Comparative Study On Lateral Load Analysis By BNBC - 1993 And Proposed BNBC - 2012

Faria S. Imam, Saimah Tahsin, Asif Hassan

Abstract: The construction industry is changing fast due to continuing invention of new technologies, construction equipments and materials. To keep pace with the advancement of technology it is required for the codes to be updated on a regular basis. Initiative has been taken to update BNBC (Bangladesh National Building Code) 1993, and a draft copy has already been prepared. Significant changes have been introduced in BNBC 2012 with regard to analysis for lateral loads. To identify the changes in design and analysis of various structures a comparative study is necessary to relook at the provisions of the present code and look for the feasibility of any change of the recent upgrading code. This study aims at the comparison of provisions of wind and earthquake analysis given in existing BNBC 1993 to that in proposed 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 proposed BNBC 2012 with respect to BNBC 1993. The basic differences in seismic base shear and maximum lateral displacement with varying number of stories using two codes are presented. The comparison in inter storey drift is also made for 6 storied and 12 storied building to show the effect in inter storey drift using two codes. Analysis is made to compare maximum reinforcement requirement for column design to provide guideline to the engineer for the most economic design.

Index Terms: building code, earthquake load analysis, inter storey drift, maximum lateral displacement, maximum reinforcement requirements, seismic base shear, and wind load analysis

1 INTRODUCTION

A LTHOUGH Bangladesh is extremely vulnerable to seismic activity, the nature and the level of this activity is yet to be defined. In Bangladesh, complete earthquake monitoring facilities are not available. The dynamic effects of wind and earthquake loads are usually analyzed as an equivalent static load in most small and moderate-sized buildings. Others must utilize the iterative potential of the computer. The design of wind and earthquake loads on a building is substantially more complex. As a result a comparative study has been made to see the basic difference between BNBC (Bangladesh National Building Code) 1993 and proposed BNBC 2012 regarding lateral load only. The developed countries in North America, Europe regularly update their codes. Even India has updated their codes time to time based on needs. In contrast to Bangladesh National Building Code (BNBC) had little change since its inception in 1993. Initiative has been taken to update BNBC 1993 and a draft copy has already been prepared. This draft copy is intended to publish in 2014 as BNBC 2012.

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2 LITERATURE REVIEW

A detailed comparison between BNBC 1993 and proposed BNBC 2012 is presented in tabular form for the lateral load analysis only. The effects of gravity load in combination with lateral loads are out of scope of this study. For earthquake load analysis equivalent static method is implemented. The case study on a typical apartment building is performed for Dhaka city only. The results may vary for other cities of Bangladesh. A total change in Wind and Earth quake provisions in the proposed draft of the code can be noticed. A previous study [6] demonstrated the similarities and differences in various codes including lateral as well as gravity loads. Another work [5] performed a comparative study regarding earthquake load provisions for a low rise building (6 storied only). However, a detailed comparison of lateral loads along with the impact on design analysis for low to medium rise buildings for Bangladesh is required. In this work, corresponding parameters of Wind and Earthquake loads found using the BNBC 1993 and BNBC 2012 codes are compared. Parameters considered for wind load are:

1. Design wind load, 2. Basic wind speed, 3. Height and exposure coefficient Cz and Kz, 4. Gust Factor G_h and G, 5. Sustained wind pressure, 6. External pressure coefficient C_{pe} and C_p, and 7. Design wind pressure Significant difference between the 2 codes can also be found in following parameters in case of earthquake load:

1. Base shear, 2. Importance of structure, 3. Seismic factor, 4. Structural System factor, 5. Time period of structure, 6. Effective weight of structure, 7. Soil factor Finally, a typical 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 analyses are 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 storey drift for 6, 12, and 18 storied buildings is also presented. For earthquake load base shear, maximum lateral displacement and inter storey drift is higher in BNBC 2012 than BNBC1993.But for

wind load maximum lateral displacement and inter storey drift is less in BNBC-1993 than BNBC-2012 than BNBC-1993. Design of reinforced concrete buildings for lateral load in BNBC-2012 is relatively economic than BNBC-1993 as the amount of reinforcement required is less in BNBC-2012.

3 Case Study and Methodology

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. The soil on which the building is to be constructed is medium dense soil. The analysis is conducted for variable number of stories (from 2 to 18). The structural analysis and design is carried out using ETABS, a finite element based software. ETABS offers the widest assortment of analysis and design tools available for the structural engineer working on building structures.

4 Discussion on Results of Earthquake Loading

4.1 Effects on Base Shear

Base shear is an estimate of maximum expected lateral force that will occur due to seismic ground motion at the base of a structure. Comparison of base shear between BNBC 1993 (red line) & BNBC-2012 (green line) is presented by fig.1and fig.2.

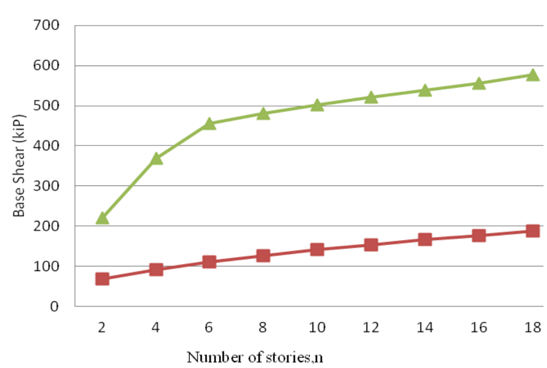

Fig.1. Vertical Distribution of Base Shear

Findings are given below:

1. Fig .1 shows the base shear vs. no of stories for BNBC-1993 and BNBC-2012.
2. The value of base shear is much higher for BNBC-2012 than BNBC-1993.
3. It is seen from the fig that base shear increases with no of stories in both codes.
4. The change in base shear with no of stories is uniform and almost linear according to BNBC-1993.
5. According to BNBC-2012 a significant change occurs from storey-2 to storey-6 and after that the change is almost linear.

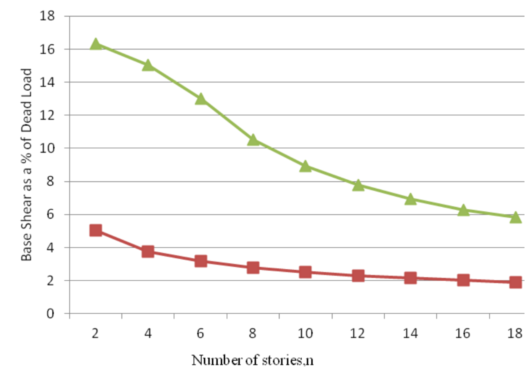

Fig.2. Comparison on Seismic Base Shear

Findings are given below:

1. Fig.10 represents the percentage of base shear in terms of total seismic weight of the building vs. no of stories graph for both BNBC-2012 & BNBC-1993.
2. It is seen from fig that base shear as a % of dead load is much higher for BNBC-2012 than BNBC-1993.
3. The change in base shear as a % of dead load is significant from storey-2 to storey-8 according to BNBC-2012.
4. The change in base shear as a % of dead load is almost negligible for higher stories according to BNBC-1993.

From the above discussion it is recommended that BNBC-2012 is more conservative than BNBC-1993.

4.2 Effects on Maximum Lateral Displacement

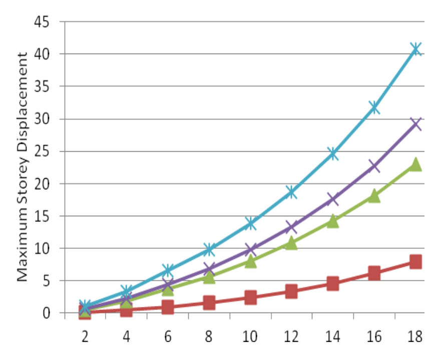

Fig.3. Comparison on Maximum Storey Displacement

Fig.3 represents the max storey displacement vs. no of stories graph for BNBC-2012 and BNBC 1993. It shows that displacement increases with no of stories and the change is greater for higher stories than lower stories. It is seen that displacement for Earthquake loading in vertical direction Ey for both BNBC 2012 (blue line) and BNBC 1993(violet line) is higher than displacement for Earthquake loading in horizontal direction Ex for both BNBC-2012 (green line) & BNBC-1993 (red line). From the above discussion we can conclude that Max Storey Displacement is greater in BNBC-2012 than BNBC-1993 due to higher base shear.

4.3 Effects on Inter Storey Drift

Maximum storey drift increases with the storey no up to a certain storey then it decreases. For a 6 storied building maximum drift in both horizontal and vertical direction Ux (red line for BNBC-2012 and blue line for BNBC- 1993) in fig. 4 and Uy (green line for BNBC-2012 and red line for BNBC-1993) in fig 5 respectively occur at storey 3 or at the mid height of the building for both BNBC-1993 & BNBC-2012. Inter storey drift is much higher for BNBC-2012 than BNBC-1993.It is almost 204% higher in BNBC-2012 than BNBC-1993. From our analysis it has been checked that the max Inter storey drift (.004918) is less than the limit L/240 (.5 inch). The rate of increase or decrease in Inter storey drift is 12% on an average in BNBC-1993 and 17% on an average in BNBC-2012.

Fig.4. Variation of Horizontal Storey Drift for a Six Storied Building

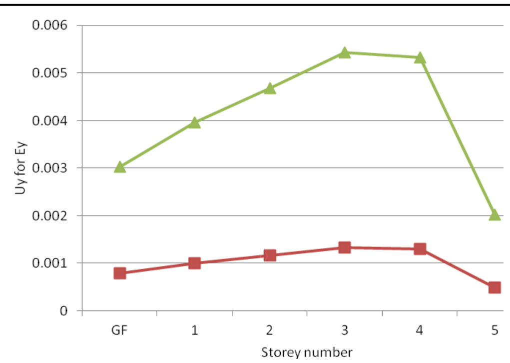

Fig.5. Variation of Vertical Storey Drift for a Six Storied Building

4.4 Effects on Design

From fig.6 it is found that maximum and minimum reinforcement is required for internal and edge column respectively. It is also seen that column reinforcement for BNBC-1993 (blue bar) is higher than BNBC-2012 (red bar). The difference is shown by green bar which is maximum for corner column and minimum for edge column.

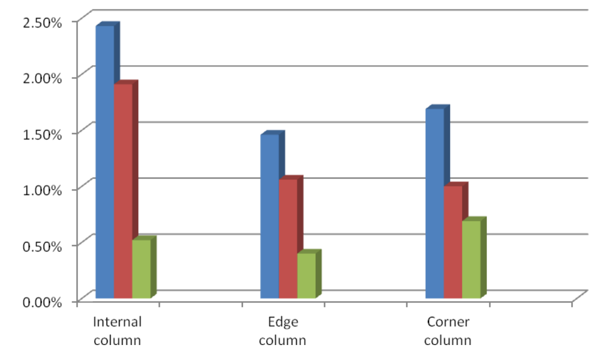

Fig.6. Comparison of Maximum Reinforcement in a Six Storied Building

Fig 7 shows similar results as fig 6 except the difference between BNBC 1993 and BNBC 2010 which is highest for edge column and minimum for corner column.

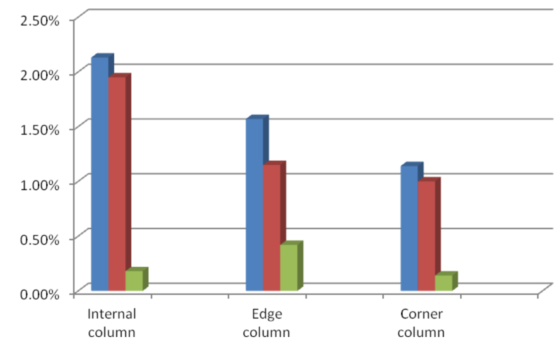

Fig.7. Comparison of Maximum Reinforcement in a Twelve Storied Building

Fig 8 shows that maximum and minimum reinforcement is required for corner and internal column respectively. Similar to fig 6 and fig 7 column reinforcement for BNBC 1993 (blue bar) is higher than BNBC 2010 (red bar). So from the above results it is obtained that BNBC 2012 is more economic for design than BNBC 1993.

5 DISCUSSION ON RESULTS OF EARTHQUAKE LOADING

5.1 Effects on Wind Load

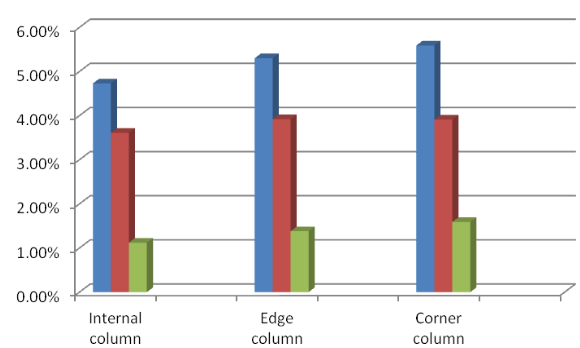

Fig.8. Comparison of Maximum Reinforcement in an Eighteen Storied Building

Figure 9 represents wind load for both vertical Wy (red line for BNBC 1993 and blue line for BNBC 2012) and horizontal Wx (orange line for BNBC 1993 and black line for BNBC 2010) direction 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. Wind load in x direction always governs in both codes.

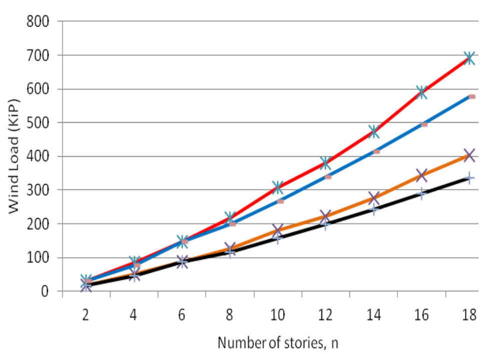

Fig.9. Comparison of Wind Loading

5.2 Effects on Maximum Displacement

Max storey displacement is higher in both vertical and horizontal direction (violet line for vertical and green line for horizontal direction) in BNBC-1993 than BNBC-2012 (orange line for horizontal and blue line for vertical direction) is presented in figure 10. The rate of increase in max storey displacement for higher storey is 52.93% for BNBC-1993 and 45.2% for BNBC-2012.

5.3 Effects on Inter Storey Drift

Maximum storey drift in both vertical (Uy) and horizontal (Ux) direction are presented in fig 12 and fig. 11 respectively. Blue and red line represents the difference between storey drifts for BNBC -1993 and 2012 respectively. For a 6 storied building maximum drift occur at storey 3 or at the mid height of the building for both BNBC-1993 & BNBC-2012. Inter storey drift is much higher for BNBC-1993 than BNBC-2012 for wind load. It is almost 8.6% higher in BNBC-1993 than BNBC-2012. From our analysis it has been checked that the maximum Inter storey drift (.001149) is less than the limit L/240(.5in).

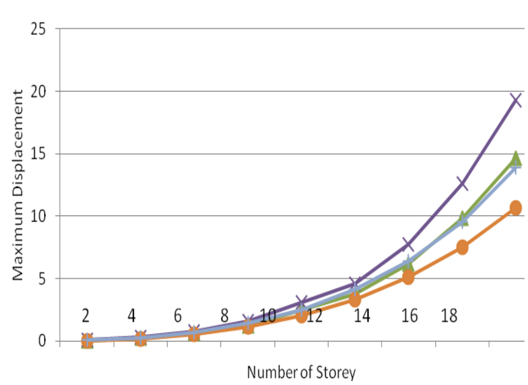

Fig.10. Comparison of Wind Loading

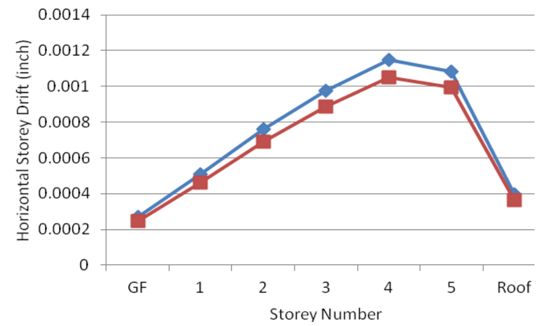

Fig.11. Variation of Horizontal Storey Drift in a Six Storied Building

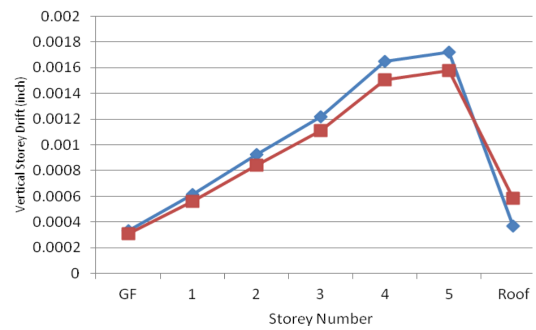

Fig.12. Variation of Vertical Storey Drift in a Six Storied Building

5.4 Effects on Design

Figure 13 represents the maximum and minimum reinforcement is required for internal and corner column respectively. It is also seen that column reinforcement for BNBC-2010 (red bar) is higher than BNBC-1993 (blue bar). The difference is shown by green bar which is maximum for edge column and minimum for corner column.

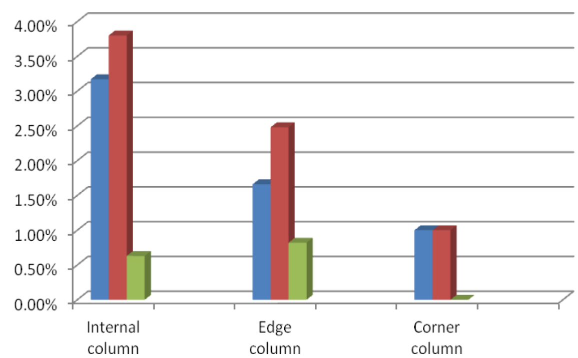

Fig.13. Comparison of Maximum Reinforcement in a Six Storied Building

Fig 14 shows the similar result except that the difference between BNBC 1993 and BNBC 2012 is maximum for internal column and minimum for corner column. Fig 15 shows a different result from Fig 13 and 14. It identifies that reinforcement for BNBC 2010 (red bar) is higher than BNBC 1993 (blue bar). It is also noted that column reinforcement is maximum for edge column and minimum for internal column. Maximum reinforcement requirement is much higher for BNBC-2012 than BNBC-1993 in case of six and twelve storied building. For twelve storied building completely different situation occurs. Required Maximum reinforcement is more using BNBC-2012.

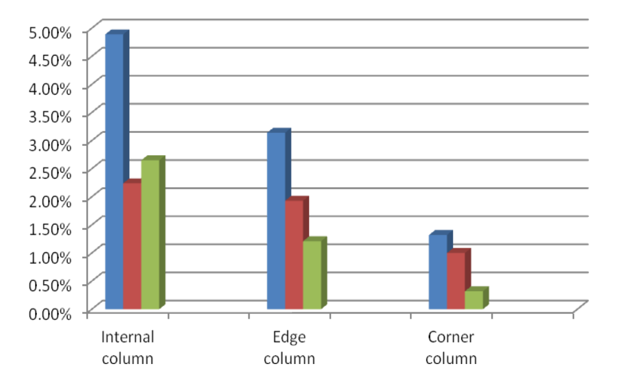

Fig.14. Comparison of Maximum Reinforcement in a Twelve Storied Building

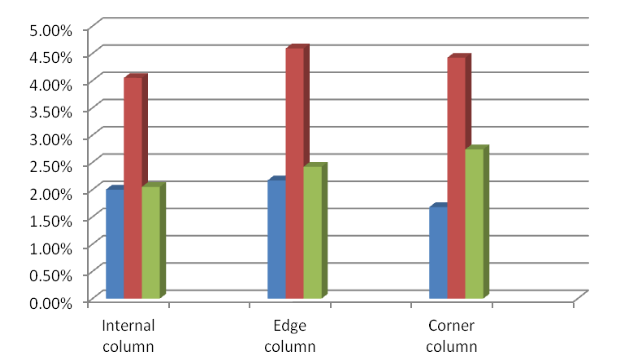

Fig.15. Comparison of Maximum Reinforcement in a Twelve Storied Building

6 CONCLUSION

Base shear is increased in BNBC-2012 than BNBC-1993 due to increase in zone coefficient (z), structural system factor(R) and self weight (W). In BNBC-1993 design basis earthquake is not clearly defined. In BNBC-2012 design basis earthquake is two third of the maximum credible earthquake. In BNBC-1993 load factor 1.4(0.75*1.7*1.1) is used with earthquake load which means the earth quake load is increased 40% because of the uncertainty of load. However this factor is quite unnecessary since the maximum credible earthquake is considered for design. BNBC-2012 gives wide variety of choices to calculate seismic force with clear guidelines as compared to BNBC-1993. From Base shear versus no of storey graph it is seen that base shear is much higher for BNBC-2012 than BNBC-1993. Base shear as a % of total dead load is higher for BNBC-2012 than BNBC-1993. Maximum lateral displacement is also found to be higher for BNBC-2012 than BNBC-1993. The curve for inter storey drift obtained in BNBC 2012 is steeper than that obtained in BNBC-1993. The drift values in BNBC 2012 also exceed the values obtained in BNBC 1993. In all cases maximum drift occurs almost at the mid height of the building. Design of reinforced concrete buildings for lateral load in BNBC-2012 is relatively economic than BNBC-1993 as the amount of reinforcement required is less in BNBC-2012. However, this comment is applicable for Dhaka City only. The calculation procedure for design wind pressure in BNBC-2012 is totally different from BNBC-1993. Two new terms topographic factor (Kzt) and directionality factor (Kd) has been introduced in BNBC-2012. There is a significant decrease in design wind pressure in BNBC-2012 than BNBC-1993. For wind load the maximum lateral displacement and inter storey drift with respect to number of stories is less in BNBC-2012 than in BNBC-1993.

7 RECOMMENDATIONS

The following recommendations can be made for future research work,

1. The case study conducted in this research is for Dhaka 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 seismic active zones.
2. Comparison of lateral load in BNBC 2012 can be made with other codes such as Euro code, Indian code, UBC, ACI, Italian code etc.
3. 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 in places with different site conditions.
4. To find the impact on design only the reinforcement requirement in columns were considered. This study can be extended on a large scale of analysis including foundations, columns, beams and slabs etc.

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