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Analysis and design of RCC and post-tensioned flat slabs

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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. For the application of design procedure a complex is considered as a case study. The plan of the office building (B+G+4) is considered. This building is designed by considering four cases with different floor systems. The quantities of reinforcing steel, prestressing 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.

Keywords: Equivalent frame method, flat slab, post-tensioned, RCC, strud, staad-pro

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 finally the cost of the structure. 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. The reason for this lies in its decisive technical and economic advantages. The most important advantages offered by post-tensioning systems are as follows

- By comparison with reinforced concrete, a considerable saving in concrete and steel since, due to the working of the entire concrete cross-section more slender designs are possible.
- Smaller deflections compared to with steel and reinforced concrete structures.
- Good crack behavior and therefore permanent protection of the steel against corrosion.
- 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 prestressing steel under alternating loads are quite small.
- If a significant part of the load is resisted by post-tensioning the non-prestressed reinforcement can be simplified and standardized to a large degree. Furthermore, material handling is reduced since the total tonnage of steel (non-prestressed + prestressed) and concrete is less than for a Reinforced Concrete floor.
- Assembling of precast elements by post-tensioning avoids complicated reinforcing bar connections with insitu closure pours, or welded steel connectors, and thus can significantly reduce erection time.
- Usually the permanent floor load is largely balanced by draped post-tensioning tendons so that only the weight of the wet concrete of the floor above induces flexural stresses. These are often of the same order as the design live load stresses. Post-tensioning usually balances most of the permanent loads thus significantly reducing deflections and tensile stresses.
- The P/A stress provided by post-tensioning may prevent tensile stresses causing the floor to crack. For the above reasons post-tensioned construction has also come to be used in many situations in buildings. In addition to the above mentioned general features of post-tensioned construction systems, the following advantages of post-tensioned slabs over reinforced concrete slabs are listed as follows:
- More economical structures resulting from the use of prestressing steels with a very high tensile strength instead of normal reinforcing steels.

- Larger spans and greater slenderness, which results in reduced dead load, which also has a beneficial effect upon the columns and foundations and reduces the overall height of buildings or enables additional floors to be incorporated in buildings of a given height.

Proposed Algorithm

The post-tensioning method is now a day's increasing widely, due to its application. By using the post-tensioning method one can design the most economic and the safe design. But while using this method more precautions has to be made for the shear and the deflection criteria for the slabs. The design of the post-tension flat slab can be done by using load balancing and equivalent frame method. Among of both the equivalent frame method is widely used. In the load balancing method the 65 to 80% of the dead load is carried by the tendon itself. So that there is an upward deflection due to tendon profile resulting the reduction in overall deflection. In the present study the design of the post-tensioned flat slab is done by using both methods, load balancing method and equivalent frame method. As the shear and deflection check is the most important for the post-tensioned slabs the detail design for the shear and deflections (short term deflection and long term deflections due to creep and shrinkage) is carried out. The parametric study of the post-tensioned flat slab by varying the span by 0.5m interval is done and results of the different parameters such as thickness of slab, grade of concrete, loss due to stress, normal reinforcement, reinforcement for the shear, number of tendons, stressing force per tendon and deflection etc. are presented in the graphical form. Continuing to this a design of post-tensioned beam is also done. For the study of post-tensioned slab and beams a case study of a multistory office building (G+4) is taken and it is designed by four cases, the post-tensioned flat slab, post-tensioned beams and the R.C.C. slab, only R.C.C. flat slab and the R.C.C. slab and beams. After the design of these four cases the comparative study with respect to the economy is carried out.

Experiment and Result

For the purpose of parametric study of post-tensioned slab the slabs with and without drop varying from 7m to 12m at an interval of 0.5m are considered.

Load considered- Dead load –self weight
Live load – 5 KN/m2
Superimposed dead load - 2 KN/m2

Analysis and design is done by using Equivalent frame method.

For the application of design procedure a commercial building is consider 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 different floor systems used for these four cases are as follows. For the above four cases the quantities of reinforcing steel, concrete required for the slab, beam and column is calculated and are presented in the tabular form. Along with this a total cost of the building per square meter is found and the comparison of all the four cases with respect to cost is given here.

In this case there are two drop panels are designed. Drop panel tends to improve the competence to resist shear failure, to enhance the negative moment capacity and to minimize the deflection through fabrication.

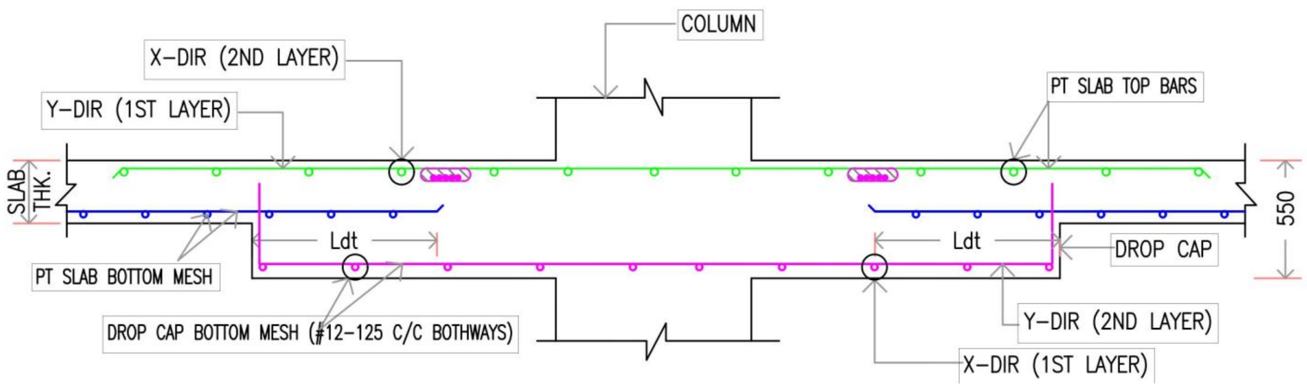

Fig 1: Typical Drop Cap Section

The analysis, design and the estimation of the commercial building for the four different floor systems is done and finally the rate per square meter for the construction of this building is found out. The design and the estimation of the commercial building for the four different floor systems is done and finally the rate per square meter for the construction of this building is found out.

(Rate of concrete=4400/-per m3, Rate of steel=50/-per kg, Rate of form work=400), Rate of prestressing steel=130/-per kg)

Fig 2: PT Slab and PT Beam Framing Layout at Lower Ground Floor LVL

1. From the economic point of view the post-tensioned flat slab is the most economical among all four floor systems and the reinforced concrete slab with reinforced concrete beam is the costlier one for this span.
2. If we consider the post-tensioned flat slab and reinforced concrete flat slab, the thickness of reinforced concrete flat slab is 12.5% greater and its cost is 27% greater than the post-tensioned flat slab.
3. From both post-tensioned floor system building the post-tensioned flat slab is more economical than the post-tensioned slab with reinforced concrete beams.
4. The quantity of prestressing steel is 4 Kg/m2 for post-tensioned flat slab and 3.2 Kg/m2 for post-tensioned slab with reinforced concrete beams i.e. the prestressing steel required for the post-tensioned flat slab is greater.
5. The reinforcing steel required for the post-tensioned flat slab and post- tensioned slab with reinforced concrete beam is 15 Kg/m2 and 20.15 Kg/m2 respectively.
6. The reinforcing steel is more in case of post-tensioned 6slab with reinforced concrete beams because the slab transfers the load on the beam and more loads is taken by the beams itself.
7. The reinforcing steel for the reinforced concrete flat slab is 41 Kg/m2 while for the reinforced concrete slab and beam it is 40 Kg/m2.
8. The amount of concrete required for a floor is more in case of post-tensioned slab with reinforced concrete beams while it is least for the post-tensioned flat slab floor system.
9. The floor to floor height available in case of post-tensioned flat and reinforced concrete flat slab is 2.65m while in case of post-tensioned slab with reinforced concrete beams and reinforced concrete slab and beams is 2.4m.
10. If we consider the period of construction for a floor it is less in case of post- tensioned flat slab than the other three cases as the post-tensioning allows the earlier removal of the formwork. In case of post-tensioned slab with reinforced concrete beams the formwork of slab can be removed earlier but the formwork for the reinforced concrete beams cannot be removed earlier.
11. While estimating the cost of the each building the labour charges are not considered, as the time period reduce the labour charges will reduce in case of post-tensioned flat slab.
12. The wall load is considered on all over the floor (KN/m2) for the post-tensioned building While analysis. So there is flexibility to the user to construct a wall wherever required in case of post-tensioning.

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