

# Bending Resistance Capacity of Steel Pile Caps Strengthened with Perfobond Shear Connectors

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## Abstract

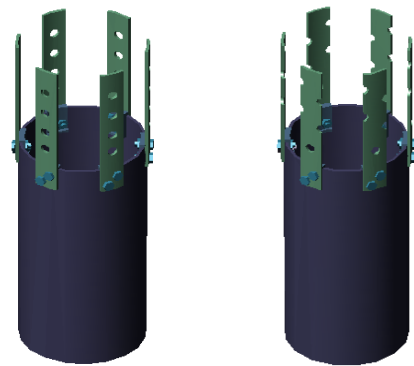
This study proposes a new perfobond shear connector, which can be used to strengthen the steel pile cap embedded into the structural foundation. The bending resistance capacity of the steel pile cap strengthened with the proposed perfobond connectors is evaluated by performing a test on seven specimens. Test parameters include the type of perfobond shear connectors, infilled concrete depths and number of L-shaped steel plates. The lateral load versus displacement curve is plotted for all specimens, and their failure modes are identified. The effects of the test parameters on the bending resistance capacity of the specimen are examined in this work.

**Keywords:** steel pipe pile, perfobond shear connector, concrete foundation, bending resistance

## 1. Introduction

At the foundation to support an upper structure, there exists a connection between piles and concrete footing. The integration of these two structural components is very important to guarantee the safe load transfer from the upper structure to the supporting layer of rocks. In general, this can be achieved by the use of steel reinforcing bars embedded into the concrete footing. In this case, the bond between the steel rebars and concrete is activated by the mechanical bearing of bar ribs, and it is essential to retain a sufficient level of their bond strength. However, since their rib size is limited and they have relatively small cross-sectional area, their bond strength is also limited to a small value as indicated in various concrete design code provisions such as ACI building code [1, 2].

In order to handle this issue, we propose a new perfobond shear connector illustrated in Fig. 1, which can guarantee an excellent composite behavior among the structural components at the steel pile cap. This type of perfobond shear connector can guarantee an excellent composite behavior among the structural components at the steel pile cap. This device is basically a steel plate with holes and embedded into concrete to ensure the perfect integration of steel members and surrounding concrete. As external loads are applied, the dowel action of concrete inside the hole is activated and enables the load from the upper structure to be safely transferred to the steel pipe piles.



(a) Perfobond shear connector with closed holes (b) Perfobond shear connector with open holes

Fig. 1 Strengthening of steel pile caps using the perfobond shear connectors

This study experimentally investigates the structural performance of the steel pile cap strengthened with the proposed perfobond connectors under lateral loading. A bending test is conducted on seven specimens by considering the type of perfobond shear connectors, infilled concrete depth and number of L-shaped steel

plates as test parameters. The failure characteristics of the test specimens are examined, and their load-displacement curves are analyzed.

## 2. Experimental Program

For this study, a total of seven specimens were manufactured and tested. Among the seven specimens, six were strengthened with the newly proposed perfbond shear connectors, and the remaining specimen with conventional steel reinforcing bars. Fig. 2 illustrates the details of typical test specimens with the perfbond connectors, including their geometrical configurations and infilled concrete depths. The perfbond shear connectors were connected to the outer surface of the steel pile cap by bolting. In addition, a number of L-shaped steel plates were connected to the inner surface of the steel pile cap by bolting. They play a role of shear keys and provide some additional shear resistance. The center of the steel pile cap coincided with that of the concrete block in all specimens.

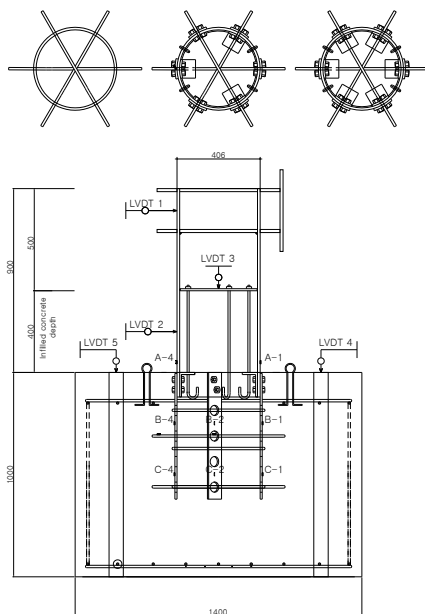


Fig. 2 Details of specimens with perfbond connectors

The list of the seven test specimens are provided in Table 1. The main test parameters include the type of perfbond shear connectors, infilled concrete depths and number of L-shaped steel plates. Two types of perfbond shear connectors were used in the test specimens. The first type (PO) has open holes while the other (PC)

closed holes. The reference specimen strengthened with conventional steel rebars (SB) had the infilled concrete depth of 700 mm, which is greater than the diameter of the steel pile. In contrast, the specimens strengthened with the perfbond shear connectors had two different infilled concrete depths corresponding to the diameter (D10) and half diameter (D05) of the steel pile, respectively. Three different numbers of L-shaped steel plates, which are 0 (NL), 3 (L3) and 6 (L6), were used in the specimens strengthened with the perfbond connectors.

As shown in Fig. 3, lateral load was applied to the test specimen by an actuator with maximum capacity of 500 kN, which allows displacement-based control. The rate of loading was 0.5 mm/min., and its magnitude was measured by the load cell attached at the end of the actuator. The load-versus-displacement data were recorded throughout the entire loading history using a computer-aided data acquisition system.

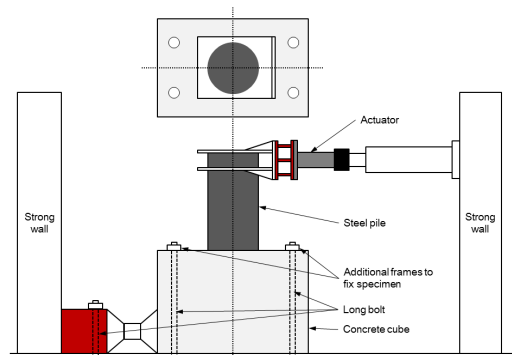


Fig. 3 Test setup

## 3. Results and Discussion

Table 1 summarizes the test results such as peak loads and displacements at peak loads. From these results, it can be seen that the specimens strengthened with the open-hole type perfbond connectors have higher bending resistance than those with the closed-hole type connectors, and almost equal strength to that of the reference specimen. For example, the ratios of the peak strength of the open-hole type perfbond specimens PO\_D05\_L3 and PO\_D10\_L3 to that of the reference specimen are 93.3 % and 95.3 %, respectively. This is remarkable considering that the concrete infilled depths of these specimens are only in the range of 200 mm and 400 mm, while that of the reference specimen is 700 mm.

In addition, it can be noted from the test results that the peak strength of the specimen is increased with increasing concrete infilled depth. For example, in the case of PC\_D10\_L3 specimen, its peak strength is increased by 9.2 % due to the increase of concrete infilled depth from 200 to 400 mm, while that of PO\_D10\_L3 specimen only by 2.2 %. Therefore, the increase of peak strength due to increasing concrete infilled depth is more pronounced with closed-hole type perfbond specimens.

Table 1 Summary of test results

Specimen	Peak load		Displacement at peak load (mm)
	Lateral load (kN)	Bending moment (kN·m)	
SB_D10_NL	342	308	50.0
PC_D05_NL	279	251	32.2
PC_D05_L3	262	236	33.2
PC_D10_L3	286	257	68.6
PC_D10_L6	303	273	48.0
PO_D05_L3	319	287	39.2
PO_D10_L3	326	293	43.6

#### 4. Conclusions

In this study, we performed an experimental investigation on the structural performance of the steel pile cap strengthened with the proposed perfbond connectors under lateral loading. A bending test is conducted on seven specimens by considering the type of perfbond shear con-

nectors, infilled concrete depth and number of L-shaped steel plates as test parameters. From the test results, it was found that the specimens strengthened with the open-hole type perfbond connectors have higher bending resistance than those with the closed-hole type connectors, and almost equal strength to that of the reference specimen. In addition, it can be noted from the test results that the peak strength of the specimen is increased with increasing concrete infilled depth.

#### Acknowledgement

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