The 2022 World Congress on
The 2022 Structures Congress (Structures22)
16-19, August, 2022, GECE, Seoul, Korea

Bearing capacity ratio control of existing piles using external post-tensioning

*Giwan Noh[1] and Thomas Kang[2]

[1], [2] *Department of Architecture & Architectural Engineering, Seoul National University, Seoul, Korea*
[2] *tkang@snu.ac.kr*

ABSTRACT

Remodeling can improve structural and functional performance of aging structures, greatly extending their service life, and can facilitate urban development in the end. However, safety issues have been raised regarding the existing foundation capacity when vertical expansion is involved, which has often inhibited the revitalization of remodeling markets in Korea (KICT, 2014; Kim et al., 2019). To solve such a problem more efficiently, a method that can control or modify a bearing capacity (or demand to be more precise) ratio of existing piles without foundation retrofit was proposed. The method of external post-tensioning, which can be applied to the wall in the first basement level just above the level of foundation, changes load pattern transmitted to the foundation. It was expected that load-transfer patterns can be determined by adjusting the positions of upper and lower anchorage of external post-tensioning system. In this study, the load-transfer performance was evaluated using full-scale tests.

1. INTRODUCTION

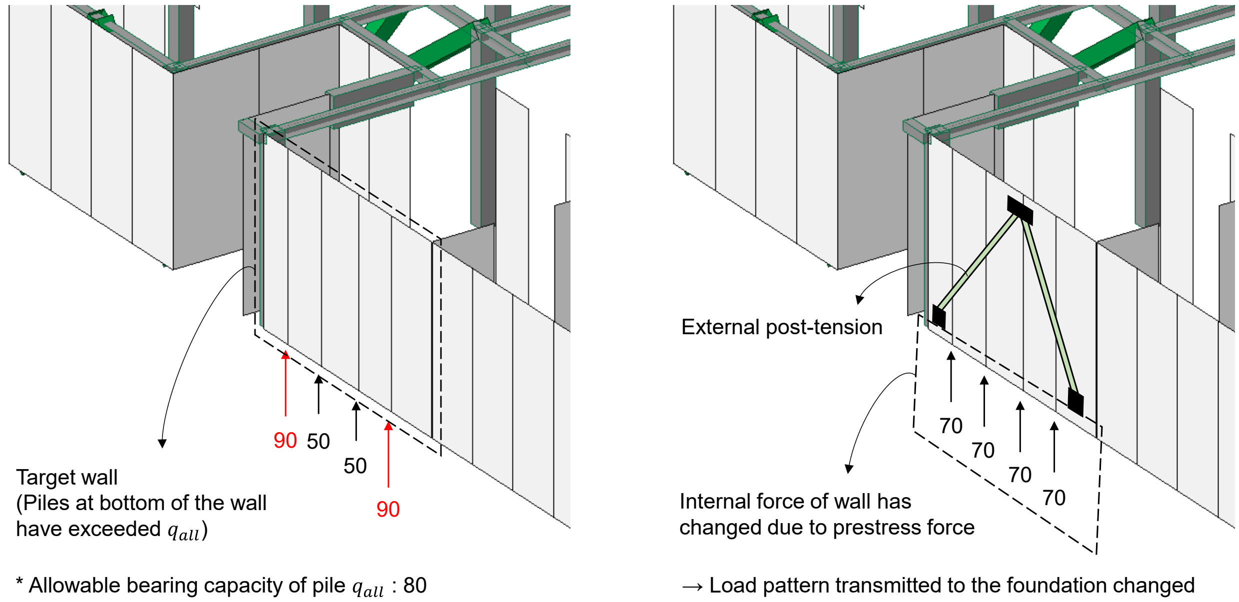
Remodeling of building structures that increases social and economic value by improving structural performance at the same time has recently been in the spotlight. Remodeling, which systematically reconstructs aging structures into modern structures, is very important for extending service life of (concrete) structures and facilitating urban development.

However, the safety issues of vertical expansion remodeling, which have been continuously raised, have prevented the revitalization of remodeling market. Many foundation retrofit studies have been conducted to solve this problem, but there are technical limitations to quantitatively examining the safety of underground structures that are complexly affected by various factors (stiffness of raft and piles, ground condition, etc.).

---

[1] Graduate Student
[2] Professor

This study proposes a method that can control bearing capacity ratio (i.e., the ratio of axial load acting on a pile to allowable bearing capacity) of piles using external post-tensioning on basement walls without foundation retrofit (Fig. 1). Load-transfer performance of the method is verified through full-scale tests.



(a) Before post-tensioning (b) After post-tensioning

Fig. 1 Bearing capacity ratio control of piles using external post-tensioning (unit : kN)

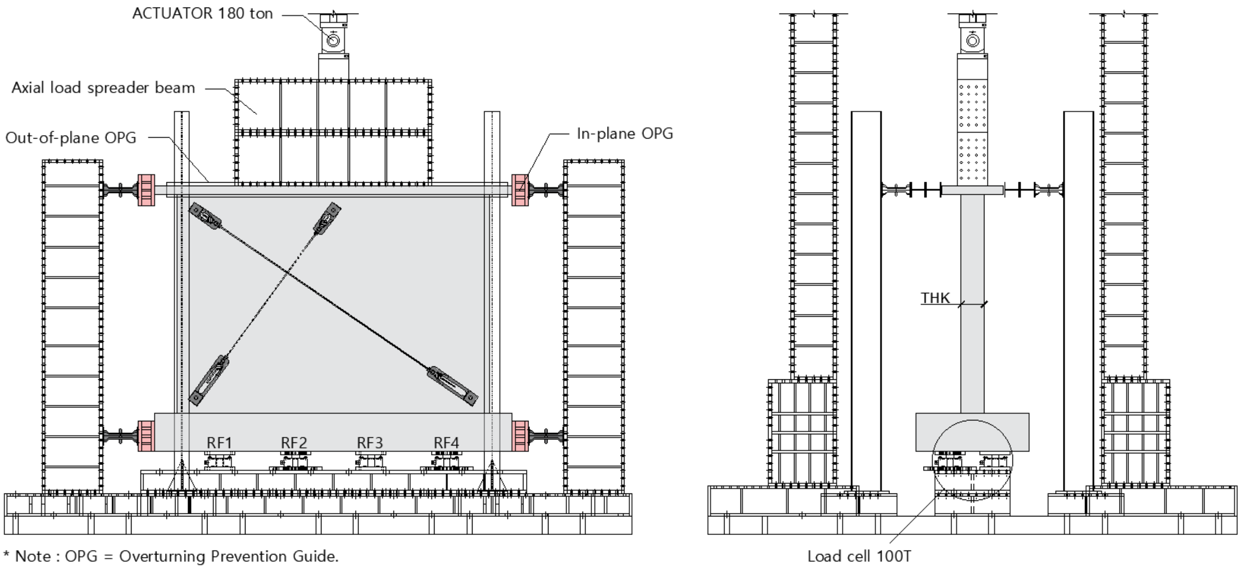
2. TEST PROGRAM

Two specimens (PT#1 and PT#2) with the same reinforcement ratio were made based on the basement wall of an apartment built in 1992. Each specimen consisted of a foundation, a wall, and a slab. The wall thickness was used as a test parameter. Dimensions of the foundation and wall were 1500 mm (width) x 500 mm (thickness) x 4730 mm (length) and 800 mm (width) x 120 mm (thickness) x 4730 mm (length), respectively. Each wall had the same length (4130 mm) and height (2880 mm), but the thickness (PT#1 = 150 mm vs. PT#2 = 300 mm) was different between two specimens. Concrete was placed in the order of foundation, wall, and slab to be consistent with the actual construction condition on site. Table 1 shows the properties of each member.

Table 1 Properties of each member

Properties	Foundation	Wall	Slab
Dimensions (mm)	1500 x 500 x 4730 (width x thickness x length)	4130 x 2880 x 150 – PT#1 4130 x 2880 x 300 – PT#2 (length x height x thickness)	800 x 120 x 4730 (width x thickness x length)
f_c' (MPa)	25.59	26.07	24.60
E_c (MPa)	16,805	25,647	23,532

Fig. 2 shows the test setup. Freyssinet's 1R15 anchorage was installed on both sides of a wall for external prestressing system, and 15.2 mm-diameter seven-wire strands were used. Four reaction forces were measured at the bottom of foundation with an interval of 1000 mm as shown in Fig. 2(a). Two load cells were placed per reaction force (Fig. 2(b)), and guides were installed in- and out-of-plane direction to prevent specimens from overturning.



(a) Front view (b) Side view

Fig. 2 Test setup

The purpose of the test was to analyze load-transfer effects depending on post-tensioning forces, and the test plan is shown in Fig. 3. Reaction forces are different for each step, and the difference between the reaction forces of Step A (only axial load) and Step C (axial load + P_e) is Δload-transfer.

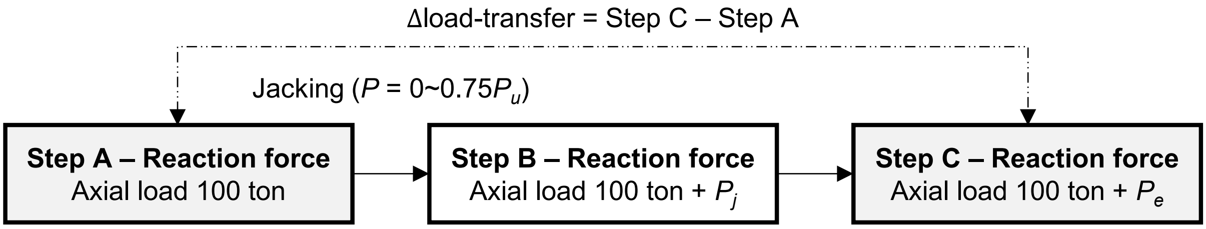


Fig. 3 Test plan

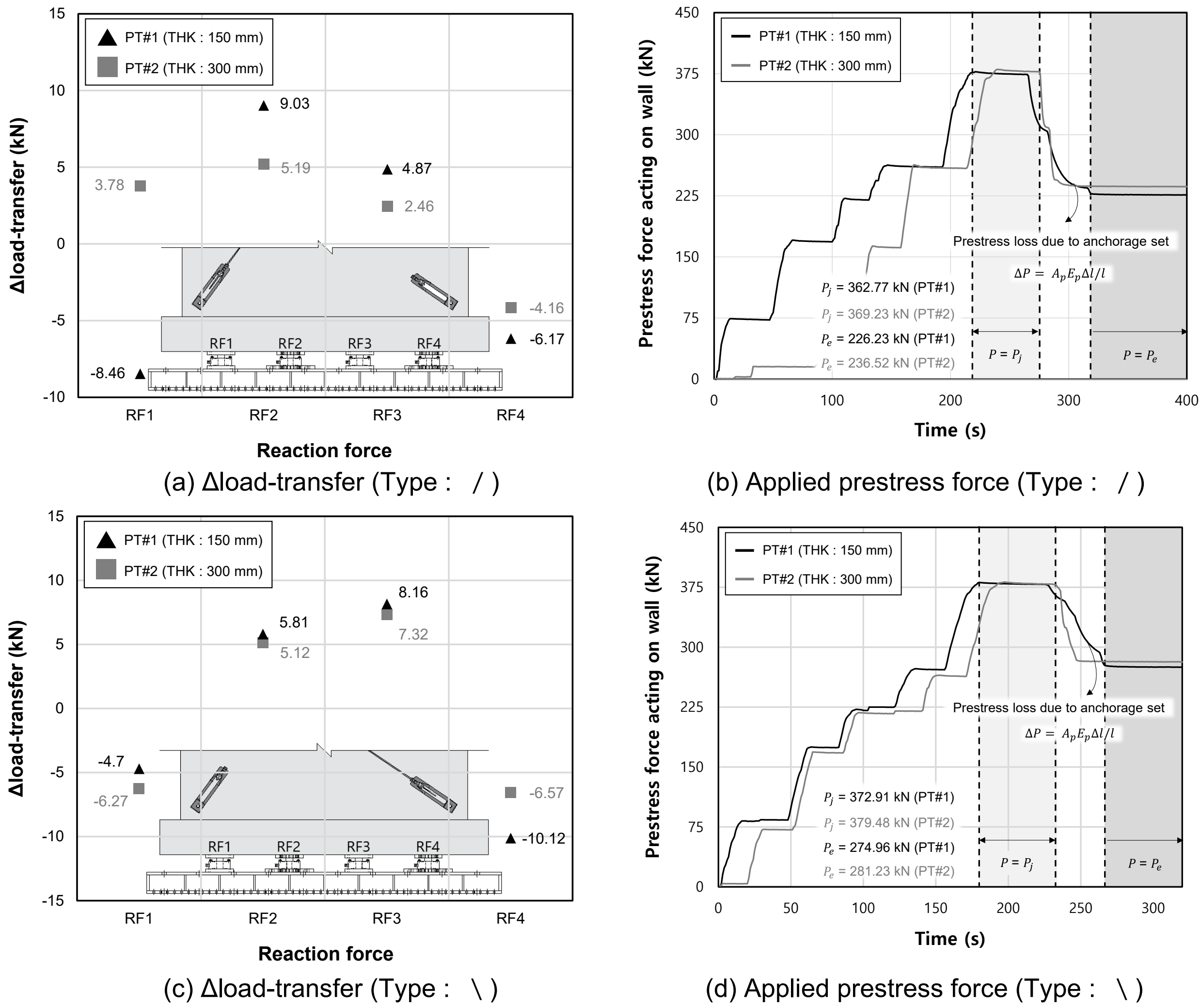
Where, P is prestress force acting on wall (kN); P_u is ultimate strength of strand (kN); P_j is jacking force (kN); and P_e is effective prestress force (kN).

3. TEST RESULTS AND DISCUSSION

Figs. 4(a) and 4(c) show amount of load-transfer (Δload-transfer) according to the prestress force, and Figs. 4(b) and 4(d) represent prestress force acting on wall. Due to anchorage set, there was a difference between jacking and effective (or initial) prestress forces as shown in Figs. 4(b) and 4(d). Assuming no friction loss, prestress change by anchor set can be calculated as in Eq. (1).

$$\Delta P = A_p E_p \Delta l / l \tag{1}$$

Where, ΔP is change in prestress due to anchorage set (kN); A_p is cross-sectional area of prestressed steel (mm^2); E_p is modulus of elasticity of prestressed steel (MPa); Δl is anchor set (mm); and l is strand length anchorage to anchorage (mm).



(a) Δload-transfer (Type : /) (b) Applied prestress force (Type : /)

(c) Δload-transfer (Type : \ ) (d) Applied prestress force (Type : \ )

Fig. 4 Test results

Depending on the lateral constraint of wall, load-transfer patterns due to external post-tensioning vary. Referring to the boundary condition and tendon arrangement of Fig. 2(a), target points for vertical load reduction are RF1 and RF4. From the tests, it was confirmed that the load could be reduced at thetarget points by adjusting tendon arrangement as shown in Figs. 4(a) and 4(c).

In addition, as shown in Figs. 4(a) and 4(c), the effect of wall thickness on load-transfer performance was also confirmed. The load transfer performance was better for the thin-walled specimen by 123.8% and 48.3% at target points RF1 and RF4 (Fig. 4(a)), respectively. In Fig. 4(c), PT#1 had the difference of transferred loads between the points RF1 and RF4 by more than twice, which was affected by the use of in-plane overturning prevention guide (OPG) constraining the specimen. Hence, it is difficult to quantitatively compare the load-transfer performance between the specimens due to different degrees of constraints for PT#1 and #2. Based on the result, the effect of constraint was lower at the location of RF4 where the anchorage was placed near the foundation level, and the wall thickness appeared to cause about 54% difference between the specimens.

4. CONCLUSIONS

Through this study, it was confirmed that load pattern transmitted to foundation can be changed by applying external post-tensioning. A characteristic of the method is that target load-transfer pattern can be implemented by adjusting the positions of upper and lower anchorage. Since load-transfer performance varies depending on the thickness of wall, it is necessary to determine the number of tendons to be installed after careful analysis. The method can control bearing demand-to-capacity ratio of existing piles without retrofitting foundation itself; thus, it is believed that it could be a viable option for remodeling with vertical expansion.

REFERENCES

KICT (2014), Development of pre-loading method for reinforcement piles of apartment remodeling, Korea Institute of Construction Technology.

Kim, D.; Kim, J.; and Jeong, S. (2019), “Estimation of axial stiffness on existing and reinforcing piles in vertical extension remodeled buildings,” *Engineering Structures*, **199**, 109466.