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Deflection Analysis with Shoring Load Transfer Coefficient for Post-Tensioned Slab

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ABSTRACT

Deflection of post-tensioned (PT) slabs of an office building is analyzed with a commercial computer program, ADAPT, which is specialized for post-tensioning. A total of four floors of slab including three shored floors are analyzed. The analysis indicates that the deflections of four slabs are almost the same. However, in reality, a deflection of the bottom slab might be the largest among four slabs. To address this discrepancy and to simplify the computing procedure, in this study, shoring load transfer coefficient is defined as the ratio of transferred load on lower slab to applied load on upper slab. The value is determined such that it coincides with the sum of maximum deflections of four slabs between the analyses with and without shores. At the pouring stage, the coefficient value turns out to be 0.73, and the maximum deflection of each slab is shown similarly to the real case where actual deflections are monitored.

1. INTRODUCTION

To prevent a large slab deflection, shores are installed between floor slabs during construction to transfer applied loads to the below slab. Among construction sequences, the largest deflection can occur at the concrete pouring step due to additional concrete weight and low stiffness of the below floors. Large initial slab deflection causes various cracking problems and may lead to a serious damage or excessive long-term deflection of the slab. To control such deflection problems, it is important to well predict sequential deflections.

A calculation method of deflections for reinforced and prestressed concrete beams was suggested by Rodriguez-Gutierrez (2007), who compared the prediction results with previous experiments. The deformation of post-tensioned (PT) beams and slabs were predicted over time (Jayasinghe 2011). However, the research of PT slabs

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deflection with shoring is hardly found.

The analysis including shoring requires a significant time in both modeling and calculating. By replacing the presence of shores with applied loads, the analysis can be simplified. In this study, the elastic deflection of cast-in-place post-tensioned slabs with and without shores is computed using a finite element analysis program, considering the case when the most upper story concrete is just poured. Based on the comparison with test results, an analysis method to predict slab deflection with equivalent transferred loads is suggested.

2. LOAD TRANSFER COEFFICIENT OF SHORING

Typically, shores are installed over 2~4 stories below the most upper slab where the concrete is poured during the construction process. The shores are remained until the strength of the concrete becomes large enough to withstand its self-weight and the construction loads.

In this study, a load transfer coefficient (s) is defined as a ratio of the transferred load through shores from above floor to the applied load on the above floor. For simplicity, it is assumed that all the shores have the same coefficient values which remain constant until the shores are removed. Table 1 shows the applied load on each floor slab when the concrete is poured on N^{th} floor. For the basic service load, no load factors for dead load (*DL*), live load (*LL*), and post-tensioning (*PT*) are applied.

Table 1 Applied load on each floor slab after concrete poured

Floor	Model with shoring	Model without shoring
$\mathbf{N^{th}}$	1.0 *SW*	(1-*s*)*SW*
$\mathbf{N\text{-}1^{th}}$	1.0 *SW* + 1.0 *LL* + 1.0 *PT*	(s+1) (1-s) *SW* + (1-s) *LL* + 1.0 *PT*
$\mathbf{N\text{-}2^{th}}$	1.0 *SW* + 1.0 *LL* + 1.0 *PT*	(s^2+s+1) (1-s) *SW* + (s+1)(1-s) *LL* + 1.0 *PT*
$\mathbf{N\text{-}3^{th}}$	1.0 *SW* + 1.0 *LL* + 1.0 *PT*	(s^3+s^2+s+1) *SW* + (s^2+s+1) *LL* + 1.0 *PT*

s = load transfer coefficient; *SW* = self-weight; *LL* = live load; *PT* = post-tensioning.

3. MODELING

The target model is an office building having two-way PT slabs. Two models are created: 1) four stories without shores (M1) and 2) four stories with shores over three stories (M2). The most top floor of the model is defined as N^{th} floor and the floors below the top floor are labeled as N-1^{th}, N-2^{th}, and N-3^{th} floor sequentially. The elastic deflection prediction is made after pouring concrete on the N^{th} floor. The strengths of concrete members are shown in Table 2. The design strength is 35 MPa for slabs and 49 MPa for columns, but different strengths are input depending on the age of each member. The concrete strength of the N^{th} slab is assumed to be 1 MPa because fresh concrete is considered as gravity load for the moment. The concrete elastic modulus is determined from the concrete strength automatically by ADAPT program (ADAPT 2015). The unit weight of 2400 kg/m^3 is used for concrete members.

For steel reinforcement, the main longitudinal steel is SD400 D13 bars and the yield strength of 460 MPa is applied in the analysis to reflect the fact that actual yield strength is generally larger than the specified yield strength. For post-tensioning, 15.2 mm diameter unbonded tendons are used. In the analysis, the ultimate tensile strength of 1860 MPa is applied and the yield strength is assumed to be 1700 MPa. For both the reinforcing bars and the post-tensioning tendons, the modulus of elasticity 200,000 MPa is input.

The slab dimension and shoring plan are shown in Fig. 1. Shores were installed over the three floors and each floor had three kinds of shores; Multiprop (MP), PERI Euro prop (PEP), and Aluminum form support (AS). In the analysis, all props are modeled as an axial member with circular section having 100 mm diameter. The elastic modulus of MP is 200,000 MPa and those of PEP and AS are 70,000 MPa, according to the materials of shores. The stiffness of each member is automatically calculated according to the modulus of elasticity by the analysis program (Aalami 2011).

Final 4-story models are shown as Fig. 2. M1 is a model with shores and M2 is a model without shoring. For both model, loads are applied on each slab according to Table. 1. The *LL* is assumed as 250 kg/m^3, a half of *DL*.

Table 2 Compressive strength of concrete (unit: MPa)

	Nth	**N-1th**	**N-2th**	**N-3th**	**N-4th**
Slab	1	31	40	45	-
Column	-	18	44	50	54

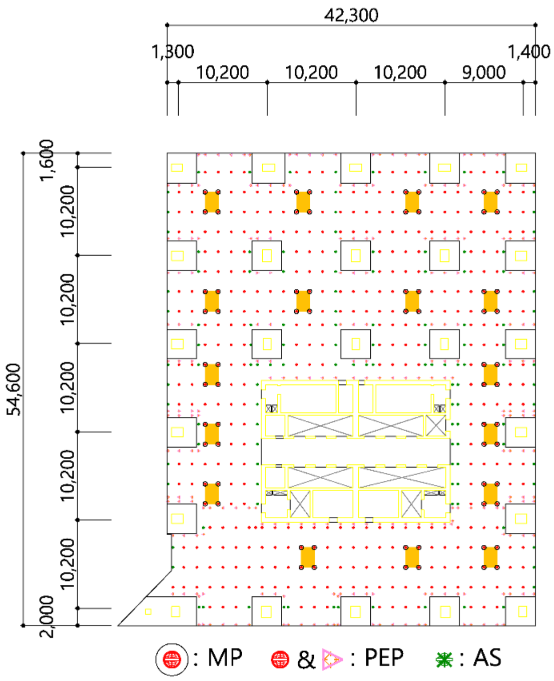
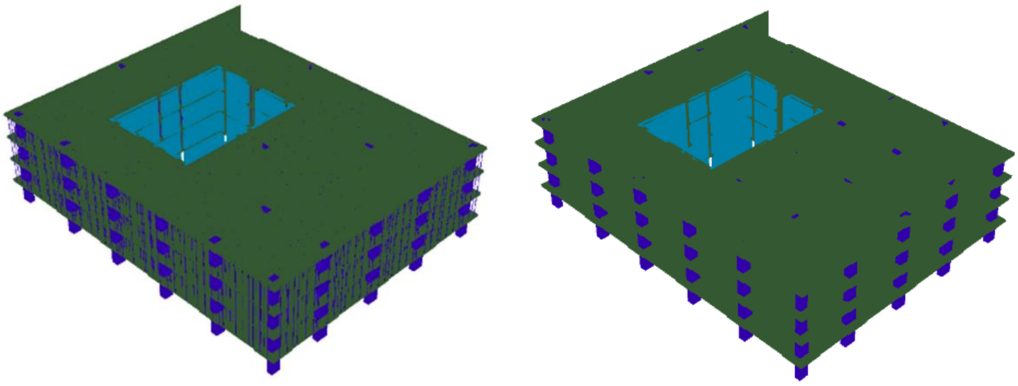


Fig. 1 Slab dimension and shoring plan



(a) M1 (with shores) (b) M2 (without shores)

Fig. 2 4-story models

4. RESULTS

The analysis results of maximum deflection for each slab are summarized in Table 3. For M1, the deflections of all slabs are almost the same because the slabs are vertically linked by the props and shoring members, the difference in deflection between the floors is not considerable. However, for the model without shoring, the deflection of N-3th floor is the largest and that of N-2th or N-1th floor is relatively small, which may be closer to the actual situation.

The analysis results are used to determine a load transfer coefficient of shoring. The coefficient is found such that the summations of the deflections of all three stories below the story where concrete is just placed are the same between the models with and without shoring. Based on the results, at the stage of concrete placement on the top floor, the load transfer coefficient of 0.73 is suggested

Table 3 Results of slab deflection analysis (unit: mm)

Model	**M1**	**M2**		
***s* (no unit)**		**0.72**	**0.73**	**0.74**
N-1th	11.27	1.75	1.65	1.54
N-2th	11.18	2.97	2.80	2.63
N-3th	11.24	28.62	29.14	29.67
Total	33.69	33.34	33.59	33.84

5. CONCLUSIONS

In this paper, 4-story part of a post-tensioned building is modeled using the finite element program, ADAPT, which is specialized for post-tensioning. For the model with shoring, the deflections for all four stories are similar unlike the common anticipation.

This tendency is because the slabs are vertically connected and integrated by the props in the model. To overcome such limitations, an analysis without shoring and a concept of the load transfer coefficient of shoring are suggested. Based on the analysis results, the load transfer coefficient of 0.73 is recommended at the stage of concrete placement on the top floor. The coefficient values can be changed for various stages of construction and also determined following the same procedure.

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