INFLUENCE OF ALKALI CONTENT ON THE PROPERTIES OF CONCRETE CONTAINING BEIJING AGGREGATE

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ABSTRACT

This paper discussed the effects of addition of KOH on compressive and flexural strengths of the concrete containing coarse aggregate with maximum size of 10mm and taken from Lu Gou Qiao at the Yong Ding River. The test results showed that a high alkali content is harmful to the strength of the concrete. When the alkali content increases from 3.0 kg/m^3 to 8.0 / 9.0 kg/m^3 and after the concrete has been cured for 81 weeks at 60° C, the compressive strength decreases by about 30 MPa. The safe alkali content of the concrete needs to be below 3.5 kg/m^3 to ensure against a loss of compressive strength.

Only a few reaction rings of alkali aggregate reaction of the aggregate were found in the concrete samples. The expansion of most of the concrete specimens was smaller than 0.05%. Therefore in this case alkali aggregate reaction is not the only reason for the reduction in the strength of the concrete. As shown by other research, the loss of strength may be attributed to the influence of additional alkali on cement hydration and nature of the solid phases produced.

Key words: alkali content, Beijing aggregate, alkali aggregate reaction

INTRODUCTION

Studies on the aggregate produced at Lu Gou Qiao, Beijing have been reported elsewhere(1). Tests showed that with a short curing age the high alkali content effected the compressive and flexural properties of the concrete. The concrete also exhibited the characteristics of alkali aggregate reaction. Detailed research on the alkali reactivity of the aggregate found in Yong Ding River near Lu Gou Qiao has also been reported in reference(2). It has been illustrated that the aggregate in this area has alkali reactivity to various degrees. Examples of alkali aggregate reaction have also been found in concrete structures in which the aggregate used was from the same river bed. This paper looks at aggregates with different alkali content and long term curing in order to establish a safe alkali content in order to avoid the loss of concrete strength.

MATERIALS AND EXPERIMENT

Micro Mortar Bar Test for the Aggregate

The coarse aggregate studied here was produced at the Yong Ding River near Lu Gou Qiao, Beijing, China. A 1 kg sample of this aggregate was weighed, classified and crushed. The crushed aggregate with a particle size range of 0.16-0.63 µm was selected to be cast in 10 x 10 x 40 mm micro mortar bars using different cement-aggregate ratios (c/a) of 10, 5 and 2 respectively. The alkali content ($Na_2O_{equiv.}$) of the micro bars was adjusted to 1.5% by weight of cement using KOH. After the bars were demoulded and their length was measured, they were cured in 100 °C water vapour for 4 hours, and then put in an autoclave containing 10% KOH solution to be heated and cured at 150 °C for 6 hours. After cooling, their lengths were again measured. In this experiment silica glass sized 0.15-0.63µm was used as a reference reactive aggregate.

Concrete Test

The coarse aggregate obtained from Yong Ding River was seived and the parts smaller than 10 mm were selected. The sand used was non-reactive. Concrete specimens of 40 x 40 x 160 mm were cast. Their mix proportion of cement : sand : coarse aggregate : water was 1 : 1.14 : 2.65 : 0.40. After being demoulded the sample lengths were measured, the specimens were then cured at 60 °C, 100% R.H. The length of the samples were measured at different ages. The specimens were divided into two groups. One group was tested for flexural and compressive strength after being cured for 81 weeks. The second group, after being cured for 81 weeks at 60°C, was frozen-thawed for 100 cycles and autoclaved at 150 °C for 2 weeks and then tested for flexural and compressive strength. A part of the specimens was also cut, ground, polished and observed by a stereo-microscope in order to investigate the characteristics of the alkali aggregate reaction. Alkali content of the concrete was adjusted to 1.8, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 8.0, 9.0 kg/m^3 respectively using KOH, and the specimens were marked B1.8, B2.0, B2.5, B3.0, B3.5, B4.0, B4.5, B5.0, B5.5, B6.0, B6.5, B7.0, B8.0, B9.0 respectively.

TEST RESULTS AND DISCUSSION

Alkali Reactivity of the Aggregate

The expansion values of the micro mortar bar tests for the aggregate are listed in Table 1. When c/a=10, 21.6% of the aggregate had an expansion above 0.08%. According to Tang etal.(3), this part of the aggregate is potentially reactive; When c/a=5, 29.8% of the aggregate had an expansion above 0.08%, (48.6% + 21.6%) above 0.10% and these parts are reactive according to Tang(3); When c/a=2, all the aggregate had expansion above 0.10% and is reactive.

Table 1 Expansion Ratio of Lu Gou Qiao Aggregate by Micro Mortar Bar Test

SAMPLE	EXPANSION (%)			WEIGHT RATIO (%)
	c/a=10	c/a=5	c/a=2	
	0.052	0.103	0.158	48.6
The Aggregate	0.061	0.088	0.166	29.8
	0.084	0.164	0.232	21.6
Silica Glass	0.988	1.185	0.918	100

The Influence of Alkali Content on the Compressive and the Flexural Strength of the Concrete Containing the Sample Aggregate

The compressive and the flexural strength of the concrete is listed in Table 2 and shown in Figures 1 and 2. With an increase in the alkali content, there exists a trend that indicates a decrease in the compressive strength of the concrete. For example, the compressive strength decreases from 94.6 MPa to 74.2 MPa and 63.5 MPa when the alkali content increases from 2.0 kg/m^3 to 5.0 kg/m^3 and 9.0 kg/m^3 (Refer to Table 2,C1). However this does not explain why the compressive strength of the concrete does not decrease when the alkali content increases from 1.8-3.5 kg/m^3 to 5.5-6.0 kg/m^3.

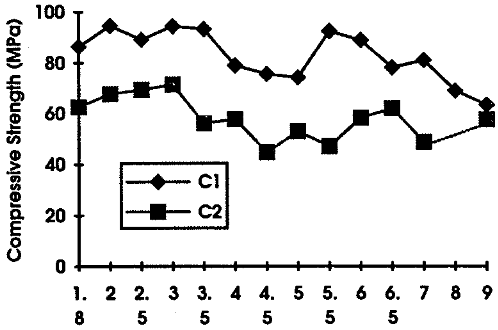
It can also be seen from Table 2 and Figures 1 and 2 that the compressive strength of group C2 is lower than that of group C1 and the flexural strength of group F2 is lower than that of group F1. This shows that the strength of the concrete is also effected by freezing-thawing and autoclaved curing.

Table 2 Compressive and Flexural Strength of Concrete Specimens Containing Different Alkali Contents

SAMPLE	B1.8	B2.0	B2.5	B3.0	B3.5	B4.0	B4.5	B5.0	B5.5	B6.0	B6.5	B7.0	B8.0	B9.0
C1(MPa)	86.5	94.6	89.1	94.4	93.2	79.0	75.5	74.2	92.4	88.9	78.3	81.2	69.1	63.5
C2(MPa)	62.6	67.7	69.3	71.4	56.0	57.8	44.7	52.9	47.0	58.2	62.1	48.8	---	57.7
F1(MPa)	8.6	10.1	11.3	11.3	9.4	8.6	9.4	8.6	8.8	12.0	9.8	10.1	7.5	8.3
F2(MPa)	7.1	9.0	9.2	8.1	8.1	7.9	6.0	---	8.1	5.4	7.9	7.1	---	7.9

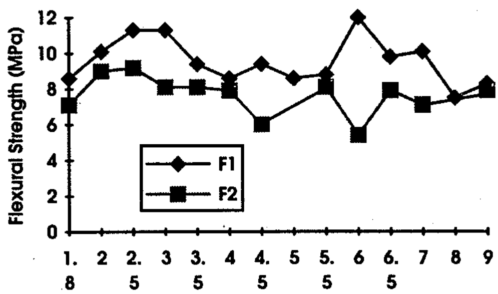
C1,F1: the compressive and the flexural strengths of the concrete after cured for 81 weeks at 60°C;

C2,F2: the compressive and the flexural strengths of the concrete after cured for 81 weeks at 60°C, frozen-thawed for 100 cycles and autoclaved for 2 weeks at 150°C.



Alkali Content(kg/m^3)

Fig.1 Influence of Alkali Content on Compressive Strength of Concrete Containing Lu Gou Qiao Aggregate

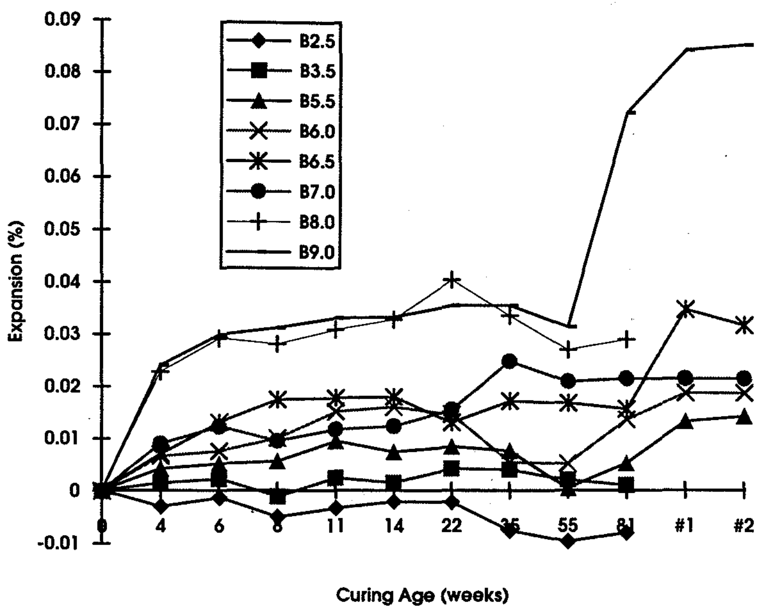


Alkali Content(kg/m^3)

Fig.2 Influence of Alkali Content on Flexural Strength of the Concrete Containing Lu Gou Qiao Aggregate

Expansion of the Concrete

The expansion values of the concrete specimens cured at 60 °C are shown in Fig.3. In order to correct the deviations resulting from the shrinkage of the concrete, the average expansion ratio of the concrete specimens with an alkali content of 1.8 kg/m^3 and 2.0 kg/m^3 was determined. This was then used to calibrate the expansion of the other concrete samples. The expansion in Fig.3 refers to that after calibration.



#1: Autoclaved for 1 week at 150°C after cured for 81weeks at 60°C;
#2: Autoclaved for 2 weeks at 150°C after cured for 81 weeks at 60°C.

Fig.3 Expansion Ratio of Concrete Containing Lu Gou Qiao Aggregate

It can be seen from Fig.3 that the expansion of the concrete with a high alkali content is generally higher than that of the concrete with a low alkali content, but only in a few cases does the expansion exceed 0.05%.

Even though the expansion of this concrete is in the low range, the compressive strength still reduces significantly with respect to that of the concrete with alkali content of 1.8 and 2.0 kg/m^3(Refer to Table 2, C1 of B1.8, B2.0, B8.0 and B9.0). The reduction in the strength could be as a result of the the following as developed by other research:
(1) That alkali effects the hydration of the cement and the formation of the concrete structure;
(2) Alkali-aggregate reaction.

It is therefore necessary to analyze why this occures.

Characteristics of Alkali Aggregate Reaction

Cross sections of the specimens were observed with a stereomicroscope after the concrete was cut, ground and polished. Only a few typical reaction rings of the aggregates were found. The reaction ring is also found in concrete with low alkali content. Therefore it can be concluded that alkali aggregate reaction is not the only factor that results in a significant reduction of the concrete strength in this experiment.

The alkali-aggregate reaction and the alkali reactivity of the aggregates found in Beijing area have been researched in references(2,4,6). In this research the characteristics of the alkali-aggregate reaction were typical of aggregates which contain alkali reactive minerals. There are examples of alkali-aggregate reaction in concrete structures which have used aggregate from this area. This experiment produced different results. It showed that alkali-aggregate reaction and alkali reactivity in aggregates is extremely complex. The alkali reactivity and the degree of alkali-aggregate reaction can differ even though the aggregate is from the same site.

Cause of Loss in Strength

Shayan and Ivanusec(7) investigated the effects of added NaOH on the mechanical properties of cement pastes and mortars with and without reactive aggregate and showed that the loss in strength of specimens containing reactive aggregate was similar in trend to that for the specimens without reactive aggregate. Their research also showed the significant interaction between cement and added NaOH. Therefore the loss of strength of the concrete due to the addition of KOH in this research may be attributed to the same cause as developped in their research.

CONCLUSION

Aggregate from Lu Gou Qiao with a high alkali content effects the strength of the concrete. When the alkali content increases from 3.0 kg/m^3 to 8.0/9.0 kg/m^3, the compressive strength of the concrete decreases by about 30 MPa. The safe alkali content level of the concrete needs to be below 3.5 kg/m^3 to ensure against a loss of compressive strength.

Fewer than expected typical rings of alkali aggregate reaction of the aggregate were found in the concrete specimens. The expansion of most of the specimens was smaller than 0.05%. Alkali aggregate reaction is therefore not the only reason for a reduction in the strength of the concrete in this case. As shown by other research, the loss in strength due to addition of alkali may be attributed to its influence on cement hydration and nature of the solid phases produced.

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