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INFLUENCE OF WATER CONTENT OF CONCRETE ON ALKALI-AGGREGATE REACTION

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ABSTRACT

The presence of water is one of the three conditions necessary for alkali-aggregate reaction to occur. When we repair concrete construction that has been damaged by such a reaction a great deal of attention must be given to the water content of the concrete. This paper reports the relation between the water content of concrete and its expansion. An understanding of such a relation should certainly have great practical use as fundamental data for repair.

In this experiment, five kinds of concrete mix were tested. These mixtures were varied in terms of kind of aggregate, alkali content and unit cement content. Concrete specimens were cured for 8 weeks at 40 ℃ and above 95% R.H.. Following this, the specimens were divided based on five conditions, and stored for 1 year. During this storage period, the weight, length, dynamic elasticity, ultrasonic pulse velocity and water content of the various concrete specimens were measured at prescribed ages along the way.

Length change was thought to be the best index of deterioration due to the fact that the dynamic elasticity and ultrasonic pulse velocity had been influenced by the water content of concrete.

The expansion of concrete with the reactive aggregate increased in proportion to the water content of concrete. Although the relation between the expansion and the water content of concrete differed to some degree among the various concrete mixes, it was possible to control the expansion below 0.1 % when the water content of concrete was kept below 4 %.

1. INTRODUCTION

The damages caused by alkali-aggregate reaction(A.A.R.) had not been reported in Japan except one in 1951. However, recently some damages in the public structures, such as breast walls, bridge piers, were reported in Hanshin district and small numbers of case in concrete buildings have also been discovered. Although several repairing works were carried out in those deteriorated or damaged concrete structures by A.A.R., the repairing technique in general has not been established yet because the mechanism of A.A.R. is still not fully known.

In general, A.A.R. occurs under those three conditions below:
(1) existence of the aggregate which contains reactive silica

(2) impermissible concentration of hydroxylic alkali-ion
(3) certain amount of water
It is considered that the third condition is the easiest one to control and the practical method to be applied to the repairing work is to keep concrete dry so as to decrease its water content. Concrete should be kept dry until the deterioration by A.A.R. in concrete is suppressed and in order to keep the water content concrete should be kept off from the water coming in from outside.

In this study, aiming at obtaining the basic data for repairing the damaged concrete by A.A.R., the permissible level of water content of concrete with reactive aggregate and high alkali content was investigated.

2. EXPERIMENTAL PROGRAM

In this experiment, five kinds of concrete containing different kinds of aggregate, unit cement weight, and unit alkali content shown in Table 1 were tested. All of them were expanded to some degree first and then divided into five different conditions of relative humidity and their expansion and water content were measured at specified ages.

Table 1 Experimental Program

No. of Mix	materials used						Mix proportion		Size of specimen (cm x cm x cm)	Temperature and relative humidity
	Water	Cement	Aggregate coarse	Aggregate fine	Chemical admixture	Added alkali	Unit cement content (kg/m³)	Unit alkali content (kg/m³)		
①	dis-tilled water	high alkali cement (R_2O: 0.97%)	N	silika sand	AE water reducing agent (air:4%)	NaOH + NaCl + $NaNO_2$	350	8	7.5 x 7.5 x 40	temp: 40℃ R.H.: 100% 90% 85% 80% 75%
②			Q+N							
③			T_2					6		
④								8		
⑤							450			

3. METHOD OF EXPERIMENT

3.1 Materials

(1) Cement
Normal portland cement was used (high alkali type, R2O=0.97%).
(2) Aggregate
1) Fine aggregate
Silica sand from Seto near Nagoya in Japan was used as fine aggregate.
It was judged innocuous by ASTM C 289
2) Coarse aggregate
As shown in Table 1, three kinds of crushed stones were used as coarse aggregate. The mark "N" indicates non-reactive sandstone, the mark "Q" indicates reactive andesite with pessimum effect and the mark "T2" is reactive andesite. Aggregate "Q" and "N" were blended at the ratio of maximum expansion, 1:1.
(3) Water
Distilled water was used as mixing water.

(4) Chemical admixture
AE water reducing agent was used as chemical admixture.
(5) Added alkali
The alkali solution was used to adjust the unit alkali content of concrete. Three kinds of alkali, that is NaOH, NaCl and NaNO2 of Na2O equivalent, were blended.

3.2 Dimension And Number Of Specimens

Two types of specimens were made in order to measure expansion and water content of concrete. The size of specimen for measuring expansion was 7.5x7.5x40cm and that for measuring water content was 7.5x7.5x20cm. Three specimens were used for measuring expansion and in order to measure water content one specimen was used for each measuring age.

3.3 Test Procedure

Concrete specimens were removed from the molds at the age of one day and stored in a big chamber for constant temperaure and humidity at 40°C 100% R.H.. At the age of 8 weeks, they were divided into five different chambers with prescribed relative humidity.

Expansion was measured every four or five weeks till the age of one year. Water content was measured at the age of 13, 17, 26 and 52 weeks.

3.4 Measuring Method

Expansion of concrete was measured in accordance with JIS A 1129 (methods of test for length change of mortar and concrete). Initial length was measured at the age of one day. In this experiment,the weight, dynamic elasticity and ultrasonic pulse velosity were also measured.

In order to determine the water content of concrete, the weight of concrete was measured twice each time, before and after the oven dry at 105°C. Water content was calculated as follows.

$$Wc=(Wo-Wl)/Wl \times 100$$

where, Wc : water content (%)
Wo : weight of specimen before dry (gr)
Wl : absolute dry weight of specimen (gr)

4. RESULTS AND DISCUSSION

4.1 Influence Of Humidity On Expansion

Fig.1 shows the influence of humidity on expansion in five kinds of concrete mix stored at 40°C. Concrete with reactive aggregate and 8kg/m3 of unit alkali content showed a tendency to expand when the humidity was over 85%R.H.. The higher the humidity became, the lager the expansion became. The expansion of concrete remained on the same level under 80%R.H..

In the case of 6kg/m3 of unit alkali content, concrete didn't show a tendency to expand below 90%R.H..

Concrete with non-reactive aggregate expand a little at 100%R.H., and it became to shrink below 90%R.H..

4.2 Influence Of Humidity On Water Content

Fig.2 shows the influence of humidity on water content of concrete. After the age of 8 weeks, every concrete stored at 100%R.H. kept the same water content value for one year. But the water content of concretes stored below 90%R.H. decresed with age. Those concretes in lower humidity showed a sharp decline of their water content at the early stage.

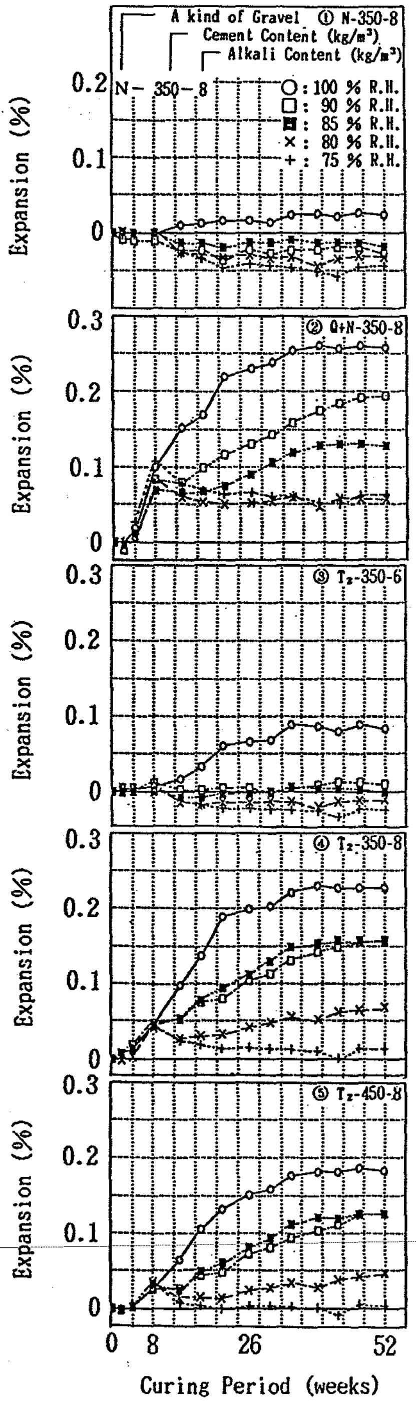

Fig.1 Effect of Humidity on Expansion of Concrete

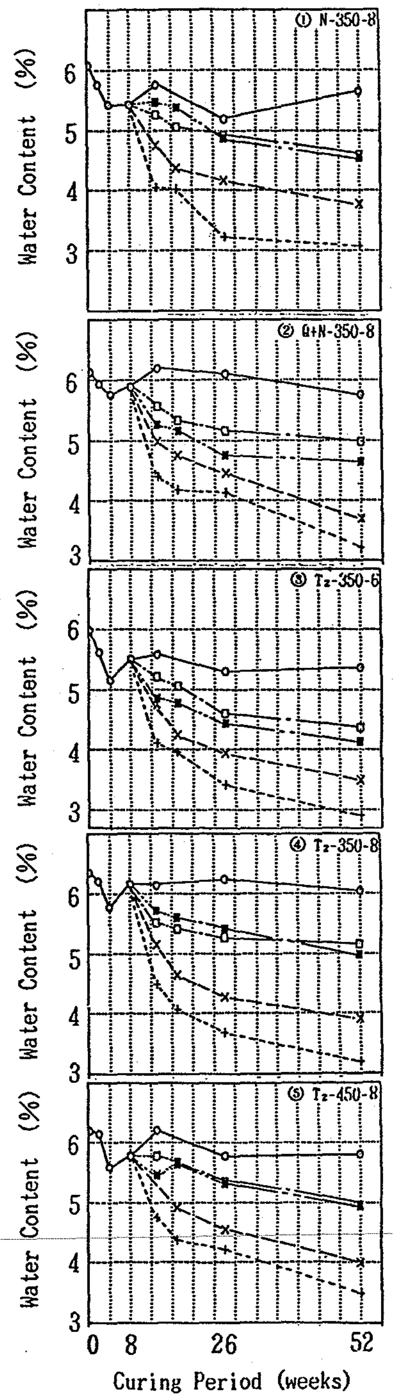

Fig.2 Effect of Humidity on Water content of Concrete

4.3 Influence Of Water Content On Expansion

As shown in Fig.1 and 2, in the case of concretes containing 8 kg/m3 of unit alkali content and reactive aggregate, water content of concrete stored in the condition of over 85%R.H. became 5% level after a year and showed a tendency to expand. But below 80%R.H. water content became 3% level, and they almost stopped expanding. In the case of concretes containing 6kg/m3 of unit alkali content and reactive aggregate, water content became 5% level, and they showed a tendency to expand only under the condition of 100%R.H.. Fig.3 shows a relation between expansion and water content of concrete. A linear relation is recognized between them and from this relation the water content can be determined so as not to exceed the permissible limit of expansion of concrete. If the limit is set up at 0.1%, the water content becomes 4.2% in the worst concrete mix.

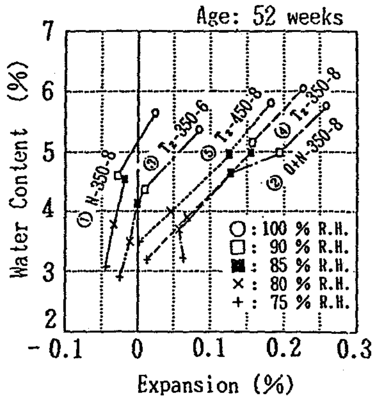

Fig.3 Relation between Expansion and Water content

5. CONCLUSIONS

The followings are obtained within the scope of this experiment.

(1) Water content of concrete keeps the same value as that at the early age in the case of 100%R.H. and decreases with the reduction of humidity.
(2) In the case of concretes containing 8kg/m3 of unit alkali content, water content of concrete becomes 4-5%, and they show a tendency to expand in the condition of over 85%R.H.. When they are stored under 80%R.H., water content becomes 3% level, and they almost stop expanding.
(3) In the case of concretes containing 6kg/m3 of unit alkali content, they shows a tendency to expand under the condition of 100%R.H. and their water content is 5% level. They almost stop expanding under 90%R.H..
(4) The expansion of concrete is in proportion to its water content. It is necessary to keep water content of concrete under 4% so that concrete should not expand.

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