# Comparative study on Rebar and Post Tensioned Transfer Girder

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***Abstract*:- Transfer girder is one of the primary component in a multi-storeyed building and offers elegant solutions to support vertical members that do not extend below lower levels of high rise buildings, which are mostly used as parking spaces, shopping malls, conference halls etc. without the obstruction of columns. The depth of transfer girders in conventional rebar concrete is very high and increases with increase in the height of the structures. Post tensioned concrete transfer plate system, with post-tensioning tendons is found to be very effective in reducing member thickness and has been widely adopted recently. In this project, a comparative analytical study is made on the structural performance and cost economy of the Rebar and Post tensioned transfer girders in a High rise building. Three-dimensional finite element model of a G+40 Multi-storeyed building is developed and analysed using ETABS 2018 software. Different load combinations and load cases are taken into consideration as per the relevant IS codes. Design of the Rebar and Post tensioned transfer girders is done using ADAPT 2019 software and comparison is done on the structural behavior of the Transfer girders with respect to tensile stress, ultimate moment, crack width, short and long term deflection etc. Cost comparison is done between the two transfer girders, to decide on the economy of the construction. Finally the study aims to highlight the advantages of Post Tensioned Transfer plate over the conventional floor systems.**

***Keywords— Transfer girder, rebar concrete, Post tensioned, Load cases, Load combinations, ETABS, ADAPT***

## I. INTRODUCTION

Recent advances in technology have extended the boundaries of the construction industry and innovative designs which were once thought to be unimaginable are now a reality. Rapid urbanization and developments have propelled the construction of many High-rise buildings which have now become the pride of any nation. Moreover, the client's requirements for more building spaces, innovative architectural designs and increase in real estate value have all contributed to surge in the construction of multi-storeyed buildings. Transfer girder is one of the primary component in a multi-storeyed building. Transfer girders offer elegant solutions to support vertical members that do not extend below lower levels of high rise buildings, which are mostly used as parking spaces, shopping malls, conference halls etc. without the obstruction of columns. The problem, however, is that transfer girders are quite massive and expensive, because heavy loads from the floating columns above them, act on the transfer girders. Hence, it has become essential to implement new and innovative technologies which can provide design economy and structural capacity while performing the same role in architectural terms.

The depth of transfer girders in conventional rebar concrete is very high and increases with increase in height of the structures. Due to this there is a substantial increase in self weight and overall load acting on the foundation. Moreover, in a typical multi storey building, the depth of transfer girder is found to be in the range of 2.5m to 3m ie. an entire storey floor of concrete mass, which is highly uneconomical for a residential multi storeyed building.

In today's world, where the modern engineering is finding new ways to build longer, more efficient and stronger structures, Post tensioned concrete has become one of their chief requirements. Post-tensioning is a method of prestressing, in which the tendons are tensioned after the concrete has hardened and the prestressing force is primarily transferred to the concrete through the end anchorages.

Post tensioned concrete transfer plate system, with post-tensioning tendons is found to be very effective in reducing member thickness and has been widely adopted recently. Post Tensioned concrete is used in different parts of the world for multi-storeyed buildings, bridges, etc., primarily due to its economy and load carrying capacity. Researches have proven Post Tensioned concrete to be more durable, cost effective and higher strength, with reduced depth than conventional concrete.

## II. SCOPE OF THE PROJECT

In this Project it is proposed to compare the rebar and post tensioned transfer girders in a multi-storeyed building, based on its structural behaviour and cost perspective. The analysis of the multi-storeyed structure is done using ETABS 2018 software and design of the transfer girder system in RC structure and Post Tensioned is done using ADAPT 2018 software.

## III. OBJECTIVES

The main objective of the project is tostudy

- Advantages of Transfer Plate when compared with other floor systems.
- To find out the structural behaviour of Conventional transfer plate and Post-tensioning transfer plate.
- Cost comparison of Conventional and Post-tensioning System.

## IV. METHODOLOGY

### 4.1 General Layout

A G+40 story building floor plan, as shown in Fig 1, 2 and 3 was chosen to study the behavior of Post Tensioned and Rebar concrete transfer girders. The building plan was selected such that one half of the Transfer girder floor is designed as Post Tensioned and the other half as Rebar Transfer Girder with similar boundary conditions and the same forces action on the floor. The transfer girder is proposed at the 7$^{th}$floor level and depth of the floor is selected as 1000mm based on the size of columns supported by transfer girder. The height of the storeys have been kept as 4 meters equally in all the floors. The general properties of Podium floors, Above Floors and Transfer girder are given in Tables 1, 2 and 3.

Software ETABS v. 18.0.2 has been used for analysis, to calculate the forces acting on the Transfer Girder and software ADAPT 2019 has been used for design of both Post Tensioned and Rebar concrete girders.

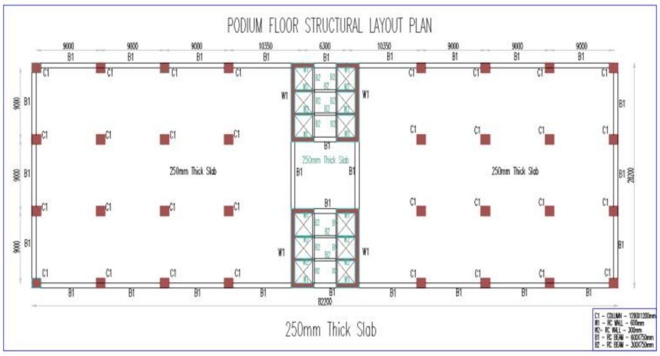



**Fig – 1**: Layout plan of Podium floor

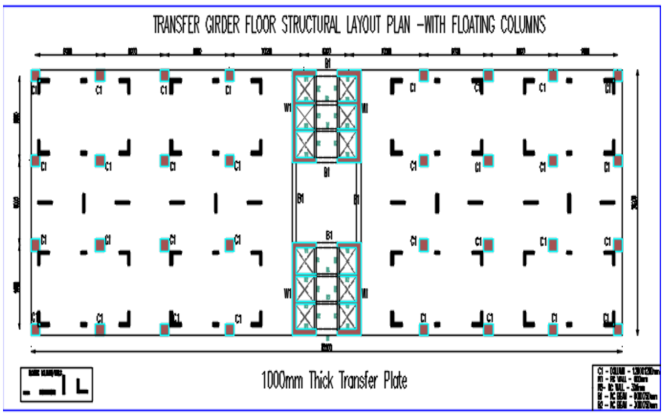



**Fig – 2**: Layout plan of Transfer floor

**Fig – 3**: Layout plan of above floors

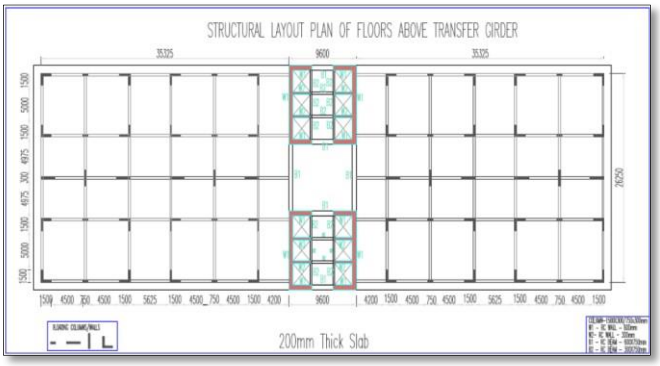



**Table 1:** General properties of Podium Floors

| Description | Podium Floors |
|---|---|
| Plan Dimension c/c | 81 m x 27 m |
| Bay width | 9 m, 10.35m, 6.3m |
| Slab Thickness | 250 mm |
| Grade of concrete of podium floors | M30 / M40 |
| Size of beams | 0.3x0.6 m, 0.3x0.75 m |
| No. of columns / shear walls | 64 columns |
| Size of columns / shear walls | 1200mm x 1200 mm |

**Table 2:** General properties of Above Floors

| Description | Above floors |
|---|---|
| Plan Dimension c/c | 81 m x 27 m |
| Bay width | 9 m, 10.35m, 6.3m |
| Slab Thickness | 200 mm |
| Grade of concrete of podium floors | M30 |
| Size of beams | 0.23x0.45 m,0.23x0.4m |
| No. of columns / shear walls | 60 Nos |
| Size of columns / shear walls | 1500 mm x 300mm, 750 mm x 300 mm |

**Table 3:** General properties of Transfer Floor

| | |
|---|---|
| Plan Dimension | 81 m x 27 m |
| Bay width | 9 m, 10.35m, 6.3m |
| Depth of transfer girder | 1000 mm |
| Grade of concrete for transfer girder | M50 |
| Span of transfer girder | 37.35 m (on each side) |
| No. of columns / shear walls supported on transfer girder | 30 Nos. on each side |
| Size of columns / shear walls supported on transfer girder | 1500 mm x 300mm, 750 mm x 300 mm |

### 4.2 Load Cases

Different load cases were taken into consideration based on relevant IS Codes as below:

- (DL) Dead Loads are taken as the self-weight of structural elements, Floor finishes
- Super Imposed Load (SDL)
- Live load (LL)
- Earth Quake in X (EQX) and Y (EQY)Directions- As per IS 1893 : 2002,
- Wind Load in X (WLX) and Y (WLY) Directions - As per IS 875 : 1987

Overall 49 different load combinations have been taken for analysis.

### 4.3 ETABS Model and Analysis

Based on the above Load cases in structural elements, model was created in ETABS 2018 software as shown in Fig. 5 and 6. Analysis of the Multi-storeyed building was carried out.

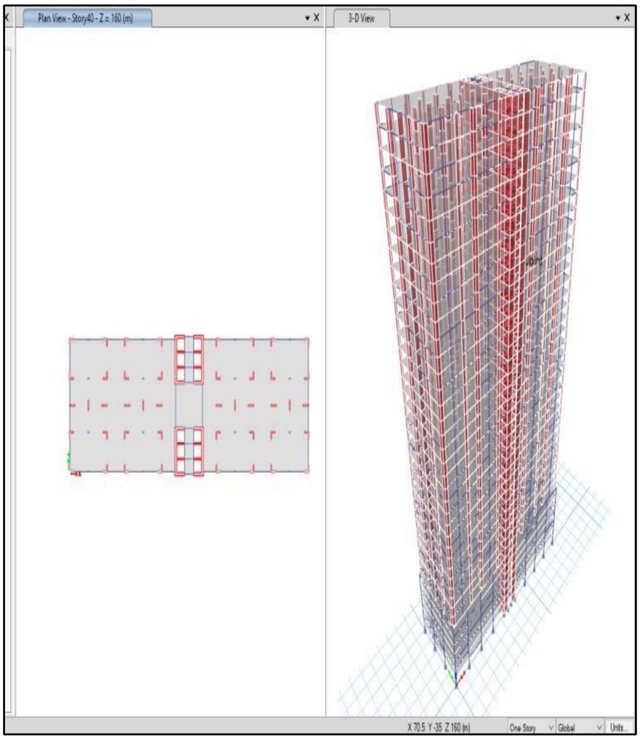
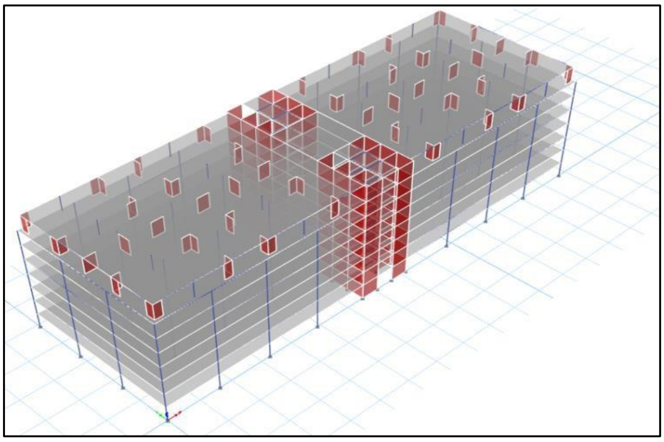


**Fig – 5**: ETABS model of the structure

**Fig – 6**: ETABS model at Transfer floor level



Resultant Axial forces and Ultimate Moments acting on the Transfer Girder at the 7th floor level were determined as shown in Figures Fig 7, 8 and 9.

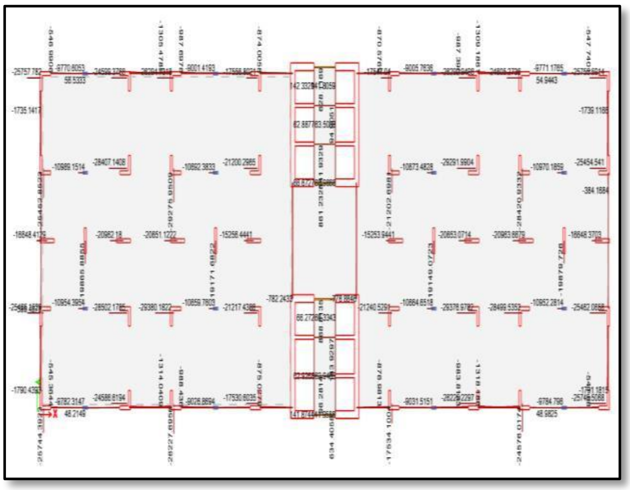


**Fig – 7:** Ultimate Axial forces on Transfer Girder

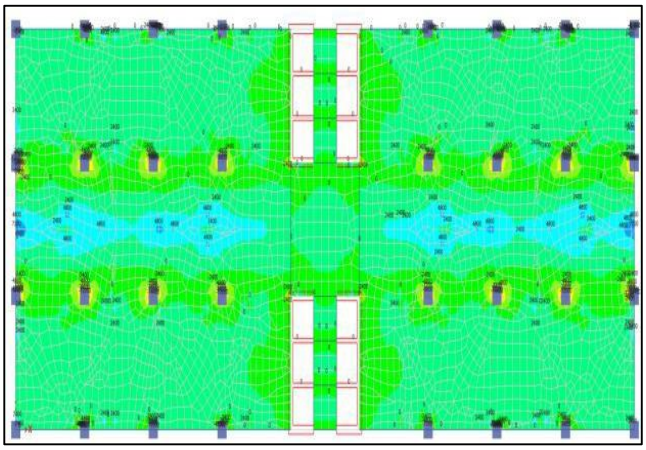


**Fig – 8**: Ultimate moment (M11) on Transfer girder KNm

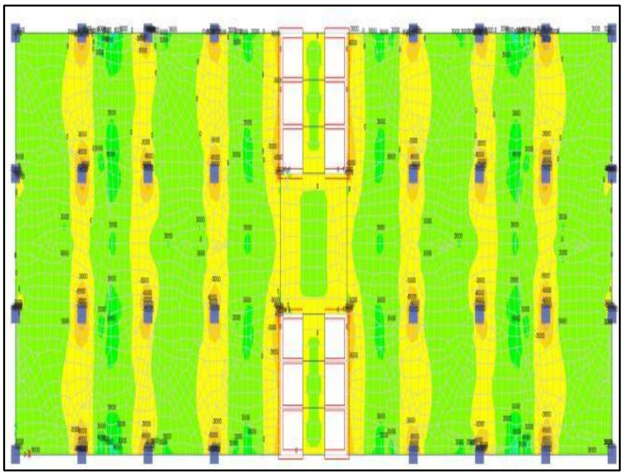


**Fig – 9**: Ultimate moment (M22) on Transfer girder (KNm)

### 4.4 Transfer girder model in ADAPT

The forces acting at the transfer girder level was exported and model was developed in ADAPT software, for detailed design of Post-Tension and RC conventional plate as shown in Fig. 10. While exporting the transfer plate from ETABS it was ensured that envelope values for flexural and serviceability load case was included.

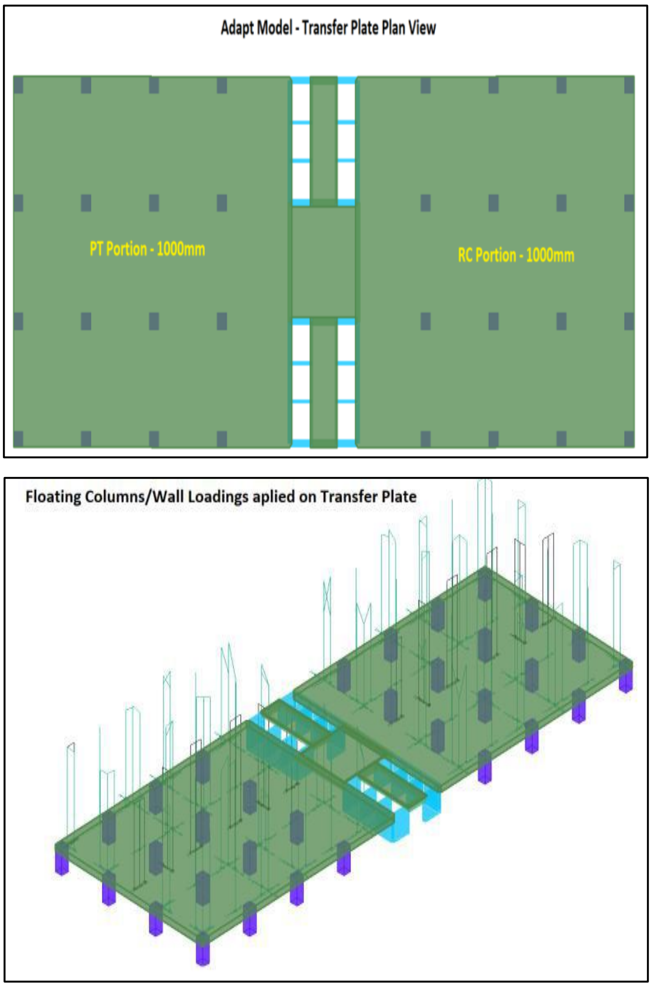
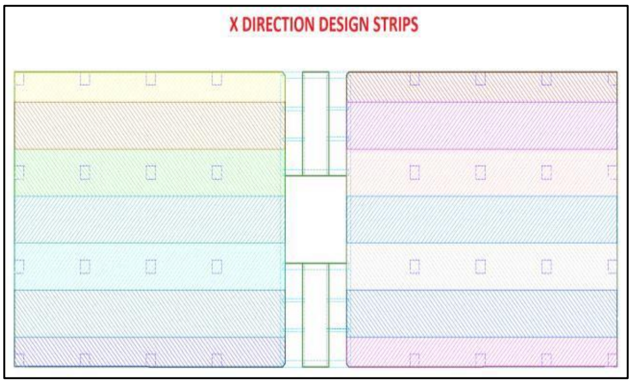



**Fig – 10**: ADAPT model of Transfer girder

Formation of strips in both X & Y directions is the basic requirement for analysis and design of any members in ADAPT software as shown in Fig. 11 & 12. Minimum one strip is required for each bay width along the spanning directions.

**Fig – 11**: Design strips in X direction



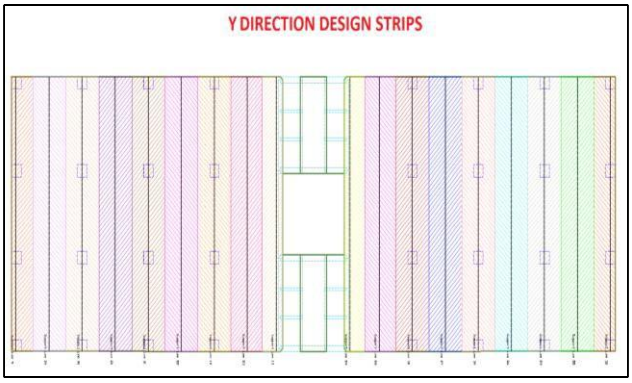
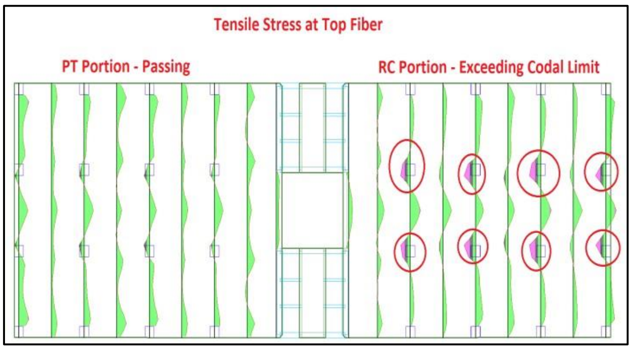



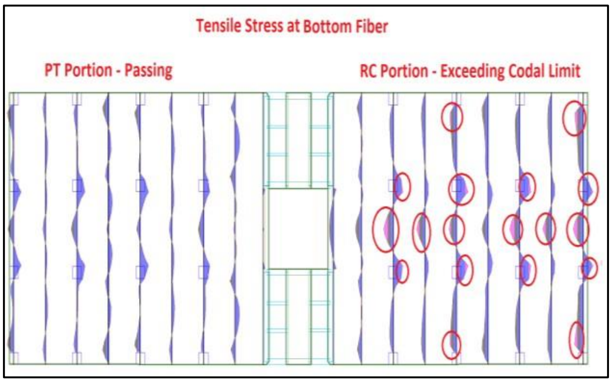

**Fig – 12**: Design strips in Y directions

## V. DERIVED OUTCOMES OF POST TENSIONED AND REBAR TRANSFER GIRDERS IN ADAPT

Axial forces due to the floating columns determined in ETABS were applied on the Transfer girders and analysis and design carried out in ADAPT. The resulting Tensile stress, shear, bending moment, crack width and long / short deflection on the Post tensioned and Rebar concrete Transfer girders is shown in Fig. 13, 14, 15 and 16.

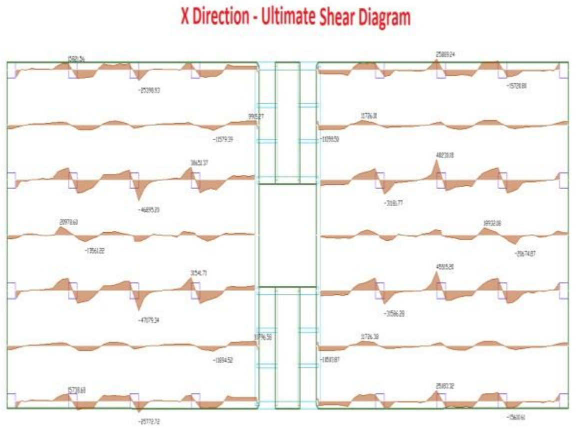
### 5.1 Tensile Stress




As per IS 456, the permissible tensile stress for Rebar slab exceeds the codal limit of 5 MPa ie. the observed stress is in the range of 5 to 6 MPa at mid span in both the top and bottom fibres. In Post Tensioned slab, the permissible tensile stress at both the top and bottom fibres are within the codal limit.

### 5.2 Shear Force



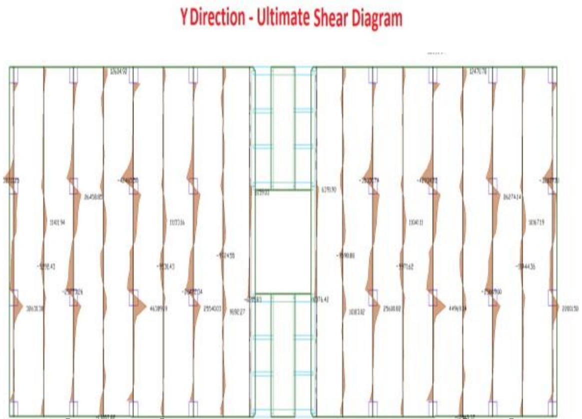
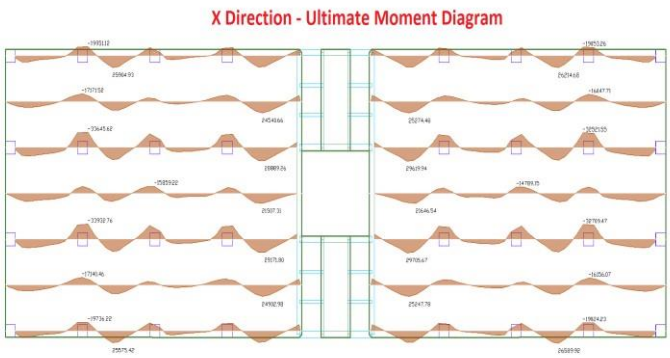




**Fig. 14** Ultimate Shear Force Diagram in X and Y direction

No significant variation in the shear resistance capacity for both the Rebar and Post Tensioned Transfer Girders as obtained from the results and calculations in ADAPT.

### 5.3 Bending Moment

When both the Transfer Girders are compared for their moment of resistance as shown in Fig.15., it is observed that there is no significant difference in the Bending moment capacity of both Rebar and Post Tensioned slab and is similar considering the results from the calculations.



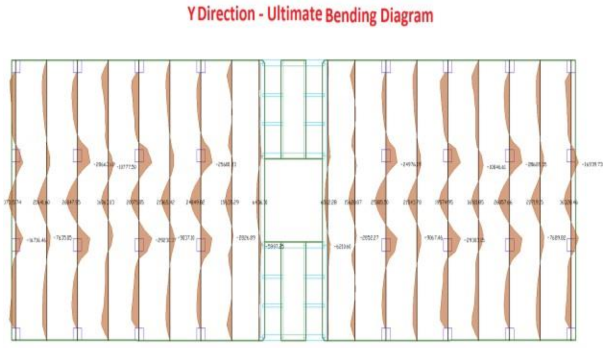
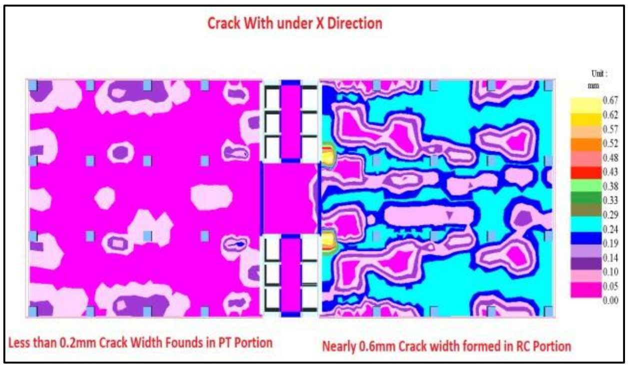




**Fig. 15 :** Ultimate Bending Moment Diagram in X and Y direction

### 5.4 Crack width



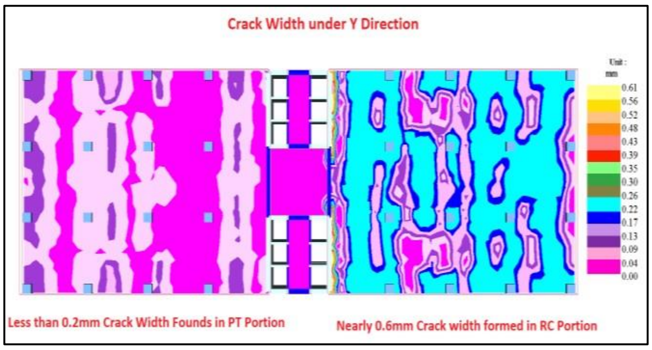




**Fig. 16 :** Crack width in X and Y direction

As per IS 1343, Clause 22.7, the allowable crack width in Post Tensioned slab is 0.2 mm and from Fig.6.4, it is observed that the crack width in both X and Y directions, is in the range of 0.05 to 0.1 mm, which is within the codal limit. In the Rebar portion, a crack width of 0.6 mm is observed at the support and 0.22 mm in spans which exceeds the codal limit by 3 times and 1.1 times respectively.

### 5.5 Deflection Performance

The theoretical long term and short term deflection obtained by calculation in RC Transfer girder is 40 mm and 15 mm respectively, which is 1.33 times greater than the deflection noticed on PT transfer girder.

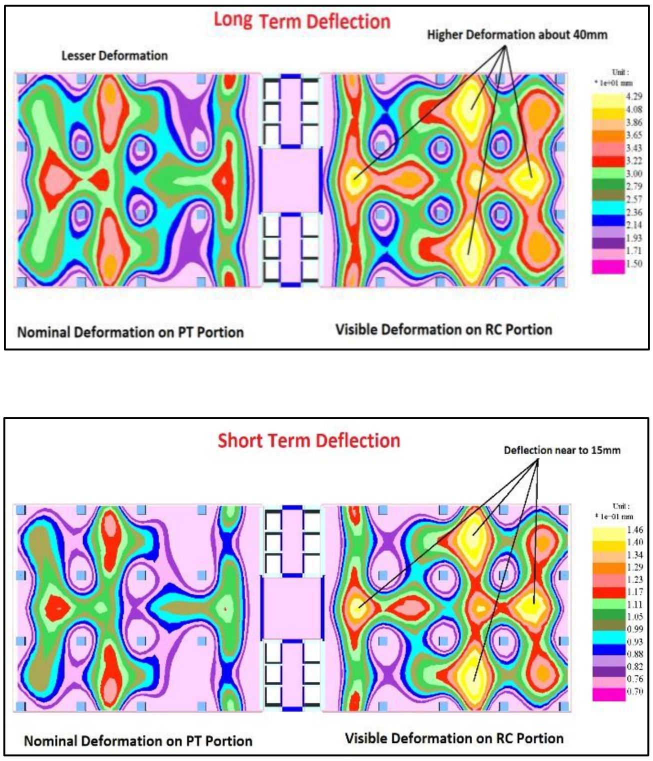



**Fig. 17 :** Long and short term deflection

## VI. REINFORCEMENT REQUIREMENT

Design of Transfer girders were carried out in ADAPT assuming a depth of 1000 mm for both Post Tensioned and Rebar concrete. It was observed that, in the RC portion, failure due to deflection occurred due to insufficient slab depth and hence the portion was redesigned assuming a depth of 2.3 m. The steel reinforcement requirement for both the Transfer girders are shown in Fig. 18 and 19.

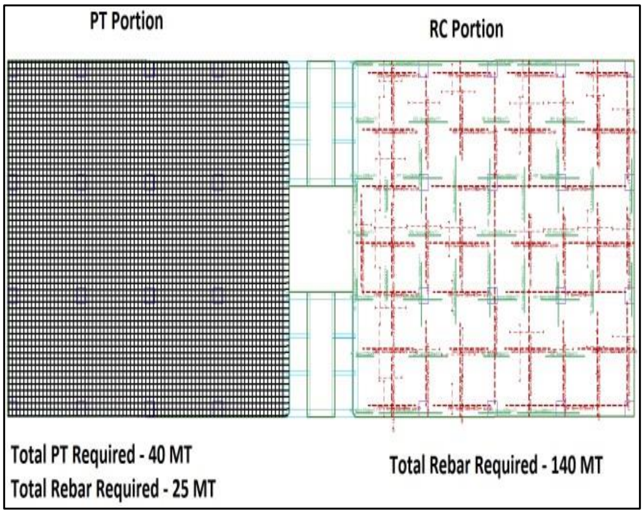



**Fig – 18** : Steel requirement for Rebar and PT floors

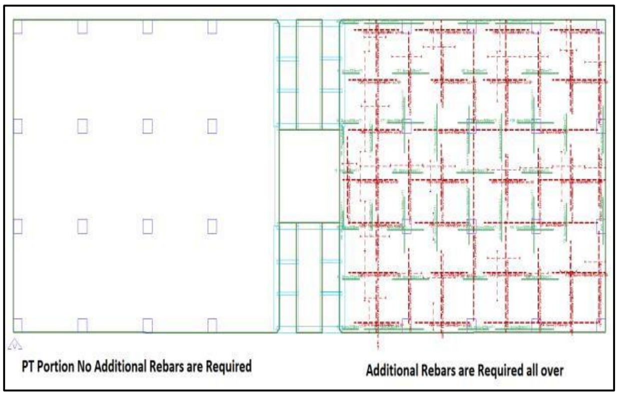



**Fig – 19** : Additional steel requirement for Rebar floor

## VII. RESULTS AND DISCUSSIONS

The analysis and design of the Post Tensioned and Rebar Transfer slabs are done and cost comparisons for concrete and steel are shown in below Graph 1 - Graph 4. Based on the above results, the following is observed

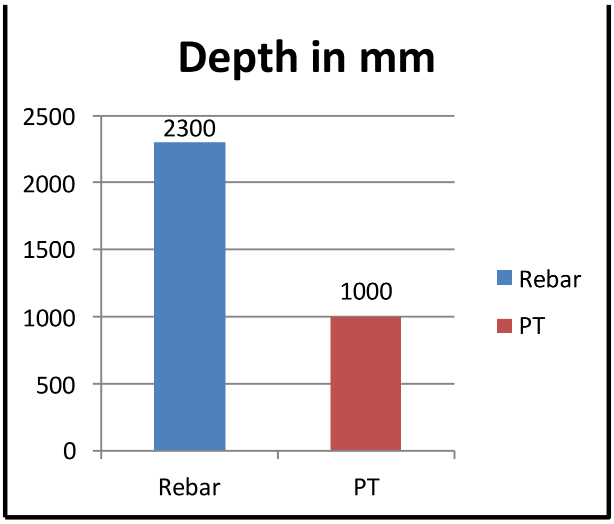
- The Tensile stresses in the top and bottom fibers in Rebar Transfer girder exceeds the IS code limit, whereas it is within the limits in Post Tensioned portion.
- Crack width in PT girder is less than 0.2 mm, compared to 0.6mm in Rebar portion.
- Long term and short deflection was maximum in Rebar concrete portion than in the Post tensioned Transfer girder.
- Depth of the slab for post tension is 60% less than for RC portion
- Quantity of Steel required for Post tension plate is 54 % less than for Rebar transfer plate.
- Huge depth of RC Transfer girder, involves mass concreting in two stages. This results in prolonged time of construction and associated increase in labour costs.

## VIII. CONCLUSIONS

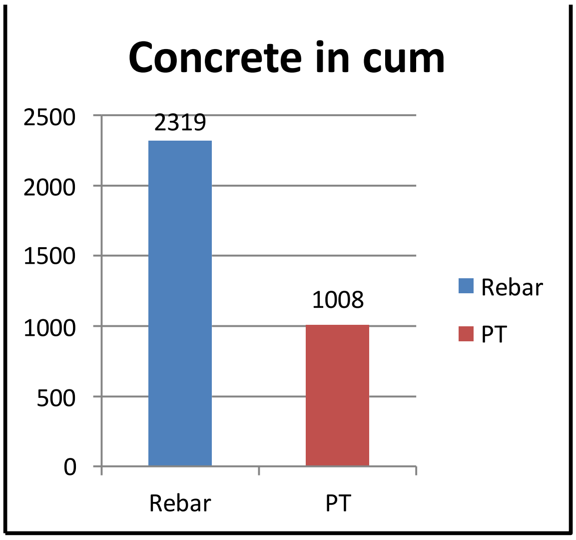
From the above study the following conclusions are made,

The structural behavior and cost analysis of Post tensioned and Rebar concrete Transfer girder was done in a multi storeyed building.

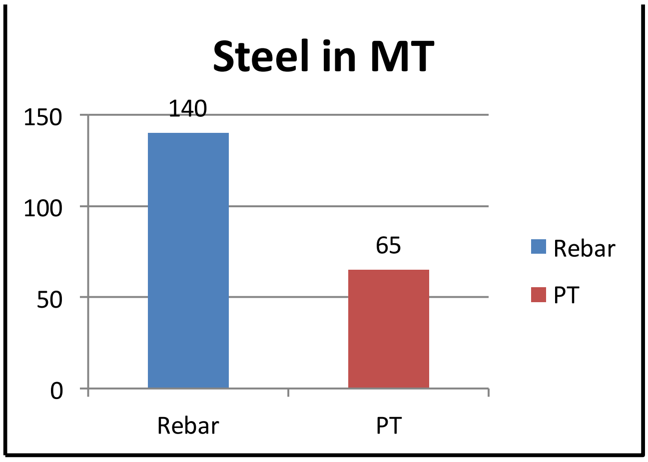
The results clearly indicate that based on structural performance and cost perspective, the Post tensioned transfer girder is more advantageous than Rebar concrete Transfer girder for multi-storeyed buildings.



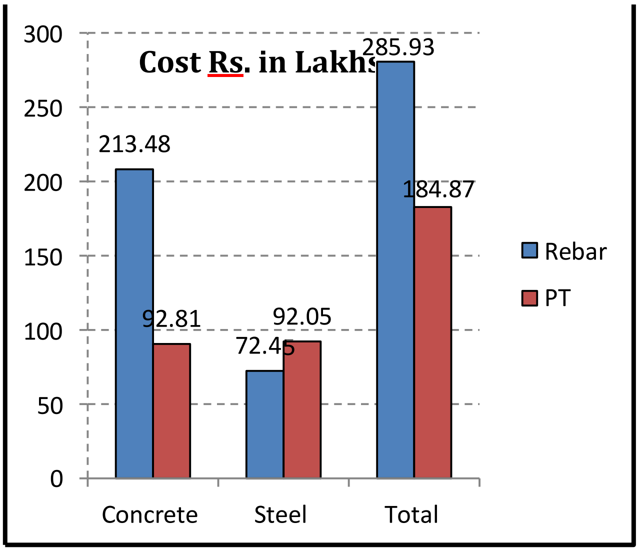

**Graph – 1:** Depth comparison of RC and PT Transfer slabs




**Graph – 2:** Concrete comparison of RC and PT Transfer slabs




**Graph – 3:** Steel requirement of RC and PT Transfer Slabs




**Graph – 4:** Cost Comparison of RC and PT Transfer slabs

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C. IS 875-1 (1987) : Code of Practice for Design Loads (other than earthquake) for Buildings and Structures : Part 1 Dead Loads – Unit weights of building material and stored materials

D. IS 875-2 (1987) : Code of Practice for Design Loads (other than earthquake) for Buildings and Structures : Part 2 Imposed Loads

E. IS 875-3 (1987) : Code of Practice for Design Loads (other than earthquake) for Buildings and Structures : Part 3 Wind Loads

F. IS 875-5 (1987) : Code of Practice for Design Loads (other than earthquake) for Buildings and Structures : Part 5 Special Loads and Loa Combination.