DYNAMICRESPONSE PREDICTION OF STEEL FRAME STRUCTURE CONSIDERING SEMI-RIGID CONNECTION BY APPLYING DAMPER

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This project is dedicated to my lovely parents who have taken great point to see me prosper in life.

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ABSTRACT

In design stage, the conventional steel buildings are commonly using the methods of pinned design which means that the behavior of the connection is fully on the basis of pin and rigid design which means that the behavior of the connection is completely rigid. In contrast, the real behavior of joints are not fully rigid or fully pinned, therefore the discrepancy between these manners is called semi-rigid connection. Therefore, this study is lead to evaluate the semi-rigid connected frame under the dynamic loading by applying damper. The numerical method on the basis of stiffness matrix method, which is developed using in Matlab Program, is used to assess this condition that can be divided in the main five steps. Firstly, mass and stiffness matrixes of semi-rigid connection frame are obtained. Secondly, formulation of damping matrix is developed. Thirdly, solving the dynamic equation by central method. Fourthly, the changes of spring coefficient, natural frequency, damper frequency and damper ratio are considered. Finally, numerical method is verified by SAP 2000 modeling. In conclusion, by increasing the spring stiffness coefficient the lateral rigidity of frame increases. In the case of the constant section area of frame member, as the spring coefficient of semi-rigid increases while it reaches to rigid connection, the text increment of spring coefficient cannot improve rigidity of the frame. It means that there is no absolute rigid connection, and vice versa it is true for pinned connection. Other noticeable results are that, applying of damper and addition of damper ratio can dissipate vibration caused by dynamic loading in the shorter time and modify the amount of frame displacement at resonance frequency.

ABSTRAK

Pada peringkat reka bentuk, bangunan keluli konvensional biasanya menggunakan kaedah reka bentuk pin yang bermaksud bahawa kelakuan sambungan sepenuhnya adalah pin manakala reka bentuk tegar yang memberi maksud bahawa kelakuan sambungan adalah benar-benar tegar. Sebaliknya, tingkah laku sebenar sambungan adalah tidak tegar sepenuhnya atau pin sepenuhnya, oleh itu ia dipanggil sambungan separa tegar. Oleh itu kajian ini tertumpu kepada penilaian kerangka separa tegar yang berkaitan di bawah pembebanan dinamik dengan menggunakan peredam. Kaedah berangka berdasarkan kaedah matriks kekukuhan, yang diprogram menggunakan perision Matlab, digunakan untuk menilai keadaan ini yang boleh dibahagikan dalam lima langkah utama. Pertama,matrik jisim dan matrik kekukuhan separa tegar diperolehi. Kedua, pengiraan matrik redaman dilakukan. Ketiga, menyelesaikan persamaan dinamik dengan kaedah pusat. Keempat, perubahan pekali spring, kekerapan semula jadi, kekerapan peredam dan nisbah peredam akan dipertimbangkan. Akhir sekali, kaedah berangka disahkan melalui modelSAP 2000. Kesimpulannya, dengan meningkatkan pekali kekukuhan spring, ketegaran sisi kerangka bertambah. Dalam kes luas keratan lintang anggota kerangka adalah malar,dengan bertambah pekali spring separa tegar sehingga ia mencapai sambungan tegar, peningkatan pekali spring seterusnya tidak boleh meningkatkan ketegaran kerangka. Ia bermakna bahawa tidak ada sambungan tegar mutlak, dan ia juga berlaku untuk sambungan pin. Hasil lain yang ketara adalah penggunaan peredam dan penambahan nisbah peredam boleh melenyapkan getaran akibat daripada pembebanan dinamik dalam masa yang lebih singkat dan mengubah suai jumlah anjakan kerangka pada frekuensi resonan.

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θ_r	-	Rotation
A	-	Cross-Section Area
M	-	Bending Moment
K	-	Stiffness
r_j	-	Dynamic Stiffness
k_j	-	Stiffness Coefficient
C_i	-	Damping Coefficient
u	-	Displacement
[k]	-	Stiffness Matrix
[c]	-	Damping Matrix
[M]	-	Mass Matrix
X	-	Displacement
$\dot{X}$	-	Velocity
$\ddot{X}$	-	Acceleration
E	-	Yaoung's Modulus
I_b	-	Moment Inertia of Beam
I_c	-	Length of Beam
a_i	-	Stiffness index at point i
a_j	-	Stiffness index at point j
N	-	Shape Function
ω_n	-	Natural Frequency

ω_n	-	Damped Frequency
ω_e	-	In Case of Eccentric Connection
ω_c	-	In Case of Centric Connection
ω_A	-	Input Frequency
T	-	Period of Structure
ξ	-	Damper Ratio
C_θ	-	Spring Coefficient
R_j	-	Rigidity Index at Point j
R_i	-	Rigidity Index at Point i
jyr	-	Total rotation at Point j
kyr	-	Total rotation at Point k
jf	-	Rotation of Beam at Point j
kf	-	Rotation of Beam at Point k
j	-	Rotation of Semi-rigid Joint at End j
k	-	Rotation of Semi-rigid Joint at End k
β	-	Coefficient of Rotation
λ	-	Coefficient of Rotation
H	-	Height of Column
Δ	-	Displacement

CHAPTER 1

INTRODUCTION

1.1 General

Frame structures are usually used in the engineering designs i.e. cranes, bridges, aerospace structures, etc. Since the presence of different joints is key factors in either damping or magnifying the structural response, this study moves to analysis the joints of frames under applying dynamic loads. After passing several decades from structural industry, there is still problems in particular dynamic analysis of connections of steel frame structures. One the basis of assumptions in conventional structural analysis that joints are either perfectly rigid or perfectly hinged. However, typical connections are in actual structures do not behave in either a perfectly rigid or a perfectly hinged manner. The different types of connections commonly used, fill the entire flexibility spectrum from flexible hinge -like connections to rigid connections, which is called" semi-rigid" connections. The behavior of frame structure against static and dynamic loads are as significant factor in civil engineering applications. In fact, the real behavior of frames are obtained from the geometrical, damping, mass and connecting properties of existing structure, but in designing stage, supports and beam to beam connections in steel frame structures are assumed to be fully rigid. However, these connections are not actually fully rigid. The constitution of almost fully rigid connections is also impractical and economically unjustifiable in most cases. In reality, connections in steel frames are mostly semi-rigid, and consequently. The internal forces and bending moment diagrams constructed under the assumption of rigid or pinned joints contain considerable errors. Another noticeable point to achieve the most sufficient of connection is choosing the best method for analyzing steel frame structures. The nonlinear behavior of structural connections, which can be caused by dynamic loads, and the consequent effects on the structural response of steel frame structures have been recognized as being important factor. Several methods for modeling and analyzing flexibility frames have been proposed. However the majority of these studies have done on the basis of constantly increasing loads but, to know about the nonlinear behavior of structural joints this study is required to focus on dynamic loading conditions. Some noticeable dynamic analysis methods are included such as: finite element and stiffness method 1. The FEM has been used very commonly in recent years in this field .However using this method has some problems due to several degrees of freedom to solve this difficulty. Various methods have been proposed for overcoming these disadvantages; one of those studies is going to focus on, is Bounding-Line model 2. (DSM) and the finite element method (FEM). DSM is used to formulate the stiffness matrix under harmonic nodal excitation as shape functions. The method required the close-form solutions of governing equations and limitations applications area, in fact by applying some definitions .The conventional moment resistant steel frames are usually designed with weak beam and strong column.it means that the two end parts of weak beam are allowed to yield during an extreme earthquake disaster .However, it has learned from Northridge Earthquake in the USA 1994 and the Hyogoken-Nanbu Earthquake in Japan 1995 that the extraordinary large plastic strain induced in the beam and parts is the key reason to result in the collapse of conventional moment resistant steel frames at the connection between beam and column.

Behavior of steel frames under earthquake excitations generally is nonlinear. Only for a low-intensity excitation, behavior may be linear. Primary sources of nonlinearity are connection behavior, material yielding and geometrical nonlinearity of the structure and its members. Two types of nonlinear analysis are applied, conventional direct structural response analysis and energy response analysis. They are in correlation as two complementary and comparable approaches. In recent years, energy approach has gained great attention used for identifying where and how the energy is dissipated within the structural system. Moreover, a part of the external (input) energy dissipated through hysteretic inelastic behavior is directly related to damage of the structure, thus the energy approach may be rational and reliable way to estimate damage that can be used as a design parameter. On the other hand, connection hysteretic energy, like friction, may even be present since joints of real structures are always more or less flexible. For the first order linear elastic analysis used by many engineers the deflection is proportional to the applied load and the structural stiffness and stress are not affected by small changes in geometry and the presence of initial stresses. In spite of so many criticisms against a linear analysis, it is the most widely used method in practice and it has been used by the engineer for the design of the overwhelming majority of structures in human history. The method has the advantages of being easy to understand simplicity in computation and concept and saving in computational effort. The widely accepted principle of superimposition can also be applied in a linear analysis such that the response of the structure is equal to the sum of all the effects due to different load cases. Linear analysis is also particularly welcomed by the profession because of its simplicity. To date, most engineers still prefer a linear analysis for determination of stresses and deformations in a structure. Another importance connected with linear analysis is the fact that the concept of a nonlinear analysis cannot be dealt with without a thorough understanding of the method for linear analysis. Indeed, most non-linear analyses are carried out by a series of linearized analyses.

Some improvement methods for the conventional moment resistant steel frames, such as, using semi-rigid connection joint at beam ends, shifting the yielding part from the welds at beam ends to the inside of the beam, have been proposed . Retrofitting of structures against lateral loads due to earthquake and wind is the main aim of the designers and structural engineers that are done by the different methods and systems, including moment frames systems, frame with steel bracing and concrete shear walls. In engineering aspects, the knowledge of geometry, mass of a structure and its beam-to-column connection model brings civil and structural engineers to simulate the real behavior under service loads. Additionally, to attach supplementary energy dissipation devices to the steel frame are one of the most effective methods to reduce the damage of moment resistant steel frames. The supplementary energy dissipation devices help the steel frame to absorb/dissipate a great amount of earthquake impute energy and protect the beam end parts from large plastic yielding or collapse.

1.2 Problem Statement

Dynamic analysis of semi-rigid jointed frames is relatively limited in comparison with static analysis, especially while in case of applying damper in semi-rigid connection. Conventionally, semi-rigidly connected frames are considered to be in appropriate for dynamic design purposes mainly due to their excessive flexibility, while the. Their advantages, in terms of lower costs and simple fabrication. On the other hand, reliance on the rigidity of fully –welded connections under dynamic loading has come under question, due to the fact that the structures are required to swing under dynamic loads.

This problem can be solved by usage of brace or shear wall in semi-rigid frames, but in some cases which architecture limitations do not allow usage of these options. Therefore, this study focuses on applying damper to modify the semi-rigid connection response under dynamic loads.

1.3 Objective of Study

The specific objectives of this study are as follows:

1. To assess of the structures' dynamical behavior due to the presence of beam-to-column semi-rigid joints.

2. To study the response of semi-rigid connected frame, aspect of displacement under the dynamic loading by applying damper in the joint.

1.4 Scope of Study

The scope of the research is listed below:

1. An assessment the linear behavior of the different connections, by stiffness matrix method with this assumption that rotational spring that works as semi-rigid exactly located at beam to column connected point under the lateral dynamic loading.

2. An Investigation of the effect of viscous damper, which is rubbery and located at semi-rigid connection, Figure 1.1 in relation to the displacement of semi-rigid connection by elastic analysis.

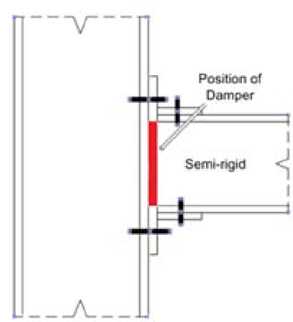

Figure 1.1: Position of damper

1.5 Significant of Study

At first, this study that can help to better understanding of basic definition of different joint to distinguish rigid ,semi-rigid and pined connections. By using stiffness matrix method to analyses the steel frame structure with semi-rigid connection without damper and also in same case with rotational damper, which is as an agent to dissipate the energy loading, earthquake ,as dynamic load under, this study is going to set some achievements. As far as, the joints have great responsibility to transfer loads from beam to column. Understanding the real behavior of connection included, pinned, semi-rigid and rigid connections, and evaluation the effect of usage damper in dissipation dynamic loading and displacement reduction of structure.

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