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Cost Effectiveness of Post - Tensioned and Reinforced Concrete Flat Slab Systems

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Abstract— ***In a developing country like India the benefits of prestressing and particularly of Post-Tensioning are yet to be recognized. The inherent hurdle is undoubtedly the higher initial investment that is required from the clients. This has to be overlooked considering the significant benefits of Post-Tensioning and the high benefit-aspect ratio that 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 were analysed using SAP and MS Excel program was developed based on the design methodology. The results indicate that Post Tensioned flat slabs are cheaper than the RCC slab systems for all the spans considered in the present study.***

Index Terms – Post Tensioning (PT), Post Tensioned Flat Slab, RCC Flat Slab.

I. INTRODUCTION

In India, presently there is a rapid need and increase in the number of high-rise buildings as a basic infrastructure for residential and commercial utility. In residential buildings, short spans are possible. In modern office buildings that required open space, longer span system is necessary. The use of Post-Tensioned reinforcement to construct floor slabs can result in thinner concrete sections and/or longer spans between supports. Post-Tensioning is a method of reinforcing concrete or other materials with high-strength steel strands or bars, typically referred to as tendons. Post-Tensioning applications include office and apartment buildings, parking structures, slabs-on-ground, bridges, sport stadiums, rock and soil anchors, and water-tanks. Post-Tensioning slab system is of recent origin in India and its finding wide application because of the significant advantages it offers over reinforced concrete systems. Designers commonly take advantage of this method to produce buildings and structures with clear open spaces allowing more architectural liberty. Reducing the thickness of each structural floor in a building can reduce the total weight of the structure and decrease the ceiling to floor height of each level. The important advantages offered by post-tensioning slabs in comparison with the reinforced concrete flat slabs are listed below:

- Prestressing results more economical structures with a very 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.
- Under permanent load, very good behavior in respect of deflections and cracking. Deflection due to loads is very less in Post-Tensioned sections when compared to reinforced concrete sections.
- Higher punching shear strength obtainable by appropriate layout of tendons considerable reduction in construction time as a result of earlier striking of formwork real slabs.
- Almost unchanged serviceability even after considerable overload, since temporary cracks close again after the overload has disappeared.
- High fatigue strength, since the amplitude of the stress changes in the pre-stressing.

Apart from the above mentioned advantages, Post Tensioning offers several advantages. Hence, in the present study an attempt is made to compare the cost effectiveness of Post-Tensioned flat slab systems with reinforced concrete flat slab systems.

II. CONTRIBUTION OF FLOOR FRAMING

Even when considering only the construction costs, it is evident that optimization of structural material consumption alone will result in relatively modest overall savings since on one hand the structural cost makes only about 30 to 50% of the total construction cost and on the other hand more than half of the structural cost is labour cost, related mainly to formwork.

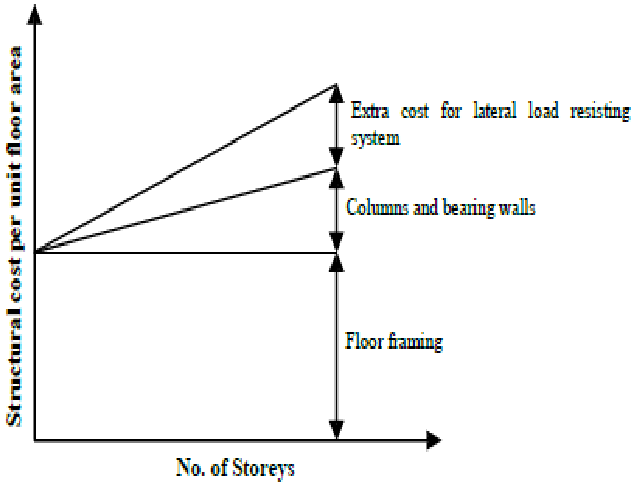

Fig.1 Contribution of Floor Framing to Total Structural Cost

The most cost significant structural element of a building is the floor framing. Fig.1 demonstrates the relative contribution of the floor framing to the total structural cost per unit floor area. While for low-rise buildings this contribution is almost 100%, the cost for columns and walls including their foundation, and for the lateral load resisting system becomes increasingly significant for taller buildings.

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Typical view of the Post – Tensioned slab system during construction is shown in Fig.2.

Fig.2 Completed Tendon Layout for the Post- Tensioned Slab system

III. SCOPE OF THE STUDY

Of all Structural costs, floor framing is usually the largest component. Likewise, the majority of a structure's formwork cost is usually associated with the horizontal elements. Consequently, the first priority in designing for economy is selecting the structural system that offers lowest overall cost while meeting load requirements. Post-tensioning is the key to cost-effective multifamily construction. In addition, Post-tensioned structures can be designed to have minimal deflection and cracking, even under full load. Thinner floors provide lower building weight, which creates a corresponding reduction in other structural elements. There are also some associated labour and time savings.

Hence, the present study aims to compare the cost effectiveness of Post-Tensioned flat slab systems with reinforced concrete flat slab systems. For this purpose, a multistoried building (G + 8) with both the slab systems with different panels were considered. Both the systems are analysed using SAP and subsequently MS Excel program was developed based on the design methodology. Finally, cost comparison graphs are plotted for RCC and Post Tensioned slab systems with respect to span of the member.

IV. METHODOLOGY

The above mentioned floor systems of RCC and Post Tensioning are analysed using SAP and the limit state design of the slab systems are done according to the specifications given in IS456:2000, BS8110:1997, ACI318:2003 and IS1343–1983 respectively. Building details, Post-Tensioning details considered in the present study is given below:

Building details

No of Storeys : G+8
Storey height : 3.5 m
No of Bays : 5
Panel sizes : (8x8)m,(9x9)m,(10x10)m, (11 x11)m, (12x12)m
Concrete grade for RCC and PT
Flat Slab : M35
Beam and Slab : M35
Concrete grade for PT : M35
Strength of steel in RCC : 415 N/mm^2
Post-Tensioning details
Nominal diameter : 12.9 mm
Nominal area : 98.7 mm^2
Weight : 0.785 Kg/m
Strength of steel : 1860 N/mm^2

The dimensions of the PT flat slab and RCC flat slab systems are given in Table.1.

V. ANALYTICAL STUDY

Flat slabs in concrete are widely used because of their economy and fast construction, especially for buildings with long spans. The analysis and design of such slabs are complicated and time consuming. Therefore, in the present study SAP2000 software is used to analyse RCC and PT slabs. Subsequently, RCC flat slabs were designed and checked using manual calculations based on limit state design given by IS: 456 – 2000. For this purpose, a design program was prepared in MS Excel and reliability of the same was checked by manual design. Likewise, PT slabs were also designed based on the working stress method and it was checked with the limit state procedure given by IS 1343-1980.

The details of the reinforcements are obtained from these designs and they are converted in quantities and corresponding cost for each system is calculated. Finally, the cost comparison graphs are generated for RCC and Post Tensioned flat slab systems. Rates are taken from Delhi Schedule of Rates (DSR 2013) published by CPWD. The typical view of the (8×8) m panel in SAP is shown in Fig.3.

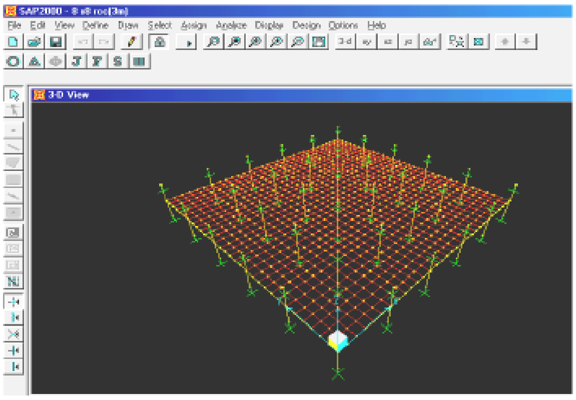

Fig.3 RCC Flat slab (8 x8) m Panel

VI. RESULTS AND DISCUSSION

The design of RCC flat slab is done by limit state method according to the specifications given in IS 456:2000, BS 8110:1997 and ACI 318:2003. The design of Post-tensioning flat slab is done limit state method according to the specifications given in IS 1343:1980, BS 8110:1997 and ACI 318:2003.Then they are checked against Punching shear and deflection. The design details (Max + ve and Max - ve moments) are listed in the following Tables. 2 and 3. Typical moment diagram for panel size (8 x8) m is shown in Fig.4.

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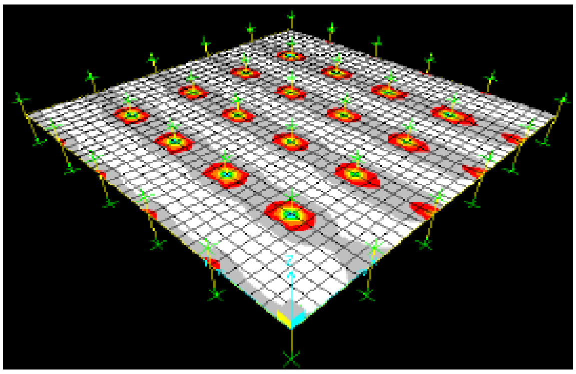

Fig.4 Typical moment diagram for panel size (8 x8) m

Quantity of steel and concrete

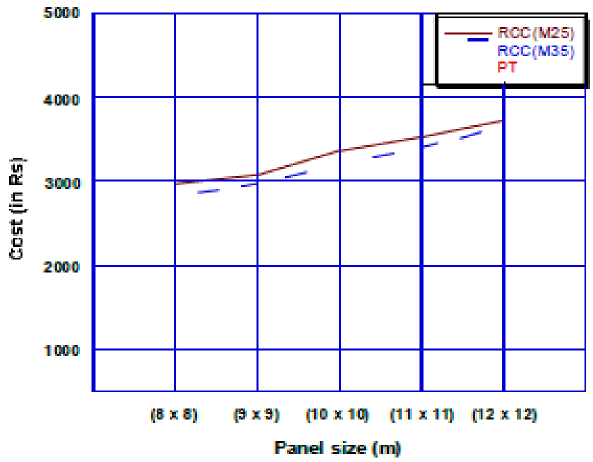

Fig.5 Cost comparison plot of RCC and PT flat slabs

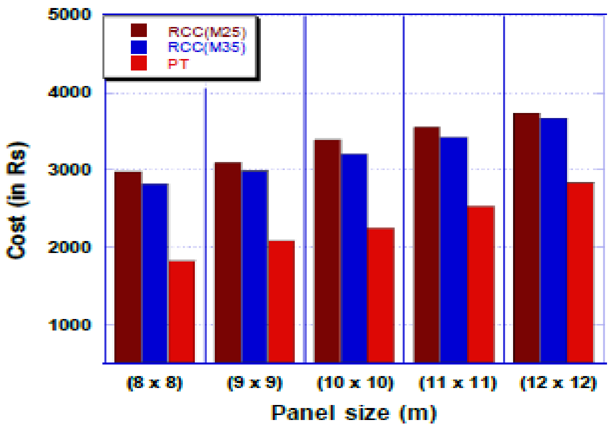

Fig.6 Cost comparison bar chart for RCC and PT flat slabs

The quantity of steel and concrete for RCC and Post Tensioned slab systems are calculated from the reinforcement details. The quantities and the cost of concrete, reinforcing steel, post tensioned steel and the shuttering excluding the labour charges for all the cases considered are given in Table.3. Trials had been made with different types of grades in concrete such as M25 and M35.

Rate of concrete = 4400/-per m^3
Rate of steel = 50/-per *kg*
Rate of form work = 400
Rate of post tensioned steel = 130/-per *kg*

Cost comparison between RCC and PT flat slabs are presented in a graphical format in Fig. 5 and 6. The plot shows that, for the increase in the panel sizes the cost savings are also increasing with Post-tensioning.

VII. CONCLUSIONS

In the present study an attempt was made to compare the above mentioned floor systems in RCC with Post-Tensioning floor systems. The conclusion arrived from the work is stated below:

- For all the panel sizes considered, Post-Tensioning floor systems has proved to be cost effective compared to Reinforced concrete floor systems.
- For the increase in the panel sizes, the cost is also increasing gradually.
- The amount of concrete required for a floor is more for RCC flat slab while it is least for the post-tensioned flat slab floor system. This work can be extended to more number of panels which will be helpful to suggest a particular slab system which is most economical for suitable conditions.

REFERENCES

1. Bijan .O.A., and Jennifer D.J., 2003. "Guidelines for Design of Post-Tensioned Floors", Concrete International.
2. Bijan.O. and Aalami., 2003. "Guidelines for the design of Post-tensioning floor systems" Concrete International 77-83.
3. Gilbert, S. G., Murray, T. K., Scott, R. H. and Cleland, D. J. 2000. "Equivalent frame analysis methods for gravity loads in flat slab structures". Journal of the American Concrete Institute, Structures Journal, 97(2),316-321.
4. IS: 1343- 1980. "Indian Standard Code of Practice for Prestressed Concrete".
5. Lin ,T.Y., and Burns, N., 1981. "Design of Prestressed Concrete Structures", John Wiley & Sons, New York.
6. Karve.S.R and Shah.V.L, "Limit State Theory and Design of Reinforced Concrete".
7. Krishna Raju, N., 2007. "Prestressed Concrete", Fourth Edition, Tata McGraw- Hill Company Ltd., New Delhi.
8. "Post-Tensioning Systems", 4.90/1, VSL Report, VSL International Ltd., Berne, Switzerland. The various rates considered for the present study is as follows:
9. Purushothaman, P., 1984. "Reinforced concret Structural elements", Tata Mcgraw- hill, New Delhi.

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Table.1 Moments for RCC Flat Slab

Panel size (m)	Column strip moments(KNm/m)		Middle strip moments (KNm/m)	
	Max +ve	Max –ve	Max +ve	Max -ve
8 x 8	20.33	-174.04	16.1	-10.82
9 x 9	24.3	-214.9	20.93	-11.79
10 x 10	28.2	-315.2	23.56	-15.83
11 x 11	41.29	-430.05	31.5	-24.04
12 x 12	58.9	-548.63	44.56	-30.79

Table.2 Moments for Post-Tensioning Flat Slabs

Panel size (m)	Column strip moments(KNm/m)		Middle strip moments (KNm/m)	
	Max +ve	Max –ve	Max +ve	Max -ve
8 x 8	17.91	-139.04	14.23	-8.74

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9 x 9	21.19	-182.47	18.5	-10.1
10 x 10	25.49	-243.93	21.32	-14.18
11 x 11	33.12	-327.31	27.51	-17.24
12 x 12	44.4	-423.08	37.4	-19.95

Table. 3 Rate analysis for the panels considered

Description	Rates for different panel sizes (in .Rs)				
	(8 x 8) m	(9 x 9) m	(10 x 10) m	(11 x 11)m	(12 x 12)m
RCC(M25)	2986	3098	3388	3556	3744
RCC(M35)	2822	2988	3212	3426	3678
PT	1820	2084	2247	2523	2833

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