STUDY OF STRUCTURAL BEHAVIOUR OF PRESTRESSED TRANSFER BEAM OF A MULTI-STORIED BUILDING UNDER SEISMIC LOAD

Lamia Tasnim Imam, Md. Syed-uz-Zaman

Abstract: Prestressed transfer beam is a new context in structural design. It is used to reduce the number of columns by transferring loads from one column to the surrounding columns with the tensioning of high strength tendons in transfer beam. Different structural behavior under seismic load of a multistoried building is studied in this paper. As a densely populated mega city, multistoried buildings may mitigate the living problem in Dhaka. Prestressed transfer beam having different dimension and at different location can be used in mixed use building for minimizing seismic load. So, a plan of 25 storied residential cum commercial building with two basements had been selected in the context of Dhaka city. The structural behaviour of RCC and prestressed transfer beams have been investigated in this study. Two cases had been established to analyze the building with the use of ETABS 17.0.1. Case 1, in which RCC transfer beams are positioned and Case 2, in which prestressed transfer beams are positioned in different location in 6th floor. Comparison of various parameters like base shear, moments, maximum lateral deflection, inter story drift and rotation between RCC and prestressed transfer beams have been analyzed from the ETABS 17.0.1 software. Prestressed transfer beam must be designed with a proper purpose and functional requirement. Prestressed transfer beams are a typical feature in the multi-storied construction as far now.

Index Terms: base shear, bending moment, building code, earthquake load analysis, maximum lateral displacement, rotation, shear force.

1 INTRODUCTION

In Bangladesh, multistoried buildings are constructed for the purpose of residential, commercial and industrial. In multistoried buildings, prestressed transfer beam is nowadays used usually for transferring high forces and loads to other structures that can resist them. Dhaka is highly vulnerable to the earthquake disaster because of its high population. So, a comparative study has been made to see the difference between the structural behavior of RCC transfer beam and prestressed transfer beams under seismic load. For this study, Materials properties, frame sections and loading pattern including dead load, live load and seismic load have been considered under the codes of BNBC 2006.

2 LITERATURE REVIEW

Prestressed transfer beam is nowadays used in multistoried building usually for transferring high forces and loads to other structures that can resist them. In current practice, the design of a prestressed transfer beam system is largely based on the experience of designers and simplification of the structure. The behaviour of a building during earthquakes depends critically on its overall shape, size and geometry, in addition to how the earthquake forces are carried to the ground. A comparison between prestressed transfer beam and RCC transfer beam under seismic load is presented here. The aim of this study is to analyse a mixed use (commercial cum residential) building situated in Dhaka with variable number of stories and identify the basic difference between RCC transfer beam and prestressed transfer beam for seismic load analysis. This study is performed for a 25 storied residential cum commercial building. The study conducted in this research is only for Dhaka city. The seismic zone coefficient varies for different parts of Bangladesh so, the result may vary for other cities.

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Earthquake load parameters are considered here:

1. Base shear, 2. Seismic zone factor, 3. Soil coefficient, 4. Structure Importance coefficient, 5. Time period, 6. Numerical coefficient, 7. Weight of structure.

3 METHODOLOGY

A 25 storied mix use (residential cum commercial) building situated in Dhaka city for the study to determine the effects of seismic load in analysis and design with BNBC 2006. The building structure modelling for analysis is dependent to some extent on the approach to analysis, which is related to structural behavior under seismic load. The structural analysis and design is carried out using ETABS 17.0.1. ETABS offers a user to perform modelling analysis, detailing and reporting. As manual analysis of a structure is time consuming and probability of error is high so ETABS may provide an easy, efficient and accurate way to analyze a structure. Here, we used the materials from the code of BNBC 2006 and ACI 318-14.

4 RESULT AND DISCUSSION

4.1 Effects of Base Shear

Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure. Calculation of base shear (V) depends on:

- Soil conditions at the site
- Proximity to potential sources of seismic activity (such as geological faults)
- Probability of significant seismic ground motion
- The level of ductility and overstrength associated with various structural configurations and the total weight of the structure
- The fundamental (natural) period of vibration of the structure when subjected to dynamic loading.

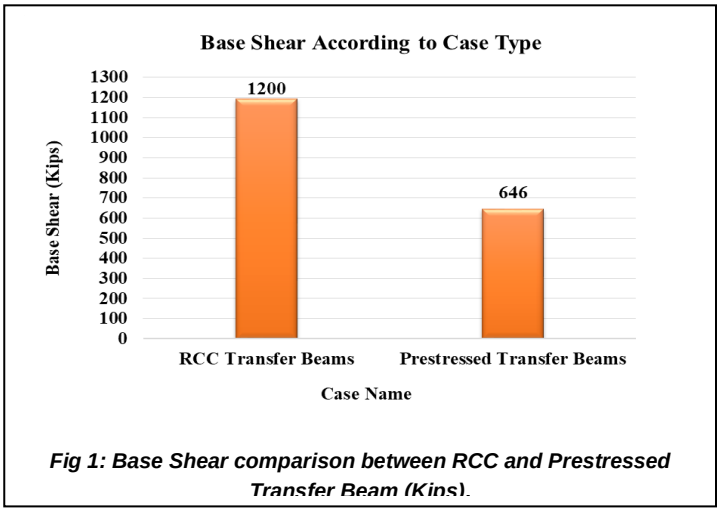

Fig 1: Base Shear comparison between RCC and Prestressed Transfer Beam (Kips).

Figure 1 shows comparison between the results with the authors, it can be clearly pointed that the base shear of RCC transfer beams have about 46% higher than the prestressed transfer beams. Base shear increases with no of story increases. It shows the variation of building base shear with respect to weight of the structure.

4.2 Effects of Shear Force

Shear force is the force acting on a substance in a direction perpendicular to the extension of the substance, acting in a direction to a planar cross section of a body. Shear force is the summation of the effect of shear stress over a surface, and often results in shear strain.

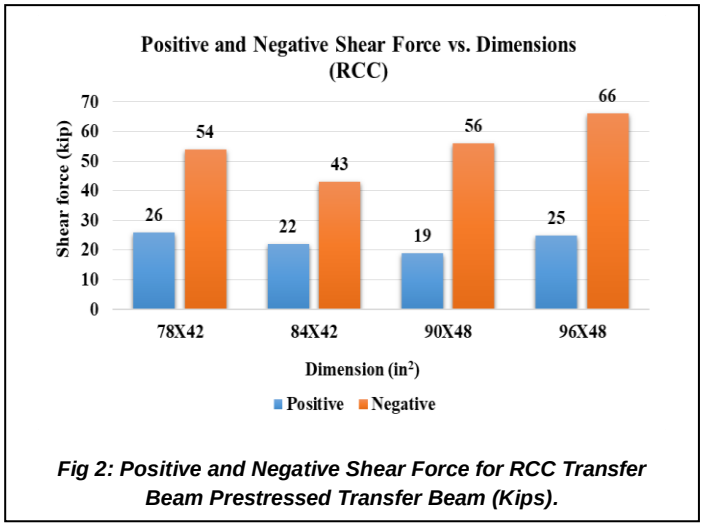

Fig 2: Positive and Negative Shear Force for RCC Transfer Beam Prestressed Transfer Beam (Kips).

From Figure 2 it can be seen that for negative shear force for transfer beam 96x48 in^2 shows maximum shear and positive shear force for transfer beam 78x42 in^2 shows maximum shear.

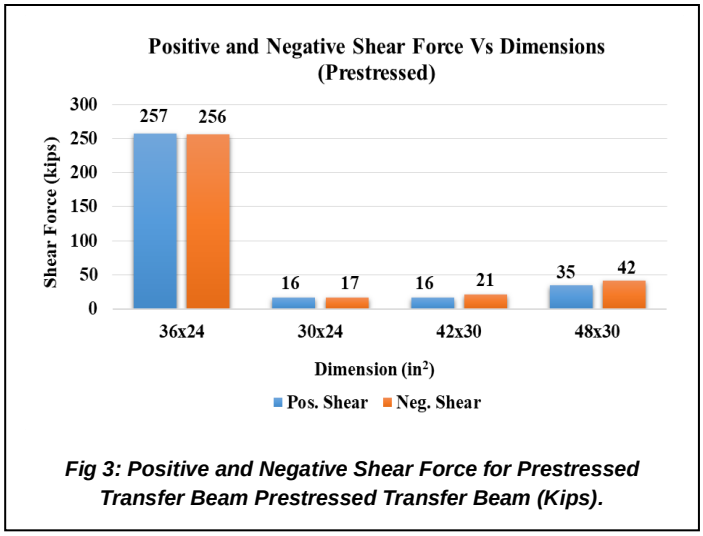

Fig 3: Positive and Negative Shear Force for Prestressed Transfer Beam Prestressed Transfer Beam (Kips).

From Figure 3 it is seen that, both positive and negative shear force for transfer beam 36x24 in^2 shows maximum shear.

4.3 Effects of Bending Moment

A bending moment is the reaction induced in a structural element when an external force or moment is applied to the element causing the element to bend transfer beams.

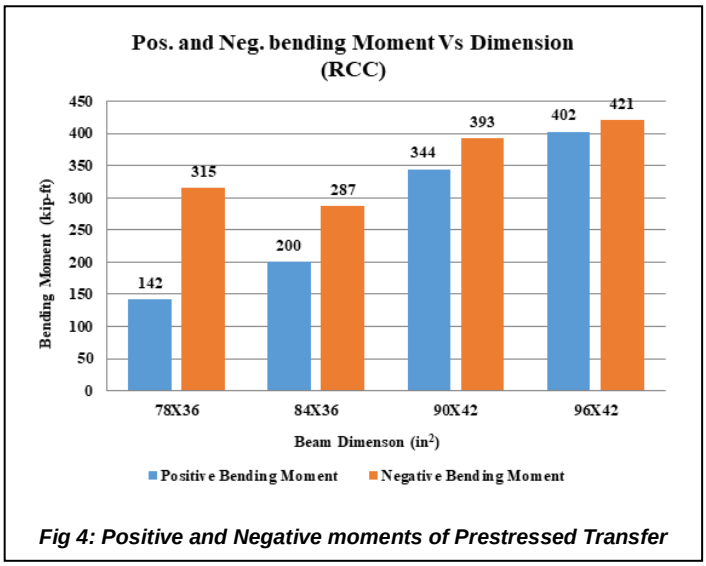

Fig 4: Positive and Negative moments of Prestressed Transfer

From Figure 4 it is seen that, both positive and negative bending moment for RCC transfer beam 96x42 in^2 shows maximum moment.

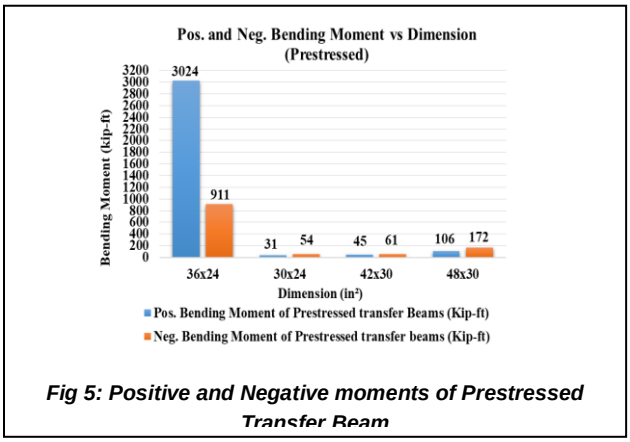

Fig 5: Positive and Negative moments of Prestressed Transfer Beam

From Figure 5 it is seen that, both positive and negative bending moment for prestressed transfer beam 36x24 in^2 shows maximum moment.

4.4 Effects of Maximum Story Displacement

Story Displacement is lateral displacement of the story with respect to ground. From figure-6 it is seen that, the maximum story displacement is 3.4 in. at top floor. According to IS: 1893 – 2002 and IS: 456 – 2000, maximum permissible story displacement is limited to H/500. Where, H – total height of building. For our 25th storied building maximum permissible story displacement is 6 in. It means our building's displacement is within limit.

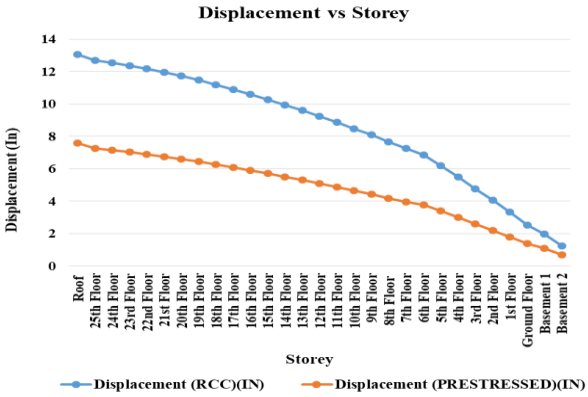

Fig 6: Story Displacement for both RCC and prestressed Transfer beams

4.5 Effects of Maximum Story Drift

Lateral (story) drift is the amount of side sway between two adjacent stories of a building caused by lateral (wind and seismic) loads. For a single-story building, lateral drift equals the amount of horizontal roof displacement. According to IS: 1893 – 2002 and IS: 456 – 2000, maximum permissible story drift is limited to 0.004 h. Where, h – story height. For our 25th storied building maximum permissible story drift is 12 in. From figure-7 it is seen that maximum drift occur in two locations, they are Basement-Ground and 6th-7th floor. But in both cases, story drift values are within limit.

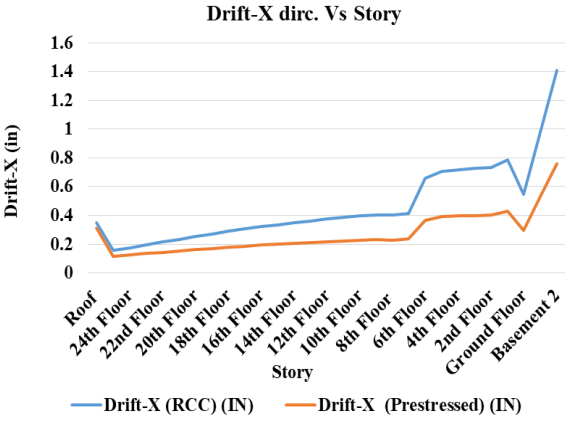

Fig 7: Variation of Maximum Story Drift

4.6 Effects of Rotation

Rotation of a building depends on wall and floor slope at critical level. The maximum rotation of reinforced concrete beams should to be limited to 0.03 for the collapse prevention performance level (FEMA 273). According to the study of prestressed and RCC beam, RCC beam rotates more than prestressed beam. But in both cases the rotation value is much less than collapse limit.

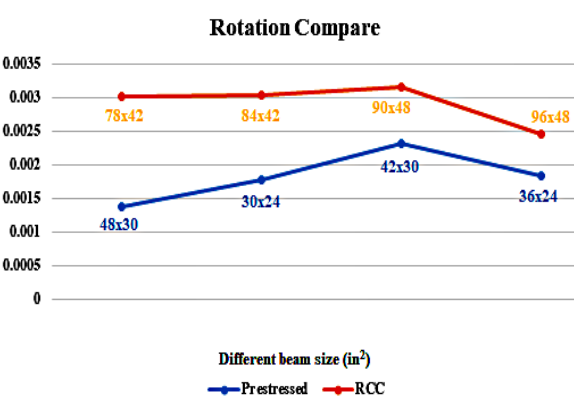

Fig 8: Maximum rotation compare for RCC & Prestressed Transfer Beam

5 Conclusion

According to the study the elementary objective was to observe the structural behaviour of prestressed transfer beam with respect to RCC transfer beam under seismic load. Prestressed transfer beams are a typical feature in the modern multi-storied construction. The present study investigated structural behaviour of RCC and prestressed transfer beams. Prestressed transfer beams in structural engineering must be designed to satisfy prescribed safety condition. Various structural effects of RCC and prestressed transfer beams had been observed under seismic loads in transfer floor.

From the study it is found that:

1. The base shear of RCC transfer beam is found about 46% higher than the prestressed transfer beam.
2. The shear force of RCC transfer beam and Prestressed transfer beam range from 18-70 kip and 16-260 kip respectively.
3. The moment of Prestressed transfer beam is 30-3025 kip-

ft which is much higher than RCC transfer beam which carry 140-425 kip-ft moment.
4. The story displacement of RCC and Prestressed transfer beam range from 0-14 in. and 0-8 in. respectively.
5. Story drift of RCC and Prestressed transfer beam range from 0.3-0.6 in. and 0.15-0.35 in. respectively.
6. In both cases, story displacement increases at same rate from basement to roof but RCC is higher between two cases.
7. In both cases, story drift decreases at same rate but drastic changes occur in transfer floor.
8. In both cases the rotation value is much less than collapse limit 0.03.

TABLE
DIFFERENT PROPERTY DATA

Analysis Property Data	
Mass Per Unit Volume	2.246 X 10^{-7} (K/in^3)
Weight Per Unit Volume	8.68 X 10^{-5} (K/in^3)
Modulus Of Elasticity	3605
Poisson's Ratio	0.2
Co-efficient Of Thermal Expansion	5.500 X 10^{-6}
Shear Modulus	1500

Tendon Property Data	
Material Type	A416Gr270
Strand Area (in^2)	0.153
Number of Strands	9
Bonding Option	Unbonded
Tendon Load Data	
Transfer Load Pattern	PT TRANSFER
Final Load Pattern	PT FINAL
Jack From This Location	J-End
Tendon Jacking Stress (lb/in^2)	216000
Tendon Jacking Force (kip)	297.432
Tendon Loss Data	
Loss Type	
Tendon Jacking Stress (lb/in^2)	27000
Long Term Loss (lb/in^2)	13500

Design Property Data	
Specified Concrete Compressive Strength, f'c	4 KSI
Bending Reinforcement Yield Stress, fy	60 KSI
Shear Reinforcement Yield Stress, fys	60 KSI

Load Chart According to BNBC 2006		
Name	Dead Load	Live Load
All Beams	0.5 K/Ft (From Partition Wall)	0.63 k/ft
Residential Slab	50 PSF (Partition Wall and Floor Finish)	103 PSF
Commercial Slab	55 PSF (Partition Wall and Floor Finish)	328 PSF

6 RECOMMENDATION

In modern times mixed use building containing transfer beam has become popular in our country. Therefore, such type of buildings should be designed properly taking care of their structural behavior. Different type of effects in the prestressed transfer beam are most important to design the beams for earthquake.

The following recommendations can be made for future research work:

1. The study model have been prepared by ETABS 17.0.1. Other methods of analysis may be done to get additional terms related to the seismic behaviour of prestressed and RCC transfer beam.
2. Prestressed transfer beam having different dimension and at different location can be used in mixed used building for minimizing seismic loads.
3. In the model analysing, BNBC 2006 has been used, other latest BNBC can be followed.

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