International Journal of Civil, Structural and Concrete Engineering
Volume 1 Issue 1

Assessment of Serviceability Fluctuation of RC Frame Building for Similar Type of Soil Based on Bangladesh National Building Codes (BNBC)

Md. Tasbirul Islam[1]*, Md. Reazul Mumin[2], Sariah Ismail[3], Shafiqul Islam[4], Sristi Das Gupta[5]
Research Assistant[1, 2, 3], Assistant Professor[4], Lecturer[5]
Department of Civil Engineering
Ahsanullah University of Science and Technology, Dhaka, Bangladesh
Corresponding Author's email id: *tasbirulislam@ymail.com*

Abstract

Since the beginning of modern age, building a structure on a soft soil has always been a challenge for engineers. Apart from gravity loads, effect lateral load like earthquake load can vary due to soil type. The problem of soil-structure interaction in the seismic analysis and design of structures has become increasingly important, as it may be inevitable to build structures at locations with less favorable geotechnical conditions in seismically active regions. The study was carried out to assess the effect of soil stiffness and conditions on RC frame displacement based on BNBC 2006 and proposed BNBC 2015. The variation in structural displacement due to different cases is investigated in this research. The structural displacements based on BNBC 2015 are always greater than that of BNBC 2006 for all proposed cases, considering similar soil condition. For all soil conditions, maximum increment in deflection generated for case 5 while the lowest increment found for case 2, as the analyses were static linear consideration, the earthquake load greatly influenced by the seismic zone coefficients. As the second highest deflection occurred in case 2 with the least increment, the structural cost in case 2 areas would be comparatively high considering the other areas but the structures will be least critical for new code consideration when the other parameters are same.

***Keywords**: Seismic analysis, Soil Condition, BNBC 2006, BNBC 2015, Deflection*

INTRODUCTION

Real challenge for an engineer is to design a structure which will be safe for all types of loading and economical. When the structure resting on the hard rock is subjected to seismic loads of an earthquake, the high stiffness of the rock compels the rock motion to be very close to the free field motion. Structures founded on the rock are assumed to be fixed base structures for the structural analysis purposes. However, the same structure would respond differently when supported on the soft soil deposit rather than the hard rock Foundation flexibility is recognized to have a significant effect on the dynamic behavior of the structures. Many researchers have considered the effect of soil-structure interaction on the dynamic behavior of structures where the structure exhibits linear behavior. However, in the structural dynamics field, a few researches have been conducted to investigate the effect of foundation flexibility on the response of structures such as reinforced concrete (RC) buildings deforming into their inelastic range. To get the superstructure's real behavior, the subgrade must be modeled sufficiently well. On the other hand, an advanced model of the superstructure needed to get the correct response in the subgrade. To capture the right behaviors of both superstructure and subgrade in one model, it must include a good soil-structure interaction (SSI).

Different studies had been carried out on seismic action in various aspects by several researches. It is found that a very few studies are carried out in these particular aspects. Earthquakes cause immense economic losses. Reducing disaster risk is a top priority for all concerns. So, the behavior of building under the influence of seismic load has been a major point of interest for the engineers over a long period of time.

Bangladesh lies well within an active seismic zone and is prone to earthquakes. To determine earthquake forces on a structure, static analysis has gained popularity in the country and also in many other countries because of the simplicity of the method. This calls for the use of an established and tested building code so as to ensure the safety of the structure and its occupants against the natural hazard. Bangladesh National Building Code (BNBC) was first organized in the year of 1993 but published in the year 2006 and known as BNBC 2006. As the number of high-rise buildings is increasing, the international codes followed for building design, detailing and construction is revised quite frequently to adopt the new practices. A drastic modification has been recommended for lateral forces (loads due to wind and earthquake forces) in the proposed code of BNBC 2015, which will be noticeable in design outputs.

The objective of the present study is to investigate the seismic response of RC stack-like structures interacting with the supporting soil where the structure exhibits nonlinear behavior. The effects of changes in the stiffness of concrete members due to cracking and yielding, as well as the foundation flexibility for a practical structure are examined. Here 8,10,12,15 & 20 storied buildings are used as practical structures to illustrate the SSI and cracking effects in reducing or increasing the response to earthquake loading.

METHOD

The displacement comparison of RC structures models, due to earthquake load in different seismic zones and different types of soil according to BNBC 2006 and BNBC 2015 are presented in this paper. Three-dimensional modeling of the structures was generated using SAP2000 software (version 20) is shown in Figure 1.

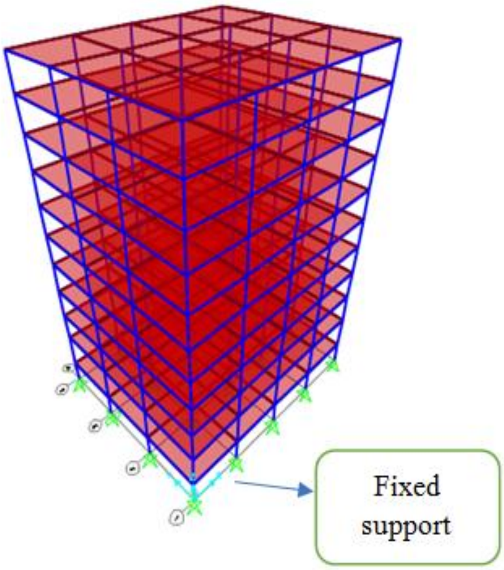


Figure 1: 3D Model of a 10 storied building (Fixed supported)

Idealization of the Structure

The analysis was carried out by the code (e.g. 2006 or 2015), height of the structure in numerical form (e.g. 8, 10, 12, 15 & 20) and seismic zone in a combination of numerical and alphabetic form (e.g. Z1, Z2, Z3 etc.). The variation of soil type in a combination of numerical and alphabetic form (e.g. S1, S2, S3 etc.) for BNBC 2006 and SA, SB, SC, SD for BNBC 2015. Designating S1 and SB by soil condition I, S2 and SC by soil condition II, S3 and SD by soil condition III. The pairs have similar properties. The story height was chosen as 90ft, 110ft, 130ft, 160ft and 210ft. 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 (Islam S. et.al;2019).

The RC frame structure considered in different zone according to the codes has been adopted for the purpose of study. The typical plan area of the buildings is 60ft x 72ft. The buildings are symmetrical about both the axis. All structures are considered as Special Moment Resisting Frame (SMRF) as lateral force-resisting system.

Properties of the Structural Elements

For different cases of height, the dimensions of reinforced concrete columns 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 (fy= 60 ksi). The design loads including Dead Load (DL), Partition Wall (PW), Floor Finish (FF), and Live Load (LL), have been determined in accordance with the provisions and in conformance with the general design requirements provided in BNBC. The earthquake force is assigned as lateral load on the structures for different seismic zone based on BNBC 2006 and 2015. The sectional, material properties and design loads of structure elements have been summarized in Table 1, Table 2 and Table 3 respectively.

Dimensions of footing were calculated with respect to safe bearing capacity. Spring stiffness representing soil flexibility is related to the size of footing. Footing area was determined using

Terzhagi’s bearing capacity for cohesive soils. To make the analysis most general, translation of foundation in two mutually perpendicular principle horizontal directions and vertical directions as well as rotation of the same about these three directions were considered here.

Table 1: Sectional Properties of the Structures

Story	**Column**			**Beam**		**Slab (in)**
	Corner column (in)	**Periphery column (in)**	**Interior column (in)**	**Internal (in)**	**Periphery (in)**	
8	**12"X18"**	**14"X18"**	**15"X25"**	**12"X22"**	**12"X18"**	**5"**
10	**12"X18"**	**14"X20"**	**15"X27"**	**12"X22"**	**12"X18"**	**5"**
12	**15"X20"**	**18"X22"**	**18"X30"**	**12"X22"**	**12"X18"**	**5"**
15	**15"X24"**	**18"X26"**	**18"X34"**	**12"X22"**	**12"X18"**	**5"**
20	**16"X24"**	**18"X32"**	**20"X40"**	**12"X22"**	**12"X18"**	**5"**

Table 2: Material Properties of the Structural Elements

SL	**Material**	**Properties**	**Symbol**	**Unit**	**Value**
1.	**Concrete**	**Unit weight**	γc	**Pcf**	**150**
2.	**Concrete**	**Compressive strength**	$f'c$	**Ksi**	**4**
3.	**Concrete**	**Modulus of elasticity**	Ec	**Ksi**	**3600**
4.	**MS Bar**	**Yield strength**	fy	**Ksi**	**60**

Table 3: 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

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 4.

RESULTS AND DISCUSSIONS

A calculative result of base shear for BNBC 2006 and BNBC 2015 has shown in Table 5. Based on the base shear, the impact of soil conditions (e.g. soil properties, soil stiffness etc.) on structural displacement was analyzed in this study. The structural displacements based on BNBC 2015 are always found greater than that of BNBC 2006 for all proposed cases, considering similar soil condition.

Top deflection increments at different cases based on BNBC 2006 and 2015 are summarized in Table 6. As shown in Table 6 maximum increment in deflection was generated in case 5 while it was minimum for case 2.

Table 4: Defined Seismic Zones for Different Cases According to BNBC 2006 and BNBC 2015 (Islam et.al, 2019)

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

These phenomena occur because of the difference in the value of Seismic Zone Coefficient, Z. The values of Z are 0.075 (Z1) and 0.2 (Z2) for BNBC 2006 and 2015 respectively. The difference between the value of is 0.125, which is the maximum between all cases. Whereas the values of Z are 0.25 (Z3) and 0.28 (Z3) for BNBC 2006 and 2015 respectively. The difference between the value of is 0.08, which is the minimum between all cases.

Table 5: Base shear for different soil conditions (case-5 as sample example)

Base Shear (Case-5)									
Storey	**Soil Condition I**			**Soil Condition II**			**Soil Condition III**		
	BNBC 2006	**BNBC 2015**	**% increment**	**BNBC 2006**	**BNBC 2015**	**% increment**	**BNBC 2006**	**BNBC 2015**	**% increment**
8 Storied	53.24	180.33	3.38	63.88	207.37	3.24	79.86	324.59	4.06
10 Storied	59.54	218.29	3.69	71.45	218.29	3.05	89.31	334.8	3.74
12 Storied	66.94	266.30	3.97	80.33	266.30	3.31	100.42	351.41	3.49
15 Storied	75.75	333.96	4.40	90.91	333.96	3.67	113.63	365.57	3.21
20 Storied	86.39	451.75	5.22	103.67	451.75	4.35	129.59	451.75	3.48

Table 6: Increment of deflection of defined cases

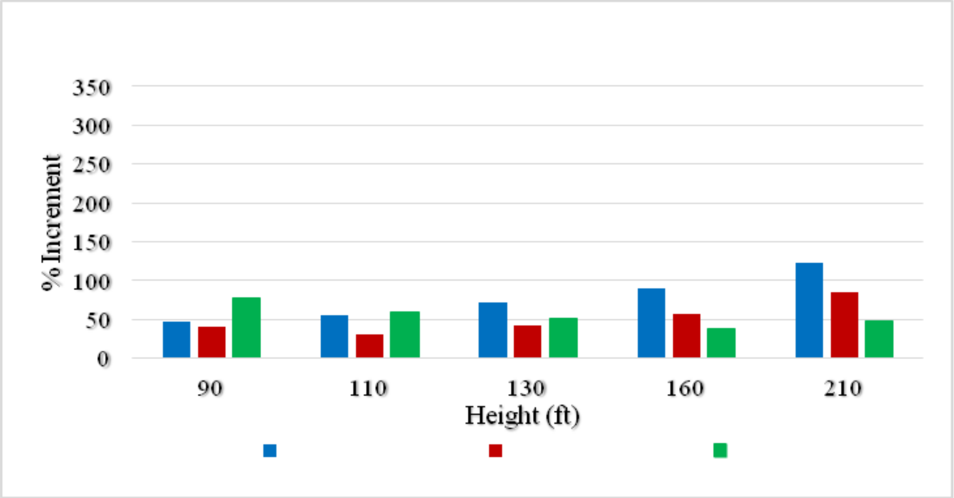
Top deflection data (in)				
	Case	**% Increment (Soil Condition: I)**	**% Increment (Soil Condition: II)**	**% Increment (Soil Condition: III)**
8 storied	1	47.0516	41.2097	76.8219
	2	14.6130	9.8210	37.5277
	3	90.9656	83.0212	129.1921
	4	36.3975	30.7200	63.7076
	5	172.8875	161.5138	227.4398
	6	63.6918	56.9196	96.4458
10 storied	1	55.9694	30.0851	59.4898

	2	21.3265	11.1915	24.0476
	3	101.5254	68.6525	107.2159
	4	43.8983	20.4255	47.9545
	5	187.7966	139.1549	195.9091
	6	72.7119	43.5211	77.5000
12 storied	1	71.6800	43.0520	50.9974
	2	33.5482	11.2788	17.4629
	3	122.5386	85.4514	95.7604
	4	58.9208	32.4359	39.8216
	5	215.9831	162.5775	176.4382
	6	89.5763	57.5352	65.8539
15 storied	1	89.1386	57.8618	38.2846
	2	47.1161	22.7884	7.3018
	3	145.6535	104.5833	79.0154
	4	75.4221	46.0938	28.1602
	5	250.8443	192.1875	156.0213
	6	110.5066	75.3125	53.5961
20 storied	1	122.5337	85.4047	48.3481
	2	73.0867	44.2077	15.3851
	3	188.4654	140.3583	92.3075
	4	106.0399	71.6789	37.3579
	5	312.1689	243.4939	174.7317
	6	147.2737	106.0733	64.8206

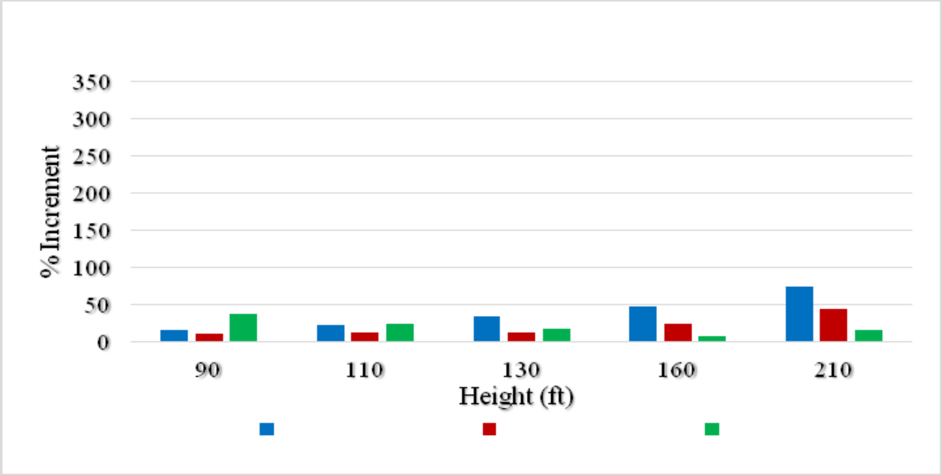
As the analyses were static linear consideration, the earth quake load and structural deflection greatly influenced by the seismic zone coefficients. The most interesting reveal is that the second highest deflection occurred in case 2 but least increment here. In this context it can be said that the structural cost in case 2 areas would be comparatively high considering the other areas but the structures will be least critical for new code consideration when the other parameters are same. The increment of variation can be shown in an ascending order (case 2< case 4 < case 1 < case 6 < case 3 < case 5). This is applicable for all proposed structure existing in soil condition I.

Variation of Deflection Increment for Different Soil Condition

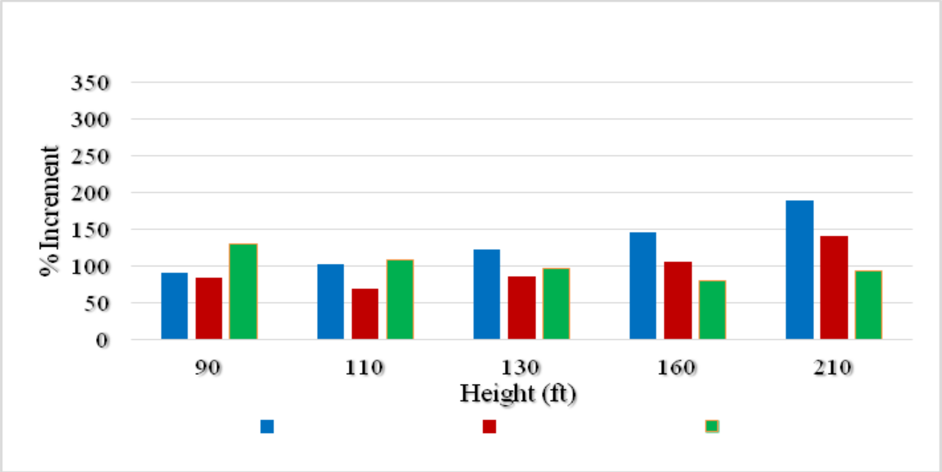
For a specific case and height, fluctuation in deflection for different soil conditions are shown in Figure 2.


% Increment
350
300
250
200
150
100
50
0
90
110
130
160
210
Height (ft)
🟦
🟥
🟩

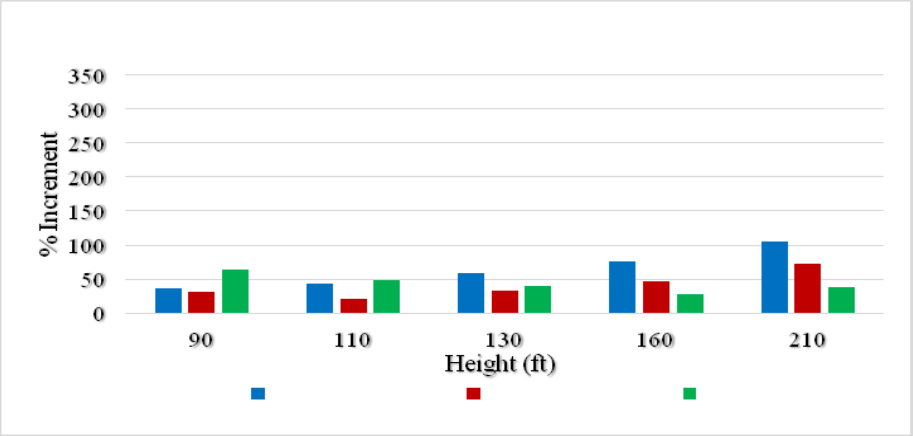
(a)


% Increment
350
300
250
200
150
100
50
0
90
110
130
160
210
Height (ft)
🟦
🟥
🟩

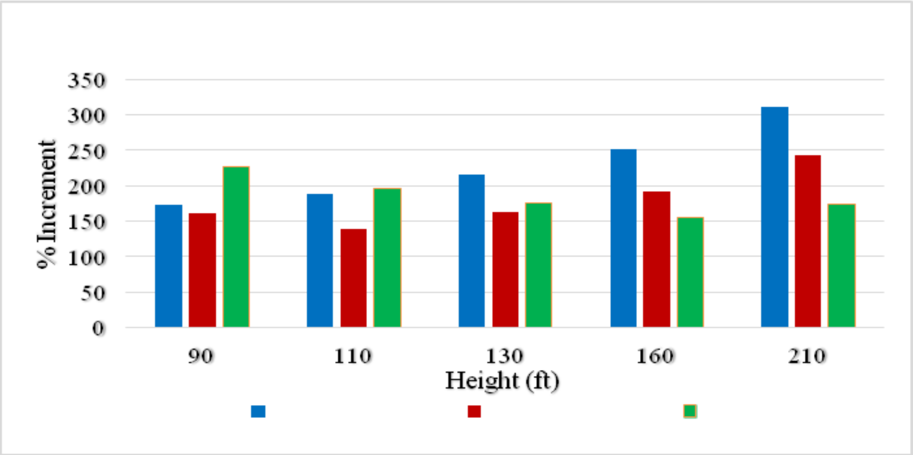
(b)


% Increment
350
300
250
200
150
100
50
0
90
110
130
160
210
Height (ft)
🟦
🟥
🟩

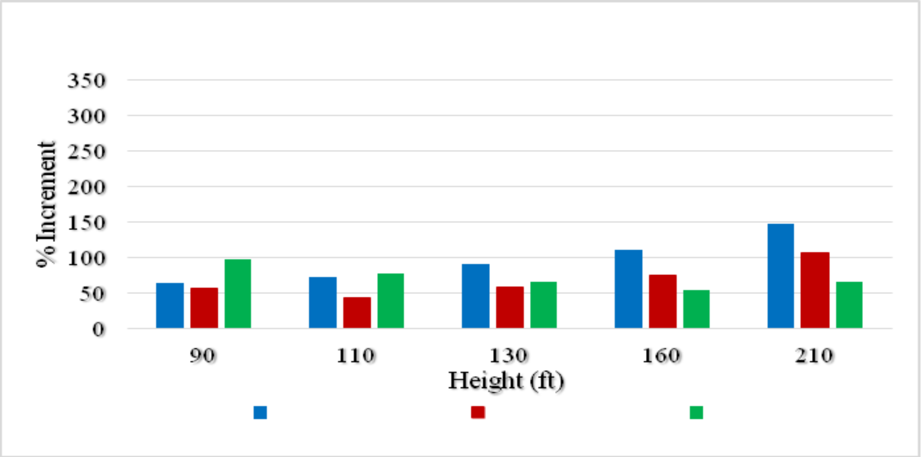
(c)



(d)



(e)



(f)

Figure 2: Variation in deflection increment with respect to soil condition for the proposed storey heights (a) Case -1, (b) Case-2, (c) Case-3, (d) Case-4, (e) Case-5 and (f) Case-6

From the Figure 2, it is observed that the variation pattern is almost similar for all cases. As the height of the structure increases, comparatively higher increment of deflection shown in better soil condition. In case of soil condition, I (better soil), with the increasing of height, the percentage of deflection is also increased and soil condition II also follow the same trend in a lower rate of increment compared to soil condition I. But in case of soil condition III the increment rate of deflection is vice-versa of soil condition I.

Figure 2, shows a better representative linear relation for all the cases, except a particular height of soil condition III. Comparing to soil condition types, Soil condition I shows a sharp increment of deflections with storey height. According to BNBC 2006 base shear is dependent on soil type and seismic zone without any lower boundary in values. But according to BNBC 2015 the value of spectral acceleration could not be less than (2/3 ZIβ). Hence soil type no longer has any effect on the base shear instead it is solely depended on seismic zone for a particular case. The spectral acceleration of 15 and 20 stories are below (2/3 ZIβ) for soil condition III. As a continuation of that the top deflection for both the structure almost same which leads to a low rate of deflection increment for soil condition III. From the graphs the deflection can be predicted with reasonable accuracy for the buildings designed on BNBC 2006 if they were to be designed on BNBC 2015.

CONCLUSIONS

After analyzing the results, the following conclusions have been drawn,

- Deflection increment for different cases with increasing height shows similar pattern for all soil types.

- From the analysis case 5 shows maximum and case 2 shows minimum variation. The increment of variation can be shown in an ascending order (case 2 < case 4 < case 1 < case 6 < case 3 < case 5).

- Soil condition I shows higher increment of deflection with the increasing height.

- Soil condition III has shown lower rate of increment of deflection for high storey building.

REFERENCES

I. ATC-40 (1996). *Seismic Evaluation and Retrofit of*

Concrete Buildings, Volume-1, Seismic Safety Commission, California.

II. Bangladesh National Building Code (BNBC, 2006), *Housing and Building Research Institute*, Bangladesh Standard and Testing Institution, Dhaka, Bangladesh.

III. Bangladesh National Building Code (2015). *Housing and Building Research Institute*, Mirpur, Dhaka, Bangladesh.

IV. Banglapedia Encyclopedia, National Encyclopedia for Bangladesh CD-ROM, February 2004, Asiatic Society of Bangladesh.

V. Banglapedia Encyclopedia, National Encyclopedia for Bangladesh CD-ROM, February 2004, Asiatic Society of Bangladesh.

VI. Bolt, B.A., *Earthquake*, Fourth Edition, W.H Freeman and company, New York, USA. (1991).

VII. Ghosh, S. K. and Domel, A.W. (1992), "Design of Concrete Building for Earthquake and Wind Forces", *International Conference of Building Officials*, 5360, South Workman Mill Road, Whittier, California 90601.

VIII. Ghosh, S.K, *"Geological map of Bangladesh,"* Geological Survey of Bangladesh (GSB) (1990).

IX. Guta D. K., "Tectonic frame work and oil and gas Prospect of Bangladesh" in Proc,*4th Conference Bangladesh Geological* (1978).

X. Gazetas, G. and Mylonakis, G. Seismic Soil-Structure Interaction: Beneficial or Detrimental?*Journal of Earthquake Engineering.*2000, Vol. 4, No. 3, 277-301.

XI. Hossain, K. M., *"Seismicity and Tectonics of Bangladesh",* Department of Geology Dhaka University, Dhaka-1000, Bangladesh. 1989.

XII. IBC (2006). International Building Code, International Code Council, USA.

XIII. Islam, S., Chowdhury, S., Islam, T., Jahan, A. & Ahmed, T.Comparative Study on RC Frame Displacement Due to Earthquake Force Based on BNBC 2006 & BNBC 2015, *Journal of Civil and Construction Engineering*.2019, Volume 5, Issue1.

XIV. Islam, M. R., *"Seismic loss Estimation for Sylhet City"* MSc. Engineering Project BUET, Dhaka. (2005)

XV. Kramer, Steven L. (1996), *"Geotechnical Earthquake Engineering"*, University of Washington, Prentice-Hall International Series in Civil Engineering and Engineering Mechanics.

XVI. Kraus, I. and Dzakic, D. (2012). *Soil-structure interaction effects on seismic behavior of reinforced concrete frames*, Josip JurajStrossmayer University of Osijek, Croatia.

XVII. Murty, C. V. R., *"Earthquake Tips,"* Indian Institute of Technology Kanpur, India. (2005)

XVIII. Sarfuddin, *"Earthquake intensity attenuation relationship for Bangladesh and its surrounding region."* M.Sc. Thesis, Bangladesh University of Engineering and Technology, Dhaka. (2001)

XIX. Schueller, "High-Rise Building Structure", *A wiley-Inter science Publication*, JOHN Wiley & Sons, New York. 1977,pp. 15-59.

XX. VERNEY, P., *The Earthquake Hand book*, Paddington Press, New York. (1979)

XXI. Wolf J. P. (1985). *Dynamic Soil-Structure Interaction*, Prentice Hall, Englewood Cliffs, New Jersey.

XXII. www.geo.mtu.edu,(2018) "Seismic waves" 11/9/2018, 6:50pm.

XXIII. www.quora.com,(2018) "Major tectonic plates" 11/10/18, 7:37pm

XXIV. www.wikipedia.org, (2005) “Encyclopaedia” seismic analysis, 29.09.2018, 10:30pm.

XXV. Sanhik Kar Majumder and Priyabrata Guha, (2014). Comparison between wind and seismic load on different types of structures, *International journal of engineering science invention*, 3(4), pp 42-54.

XXVI. Dae Kun Kwon and Ahsan Kareem, (2015). Wind load factors for dynamically sensitive structures with uncertainties, *Engineering structures (Elsevier)*, 10(3), 53-62.

XXVII. Tsuyoshi Nozu and Tetsuro Tamura, (2015). Mesh-adaptive LES for wind load estimation of a high-rise building in a city, *Journal of wind engineering and industrial aerodynamics (Elsevier)*, 144, 62-69.

XXVIII. Mahesh Suresh Kumawat and L.G.Kalurkar, (2014). Analysis and design of multi-story building using composite structure, *International Journal of Research in Engineering and Technology*, 3(2), 125-137.

XXIX. Balaji and Selvarasan, (2016). Design and analysis of multi-storeyed building under static and dynamic loading conditions by using E-TABS. *International Journal of Technical Research and Applications*, Volume 4 , Issue 4, PP.1-5.

XXX. Alberto Carpinteri, Mauro Corrado, Giuseppe Lacidogna and Sandro Cammarano. (2012). Lateral load effect on tall shear wall structure of Different height. *Structural engineering and mechanics*, vol. 41, No.3 PP 313-337