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Comparative Analysis of Building Seismic Response: Exploring the Impact of Evolving Design Standards on Structures.

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Abstract

This paper presents the findings of a finite element modeling computational study into the behavior of a 7-story building. According to the BNBC 1993 and BNBC 2020 regulations, this study's focus was on evaluating key loading parameters such as the base shear, normalized acceleration response spectrum, structure period, story displacement, shear, drift, and overturning moment. Also, the response spectrum analysis was carried out using the BNBC 1993 and 2020 codes, and a graph showing the relationship between time and acceleration was created. The findings showed that the BNBC 2020 code's calculation of the building period was the same as the BNBC 1993 code's calculation of the same factor. Moreover, the BNBC 2020 code has a greater normalized acceleration response spectrum than the BNBC 1993 code. In contrast, the base shear calculated using the BNBC 1993 code was lower than that found using the BNBC 2020 code. The study also reveals that the ratio of story displacement, story shear, and story overturning moment between BNBC 2020 and BNBC 1993 is around 2.00 in all stories. This study highlights the significance of applying modern design regulations for maintaining structural safety by offering insightful information regarding the seismic reaction of a 7-story building.

Keywords: *Base Shear; Story Response; Response Spectrum; Earthquake, Building Period.*

1 Introduction

Bangladesh is under the threat of a massive earthquake in the coming years. Bangladesh has been the victim of several destructive as well as minor earthquakes during the past 200 years. [1] Bangladesh has seen more than 250 earthquakes since gaining its independence in 1971, some of which were stronger than 6.0 magnitude. [2] The country's leading experts are of the opinion that as much as 70 percent of the total land area of Bangladesh is vulnerable to earthquakes while 80 percent of the total population faces tremor threats. If a tremor strikes the country, Dhaka, the capital city, will be the worst affected. More than a crore people are staying in Dhaka for their livelihood. So, there are a huge number of residential buildings. Many areas were built 10-15 years back. Being densely populated and having the highest concentration of wealth, Dhaka will be the highest casualty.
Bangladesh National Building Code must be strictly enforced to avoid casualties from natural disasters like earthquakes. Weak and defectively designed buildings must be immediately identified as the quickest and retrofitted. Recently there have been significant changes in various codes of the Bangladesh National Building Code (BNBC), especially the Seismic Codes. So, in our study, there has been an analysis of the behavior of a reinforced concrete building following the new BNBC codes and a comparison with the old one.

Chowdhry and Bokare [2017] studied different types of dynamic analysis for building displaying earthquake threats. [3] Saiful et al [2011] researched to develop a reliable Dhaka earthquake time history, functioning as a competent seismic record that can be used for precise nonlinear dynamic analysis of various structures as there is a lack of earthquake data for Dhaka. The study revealed that the generated time history is of a similar pattern to the prominent earthquake like the 1952 Kern County earthquake [4] and 2008 Pomona earthquake records selected for evaluation of the generated data. So, time history data according to BNBC can be used as suitable seismic data for the dynamic analysis of structures. In their 2014 study, Bari and Das compared various seismic analysis requirements from various building codes from various nations. They first investigated several seismic characteristics in the draft version of BNBC 2010 and contrasted them with those in BNBC 1993. Then, they graphically contrasted the BNBC regulations from 1993 and 2010 with those from other nations, including the

National Building Code of India from 2005 (NBC-India 2005) and the American Society of Civil Engineering's 7-05 (ASCE 7-05) [5]. Imam et al. (2014) evaluated the contrast between the wind and earthquake analysis provisions provided in the then-current BNBC 1993 and those in the BNBC 2012 that were then being proposed. They carried out a structural study and design of a typical apartment building in Dhaka City to show the differences between the planned BNBC 2012 and BNBC 1993 in relation to lateral load. Additionally, they compared inter-story drift and the maximum reinforcement needed for column design to give the engineer instructions for the most cost-effective design. It was discovered that the BNBC-2012 design of reinforced concrete structures for lateral load is relatively more cost-effective than BNBC-1993 because BNBC-2012 in Dhaka City requires less reinforcement. [6]

This study intends to examine the behavior of a reinforced concrete building following the new BNBC codes and a comparison with the old one. Using the ETABS 2017 software for both BNBC 1993 and BNBC 2020 seismic standards, a model of a seven-story reinforced concrete building is created to achieve the goals of this article. A static analysis is performed to examine the behavior of the building under regular and earthquake loads to ensure that the structure is earthquake resistant. Finally, a comparative analysis of building seismic responses is evaluated according to BNBC 1993 and BNBC 2020.

2 Methodology

2.1 Building Geometry and Loading Pattern

The study is performed on a 7-story RC building. The building, for example, has four bays in the longitudinal direction and three bays in the transverse direction. The height of each floor is 10 ft. Two types of beam sections are considered for the building in the example. Grade beam (GB) and Beam 1 (B1). The dimension of GB is 550×300 and the dimension of B1 is 450×300. Three types of column sections are used during the modeling of the studied building. The dimensions of column C1, C2, C3 are respectively 500×300, 400×300 and 550×300. Two different slab thicknesses are used during modeling. Slabs defined as 'Roof slabs' are used in roofs with a thickness of 125 mm. The slab used on other floors has a thickness of 150 mm. The constructed model is assumed to be fixed on the ground.

Table 1. Material Properties for the 7-story Building

Material Properties	Value
Concrete compressive strength (fc ')	27.6 MPa
The modulus of Elasticity E(Concrete)	24855.58 MPa
Poisson’s Ratio (U)	0.2
Grade of Steel	60 Gr
Minimum Yield strength (Fy)	413.69 MPa
The modulus of Elasticity E (Rebar)	199947.98 MPa

Table 2. Considered Load Intensity

Load	Floor	Roof
Live Load (LL)	2.0 kN/m2	3.0 kN/m2
Floor Finish (FF)	1.0 kN/m2	0.5 kN/m2
Partition Wall Load (PW)	12 kN/m	3.2 kN/m2

Table 3. Comparison of seismic different parameters as Per BNBC 1993 and BNBC 2020

Parameters	BNBC 1993	BNBC 2020
The Building Period (sec)	0.721	0.721
Normalized acceleration response spectrum (Cs)	1.87	2.39
Base Shear (kN)	228.01	414.467

2.2 Response spectrum analysis as per BNBC 1993 and BNBC 2020

As per BNBC 2020, response spectrum analysis evaluates a linear structure's dynamic response to ground movement. It determines lateral loads, displacement, shear forces, and overturning moments using a design acceleration response spectrum. This method accounts for various vibration modes, making it a modal analysis procedure. [3]

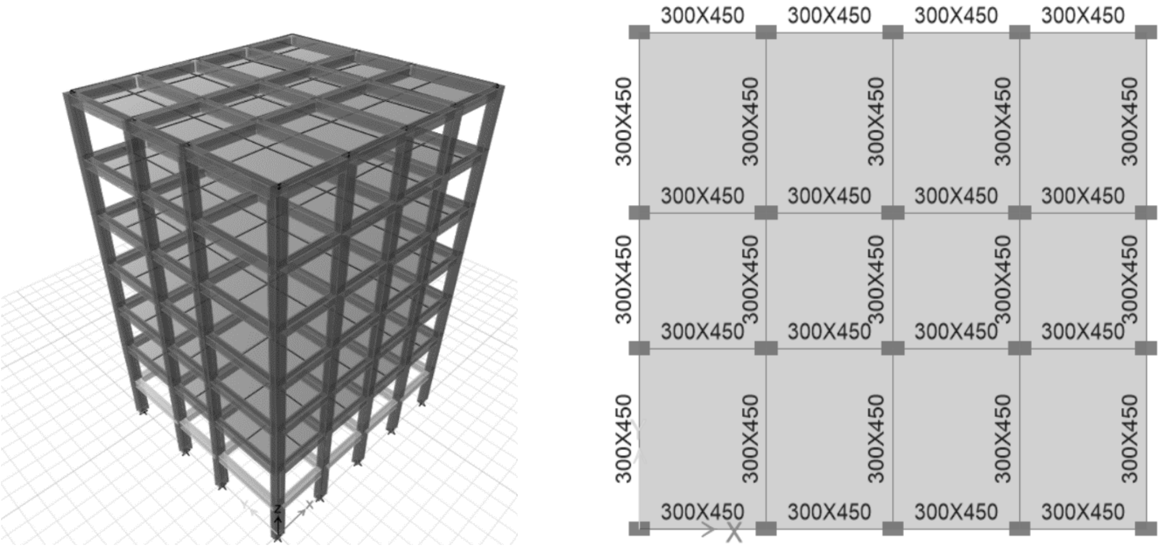

Figure 1. (a) 3-Dimensional model of the building (b) Plan view of 1st Floor of the Building

2.2.1 Response spectrum function graph

A response spectrum function consists of a lineup of the period versus spectral acceleration values. In ETABS the acceleration values in the function are not assumed to have specific units and so the acceleration value is considered normalized. Instead, when the response spectrum case is defined, a scale factor is specified with which the units are multiplied. [7] The function graphs for BNBC 1993 and BNBC 2020 are displayed in Fig 2.

2.2.2 Structure responses for response spectrum analysis

According to BNBC 2020, in the response spectrum analysis method, the base shear Vrs; each of the story shear, moment, and drift quantities; and the deflection at each level shall be determined by combining their modal values. The combination shall be carried out by taking the square root of the sum of the squares (SRSS) of each of the modal values or by the complete quadratic combination (CQC) technique. The complete quadratic combination shall be used where closely spaced periods in the translational and torsional modes result in the cross-correlation of the modes. The amplification of accidental torsion is not required where accidental torsional effects are included in the dynamic analysis model by offsetting the center of mass in each story by the required amount. A base shear, V shall also be calculated using the equivalent static force procedure. Where the base shear, Vrs is less than 85 percent of V all the forces but not the drifts obtained by response spectrum analysis shall be multiplied by the ratio $0.85VVrs$. The displacements and drifts obtained by response spectrum analysis shall be multiplied by Cd/I to obtain design displacements and drifts, as done in an equivalent static analysis procedure. [3]

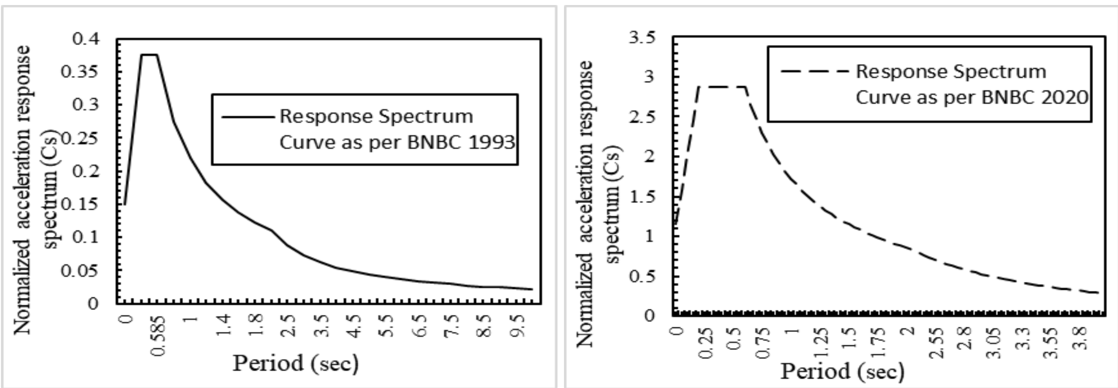

Figure 2. Response Spectrum Curve as per (a) BNBC 1993 and (b) BNBC 2020.

3. Results and Discussion

Response Spectrum Analysis is performed on a linear mathematical model of a structure in accordance with the BNBC 1993 and BNBC 2020 codes. The objective of this analysis is to examine the distinctions among various parameters pertaining to structural responses, such as base shear, maximum displacement, shear forces, and overturning moment. These distinctions are visually presented through graphical illustrations.

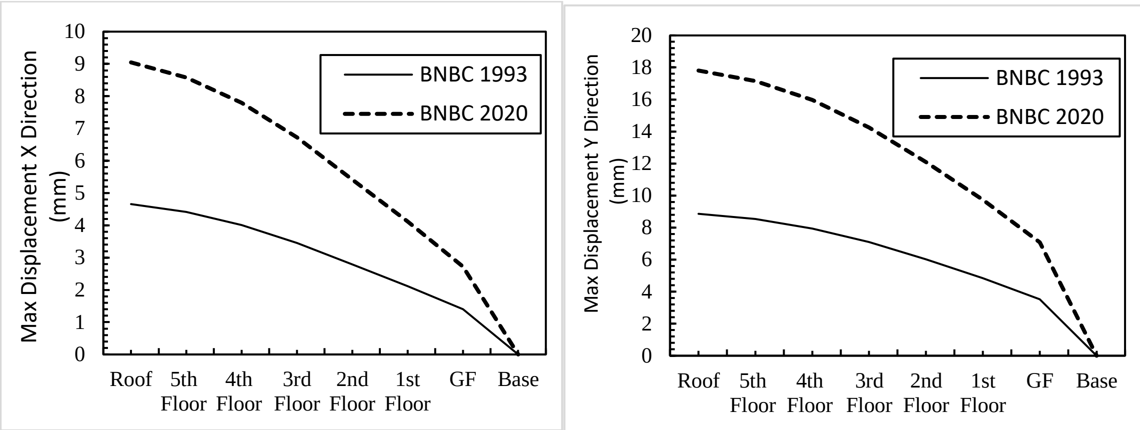

Figure 3. Comparison of Maximum Story Displacement as per (a) BNBC 1993 and (b) BNBC 2020.

The vertical earthquake loading in the Y direction induces greater displacement in each story compared to the horizontal earthquake loading in the X direction. This displacement ratio remains consistent across all stories for both directions, as stipulated by the BNBC (Bangladesh National Building Code) in 2020 and 1995. Specifically, the maximum displacement ratio for the X direction is 1.94, while for the Y direction, it is 2.01.

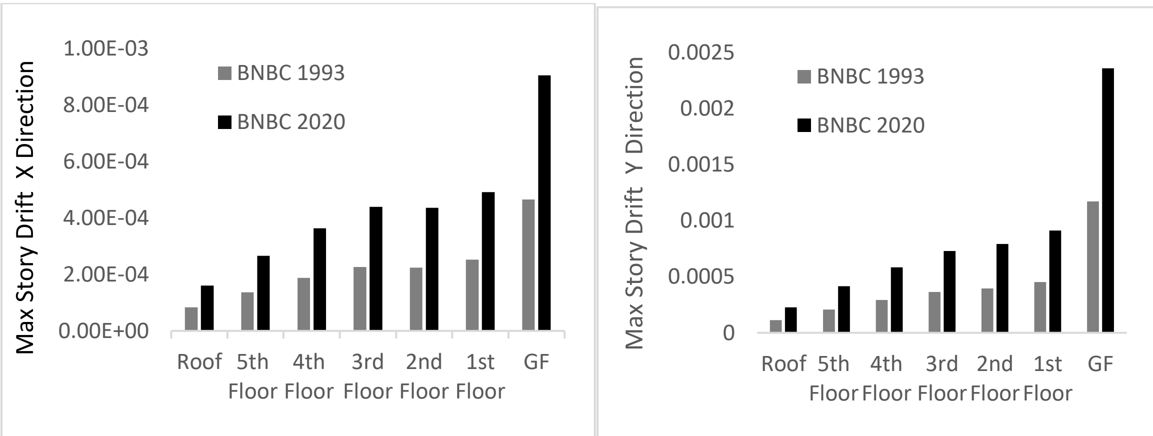

Figure 4. Comparison of Maximum Story Drift as per (a) BNBC 1993 and (b) BNBC 2020.

Based on the provided figure, it is evident that the Story Drifts are more pronounced under the regulations of BNBC 2020 compared to those prescribed by BNBC 1993. Specifically, in the bottom story for both the X direction and Y direction, the maximum story drift ratio between BNBC 2020 and BNBC 1995 is 1.944 and 2.012, respectively.

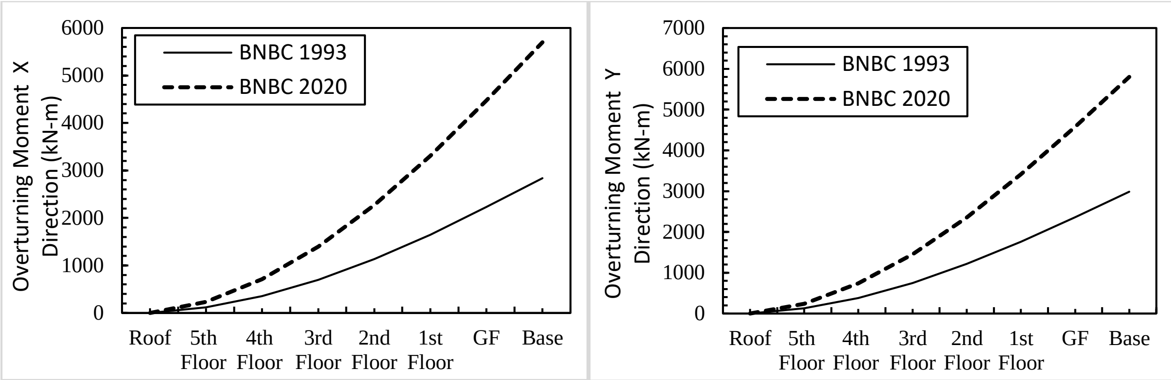

Figure 5. Comparison of Story Overturning Moment as per (a) BNBC 1993 and (b) BNBC 2020.

The story overturning moment according to BNBC 2020 is much higher than that of BNBC 1993. In the base, the ratio of story overturning moment according to BNBC 2020 and BNBC 1993 is about 2.00 and in the upper stories, it reduces and becomes 1.97 at Roof at X direction.

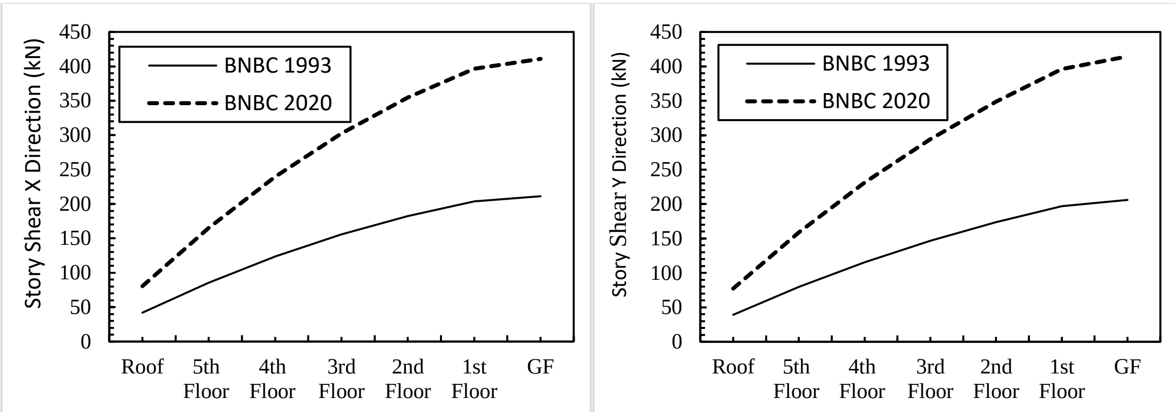

Figure 6. Comparison of Story Shear as per (a) BNBC 1993 and (b) BNBC 2020.

The figure shows that the story shear is maximum at the base and gradually decreases with the increase of the number of stories. It is minimum at Roof. According to BNBC 2020, the story shear is much higher than that of BNBC 1993.

4. Conclusion

This study presents the calculation of Base shear and Response Spectrum Analysis as per BNBC 1993 and BNBC 2020 of a 7-story building structure. The objective of the study is to understand the behavior of a reinforced concrete building against earthquake load as per BNBC 1993 and BNBC 2020. The analysis's findings allow us to reach the following conclusion.

- Linear static analysis and Response Spectrum analysis were carried out using Etabs to evaluate the structural behavior of the building. The obtained values for the base shear were 238.706 kN and 481.36 kN in accordance with the BNBC 1993 and BNBC 2020 codes, respectively. Upon performing the response spectrum analysis, the resulting base shear values were determined to be 209 kN and 406 kN for BNBC 1993 and BNBC 2020, respectively. These values represent approximately 85% of the static base shear.
- The manually computed base shear for earthquake load in accordance with the BNBC 2020 code is found to be 81.77% higher compared to the base shear specified by the BNBC 1993 code.
- After analyzing various structural response parameters, including story displacement, shear, drift, and overturning moment, it has been observed that the values corresponding to the BNBC 2020 code are significantly greater than those prescribed by the BNBC 1993 code. On average, the ratio between the

values of these parameters is approximately 1.94 to 2, indicating a substantial increase under the BNBC 2020 provisions.

- The analysis of the structure reveals that the story displacement and story shear exhibit higher values in the upper stories compared to the lower stories. Moreover, the maximum story drift and overturning moment are observed at the base level, gradually decreasing as the number of stories increases.

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