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Analysis and Design Comparison of RCC Buildings with Shear Wall by BNBC-1993 and BNBC-2012

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Significant changes in lateral loads and design guidelines for buildings have been introduced in new Building code (BNBC 2012) of Bangladesh. In this paper, a comparative study is presented to observe the responses and also the differences in design of RCC buildings with respect to BNBC 1993 and BNBC 2012.The structures are considered to be situated at a location with severe earthquake prone zone of the country like Chittagong. At the same time, the location is also with very high wind speed, which may dominate over the seismic load in the design of high-rise buildings. Analysis of a typical six and a twelve storied RCC buildings with shear walls are performed considering both these high wind and intense seismic load together. Load combinations between the two codes are also significantly different. Hence, design comparison of structural components, such as beams and columns are also performed considering the different load combinations.

1. Introduction

In 1993 Bangladesh national building code (BNBC) was first drafted and kept unchanged for almost 20 years. Since, then various changes have taken place in every discipline of the building technology. Ministry of housing and public works formed a steering committee with the responsibility of updating BNBC-1993 to make this code time worthy. Consequently draft copy is published in 2014 as BNBC 2012.There are so many changes in BNBC 2012 as compared to BNBC 1993.

Major differences between BNBC 1993 and BNBC 2012 and Comparative study on lateral load analysis are reviewed here.The differences between the codes for lateral loading can be divided in two parts. Earthquake and wind load parameters having major changes are briefly discussed.

Seismic Loading:

Bari &Das (2013) made a comparative analysis of BNBC for earthquake parameters. The method of calculation of seismic loading is more or less same in BNBC 2012 and BNBC 1993. Both these codes consider the earthquake force as a lateral force. The forces are determined on the basis of a base shear by Equivalent Lateral Force procedure. Base shear is calculated on the basis of seismic zone factor, structural importance factor and response reduction factor which is a function of structural system. Time period and soil type as a function of acceleration spectrum (Cs) defined by BNBC 2012 and as a function of numerical coefficient (C) defined by BNBC 1993 are used in the expression of base shear.Major changes are discussed for soil factor(S), Response Reduction Factor (R), Time Period (T), Normalized Response Spectrum Acceleration (Cs) and Seismic Weight (W).

Wind Loading:

Faysal (2014) has shown a comparative study of BNBC for wind loading as wind load as a part of lateral load is very important concern in structural analysis.The

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investigation reveals that wind load in urban areas (Exposure A) according to BNBC 2012 is slightly higher than BNBC 1993. But wind load in obstructed and unobstructed open terrain type areas (Exposure B and C) according to BNBC 2012 is notable lower than BNBC 1993. This paper aims at the comparison of provisions of wind load analysis given between BNBC 1993 and BNBC 2012. The designers who use BNBC 1993 as their basis to calculate the design wind load, this comparative study will provide them with a relation showing percent increase or decrease of design wind load in the new code with respect to the old one.

In BNBC 1993, first the sustained wind pressure is calculated on the basis of importance of structure, height and exposure condition and basic wind speed, which in turn depends on the region the structure is located in.

In BNBC 2012, first the sustained wind pressure is calculated on the basis of importance of structure, exposure and topographic condition of the region, directionality factor and wind basic wind speed, which in turn depends on the region where the structure is located. Finally, the design wind pressure is calculated by multiplying the sustained wind pressure with gust effect factor and external pressure co-efficient and adjusting the value for internal pressure.

In comparing the basic wind speeds given between BNBC 1993 and BNBC 2012, it is important to note that BNBC 1993 specifies fastest-mile wind speeds whereas BNBC 2010 provides basic wind speed in terms of 3-second gust wind speeds. Both BNBC 1993 and BNBC 2012 provide basic wind speed associated with an annual probability of occurrence of 0.02 (50 year recurrence interval) measured at a point 33 ft (10m) above the mean ground level in a flat and open terrain. In both BNBC 1993 & BNBC 2012, tornadoes have not been considered in developing the basic wind speed distribution.

Comparative Study on Lateral Load Analysis

Imamet. al.(2014) compared the analysis data between BNBC 1993 and drafted 2012 which is most relevant to this paper. A brief description of their work is thus helpful to understand the comparison.The study aims at the comparison of provisions of wind and earthquake analysis given in existing BNBC 1993 to that in BNBC 2012. It is found that seismic base shear of the building calculated by BNBC 2012 varies significantly from seismic base shear calculated by BNBC 1993. Finally structural analysis and design of a typical apartment building situated in Dhaka City is conducted to demonstrate the changes regarding lateral load in BNBC 2012 with respect to BNBC 1993. Analysis is made to compare maximum reinforcement requirement for column design to provide guideline to the engineer for the most economic design.A typical multistoried residential building situated in Dhaka is selected for the case study to identify the changes in analysis and design with BNBC 2012 as compared to BNBC 1993. The building is a Reinforced Cement Concrete (RCC) building with intermediate moment resisting frame system.

For earthquake load, the analysis is conducted for base shear, maximum lateral displacement with respect to variable number of stories (from 2 to 18). A basic difference in maximum reinforcement requirement and inter story drift for 6, 12, and 18 storiedbuildings are also presented. For earthquake load base shear, maximum lateral displacement and inter story drift is higher in BNBC 2012 than

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BNBC1993.Discussions on analysis results are significant and described briefly as follows.

(i) The rate of increase or decrease in story drift is 12% on an average in BNBC-1993 and 17% on an average in BNBC-2012.
(ii) Maximum and minimum reinforcement is required for internal and edge column respectively. It is also seen that column reinforcement for BNBC-2012 is higher than BNBC-1993.

The wind load is higher in BNBC-1993 than BNBC-2012. The rate of increase in wind load with respect to number of stories is more uniform in BNBC-2012 than BNBC-1993. The rate of increase in maximum story displacement for higher story is 52.93% for BNBC-1993 and 45.2% for BNBC-2012.

For better understanding of the effects of lateral loads and other issues of adual-system building with shear wall situated at Chittagong is considered for this study. The major changes related to seismic and wind load parameters are considered here.To compare the effects, two buildings with shear wall, six storied with ground floor(G+6) and twelve storied with ground floor (G+12) are analyzed.The objectives of this study are to analyze the lateral load effect on multistoried building with shear wall, situated in the severe seismic zone having highest wind speed and also to compare the design of beam and column, designed according to both codes. The study is done using the finite element package software ETABS.

2. Finite Element Modelling of the Structure

Two 3D finite element models are considered for analyzing with different heights with same plan dimension having 2880sq-ft area. Figure 1 and Figure 2 show the finite element model of the G+6 storied and G+12 storied buildings respectively. Figure 3 shows a typical elevation of G+6 storied building. Figure 4 shows a typical plan view of the buildings. Typical story height is 10 ft and from ground floor to base is 8 ft. The material properties are considered as concrete compressive strength, $f_c^{'}$ = 3000 psi and steel yield strength, f_y= 60000 psi. Table 1 represents the section properties of both the structures. The different vertical loads considered for the present study are tabulated in Table 2.

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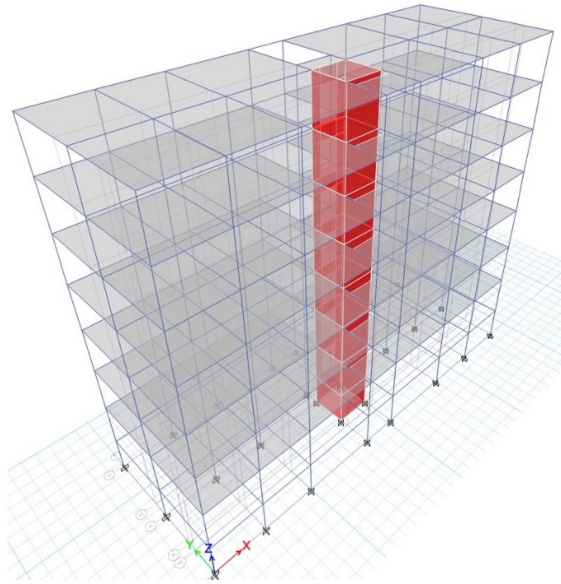


Figure 1: 3D view of G+6 Storied Building

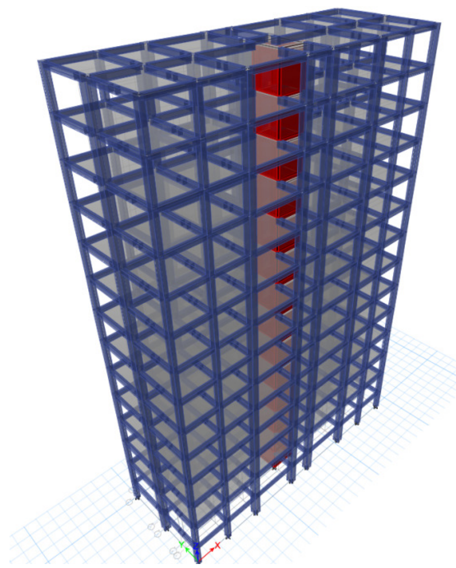
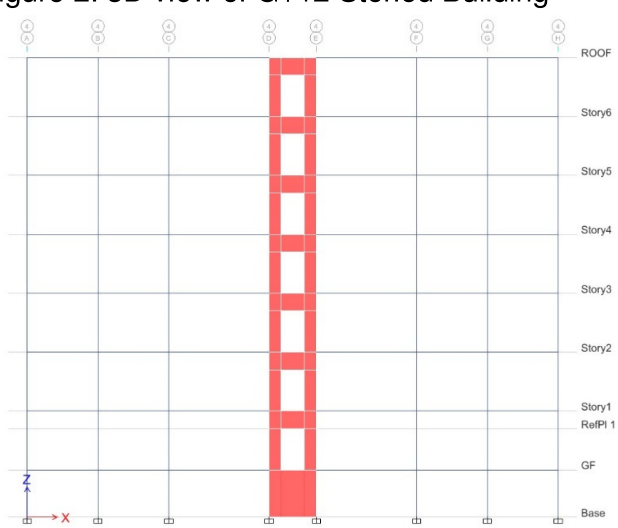


Figure 2: 3D view of G+12 Storied Building



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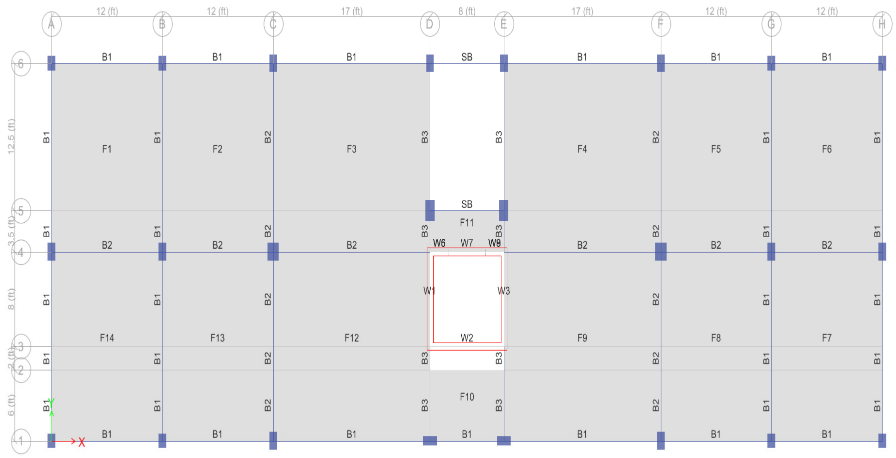

Figure 4: Plan view of thebuildings

Table 1: Section Properties

Member	Section		Dimension
Beam	G+6 Story	B_1	16 x 14 in
		B_2	18 x 14 in
		B_3	21 x 16 in
	G+12 Story	B_1	18 x 16 in
		B_2	20 x 16 in
		B_3	21 x 18 in
Grade Beam	GB_1		12 x 10 in
	GB_2		15 x 12 in
Stair Beam	6 Story	SB	18 x 12 in
	12 Story	SB	18 x 16 in
Column	G+6 Story	C_1	12 x 12 in
		C_2	15 x 12 in
		C_3	16 x 12 in
		C_4	18 x 12 in
	G+12 Story	C_1	20 x 16 in
		C_2	20 x 16 in
		C_3	20 x 14 in
		C_4	28 x 24 in
Slab	Thickness		5 in
Shear Wall	G+6 Story		8 in
	G+12 Story		10 in

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Table 2: Different vertical Load Cases

Load Name	Load Type	Details	Value
Dead	Dead Load	Self weight of structural members Calculated automatically using self weight multiplier in ETABS	--
		Floor Finish	20 psf
		Partition Wall	25 psf
		Wall	0.5 k/ft
		Stair	1.0 k/ft
		Lift core weight (on Shear Wall)	200 psf
Live	Reducible Live Load	On floor	40 psf
		On Stair Beam	1 k/ft

The lateral load, earthquake load and wind load considered according to the code are tabulated in Table 3 and 4 respectively. The Load Combinations are tabulated in Table 5.

Table 3: Seismic Load Parameters

BNBC 1993	BNBC 2012
Seismic Zone Factor, Z= 0.15 Site Coefficient, S= 1.5 Response Modification, R= 9 (Other Parameters are kept same in both code)	Time Period: Ct(ft)= 0.03 and m=0.75 Story Range: Base to Roof Response Modification, R= 5.5 System overstrength, omega= 3 Deflection Amplification, C_d= 4.5 Occupancy Importance, I= 1 0.2 sec Spectral Acceleration, S_s = 0.952 1 sec Spectral Acceleration, S_1 = 0.532 Long period Transition Period = 8 Site class= SD

Table 4: Wind Load Parameters

BNBC 1993	BNBC 2012
Wind Pressure Coefficient= Hand Calculated Wind Speed = 162.5 mph (Other Parameters are kept same in both code)	Wind Pressure Coefficient= Program Determined Wind Speed = 180 mph Exposure Type = B Importance Factor = 1 Topographical Factor, K_{zt} = 1 Gust Factor = 0.85 Directionality Factor, K_d = 0.85 Exposure Height= GF to Roof Parapet Height= 3ft

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Table 5: Load Combinations

BNBC 1993	BNBC 2012
1) 1.4DL	1) 1.4DL
2) 1.4DL+1.7LL	2) 1.2DL+1.6LL
3) 1.05DL+1.275LL+1.275WLx	3) 1.2DL+LL+1.6WLx
4) 1.05DL+1.275LL-1.275WLx	4) 1.2DL+LL-1.6WLx
5) 1.05DL+1.275LL+1.275WLy	5) 1.2DL+LL+1.6WLy
6) 1.05DL+1.275LL-1.275WLy	6) 1.2DL+LL-1.6WLy
7) 0.9DL+1.3WLx	7) 0.9DL+1.6WLx
8) 0.9DL-1.3WLx	8) 0.9DL-1.6WLx
9) 0.9DL+1.3WLy	9) 0.9DL+1.6WLy
10) 0.9DL-1.3WLy	10) 0.9DL-1.6WLy
11) 1.05DL+1.275LL+1.4025EQLx	11) 1.2DL+0.8WLx
12) 1.05DL+1.275LL-1.4025EQLx	12) 1.2DL-0.8WLx
13) 1.05DL+1.275LL+1.4025EQLy	13) 1.2DL+0.8WLy
14) 1.05DL+1.275LL-1.4025EQLy	14) 1.2DL-0.8WLy
15) 0.9DL+1.43EQLx	15) 1.2DL+LL+EQLx
16) 0.9DL-1.43EQLx	16) 1.2DL+LL-EQLx
17) 0.9DL+1.43EQLy	17) 1.2DL+LL+EQLy
18) 0.9DL-1.43EQLy	18) 1.2DL+LL-EQLy
	19) 0.9DL+EQLx
	20) 0.9DL-EQLx
	21) 0.9DL+EQLy
	22) 0.9DL-EQLy

3. Result and Discussion

Analysis data for seismic loading are extracted for both X and Y direction which are discussed here. For earthquake loading, values of base shear for BNBC 2012 is much higher than BNBC 1993 as shown in Table 6. Therefore, maximum story displacement is much higher in BNBC-2012 than BNB-1993 as shown in Table 7. Maximum story drift is higher in BNBC-2012 than BNBC-1993 as shown in Figure 5 and Table 8.

Table 6: Comparison of BNBC 1993 & BNBC 2012 with respect to base shear (kip)

	G+6 Story		G+12 Story	
BNBC	**X**	**Y**	**X**	**Y**
1993	180.5	192.5	260	265
2012	558	614	687	707

Table 7: Comparison of BNBC 1993 & BNBC 2012 with respect to maximum story displacement (in) for seismic loading

	G+6 Story		G+12 Story	
BNBC	**X**	**Y**	**X**	**Y**
1993	0.7	0.5	1.225	1.076
2012	2.174	1.6	3.325	2.943

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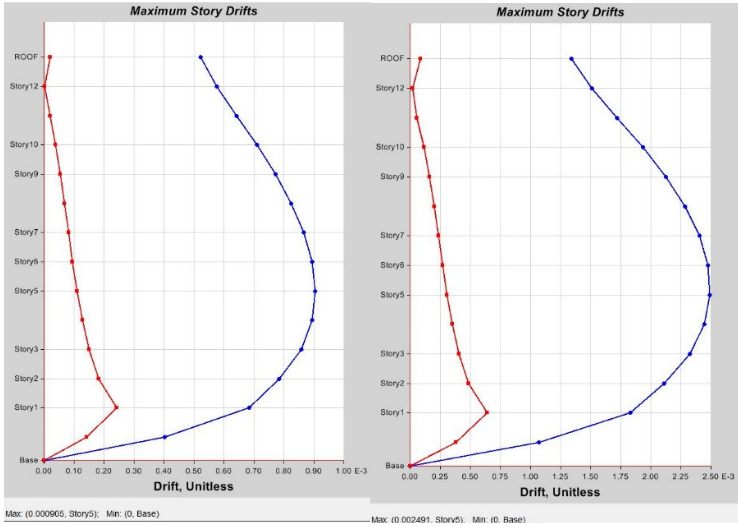

BNBC 1993 BNBC 2012

Figure 5: Story drift for seismic loading

Table 8: Comparison of BNBC 1993 & BNBC 2012 with respect to maximum Story drift for seismic loading

BNBC	G+6 Story		G+12 Story	
	X	Y	X	Y
1993	0.000889	0.000642	0.0009	0.000772
2012	0.0028	0.0021	0.0025	0.002143

For wind loading, it is found that the base shear is much high in BNBC 1993 than BNBC 2012 as shown in Table 9. Maximum displacement and story drift are also higher in BNBC -1993 than BNBC-2012 (Table 10 and 11 and Figure 6).

Table 9: Comparison of BNBC 1993 & BNBC 2012 with respect to base shear (kip) (For Wind Load)

BNBC	G+6 Story		G+12 Story	
	X	Y	X	Y
1993	153	552	356	1285
2012	118	406	249	872

Table 10: Comparison of BNBC 1993 & BNBC 2012 with respect to Maximum Story Displacement (in) for wind loading

BNBC	G+6 Story		G+12 Story	
	X	Y	X	Y
1993	0.48	1.16	1.305	3.99
2012	0.4	0.9	0.96	2.79

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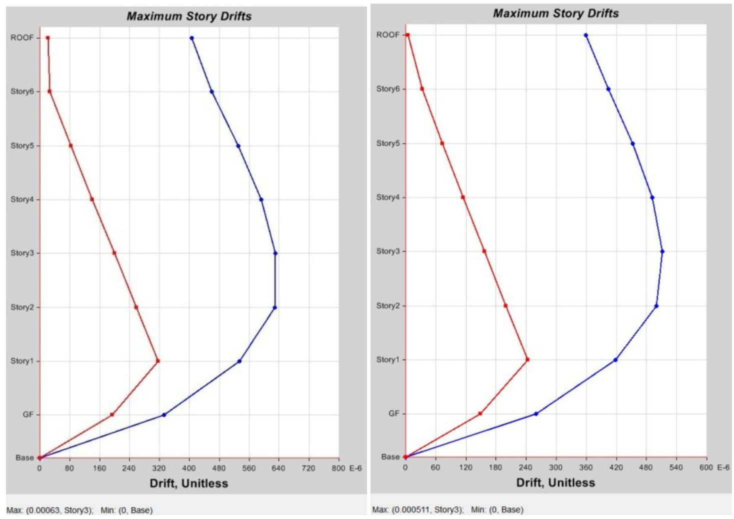

BNBC 1993 BNBC 2012

Figure 6: Story drift for wind(X) loading (6 story)

Table 11: Comparison of BNBC 1993 & BNBC 2012 with respect to maximum story drift for wind loading

BNBC	G+6 Story		G+12 Story	
	X	**Y**	**X**	**Y**
1993	0.00063	0.0015	0.00104	0.003
2012	0.0005	0.0011	0.000747	0.002037

The effect of these change in lateral load on design are calculated by determining the rebar percentage. The rebar percentage considering the same concrete dimensions in both cases are tabulated in Table 12. Three different types of column are considered. Rebar percentage of the columns are showing that for every column BNBC 2012 require more reinforcement than BNBC 1993. A particular beam is design based on both codes. The same results are also observed for the reinforcement required for beams as shown in Table 13. The reinforcement is determined at three locations (Left, Mid and Right) of the beam. The reinforcement required for beams are higher for BNBC-2012 than BNBC-1993.

Table 12: Comparison of BNBC 1993 & BNBC 2012 with respect to rebar percentage for column

COLUMN	G+6 Story		G+12 Story	
	BNBC 1993 (%)	**BNBC 2012 (%)**	**BNBC 1993 (%)**	**BNBC 2012 (%)**
Internal	2.74	4.47	5.56	5.48
Edge	2.42	3.18	4.36	4.13
Corner	1.71	3.58	2.13	2.85

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Table 13: Comparison of BNBC 1993 & BNBC 2012 with respect to rebar percentage for beam

		G+6 Story			**G+12 Story**		
BNBC	Beam	Left	Mid	Right	Left	Mid	Right
1993	Top	0.29	0.28	0.5	0.3	0.35	1.52
	Bottom	0.18	0.17	0.41	0.21	0.26	1.24
2012	Top	0.38	0.41	0.55	0.48	0.56	1.35
	Bottom	0.28	0.28	0.45	0.32	0.37	0.99

4. Conclusion

The findings of the study aresummarized below:

i) Seismic base shear is much higher for BNBC 2012, but for the wind loading base shear is higher for BNBC 1993. This happened because of the calculation procedure for design wind pressure in BNBC-2012 is totally different from BNBC-1993. Two new terms topographic factor (K_{zt}) and directionality factor (K_d) has been introduced in BNBC-2012 which are responsible for the decrease of wind pressure.

ii) As a result of lateral load differences, maximum story displacement and story drifts are higher for BNBC 2012 for earthquake. On the other hand displacement and story drift are higher for BNBC 1993 due to wind loading.

iii) Required reinforcement for lateral load in BNBC 1993 is relatively economic than BNBC 2012 as the amount of reinforcement required for columns and beams are less in BNBC 1993. This results are applicable for the buildings in Chittagong city only.

iv)

Similar study can be performed for other types of buildings such as steel frames, ordinary moment resisting frames and masonry structures etc. located in different places with different site conditions. The study conducted in this research is for Chittagong City only. However the seismic zone coefficient and wind speed varies for different parts of Bangladesh. Similar study can be performed for other parts of Bangladesh especially for highly seismic active zones.More buildings with different height and aspect ratio may also be considered.

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