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Alkali-Aggregate Reaction in Concrete

ANALYSIS OF THE ALKALI CONTENT OF CONCRETE IN CHONGQING

Li Dan
Chongqing Research Institute of Building Science
No.50, Jiandongercun, Jiangbei District, Chongqing, 400020, China

ABSTRACT
The alkali content of the cements, chemical admixtures and supplementary blending materials currently used in concrete in Chongqing area was surveyed and the alkali content of concrete was analyzed. Technical measures to prevent alkali-aggregate reactions in concrete engineering were suggested.

Keywords: Concrete, Alkali-aggregate reaction, Alkali content

1 INTRODUCTION

The alkali-aggregate reactions have brought serious damages to concrete works and become a global disaster. Domestic and overseas studies show that the excessive alkali content is one of the main reasons that cause the alkali aggregate reaction in the concrete. It is of great importance to strictly observe the alkali level limit of the concrete prescribed in the standards and control the alkali content in each cubic meter of concrete. The limit of alkali content for each cubic meter concrete is stipulated in many countries based on the reactivity of aggregate and the environments of engineering construction. For example, in the US, England, Japan, West Germany and other countries, it is considered safe if the alkali content is controlled under 3kg/m^3. In New Zealand the alkali content lower than 2.5kg/m^3 is considered harmless while in South Africa the alkali content higher than 2.8kg/m^3 is considered potentially harmful[1]. In China, according to the conditions of concrete structures, the Standard Of Limitation For Concrete Alkali Content CECS53:93 was issued and approved by China Association for Engineering Construction Standardization (CECS). The requirement of a maximum alkali content of 3kg/m^3 in concrete is specified.

The commercial concrete industry in Chongqing area has been experiencing a rapid development since Chongqing became the municipality under the direct jurisdiction of the central government. The premixed concrete develops at a very high speed. Because the quantity of cement in the concrete is increased to improve its strength, and admixtures such as set accelerating admixtures and water reducing admixtures are applied in large amounts, the total alkali content of concrete increases tremendously. Whether the alkali content of concrete used in Chongqing area is above the marginal value for potential alkali-aggregate reactions become an issue of great concern. The author and his colleagues, having tested the alkali reactivity of the aggregates used in this area, conducted a status survey and made an predictive analysis of the alkali content of the cements, admixtures and supplementary blending materials in order to find out the present general situation of alkali content in Chongqing area and provide a technical reference to the research of alkali-aggregate reactions.

2. INESTIGATION AND ANALSIS

2.1 Cement

The alkali in concrete mainly comes from cement. Generally, the alkali content of cement less than 0.60% Na_2O equivalent is taken as the safe limit in many countries and listed in the related standards and codes. But in the actual application in the concrete works, the alkali content of cement is higher than 0.60%. We have examined the alkali contents of more than ten cements from six cement factories in Chongqing according to the standard GB176. Table 1 shows the test results:

Table 1: The alkali contents of cements

No.	Type of cement	Alkali content (Na_2O equivalent, %)
1	P.O 32.5	0.82
2	P.S 32.5	0.73
3	P.O 42.5	0.91
4	P.O 42.5	0.67
5	P.O 42.5	0.86
6	42.5R	0.79
7	32.5R	0.57
8	P.O 42.5	0.76
9	P.O 42.5	0.69
10	P.O 42.5	0.59

Tel: 0086-023-63612979 Fax: 0086-023-63852871 E-mail: cqsjky@cta.cq.cn

2.2 Admixtures

Admixtures is also a chief source of alkali in concrete. The alkali in the admixtures is also involved in the alkali-aggregate reactions. At present, the set accelerating admixtures, water reducing admixtures and water-proof admixtures widely used in our country contain large amounts of alkali salts, e.g. Na_2SO_4 (K_2SO_4), $NaNO_3$($K NO_3$), $KAlSO_4$ etc. The alkali content in concrete carried by these admixtures is always higher than the safe limit prescribed by the national standards. We tested the total alkali contents of more than twenty kinds of admixtures from over ten factories in Chongqing according to the standard GB8077. Table 2 shows the test results:

Table 2: The total alkali content of different admixtures

No.	Admixture Type	Trade Name	Alkali content (Na_2O equivalent, %)
1	accelerating and water-reducing agent	MZS	14.33
2	water-reducing agent	CG	12.59
3	superplasticizer	FDN	10.79
4	Pumping agent	UNF	5.63
5	accelerating and water-reducing agent	GT	6.91
6	water reducing agent	HD-1	10.46
7	accelerating and water-reducing agent	GM	10.27
8	dispersing agent	NNO	6.86
9	water reducing agent	MS	7.09
10	water reducing agent	CG	10.59
11	water reducing agent	/	8.38
12	water reducing agent	FST-CG	8.98
13	superplasticizer	FDN-OR	7.13
14	superplasticizer	FDN-O	8.13
15	accelerating and water-reducing agent	/	18.57
16	accelerating and water-reducing agent	CG	17.29
17	superplasticizer	/	12.58
18	superplasticizer	NF-1	6.93
19	accelerating and water-reducing agent	FDN-E5	22.01
20	superplasticizer	/	9.97

2.3 Supplementary blending materials

Alkali from supplementary blending materials also partly participates in the alkali aggregate reaction. The slag, fly ash and silica fume are often used. At present, fly ash is used in large quantities in Chongqing. Fly ash is discharged from the power station. Because of the difference in coal source, burning status and conditions of dust collecting in each power station, the quality of fly ash varies considerably. The chemical components and alkali contents of the fly ash discharged by the main power stations in Chongqing are tested in accordance with GB176 and listed in Table 3.

Table 3: The comparison of the chemical components and alkali contents of fly ash from different power stations (%)

No.	Loss of Ignition	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3	Alkali content (Na_2O equiv alent, %)
1	3.15	42.52	21.61	24.38	3.02	2.21	1.07	1.45
2	14.83	41.22	15.14	20.19	4.17	0.92	1.58	0.91
3	6.90	42.30	14.86	29.21	2.97	0.67	0.64	1.14
4	7.78	50.35	6.22	26.73	2.79	1.15	1.71	2.48

2.4 The alkali content in concrete

Studies show that one of the most effective ways to prevent concrete from the alkali aggregate reactions is to control its alkali content. According to the actual alkali content of the raw materials i.e. cements, admixtures and supplementary blending materials used in concrete in Chongqing and the mix ratio of concrete, the range of the alkali content per cubic meter of C30, C40 and C50 concrete was calculated. The total alkali content of the most unfavorable combination is calculated according to the standard CECS53:93 to assess the status of alkali content of concrete in Chongqing area.

a.The alkali content of cement Ac is calculated based on the actual alkali content of P.O. 42.5 and P.O. 32.5 cements and the actual cement content in concrete.

$$Ac=WcKc(kg/m^3)$$

Wc——cement content(kg/m^3);

Kc——alkali content of cement (%)

b. The alkali content brought by the chemical admixture Aca is calculated based on the actual alkali content of the admixture. To simplify the calculation, it was assumed that the dosage of the chemical admixture is 1% by weight of cement.

$$Aca=WcWaKca(kg/m^3)$$

Wa——the proportion of admixture (%)
Kca——alkali content of admixture (%)

c. The alkali content of fly ash.

It has been well established that the effective alkali content, i.e. the amount of alkali available for ASR in concrete with fly ash depends on the amount of the fly ash added and that the more the fly ash, the lower the effectiveness of the alkali [2].

In this study, the percentage of the effective alkali content in the total alkali is taken as 100%, 20% and 0%, respectively for <20%, 20-24% and >25% fly ash added in the concrete. The alkali brought by fly ash Ama is given as follows:

$$Ama = \beta\ \gamma WcKma(kg/m^3)$$

β ——the percent of effective alkali content of fly ash in the total alkali content (%)
γ——the content of fly ash(%)
Kma——alkali content of fly ash (%)

d. Aggregate and mixing water

Chongqing is a inland city. The aggregates used in Chongqing would not be affected by the seawater and contain no chlorides and the seawater would not be used as mixing water. So alkali brought by the mixing water and aggregates can be ignored.

Table 4 shows the range of unit alkali content of concrete in common use:

Table 4: The range of unit alkali content of concrete in common use.

Grade of concrete strength / Testing item	C30	C40	C50
Cement content (kg/m^3)	300~340	380~420	450~490
Alkali content of cement (%)	0.57~0.91	0.57~0.91	0.57~0.91
Alkali content brought by cement (kg/m^3)	1.71~3.09	2.17~3.82	2.57~4.46
Admixture content (kg/m^3)	3.0~3.4	3.8~4.2	4.5~4.9
Alkali content of admixture (%)	5.63~22.01	5.63~22.01	5.63~22.01
Alkali content brought by admixture (kg/m^3)	0.17~0.75	0.21~0.92	0.25~1.08
Fly ash content (%)	30~26	22~18	17~13
Alkali content of fly ash (%)	0.91~2.48	0.91~2.48	0.91~2.48
The effective alkali content of fly ash (kg/m^3)	0	0.15~1.87	0.70~1.58
Unit total alkali content (kg/m^3)	1.88~3.84	2.53~6.61	3.52~7.12

2.5 Analysis of the present situation

According to the tests and the calculations above, at present, except for the low strength grade concrete, the total alkali content of part of the concrete works in Chongqing is higher than the safe limit of $3kg/m^3$. It should be brought to special attention that the alkali content increases not only due to the increase of cement proportion in concrete but also due to the alkali from the admixture, which is over $1kg/m^3$ as prescribed in the national standard (no more than $1kg/m^3$ in the Ja

panese standard). Thus, hidden trouble of alkali-aggregate reaction does exist in the concrete works if the reactive aggregate with potential alkali-silica reaction is used. Moreover, some articles show that even if the non-reactivity or weak reactivity aggregates are used the long-term durability of the concrete ought to be studied carefully when the alkali content is over $5\sim10kg/m^3$ [3].

3.CONCLUSIONS AND SUGGESTIONS

3.1 Conclusions

a. The alkali content of some concrete in Chongqing area is beyond the safe limit as stipulated in the standards, so special attention must be paid in the engineering field.

b. From the test of the alkali content of concrete the alkali-aggregate reaction could possibly occur though it has never happened in Chongqing before.

3.2 Suggestions

a. The related government departments prescribe requirement that the alkali reactivity of aggregates be tested before being used for the important and large concrete works in Chongqing.

b. Use higher grade cement in concrete and decrease the water content; replace ordinary water reducing agent with superplasticizer These measures may effectively reduce the total alkali content in concrete and prevent the alkali aggregate reaction from happening in Chongqing area.

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