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Performance Evaluation of the High Performance Concrete Deck of Floating Pier

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ABSTRACT: The steel floating pier as a floating structure is constructed in aquatic or marine environment, which raises problems related to corrosion, water-tightness and the need to secure buoyancy. The floating structure made of high performance concrete can provide an alternative complementing the drawbacks of former floating piers. This study evaluates experimentally the performance of the floating pier deck using the high performance concrete with compressive strength of 100 MPa under development at the Korea Institute of Civil Engineering and Building Technology.

KEYWORDS: Floating pier, High performance concrete, Deck.

I. INTRODUCTION

Steel was the primary material used for the erection of previous floating piers, which raised problems related to corrosion, water-tightness and buoyancy. Among the alternative materials enabling to complement such drawbacks, high performance concrete with remarkable water-tightness and strength appears to be adequate for the erection of economic and safe marine structures that can overcome the problems met in former steel floating piers. This study constitutes the first stage for the application to floating structures of the high performance concrete (SUPER Concrete, SC) with compressive strength ranging between 80 and 180 MPa under development at the Korea Institute of Civil Engineering and Building Technology (KICT). Choi et al.[1] are currently studying the material characteristics for the analysis, design and construction of the floating structure using such SC. The present study evaluates experimentally the performance of the component of the integral floating pier that is the deck made of SC with compressive strength of 100 MPa.

II. STRUCTURAL TEST

A. COMPRESSIVE TEST OF CONCRETE

Compared to normal concrete, the high strength concrete (SC) under development at KICT features extremely high compressive strength. In addition, its remarkable water-tightness is believed to be effective in complementing the drawbacks of previous steel floating piers. Despite of its outstanding performances, the admixing of steel fibre in ultra high performance concrete (UHPC) is likely to cause corrosion problems in the floating pier erected in aquatic or marine environment. Accordingly, using SC instead of UHPC appears to be more appropriate for the fabrication of the floating pier. The target strength of concrete to be applied to the floating pier being 100 MPa, test was conducted to verify the convergence of the compressive strength of the concrete under development to the target strength and its elastic modulus.

Fig.1.View of compressive test

The mould adopted for the fabrication of the compressive test specimens is the widely used ϕ100 mm × 200 mm cylinders and the specimens were fabricated considering the curing conditions as variable. The specimens were

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subjected to water- and atmosphere-curing to examine any eventual variation of the compressive strength according to the curing conditions. Moreover, strain gauges were attached to the sides of the specimens in the compression direction to evaluate the elastic modulus in compression. The tests were performed by installing a jig for the measurement of the elastic modulus. Figure 1 shows the compressive test.

B. TEST OF DECK

The considered floating pier shown in Fig. 2 was designed to present dimensions of approximately 15 m × 30 m × 2 m. The analysis was performed on the whole system as shown in Fig. 3.

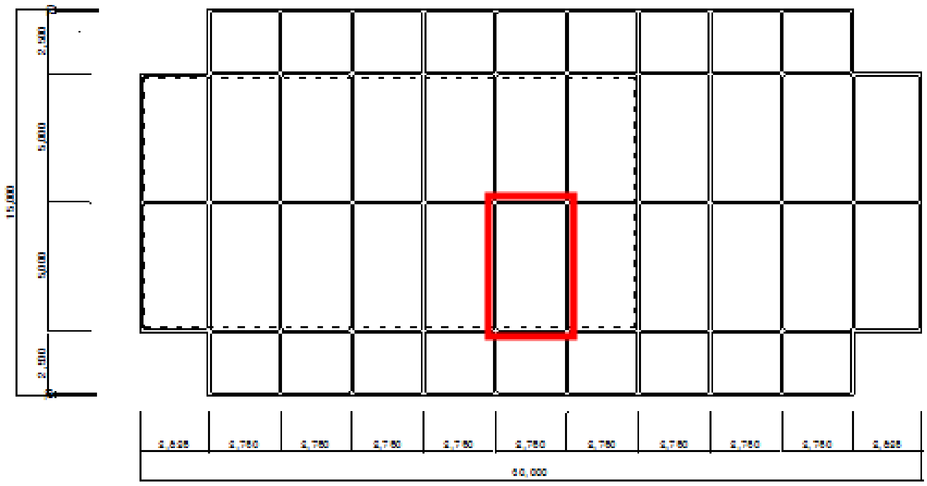

Fig. 2Drawing of the whole floating pier

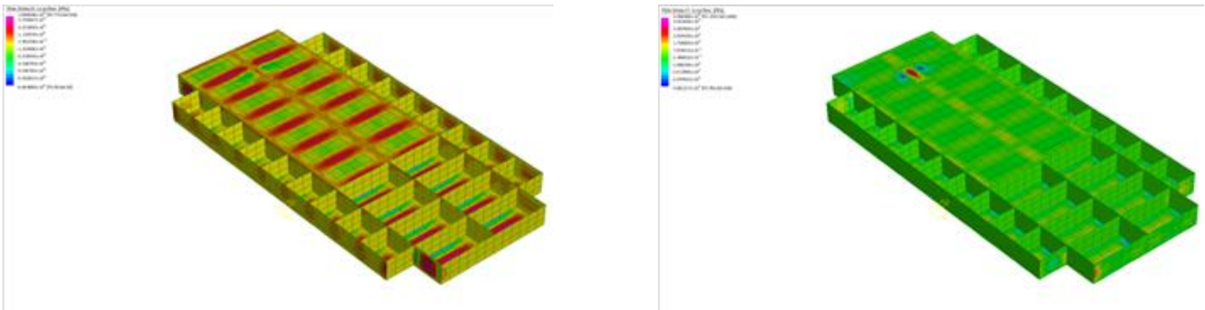

Fig. 3Analysis of the whole floating pier

Since the experiment is part of the early stage of the study, the tests were planned for each component prior to the test on the full-scale structure. Accordingly, the portion corresponding to the block highlighted in Fig. 4 was selected, and a specimen was fabricated to conduct test on the bottom and top flanges of the deck as depicted in Fig. 5. The thickness of the top flange of the deck is 100 mm and that of the bottom flange is 80 mm. Figure 6 presents the dimensions of the deck specimen and the arrangement of the reinforcement. The reinforcing bars arranged at the top flange of the deck are not straight as shown in Fig. 6(a) but are arranged to lie below the neutral axis at the centre of the deck specimen and above the neutral axis at the ends.

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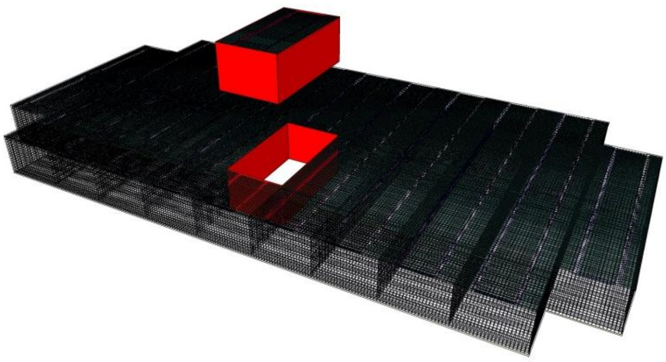


Fig. 4Selected portion of the floating pier

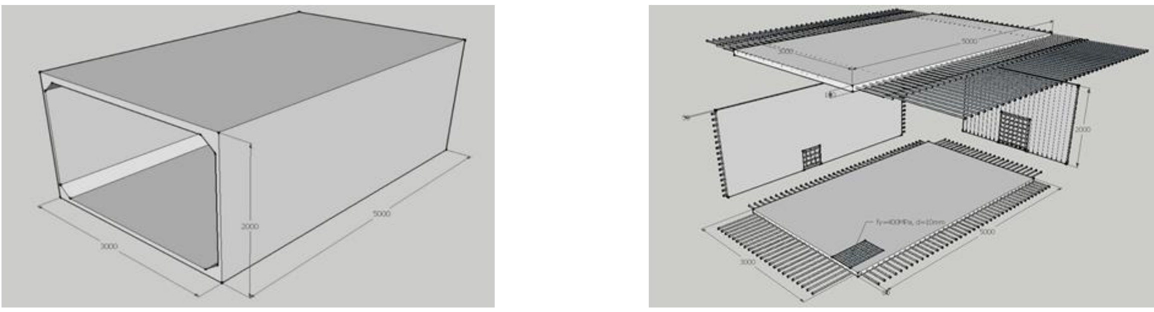
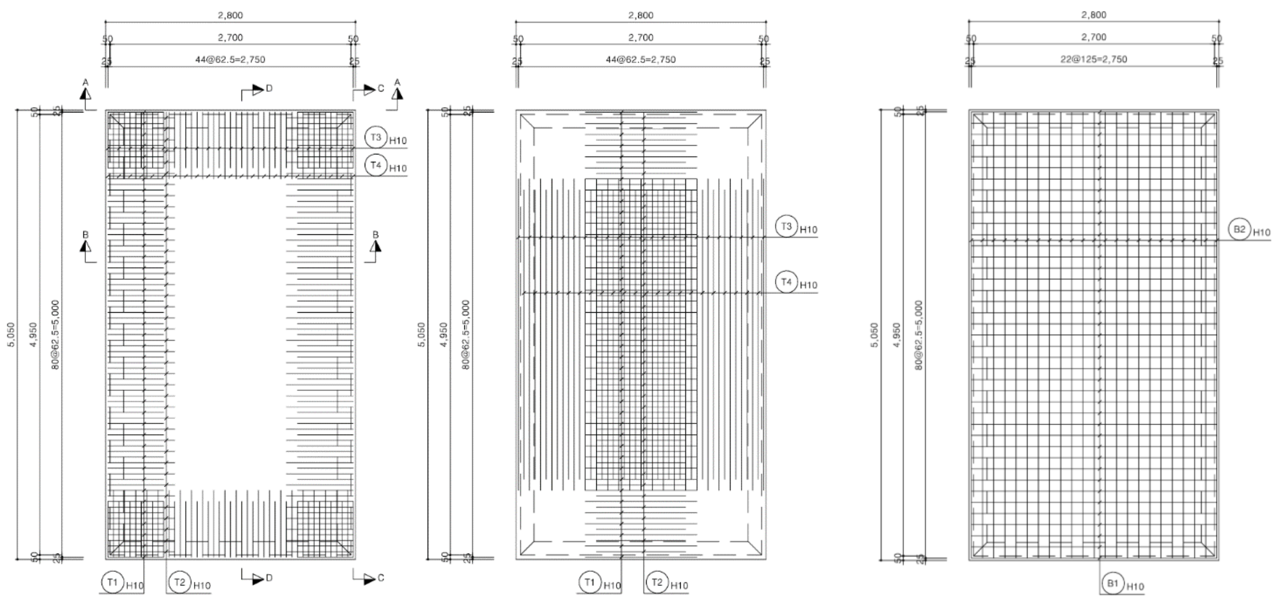


Fig. 5Shape of specimen



(a) Reinforcement arrangement in top flange of deck (thickness = 100 mm)

(b) Reinforcement arrangement in bottom flange of deck (thickness = 80 mm)

Fig. 6Arrangement of reinforcement at top and bottom flanges of deck specimen

Fig. 7Fabrication of specimen

Fig. 8Preparation of test

Figure 7 depicts the fabrication and preparation of the specimen and Fig. 8 presents the preparation of the test. Displacement sensors are disposed at the centre, the quarter points and the ends of the specimen to measure the deflection. The angle of rotation at the end is measured by means of sets of 2 displacement sensors installed at the ends of the top deck. In addition, the strain in the reinforcement is measured by strain gauges installed at the same locations of the displacement sensors for the deflection.The test was carried out by static loading using an actuator with capacity of 3,500 kN. Loading was applied through displacement control at speed of 2 mm/min. The load applied on an area of 230 mm×580 mm.As shown in Fig. 8, the specimen was fixed-supported for the test. Concrete strain gauges were attached to the lower and upper faces of the specimen to observe any change during loading. The loading scenario proceeded by applying 5 kN after the placement of the specimen to induce the fixed supports followed by the increase of the load to generate a deflection of about 100 mm at the centre or until the punching failure of the specimen.

III.EXPERIMENTALRESULTS

Figure 9 and Table 1 arrange the results of the compressive test. A variation of ±20 MPa occurs around the target strength of 100 MPa with a mean compressive strength of 100.5 MPa and the mean elastic modulus runs around 39,171 MPa. This indicates that the material properties of concrete SC-100 under development are practically stabilized.

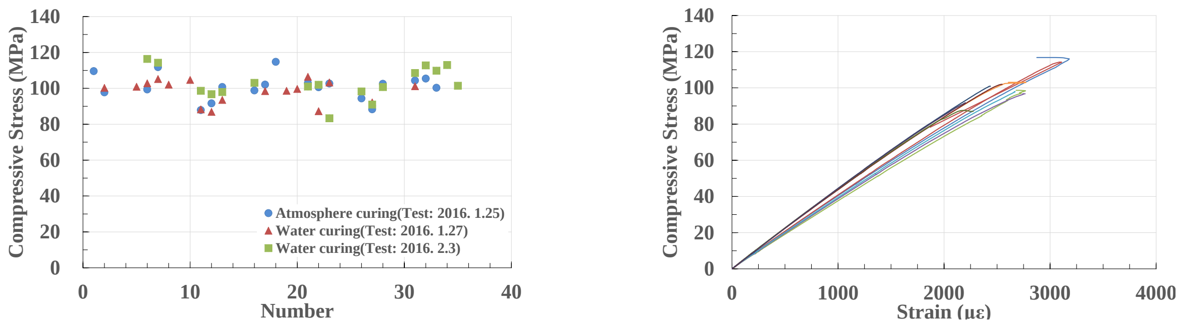


Fig. 9Experimental compressive strength and elastic modulus of SC-100

Table 1. Compressive strength and elastic modulus of SC-100

No.	Compressive strength (MPa)			Elastic modulus (MPa)
	Atmosphere-curing (test on 2016.1.25)	Water-curing (test on 2016.1.27)	Water-curing (test on 2016.2.3)	Water-curing (test on 2016.2.3)
1	109.6	100.2	116.4	37,402
2	97.8	100.9	114.3	38,522
3	99.4	102.8	98.6	35,607
4	111.8	105.2	96.8	36,099
5	87.9	102.1	97.9	37,055
6	91.6	104.7	103.1	39,935
7	100.7	88.3	101.0	40,929
8	98.8	86.9	102.0	40,154
9	102.1	93.5	83.3	41,138
10	114.8	98.5	98.3	40,590
11	103.0	98.6	90.9	39,834
12	100.6	99.6	100.7	39,298
13	102.7	106.4	108.5	41,686
14	94.4	87.3	112.8	38,483
15	88.3	103.3	109.8	39,592
16	102.5	92.2	113.0	38,891
17	104.4	101.2	101.4	40,696
18	105.4			
19	100.3			
Average	100.8	98.3	102.3	39,171

Fig. 10Failure pattern of specimen

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The failure pattern after the end of the test takes the form of typical cracking of the deck as shown in Fig. 10. The top of the deck fixed at its 4 sides exhibits quasi-elliptic cracking around the loading point whereas the bottom experienced radial cracking.

Figure 11 plots the deflection of the deck measured during the test. A deflection of about 74 mm occurs at the centre under the maximum load of 340 kN for the top flange of the deck and of about 96 mm under the maximum load of 124 kN for the bottom flange of the deck.

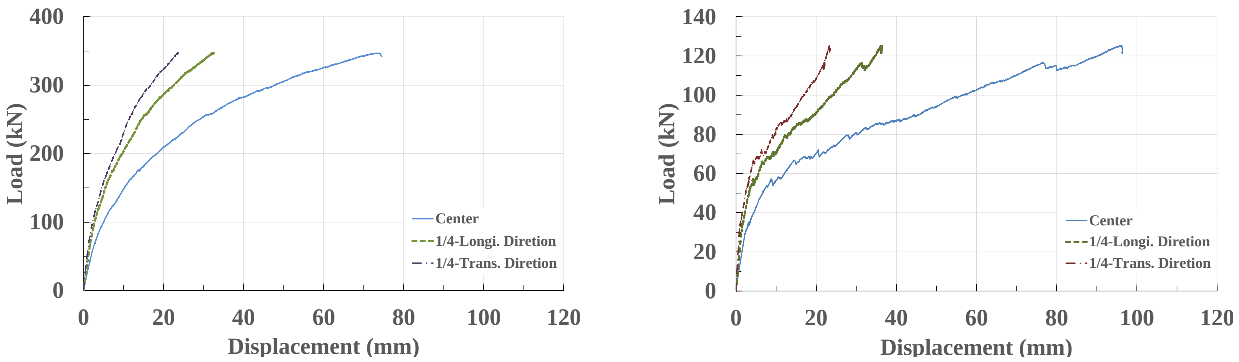

Fig. 11Experimental deflection of deck

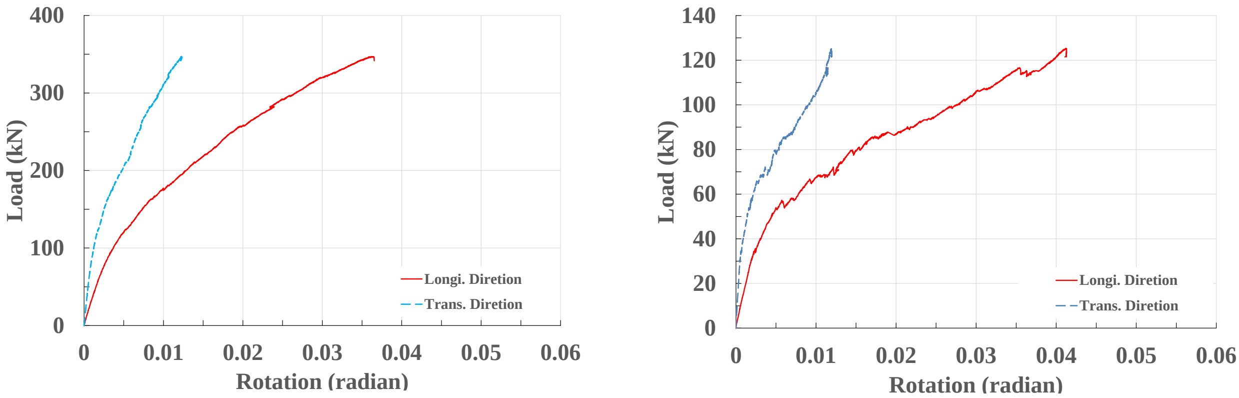

Fig. 12Experimental end angle rotation of deck

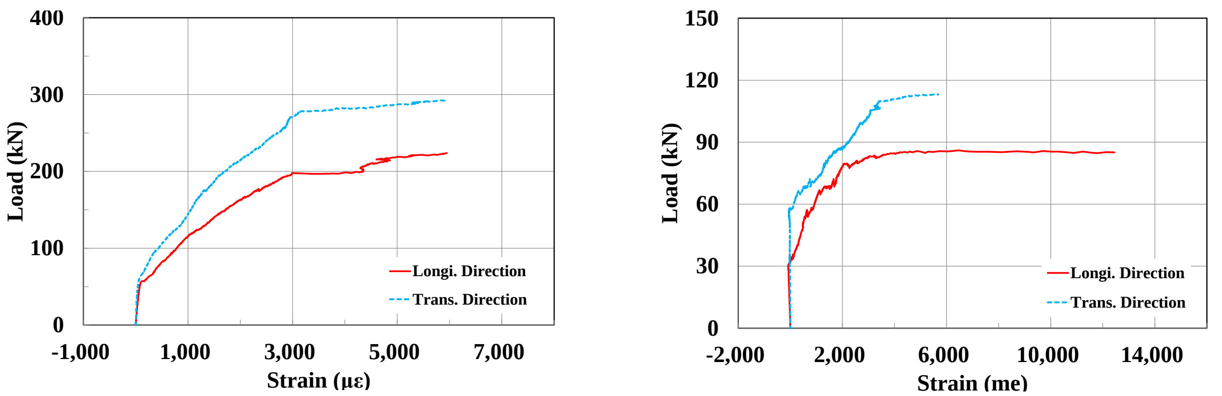

Fig. 13Experimental strain at centre of deck

For the rotation angle measured at the end of the deck plotted in Fig. 12, the end rotation angle for the top deck reaches approximately 0.0123 rad in the transverse direction (major axis direction) and about 0.0365 rad in the longitudinal direction (minor axis direction) under the maximum load. For the bottom deck, the end rotation angle is measured to be

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about 0.0119 rad in the transverse direction and about 0.0413 rad in the longitudinal direction under the maximum load. Since larger values are measured on the longitudinal direction than in the transverse direction, it appears that the measurement has been appropriately conducted.

In Fig. 13, the strain of the reinforcement is seen to be positive in all major and minor directions. This result can be explained by the fact that the reinforcing bars on which the strain gauges are attached are all located below the neutral axis. In view of the strain in the reinforcement arranged at the center, it appears that the longitudinal reinforcement yielded before the transverse reinforcement. The measurements show that the longitudinal reinforcement yielded at about 197 kN and the transverse reinforcement at about 277 kN in the top flange of the deck and, that longitudinal reinforcement yielded at about 80 kN and the transverse reinforcement at about 104 kN in the bottom flange of the deck. For the transverse reinforcement, there was practically no change until approximately 58 kN but this was followed by the sudden occurrence of tensile deformation after cracking at the bottom.

IV. CONCLUSIONS

This paper presented the first stage of the study intending to apply the high performance concrete (SC) under development at KICT to floating piers. To that goal, tests were conducted to evaluate the material characteristics and structural performance of the deck of the floating pier using SC and the experimental results were analysed. The experimental results for the top and bottom decks of the floating pier showed the applicability of SC to the floating pier in term of the structural performance. Further studies will be implemented to apply SC to the floating pier.

ACKNOWLEDGEMENTS

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