MAT JOURNALS
Journal of Civil and Construction Engineering
e-ISSN: 2457-001X
Volume 5 Issue 2

Comparative Study on RC Frame Displacement Due to Earthquake Force Based on BNBC 2006 and BNBC 2015

[1]Shafiqul Islam, [2]Sabuj Chowdhury, [3]Tanvirul Islam, [3]Anika Jahan, [3]Tanvir Ahmed
[1]Assistant Professor, [2]Lecturer, [3]Undergraduate Student
Department of Civil Engineering, Ahsanullah University of Science and Technology, Dhaka, Bangladesh
Email: *[1]shafiqul.ce@gmail.com, [2]sabuj2611@gmail.com*

Abstract
The study was carried to have a comparative study on the displacement of structures of specific areas' due to earthquake forces based on both the code BNBC 2006 and proposed BNBC 2015. Three dimensional modeling of the structures was generated using ETABS software (version 2009). By comparing BNBC 2006 and 2015, a specific area of Bangladesh could be in different seismic zones with different co-efficient. In that context, some cases (case 1 to case 6) have been idealized to understand the variation in structural response due to the changes in codes. For all the cases, the structures are displaced more for BNBC 2015 considerations rather than BNBC 2006. The column sizes and orientations are applied considering the base shear of respective structure. The analysis based on BNBC 2015 showed that the displacements of 5 storied structures significantly low for the most critical condition case 1 and by this understanding 5 story is not considered for the other cases. Except for case 1, the 10 storied structures are within allowable limit for other cases but the increments of top displacement are considerably high in case 3 and case 5. The 15 storied building exceed the allowable displacement limit at the height of approximately 80ft, 105ft and 115ft for case 1, case 2 and case 3 respectively. For case 4, case 5 and case 6 the structural displacement of 15 storied buildings are within allowable limit for BNBC 2015 also. The analysis result indicates that the existing structures in the areas of case 1, 2 and 3, as mentioned in methodology, may require intense assessments considering the new BNBC code. The increment in top displacements for the cases 4, 5 and 6 are considerable high, whatsoever the top displacements are within allowable limit for all the cases. In this context the structures in the areas of cases 4, 5 and 6 may also require assessments for compliance consideration.

Keywords**:** *Base shear, BNBC 2006, BNBC 2015, Drift, Seismic zone*

INTRODUCTION

Bangladesh is in earthquake hazard due to major active fault line closely run-through it's border. Due to simplified methodology, static equivalent analysis of earthquake force for structure became popular among the practicing engineers'. In this context, as like many other countries Bangladeshi building code also incorporate the static equivalent analysis of earthquake force considering the geography and geology of this country. Bangladesh National Building Code (BNBC) was first organized in the year of 1993 but published in the year 2006 and known as BNBC 2006. International codes are going through frequent changes to integrate the versatile model and purposes of buildings. As like others, Bangladeshi building code also need modifications to adopt the new practices. Initiative has already been taken to update BNBC code and a draft copy has already been proposed by House Building Research Institute (HBRI) called BNBC 2015 (final draft), which will be published very soon. A drastic modification has been recommended for lateral forces (loads due to wind and earthquake forces) in the proposed code, which will be noticeable in design outputs.

Journal of Civil and Construction Engineering
e-ISSN: 2457-001X
Volume 5 Issue 2

LITERATURE REVIEW

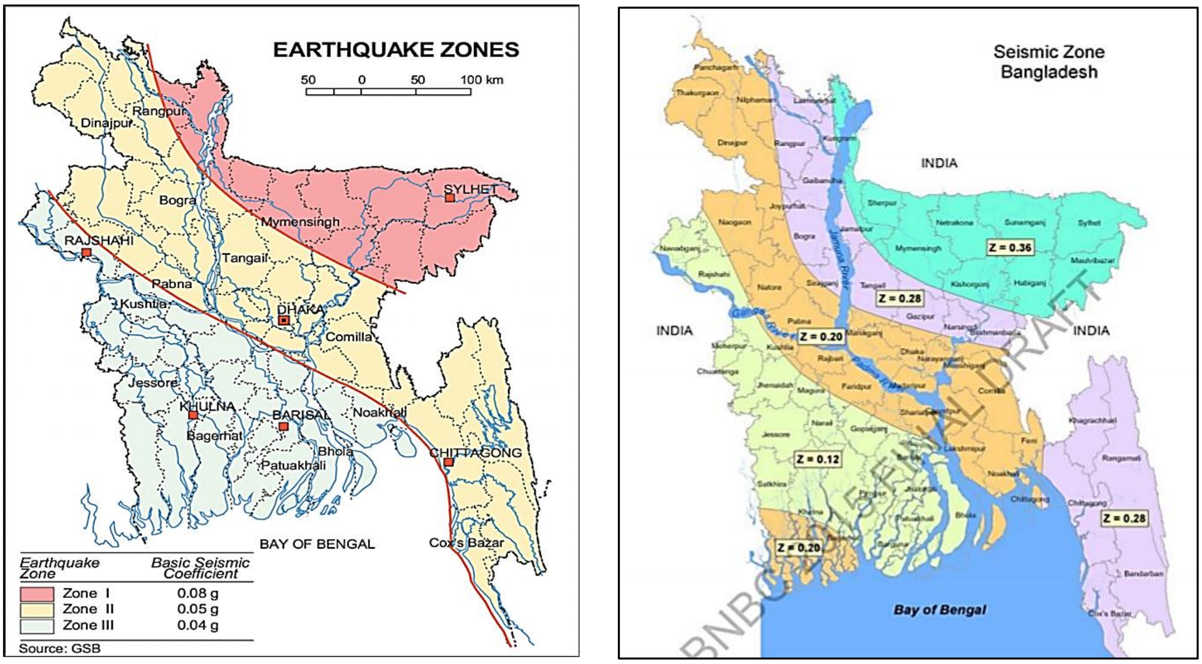
An earthquake is caused by volcanic eruption and plate tectonics which lasts for a short time. In general, earthquakes can be classified according to the focal depth. Earthquakes with focal depth within 70 km are called shallow earthquakes, those from 70 to 300 km are called intermediate earthquakes, and those beyond 300 km are called deep earthquakes [6].

Seismic hazard can be determined by using different methodology but attenuation laws of peak ground acceleration is much related to find out hazards of an area. It is also observed that to prepare a seismic hazards information about past earthquakes are very much required. The seismic hazard is categorized considering seismological, morphological, geological and geotechnical investigations the earthquake history in that region. Bolt analyzed different seismic sources in and around Bangladesh and arrived at conclusions related to maximum likely earthquake magnitude. Bolt identified the following four major sources: Assam fault zone, Tripura fault zone, Sub- Dauki fault zone and Bogra fault zone [7]. The magnitude of earthquake suggested by Bolt is given in Table 1 are the maximum magnitude generated in these blocks as recorded in the historical seismic catalogue. The historical seismic catalogue of the regions covers approximately 250 years of (starting 1762) earthquake data [7].

Table 1: *Significant seismic sources and maximum.*

Location	Maximum Likely Earthquake Magnitude
Assam fault zone	8.0
Tripura fault zone	7.0
Sub-Dauki fault zone	7.3
Bogra fault zone	7.0

The northeastern cities of Bangladesh are supreme susceptible toward earthquake hazards than the supplementary regions of the country. The most vulnerable cities in the northeast are Mymensingh, Kishorognj and Sylhet. The north western, central and southeastern cities which include Dinajpur, Rangpur Dhaka, Comilia, Chittagong and Cox's Bazar are comparatively less vulnerable than northeastern cities. The southwestern and western cities are the least vulnerable and include cities: like Rajshahi, Faridpur, Khulna, Barishal, etc, as shown in Fig. 1 [1]. The first seismic zoning diagram of the subcontinent was accumulated via Geological Survey of India in 1935. The Bangladesh Meteorological Department accepted a seismic zoning map in 1972. In 1977, the government of Bangladesh constituted a committee of specialists to investigate the seismic difficulties and create suitable recommendations. In the same The Committee recommended a zoning map of Bangladesh. The occurrence of earthquakes cannot be prevented. Rather, all that could be done is to make a prediction and issue a warning system to minimizing the loss of life and property [2].



(a) (b)

Figure 1: *Seismic zoning map of Bangladesh (a) BNBC 2006 and (b) BNBC 2015 (Final draft).*

Different studies had been carried out on seismic action in various aspects by several researches.

Sharfuddin (2004) studied to develop a homogenous and complete earthquake catalogue of Bangladesh. He also focused on to develop seismic hazard maps of Bangladesh [10]. Islam (2005) did research on Sylhet city to improve the understanding of the seismic risk in the study area. He compares the seismic risk with other natural hazards. He also provides a base line for earthquake policy development and comparison of mitigation alternating [8]. Masud (2007) works on to develop seismic micro zonation maps for Chittagong for liquefaction, for site amplification and for landslide. He gave effort to overlay seismic micro zonation maps and geographic information and to combine their attributes to produce map of local seismic hazards [9].

METHODOLOGY

The idealization of structure models, selection of RC sections, different type of gravity, lateral loads based on BNBC code and step by step model the structures as well as the analysis process have been discussed in this chapter.

Idealization of the Structure

The conditions of the analysis are designated by the code (e.g. 2006 or 2015), height of the structure in numerical form (e.g. 5, 10 and 15) and seismic zone in a combination of numerical and alphabetic form (e.g. Z1, Z2 etc). The slenderness ratios are also defined in a combination of numerical and alphabetic form (e.g. S1.2, S1.5 etc.). To study the structural displacement while considering the effect of earthquake load, building frames according to BNBC 2006 and BNBC 2015 namely Structure A and Structure B, respectively, has been idealized. That is a 5 story building frame according to BNBC 2006 with a slenderness ratio of S1.2 in seismic zone 3 will be symbolized as A5S1. 2Z3. All the symbols for different considerations are presented in Table 2 and Table 3 for BNBC 2006 and BNBC 2015, respectively. The story height was chosen as 60ft, 110ft and 160ft. The depth of foundation for all structures was considered as 8ft below the grade and ground floor height was taken as 12ft. The typical height of each story was 10ft as regular practice in Bangladesh for residential building. The reinforced concrete frame structure considered in different zone according to the codes has been adopted for the purpose of study. The typical plan areas of the buildings are 60ft × 72ft, 60ft × 90ft and 60ft × 108ft. The buildings are symmetrical about both the axis. All structures are considered as Special Moment Resisting Frame (SMRF) as lateral force-resisting system. Floor and roof solid reinforced concrete slab are assumed to satisfy all criteria to be treated as rigid diaphragms.

Properties of the Structural Elements

For different cases of height and slenderness ratio, the dimensions of reinforced concrete beams are considered for gravity load with some factor of safety due to lateral load and the thickness of the slab element is taken as 5 inches. The columns have uniform cross sections along their height. These variations in dimensions are arrived based on the variation in base shear for different storied structure. The materials considered for design of the elements are concrete (f'_c =4 ksi) and steel (f_y= 60 ksi). The sectional and material properties of structure and the structure elements have been summarized in Table 4 and Table 5, respectively.

Considered Load on Structures

The design loads including Dead Load (DL), Partition Wall (PW), Floor Finish (FF), Live Load (LL), and Superimposed Dead Load (SDL) have been determined in accordance with the provisions and in conformance with the general design requirements provided in BNBC and summarized in Table 6. The earthquake force is assigned as lateral load on the structures for different seismic zone based on BNBC 2006 and 2015.

Idealization of Different Cases

By comparing BNBC 2006 and 2015, a specific area of Bangladesh could be in different seismic zones with different co-efficient. In that context some cases have been idealized to understand the variation in structural response due to the changes in codes, which has been summarized in Table 7.

Development of Structure Model

The structures are modeled using ETABS 2009 considering the structural properties as discussed earlier subsections. Orientations of columns are represented in Fig. 2.

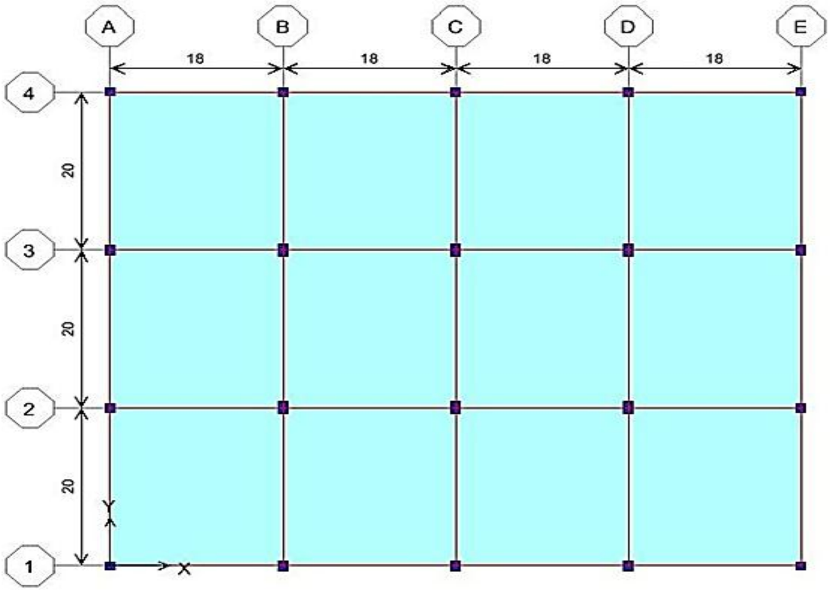


Figure 2: *Typical plan view exhibiting the location and orientation of columns.*

Journal of Civil and Construction Engineering
e-ISSN: 2457-001X
Volume 5 Issue 2

Table 2: *Symbols of the structures according to BNBC 2006.*

According to BNBC 2006	Symbol
5 storied structure with a slenderness ratio of 1.2 in seismic zone 3	A5S1.2Z3
5 storied structure with a slenderness ratio of 1.5 in seismic zone 3	A5S1.5Z3
5 storied structure with a slenderness ratio of 1.8 in seismic zone 3	A5S1.8Z3
10 storied structure with a slenderness ratio of 1.2 in seismic zone 3	A10S1.2Z3
10 storied structure with a slenderness ratio of 1.5 in seismic zone 3	A10S1.5Z3
10 storied structure with a slenderness ratio of 1.8 in seismic zone 3	A10S1.8Z3
15 storied structure with a slenderness ratio of 1.2 in seismic zone 3	A15S1.2Z3
15 storied structure with a slenderness ratio of 1.5 in seismic zone 3	A15S1.5Z3
15 storied structure with a slenderness ratio of 1.8 in seismic zone 3	A15S1.8Z3
15 storied structure with a slenderness ratio of 1.8 in seismic zone 1	A15S1.8Z1
15 storied structure with a slenderness ratio of 1.8 in seismic zone 2	A15S1.8Z2

Table 3: *Symbols of the structures according to BNBC 2017.*

According to BNBC 2006	Symbol
5 storied structure with a slenderness ratio of 1.2 in seismic zone 4	B5S1.2Z4
5 storied structure with a slenderness ratio of 1.5 in seismic zone 4	B5S1.5Z4
5 storied structure with a slenderness ratio of 1.8 in seismic zone 4	B5S1.8Z4
10 storied structure with a slenderness ratio of 1.2 in seismic zone 4	B10S1.2Z4
10 storied structure with a slenderness ratio of 1.5 in seismic zone 4	B10S1.5Z4
10 storied structure with a slenderness ratio of 1.8 in seismic zone 4	B10S1.8Z4
15 storied structure with a slenderness ratio of 1.2 in seismic zone 4	B15S1.2Z4
15 storied structure with a slenderness ratio of 1.5 in seismic zone 4	B15S1.5Z4
15 storied structure with a slenderness ratio of 1.8 in seismic zone 4	B15S1.8Z4
15 storied structure with a slenderness ratio of 1.8 in seismic zone 1	B15S1.8Z1
15 storied structure with a slenderness ratio of 1.8 in seismic zone 2	B15S1.8Z2
15 storied structure with a slenderness ratio of 1.8 in seismic zone 3	B15S1.8Z2

Table 4: *Sectional properties of the structures.*

Story	Column			Beam		Slab (in)
	Corner column (in)	Periphery column(in)	Interior column (in)	Internal (in)	Periphery (in)	
5	12"×12"	12"×14"	12"×18"	12"×22"	12"×18"	5"
10	12"×18"	12"×20"	15"×27"	12"×22"	12"×18"	5"
15	15"×24"	18"×26"	18"×34"	12"×22"	12"×18"	5"

Table 5: *Material properties of the structural elements.*

SL	Material	Properties	Symbol	Unit	Value
1.	Concrete	Unit weight	γ_c	Pcf	150
2.	Concrete	Compressive strength	f_c'	Ksi	4
3.	Concrete	Modulus of elasticity	E_c	Ksi	3600
4.	MS Bar	Yield strength	f_y	Ksi	60

Table 6: *Loads on typical slab.*

SL	Load Type	Location	Unit	Value
1.	Live load (LL)	Typical slab	Psf	40
2.	Partition wall (PW)	Typical slab	Psf	30
3.	Floor finish (FF)	Typical slab	Psf	20

Table 7: *Defined seismic zones for different cases according to BNBC 2006 and BNBC 2015.*

Case	Considered Districts	Seismic Zone	
		BNBC 2006	**BNBC 2015**
01	Sylhet, Sunamganj, Netrokona, Srimongal, Kishoreganj, Jamalpur, Mymensingh.	Z3	Z4
02	Bogra, Sirajganj, Brahmanbaria, Jamalpur	Z3	Z3
03	Chattogram, Rangamati, Khagrachari, Bandarban, Cox's bazar, Tangail, Narshingdi, Rangpur	Z2	Z3
04	Panchagarh, Thakurgaon, Dinajpur, Joypurhat, Naogaon, Manikganj, Gazipur, Dhaka, Munshiganj, Chandpur, Comilla, Feni.	Z2	Z2
05	Nature, Pabna, Rajbari, Faridpur, Madaripur, Noakhali, Lakshipur, Kushtia.	Z1	Z2
06	Jessore, Khulna, Satkhira, Bagerhat, Barisal, Patuakhali, Barguna, Bhola.	Z1	Z1

TEST RESULT

Structural displacements at different stories of the proposed models for both the conditions, A (BNBC 2006) and B (BNBC 2015) are presented in this chapter. The top displacements of the structures for different cases are also comprised here.

Comparison of Structural Displacement for Condition, A and B

The conditions of the analysis are designated by the code (e.g. 2006 or 2015), story of the structure in numerical form (e.g. 5, 10 and 15) and seismic zone in a combination of numerical and alphabetic form (e.g. Z1, Z2 etc.). The slenderness ratios are also defined in a combination of numerical and alphabetic form (e.g. S1.2, S1.5 etc.).

Comparison of Structural Displacement for Case 1

The districts in the north-east part of Bangladesh, e.g. Sylhet, Sunamganj, Habiganj, Mymensingh etc., are in the most active seismic zone in the context of Bangladesh. Considering this, the effects of slenderness ratio in the perspective of plan dimension and height are assessed for case 1 only. The analysis results for structural displacement are presented in Fig. 3 to Fig. 11. As expected maximum displacement is found for 15 storied building with the dimension of 60′×108′ (slenderness ratio of 1.8). As the column size and orientation is considered based on the developed base shear, the effect of slenderness ratio is insignificant for this cases. The top displacement is approximately "5" and "13" for BNBC 2006 and BNBC 2015, respectively. In this context, the structures of 15 storied with the dimension of 60′×108′ are analyzed for rest of the cases. The structural displacements for different cases are demonstrated from Fig. 12 to Fig. 21, Difference of top displacement with the change of different cases is presented in Fig. 22 and in Fig. 23, the top displacements for different cases are summarized in Table 8 and Table 9 for 15 storied building and 10 storied building, respectively.

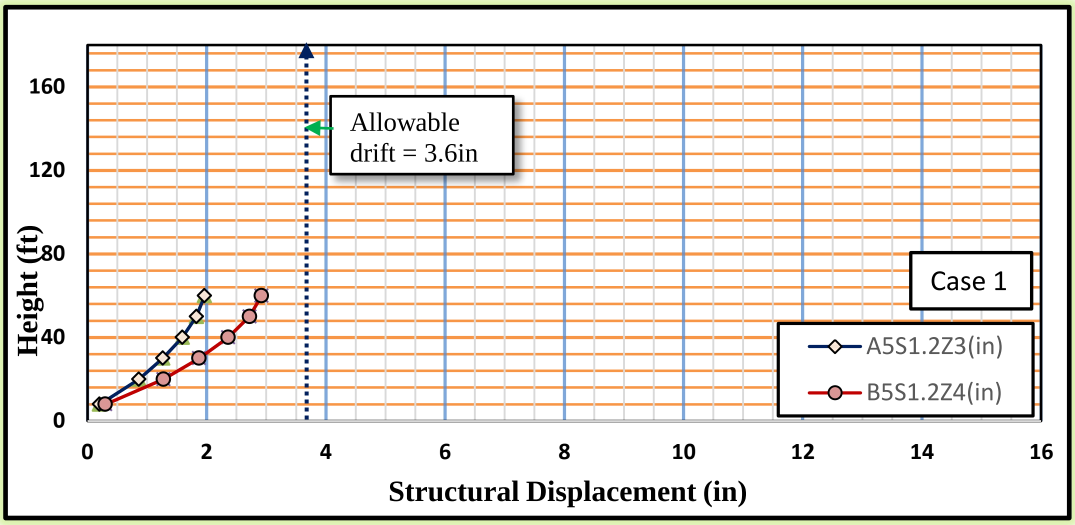


Figure 3: *Comparison of structural displacement for A5S1.2Z3and B5S1.2Z4.*

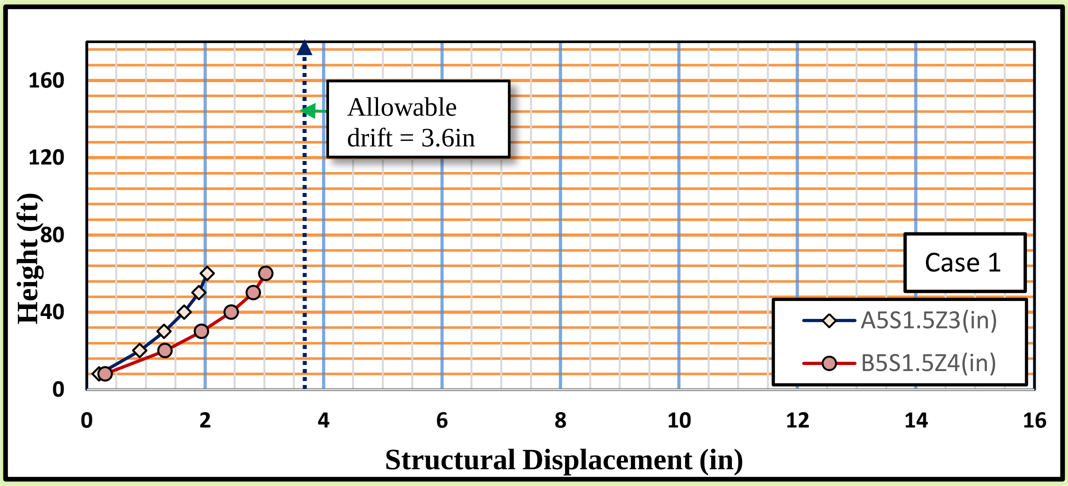


Figure 4: *Comparison of structural displacement for A5S1.5Z3 and B5S1.5Z4.*

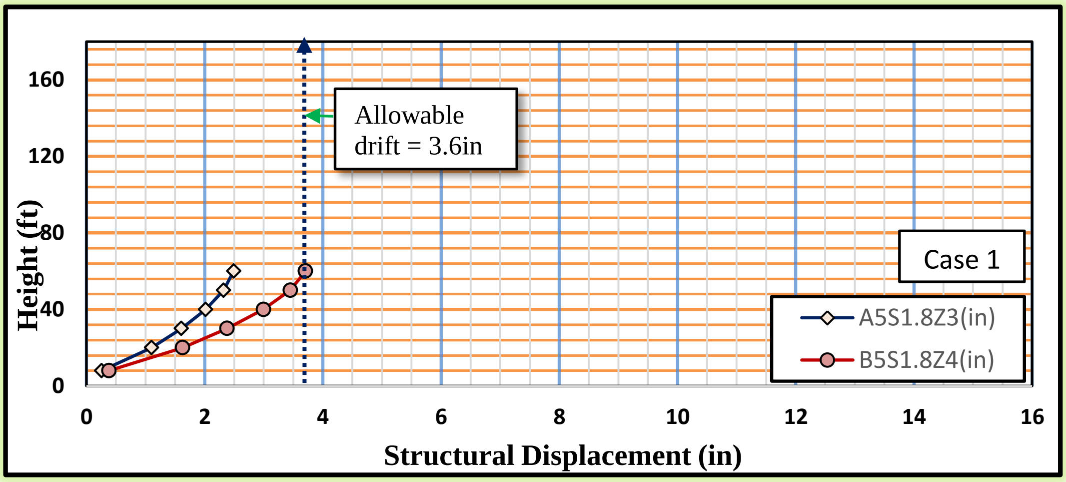


Figure 5: *Comparison of structural displacement for A5S1.8Z3 and B5S1.8Z4.*

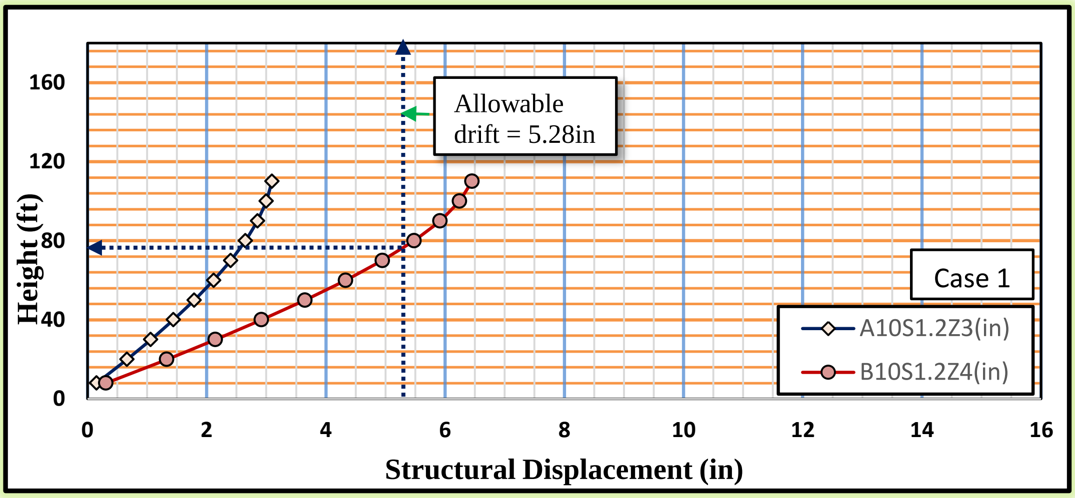


***Figure 6:** Comparison of structural displacement for A10S1.2Z3 and B10S1.2Z4.*

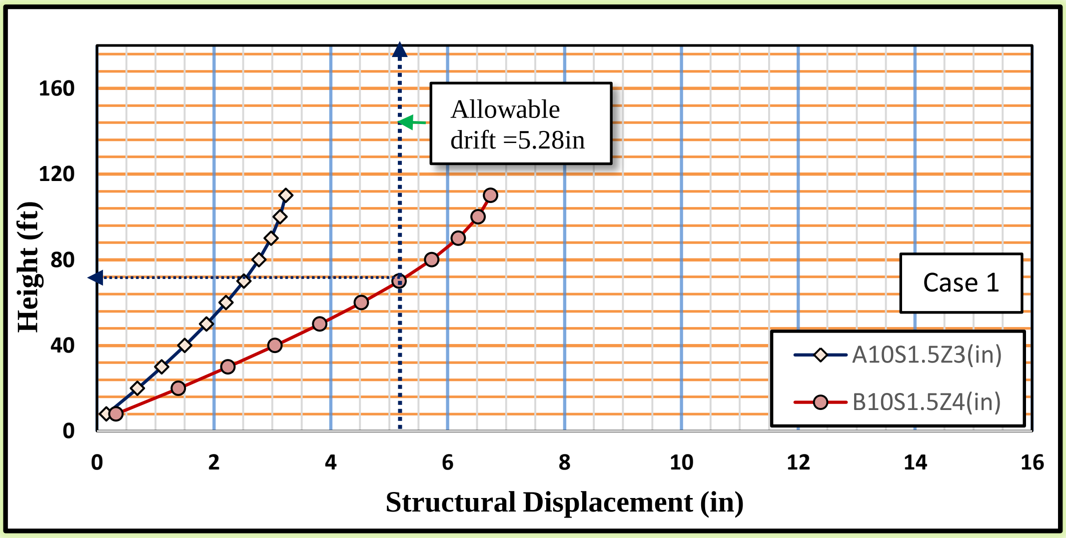


***Figure 7:** Comparison of structural displacement for A10S1.5Z3 and B10S1.5Z4.*

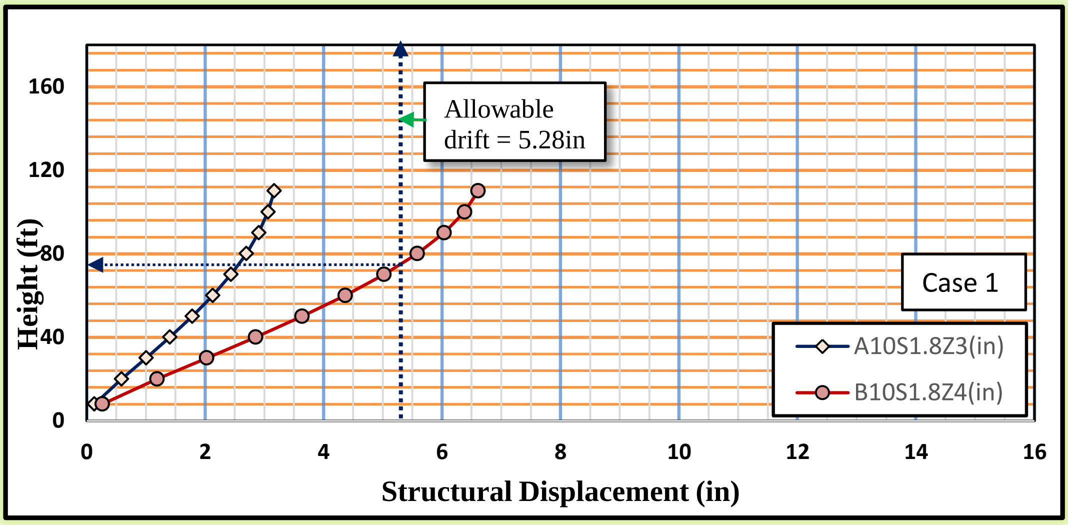


***Figure 8:** Comparison of structural displacement for A10S1.8Z3 and B10S1.8Z4.*

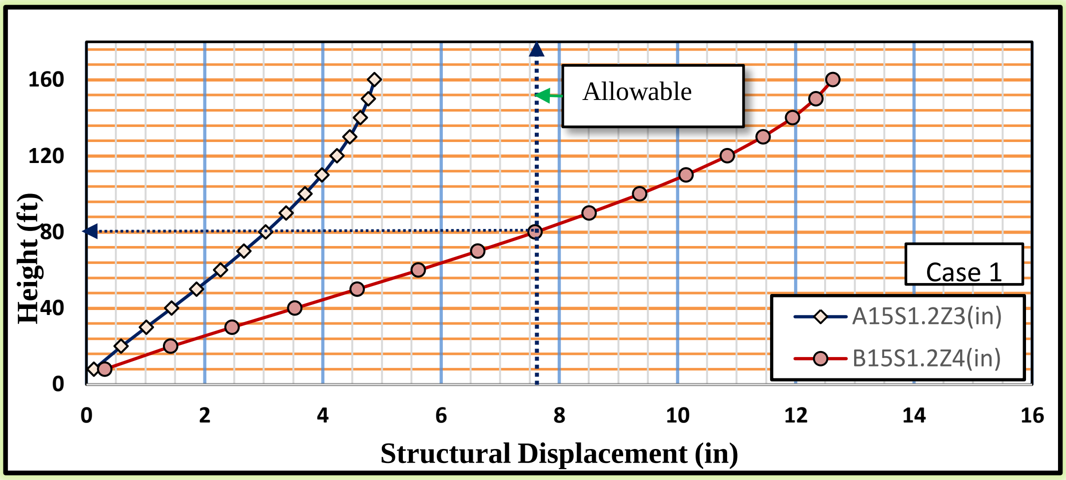


Figure 9: *Comparison of structural displacement for A15S1.2Z3 and B15S1.2Z4.*

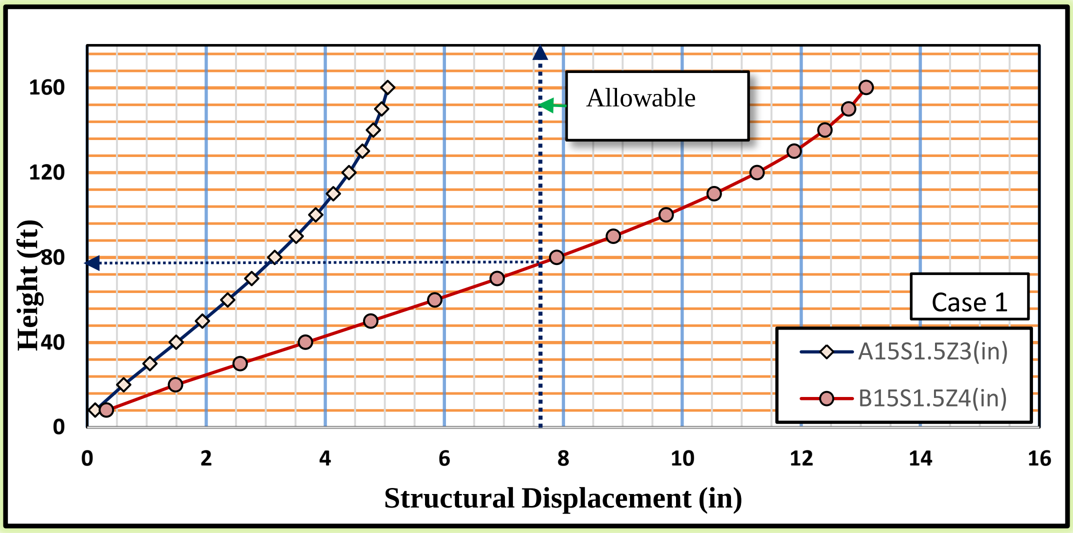


Figure 10: *Comparison of structural displacement for A15S1.5Z3 and B15S1.5Z4.*

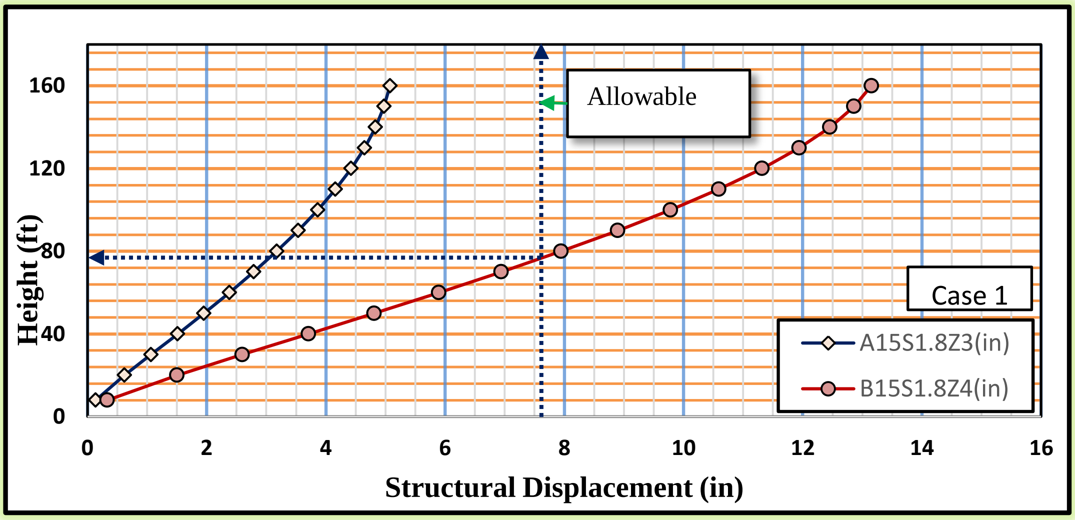


Figure 11: *Comparison of structural displacement for A15S1.8Z3 and B15S1.8Z4.*

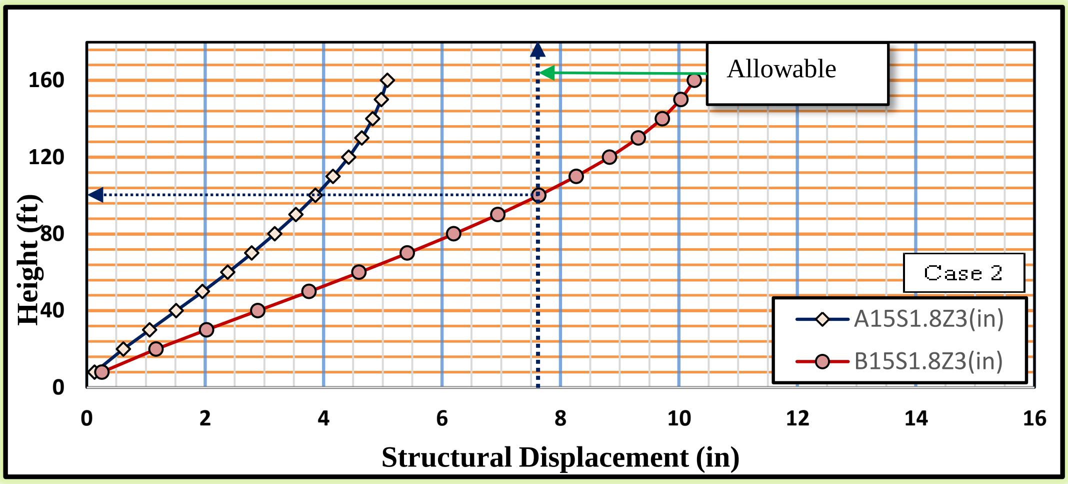


Figure 12: *Comparison of structural displacement for A15S1.8Z3 and B15S1.8Z3.*

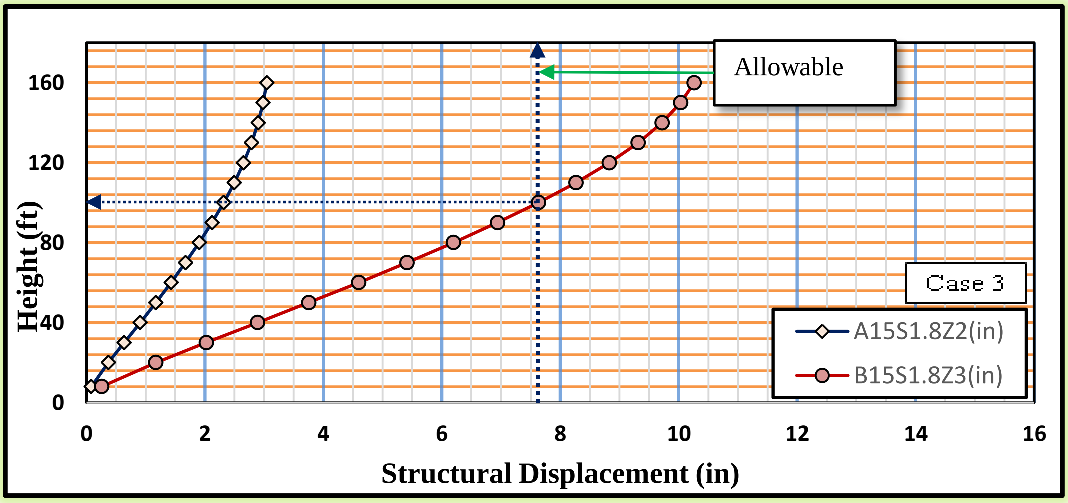


Figure 13*: Comparison of structural displacement for A15S1.8Z2 and B15S1.8Z3.*

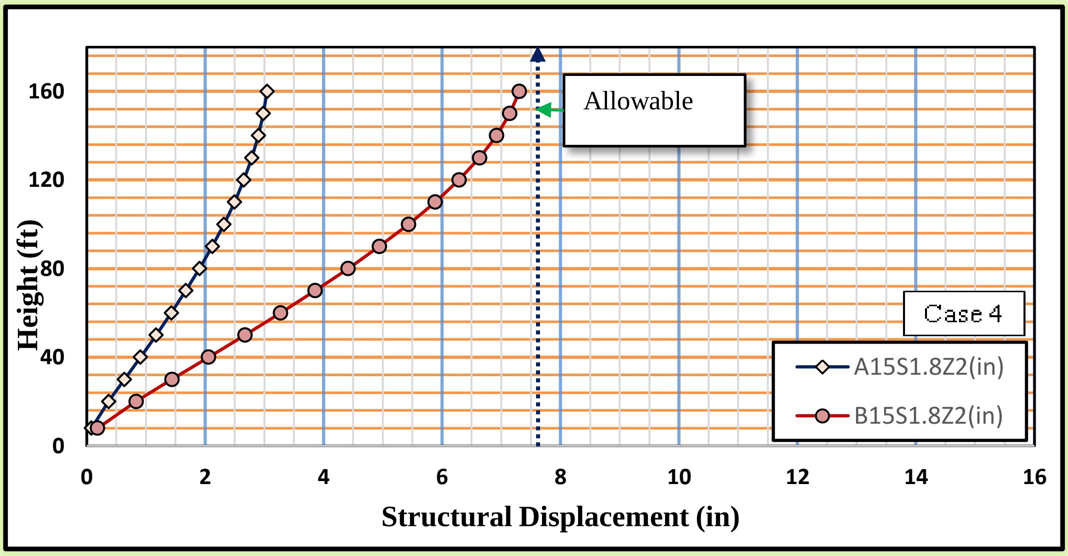


Figure 14*: Comparison of structural displacement for A15S1.8Z2 and B15S1.8Z2.*

MAT JOURNALS
Journal of Civil and Construction Engineering
e-ISSN: 2457-001X
Volume 5 Issue 2

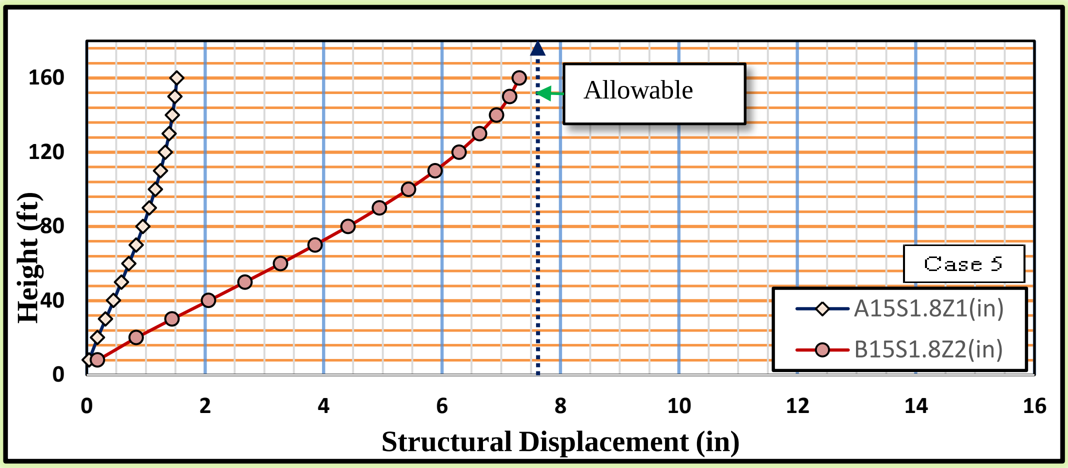


Figure 15: *Comparison of structural displacement for A15S1.8Z1 and B15S1.8Z2.*

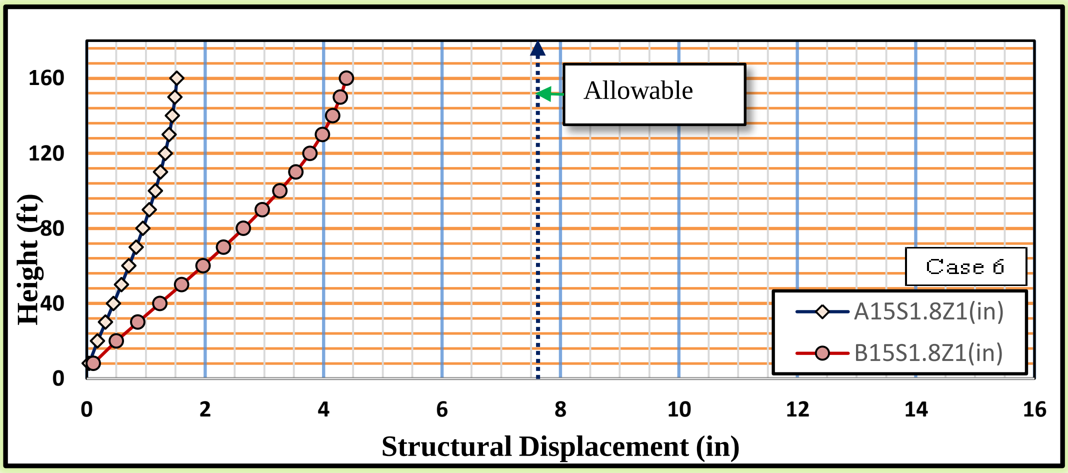


Figure 16: *Comparison of structural displacement for A15S1.8Z1 and B15S1.8Z1.*

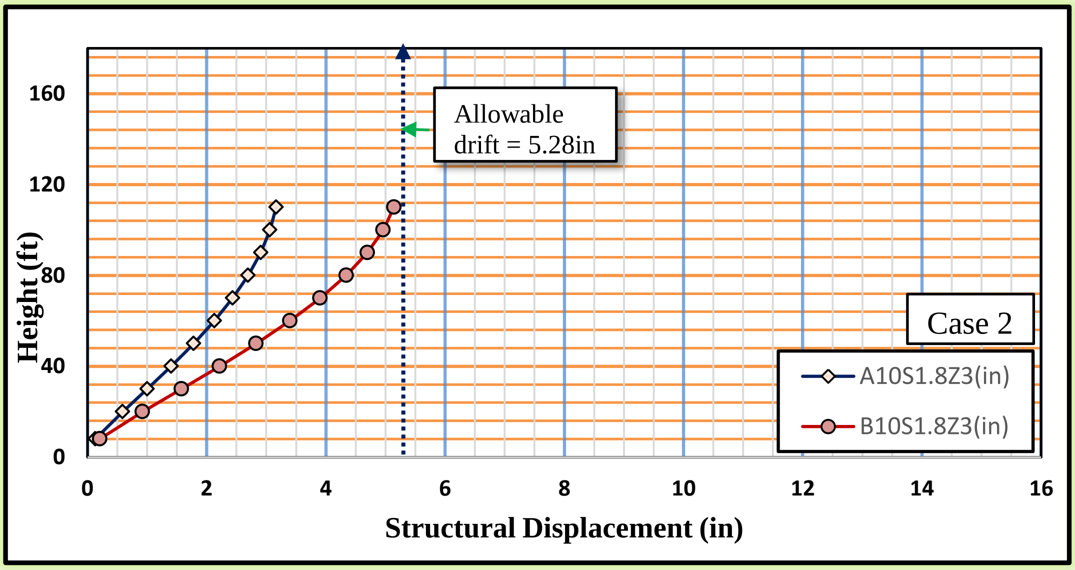


Figure 17: *Comparison of structural displacement for A10S1.8Z3 and B10S1.8Z3.*

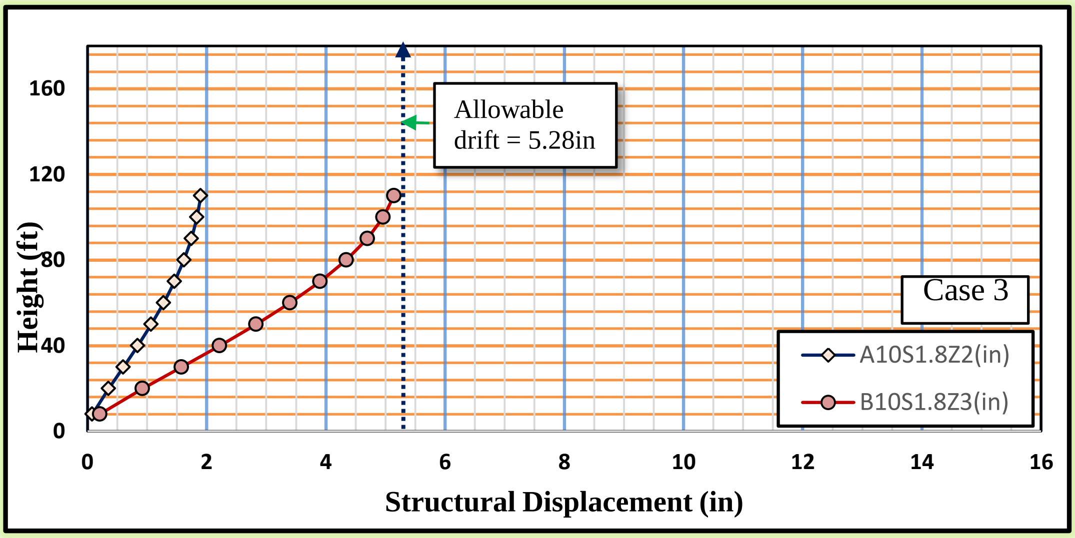


Figure 18: *Comparison of structural displacement for A10S1.8Z2 and B10S1.8Z3.*

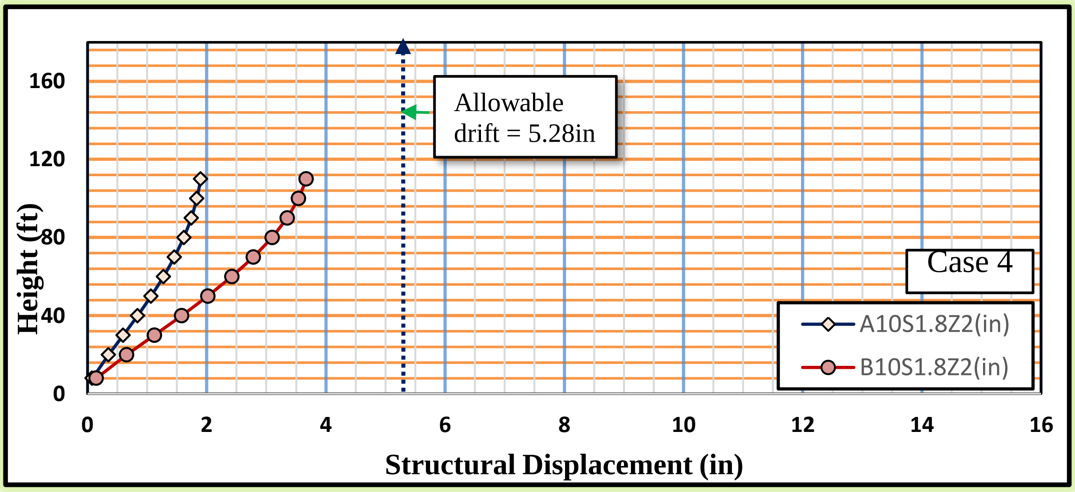


Figure 19: *Comparison of structural displacement for A10S1.8Z2 and B10S1.8Z2.*

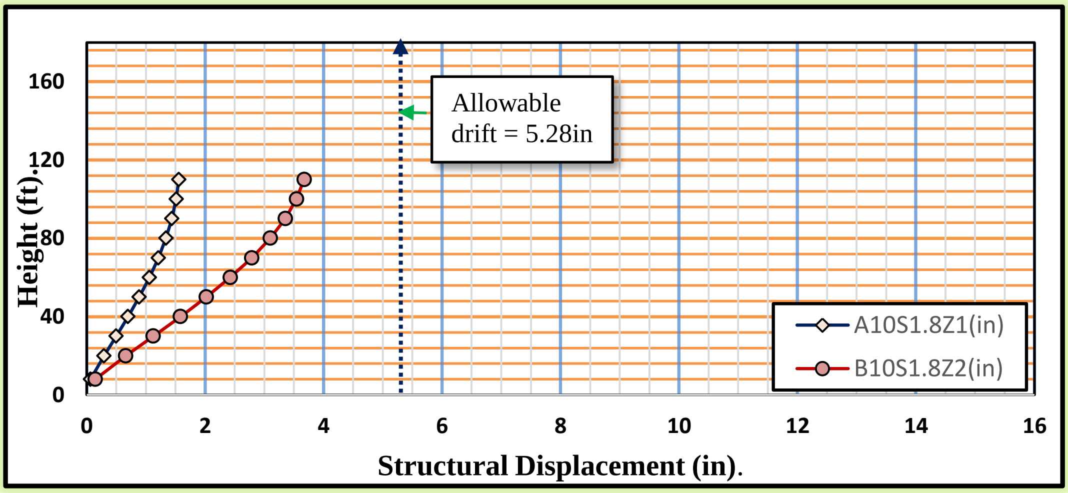


Figure 20: *Comparison of structural displacement for A10S1.8Z1 and B10S1.8Z2.*

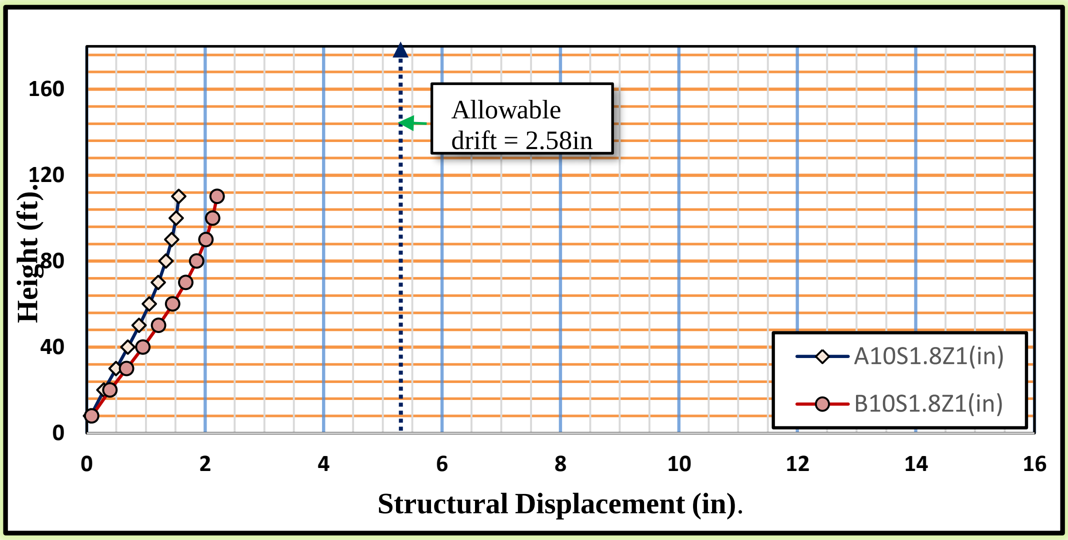


Figure 21: *Comparison of structural displacement for A10S1.8Z1 and B10S1.8Z1.*

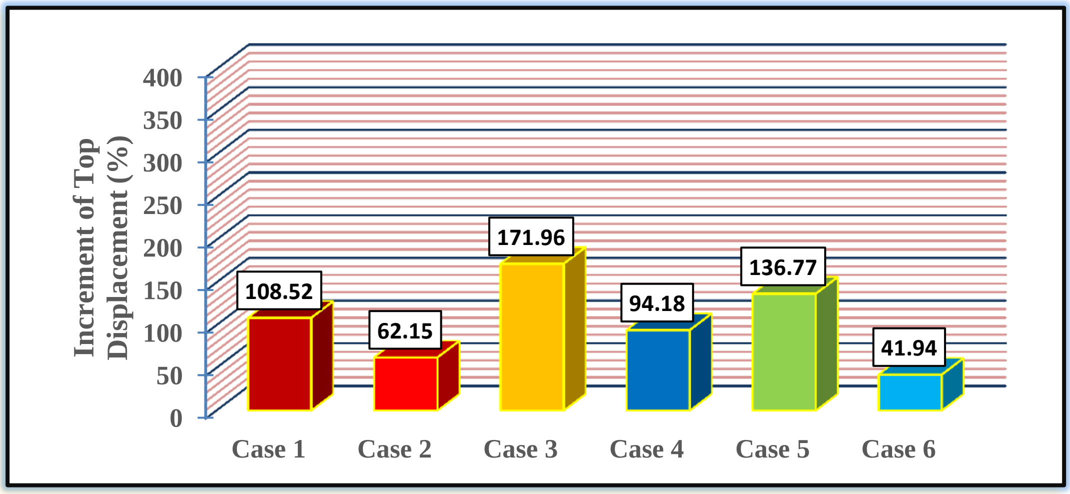


Figure 22: *Increment of top displacement in different cases for 15 story.*

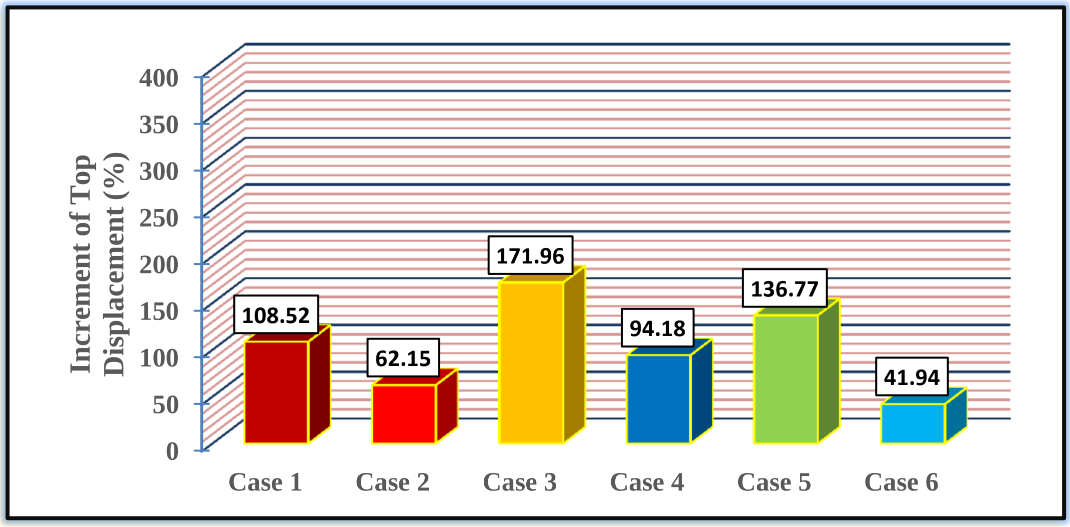


Figure 23: *Increment of top displacement in different cases for 10 story.*

Table 8: *Top displacements for different cases (15 story building).*

Case	Top Displacement (in)			
	Symbol	**BNBC 2006**	**Symbol**	**BNBC 2015**
01	A15S1.8Z3	5.08	B15S1.8Z4	13.15
02	A15S1.8Z3	5.08	B15S1.8Z3	10.26
03	A15S1.8Z2	3.05	B15S1.8Z3	10.26
04	A15S1.8Z2	3.05	B15S1.8Z2	7.31
05	A15S1.8Z1	1.52	B15S1.8Z2	7.31
06	A15S1.8Z1	1.52	B15S1.8Z1	4.38

Table 9: *Top displacements for different cases (10 story building).*

Case	Top Displacement (in)			
	Symbol	**BNBC 2006**	**Symbol**	**BNBC 2015**
01	A10S1.8Z3	3.17	B10S1.8Z4	6.61
02	A10S1.8Z3	3.17	B10S1.8Z3	5.14
03	A10S1.8Z2	1.89	B10S1.8Z3	5.14
04	A10S1.8Z2	1.89	B10S1.8Z2	3.67
05	A10S1.8Z1	1.55	B10S1.8Z2	3.67
06	A10S1.8Z1	1.55	B10S1.8Z1	2.20

From the analysis result, it showed that, in all the cases the structures are displaced more for BNBC 2015 considerations, rather than BNBC 2006. For case 1, the 5 storied structures are displaced within allowable limit for all the conditions as shown from Fig. 3 to Fig. 5. For BNBC 2006, the displacements for 10 storied structures are within allowable limit but for BNBC 2015, the structures exceed the allowable limit at a height of around 80ft as shown from Fig. 6 to Fig. 8. For 15 storied structures the displacements are within allowable limit for BNBC 2006. Whereas, in BNBC 2015 the total displacement of 15 storied structures is higher than 10 storied but the structures exceed the allowable limit at a height of around 80ft as like 10 storied structures as shown from Fig. 9 to Fig. 11.

The displacement of 10 storied structures are within allowable limit for all other cases as shown in Fig. 17 to Fig. 21 (case 2 to case 6) due to both code BNBC 2006 and BNBC 2015. Fig. 12 and Fig. 13 showed that the 15 storied structures exceed the allowable displacement limit at a height of 115ft to 125ft for case 2 and case 3 due to BNBC 2015 only. For the cases 4, 5 and 6, the 15 storied structures are in allowable limit, as shown in Fig. 14 to Fig. 16, for the condition BNBC 2015. It indicates that the existing structures in the areas of case 1, 2 and 3, as mentioned in chapter three, may require intense assessments considering the new BNBC code.

Except for case 1, the 10 storied structures are within allowable limit (Fig. 8) for other cases but the increments of top displacement are considerably high in case 3 and case 5 as shown in Fig. 23. Fig. 22 indicates that the increment in top displacements of 15 storied structures for the cases 4, 5 and 6 are considerable high, whatsoever the top displacements are within allowable limit for the cases. In this context, the structures in the areas of cases 4, 5 and 6 may also require assessments for compliance consideration.

CONCLUSION

After analyzing the results, the following conclusions has been drawn, For all the cases the structures are displaced more for BNBC 2015 considerations rather than BNBC 2006.

The structural displacement of buildings' with three different heights are in allowable limits for BNBC 2006, as the column size and orientations are applied

Journal of Civil and Construction Engineering
e-ISSN: 2457-001X
Volume 5 Issue 2

considering the base shear of respective structure.

The analysis based on BNBC 2015 showed that, the displacements of 5 storied structures will be within allowable limit, as it didn't exceed the limit for the most critical condition case 1. Except for case 1, the 10 storied structures are within allowable limit for other cases but the increments of top displacement are considerably high in case 3 and case 5 as shown in Fig. 23. The 15 storied building exceed the allowable displacement limit at the height of approximately 80ft, 105ft and 115ft for case 1, case 2 and case 3, respectively. For case 4, case 5 and case 6 the structural displacement of 15 storied buildings are within allowable limit for BNBC 2015 also.

The analysis result indicates that the existing 15 storied structures in the areas of case 1, 2 and 3, as mentioned in chapter three, may require intense assessments considering the new BNBC code. The increment in top displacements for the cases 4, 5 and 6 are considerable high, whatsoever the top displacements are within allowable limit for all the cases. In this context, the structures in the areas of cases 4, 5 and 6 may also require assessments for compliance consideration.

RECOMMENDATIONS

Since, the purpose of this research work was to investigate the variation in structural response of a structure due to different seismic zone, considering both the code, BNBC 2006 and BNBC 2015 and some refinements are recommended to make this research work more comprehensive for practical applications. Future research work may be carried out in the following areas:

For seismic response of tall structures where higher mode effects are judged to be important, nonlinear dynamic analysis (i.e. Time-history) can be performed.

In the present study, the inertial soil-structure interaction has not been considered to get the response of the structure. The soil-structure interaction may have another option for analysis.

For the experimental study prototype soil-structure interaction model using shaking table test can be performed considering pile foundations underneath including floating piles and end bearing piles with different section properties and arrangements.

REFERENCES

1. Ali, M. H. (1998), "Earthquake Database and seismic Zoning of Bangladesh", *INCEDE Report II Bangkok.*
2. Banglapedia Encyclopedia (2004), "National Encyclopedia for Bangladesh CD-ROM, February 2004", *Asiatic Society of Bangladesh.*
3. BNBC 2006. Public Work Department, People's Republic of Bangladesh.
4. BNBC 2015, Final Draft. Housing and Building Research Institute, Mirpur, Dhaka, Bangladesh.
5. Bolt, B.A. (1991), "Earthquake, Fourth Edition", *W.H Freeman and company,* New York, USA.
6. Murty, C. V. R. (2005), "Earthquake Tips". *Indian Institute of Technology Kanpur*, India.
7. Bolt, B.A. (1987), "Site Specific Study of Seismic Intensity and ground motion Parameters for Proposed Jamuna river bridge, Bangladesh, Report on Jamuna bridge study".
8. Islam, M. R. (2005), "Seismic loss Estimation for Sylhet City" *M.Sc Thesis, Bangladesh University of Engineering and Technology*, Dhaka.
9. Masud, M. A. (2007), "Earthquake Risk Analysis for Chittagong City", *M.Sc Thesis, Bangladesh University of Engineering and Technology*, Dhaka.
10. Sarfuddin (2001), "Earthquake intensity attenuation relationship for Bangladesh and its surrounding

region." *M.Sc Thesis, Bangladesh University of Engineering and Technology,* Dhaka.