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EXPOSURE TEST RESULTS FOR UNDERGROUND STRUCTURES DAMAGED BY ASR

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ABSTRACT

Recently, underground structures, for example footings and columns, which have degenerated due to Alkali Silica Reaction (ASR) have been discovered in Japan. In order to perform appropriate diagnosis of these structures, it is necessary to acquire a large amount of knowledge regarding underground structure degeneration caused by ASR, such as the conditions under which ASR occurs in underground structures, and the internal degradation conditions. For this reason, road administrators are unable to perform sufficient maintenance, and this constitutes a serious problem with respect to safe operation of the road network. Hence, in order to obtain the relevant knowledge, a long term exposure test has been performed under actual conditions, up to the present time, and the cracks and strain in the footings and temperature and water level in the exposure environment have been measured. In addition, we have analyzed the differences in the degradation of footings caused by the environment with respect to the water, air and underground conditions, and used the measured data to examine the reasons for these differences.

Keywords: Underground structure, Alkali Silica Reaction, Exposure test, Strain, Crack.

1. INTRODUCTION

Recently, underground structures damaged by ASR have been reported. Some have been seriously damaged, such as the steel being fractured. Since they are underground, these structures are not generally visible. Hence, not much is known about footings damaged by ASR. Nothing is known

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about how ASR progresses in underground structures, or how it results in a decrease in load carrying capacity. Therefore, we conducted an exposure test in order to acquire relevant knowledge regarding footings damaged by ASR. This test was conducted under actual conditions over a long period, i.e. 6 years. We evaluated the extent of the damage occurring in the underground structures by measuring strain.

2. EXPOSURE TEST DIAGRAMS

The factors affecting damage by ASR are temperature, water and amount of reinforcing steel. Therefore, the exposure environment, scale and arrangement of the reinforcement were determined in consideration of these factors.

Fig-1 shows the details of the model. It is expected that structures damaged by ASR are those constructed before 1980. Hence, the models were designed with reference to the footings used at the time. The reinforcement used in the models was SD 295A, the ratio for the tensile reinforcement was 0.20%, and that for the compressive reinforcement was 0.05%.

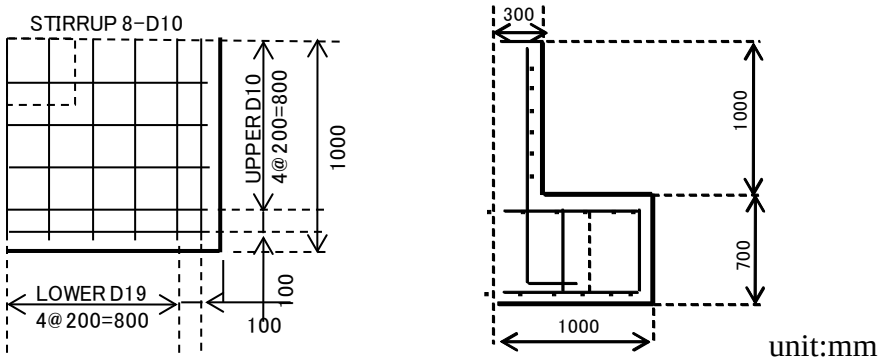


Fig. 1 Drawing showing dimensions and bar arrangement of footing models (For Cases 1 and 2. Left: plane section for footing, Right: vertical section)

Three test models were used. They consisted of a pier and footing. The sizes of the footings were the same, the width and length being 2.0m and the height 0.7m. The width and length of the pier were 0.6m. The height of the pier was 1.0m in Cases 1 and 2, and 2.6m in Case 3. The cement used was ordinary Portland cement. The design strength of the concrete was 21N/mm^2. The ratio of alkali reactive aggregate to non-reactive aggregate was 50:50 for the coarse aggregate, and 40:60 for the fine aggregate.

Table-1 shows the exposure test cases, and Figure-2 shows a photograph of the exposure test conditions. The test models for Cases 1 and 2 were exposed in water, and that for Case 3 was exposed underground. The groundwater level in Case 3 was around the footing, and the water level

in Case 1 was changed based on the groundwater level in Case 3. The water level in Case 2 did not change. The cracks and strain in the concrete surface and reinforcement were measured.

Table. 1 Exposure test cases for footing models

Case	Exposure environment
1	In the cistern. The water level changed between 3 levels (above the surface of the footing, half way up the footing, and around 5cm above the bottom of the footing)
2	In the cistern. The water level did not change (was always above the surface of the footing)
3	In the ground.

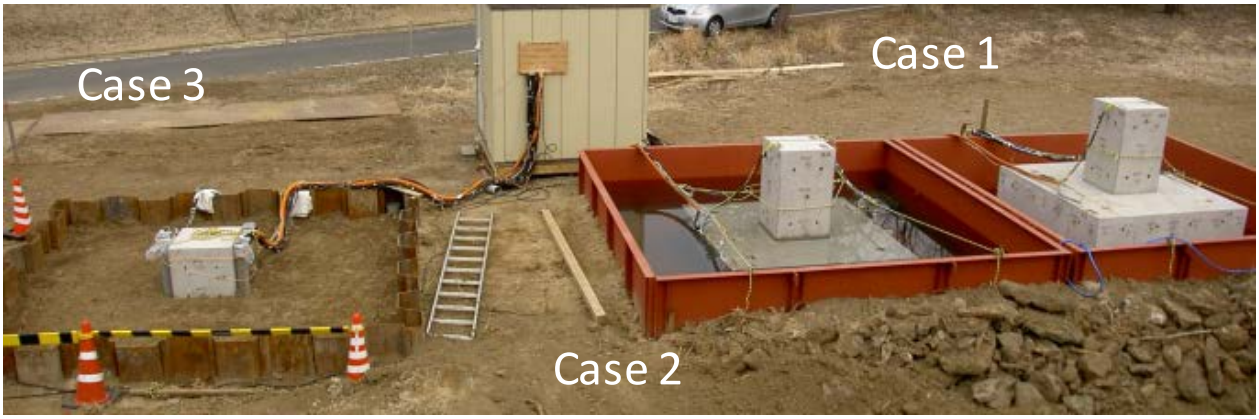


Fig. 2 Photograph showing exposure test conditions

3. EXPOSURE TEST RESULTS

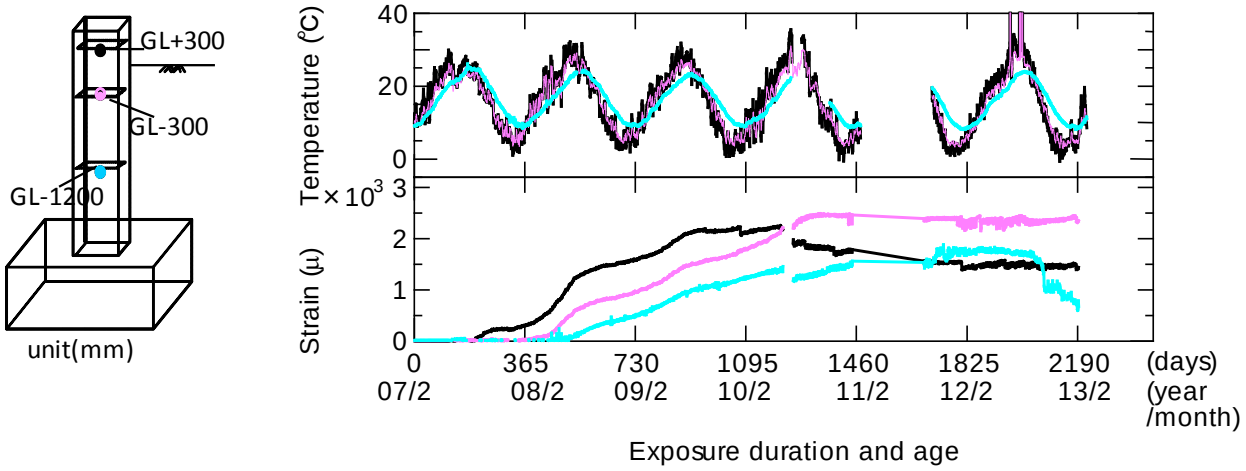
Figure-3 shows the variation of the groundwater level over time, and the temperature and strain in the reinforcement of the column in Case 3. Strain and temperature were measured at the same point. The groundwater level was below the bottom of the footing. The amount of reinforcement of the column does not vary with depth. Therefore, environmental conditions constitute the only reason for differences in the strain at each point.

The variation of temperature over time shows that the closer the point of measurement to the ground surface, the higher was the maximum temperature, and the lower was the minimum temperature.

The trend toward increasing strain differs depending on depth. The strain measured at GL. + 300, which is the point at which the highest temperature was measured, had reached 2000μ after around 760 days.

Conversely, the deeper the point at which the strain was measured, the later the onset of strain increase. For example, the strain measured at GL. -300 increased 1 year and 3 months after the exposure test began, and that at GL. -1200 increased at 1 year and 6 months. In addition, the deeper the point of measurement, the smaller was the increase in speed. Furthermore, the strain at GL. +300 did not increase in winter, during which the temperature became lower than 10 degrees. Conversely, at GL. -1200, the increase in speed was similar regardless of season. At this point, the temperature was close to exceeding 10 degrees. From these results, it can be seen that the trend toward increasing strain is dependent on temperature.

Figure-4 shows the strain and temperature values measured in the upper steel of the footings. The temperatures measured in Cases 1 and 2 were almost the same. In contrast, the temperatures measured in Case 3 were different from those in Cases 1 and 2, both the maximum and minimum temperatures in Case 3 being lower. These results are similar to those shown in Figure-3.

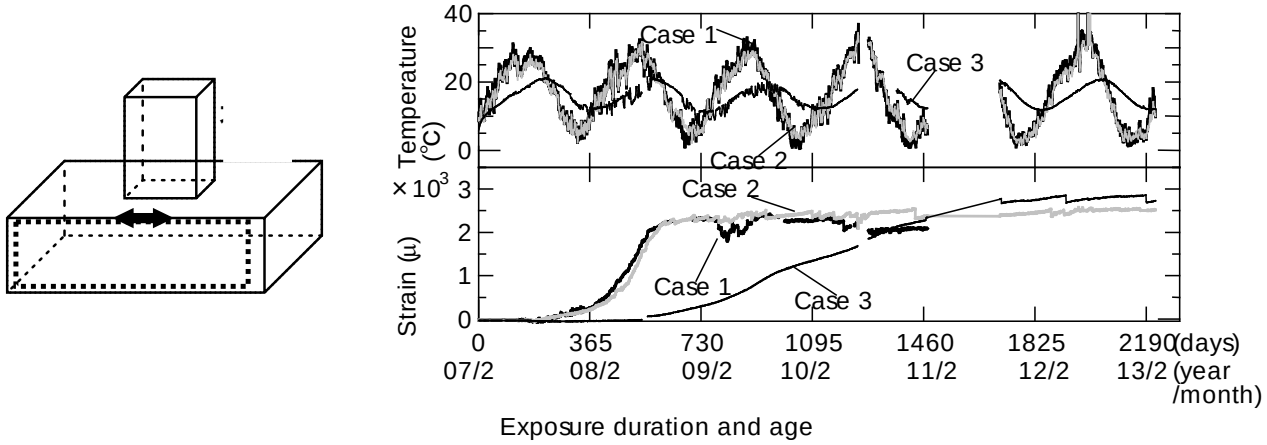


(a) Measurement points (b) Measurement results

Fig. 3 Time variation of steel strain and temperature in column

The strain results for the exposure tests show that strain values increased in all cases. However, these cases show differences in the trends that they exhibit. The strain value in Cases 1 and 2 started increasing at around 180 days. In contrast, the strain value in Case 3 started increasing at around 560 days. In addition, the speed of increase in Case 3 was similar regardless of season, but that in Cases 1 and 2 was larger in the summer when the temperature was high, and smaller in the winter when the temperature was low.

The strain values in Cases 1 and 2 converged 9 months after commencement of the exposure test. In contrast, those in Case 3 had still not converged after 2 years. However, after 4 years, the strain values in Case 3 became higher than those in Case 2. From this result, it can be concluded that the strain resulting from exposure at low temperature increases more slowly but reaches a higher final value than that resulting from exposure at high temperature.



(a) Measurement points (b) Measurement results

Fig. 4 Time variation of steel strain and temperature in footings

4. CONCLUSION

We conducted an exposure test on underground structures. This was conducted in the field, over a long period. From this test, we acquired knowledge regarding ASR in underground structures, the results determining the relationship between the strain in the steel due to ASR and temperature.