

AN OCCURRENCE OF AAR IN A COOLING TOWER IN CHINA

Zhongzi Xu, Duyou Lu, Sufen Han and Mingshu Tang

Department of Materials Science and Engineering, Nanjing University
of Chemical Technology, Nanjing, Jiangsu, 210009, China.

ABSTRACT

Various characterizing and analytical methods including petrographic examination, autoclave method, chemical analysis, XRD, SEM/EDAX and DTA were employed to investigate the cause of concrete deterioration of a cooling tower at a power plant in China. Results show that the deterioration is mainly due to the occurrence of serious alkali-aggregate reaction (AAR) and corrosion in concrete.

Key words: alkali-aggregate reaction, concrete durability, cooling tower.

INTRODUCTION

Alkali-aggregate reaction (AAR) has been studied for several decades in China, the cases of deterioration caused by AAR were widely confirmed in recent five years^[1]. The cases involved industrial buildings, concrete bridges and railway sleepers. A new case of deterioration reported here is in concrete structures of a cooling tower at a power plant in Tongliao City, Northern China. The increasing discoveries of concrete structures suffering from AAR will encourage studies on AAR, and much more attention must be paid on this problem with the great development of basic constructions in China.

FIELD SURVEYS

There are four cooling towers in the power plant, which are concrete structures with dimensions of Φ 70m at bottom and 90m highness. This project dealt with two towers of them. Precast concrete members were used in No.2 cooling tower, and field concrete used in No.3 cooling tower. Concrete members of the No.2 cooling tower were completely deteriorated after servicing for one year and were replaced wholly later. The failure was attributed to the low quality of precast concrete members and freezing and thawing during servicing by initial research. As for No.3 cooling tower, asbestos boards were put up around the tower in winter to avoid freezing and thawing. After four years servicing, cracking of beams and pillars still occurred evidently. Some members have peeled off and exposed gravel aggregates. Furthermore, some beams and pillars were covered with stalactite-like deposit. DTA result indicate that the deposit is CaCO_3 , it suggested that Ca(OH)_2 in concrete have run off and carbonized. Information about cement content in concrete, alkali content in cement, w/c, etc. were not available.

Concrete samples from the beams and pillars of the towers and gravel aggregates from stone pit were picked up in order to evaluate the cause of the deterioration. But studies were emphasized on No.3 cooling tower.

EXPERIMENT AND RESULT

Reactivity of Aggregate in Concrete

The coarse aggregate, fine aggregate and cementing material in concrete samples were separated from each other. The coarse aggregates were classified by their composition. The reactivity of coarse aggregates and fine aggregate was determined by autoclave method suggested by Tang et al[2]. According to this method, the aggregate will be reactive if the value of expansion exceed 0.1%, and non reactive when lower 0.05%. When the value lies between 0.05% and 0.1%, the aggregate will be potential reactive. Results are shown in table 1.

Table 1 Expansion of autoclaved mortar bars made from aggregates in concrete (%)

No.	1	2	3	4	5
Cool tower No.2	0.087	0.080	0.174	0.072	0.038*
Cool tower No.3	0.089	0.100	0.176	0.073	0.036*
Original stone pit	0.144	0.166	0.186	0.164	0.049

*fine aggregate — sand

Results indicate that almost all coarse aggregates used in the concrete were reactive or potential reactive, while fine aggregate is non reactive. In addition, their mineral component were examined by XRD and optical microscope. Results show that the main minerals in gravel are siliceous, and a lot of pure microcrystalline quartz and chalcedony were found. A few carbonate was found in some gravel, but no rhombus fine dolomite was observed.

Examination of Polished Slabs and Petrographic Thin Sections

Polished slabs and thin sections were prepared from concrete samples from the cooling towers. Evidence of AAR was found in almost all polished slabs from No.3 cooling tower. Cracking is common in concrete slabs and frequently traverse both aggregate particles and surrounding mortar. Reaction rims, another feature of aggregate affected by alkali-silica reaction (ASR), are also evidently observed and some aggregates have been ulcerated.

Texture and composition characteristic of aggregate was examined in thin sections. Reactive siliceous components are common in samples, and microcrystalline quartz and chalcedony, which are typical for reactive siliceous components, were clearly determined as shown in fig.1.

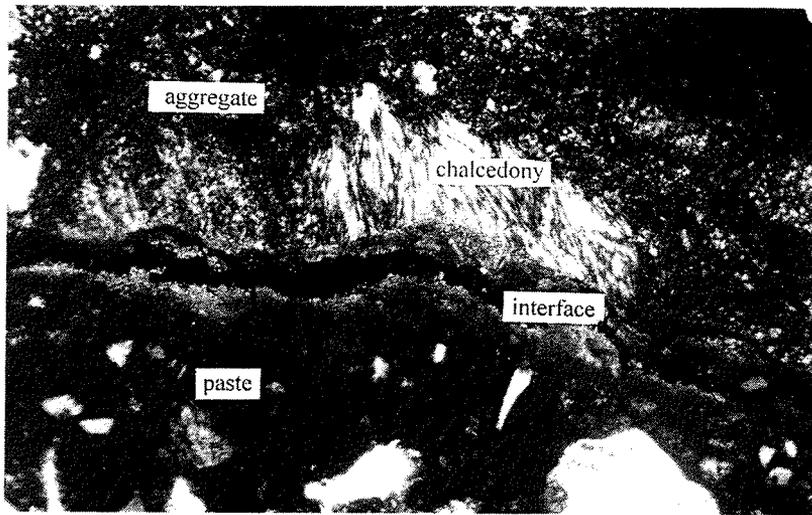


Fig.1 Reactive aggregate and its reaction rim crossed polarized light $\times 60$

Chemical Examination of the Concrete

The chemical examination of the concrete is necessary to ascertain whether there is any evidence of chemical attack[3]. The concrete samples were crushed roughly and the aggregates were sieved off as much as possible. Then the cementing material was finely ground before analysis. The results were listed in table 2.

Table 2. Chemical composition of cementing material in the concrete

concrete	percentage content in concrete separated part of aggregate	
	CaO	SiO ₂
No.2	57.62	20.49
No.3	47.32	26.62

Sample No.3 contains a high content of SiO₂. This is clear in sample No.3 has leached out, but Ca(OH)₂ in sample No.2 has not be attacked by water.

SEM and EDAX Examinations

SEM/EDAX were also used to ascertain the cause of deterioration. No ettringite was found in cementing material, therefore, the deterioration was not caused by sulfate attack. In fact, K⁺ was rich around reactive aggregate as shown in Fig.2. It indicates that alkalis in cementitious material has migrated to the aggregate surface.

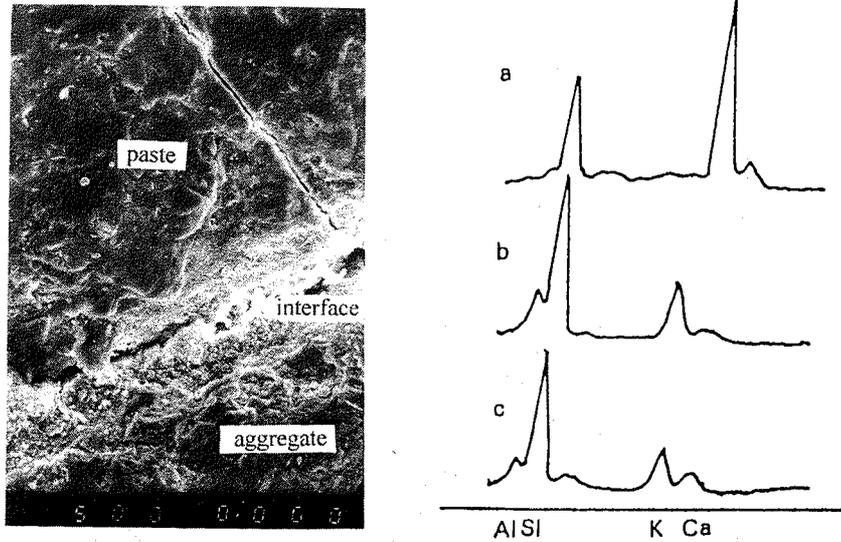


Fig.2 Morphology of interface between paste and aggregate and EDAX results
 a) cementing material, b) periphery of aggregate, c) aggregate

Differential Thermal Analysis (DTA)

Cementing materials obtained in 3.3 were also analyzed by DTA, as shown in Fig.3. It is noted that no clear endothermic effect existed at 420 °C which reflected the presence of $Mg(OH)_2$. Only $CaCO_3$ and water were detected. Besides, no $Ca(OH)_2$ was detected in samples due to long-term carbonization and/or corrosion. DTA results indicate that the deterioration was not caused by late expansion of MgO in cement.

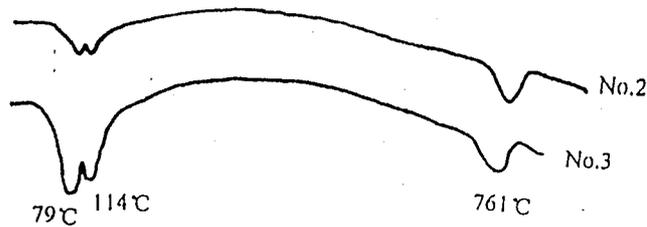


Fig.3 DTA curves of cementing material in concrete samples

In addition, ground water in this area and circulating water in cooling towers were also analyzed. Results showed that the contents of SO_4^{2-} , Cl^- , Mg^{2+} and CO_2 in water have no fatal effect on concrete according to correlative specifications.

DISCUSSION AND CONCLUSION

Discussion

The deterioration of concrete, apart from structural failures, may be due to a great variety of causes. It is very difficult to determine the responsible factor or factors. In general, freezing and thawing, physical and chemical properties of aggregate, effect of circumstance agents and alkali aggregate reaction are often responsible for the durability of concrete apart from defective cement, defective design and errors in preparation, placing and curing. According to the present examination and experiment results, freezing and thawing and circumstance agents are not responsible factors for the deterioration. On the other hand, serious corrosion occurred in concrete members of No.3 cooling tower. However, AAR in concrete can cause inner cracking and accelerate corrosion. Above results indicate that most aggregates used in the concrete were reactive or potential reactive and serious alkali aggregate reaction occurred in the concrete members of No.3 cooling tower. Therefore, the deterioration of No.3 cooling tower resulted from the occurrence of AAR in the first place, which caused cracks in the concrete and accelerated corrosion.

Conclusion

- 1 The aggregates used in the cooling tower contain reactive components, microcrystalline quartz and chalcedony.
- 2 The deterioration of No.3 cooling tower was caused by AAR and corrosion, but AAR is the responsible factor.

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