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Summary

Experiments with existing prestressed concrete floors have shown that with use of traditional models the calculated value underestimate the real load bearing capacity of reinforced concrete flat slabs. Based on theoretical and experimental considerations propositions for estimating the variation of the prestressing force during the loading and models to calculate the load carrying capacity of post-tensioned concrete flat slabs with second order effects taken into account are developed in this paper.

Keywords: flat slabs, post-tensioning, load carrying capacity, second order effects.

1. Introduction

Because of their technical and economical advantages, post-tensioned reinforced concrete flat slabs are widely used around the world to construct various type of buildings and other constructions. After a short presentation of linear elastic methods used mainly in serviceability limit states, proposition for estimating the variation of the prestressing force during the loading and analytical formulae to estimate the load carrying capacity of prestressed post-tensioned concrete flat slabs taking second order effects into account will be developed in the paper.

2. Modelling in serviceability Limit States

Linear elastic methods of analysis should be used to determine the internal forces of the slab in this states. The influence of post-tensioning may be taken into consideration with the use of the equivalent load method. In the case of applying non uniformly distributed tendons in plain, the variation of the normal forces in the slab has significant effect on its behavior. Linear elastic finite element method with combined plate-membrane or mainly for waffle slabs, with grid-membrane elements gives suitable result in this case.

3. Modeling to estimate the load bearing capacity

Experiments [1] show that the classical methods do not give appropriate results in ultimate limit states to estimate the load bearing capacity of reinforced concrete flat slabs post-tensioned by unbonded tendons. These results indicate that to obtain more exact estimation of the load carrying capacity of these structures it is reasonable to take also second order effects into consideration.

The analysis of a post-tensioned reinforced concrete internal floor field in ultimate limit states may be transformed to the examination of the equilibrum of a compressed and a tensioned membrane. Based on the principle of the equilibrum of the compressed membrane, we developed a membrane dome model. This model permits to determine the load carrying capacity of the floor filed by the expression

$$q_u = p \cdot 3 \cdot t / R^2, \tag{1}$$

where p represents the radial component of the uniformly distributed prestressing forces, f_c is the rise of the substitutive membrane dome, t is the thickness of the slab and R is its equivalent radius at the base. If the prestressing tendons of the floor are concentrated mainly to the column lines, a double arch model is proposed to determine the ultimate limit load. The horizontal component of the reaction of the third-degree parabolic arches is equilibred by the prestressing forces. From this condition the uniformly distributed load bearing capacity of a floor field will be given by the lower value from the expressions

$$q_{ux} = P_x \cdot 9 \cdot t / \ell_x^{\,2} \cdot \ell_y \quad \text{and} \quad q_{uy} = P_y \cdot 9 \cdot t / \ell_x \cdot \ell^2{}_y, \tag{2}$$

where P_x and P_y are respectively the prestressing forces in direction x and y concentrated in column lines. When considerable deflections develop on the floor the compressed membrane and arch models are no more applicable. The use of a tensioned membrane analogy or a modified yield line analysis can give appropriate results in this case. In any case the elongation of the prestressed tendons due to the deflection of the slab during the loading has an important influence to the calculated load bearing capacity of the floor. The effect of elongation of the tendons to the load bearing capacity of the slab must be taken into consideration. In the case of large deflection of the slab the yield line analysis of the theory of plasticity can be applied to determine the load carrying capacity of the floor. With the supposition that the effect of the slab's prestressing is replaced by an equivalent external upward pressure, the ultimate limit load of an internal floor field prestressed by uniformly distributed tendons may be calculated according by the following expression

$$q_u = \frac{8 \cdot p}{\ell}\left[1 + \frac{16}{3} \cdot \frac{f_t}{\ell} \cdot \frac{w}{\ell} \cdot \frac{1}{\varepsilon_p} + \frac{8}{3} \cdot \left(\frac{w}{\ell}\right)^2 \cdot \frac{1}{\varepsilon_p}\right] \cdot \left(\frac{f_t}{\ell} + \frac{w}{\ell}\right), \tag{3}$$

where p is the uniformly distributed prestressing force in direction x or y, ℓ is the span of the slab in the same direction, f_t is the maximum deviation of the tendon, w is the maximum deflection of the slab and ε_p is the strain of the tendon due to the efficient prestressing force.

4. Conclusions

Experiments with existing post-tensioned reinforced concrete flat slabs have shown that the use of classical models generally underestimate the real load bearing capacity of these structures. Second order effects are reasonable to be taken into consideration for dimensioning these floors. Application of a membrane dome model, a double arch model and a modified yield line analysis are shown in this paper to estimate the ultimate limit lcad of prestressed concrete flat slabs using unbonded tendons. The numerical result approve the suitability of the developed method.

5. References

[1] Farkas Gy., "Strengthening of Prestressed Floors by Additional Post-tensioning", *FIP Symposium on Post-Tensioned Concrete Structures*, Symposium Papers, Vol. 1., 1996, pp. 454-462.