Seismic Response Prediction Of Steel Frame Building

Wai Mie Kyaw
Zaw Minn Htun

Abstract

As structure can deform inelastically, when subjected to severe earthquake, seismic response prediction of structures are conducted considering post-elastic behavior. In this study, computer aided analysis of eighteen storied steel frame building is carried out for static and dynamic (Response Spectrum) approach by using ETABS (Extended Three dimensional Analysis of Building System) software. This proposed building is regular shape and located in seismic zone 4.Seismic forces are essentially considered in the design of this design and shear wall are also considered to resist seismic forces. The analysis of building considered in elastic linear analysis. Design of structural elements is calculated by using provision of American Concrete Institute (ACI318-05), Load and Resistance Factor Design (AISC-LRFD) code and load consideration is base on UBC-97. Firstly, the proposed building is analyzed with static approach. Secondly, dynamic (response spectrum) approaches is utilized for horizontal earthquake. Finally, comparison of the analysis results such as displacement and base shear at various levels of building are presented. Response Spectrum curves is considered with different time periods and acceleration. In response spectrum analysis, the displacements of four cases are not quite different in X and Y direction, but displacement in Y-direction for Case-2 is 1.2 times greater than Case-1.Base shear comparison for Case-1and Case-2 are less than Case-3 and Case-4 in both directions..From response spectrum curve, maximum acceleration is 1.6 times greater than minimum acceleration for different time periods.

Keywords: ETABS, AISC-LRFD, ACI318-05, UBC-97 Response-Spectrum Analysis,

1. Introduction

HIGH-RISE buildings are closely related to the city, they are a natural response to dense population concentration, scarcity of land, and high land cost. Our country, Myanmar is a developing country; so many residential and other public buildings are needed for social, ecological, economical and public demands. The structural elements of the building are subjected to gravitational forces, meteorological loads, seismological force and other man made forces. Therefore the structural elements must be designed to resistance. In addition, the structural engineer should be able to analyze three basic aspects of structural behavior

1) Stress, strain and deflection characteristics under static loading condition.
2) Response and vibration characteristics under dynamic loading condition.
3) Bulking characteristics usually under static loading condition but occasionally under dynamic loading condition.

In this study, response spectrum analysis under dynamic loading is considered. Nowadays, the multistory buildings are widely used in Myanmar. Myanmar is located on the Alpide Earthquake Belt. Therefore, in this study the hypothetical steel building is designed to withstand the lateral force due to earthquake by using ETABS software.

2. Behavior of Earthquake and Wind

Earthquake consists of random horizontal and vertical movements of the earth's surface. The earthquake response depends strongly on geometric properties of a structure, especially height. The taller a structure, the more susceptible it is to the effects of higher mode of vibration, and tends to have the greatest influence on the upper stories.

A. Earthquake-resistant Design

The purpose of earthquake provision is to safeguard against major structural failures and loss of life, not to limit damage or maintain function. The general philosophy of earthquake resistant design for buildings is based on the principles that they should-

1) resist minor earthquake without damage
2) resist moderate earthquake without structural damage but accepting the probability of nonstructural damage
3) resist average earthquake with the probability of structural as well as nonstructural damage, but without collapse.

B. Philosophy of wind design

Every building or structure shall be designed and constructed to resist wind effects determined in accordance with the requirements of wind design. Wind shall be assumed to come from any horizontal direction. No reduction in wind pressure shall be taken for the shielding effect of adjacent structures. Wind resisting design of the building is designed according to UBC 97.

3. Aims and Objectives

This study aims to identify damage venerability of structures and to determine an acceptable level of safety. The following objectives serve as the guidelines for research:

1) To study elastic linear behavior of building under design earthquake
2) To assess how these linear response of steel frame building
3) To propose values to estimate the maximum lateral displacement for severe earthquake
4) To study the capacities of the existing frame building depending on response spectrum analysis cases
5) To develop seismic evaluation for selected earth-quake resistant frame building

4. Preparation for Design of Superstructure

A. Modeling

The proposed steel superstructure is designed as Special Moment Resisting Frame and based on UBC - 1997. The building is eighteen–storey steel frames building and is analyzed with ETABS software.

- 11 ft height for storey one
- 12 ft height for each storey

Maximum length	=	108 ft
Maximum width	=	56 ft
Overall height	=	222 ft
Shape of Building	=	Rectangular
Location	=	Zone-4

There are two lifts and one stair in this building. Wide flange steel section will be used.

B. Determination of Loading Consideration

1) Dead Load

- Unit weight of concrete	=	150 pcf
- 41/2 inches thick brick wall weight	=	55 psf
- 9 inches thick brick wall weight	=	100 psf
- partition weight	=	35 psf
- weight of glass area	=	30 psf
- weight of lift	=	3 tons
- weight of ceiling	=	25 psf

2) Live Load

- Live load on residential	=	40 psf
- Live load on public areas	=	100 psf
- Live load on stair case	=	100 psf
- Live load on lift	=	100 psf

3) Wind Load

- Overall height of building	=	222 ft
- Exposure type	=	Type C
- Basic wind velocity	=	80 mph
- Windward coefficient	=	0.8
- Leeward coefficient	=	0.5
- Importance factor	=	1.0
- Gust factor	=	1.1

4) Earthquake Load

- Seismic Zone	=	4
- Seismic Source Type	=	B
- Soil Type	=	S_D
- Structure = Special Moment Resistig Frame		
- Zone Factor	=	0.4
- Seismic Response Coefficient, Ca	=	0.44
- Seismic Response Coefficient, Cv	=	0.64
- Importance Factor, I	=	1.0
- Response Modification Factor, R	=	8.5
- Near Source Factor, Na	=	1.0
- Near Source Factor, Nv	=	1.0
- C_T value	=	0.035

C. Material Properties

Analysis property data

- Modulus of elasticity for steel	=	29×10^6 psi
- Poisson's ratio	=	0.3
- Coefficient of thermal expansion	=	6.5×10^{-6}

Design Property data

- Minimum yield stress, Fy	=	50 ksi
- Minimum tensile stress, Fu	=	65 ksi

D. Determination of Loading Combination

Design is the process of determining the size and the arrangement of structural members to withstand the various load combinations. To perform the design, the response of structure to various load combinations must be first known. The analysis procedure is in dynamic approach. There are 40 numbers of loading combination.

5. Methodology

Author has studied back ground theory and design of structural framing system. Eighteen-story steel frame building has been chosen as description of case study. Then eighteen-story steel frame building has been analysed by using static analysis so as to obtain the gravity load. Finally, the building has also been analysed by using dynamic analysis (response spectrum analysis) in linear condition. Comparison of the analysis results such as displacement, drifts and base shear at various levels of building are received from the response spectrum analysis results. By using different time periods(10sec,2.5 sec,2sec,1.4sec),four types of response spectrum curve are received with different acceleration.

6. Results and Discussions

A. Comparison of Displacement for Different Response-Spectrum Cases(X-direction)

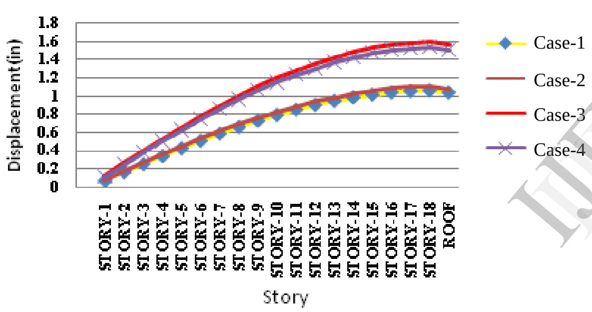

Figure. 1 Comparison of Displacement for Different Response-Spectrum Cases(X-direction)

In this comparison displacement are nearly same in different response spectrum cases.

B. Comparison of Displacement for Different Response-Spectrum Cases(Y-direction)

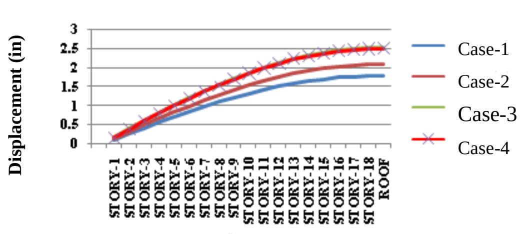

Figure. 2 Comparison of Displacement for Different Response-Spectrum Cases(Y-direction)

In this comparison of displacement for response spectrum analysis Case-2 is 1.2 times of Case-1, Case-3 and Case-4 are coincide.

C. Comparison of Base Shear for Different Response-Spectrum Cases(X-direction)

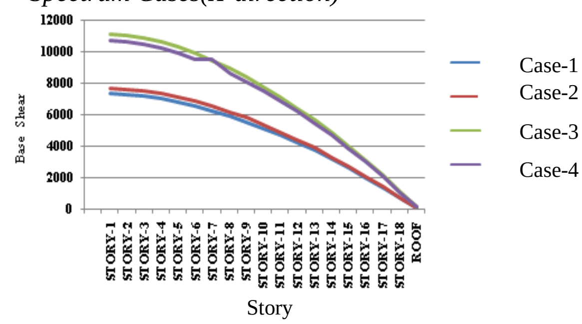

Figure. 3 Comparison of Base Shear for Different Response-Spectrum Cases(X-direction)

Base shear comparison of Case-1 andCase-2, Case-3 and Case-4 are approximately equal.

D. Comparison of Base Shear for Different Response-Spectrum Cases(Y-direction)

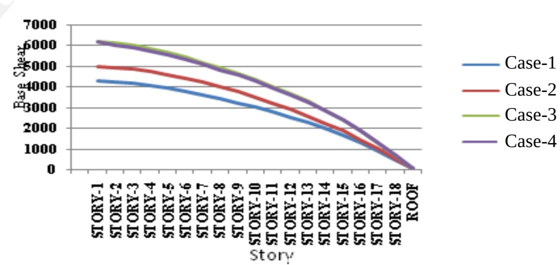

Figure. 4 Comparison of Base Shear for Different Response-Spectrum Cases(Y-direction)

Comparison of base shear in response spectrum analysis for Case-2 is slightly greater than Case-1, Case-3 and Case-4 are coinciding.

E. Response-Spectrum Curve for Maximum Time Periods (10 seconds)

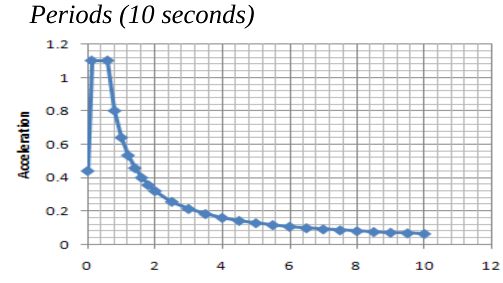

Figure. 5 Response-Spectrum Curve for Maximum Time Periods (10 seconds)

This curve describes the various accelerations for maximum time periods 10 seconds.

F. Response-Spectrum Curve for Maximum Time Periods (2.5 seconds)

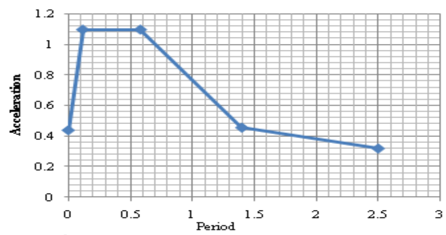

Figure. 6 Response-Spectrum Curve for Maximum Time Periods (2.5 seconds)

Changing of acceleration depend on maximum time periods 2.5 seconds are shown in above curve.

G. Response-Spectrum Curve for Maximum Time Periods (2 seconds)

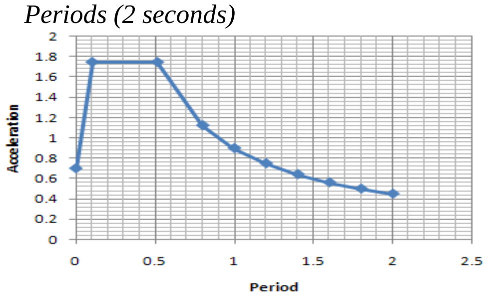

Figure. 7 Response-Spectrum Curve for Maximum Time Periods (2 seconds)

Response spectrum curve for time periods 2 seconds are present in this figure.

H. Response-Spectrum Curve for Maximum Time Periods (1.4 seconds)

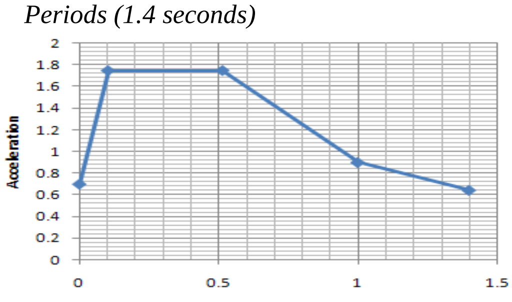

Figure. 8 Response-Spectrum Curve for Maximum Time Periods (1.4 seconds)

Maximum time periods 1.4 seconds and changes points of acceleration are showing in this curve.

I. Design Results for Steel Structure

For column section, W 12× 96 is used at story 1 to story 5, W12 × 58 is used at story 6 to story 10 and W 12 × 53 is used at story 11to story 18. For beam section, typical for 18 × 50 and W16x26, roof beam is W10 × 33.

7. Conclusion

In this study, twenty-one storied reinforced concrete building with rectangular shape was selected. The building is analyzed for both static and dynamic approach. This structure is located in seismic zone 4. Dead load and live load were considered based on ACI 318-05 and AISC-LRFD design. Earthquake load and wind forces were considered base on UBC-97. In this thesis, base shear and displacement for response spectrum analysis with different case for X and Y directions are compared. Maximum displacement for Y- direction is 1.5 times greater than X-direction because of response spectrum analysis is base on UBC-97 lateral force procedure. Comparison of base shear in response spectrum analysis for different cases is also considered. In these cases, base shear in X-direction is 1.2 times greater than Y-direction. Next, response spectrum curve for different time periods are also discussed. Acceleration in different time periods are gradually decreased after long time because acceleration is usually negative, as it causes a gradual slowing.

APPENDIX

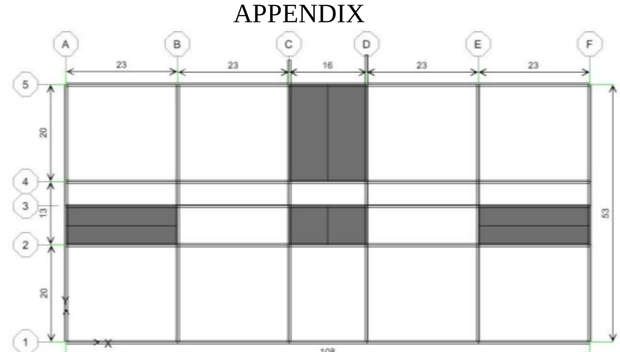

Figure. 9 Typical floor plan

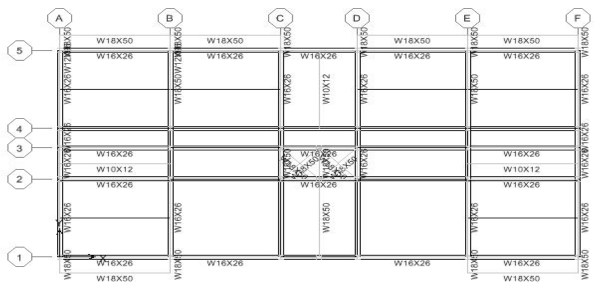

Figure. 10 Typical beam plan

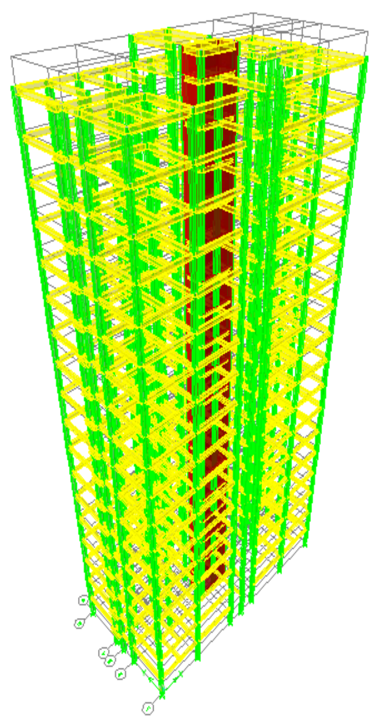

Figure. 11 3D-view of rectangular shape steel structure

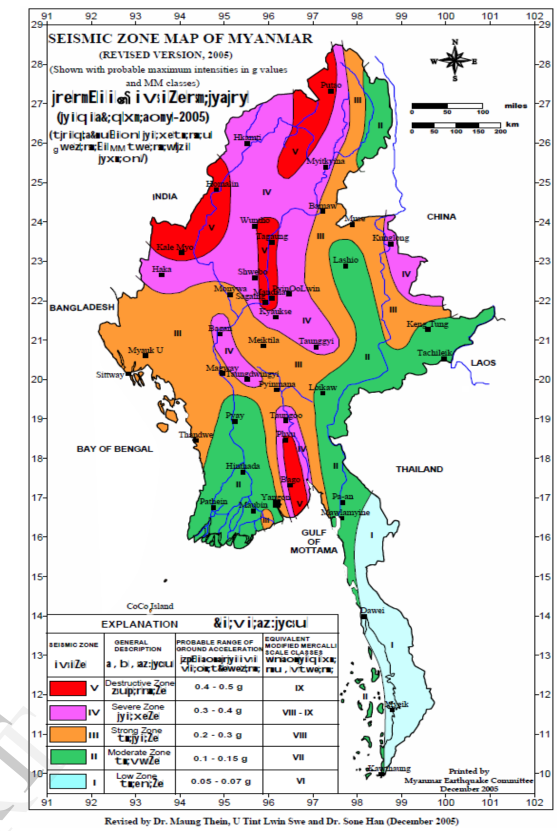

Figure. 12 Seismic Zone Maps of Myanmar

8. Acknowledgements

The author is very thankful to Dr Mya Mya Oo, Rector, Mandalay Technological University, for her invaluable permission and kind support in carrying out this research work. The author would like to express her gratitude to Dr. Kyaw Moe Aung, Associate Professor and Head, Department of Civil Engineering, Mandalay Technological University, for his kind help and in valuable advice. The author is deeply indebted to her supervisor Dr, Zaw Minn Htun, Associate Professor, Mandalay Technological University, for his accomplished supervision, encouragement, enthusiastic instructions, invaluable help, and in dispensable guidance and editing this thesis. Finally, the author specially thanks to all my teachers and my family, especially my parents, for their supports and encouragement to attain my destination without any trouble.

REFERENCES

[1] Charles G. Salmon, John E.Johnson, Steel structures (Design andBehavior). 3rd ed.
[2] Edwin H. Gaylord Jr, Charles N. Gaylord. James E. Stallmeyer, 1992.Design of steel Structures. 3rd ed. Mc Graw Hill Co. Inc.
[3] Mario Paz, 1980, "Structural Dynamic", 2^{nd} Edition.
[4] Michael R. Lindeburg and Majid Baradar,2001, Seismic Design of Building Structure, Eighth Edition.
[5] Uniform Building Code, Volume 2. Structural Engineering Design Provisons. 1997, 8th ed. International Conference of Building Officals
[6] Bungale S. Taranath, "Steel, Concrete and Composite Design of Tall Building," 2nd Edition. Mc Graw Hill Co. Inc.
[7] Charles K. Erdey. 2007, Earthquake Engineering Application to Design.
[8] Chopra, A.K. 1995, Dynamic of Structure
[9] Taranth, Bungale S. 1998. Structural Analysis and Design of Tall Buildings. Singapore: McGraw-Hill Companies, Inc.