STATIC & TIME HISTORY ANALYSIS OF RCC STRUCTURE: A COMPARATIVE STUDY

S. A. Haque[1], T. Haque[2*], S. Sanjida[1] & Y. Masud[1]

[1]*Department of Civil Engineering, Ahsanullah University of Science & Technology, Dhaka, Bangladesh*
[2]*Department of Water Resources Engineering, Bangladesh University of Engineering and Technology, Dhaka,Bangladesh*
[*]*Corresponding Author: tamanna.haque.himi@gmail.com*

ABSTRACT
This paper reports on the response of RCC structures over time due to Static and Dynamic loading. Here structures with different span lengths are modeled. Three different cases based on span lengths are considered (Case-01: Length/Breadth (L/B) ratio 0.60, Case-02: L/B ratio 0.80 and Case-03: L/B ratio 0.95). These structures are designed within reasonable drift limits and analyzed for probability of occurrence of the most unfavorable effect resulting from the combination of different loads. The effect of same loading on different span lengths are compared with each other. The effects of four Earthquakes of different magnitudes: Imperial Valley 1940 (Magnitude-6.95), Imperial Valley 06 (6.53), Imperial Valley 07 (5.01) and Imperial Valley 08 (5.62) – on the same structure are determined by Time History Analysis and results are compared with each other. This paper highlights on the variations observed in Column Bending Moment, Column Shear Force and Joint Displacements due to Static and Time history analysis. From the analysis, it is found that Maximum Moment for dynamic analysis is 245% of the Maximum Static Moment, Maximum Shear for dynamic analysis is 167% of the Maximum Static Shear and Maximum Joint Displacement for dynamic analysis is 255% of the Maximum Static Joint Displacement.

Keywords: Static Analysis; time history analysis; column bending moment; column shear force; joint displacement

INTRODUCTION

Earthquake forces are random in nature and unpredictable, the engineering tools need to be sharpened for analyzing structures under the action of these forces. Earthquake loads are required to be carefully modeled so as to assess the real behavior of structure with a clear understanding that damage is expected but it should be regulated. Various simplified nonlinear analysis procedures and approximate methods to estimate maximum inelastic displacement demand of structures are proposed in the literature. Within this framework, two analysis tools are currently offered with different levels of complexity and of required computational effort, nonlinear static analysis (Pushover) and nonlinear dynamic analysis (Time-history).

A full time history analysis will give the response of a structure over time during the application of dynamic loading. Time history analyses are required to define the real seismic response of structures, especially for irregular, highly ductile, critical or higher modes induced structures.

The main objectives of this paper are-

- Determination of the displacement and ductility demands of a building structure, which may exhibit inelastic behavior during an earthquake.
- Determination of the nonlinear behavior of building structures by utilizing time-history analyses of various deformation levels.

METHODOLOGY

Model Development

The building model considered for this study is a ten-storied building.

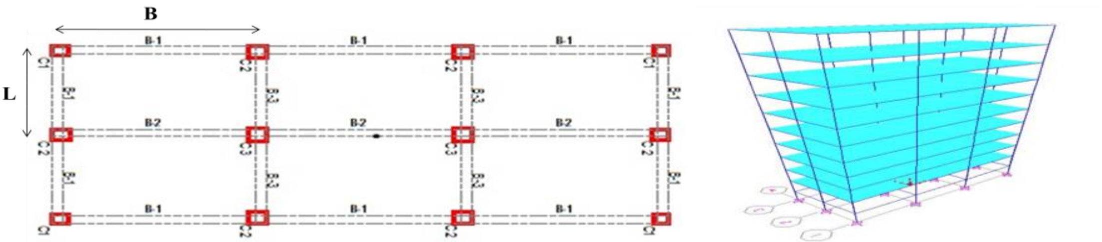

Fig. 1: Plan Layout (Left), 3D view of the structure (Right)

Table 1: Different Span length

Case	Length	Breadth
01. (L/B= 0.60)	12´	20´
02. (L/B= 0.80)	12´	15´
03. (L/B= 0.95)	12´	13´

All structural models consist same beam-column layout; just the spacing between columns varies. All building models of Ordinary Moment Resisting Frame have been developed with Concrete beam, column and 6´´ concrete slab. Material properties for all members is 4000 psi and yield stress is 60 ksi. Here fixed support condition has been selected. The effects on the structures are analyzed using SAP2000 V-14 software.

Loads that act on structures can be divided into three general categories. They are:

- Dead load: The dead loads are Floor finish (25 psf), Partition Walls (20 psf), which will act along with the self-weight of the beam, column & slab.
- Live load: Live Load 60 psf has been used according to the BNBC.
- Lateral load*:* Two types of lateral loads are considered – Wind Load and Earthquake Load.

These loads are applied using ten different combinations according to BNBC. These combinations are:

i) 1.4 DL + 1.7 LL
ii) 1.05DL + 1.275 LL + 1.275 W_X
iii) 1.05DL + 1.275 LL - 1.275 W_X
iv) 1.05DL + 1.275 LL + 1.275 W_Y
v) 1.05DL + 1.275 LL - 1.275 W_Y
vi) 1.05DL + 1.275 LL + 1.405 EQ_X
vii) 1.05DL + 1.275 LL – 1.405 EQ_X
viii) 1.05DL + 1.275 LL + 1.405EQ_Y
ix) 1.05DL + 1.275 LL – 1.405EQ_Y
x) ENVELOPE

In this study, we have also used four different earthquake data. They are:

- Imperial Valley 1940 of Magnitude 6.95
- Imperial Valley 06 of Magnitude 6.53
- Imperial Valley 08 of Magnitude 5.62
- Imperial Valley 07 of Magnitude 5.01

RESULT AND DISCUSSION

Variations are observed on the effects of same parameters such as Column Bending Moment, Column Shear Force and Joint Displacements.

Static Analysis

Different structures are analyzed with the same arrangements of beams and columns, but with three different L/B ratios of 0.6, 0.80 and 0.95. In case of static loading the structures are analyzed for probability of occurrence of most unfavorable effects resulting from different load combinations provided by BNBC. Effects of the same type of loading on different spans are described below:

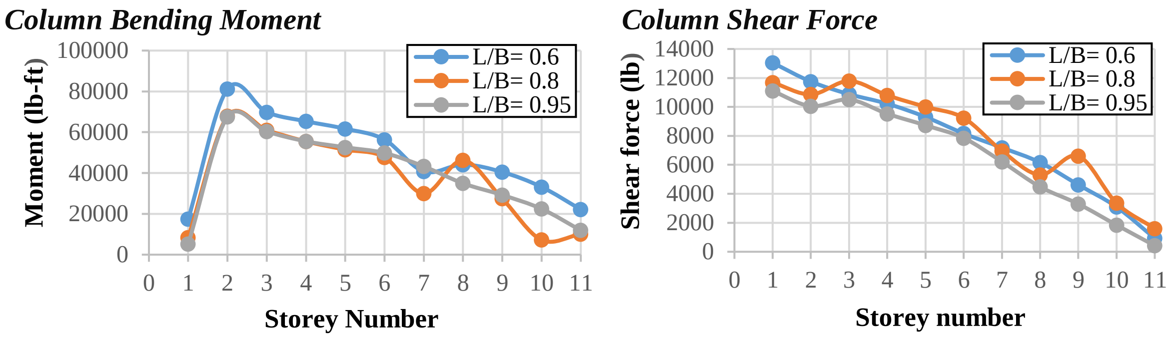

Fig. 2: Moment distribution and Shear force distribution of Column C1 along different story levels

For Column C1 the maximum moment 81155.85 lb-ft is obtained at Ground Floor of the structure with L/B ratio 0.6 and minimum moment 5234.15 lb-ft is obtained at Base Level with L/B ratio 0.95. For Column C1 the maximum shear 13047.7 lb is obtained at Base level of the structure with L/B ratio 0.6 and minimum shear 422.57 lb is obtained at Roof Level with L/B ratio 0.95

Joint Displacement due to Static Loading (Wind-X and Wind-Y)

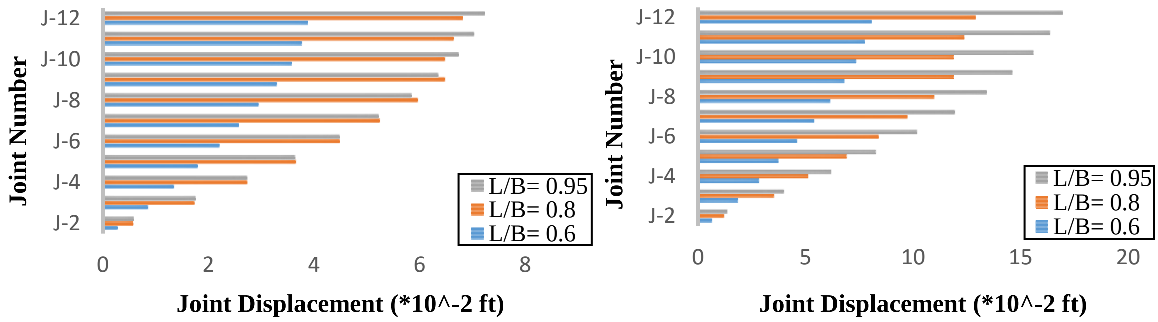

Fig. 3: Joint Displacement due to Static Loading Wind-X (Left) and Wind-Y (Right)

For Wind-X and Wind-Y the maximum joint displacement 7.24*10^-2 ft is observed at joint-12 and 16.97*10^-2 ft is observed at joint-12 of the structure with L/B ratio 0.95. Again, minimum joint displacement 0.28*10^-2 ft is observed at joint-02 and 0.64 ft. at joint-02 with L/B ratio 0.6.

Joint Displacement due to Static Loading (EQ-X and EQ- Y)

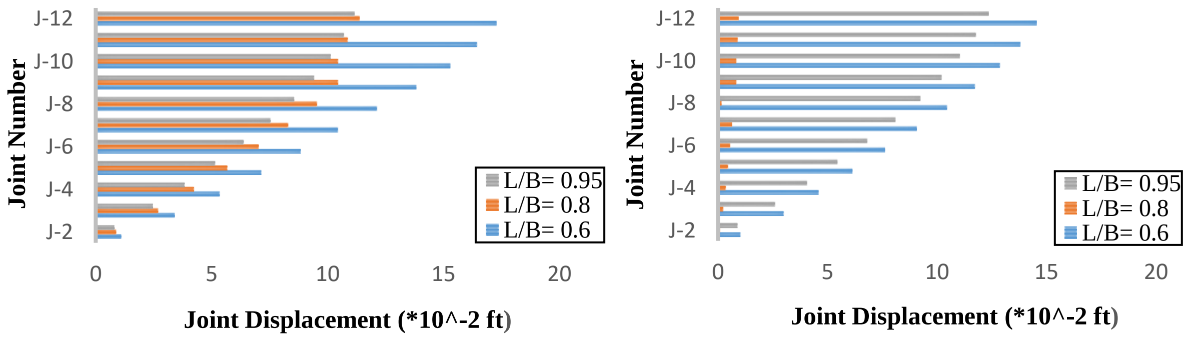

Fig. 4: Joint Displacement due to Static Loading Earthquake-X (Left) and Earthquake-Y (Right)

For Earthquake-X and Earthuake-Y the maximum joint displacement 17.28*10^-2 ft is observed at joint-12 and 14.56*10^-2 ft is observed at joint-12 of the structure with L/B ratio 0.60. Again, minimum joint displacement is 0.82*10^-2 ft is observed at joint-02 with L/B ratio 0.95 and 0.08*10^-2 ft. is observed at joint-02 with L/B ratio 0.80.

Time History Analysis

Time history analysis is a step by step analysis of the dynamic response of a structure to a specified loading that may vary with time. The dynamic time history analysis is used to determine the dynamic response of a structure through the direct numerical integration of the dynamic equilibrium equations. Here the dynamic time history analysis is done to analyze parameters like Column Bending Moment, Column Shear force and Joint displacement. Two types of comparisons are shown here:

Comparison of Effects of Different Span Length

In this study different structures are analyzed with the same arrangements of beams and columns, but with three different Length/Breadth (L/B) ratios of 0.6, 0.80 and 0.95. Time History Analysis is done only for Earthquake data 'Imperial Valley 1940' of magnitude 6.93 for different L/B ratios of 0.6, 0.80 and 0.95 .

Column Bending Moment ***Column Shear Force***

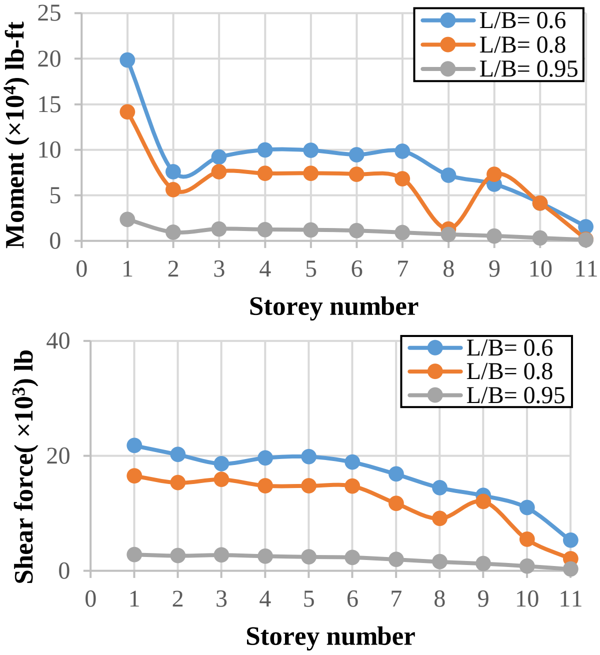

Fig. 5: Moment distribution and Shear force distribution of Column C1 along different story levels

For Column C1 the maximum moment 19.86*10^4 lb-ft is obtained at Base level of the structure with L/B ratio 0.6 and minimum moment 0.12*10^4 lb-ft is obtained at Roof Level with L/B ratio 0.95. For Column C1 the maximum Shear 21.78*10^3 lb is obtained at Base level of the structure with L/B ratio 0.6 and minimum Shear 0.28*10^3lb is obtained at Roof Level with L/B ratio 0.95

Joint Displacement due to Dynamic loading

Joint displacement due to Dynamic Loading (Earthquake data of Imperial Valley 1940 of magnitude 6.93) along the X - direction at different elevations (from Joint-02 to Joint-12) is shown below:

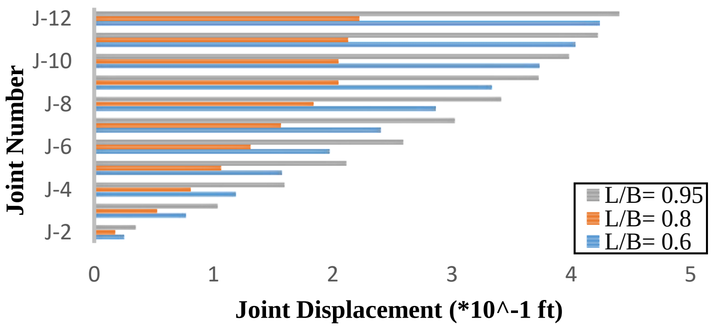

Fig. 6: Joint Displacement due to Dynamic Loading

Maximum joint displacement 4.405*10^-1 ft is observed at Joint-12 of the structure with L/B ratio 0.95. Again, minimum joint displacement is observed at joint-02 with L/B ratio 0.80, the value of which is 0.1752*10^-1 ft.

Comparison of the Effects of Four Different Earthquakes
The effects of four earthquakes are compared for the same structure of L/B ratio 0.6. Comparisons are done for Column Bending Moment and Column Shear Force by Time History analysis using SAP.

Comparison for Column Bending Moment ***Comparison for Column Shear Force***

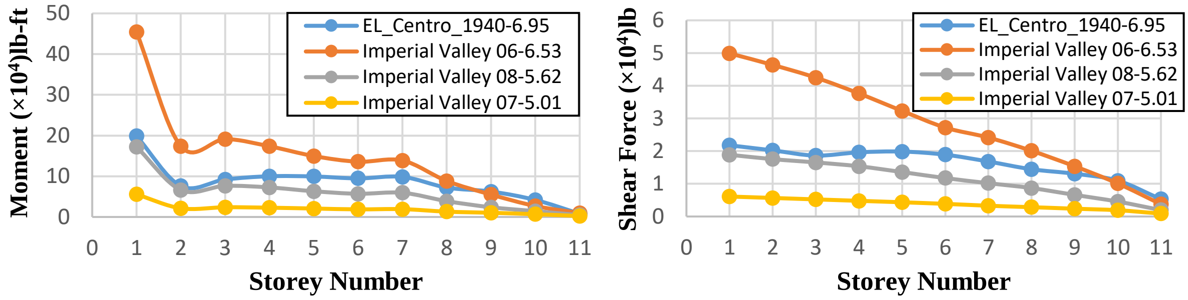

Fig. 7: Moment distribution and Shear Force distribution of Column C1 along different story levels

For Column C1 maximum moment 45.43*10^4 lb-ft at Base Level of the structure for earthquake Imperial Valley 06 (magnitude 6.53) and minimum moment 0.24*10^4 lb-ft and 0.91*10^4 lb-ft is obtained at Roof Level for earthquake Imperial Valley 07 (magnitude 5.01)
For Column C1 maximum shear 4.989*10^4 lbs. is obtained at Base Level of the structure for earthquake Imperial Valley 06 (magnitude 6.53) and minimum shear 0.09*10^4 lbs. is obtained at Roof level for earthquake Imperial Valley 07 (magnitude 5.01).
Comparison between Static and Dynamic (Time History Analysis)
Two types of analysis have done here. Static for different load cases and dynamic time history analysis for Earthquake Data 'Imperial Valley 1940' (magnitude 6.95). Variations are observed on the effects of same parameters such as Column Bending moment, Column Shear force and joint displacements.

Variation in Column Bending Moment ***Variation in Column Shear Force***

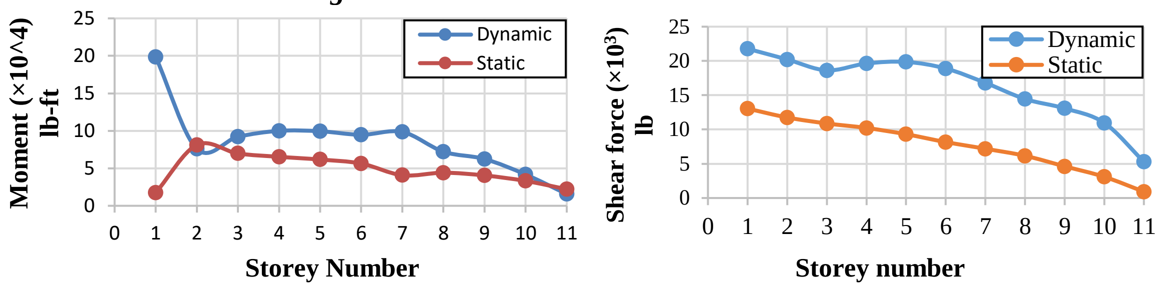

Fig. 8: Variation in Column Bending Moment for (C1), Variation in Column Shear Force for (C1)

Here it is observed that for dynamic analysis the value of moment (19.46×10^4 lb-ft/ft) at base level is maximum, for static analysis at the same level we get the minimum moment value (1.74×10^4 lb-ft). From the Column shear force graph we can see that the values of Column Shear Force for C1 are higher in dynamic analysis whereas that is lower for static analysis.
Variation in Joint Displacement
For Joint Displacement variation in the result obtained from static (Wind-X, Wind-Y, EQ-X and EQ-Y) and dynamic analysis is shown below:

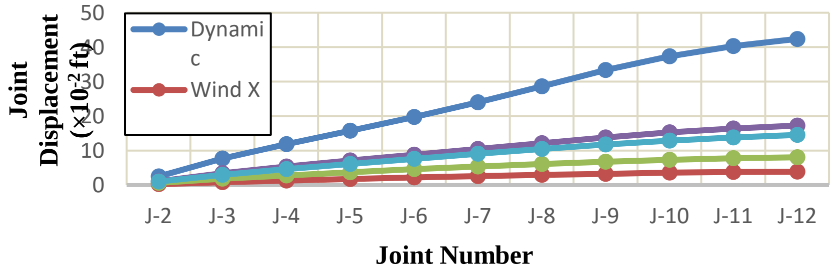

Fig. 9: Variation in Joint Displacement for static and dynamic analysis

The above curves show the variation of joint displacement due to static and dynamic loadings. Due to dynamic loading joint displacement is much higher than that of any static loadings (Wind-X, Wind-Y, EQ-X, and EQ-Y).

CONCLUSION

In this study structures with different span lengths are modeled to attain adequate stiffness against lateral loading and designed within reasonable drift limits and according to other safety parameters. The outcomes of this study are discussed below:

Variation due to different Span Length

1) For same plan layout, values of Bending Moments (BM) of Columns decrease with increasing span length.
2) The variation of Column Shear Force (SF) is similar to the variation of Bending Moments of Columns. Shear Force in Columns also decreases with increasing span length.
3) Joint Displacement increases with the increasing elevation of the joint from ground level.

Variation due to four different Magnitudes

1) Column Bending Moment and Column Shear Force each increases with the increasing magnitude of earthquake data.
2) Column Bending Moment and Shear Force decreases and joint displacement increases with the increasing elevation above ground level.
3) We also observe an exception. For Imperial Valley 06 each parameter shows considerably higher values, though its magnitude is smaller (i.e. 6.53) than that of Imperial Valley 1940 (6.95).

Variation due to Static and Dynamic Analysis

1) ***Column Bending Moment -*** Maximum moment for dynamic analysis is 19.86×10^4 lb-ft at Base Level of Column C1 for L/B=0.60 which is 245% or 2.45 times of the Maximum Static Moment (81155.85 lb-ft at the Ground Level of Column C1 for L/B=0.60)

2) ***Column Shear Force -*** Maximum shear for dynamic analysis is 21.78×10^3 lb at Base Level of Column C1 for L/B=0.60 which is 167% or 1.67 times of the Maximum Static Shear (13047.7 lb at Base Level of Column C1 for L/B=0.60).

3) ***Joint Displacement -*** Maximum Joint Displacement for Dynamic Analysis is 4.41×10^{-1} ft at Joint-12 for L/B=0.95 which is 255% or 2.55 times of the Maximum Static Joint Displacement (17.28×10^{-2} ft at Joint-12 for L/B=0.60 due to EQ-X).

REFERENCES

Atkinson, GM. 2009. Earthquake time histories compatible with the 2005 National Building Code of Canada uniform hazard spectrum. *Canadian Journal of Civil Engineering*, 36: 991-1000.

Izmir, Dokuz Eylul University, Turkey "A Comparative Study on Nonlinear Static and Dynamic Analysis of RC Frame Structures."

Lew, M; Naeim, F. 2008. Challenges in specifying ground motions for design of tall buildings in high seismic regions of the United States. *Proceedings of the 14th World Conference on Earthquake Engineering*, Beijing, China.

Malaga-Qhuquitaype, C; Bommer, J; Pinho, R and Stafford, P. et al. 2008. Selection and scaling of ground-motion records for nonlinear response-history analysis based on equivalent SDOF systems. *Proceedings of the 14th World Conference on Earthquake Engineering*, on CD-ROM, Beijing, China.

Naeim, F and Lew Marshall. 1995. On the use of design spectrum compatible time histories. *Earthquake Spectra*, 11(1): 111-127.