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Comparative Study of Post Tensioned and RCC Flat Slab in Multi-Storey Commercial Building

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Abstract - *The post-tensioning method is now a day's increasing widely, due to its application. By using post-tensioning method one can design the most economic and the safe design. While using this method more precautions has to be made for shear and deflection criteria for the slabs. The design of post-tensioned flat slab can be done by using load balancing and equivalent frame method. In a developing country like India the benefits of post stressing and particularly of Post-Tensioning are yet to be recognized. This has to be overlooked considering the significant benefits of Post- Tensioning can be advantageously procured. In the present study an attempt is made to compare the cost effectiveness of Post- Tensioned flat slab systems with respect to reinforced concrete flat slab system. Both the systems are analyzed using RAPT and ETABS respectively which is based on the design methodology. The results indicate that Post Tensioned flat slabs are cheaper than the RCC slab systems.*

Key words: **Equivalent Frame Method, Load Balancing, Flat Slab, Post Tension, safe design, RCC.**

1. INTRODUCTION

As the floor system plays an important role in the overall cost of a building, a post-tensioned floor system is invented which reduces the time for the construction and overall cost. In some countries, including the U.S., Australia, South Africa, Thailand and India, a great number of large buildings have been successfully constructed using post-tensioned floors. Post stressed concrete has been used in seismic resistance building structure. Hence the structure will be safe from earthquake.

Post stressed concrete is basically concrete in which internal stresses of a suitable magnitude and distribution are introduced so that the stresses resulting from external loads are counteracted to a desired degree. In Reinforced Concrete members, the post stress is commonly introduced by tensioning the steel reinforcement.

The earliest examples of wooden barrel construction by force fitting of metal bands and shrink fitting of metal tyres on wooden wheels indicate that the art of post stressing has been practiced from ancient times.

The tensile strength of plain concrete is only a fraction of its compressive strength and the problem of it being deficient in tensile strength appears to have been the driving factor in the development of the composite material known as "Reinforced Concrete".

The development of early cracks in reinforced concrete due to incompatibility in the strains of steel and concrete was perhaps the starting point in the development of a new material like "post stressed concrete".

The application of permanent compressive stress to a material like concrete, which is strong in compression but weak in tension, increases the Apparent tensile strength of that material, because the subsequent application of tensile stress must first nullify the compressive post stress.

Post stressing results more economical structures with avery high tensile strength instead of normal reinforcing steels.

It offers larger spans and greater slenderness which results in reduced dead load. Thus, the load and size of the column and foundation reduce. Subsequently, the overall height of buildings reduces which enables additional floors to be incorporated in buildings of a given height.

The use of unbounded tendons was first demonstrated by Dischinger in 1928, in the construction of a major bridge of the deep girder type, in which post stressing wires were placed inside the girder without any bond. Losses of post stress were compensated by the subsequent re-tensioning of the wires. Other advancements like development of vibration techniques for the production of high strength concrete and the invention of the double-acting jack for stressing high tensile steel wires are considered to be the most significant contributions.

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The following photo shows the ducts and reinforcement at the slab-column junction in a slab with a drop panel.

2. Literature Review

Boskey Vishal Bahoria and Dhananjay K. Parbat, [5] (2013) The post-tensioning method is now a day increasing widely, due to its application. By using post-tensioning method one can design the most economic and the safe design. While using this method more precautions must be made for shear and deflection criteria for the slabs. The design of post-tensioned flat slab can be done by using load balancing and equivalent frame method. For the application of design procedure an office building is considered as a case study. The plan of the office building (G+4) is considered. This building is designed by considering four cases with different floor systems. The quantities of reinforcing steel, post stressing steel, concrete required for the slab, beam and column is calculated for the same and are presented in tabular form. Along with this total cost of the building per square meter is found and comparison of all the four cases with respect to cost is done.

R. P. Apostolska , G. S. Necevska-Cvetanovska , J. P.Cvetanovska3 and N. Mircic, [4] (2008) Flat-slab building structures possesses major advantages over traditional slab-beam-column structures because of the free design of space, shorter construction time, architectural – functional and economical aspects. Because of the absence of deep beams and shear walls, flat-slab structural system is significantly more flexible for lateral loads then traditional RC frame system and that make the system more vulnerable under seismic events. The results from the analysis for few types of construction systems which is presented in the paper show that flat slab system with certain modifications (design of beam in the perimeter of the building and/or RC walls) can achieve rational factor of behaviour considering EC8 and can be consider as a system with acceptable seismic risk. Modifications with additional construction elements improve small bearing capacity of the system and increase strength and stiffness, improving seismic behaviour of flat-slab construction system. Selected result from the analysis are presented in the paper.

Pradip S. Lande1, Aniket B. Raut, [7] (2015) The flat plate system has been adopted in many buildings construction taking advantage of the reduced floor height to meet the economical and architectural demands. Flat slab RC buildings exhibit several advantages over conventional beam column building. However, the structural effectiveness of flat-slab construction is hindered by its alleged inferior performance under earthquake loading. Although flat-slab systems are widely used in earthquake prone regions of the world, unfortunately, earthquake experience has proved that this form of construction is vulnerable to more damage and failure, when not designed and detailed properly. Therefore, careful analysis of flat slab building is important. In the present study a parametric investigation was carried out in order to identify the seismic response of systems a) flat slab building b) flat slab with perimetric beams c) flat slab with shear walls d) flat slab with drop panel. e) Conventional building a aforementioned hypothetical systems were studied for two different storey heights located in zone v. and analysed by using ETABS Nonlinear version 9.7.3. Linear dynamic analysis i.e. response spectrum analysis is performed on the system to get the seismic behaviour.

Y. H. Luo and A. J. Durrani, [1] (March 1, 1995) In analyzing flat-slab buildings for gravity and lateral loading, the same effective slab width is used at both interior and exterior slab-column connections. Tests of slab-column connections have clearly shown the moment-transfer mechanism at interior connections to be distinctly different than the one at exterior connections. The effective slab width and stiffness of the exterior connections is therefore significantly different from those of the interior connections. Recognition of this fact is important in accurately predicting the lateral drift and unbalanced moments at connections in flat-slab buildings. The equivalent beam model for slabs at exterior slab-column connections is presented. Based on test results of 41 exterior connections, the ultimate moment-transfer capacity is found to be a combination of the torsional capacity of the slab edge and flexural capacity of the slab portion framing into the front face of the column. The test results also show the actual torsional capacity of the spandrel beam or slab edge at exterior connections to be considerably larger than the theoretical capacity calculated as an isolated beam. An equivalent beam model is proposed for exterior connections that gives a better prediction of the unbalanced moment at connections and lateral drift of flat-slab buildings.

M.G.Sahab, A.F.Ashour, V.V.Toropov, [2] (February, 2005) Cost optimisation of reinforced concrete flat slab buildings according to the British Code of Practice (BS8110) is presented. The objective function is the total cost of the building including the cost of floors, columns and foundations. The cost of each structural element covers that of material and labour for reinforcement, concrete and formwork. The structure is modelled and analysed using the equivalent frame method. The optimisation process is handled in three different levels. In the first level, the optimum column layout is achieved by an exhaustive search. In the second level, using a hybrid optimisation algorithm, the optimum dimensions of columns and slab thickness for each column layout are found. In this hybrid algorithm, a genetic algorithm is used for a global search, followed by a discretised form of the Hook and Jeeves method. In the third level, an exhaustive search is employed to determine the optimum number and size of reinforcing bars of reinforced concrete members. Cost optimisation for three reinforced concrete flat slab buildings is illustrated and the results of the optimum and conventional design procedures are compared.

Jong-Wha , Bai, [3] (2006) The effectiveness of seismic retrofitting applied to enhance seismic performance was assessed for a five-story reinforced concrete (RC) flat-slab building structure in the central United States. In addition to this, an assessment of seismic fragility that relates the probability of exceeding a performance level to the earthquake intensity was conducted. The response of the structure was predicted using nonlinear static and dynamic analyses with synthetic ground motion records for the central U.S. region. In addition, two analytical approaches for nonlinear response analysis were compared. FEMA 356 (ASCE 2000) criteria were used to evaluate the seismic performance of the case study building. Two approaches of FEMA 356 were used for seismic evaluation: global-level and member-level using three performance levels (Immediate Occupancy, Life Safety and Collapse Prevention). In addition to these limit states, punching shear drift limits were also considered to establish an upper bound drift capacity limit for collapse prevention. Based on the seismic evaluation results, three possible retrofit techniques were applied to improve the seismic performance of the structure, including addition of shear walls, addition of RC column jackets, and confinement of the column plastic hinge zones using externally bonded steel plates. Finally, fragility relationships were developed for the existing and retrofitted structure using several performance levels. Fragility curves for the retrofitted structure were compared with those for the unretrofitted structure. For various performance levels to assess the fragility curves, FEMA global drift limits were compared with the drift limits based on the FEMA member-level criteria. In addition to this, performance levels which were based on additional quantitative limits were also considered and compared with FEMA drift limits.

3. Objectives of the work

Analysis of the structure (R.C.C Flat Slab).Design and detailing of R.C.C flat slab. Analysis of the structure (using PT Slab with drop panels). Design and detailing of PT Slab. Comparison of designs of PT Slab and R.C.C Flat Slab. Cost Analysis between PT Slab and R.C.C Flat Slab.

Structural detailing

The structure is modelled using the ETABS, and the model considered is having basement, ground and 4 floors with dimensions 38.13 m*28.85 m, with largest spans of 9.44 m*6.16 m (flat slab). The column dimensions are 750*750 mm.

Grade of concrete considered is M30 and grade rebar is fe415 for columns, beams, and slabs. Slab is loaded for self-weight, live load of 5 kn/m2 (as per IS 875 part 2).

Methodology

The structure is modelled using ETABS. The flat slab modelled is analysed using ETABS 2016 for RCC flat slab and the post tensioned slab is analysed using RAPT software.

The results are tabulated and compared. The cost analysis of the post tensioned and RCC flat slabs are calculated and compared, based on the comparisons the conclusions are drawn.

MODEL

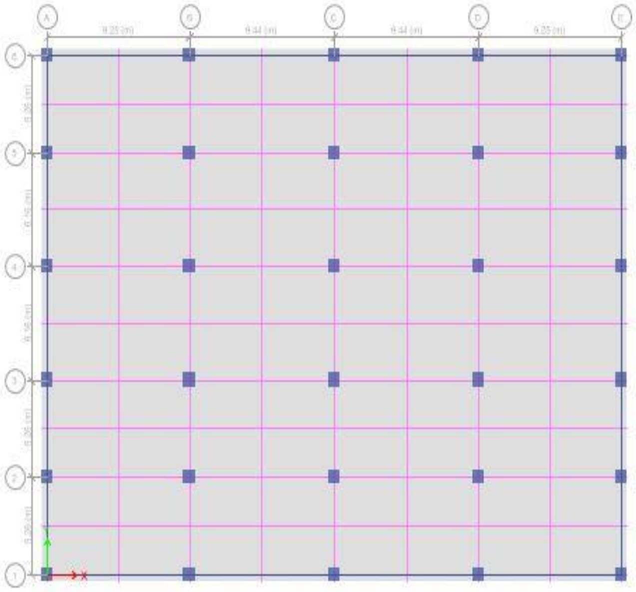

Figure 1: PLAN OF THE STRUCTURE

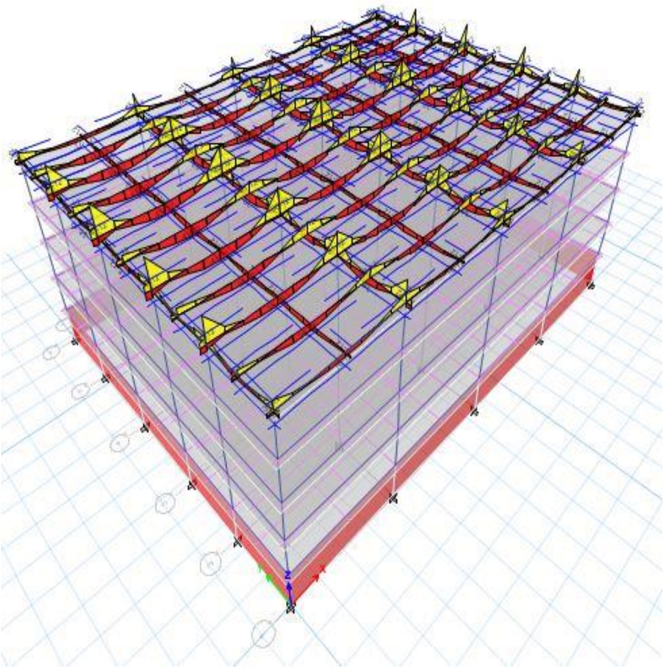

Figure 2: 3D VIEW OF STRESS DISTRIBUTION OF SLAB

AS PER ETABS SLAB DESIGN					
no of bars	length, m	total l, m	steel, kg	area, m2	kg/sqm
163	4.72	769.36	684.7304		
68	6.16	418.88	372.8032		
39	7.08	276.12	245.7468		
12	4.62	55.44	49.3416		
42	9.44	396.48	352.8672		
SUB TOTAL			1705.4892	58.1504	
TOTAL			32263.30768	1100.051	29.3289

AS PER RAPT SOFTWARE PRESTRESSING					
Along length					
Ast	ength cors	no of bars		Total bars	sub total
1641	3.5	50.82743	52	518	13310.5045
2734	3.5	84.68142	86		
1653	1.75	25.59956	27		
2963	3.8	99.64071	101		
2004	2.05	36.35575	37		
2496	4.1	90.56283	92		
549	2.05	9.959735	11		
2259	3.8	75.96637	77		
1662	1.75	25.73894	27		
585	1.75	9.059735	10		
Along breadth					
710	6	37.69912	39	497	16857.5139
2766	6.14	150.2942	151		
710	3.14	19.7292	21		
1319	6.28	73.30372	74		
710	3.14	19.7292	21		
2766	6.14	150.2942	151		
710	3	18.84956	20		
710	3	18.84956	20		
TOTAL					30168.0184
kg/sqm					27.43

Description	percentage saved
concrete	25
steel & prestressing	-1.2615852

4. CONCLUSIONS

1. From the quantity estimations and costing it is observed that concrete needed for R.C.C Flat Slab construction with edge beams is 330 m3 and that for PT Slab with drop panels is 247 m3 . Cost of steel required for the R.C.C Flat Slab construction is Rs. 3915751 /- and the cost of steel & tendons required for PT Slab construction is Rs. 3445148 /- .

2. Hence, for the structure considered (commercial complex), as the concrete needed and the cost of steel required is much less in case of PT slab

construction than in the case of R.C.C Flat Slab construction , it is more economical to construct the structure considered with PT Slab than with the R.C.C. Flat Slab.

3. When a concrete slab is stressed by the post-tensioning method, it means the steel is being tensioned and the concrete is being compressed. As a building material, concrete is very strong in compression but relatively weak in tension. Steel is very strong in tension. Putting a concrete slab into compression and the steel into tension. before any substantial service loads are applied puts both building materials into their strongest states. The result is a 'stiffer concrete slab' that actively is compressed and has more capacity to resist tensile forces. Therefore, the stiffness and strength of the structure using PT Slab will be more than the structure constructed using R.C.C Flat Slab.

4. There are many other benefits of using PT slab. As the thickness of the slab is much lesser than the R.C.C flat slab , aesthetic look of the building may get enhancedleading to a clear height for a longer distance. Hence, using a PT Slab is moreadvisable for a commercial building than using a R.C.C Flat Slab. Construction of a structure using PT Slab also leads to a lighter structure as the Dead Load gets reduced.

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BIOGRAPHIES

Jnanesh Reddy R K is presently studying M.Tech (Computer Aided Design of Structures) in SSIT, Tumakuru, Karnataka. He received her B.E Degree in (SIT) Civil Engineering from VTU during 2007-2011. The areas of research interest included Structural Engineering.

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