane steel frames with semi-rigid connections. To describe the non-linear behaviour of the semi-rigid connections, the three-parameter power $M\text{-}\phi_r$ model is used. ANSYS software package is used for the non-linear analysis of the frames. Finite element models that include geometrical, material and connection non-linearities are considered in this study. Material and geometrical non-linearities are modeled by a bilinear defined stress-strain curve and specifying large displacement for the analysis. The influence of connection fixity on the force transfer mechanism and stability behaviour of semi-rigid steel plane frame structural system under uniformly distributed vertical loads and lateral loads are investigated. It can be concluded from the results that the connection flexibility has significant influence on the behaviour of the frames. The connection flexibility contributes to significant increase in the point displacements and change in the distribution of internal forces in the system. The influence of the geometric non-linearity increases with the loads. The influence is higher when semi-rigid type of connections are used than in the case of fully rigid connections. It is also observed that the critical load carrying capacity of the system significantly decreases with the increase in the flexibility of joints.

ABSTRAK

Projek in mengkaji kelakuan statik bukan-linear bagi kerangka keluli bersambungan separuh tegar. Model Kuasa M-ϕ_r Tiga-Parameter model telah digunakan untuk menerangkan sifat bukan-linear bagi sambungan separuh tegar. Perisian ANSYS telah digunakan untuk analisis bukan-linear bagai kerangka. Model elemen terhad yang mengrangkumi geometri, bahan and sambungan yang bersifat bukan-linear telah dipertimbangkan dalam kajian ini. Bahan dan geometri bukan-linear dimodelkan dengan menggunakan lengkung tekanan-regangan dwi-linear dan menetapkan unjuran yang besar bagi tujuan analisis ini. Pengaruh kekuatan sambungan ke atas mekanisma daya dalaman and kestabilan kerangka dibawah pengaruh daya tegak and ufuk telah dikaji. Keputusan analisis memberi kesimpulan bahawa kebolehlenturan sambungan memberi kesan yang ketara ke atas kelakuan kerangka. Ia menyebabkan pertambahan unjuran titik and perubahan daya dalaman. Kesan geometri bukan-linear bertambah dengan daya kenaan. Kesan ini adalah lebih tinggi jika sambungan separuh-tegar digunakan berbanding dengan sambungan sepenuh-tegar. Permerhatian menunjukkan bahawa daya kritikal yang boleh ditanggung oleh kerangka berkurangan apabila kekuatan sambungan rasuk dan tiang bertambah.

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LIST OF SYMBOLS

H	-	Defined horizontal force
W	-	Defined vertical distributed forces
M	-	Bending moment
ϕ_r	-	Relative rotation of point at beam and column connection
R_{ki}	-	Initial connection stiffness
M_u	-	Ultimate moment capacity of connection
n	-	Shape parameter
IR	-	Interaction Ratio

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CHAPTER 1

INTRODUCTION

Steel frame system with beams and columns is the most conventional system in modern construction. In current practice of stability analysis of steel-framed building structures, the connections of beam and column are normally simplified as two idealized extremes of either fully-rigid behaviour or ideally-pinned behaviour.

In limit state design which warrants extensive studies on the response at ultimate loads, the beam-to-column connections stiffness play an important role of governing effect on the ultimate carrying capacity of a frame. The predicted response of the idealized structure may be quite unrealistic compared to that of the actual structure if connection stiffness is ignored in the analysis. Most connections used in current practice actually exhibit semi-rigid deformation behaviour that can contribute substantially to the stability of the structure or post-critical response as well as to the distribution of member force. Numerous experimental investigations on connection behaviour have clearly demonstrated that a pinned connection possesses certain amount of rotational stiffness, while a rigid connection possesses some degree of flexibility (D. A. Nethercot, T. Q. Li & B. Ahmad, 1998). Connections are mediums through which forces and moments from the beam are transferred to the column. A fully rigid connection implies that no relative rotation of the connection occurs and the end moment of the beam is completely transferred to the column. On the other hand, pinned connection implies no restraint for rotation of the connection exists and the connection moment is always zero. Neglecting realistic connection behaviour may lead to unrealistic predictions of the response and strength of structures. Therefore, extensive study had been carried out to classify beam-to-column connections in order to improve analysis accuracy of steel frames.

Beam-to-column connection fixities are normally classified into three categories as shown in Figure 1.1. The connection fixities are represented by the moment-rotation relation of a particular type of connection. Most experiments have shown that the M-ϕ_r curve is non-linear in the whole domain and for all types of connections. As a result, modeling of the nodal connection is vital for the design and accuracy in the frame structure analysis. There are several approaches on how to incorporate the flexibility of the nodal connections in the analysis. The most common and simplest is the linear model which will also be used in this study.

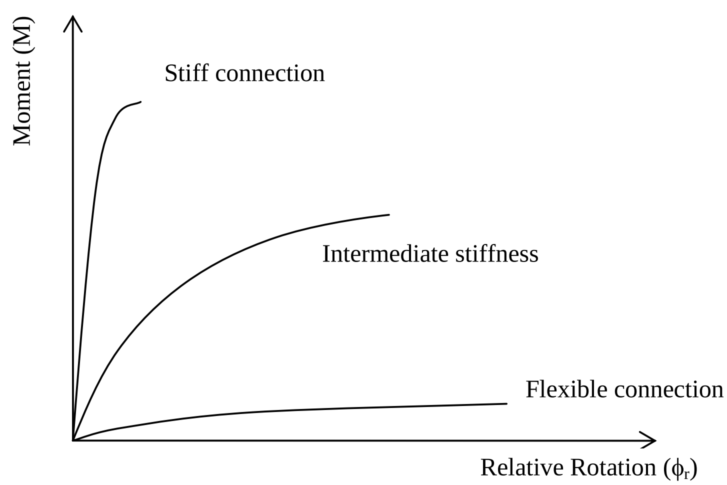

Figure 1.1 : M-θ_r Relationship

Apart from connection non-linearities, the effects of geometrical non-linearity and material non-linearity of the beams and columns are also of practical interest. Structural analysis that includes geometrical non-linearity is termed second-order analysis or P-delta (P-Δ) analysis. Geometrical non-linearities occur when members bend and the structure sways or deflects laterally under loading. The lateral displacement of the column results in second-order moment to the column which can be calculated from the applied load multiplied by the appropriate lateral displacement. As a result, the inclusion of second-order analysis will represent the appropriate behaviour of the frame.

With the advancement in computer technology, the non-linearity of material can be included with the appropriate material stress-strain curve. The material stress-strain relationship can be idealized as simple models of elastic, rigid-plastic and elastic-plastic. Compared to the linear stress-strain relationship in linear analysis, where the material never reaches its yield point, elastic-plastic model better represents the non-linear behaviour of structural system. In the elastic-plastic model, the material deforms elastically under increasing loads initially and when the yield stress is reached, the material becomes plastic. The stress remains constant with further increase in strain.

1.1 Objectives and Scope of Study

The objectives of this research are :

i. To present finite element analysis and analytical results for semi-rigid structural frames that include the material, geometry and connection non-linearities.

ii. To investigate the bending moment at the base of the frames at ultimate loads with fully fixed, semi-rigid and flexible beam-to-column connection.

iii. To demonstrate, through a series of analysis under different structural frame configurations, loads and semi-rigid joint conditions, the influence of the semi-rigid beam-to-column connections to the load carrying capacity and stability of the steel frames. This enables a better understanding of the force transfer mechanism within the structural system.

The scope of study for this research includes :

i. Non-linear behaviour of semi-rigid steel frame.
ii. Two-dimensional plane frame.
iii. The base supports of the frames are assumed to be fully restrained.

However, this research does not include the effects of eccentricity in the nodal connection of plane frames due to static loads.