PUNCHING SHEAR OF I-SLAB WITH POLYSTYRENE VOID FORMS

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ABSTRACT :

Where the self weight of the overall slab needs to be considered, the quantity of in-situ concrete required can be reduced by the introduction of polystyrene void forms supplied and fixed to the precast panel during manufacture. In this study, new I-slab system with polystyrene form and precast concrete deck is proposed to reduce the construction period and the self weight of the slab. This paper presents experimental data on the punching shear of the connections between I-slabs and column. Five interior slab-column connections were tested. The main objectives of experiments were to investigate the effects of the arrangement of polystyrene form, the effects of shear reinforcements, the shapes of column, and the effects of the existence of polystyrene form. Structural performance of slab-column connections was evaluated on the basis of failure mode, load-displacement curve, and punching shear strength. Based on the test results, the critical punching shear sections were changed as test variables, so the punching shear strengths were very different.

KEYWORDS: precast concrete, polystyrene, slab-column connection, punching shear

1. STUDY BACKGROUND AND OBJECTIVE

Concrete deck construction using the precast concrete (PC) wide slab is divided into two separate operations. In the first, PC forms reinforced with lightweight steel trusses and the required bottom steel, accurately positioned in the concrete, are prefabricated off-site. In the second operation, these elements, used as forms, are combined with the balance of the reinforcing steel and the upper, poured-in-place layer of the slab on the structure. The wide slabs replace conventional formwork and become an integral part of the finished deck.[1] Where the self weight of the overall slab needs to be considered, the quantity of in-situ concrete required can be reduced by the use of polystyrene forms supplied and fixed to the precast panel during manufacture. The void formers developed at America and Europe are normally rectangular form and are fixed between the lattice girders.

In flat plate system, punching shear is assumed to be critical on a vertical section through the slab extending around the column. According ACI 318-05, the critical shear section which is located at the d/2 from the face of the column is taken as rectangular if the columns are rectangular. When the polystyrene void forms are used close to the column, the critical perimeter will be reduced. It is not defined in the previous design codes.

This study has two objectives. The one is suggesting a new I-slab system. The other one is evaluation about performance of slab-column connection supposed critical segment for punching shear.

I-slab system has new polystyrene form and precast concrete deck, as shown in Figure 1. It reduces the construction period and the self weight of the slab. New polystyrene form is 400 mm long and 400 mm wide with 200 mm diameter hole, as shown in Figure 2. The depth of polystyrene form is changed by slab thickness. Figure 3 shows the construction process of the flat plate system with I-slab.

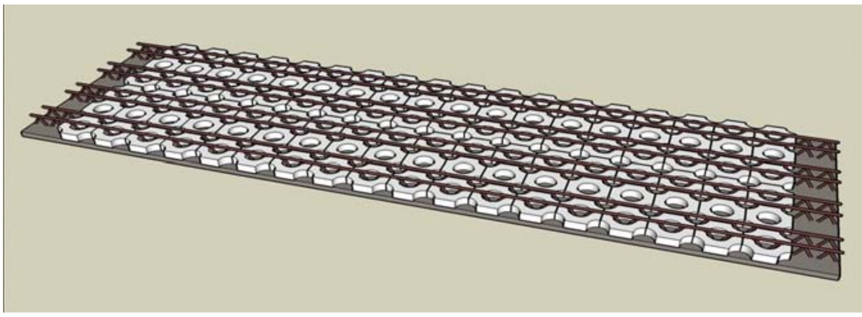


Figure 1 I-slab system

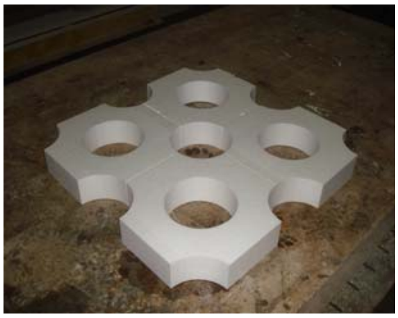


Figure 2 New polystyrene form

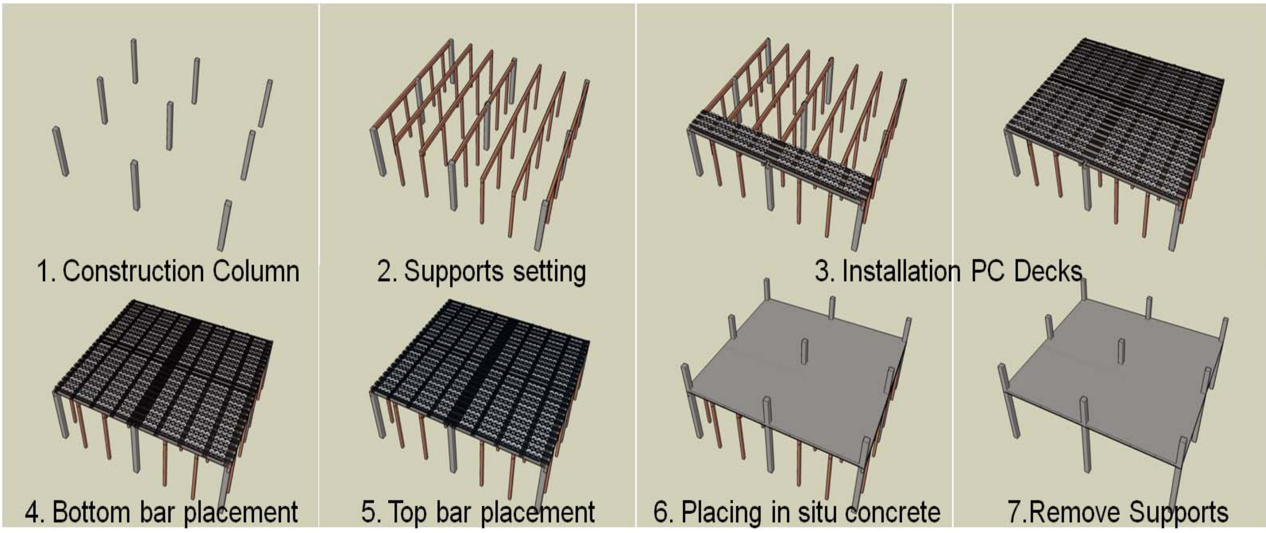


Figure 3 Construction method of I-slab system

2. EXPERIMENTAL PROGRAM

2.1. Specimens

Five interior slab-column connections in two-way slab were tested. The main objectives of experiments were to investigate the effects of the arrangement of polystyrene form, the effects of shear reinforcements, the shapes of column, and the effects of the existence of polystyrene form. All specimens have same slab thickness of 210mm. And the dimension of slab is 2200 mm by 2000 mm or 2000 mm by 2000 mm, for same distance between column side and supports.

Top bar is decided with quantity for bending fracture. Deformed bar (D16), and truss is longitudinally placed in PC slab. The truss is consisted of D13 (horizontal), φ9 (diagonal). Table 1 summarizes the specimens. Figure 4 shows the details and configuration of P-1 specimen.

Table 1 List of specimens

Specimens	Column section, $C_1\times C_2$(mm·mm)	Slab Thickness, H (mm)	Form Type	Form arrangement situation	Shear Reinforce
P-1	600×400	210	PF1	From just column side	-
P-2	600×400	210	PF1	At a distance of 1.5H from column side	-
P-3	600×400	210	PF1	At a distance of 1.5H from column side	shear stud
P-4	400×400	210	PF1	From just column side	-
P-6	400×400	210	-	-	-

2.2. Materials and test methods

The design strengths of PC and RC were 30 MPa and 24 MPa, respectively. All the reinforcements steel used in the specimens conformed to KS SD40. For punching shear test, the concentrated load was applied to the center of column by 2000 kN oil jack as shown as Figure 5. Specimen was controlled by values of LVDT, which was located on the center of column. Strain gauges measured the strain of rebar in precast concrete and bottom of in-situ concrete.

Figure 5 Test setup

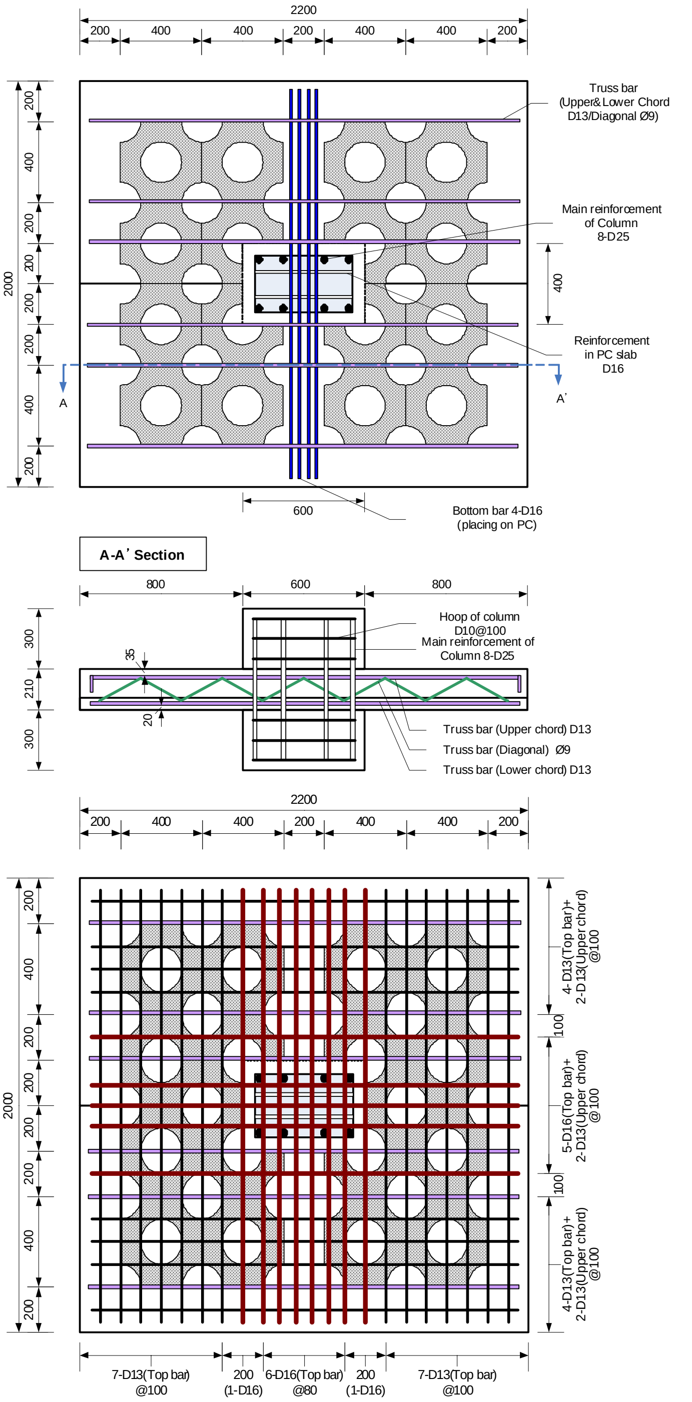


Figure 4 Details of P-1 specimen

3. TEST RESULTS

3.1. Failure patterns

Figure 6 shows the failed top surfaces of topping concrete for all specimens.

For all specimens, the inclined crack patterns were observed by the punching shear failure. For P-2 and P-3 specimens which have polystyrene forms outside the distance of 1.5H from column side, the failure surface moved further outside for other specimens. For P-6 specimen without polystyrene forms, the flexural cracks occurred with the inclined crack.

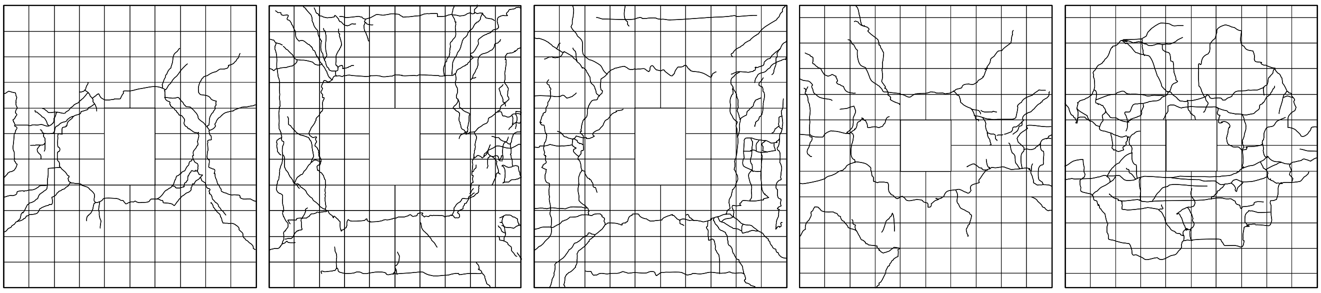
3.2. Load-Displacement Responses and Strengths

The load-displacement responses for all specimens are shown in Figure 7.

All specimens had the ultimate shear strengths around 10mm in displacement, and they showed the brittle failures by punching shear. P-6 specimen had the greatest ultimate strength.

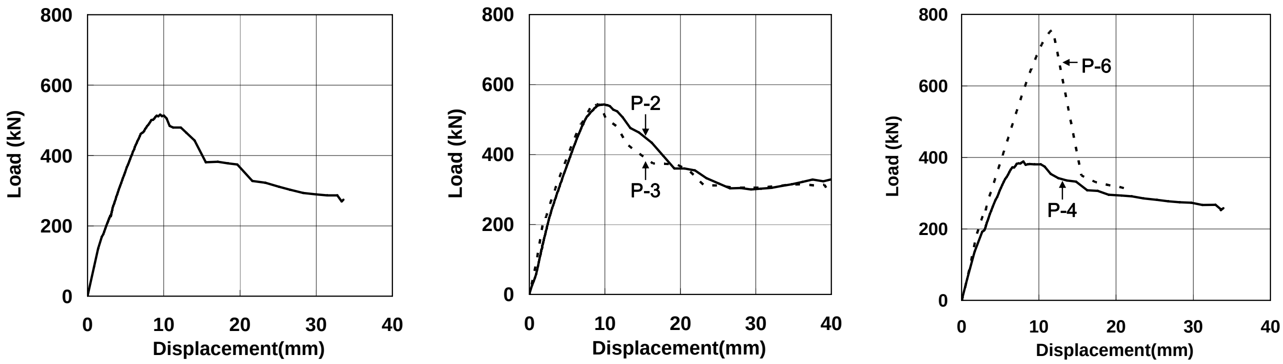
Table 2 shows the comparison of the test maximum strengths (V_{test}) with the nominal strengths (V_n) calculated by using ACI 318-05[2]. V_n was calculated on the assumption that the rectangular critical-shear perimeter was located at d/2 away from the face of the column. For P-1 and P-4 specimens, the critical section area was calculated except void area by the polystyrene forms. From Table 2, V_{test}/V_n measured 0.86~1.32.

For P-2 specimen, the test maximum nominal strength, 543.16 kN, was less than the nominal strength, 634.45 kN. It was caused by the change of critical section. The section area at a distance of 1.5H from column side is



(a) P-1 (b) P-2 (c) P-3 (d) P-4 (e) P-6

Figure 6. Failure patterns



(a) P-1 (b) P-2 and P-3 (c) P-4 and P-6

Figure 7. Load-Displacement Responses

Table 2 Comparison of the test maximum strengths and the nominal strengths by ACI 318-05

Specimens	V_{test} (kN)	Displacement at V_{test} (mm)	V_{test} / V_T (V_T, Target specimen)	V_n (kN)	V_{test}/ V_n
P-1	515.95	9.52	1.00 (P-1)	390.11	1.32
P-2	543.16	9.89	1.05 (P-1)	634.45	0.86
P-3	543.76	9.12	1.05 (P-1)	472.85	1.15
P-4	388.70	7.98	1.00 (P-4)	341.16	1.14
P-6	755.94	11.71	1.94 (P-1)	602.44	1.25

less than the section area at a distance of d/2 from column side. For P-3 specimens, the effect of shear stud did not appear because of the change of critical punching shear section like P-2 specimens. For the accurate calculation of punching shear strength, it needs to consider the change of critical section by polystyrene forms.

4. CONCLUSIONS

In this study, the new I-slab system was proposed for flat plate system and the experimental works were conducted to evaluate the punching shear strengths of the I-slabs. The conclusions obtained in this study can be summarized as follows; 1) All of the specimens showed the punching shear failure. 2) According arrangement of polystyrene form, the critical punching shear sections were changed. 3) For the accurate calculation of punching shear strength, it needs to consider the change of critical section by polystyrene forms.

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