Investigation of the Effect of Number of Story on Different Structural Components of RC Building

Zasiah Tafheem, Mahadee Hasan Shourav, Zahidul Islam, Saima Islam Tumpa

***Abstract*—**The paper aims at investigating the effect of number of story on different structural components of reinforced concrete building due to gravity and lateral loading. For the study, three building models having same building plan of three, six and nine stories are analyzed and designed using software package. All the buildings are residential and are located in Dhaka city of Bangladesh. Lateral load including wind and earthquake loading are applied to the building along both longitudinal and transverse direction as per Bangladesh National Building Code (BNBC, 2006). Equivalent static force method is followed for the applied seismic loading. The present study investigates as well as compares mainly total steel requirement in different structural components for those buildings. It has been found that total longitudinal steel requirement for beams at each floor is 48.57% for three storied building, 61.36% for six storied building when the total percentage is taken as 100% in case of nine storied building. For an exterior column, the steel ratio is 2.1%, 3.06%, 4.55% for three, six and nine storied building respectively for the first three floors. In addition, it has been noted that total weight of longitudinal reinforcement of an interior column is 14.02 % for three-storied building and 43.12% for six storied building when the total reinforcement is considered 100% for nine storied building for the first three floors.

***Keywords*—**Equivalent Static Force Method, longitudinal reinforcement, seismic loading, steel ratio.

I. Introduction

REINFORCED CEMENT CONCRETE (RCC) is a construction technology which evolved with the evolution of different structural materials in the 18th century during the Industrial Revolution. Industrial Revolution brought in new technology which helped in the manufacture of various materials. During the last three decades, increased design and construction of high-rise reinforced concrete buildings are noted. Current trend indicates that in the future there will be an increase in the heights of this type of construction. Several factors account for this rapid development of reinforced construction, which may range from economic factors, like the lack of a strong steel industry in certain countries, which makes high-rise steel buildings very expensive as compared to high-rise concrete ones, to aesthetic requirements and architects' personal preferences [6]. The structural design of a building is usually carried out considering the massive vertical compressive dead load, live load, lateral load including earthquake load, snow load, wind load etc. Every component is designed according to the load it carries and its position in the structure. The study of the design of RCC components leads to understand the basis of RCC design and the method of its implementation [5]. A comparative study has been carried out on total longitudinal reinforcement requirement of columns and beams of six-storied RC building located in Dhaka and Sylhet of Bangladesh [4].

The main objective of the present study is to investigate the effect of number of story on different structural components of three, six and nine story building having the same layout plan. At first, three RC buildings have been modeled and then linear static analysis has been performed under gravity load including dead load, super dead load, live load and lateral load including wind and earthquake load. Then structural design of different structural components such as columns and beams has been performed. Finally, a comparative study has been carried out on steel ratio, total longitudinal steel requirement for columns at different positions such as corner, exterior and interior locations of those buildings. Another comparative study is done on total longitudinal steel requirement for beams at each floor of those buildings [7].

II. Material and Geometric Properties

For modeling, the material properties used for the structure have been given in Table I. Normal weight concrete has been chosen for those buildings.

TABLE I
MATERIAL PROPERTIES

Properties	Values
Weight per unit volume of Concrete, N/mm^3 (k/in^3)	2.356×10^{-5} (8.68×10^{-5})
Modulus of Elasticity of Concrete, MPa (ksi)	20,000 (2900)
Poisson's ratio of Concrete	0.2
Compressive strength, $f_c^{\prime}$, of Concrete MPa (ksi)	27.58 (4)
Yield strength of Steel, f_y, MPa (ksi)	413.69 (60)

In the present study, three structural models of three, six and nine storied residential buildings have been taken into account. Different dimensions of columns used for the study are given in Table II.

As like as columns, beam sizes are also different for various storied building. The size of exterior beams, interior beams, grade beams, stair beams all are different for those buildings. But all buildings have uniform slab thickness of 5 inch. The dimensions of beams are given in Table III.

III. Structural Models

In the present study, three structural models of three, six

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and nine storied residential buildings have been modeled, analyzed and then designed using structural analysis and design software package ETABS [2]. All the buildings are located in Dhaka city of Bangladesh. Those models include different structural components such as Reinforced Concrete (RC) columns, beams (i.e. grade beams, floor beams, stair beams etc.), shear walls for lift cores and slab. There is also an overhead water tank and a staircase. The dimension along longitudinal direction is 29.85m (97.9ft) and transverse direction is 9.91m (32.5ft). The longest bay is 5.97m (19.58 ft) long in longitudinal direction and the shortest bay is 4.95m (16.25ft) long in transverse direction. The height of each storey is 3.049m (10ft). All structural models are consisting of same beam-column layout as architectural design is the same for all. The Architectural plan has been given in Fig. 1. A generalized column-beam layout plan of those building models is shown in Fig. 2. Three dimensional view of three, six and nine storied building models are schematically shown in Fig. 3. For the analysis, all the loads including the wind load and earthquake loading are calculated as set forth by the provision of Bangladesh national building code BNBC, 2006 [1]. Linear static analysis has been performed for the study.

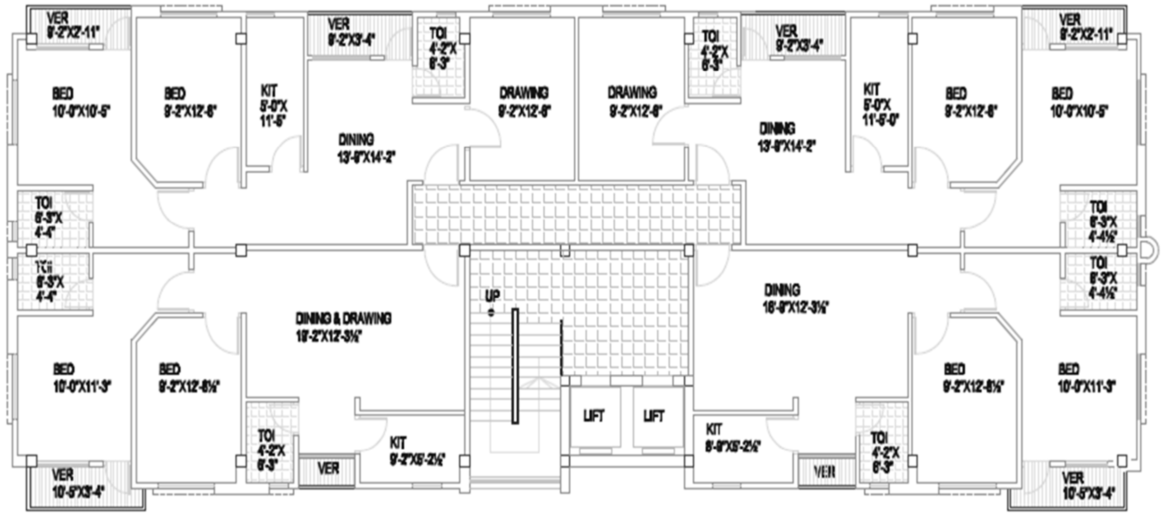


Fig. 1 Architectural Plan of three, six and nine storied building

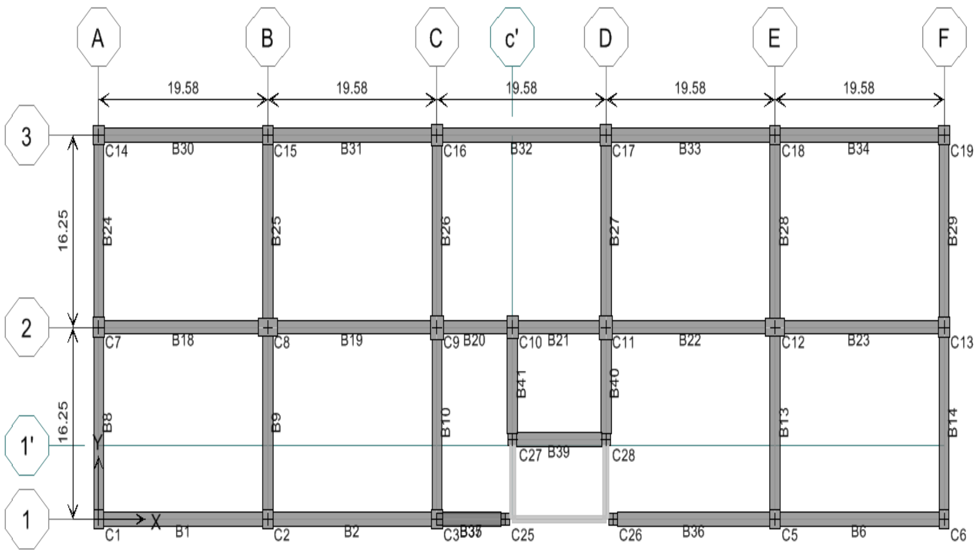
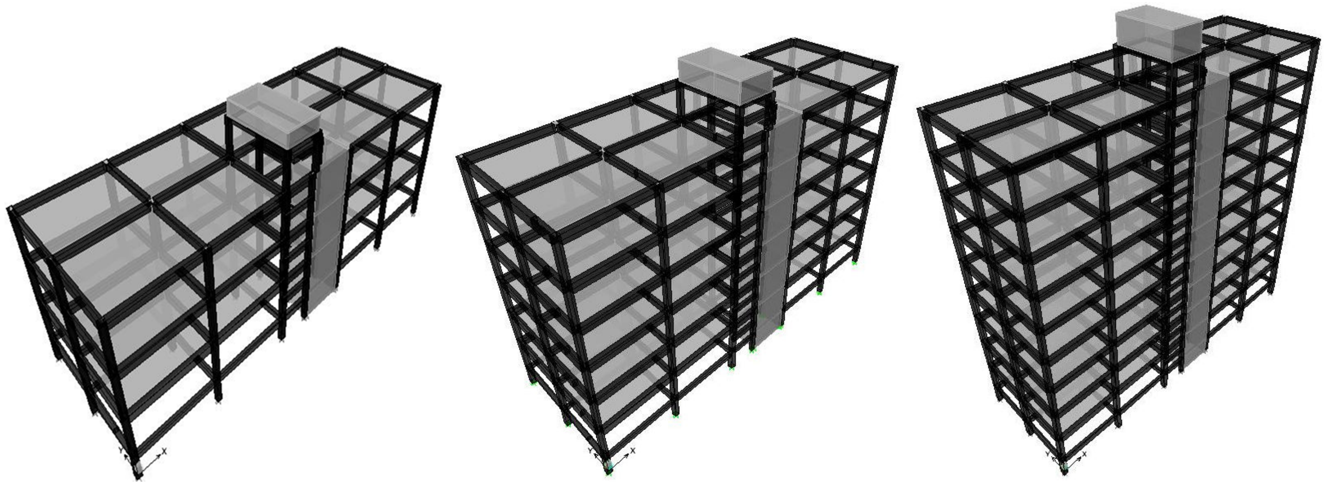
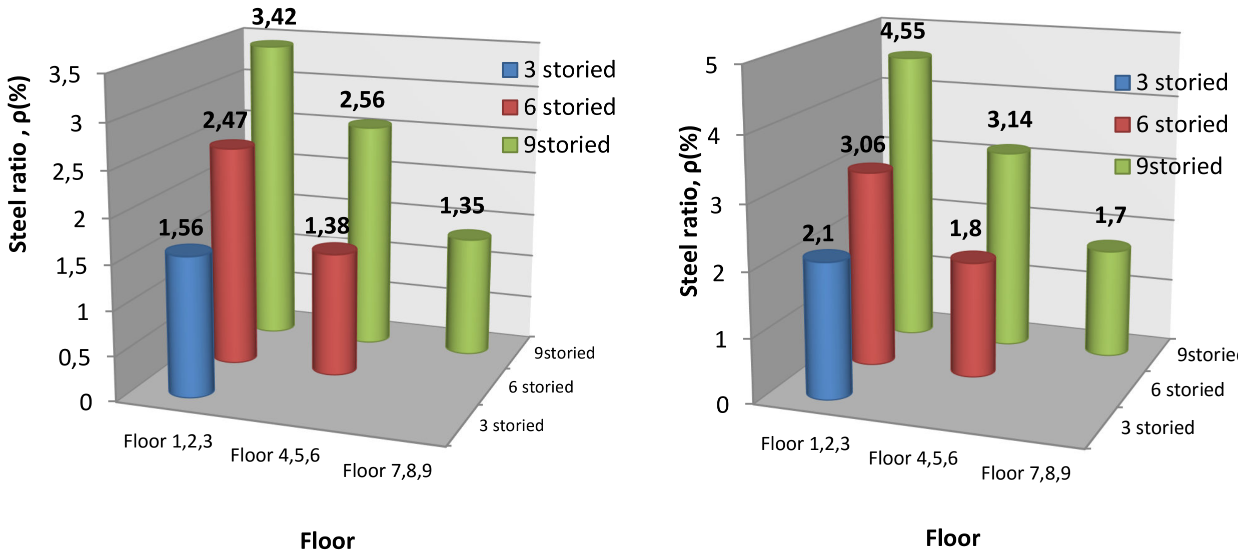


Fig. 2 Column-beam layout Plan (all dimensions are in feet)



(a) (b) (c)

Fig. 3 3D view of (a) Three storied building (b) Six storied building (c) Nine storied building



(a) (b)

Fig. 4 Steel ratios, ρ (%) of (a) Interior column 2B (b) Exterior column 3C at different story level

TABLE II
GEOMETRIC DIMENSIONS OF COLUMNS

Column ID	Three Storied m×m (inch×inch)	Six Storied m×m (inch×inch)	Nine Storied m×m (inch×inch)
C1	4.27× 4.27 (14×14)	4.27× 4.27 (14×14)	4.88× 6.1 (16×20)
C2	4.27× 4.88 (14×16)	4.27× 4.88 (14×16)	4.27× 6.1 (14×20)
C3	4.27× 6.71 (14×22)	4.88× 7.32 (16×24)	4.27 ×7.93 (14×26)
C4	4.27× 5.49 (14×18)	4.88× 5.49 (16×18)	4.88× 6.71 (16×22)
C5	3.66× 6.1 (12×20)	3.66× 6.1 (12×20)	5.49× 7.62 (18×25)
C6	3.66× 3.66 (12×12)	3.66× 3.66 (12×12)	4.27× 6.1 (14×20)

TABLE III
GEOMETRIC DIMENSIONS OF BEAMS

Name of Beam	Three Storied m×m (inch×inch)	Six Storied m×m (inch×inch)	Nine Storied m×m (inch×inch)
Exterior Beams	3.05× 6.1 (10×20)	3.66 ×7.32 (12×24)	4.27× 6.71 (14×22)
Interior Beams	3.05× 6.1 (10×20)	3.05× 6.10 (10×20)	4.27× 7.32 (14×24)
Grade Beams	3.66× 4.27 (12×14)	3.66× 3.66 (12×12)	3.66 ×4.88 (12×16)
Stair Beams	3.66× 4.27 (12×14)	3.66× 4.27 (12×14)	3.66× 4.27 (12×14)

IV. RESULT AND DISCUSSION

A. *Steel Ratio for Different Columns*

Steel ratio of a column is defined as the ratio of steel area and gross area of the column section [3]. For the building models at hand, the column design has been done with the aid of a useful software package PCA-Col. The comparison of steel ratio, ρ (%) for three storied, six storied and nine storied buildings is clearly shown in Fig. 4.

B. Steel Weight for Different Columns

Fig. 5 shows the variation of longitudinal steel weight in corner, exterior and interior column per floor only for the first three floors for three, six and nine storied building.

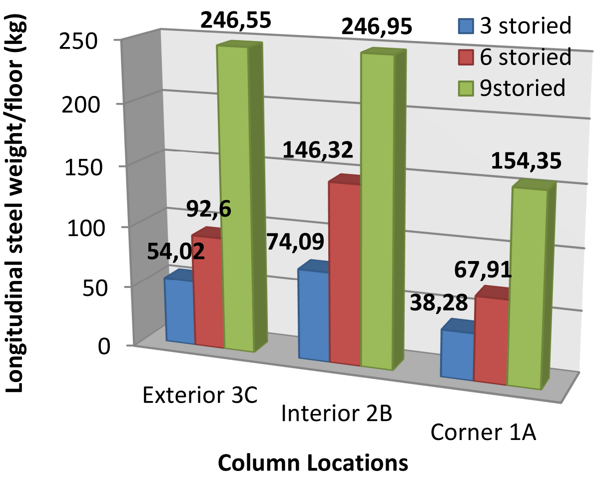


Fig. 5 Longitudinal steel weight in columns per floor (first 3 floors)

As shown in Fig. 5, it has been observed that total steel weight of exterior column 3C for six storied building is 38% and for three storied building, it is about 22% of nine storied building while steel weight is considered as 100% for nine storied building. In addition, total steel weight of interior column 2B for six storied building is 59% and for three storied building, it is about 30% of nine storied building. In case of corner column 1A, total steel weight for six storied building is 44% and for three storied building it is about 25% of nine storied building.

C. Longitudinal Steel Weight for Beams

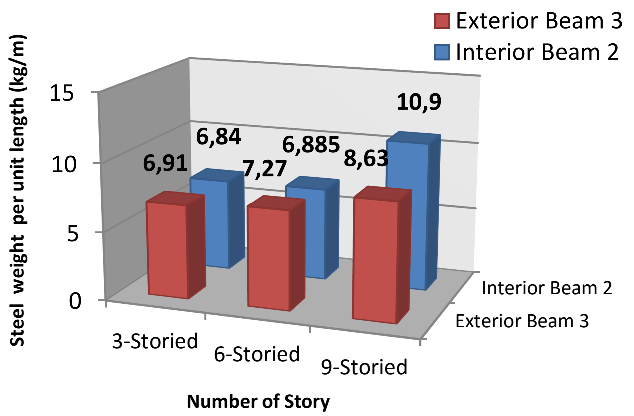


Fig. 6 Steel weight per unit length of beam in longitudinal direction

From Figs. 6 and 7, it has been clearly observed that longitudinal steel weight per unit length of exterior and interior beams along both longitudinal and transverse direction at each floor are more or less same.

Structural design of beams is kept same for each floor. The comparison of total longitudinal steel weight of beams at each floor for those buildings is shown in above bar graph 8. If total weight of longitudinal reinforcing bars in beams of nine storied building is considered as 100 % then in case of six storied building, total weight of steel bars is 61.36 % and for three storied building, it is about 48.57 % of nine storied structure.

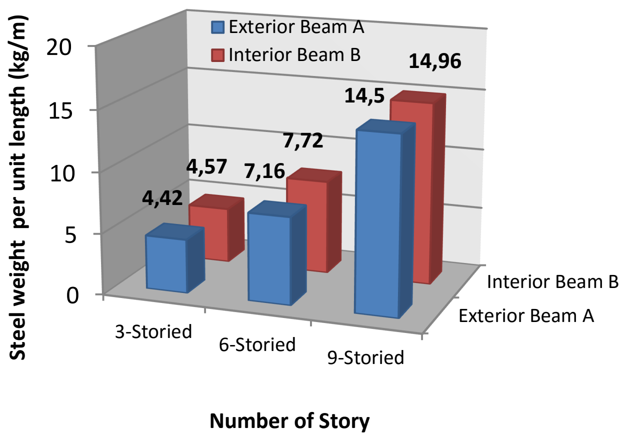


Fig. 7 Steel weights per unit length of beam in transverse direction

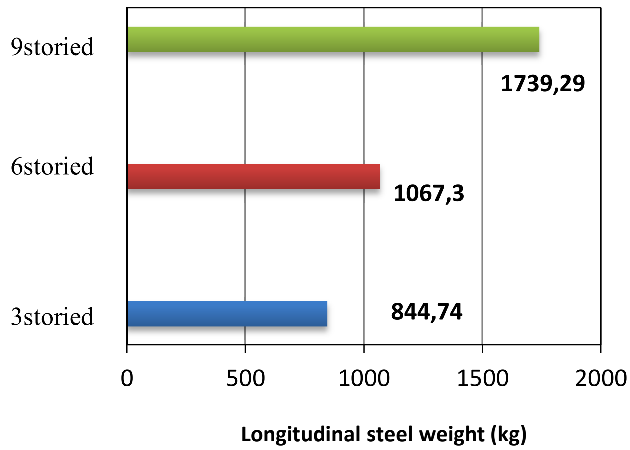


Fig. 8 Total Longitudinal steel weight of beams at each floor

V. Conclusion

The following conclusions have been drawn from the present study:

- For an exterior column, steel ratio (ρ) is 2.1%, 3.06%, 4.55% for three, six and nine storied building respectively for the first three floors. In case of an interior column, steel ratio (ρ) is 1.56%, 2.47%, 3.42% for three, six and nine storied building.
- For the first three floors,Total longitudinal steel weight of an interior column for six storied building is 59% and for

three storied building, it is about 30% of nine storied building. In case of a corner column, total steel weight for six storied building is 44% and for three storied building, it is about 25% of nine storied building.

- The total weight of longitudinal reinforcing bars of beams per floor for three, six and nine storied building is 0.844 tons, 1.0673 tons and 1.739 tons respectively.
- Total longitudinal steel weight of beams per floor for three storied building is 48.57% of nine storied building and in case of 6 storied building; it is about 61.36% of nine storied building whereas 100% is considered for nine storied building.

REFERENCES

[1] BNBC, Bangladesh National Building code, Housing and Building Research Institute, Dhaka, Bangladesh, 2006.
[2] ETABS nonlinear Version 9.6.0, Extended 3D analysis of the building systems, Computer and Structures Inc., Berkeley, California, USA, 1999.
[3] Nilson, A.H., Darwin, D., Dolan, C.W., Design of Concrete Structures, 13th edition, Mc. Graw Hill, 2003.
[4] Tawhid, K., Rahman, S.M. and Iftekthar, A., Comparative study on structural component design of a residential building located in Dhaka and Sylhet, B.Sc. Engg. Thesis, Department of Civil Engineering, Ahsanullah University of Science & Technology, Dhaka, Bangladesh, 2012.
[5] Coull, A. and Stafford, S. B., “Tall Building Structures, Analysis and Design,” John Wiley and Sons, Inc., 1991.
[6] Fintel, M., “Handbook of Concrete Engineering,” 2nd Edition, CBS Publishers and Distributors, India, 1974.
[7] Shourav, M.H, Islam, M.Z. and Tumpa, S.I., 'Investigation on the effect of Number of Story on different Structural Components of RC Building', B.Sc. Engg. Thesis, Department of Civil Engineering, Ahsanullah University of Science and Technology, Dhaka, Bangladesh, 2014.