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A Study of Seismic Design Procedures in Local and International Building Codes

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The Research work was conducted to study the seismic design procedures in local and international building codes. Bangladesh National Building Code-1993 was taken as local code and International Building Code-2000 was taken as international codes. As building constitutes the major part of construction for physical infrastructure development of the country, a substantial portion of national resource is invested in building construction in both public and private sectors. In order to ensure optimum return of this investment and also to save them from natural hazards like earthquake, building construction needs to be controlled and regulated. This work is not possible without a building code. It has been seen in the past that lots of buildings damaged during an earthquake for not following the building codes properly. Both the codes under consideration have used the equivalent static force method for analysis up to a certain height of a building, in case of an earthquake. It has been found that the main difference between BNBC-1993 and IBC-2000 is that, IBC-2000 involves soil dynamic characteristics such as –spectral acceleration in calculating base shear and other parameters. But BNBC-1993 does not involve soil dynamic properties in the analysis procedure. The seismic analysis procedures will be more accurate, if dynamic soil properties are involved.

Field of Research: Civil Engineering (Structural)

Keywords: IBC-2000, BNBC-1993, earthquake, base shear co-efficient, time period.

1. Introduction

Earthquake is one of the most deadly natural disasters affecting human environment. Even a relatively moderate earthquake can lead to a very large number of deaths. For example, the February 29, 1960 Morocco earthquake with magnitude of only 5.8 caused as many as 15000 deaths. In statistics, it is shown that, about 60% of the world wide causalities was associated with natural disasters, caused by earthquake.

Although earthquake may affect rural as well as urban areas, damage due to earthquakes is usually maximum when urban areas are affected. There are records of whole cities being destroyed by earthquakes.

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Bangladesh is one of the most disaster-prone countries of the world. It lies between $20^o30^/$ and $26^o40^/$ north latitude and $88^o03^/$ and $92^o40^/$ east longitude and has an area of about 148000 sq. km. and a population of 165 million. Although it is vulnerable to a wide variety of natural hazards, viz., flood, cyclone and storm surge, drought, river bank erosion and earthquake, most of the recent disasters have been caused by floods and cyclones. The low incidence of severe earthquakes during recent times has led to a situation where most of the population and some of the policy-makers don't perceive seismic risks to be important. However, due to increasing number of bridges, buildings and industrial structures being built during the last two decades, assessment of seismicity of different regions in the country is receiving more and more attention of engineers and scientists.

A substantial portion of national resource is invested in building construction in both public and private sectors. In order to ensure optimum return of this investment and to achieve satisfactory performance of the building in terms of safety, serviceability, health, sanitation and general welfare of the people, building construction needs to be controlled and regulated. This work is not possible without a building code. The building code is a collection of provisions and regulations to ensure minimum standards of every aspect of a building. These include location, design, and construction, quality of materials, use and occupancy and maintenance of building.

The building code is a national level approved document that shall form the basis for standard of design construction and maintenance of buildings. The design of buildings considering earthquakes usually employs static loads that are determined in accordance with provisions in the applicable building code. The appropriate earthquake-resistant regulation for one country is not necessarily the same for as for other countries. But the prime objectives and aims of formulating empirical formulae and code for earthquake resistant structures are mainly

- To keep the number of deaths from earthquakes to an acceptably small number.
- To design and construct buildings so that the long term cost of repairing damage does not exceed the extra cost that would have been required to prevent damage.

The principal objectives of the present paper are:

- Study of the existing literature on seismicity in Bangladesh.
- Collect information on damage of reinforced concrete frame buildings in recent earthquakes.
- Study of BNBC-1993 and IBC-2000 with respect to seismic analysis methods.
- Comparison of BNBC-1993 and IBC-2000 code provisions

2. Major Earthquakes Affecting Bangladesh

During the last 150 years, 7 major earthquakes (with $M \geq 7.0$) have affected Bangladesh (Table 1). Out of these, only two (viz.,1885 and 1918) had their epicenters within Bangladesh.

The Cachar Earthquake had epicenter in the northern border of Jaintia hills of Assam and caused great damage in Manipur and Cachar districts of Assam. In Bangladesh, major damage occurred only in the eastern parts of the Sylhet district but the tremor was felt all over the country. The magnitude is estimated to be 7.5 in the Richter scale.

There were seismographic records available for the Bengal earthquake. Only the reports of feeling of shock, and observed damage to buildings, walls, factory chimneys, tombs, cemeteries, and towers like octagonal templates with conical apex, earth fissures and vents were described in report of the Bengal Earthquake. According to this report, the shake was severely felt throughout the Bengal province. The area where shock was felt extended west-ward into Chota Nagpur and Bihar, northwards into Sikim and Bhutan, and eastwards into Assam, Manipur and Burma.

Table 1: List of Major Earthquake Affecting Bangladesh

Date	Name of Earthquake	Magnitude (Richter)	Epicentral distance from Dhaka (km)
10 January, 1869	Cachar Earthquake	7.5	250
14 July,1885	Bengal Earthquake	7.0	170
12 June, 1897	Great Indian Earthquake	8.7	230
8 July, 1918	Srimongol Earthquake	7.6	150
3 July, 1930	Dhubri Earthquake	7.1	250
15 January, 1934	Bihar-Nepal Earthquake	8.3	510
15 August, 1950	Assam Earthquake	8.5	780

Table 2: Significant Seismic sources for Earthquake hazard in Bangladesh

Location	Maximum likely earthquake Magnitude (in Richter scale)
Assam fault zone	8.0
Tripura fault zone	7.0
Sub-Dauki fault zone	7.3
Bogra fault zone	7.0

The area over which the shock of the great earthquake was felt amounted to not less than 31,20,000 km^2. This does not include the detached areas near Ahmedabad or any part of Bay of Bengal, nor the large areas in Tibet and western China over which the stock was certainly felt. If the areas included in these tracts are taken into consideration, the total area over which the shock was detectable amounts to 45,50,000 km^2 of which the area over which serious damage to masonry buildings are known to have occurred was not less than 3,77,000 km^2.

The greatest damage of Srimangal earthquake occurred in the tea garden areas of the Balisera, Doloi and Luskerpore valleys. The epicentral area of the earthquake was located at the Balisera valley and part of the Doloi valley. With the few exceptions, all brick buildings were found to be destroyed within this area. Water and sand spouted up to a height of several feet and numerous vents opened in the ground in various places. The intensity of the shock was so great that it was impossible to stand on foot.

Dhrubi earthquake originated near the north-westeren end of the Garo hills and the adjoining valley of the Brahmaputra river, a short distance to the south of Dhrubi town. The influence area of the earthquake was about 8,35,000 km^2. This earthquake had disastrous results in the northern Bengal and in western Assam, and was felt very distinctly over a wide area, extending from Dibrugarh and Manipur in the east, to Chittagong and Calcutta in the south, Patna in the west, and beyond the frontiers of Nepal, Sikkim and Bhutan in the north.

For Bihar earthquake, the area of greatest devastation was in northern Bihar and Nepal, but the damage gradually diminished into adjacent provinces. The shock was felt by persons over a distance upto 1800 km from the central tract as far as Peshwar in the north-east, Fort-Hertz in the east, Akyab in the south-east, Bezwada and Ongole in the south and Bombay in the south-west.

Shock was reported over an area of approximately 4,92,00 km^2 in India and Tibet. The earthquake affected the three main geological units of India, the Peninsula, the Gangetic alluvium and the Himalaya. Over a large area roads were badly damaged, railway tracts were completely destroyed, telegraph and telephone communications were entirely dislocated.

Assam earthquake was again one of the severest earthquakes of the world. Its epicentre was in the Arunachal Pradesh, northeast of Assam. The tremor was felt throughout Bangladesh but no damage was reported anywhere. The magnitude was 8.5 in the Richter scale.

3. Comparison Of Bnbc-1993 And Ibc-2000 Code Provisions

A simple 10-storied building located in Dhaka city was taken to compare the base shear coefficients in accordance with BNBC-1993 and IBC-2000 codes. According to the BNBC-1993, the necessary parameters are as follows: Seismic Zone coefficient, Z = 0.15; Site soil Coefficient, S =1.5; Response Modification Coefficient, R = 5 and for International Building Code-2000, the necessary parameters are as follows: S_{DS} = the 5% damped design spectral response acceleration at 0.2 second period=0.375, extracted from the response spectra in Figure 2; S_{DL} = the 5% damped design spectral response acceleration at 1 second period = 0.33, obtained from the response spectra shown in Figure 2 and R = Response modification factor = 3. The structural Importance Coefficient (I) for both codes was taken as unity. Details of calculation have been shown on the Table 4 and Table 5. From the calculations, a plot of Base shear coefficient vs. Number of stories for the same soil has been plotted, which has been shown in Figure 3.

Table 3: Comparison of IBC-2000 & BNBC-1993 for various parameters

Parameter	IBC-2000	BNBC-1993
Base shear	Soil dynamic characteristics such as spectral acceleration have been involved in calculating base shear.	Soil dynamic characteristics have not been involved in calculating base shear.
Site soil	Has been classified according to their respective spectral acceleration.	Has been classified according to their physical property.
Response Spectra	Is to be used both in the static & dynamic analysis.	Is to be used only in the dynamic analysis.
	Specific procedure has been mentioned to develop these curves.	No procedure has been mentioned to develop these curves.
Base shear	$V = C_S W$	$V=ZICW/R$

Table 4: Calculation of Base Shear Coefficient according to IBC-2000

Storey	C_S	T	T_{MAX}	Corrected T	C_S (MAX)	Corrected C_S
1	0.13	0.17	0.13	0.13	0.83	0.13
2	0.13	0.28	0.26	0.26	0.42	0.13
3	0.13	0.38	0.38	0.38	0.28	0.13
4	0.13	0.47	0.51	0.47	0.23	0.13
5	0.13	0.56	0.64	0.56	0.19	0.13
6	0.13	0.64	0.77	0.64	0.17	0.13
7	0.13	0.72	0.90	0.72	0.15	0.13
8	0.13	0.79	1.02	0.79	0.13	0.13
9	0.13	0.86	1.15	0.86	0.12	0.12
10	0.13	0.94	1.28	0.94	0.11	0.11

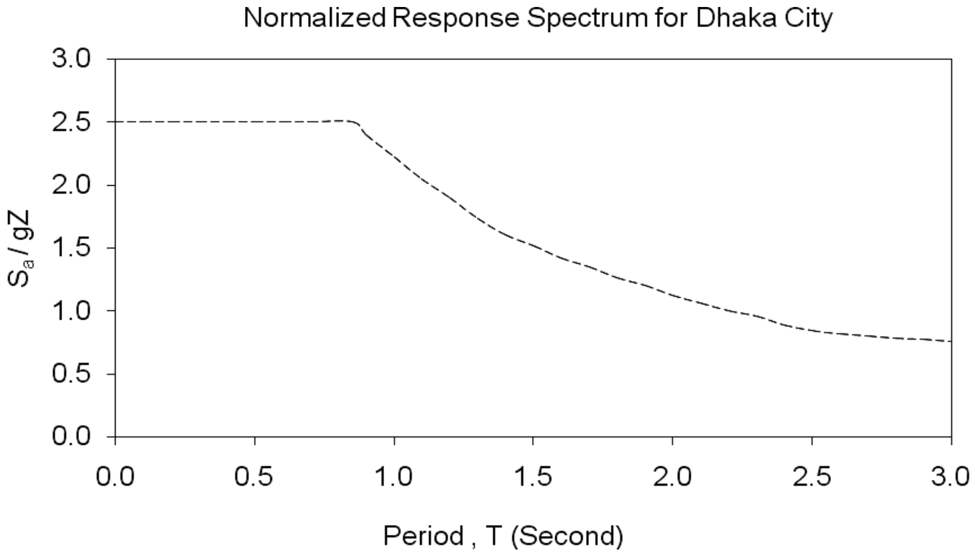

Figure 1: Normalized Response Spectrum for 5% Damping Ratio for soft to medium clay and sand (soil type S3) in Dhaka (from BNBC-1993)

Table 5: Calculation of Base Shear Coefficient according to BNBC-1993

Number of storey	T (sec) from equation	T (sec) form empirical relation	Coefficient 'C'	Base shear Coefficient
1	0.17	0.1	8.7	0.12
2	0.28	0.2	5.5	0.12
3	0.38	0.3	4.2	0.12
4	0.47	0.4	3.5	0.12
5	0.56	0.5	3.0	0.12
6	0.64	0.6	2.6	0.12
7	0.72	0.7	2.4	0.11
8	0.79	0.8	2.2	0.10
9	0.86	0.9	2.0	0.09
10	0.94	1.0	1.9	0.08

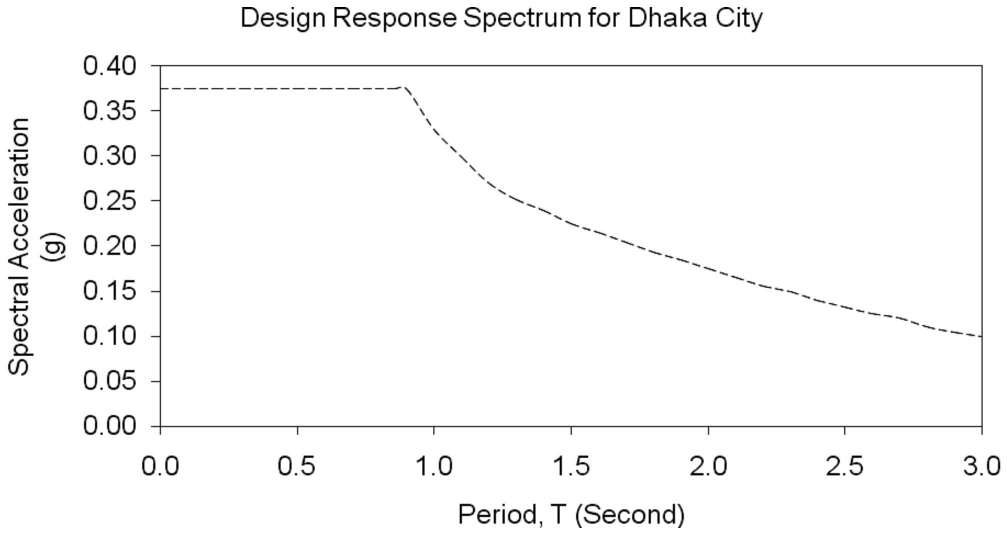

Figure 2: Design Response Spectrum for Dhaka City

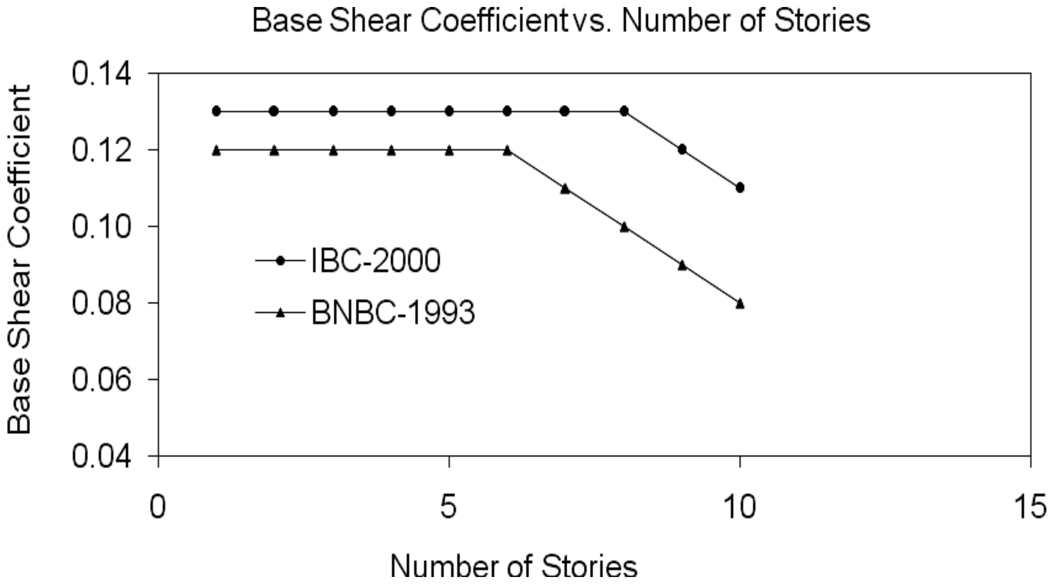

Figure 3: Base shear coefficient vs. number of stories according to IBC-2000 and BNBC-1993.

4. Conclusion

Almost all the two codes, considered here, adopt a similar definition for the various coefficients in the equation of the base shear in the equivalent static method. However, a direct comparison of seismic forces is not possible because there are large differences in the seismic intensity from country to country, leading to differences in the design value of zone factor ‘Z’. The requirements of equivalent static method are primarily intended to provide life safety, not property protection, at the maximum expected earthquake level. Observations of structural systems responding in the inelastic range indicate that as the structure yields, the period, damping, and other dynamic properties change, often substantially. The effect of these changes in dynamic properties is that, while the force levels actually experienced by the structure are greater than those used in the design, they are less than those that would occur in a fully elastic response. The more ductile is the systems performance, the greater is its capacity to accommodate inelastic displacements & forces. The development of earthquake resistant design regulations is considered to be steady task. It is expected that code provisions are to be revised on regular basis. In future versions of this codes additional factor, such as soil foundation factor, may be incorporated. It is expected that in future seismic conditions will be described in terms of a system of maps with different return periods and that the level of protection will be specified by return periods and construction verification criteria of structures along with the importance of the structures.

From the above discussion, it is noted that further refinement in the equation pertaining to the calculation of time period may not be rewarding. Further research may be undertaken in order to improve zone factor, importance factor, site dependent spectral coefficient, and structural system factor. For a single research project, it is not possible to faithfully cater for all these aspects of improvements. In this research project only one aspect, the development of a site response spectra, have been dealt with. This is, perhaps, the most important factor, which could be looked into. It should be noted that seismic code provisions of BNBC-1993 are not based on a thorough study of the topic and that there has been no research work done to formulate site specific response spectra, which eventually leads to the site factor in equivalent static method. This site factor is introduced in the equivalent static method to mimic the acceleration spectra curve in dynamic analysis. During the course of the present study, in addition to formulate soil specific simulated response spectra, response spectra based on several recent earthquakes is developed. From this work, it is expected that, the next editions of BNBC will involve the soil dynamic properties in the analysis procedures, to make it more accurate.

References

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