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Lateral Load and Design Disparity between BNBC1993 and BNBC2020

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Abstract **Original Research Article**

Building codes are the minimal requirements for design and construction to assure a safe and resilient structure. A building code recognized as the Bangladesh National Building Code (BNBC) is existent in Bangladesh (BD), just like in other developing nations. It's now a difficult task to comply with the code because of the extensive update after two decades. The main goal of this work is to compare the analytical and design requirements for lateral loads between BNBC2020 and BNBC1993. To do so, a large number of structural models are assessed using ETABS following the considered code procedure at different locations in the country. It also compares the lateral load parameters such as zone coefficient, wind velocity, building period, story shear, base shear, drift, deflection, reinforcement ratio etc. The parametric comparison of the outcomes has demonstrated that BNBC2020 is more conservative and boosts the safety factor against lateral loads. Engineers will be able to comprehend the differences in lateral load between these codes after perusing this study.

Keywords: BNBC, Earthquake, Wind, FEM, Design

INTRODUCTION

The purpose of a building code is to establish minimum standards for design, construction, quality of materials, use and occupancy, location and maintenance of all buildings within the region to safeguard, within achievable limits, life, limb, health, property and public welfare. Building codes are a set of rules and minimum standards that a governing body uses to regulate structures. A building code not only addresses many of a society's most important concerns including public health, safety and environmental protection but also addresses cost efficiency and investment expenditure. As a developing country, Bangladesh (BD) [1] has a code like other countries to protect buildings and the people and property inside them from earthquakes, windstorms, fires and other extreme events. In BD, the first building code or rule was formulated in 1993 and named Bangladesh National Building Code (BNBC-93) [2]. But the rule was not published as a gazette for the following 13 years due to legal issues. That rule too had no specification about its implementing authority. The building code got legal status after the Building Construction Act 1952 was amended in 2006 [3]. Code updates spur innovation that creates better products and stimulates economic development [4]. State and local building codes need to keep up with continuing advancements in building science and technology. By the end of the year, many new products have emerged that were not contemplated by the previous model codes. The code must be updated to keep up with the times [5]. For which BD government initiated a revision of the building code in 2009. After going through a long procedure, an amended building code was finalized but had not been published in a gazette for several years. Finally on 11th February 11, 2021, the government published the Bangladesh National Building Code (BNBC-20) [6] in a gazette. Building construction across the country now needs to comply with the new code. But a transition in wind load and earthquake load provisions in the modernization code can be observed [2, 6]. From the previous study, it has been shown that the lateral load calculation method of BNBC93 is more or less similar to UBC94 [7] and BNBC20 like ASCE7-05 [8]. This paper focuses on the considered lateral load actions for structures at different locations in the country. Similarities and differences between the considered design codes are evaluated.

METHODOLOGY

To find out the disparity of lateral load between BNBC93 and BNBC20, first of all different parameters for lateral load are evaluated and compared for four compatible locations to cover the whole country. Then for every considered location, several building models are built in ETABS [9] in which the structural configuration is regular and the structural system for lateral resistance is a special concrete moment resisting frame. The building geometry in plan 100ft x 45ft and variable building height is selected for the study as in Fig. 1 & 2. Both code provisions are implemented on all models having similar circumstances, such as structural occupancy category, importance factor and soil condition. After analyzing all models, force and other outcome parameters are assessed and compared as a table or graph. The section and material properties of structural elements are fixed through the analysis as follows: all beams (12x20) in, all columns (15x20) in, concrete cylinder strength 4000psi and steel yield strength 60000psi.

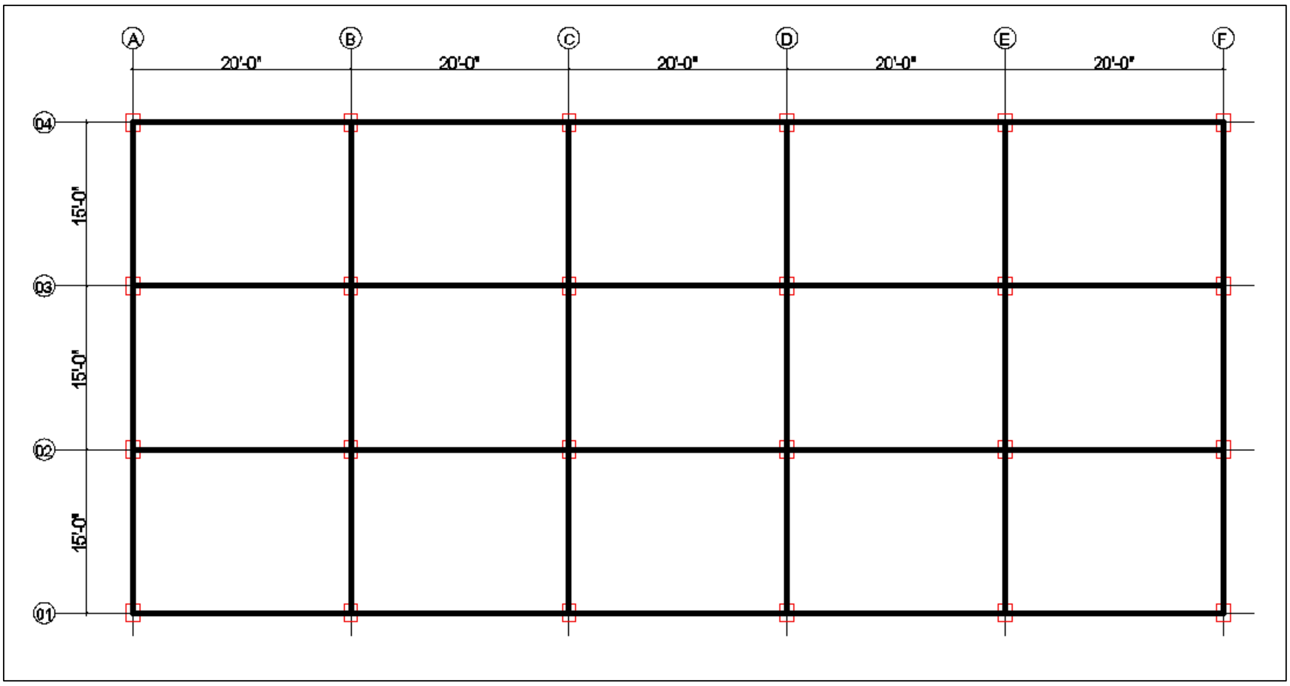

Figure 1: Typical floor plan and structural system of the studied building

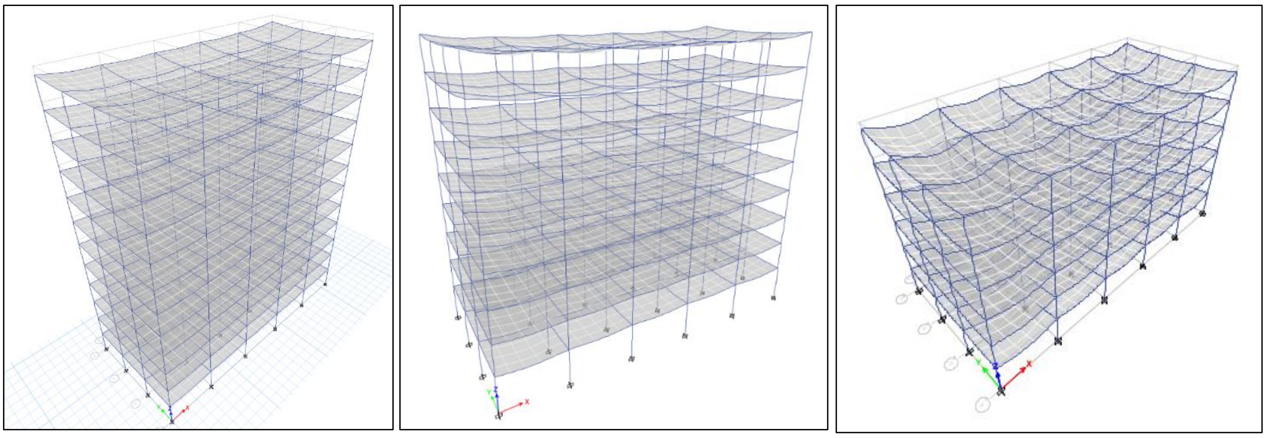

Figure 2: Three-dimensional finite element model (6, 9 & 12 storied)

Modeling and analysis

Using ETABS software, 3D finite element models were built for four distinct locations; i.e., Dhaka, Chittagong, Pirojpur, and Sylhet. This software is used for the analysis of engineering structures and it was recommended by Abdo [10] for the analysis and design of multi-story RCC buildings. The structural elements, beams and columns were assigned in the model as frame elements and slabs were modeled as thin shell elements. The shell elements were mashed by auto mesh. Supports were fixed at the base level. Rigid diaphragms were assigned to each floor. Self-weight and floor finish of 20 psf were assigned as dead load and the live load was assigned 43 psf as a uniform load on the floor in each model. Wind and earthquake loads were assigned as per locations that comply with codes.

RESULTS AND DISCUSSIONS

Wind load in the considered codes

The minimum design wind load on the building is determined based on the velocity of the wind, exposure conditions and the shape and size of the building. To detect the discrepancy between the codes clearly, structure shape, size and exposure conditions are assumed to be similar throughout the research. Basic wind speed in BNBC20 is comparatively higher than BNBC93 which is compared in the bar chart Fig. 3. In BNBC93, basic wind speed is the fastest mile wind speed whereas BNBC20 is the 3sec guest speed.

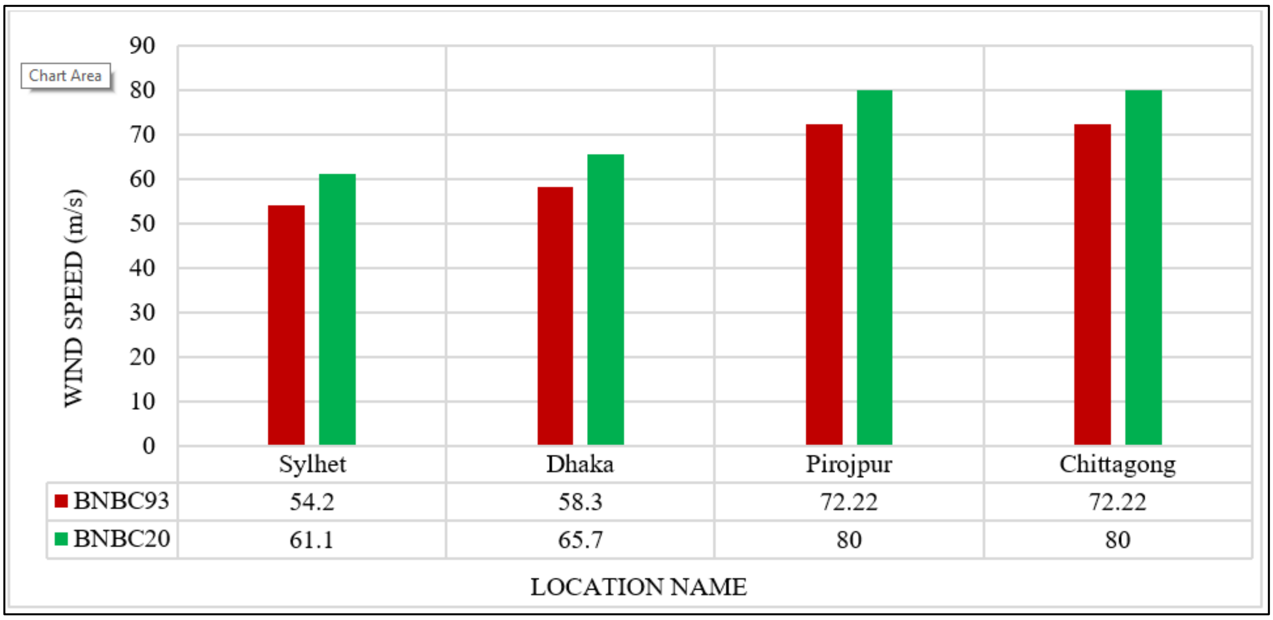

Figure 3: Compression of basic wind speed

Though the basic wind speed is comparatively more in BNBC20 but the design wind load is less than BNBC93 in the structure (Fig 4 & 5). Design wind load is calculated projected area method as per BNBC93 and the analytical procedure as per BNBC20. The overall wind force in BNBC20 decreased from 2 to 40% as compared to BNBC93. Since the wind load is more generated in BNBC93, building deflection is also more. Table 1 represents the comparison of building deflection at wind load. In BNBC93 building deflection check for only wind load case whereas BNBC20 deflection check for (D+0.5L+0.7W) combination, where D = dead load, L= live load, W= wind load. Values are derived from code-specific cases in Table 1.

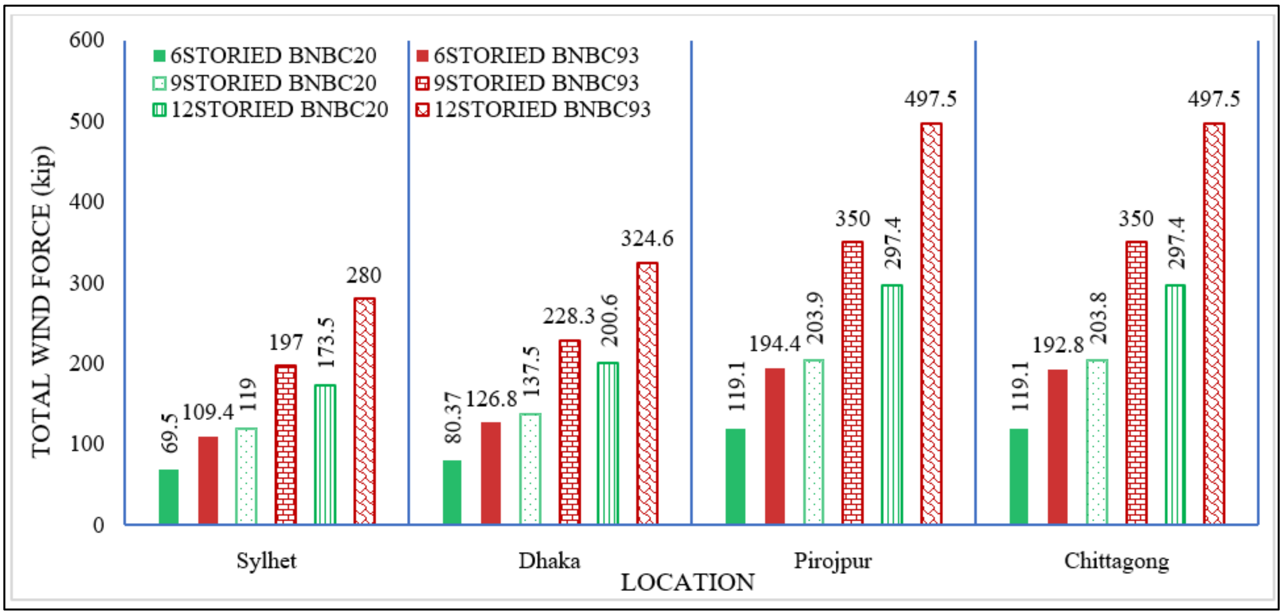

Figure 4: Compression of total wind force at X direction

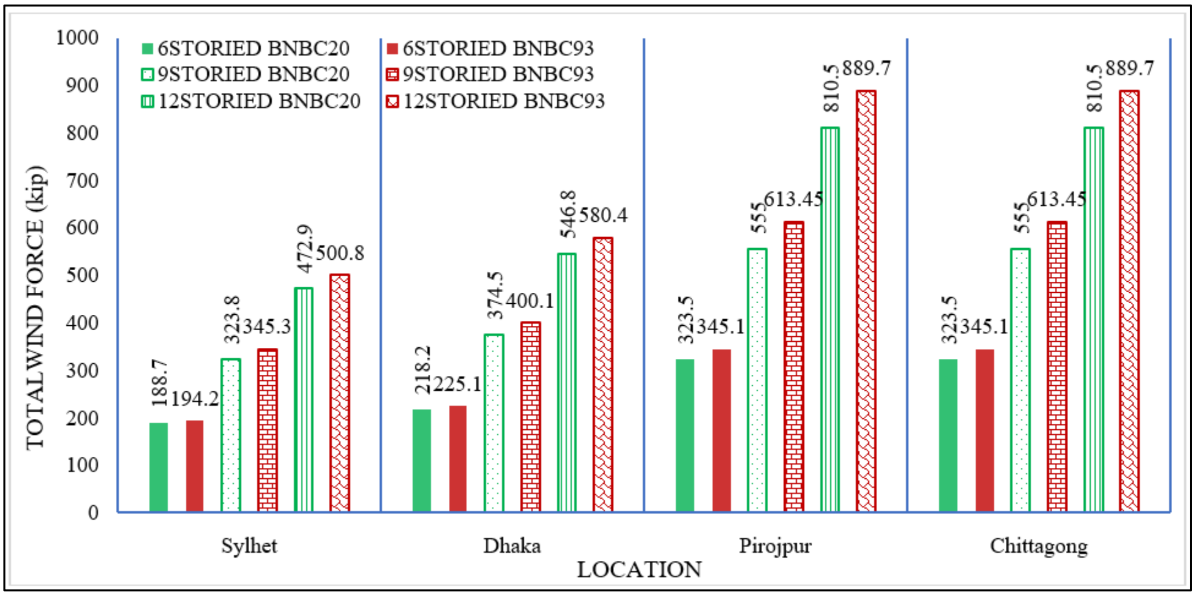

Figure 5: Compression of total wind force at Y direction

Table 1: Difference between maximum deflection at selected locations

Location	BNBC 93			BNBC 20		
	Maximum Deflection [in]			Maximum Deflection[in]		
	6 storied	9 storied	12 storied	6 storied	9 storied	12 storied
Sylhet	0.331	0.941	1.958	0.253	0.692	1.424
Dhaka	0.384	1.091	2.269	0.293	0.801	1.647
Pirojpur	0.589	1.672	3.478	0.434	1.186	2.441
Chittagong	0.589	1.672	3.478	0.434	1.186	2.441

Earthquake load in the considered codes

Bangladesh can be affected by moderate to strong earthquake events due to its proximity to the collision boundary of the northeast moving Indian plate and the Eurasian Plate [11]. In this paper, the earthquake forces are determined on the basis of a base shear by the Equivalent lateral force (ELF) method [12]. Base shear depends on the seismic zone, building period, response reduction factor and seismic weight, etc. The design basis earthquake is taken as 2/3 of the maximum considered earthquake in BNBC20 where BNBC93 was considered full. Table 2 presents the comparison of base shear equations.

Table 2: Difference between base shear equations

BNBC93	BNBC20
$V = \frac{ZIC\ W}{R}$ V= Base shear, Z = Seismic zone coefficient, I = Structural importance coefficient, C = Numerical coefficient, W = Total seismic load, R = Response modification coefficient	$V = \frac{2ZIC_s\ W}{3R}$ V= Base shear, Z = Seismic zone coefficient, I = Structural importance coefficient, C_s =Normalized acceleration response spectrum, W = Total seismic weight, R = Response modification coefficient

Seismic zone factor (Z)

The seismic zoning map intends to indicate the maximum considered earthquake (MCE) motion in different parts of the country. Based on the severity of the probable intensity of seismic ground motion and damage, Bangladesh was mapped and divided into three generalized seismic zones in BNBC93 with zone 3 being the most severe. The seismic zoning map is revised in the update BNBC20 with provisions for four seismic zones with different levels of ground motion (Table 3). Each zone has a seismic zone coefficient (Z), which represents the maximum considered peak ground acceleration (PGA) on very stiff soil or rock (site class SA) in units of g (acceleration due to gravity).

Table 3: Comparison of the seismic zone and zone coefficient at the considered place

Location	BNBC 1993		BNBC 2020	
	Seismic zone	Zone Coefficient	Seismic zone	Zone Coefficient
Pirojpur	1	0.075	1	0.12
Dhaka	2	0.15	2	0.20
Chittagong	2	0.15	3	0.28
Sylhet	3	0.25	4	0.36

Building Period (T)

The building period plays an important role in the design of earthquake-resistant structures. For the determination of the lateral loads, it is first required to estimate the fundamental period of the building either theoretically or experimentally [13]. Though it depends on mass and stiffness [14], both codes use the empirical formula to find out the building period. The form $T = C_t h^m$, where h = structural height, C_t & m = numerical coefficient, Tables 4 & 5 show the numerical coefficient difference between the codes and the approximate building period.

Table 4: Comparison of the values for coefficients to estimate the approximate period

Structural Framing system[a]	BNBC93		BNBC20	
	C_t	m	C_t	m
Concrete moment-resisting frame	0.073	0.75	0.0466	0.9
Eccentric braced steel frame	0.073	0.75	0.0731	0.75
Steel moment-resisting frame	0.083	0.75	0.0724	0.8
All other structural systems	0.049	0.75	0.0488	0.75

[a]Structural height in meters.

Table 5: Comparison of Building period (T)

Position	BNBC93			BNBC20		
	Approximate period [s]			Approximate period [s]		
	6 storied	9 storied	12 storied	6 storied	9 storied	12 storied
Pirojpur Dhaka Chittagong Sylhet	0.646	0.877	1.087	0.637	0.918	1.189

Response Reduction Factor (R)

The earthquake forces acting on the structure are reduced using the response modification/reduction factor (R) in order to take advantage of the inelastic energy dissipation due to inherent ductility and redundancy in the structure as well as material over-strength. The value of the response modification factor (R) is significantly reduced in BNBC20 because of the enhancement of the design of basic earthquake motion. In this study, the lateral force resisting system is considered as a moment resisting system for which in Table 6 comparison is shown only for this structural system.

Table 6: Comparison of Response Modification Coefficient between considered codes

Basic structural system	Seismic force resisting system	BNBC93	BNBC20
Moment Resisting Frame System	Special steel moment frames	12	8
	Intermediate steel moment frames	-	4.5
	Ordinary steel moment frames	6	3.5
	Special reinforced concrete moment frames	12	8
	Intermediate reinforced concrete moment frames	8	5
	Ordinary reinforced concrete moment frames	5	3

Seismic weight (W)

Seismic weight (W) is the total dead load of a building or a structure including partition walls, and applicable portions of other imposed live loads. In the case of dead load both code considerations are similar but for live load not equal.

Base shear (V) & drift

Seismic effects are reflected by base shear on the structure. Base shear is the essence of the seismic load. Fig.6 shows the comparison of building base shear for different heights of the building. It has been found that for earthquake design BNBC20 is more conservative than BNBC93 in Fig.6. Response modification is scaled down and the seismic zone factor is raised for earthquake load in BNBC20. It resulted in an increase in base shear of the building of 1.5 to 3 times. Also, it can be realized that seismic zone transition has a great impact on base shear. According to BNBC20, every location's base shear value is greater than BNBC93 which is reflected also comes in the drift ratio in Fig. 7. Although the permissible limits differ in both codes, the graph shows that the drift ratio average of 10 to 15 times is greater in BNBC20. The allowable drift ratio is 0.0025 for the study's structure pursuant to BNBC93 whereas 0.020 in BNBC20 is 8 times more comparatively.

Load Combination

The load combination plays a significant role in the strength design method. The Load Factor is applied to the nominal loads. They persist in combination with other loads and are referred to as factored Loads. Table 7 displays the load combinations for each of the codes that are compared. It can be observed that even though the wind speed rises in BNBC20, the overall wind force falls. In the load combination that is necessary for building design, the wind load factor is enhanced by 23% in BNBC20. Besides this, compared to BNBC93, the total base shear in BNBC20 ascended from 50 to 200% but the seismic load factor decreased by 30%.

Reinforcement ratio

In contrast to strained action results, reinforcement results are the most essential since they may be transformed into money. Additionally, the price of reinforcement steel is almost four times higher than concrete in BD. Column cross-sectional dimensions and concrete strength are adjusted for design in Table 8 to order to assess the economic viewpoint. Fig. 8, 9 & 10 respectively exhibit the reinforcing ratios for the 6, 9 and 12-story buildings. According to studies, BNBC93 is much more conservative for reinforcement than BNBC20. It has been also noticed from the research study that wind combinations control the majority of building column design. BNBC20 column reinforcement is more than (0-75) % of BNBC93. As the amount of reinforcements rises, so will the building's cost.

Table 7: Comparison of basic load combination

BNBC93 Basic Load Combination	BNBC20 Basic Load Combination
1.4 D	1.4 D
1.4D+1.7L	1.2D+1.6L+0.5L_r
0.9D+1.3W	0.9D+1.6W
0.9D+1.43E	0.9D+1.0E
1.05D+1.275W	1.2D+1.6L_r+0.8W
1.05D+1.4025E	1.2D+1.0L+1.6L_r
1.05D+1.275L+1.275W	1.2D+1.0L+0.5L_r+ 1.6W
1.05D+1.275L+1.4025E	1.2D+1.0L+1.0E
D= Dead load, L= Live load, W= Wind load, E= Earthquake load.	D= Dead load, L= Live load, L_r= Roof live load, W= Wind load, E= Earthquake load.

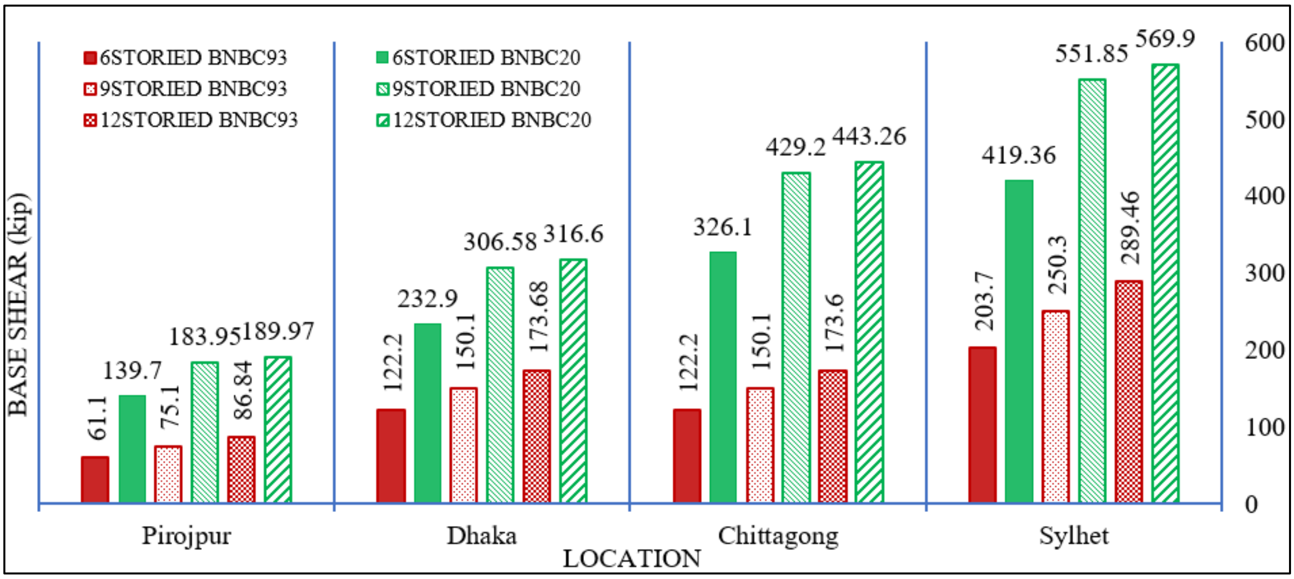

Figure 6: Base shear based on ELF analysis

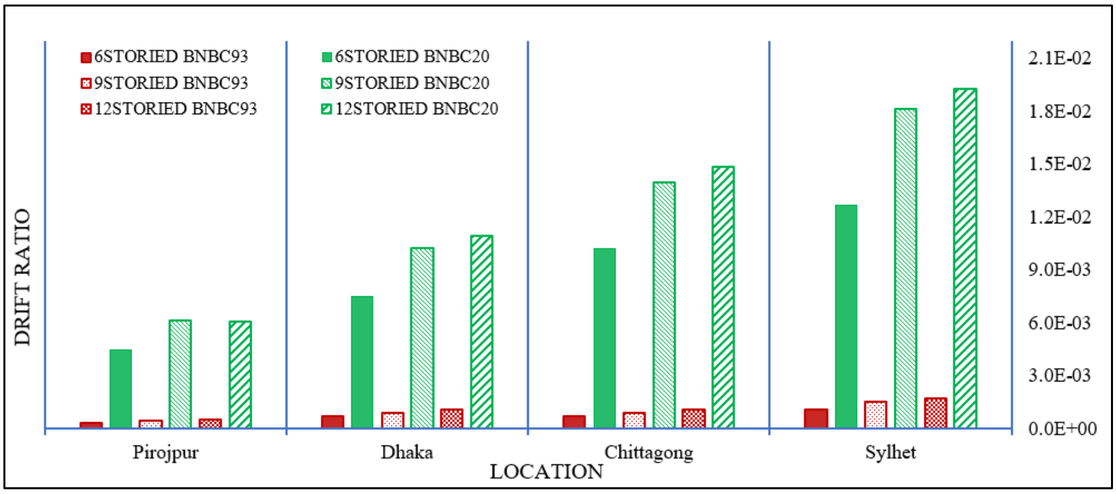

Figure 7: Maximum drift ratio based on ELF analysis

Table 8: Column shape, size and properties for design

No of stories	Building height(ft)	Column size(in)	Concrete strength (psi)	Reinforcement yield strength
6	60	15*18	3000	60000
9	90	15*20	4000	60000
12	120	15*24	4000	60000

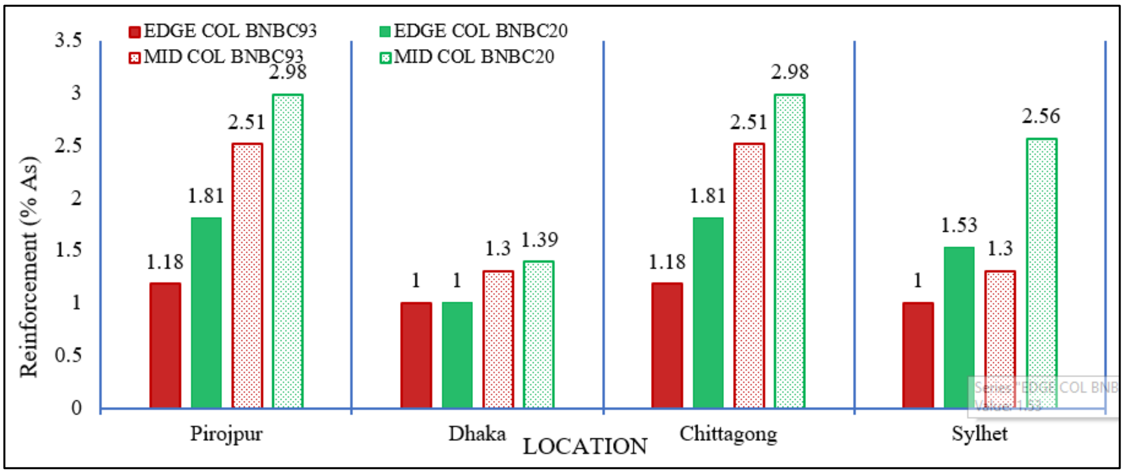

Figure 8: Reinforcement (%) for 6 storied building

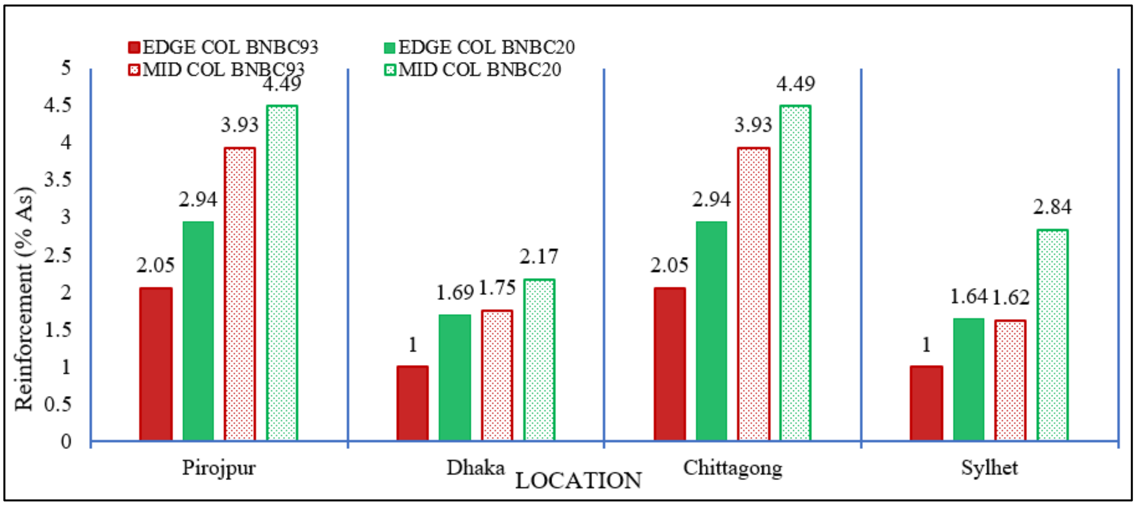

Figure 9: Reinforcement (%) for 9 storied building

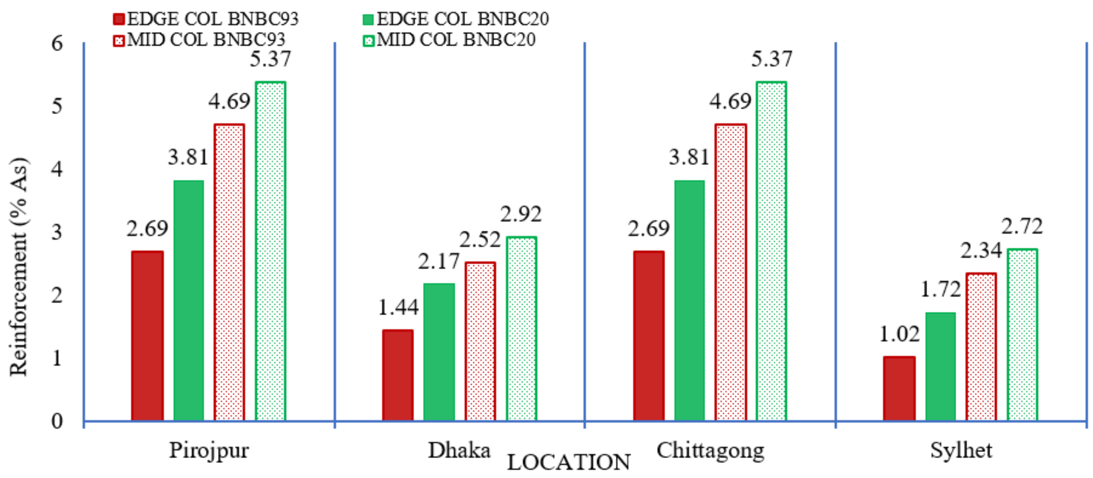

Figure 10: Reinforcement (%) for 12 storied building

CONCLUSIONS

Throughout the study, the lateral load provisions and results of analytical and design the widespread of 4 locations 60ft, 90ft & 120 ft height buildings were reviewed for both BNBC. Based on the findings, the following conclusions can be made:

- A lower wind force is exerted by BNBC20 while having a faster wind speed than BNBC93. However, the most of building structure design is controlled by the wind combination as the wind load factor increases in BNBC20.
- As a result of lengthening the building period, improving the seismic zone factor, and lowering the response modification factor, the base shear at BNBC20 is significantly enhanced compared to BNBC93. Because of this, the BNBC20 combination has a low seismic load factor while yet providing a high level of earthquake protection.
- The lateral load of the structure is significantly impacted by the seismic zone transition position in update BNBC20.
- Due to a more conservative approach, complying with BNBC20 will become a stressful process that involves not only new structures but also extending or reorienting the existing structure.
- Buildings that are designed and constructed in accordance with the BNBC20 code cost roughly 0–75% more in steel, which slows down national development and leads to the reluctance of people to abide by the code's requirements. Further studies need to be made in this aspect.

Ethical Approval

Not Applicable.

Competing interest

The authors have no relevant financial or non-financial interests to disclose.

Consent for publication

Not Applicable.

Authors' contributions

Md. Golam Rabbi wrote the manuscript and made all of the finite element models for this research, Md. Faishal Hasan prepared the figures. All authors reviewed the manuscript.

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Availability of data and materials

All data generated or analyzed during this study are included in this article. If there are any more issues regarding the dataset, you may contact the corresponding author.

REFERENCES

1. Badiuzzaman, M. H. O. R., Sarkar, M. S. K., & Rahman, M. T. (2018). Development transition from least developed country (ldc) to developing country: current progress and challenges of Bangladesh. *International Journal of Development Research*, *8*(09), 22812-22818.
2. Housing and Building Research Institute, Bangladesh National Building Code 1993.
3. https://www.blast.org.bd/content/key-note/national-building-code-29June.pdf
4. Edwards, N., Chauvin, J., & Blanchet, R. (2019). Advocating for improvements to building codes for the population's health. *Canadian Journal of Public Health*, *110*, 516-519.
5. David L. Pierson, S.E. (n.d). SECB in articles, https://www.structuremag.org/?p=322.
6. BNBC, "Bangladesh National Building Code (BNBC) 2020," House Build. Res. Inst., 2020.

7. Atique, F., Wadud, Z. (2001). A comparison of BNBC-93 with other building codes with respect to earthquake and wind analysis, in The Eighth East Asia-Pacific Conference on Structural Engineering and Construction (Nanyang Technological University, Singapore).
8. Information at https://www.secure.skghoshassociates.com/seminar/bnbc/wind-loads.pdf
9. Computers and Structures Inc. Extended Three-Dimensional Analysis of Building Systems,Berkeley, (CA, USA); 2010.
10. El-Kholy, A.M. SAP-Etabs-Safe-Course-550(R)-PART 02 ‘‘Class notes” – Pages 159-160. Fayoum University; 2017. Accessed 31 January 2018, http://www.fayoum.edu.eg/amk00.
11. Ali, M.H. (1998). Earthquake database and seismic zoning of Bangladesh.
12. Seismic Loads: Guide to the Seismic Load Provisions of ASCE 7-05, Finley A. Charney https://doi.org/10.1061/9780784410769
13. Salama, M. I. (2015). Estimation of period of vibration for concrete moment-resisting frame buildings. *HBRC Journal*, *11*(1), 16-21.
14. Cutinha, L. L., & Karanth, P. (2018). Study on time period as per IS CODE using Etabs software. *Int J Curr Eng Sci Res*, *5*(5), 2394-2697.