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Long term settlement of soft clay improved by low replacement ratio SCP under backfilled caisson loading

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Introduction

This study focussed on the long term settlement of soft clay improved by SCP with low replacement ratios subjected to gravity caisson and backfill loading. Centrifuge model tests has been conducted to investigate the long term behavior of soft clay improved by SCP with replacement ratios 30~50% where construction sequence from the installation of the caisson to the backfilling was simulated in-flight in the tests.

Centrifuge Model Tests

The physical and mechanical properties of soils used in the tests are shown in Table 1. Tests were performed using two strong boxes in two series. Fig.1 shows the schematic illustration of test setup showing different parameters using dimensions of small box. The large box was 700mm in length, 450mm height and 150mm in width. The thickness of clay layer was maintained same in all test series. Test procedure was presented by Yasumoto et. al. (1998). The purpose of sand drain (SD) behind the SCP portion is to accelerate the consolidation under backfill load so that the effect of consolidation settlement of SD portion on the long term settlement of caisson could be investigated. Behavior of improved ground is not precisely known and depends on several factors such as replacement ratio (As), improvement width ratio (W/B, where W=width of SCP improved portion, B= caisson width), SCP location (L), Caisson pressure increment (W_c), backfill weight and loading condition (rate and inclination of loading). The investigation was done changing the influential parameters as shown in Table 2. The test results are presented here in prototype scale.

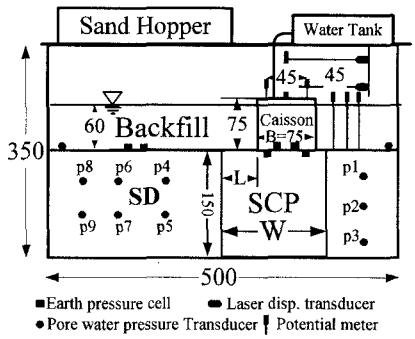

Fig.1 Test Setup (dimension in mm)

Table1: Material Properties

Ariake clay		Toyoura sand		Zircon sand	
Gs	2.67	Gs	2.64	γ'	20 kN/m^3
Ip	33.1	R_d (SCP)	80 %	ϕ	39.7°
Cu/p′	0.42	R_d (SD)	30%		

Test Results and Discussions

Long term refers to the time started after completion of construction and the period of time is taken into account until the consolidation finishes where deformation is concerned. Settlement of the ground and the superstructures are caused mainly consolidation settlement of the foundation ground. Settlement of caisson and ground surface under fill after backfilling are shown in Fig.3 and 4 respectively. Settlement of ground surface was measured from the photograph taken inflight. Settlement in series2 was little higher than that in series1. It was supposed to occur because in the tests in series2 the load in last two steps were larger as shown in Fig.2 and also larger box used in series2 might reduce the boundary effect. Settlement at SD portion is greater than that of caisson but similar trends were observed. From this it can be confirmed that the long term settlement of caisson could be influenced by the settlement of SD portion behind the caisson which is explained later.

Table2: Test conditions

Series	Test	A_s (%)	W	L	Caisson pre. W_c kPa	Back-fill pre. kPa
1	case2	30	2.0B	0.9B	85	140
1	case3	50	1.2B	0.1B	85	140
1	case4	30	2.0B	0.6B	85	140
1	case7	50	2.0B	0.9B	85	140
2	case8	30	1.2B	0.1B	130	140
2	case9	30	2.0B	0.9B	130	140
2	case11	50	1.2B	0.1B	130	140

Fig.3 shows settlement of caisson in case3 (A_s=50%, W=1.2B) and case7 (A_s=50%, W=2.0B) were less than that in case2 (A_s=30%, W=2.0B). Similar response was also observed in series 2. In case11 (A_s=50%, W=1.2B) was less than that in case8 (A_s=30%, W=1.2B) and case9 (A_s=30%, W=2.0B). From this it can be noticed that higher replacement ratio SCP can reduce long tern settlement of caisson. Settlement in case2 and (L=0.9B) was smaller than in that in case4 (L=0.6B). In series 2 it was also observed that settlement in case9 (L=0.9B) was smaller than that in case8 (L=0.1B). So, it is confirmed

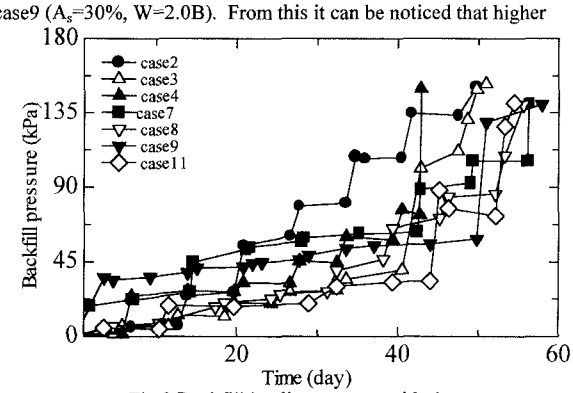

Fig.2 Backfill loading process with time

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Key Words: *Soft clay, SCP, Low replacement ratio, Long term, Backfill*

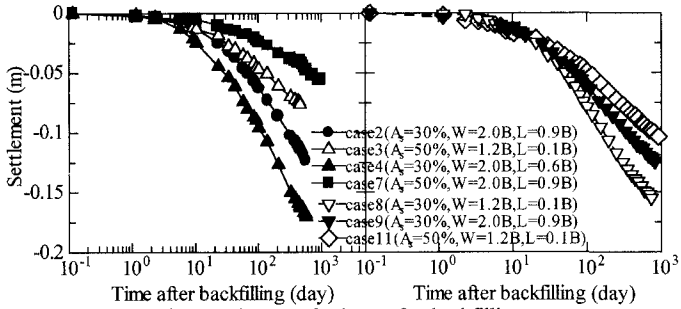


Fig.3 Settlement of caisson after backfilling

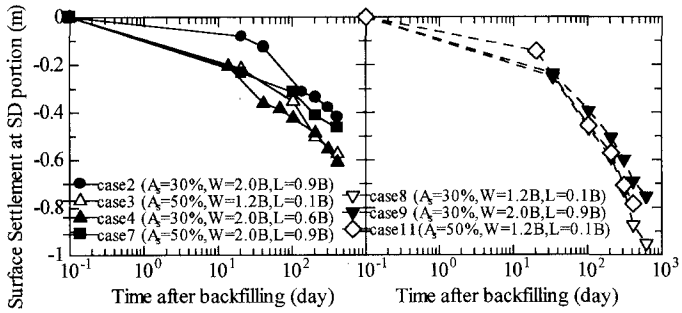
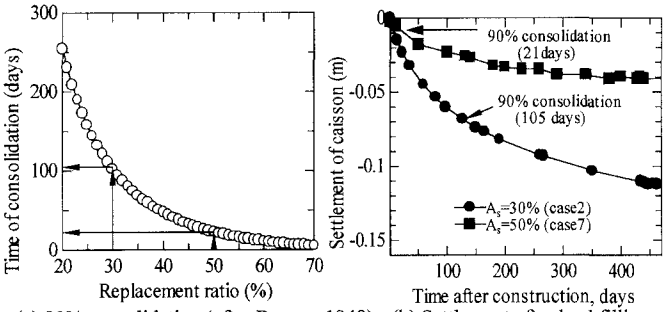


Fig.4 Settlement of ground surface at SD portion after backfilling



(a) 90% consolidation (after Barron, 1948) (b) Settlement after backfilling

Fig.5 Time of 90% consolidation in SCP ground

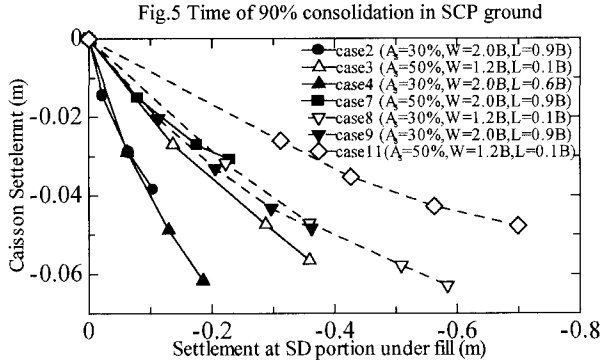


Fig.6 Relationship between the settlement of caisson and ground surface at SD portion

that widening of SCP area behind the caisson (under fill) is effective to reduce the long term settlement of caisson.

In SCP portion the consolidation is completed much more rapidly than that in SD portion. But the time of completion of consolidation depends on the replacement ratio for SCP of same diameter. Time required in achieving 90% consolidation for different replacement ratios using Barron's theory is shown in Fig. 5(a). In SCP with A_s=50% 90% consolidation can be achieved in 3 weeks (3min in model) whereas SCP with A_s=30% it takes about 15 weeks (15 min in model). In SD portion consolidation continue more than 1 hour (1 hour in model). Just after construction the consolidation both in SCP and SD portion are in progress but the rate of settlement is different. Both of these effects caused settlement of caisson. Caisson settlement must be accompanied by SCP settlement. Figure 5(b) shows the settlement of caisson continued beyond the point of 90% consolidation of SCP portion. This settlement of caisson was caused by the settlement. in SD portion behind the caisson. Relationship between the settlement of caisson and ground surface of SD portion after achieving 90% consolidation in SCP portion, which is obtained from the settlements shown in Fig.3 and 4 is shown in Fig. 6. Settlement of caisson was increasing with the increase of settlement at SD portion even consolidation in SCP portion becomes insignificant. Settlement of caisson in series2 was less than that in series1 even the higher settlement at SD portion. It is because of two reasons. One is higher caisson load increased the caisson settlement during caisson loading resulting less differential settlement and the other is higher load may increase the stiffness of SCP portion under the caisson. But the trend was similar in both series. From this it is confirmed that the long term settlement of caisson is mainly caused by the settlement in SD portion behind the caisson.

Concluding Remarks

Long term settlement of caisson is highly influenced by the settlement of ground behind the caisson. Both the increasing the replacement ratio and increasing the caisson weight to some extent can also reduce the long term settlement.

Reference

Barron, R. A. (1948) Consolidation of fine grained soils by drain wells, Trans. ASCE, Vol. 113, 1948, pp. 718-754.

Yasumoto et. al. (1998) Deformation of backfilled gravity caisson supported by low replacement area ratio SCP ground, Proc. JGS, Vol.33, No.2, pp. 2161-2162.