STABILITY OF A SIX STOREY STEEL FRAME STRUCTURE

SHAMSHINAR BINTI SALEHUDDIN

A dissertation submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Civil - Structure)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

MAY, 2011

To my beloved husband, family, lecturers and friends

ACKNOWLEDGEMENT

In the process of preparing and completing this report, I was in contact either directly or indirectly with many people, academicians and wholesaler. They have contributed towards my understanding and thought.

In particular, I wish to express my greatest appreciation to my supervisor, Assoc. Prof. Dr. Suhaimi Abu Bakar for his encouragement, guidance, critics, and motivations. Without his continued support and interest, this report would have been the same as presented here.

At the same moment, I am grateful to all my family members for their support and encouragement. My sincere appreciations also to my beloved husband, Mohd Faisal bin Mohd Azlan and my father in law, Dr. Mohd Azlan bin Yahya who have provided assistance and useful tips indeed. Finally, special thank dedicated to Universiti Malaysia Perlis and Ministry of Higher Education for giving opportunity to sponsor my master and those who directly or indirectly involve in the process of producing this study.

I hope my findings in this study will expand the knowledge in this field and contribute to all of us in future.

ABSTRACT

The world nowadays requires more tall buildings to overcome limited land space and creating high esthetic value. However, these high rise buildings require high frame structure stability for safety and design purposes. This research focused on non linear geometric analysis to be compared to previous studies on linear analysis. The linear analysis did not consider deformed configuration which can be considered as least accurate. On top of this, several designers did not incorporate the wind load which could lead to sway effect to tall buildings. In this study, a six storey 2-D steel frame structure with twenty four meter height has been selected to be idealized as tall building model. The model was analyzed by using SAP2000 structural analysis software with the consideration of geometric non linear effect. At the same time, several factors including the use of bracing, varying distributed loads on beam's element and an increased in column size at bottom part of the building were also applied to study the sway and stability of the building. In addition, several cases including placing a fully bracing, bracing at half height of the building and alternate bracing were also studied. This study showed that a steel frame with the consideration of wind load produce greater sway value as compared to the steel frame without wind load. The sway prediction by using linear analysis was found to be less than 4% compared to the sway prediction from non linear analysis. This indicates that the non linear analysis is vital and significant element to be adopted for the analysis of tall building. The study also found that the use of bracing system results in small sway values compared to the frame without bracing system. As for consideration to costing aspect, the use of alternate bracing provide better option compared to half bracing in terms of stability of the building. The analysis results also showed that the adjustment of distributed load at upper part of steel frame structure able to provide different sway values, creating higher stiffness at lower part of the building which reduces the sway values and increases the stability of the building. SAP2000 software is found as reliable tool in evaluating structural analysis especially when involving non linear analysis.

ABSTRAK

Pada masa sekarang, dunia memerlukan lebih bangunan tinggi untuk mengatasi masalah kekurangan ruang tanah dan untuk mencipta nilai estetika yang tinggi. Walaubagaimanapun, bangunan tinggi ini memerlukan lebih kestabilan dalam struktur kerangka untuk tujuan keselamatan dan rekabentuk. Kajian ini menumpu lebih kepada analisis geometrik tak linear kerana kajian sebelumnya lebih kepada analisis linear. Analisis linear tidak mengambil kira perubahan bentuk yang boleh di anggap kurang tepat. Selain daripada itu, ramai jurutera kadang kala tidak mengendahkan beban angin yang juga boleh menyumbang kesan huyung kepada bangunan tinggi. Dalam kajian ini,enam tingkat struktur kerangka keluli 2-D setinggi dua puluh empat meter dipilih sebagai bahan kajian untuk bangunan tinggi. Model ini telah dianalisis menggunakan perisian SAP2000 dengan mengambil kira analisis geometrik tak linear. Pada masa yang sama, beberapa pendekatan dilakukan seperti meletak perembat, mempelbagai beban teragih seragam di atas rasuk dan menambah saiz tiang di bahagian bawah di aplikasi untuk mengkaji huyung atau kestabilan bangunan. Tambahan lagi, beberapa kes seperti meletak keseluruhan kerangka dengan perembat, hanya separuh di bahagian atas dan berselang seli juga dikaji. Jelas menunjukkan bahawa kerangka keluli dengan beban angin memberi lebih tinggi nilai huyung dari kerangka keluli tanpa beban angin. Ramalan huyung menggunakan analisis linear didapati kurang melebihi 4% dari ramalan huyung oleh analisis tak linear. Ini menunjukkan analisis tak linear adalah keperluan dan penting digunakan untuk menganalisis bangunan tinggi. Sistem kerangka berperembat memberi nilai huyung yang lebih kecil berbanding sistem kerangka tanpa berperembat. Dari aspek kos pembinaan, pilihan antara hanya separuh perembat di bahagian atas dan berselang seli menunjukkan kerangka berselang seli adalah lebih baik untuk meningkatkan kestabilan bangunan. Keputusan analisis jelas menunjukkan ubahsuai beban teragih seragam di atas rasuk di bahagian atas bangunan boleh memberi nilai huyung yang sedikit. Tambahan lagi, meningkatkan kekukuhan bangunan pada bahagian bawah juga boleh mengurangkan nilai huyung dan meningkatkan kestabilan bangunan. Perisian SAP2000 didapati adalah alat yang boleh digunakan untuk menganalisis struktur terutama yang melibatkan analisis non linear.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

NOTATIONS

P	- Axial load
$P - delta$	- Non linear effect
A	- Area
I	- Moment of inertia
Φ	- Angle
$2D$	- Two dimensional
BS	- British Standard
V	- Wind speed
V_s	- Design wind speed
S_1	- Topography factor
S_2	- Ground roughness, building size and height above ground
S_3	- Exposure to wind
q	- Dynamic pressure of wind
k	- Wind coefficient
W_k	- Wind load
C_f	- Force coefficient
k_e	- Linear elastic stiffness matrix
k_g	- Geometric stiffness matrix
Γ	- Diagonal matrix

K_e	- Global linear elastic stiffness matrix
T	- Transform
u	- Member displacement for local
v	- Member displacement for global
Q	- Member force
E	- Modulus of elasticity
W	- Distributed load
L	- Length
$U1$	- Displacement value in X direction
$U2$	- Displacement value in Y direction
$U3$	- Displacement value in Z direction
$R1$	- Rotation value in X direction
$R2$	- Rotation value in Y direction
$R3$	- Rotation value in Z direction

CHAPTER 1

INTRODUCTION

There are several types of structure in this modern world. Most of the structures behaves like linear elastic under a service loads. Slender structures such as suspension systems, arches and tall buildings can be considered as non linear elastic. In general, buildings having 30 to 50 stories can be classified as tall buildings. While, for buildings with 50 stories or more can be considered as super tall buildings.

Tall building is the most structure that requires stability because it consist a lot of frame structure with different width and height. Building will be unstable if inadequate of lateral support and may resulted to collapse. Buildings and structures are considered stable with lateral supports by using either bracing system or shear system or both such as wall to ensure the stability of the building. Moreover, the important thing to consider are the software to be used to analysis the tall building structure and a wind speed at construction area to avoid any problem in future.

1.1 Statement of Problems

There are several problems that require scientific explanation in this study:

1. 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. Therefore it is important to understand the difference between both non linear and linear analysis and able to justify the application of these approach. At the same time the verification of the software is necessary to identify the reliability of the tool.
2. The wind speed in Malaysia is less than 35 km/h at 10 m height refer to Malaysia Standard. Eventhough the wind speed is small, it can still give adverse effect to the tall building. Therefore, the identification of suitable wind speed is important to ensure the stability of the steel frame.
3. Client or project initiator always focuses on capital cost and not the quality of the building construction. Intergration of additional structure such as bracing may increase the operation cost but at the same time it will improve the sway and crack and therefore increase the life time of the building. Hence, it is important to identify the requirement and the positioning of the braces in steel frame structure.

1.2 Objectives of Study

The objectives of this study are:

1. To analyze the steel frame structure subjected to wind and without wind load by using linear and geometric non linear analysis and to observe the effect.
2. To compare the difference of lateral displacement or sway values between linear and geometric non linear analysis prediction.
3. To observe if there is an alternative approach to decrease sway for steel frame that being idealized as tall building.
4. To verify whether SAP2000 software is reliable tool for the evaluation of tall building structure.

1.3 Scope of the Study

The scope of works in this research includes:

1. A six storey building which made up of steel material and was analyzed by using SAP2000 software for linear and geometric non linear analysis.
2. The atmospheric wind speeds which will be use to study the wind behavior. The evaluation will be based on data from Malaysia Standard and wind calculation by using CP3, Chapter V (Part 2).

1.4 Significance of the Study

This study can be used as a reference to other researchers and designers to explore the stability in frame structure and design application. It can also provide a good design, more stable and longer last tall building which able to provide better service to consumers.

REFERENCES

[1] Daniel L. Schodek (2004). *Structures*, Fifth Edition, Pearson Prentice Hall, page 15 -21.

[2] Mc Guire, W., Gallagher, R.H. and Ziemian, R.D. (2000). *Matrix Structural Analysis Second Edition*, John Wiley & Sons Publication, page 217-218.

[3] Robert D. Cook, David S. Malkus, Michael E. Plesha and Robert J. Witt (2002). *Concepts and Applications of Finite Element Analysis*, John Wiley & Sons Publication.

[4] E.S. Kameshki, M.P. Saka (2003). *Genetic Algorithm based Optimum Design of Nonlinear Planar Steel Frames with Various Semi – Rigid Connections*, Journal of Construction Steel Research, Volume 59.

[5] El Zanaty, M. H and Murray, D.W (1983). *Nonlinear Finite Element Analysis of Steel Frames*, Journal of Structural Engineering, Volume 109, No. 1 - 4.

[6] Hingginbotham , A.B. and Hanson (1976). *Axial Behaviour of Steel Members*, Journal of the Structural Engineering Division, ASCE, Volume 106.

[7] Emil Simiu and Robert H. Scanlan (1996). *Wind Effects on Structures*, 1996, John Wiley & Sons Publication.

[8] Seshasayee Ankireddi and Henry T. Y. Yang (1996). *Simple ATMD Control Methodology for Tall Buildings Subject to Wind Load*, Journal of Structural Engineering, Volume 122, No. 1 - 3.

[9] British Standard (1972), CP3 Chapter V (Part 2). *Wind Loads*, London.

[10] Yi Kwei Wen (1983). *Wind Direction and Structural Reliability*, Journal of Structural Engineering, Volume 109, No. 1 - 4.

[11] K. C. Mehta, J. E. Minor and T. A. Reinhold (1983). *Wind Speed Damage Correlation in Hurricane Frederic*, Journal of Structural Engineering, Volume 109, No. 1 - 4.

[12] W F Chen (1999). *Practical Analysis for Semi-Rigid Frame Design*, World Scientific Publishing Co. Pte. Ltd. Singapore, page 2.

[13] M. Farshad (1994). *Stability of Structures*, Elsevier Science B.V, page 2.

[14] Malaysia Standard (2002). *Code of Practice on Wind Loading for Building Structure*, Malaysia.