Study on the mechanical properties of a confined concrete deteriorated by Alkali-aggregate reaction

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Summary

Recently, in Japan, some concrete structures deteriorated severely by an excessive alkali-silica expansion have been reported and the decrease of compressive strength and Young's modulus of inside concrete, the fracture and/or yield of steel bar in the bending part have found in these deteriorated concrete structures. On the other hand, in previous studies, it was clear that the structural performance of ASR deteriorated members was not significantly reduced in cases where alkali-silica expansion was appropriately confined by steel bars arranged in the concrete member. However, it is inferred that the influence of Alkali-silica expansion on structural performance of ASR deteriorated concrete member is affected by the confinement ratio of steel bars in a concrete member. In this study, the mechanical properties of the confined concrete deteriorated by alkali-silica expansion were investigated. Thereby, a concrete specimen that had a various confinement level was loaded when these specimens attained at the maximum alkali-silica expansion. As the results, it was cleared that the influence of alkali-silica expansion on the mechanical properties of confined concrete deteriorated by alkali-silica reaction was not significant in cases where the confinement level of concrete member was as much as the normal existing concrete member.

Keywords: Alkali-silica reaction, compressive strength, expansion, confinement

1. Outline of experiment

The size of prism specimen was 150 mm x 150 mm x 492 mm. PVC (polyvinyl chloride) pipe was embedded in specimen at a center of section and PC rod was arranged into PVC tube. Steel plates were set in both end side of specimen. PC rod was fixed on both end side plate using a nut. The appearance diagram of the specimen and arrangement of PC rod and PVC pipe were shown in Figure 1.

Table 1: List of Specimen

Name	Longitudinal confinement	Steel ratio (%)	Lateral Confinement
0	No	0	No
3	PC rod φ9.2	0.30	FRP sheet (0.2 %)
8	PC rod φ15	0.80	FRP sheet (0.2 %)
12	PC rod φ19	1.29	FRP sheet (0.2 %)
24	PC rod φ26	2.37	FRP sheet (0.2 %)
D3	Steel rebar D10	0.28	FRP sheet (0.2 %)

After fabrication of the specimen, it was kept under ASR acceleration condition (40 °C, 98 % R.H.). The expansion was measured by contact gauge. As control, a plain concrete without PC rod and FRP sheet was prepared. List of specimen is shown in Table 2. Uniaxial loading test was done when the maximum expansion of specimen was attained after an acceleration of ASR.

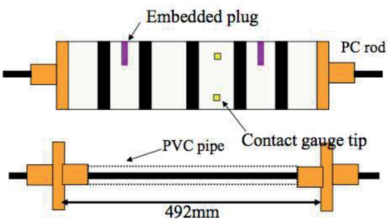

Fig. 1: appearance of specimen

2. Results and discussion

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2.1 Expansion behaviour

The influence of the confinement on the expansion of the specimen is shown in Figure 2.

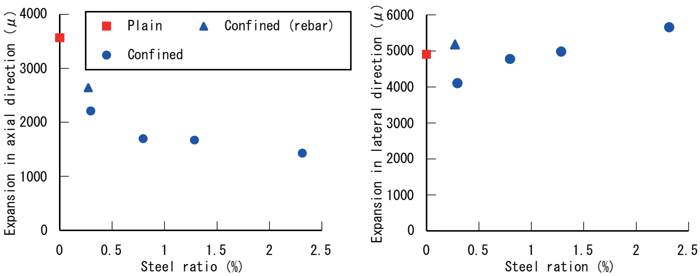

Fig. 2: The influence of steel ratio on the expansion

Assuming the total volumetric expansion and/or expansion potential is not changed, the decrease of the expansion in the longitudinal direction due to the confinement results in the increase of the expansion in the lateral direction. Therefore, it is consider that the increase of the steel ratio results in the increase of the lateral expansion.

2.2 Mechanical property of the confined concrete

2.2.1 Maximum Load and Rigidity

The reduction in maximum load and the rigidity of the confined concrete affected by ASR expansion was not significant. In contrast, the reduction in maximum load and the rigidity of the plain concrete was significant.

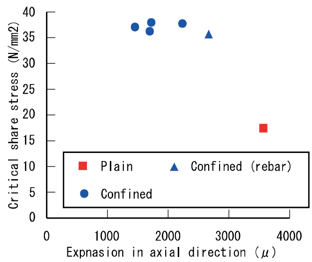

Fig. 3: Critial share stress for concrete

2.2.2 Critical share stress for concrete σ cr

The influence of the expansion on the critical share stress for concrete (σ cr = σ max + σ cs, Pcs : the prestress due to ASR expansion) was shown in Figure 3. The critical share stress for concrete of specimen with the confinement was almost same regardless of the expansion. It is considered that the reduction in a compressive strength of a confined concrete is not caused by ASR expansion since ASR expansion is restricted by the confinement and the macro cracks are not formed in inside concrete.

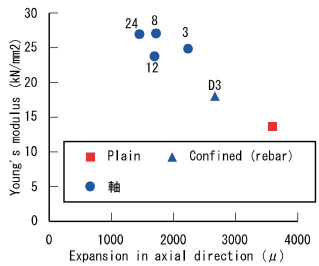

Fig. 4 : Young's modulus

2.2.3 Young's modulus

The influence of the expansion on Young's modulus was relatively large compared with the compressive strength. Although the macro crack of the confined concrete was restricted by the confinement that reduced the expansion, the micro crack was induced by ASR expansion even when the specimen was confined by reinforcement. And the number of the induced micro crack was decreased with the increase of the confinement. It is concluded that the micro crack that is induced into the confined concrete due to ASR resulted in the reduction of Young's modulus of concrete and the reduction of Young's modulus is proportional to the longitudinal expansion.

It should be noted that the mechanical properties of the confined concrete was kept in sound condition (no or a slight reduction) when the confinement lever was exceeded 0.8% of the longitudinal reinforcement with a lateral confinement. The main reason is that the expansion of the specimen with less than 0.8 % of reinforcement exceeds the yield strain of steel bar. It is clear that the influence of alkali-silica expansion on the mechanical properties of confined concrete deteriorated by alkali-silica reaction was not significant in cases where the confinement level of concrete member was as much as the normal existing concrete member.