

Environmental impacts on ASR expansions -modeling, field exposure and alkali-wrapped concrete prism test-

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Abstract

Environmental conditions critically influence the expansive behavior of concrete due to the alkali-silica reaction (ASR) and therefore must be modeled to predict ASR expansive behavior. Laboratory tests are also important for the provision of useful data for numerical models, since these models often require the calibration of some unknown parameters according to the materials tested. To address this, the authors have developed a test method for concrete expansion, the alkali-wrapped concrete prism test (AW-CPT). Previous study results found that the predicted expansion using the results of AW-CPT agreed well with field-exposure tests. The previous study also emphasized the importance of modeling environmental conditions. In this study, the impact of environmental conditions on ASR expansive behaviors was found through exposure and laboratory tests. The environmental conditions were modeled and implemented in numerical simulations. As a result, the number of rainy days was found to be critical for modeling the environmental conditions.

Keywords: *environmental conditions, numerical simulation, alkali-wrapped concrete prism test, temperature, sunshine, rainfall.*

1. INTRODUCTION

Many test methods have been developed to assess the reactivity of aggregate or the expansion potential of concrete. To mitigate or avoid the effects of alkali leaching and drying, a new performance testing protocol, the Alkali-Wrapped Concrete Prism Test (AW-CPT), was recently proposed. Using the results obtained by AW-CPT, simplified simulation provided results consistent with the expansion of concrete blocks in the field, although further research is necessary to elucidate the impact of each parameter on ASR expansion. In the present study, the most recent results of field exposure tests are firstly presented. Then, the method used and the results of a simulation are described. Finally, through the results of a parametric study, the effect of environmental conditions on the expansive behavior of concrete in the field is discussed.

2. EXPANSION OF CONCRETE UNDER DIFFERENT ENVIRONMENTAL CONDITIONS

2.1 Field exposure tests

The expansion behavior of the concrete blocks is illustrated in Figure 1. The environmental conditions of the exposure sites in 2016-2019 are also summarized in Figure 1. In the figure, the average of the expansion of each lateral side was used as a measure of the expansion although the expansion was different on each side. At each site, the upper side showed the largest expansion, possibly due to solar insolation. The concrete block in Okinawa shows an earlier expansion. The onset of expansion is almost the same at Fukuoka and Monbetsu while the rate of expansion varies. Below 0.1% of expansion, the rate of expansion was 0.142%/year in Okinawa, 0.108%/year in Fukuoka, and 0.051%/year in Monbetsu. The expansion of the block at Monbetsu gradually increased with time despite the lower environmental temperatures and the relatively lower total alkali content of the concrete (3.0 kg/m³). The test results show that the environmental conditions critically influence the expansion behavior of concrete blocks exposed to field conditions. In particular, temperatures including solar insolation have a significant impact on the ASR expansion.

2.2 Numerical simulation

In order to simulate the expansion behavior of concrete, the numerical simulation was carried out. First, the moisture profile is calculated by the partial differential equation. For the thermal calculation, it was assumed that the temperature of the concrete blocks was instantaneously equal to the ambient temperature. Then, using the moisture profiles and temperature, the incremental ASR expansion, and thermal and shrinkage strains are calculated and all the strains are summed to obtain the total strain of the block. After exposure, the actual temperatures and R.H. were used. It was assumed that, if precipitation occurred, the R.H. was 1.0 during that day. In the expansion model, the model devised by Brunetaud was used. The expansion model parameters were identified by performing AW-CPT. The temperature and moisture dependencies of the parameters were set from the previous studies.

The simulated results are shown in Figure 1. The calculated results show a slightly earlier onset of expansion; however, they were generally consistent with the exposure results. The consistency of the simulated and exposure results for all the sites show that the numerical simulation combined with AW-CPT can predict the behavior of concrete blocks exposed to real environmental conditions.

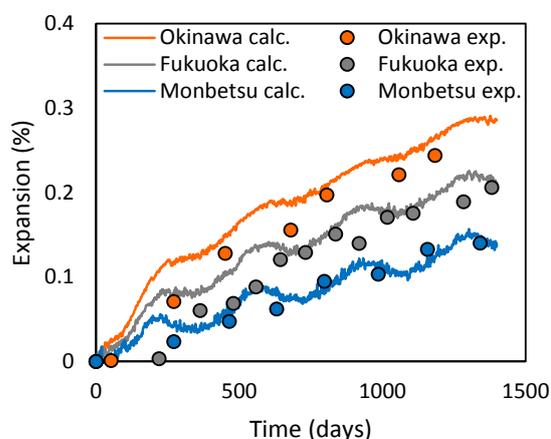
2.3 Discussions

The experimental and numerical results showed that environmental conditions critically influence the hygro-thermal behavior of concrete, resulting in different ASR expansive behavior at each exposure site. Our parametric analysis (see full paper) showed that it is important to consider the solar insolation and rainfall in the simulation. In the simulation, temperature had a significant impact on expansion behavior. Also, it is insufficient to consider only R.H., which resulted in drying and no ASR expansion. Through these simulations, it was found to be necessary to implement solar insolation and rainfall in the thermo-hygro-chemo-mechanical simulation.

3. CONCLUSIONS

This paper presented the impact of the environmental conditions on the ASR expansion of field-exposed concrete blocks through field exposure tests and numerical simulations. The following conclusions may be drawn from this work:

- A clear difference in the ASR expansive behavior at different exposure sites in Japan (Fukuoka, Okinawa, and Monbetsu) was confirmed through exposure tests and numerical simulation.
- A comparison between the exposure tests and numerical simulation showed that the modeling of the environmental conditions has a significant impact on the ASR expansive behaviors.
- Numerical simulations based on the AW-CPT were consistent with the expansion of the concrete blocks, indicating that the AW-CPT is beneficial for the prediction of the ASR expansion of concrete subjected to actual environmental conditions.



	Fukuoka	Okinawa	Monbetsu
Mean annual temperature (K)	291	297	280
Mean annual R.H. (%)	70	74	76
Total annual precipitation (mm)	6776	8954	3491
Total hours of sunlight in 1 year (hr/year)	7807	6778	6632

Figure 1 Simulated expansion results compared with experimental expansion behavior of concrete block exposed to field conditions (Noted that expansion of upper face is not included.).

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