Pergamon

Cement and Concrete Research, Vol. 27, No. 3, pp. 329-336, 1997

0008-8846/97 $17.00 + .00

PII S0008-8846(97)00012-4

A CASE STUDY OF TWO AIRPORT RUNWAYS AFFECTED BY ALKALI-CARBONATE REACTION PART TWO: MICROSTRUCTURAL INVESTIGATIONS

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(Communicated by Z. Wu)
(Received May 7, 1996, in final form January 17, 1997)

ABSTRACT

Through detailed petrographic examination of the aggregates in damaged concrete structures affected by alkali-carbonate reaction (ACR), it was found that the presence of brucite in the reacted aggregate particles is not a critical determination of the presence of ACR. The occurrence of the reaction product layers between dolomite crystals and surrounding matrix in reactive aggregates is understood as an important indicator to evaluate the presence of ACR. It is suggested that detailed microstructural study should be performed in diagnosis. © *1997 Elsevier Science Ltd*

Introduction

In the late 80's, several concrete structures affected by alkali-carbonate reaction (ACR) were recognized in China. In previous study (1), we evaluated the reason of two airports runway concrete as alkali-carbonate reaction through detailed petrographic examination and evaluation of alkali reactivity of carbonate aggregate used. However, careful microstructural investigation of the deleterious reaction is very limited (2-5) in literature, and little work on affected field concrete have been reported. In fact, ACR is very hard to detect and monitor especially in affected field concrete. This leads to many arguments on ACR diagnosis and its expansion mechanism due to lack of knowledge. This paper tries to present some observations on microstructural changes in affected field concrete, which may improve our interpretation on the characteristics and mechanism of the reaction and expansion.

Experimental Method

Concrete cores of deferent damage degrees were collected from the two airport concrete runways which were described in part one of this study. Based on the detailed petrographic examinations, the interested parts were separated carefully for further microstructural investigation. The interfacial reaction occurred at the interface between reactive aggregate and cement, and dolomite crystals and surrounding matrix were the main interesting sites. After being carefully separated from the surrounding cement paste, the interested aggregate particles were broken apart to show the cracked surface and to expose some new fracture faces and then covered by gold for scanning electronic microscope (SEM-EDXA) observation. The remaining part of the aggregate was powdered and examined by X-ray diffraction (XRD), differential thermal analysis (DTA) and infrared spectroscopy (IR) techniques. In order to sensitively detect the very small amount of brucite produced by dedolomitization, step-scan mode with fix time 2 seconds was chosen in XRD study.

Results And Discussions

JN Airport Concrete. In previous investigation (1), it was concluded that dolomitic limestone JN-2 and JN-3 are alkali reactive because cracks generated from the aggregate particles can be observed in the collected concrete cores and the autoclave test showed considerable expansion. FIG. 1* illustrates the SEM image of a cracked JN-2 aggregate particle. A crack crossed through the aggregate and the surrounding cement paste. The texture of this aggregate particle shows in FIG. 2. It was composed of large amount of fine-grained dolomite rhombs surrounded by even finer calcite matrix. Very little amount of clays contained in the aggregate. Cracks were also observed surrounding or within JN-2 aggregate particles as shown in FIG. 3. No such inside cracks were found in the unused JN-2 aggregate. Thus it is understood that cracks inside the aggregate pieces were caused by unbalanced inside expansion due to ACR.

The morphology of a newly exposed surface of the aggregate particle showed in FIG. 1 is shown in FIG. 4. It was found that a layer of products had been produced between the interface of dolomite rhombs and surrounding calcite grains. The EDXA results (point 1~3) showed that the composition of the products may change from point to point. But, for all tested points, the product contained considerable amount of magnesite with small amount of silica. It seemed that the product layer may be a mixture of brucite ($Mg(OH)_2$) and calcite as well as some silica which may be absorbed by the products as Hadley suggested (6). According to the TEM investigations of laboratory cured specimens by Lu (5) and Tong (7), it was found that brucite and calcite produced by dedolomitization were unevenly distributed as individual clusters in the layer. This may lead to the unfixed composition of EDXA results. Because of the influence by dolomite under the product layer, no spots containing only Mg were found by EDXA. However, brucite has been detected in this aggregate particle by XRD as shown in FIG. 5. The reflections at d = 4.767Å and 2.365Å represented the presence of brucite. No brucite was found in the original aggregate. DTA result also got the same conclusion as shown in FIG. 6. The heat-absorbing peak at 380°C is due to the decomposition of brucite while peaks at 740°C and 885°C are the result of Mg^{2+}-CO_3^{2-} and Ca^{2+}-CO_3^{2-} bonds' collapse. These facts mean that dedolomitization occurred inside the reactive particle. By comparison, the broken surface of the unused aggregate JN-2 showed no deposits at the interface of the dolomite rhombs and calcite matrix as shown in FIG. 7. No

*If not specified, all photos showed in this document are SEM secondary electron images.

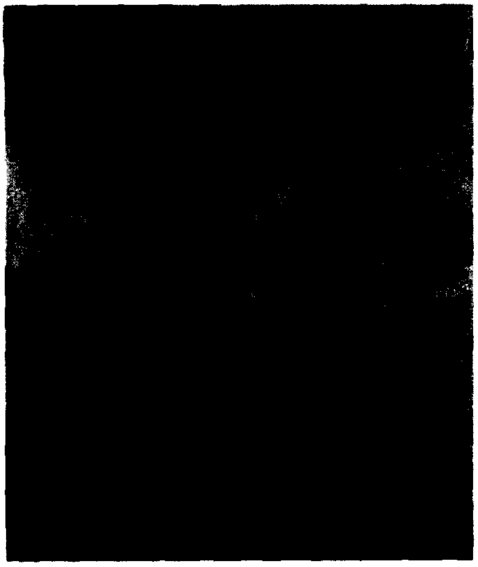

FIG. 1.
A crack crossed through a JN-2 aggregate particle to cement paste in JN airport concrete.

FIG. 2.
Enlargement of the marked part in FIG. 1 showing the petrographic texture of JN-2 aggregate.

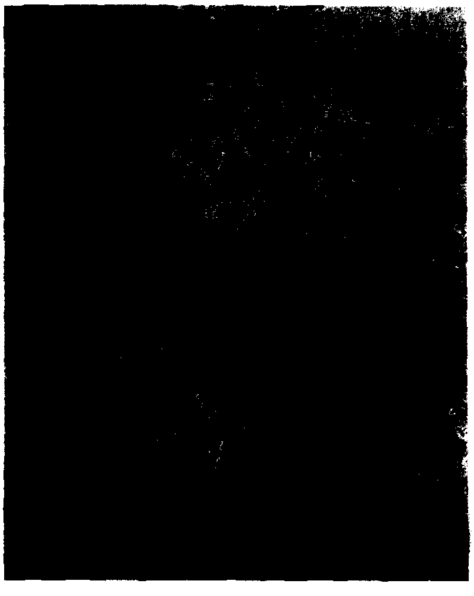

FIG. 3.
Cracks inside a JN-2 aggregate and between the aggregate and cement in JN airport concrete.

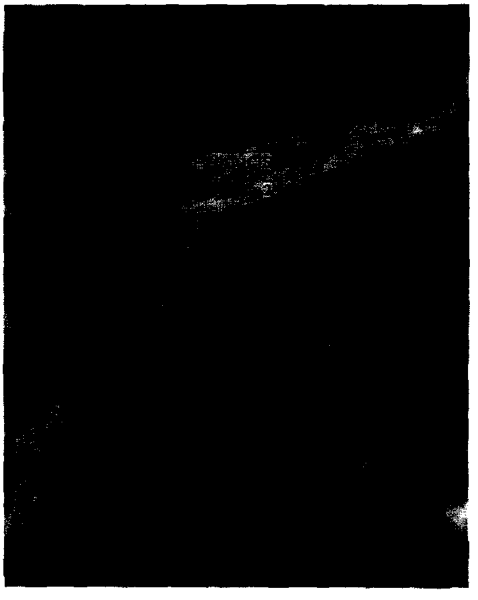

FIG. 4.
Newly broken surface of the aggregate particle in FIG. 1 showing reaction products deposited on the surface of the dolomite rhombs.

noticeable silica component was detected at the margin of dolomite crystals by EDXA study (point 5). The EDXA results of the present study are listed in TABLE 1.

Inside the crack as showed in FIG. 1, two kinds of particles with different morphology and composition can be distinguished as shown in FIG. 8. The particle composed of Ca, which detected by EDXA, was calcite while the needle-like one containing large amounts of silica may be a product produced by the reaction between CaO and SiO_2. Because the penetrated depth of electrons is about 2μm in the operation condition (20KeV), the composition analyzed by EDXA is not conclusive. Secondary calcite may be produced due to dedolomitization. The morphology of the interface between aggregates and cement was quite similar to case showed in FIG. 8. Because there is little difference of the reaction and morphology between reactive and non-reactive aggregates, it is believed that reactions in the cracks and in the interface of aggregates and cement do not play significant roles in the expansion.

WF Airport Runway. In previous study, it was found that dolomitic limestone WB-2 used in WF airport concrete was highly reactive. It was also observed by SEM investigation that similar products formed at the interface of dolomite rhombs and surrounding matrix. WB-2 aggregate is characterized by its partial reactive texture. Rhombic dolomite crystals embedded in the matrix of fine-grained calcite and clays. The broken surface of the original WB-2 aggregate is shown in FIG. 9 and the aggregate used in the runway concrete is shown in Figure 10. Although clear evidence in FIG. 10 suggests the presence of reaction products, brucite was not detected by DTA as shown in FIG. 11 and XRD examinations in the same

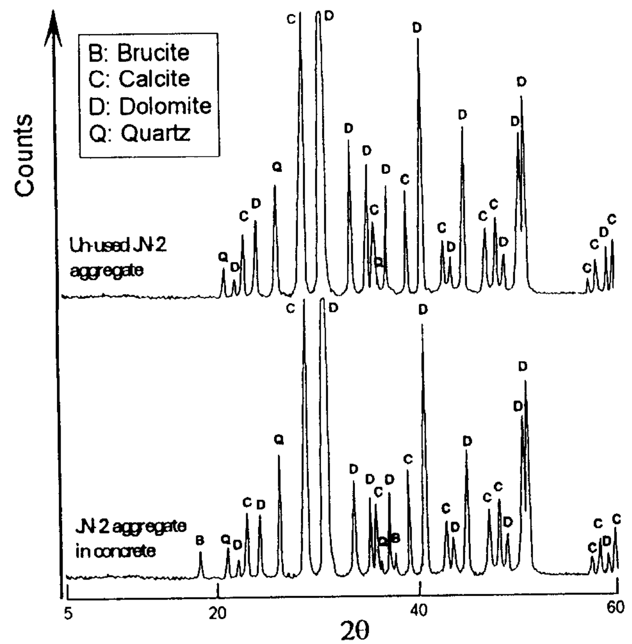

FIG. 5.
XRD pattern of JN-2 aggregate before and after used in concrete (the cracked particle in FIG. 1) shows the formation of brucite due to dedolomitization.

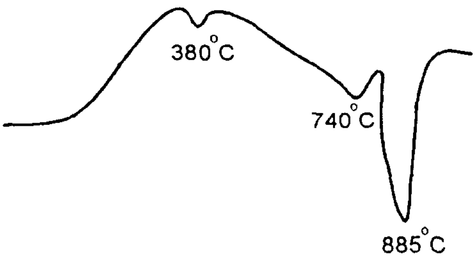

FIG. 6.
DTA curve of the cracked JN-2 aggregate particle showed in FIG. 1 in the airport (JN) concrete.

aggregate particle. This may be because the amount of brucite is too small or may result from the possible reaction between brucite and silica dissolved in the alkali pore solution in the aggregate. Thus, it seems that the presence of brucite is not always a critical evidence to evaluate the occurrence of dedolomitization.

Mechanism of the Deleterious Expansion. Based on the previous investigation, it is suggested that deleterious alkali-carbonate reaction (dedolomitization) had occurred in the two

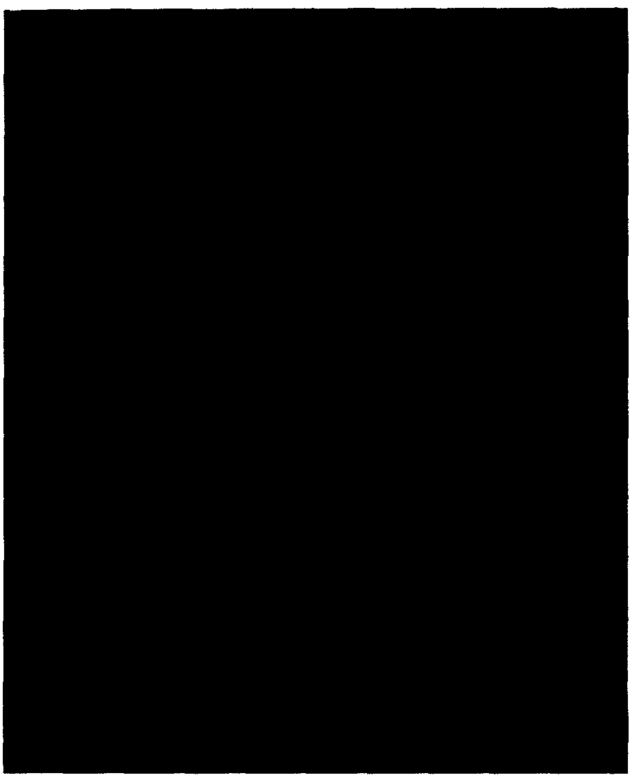

FIG. 7.
Broken surface of the original JN-2 aggregate showing close compactness of dolomite and calcite grains.

TABLE 1

EDXA Results of the Marked Points Showed in the Figures

Marked Points	The percentage of the atomic numbers at the marked points					
	Mg	Si	Al	K	Ca	O**
1	12.12	6.69	0.77	2.14	25.38	52.90
2	4.87	2.72	---	---	41.06	51.36
3	7.83	3.12	---	---	37.44	51.61
4	11.84	0.98	---	---	36.69	50.49
5	10.03	0.82	---	---	37.85	51.30
6	0.75	---	---	---	48.12	51.13
7	---	12.31	0.35	4.86	29.31	53.17
8	0.63	0.54	---	---	46.53	52.30
9	8.21	5.62	---	2.06	31.51	52.60
10	15.34	0.36	---	---	34.12	50.18

** It actually includes O, C and H in this case. In calculation it only considered the listed elements.

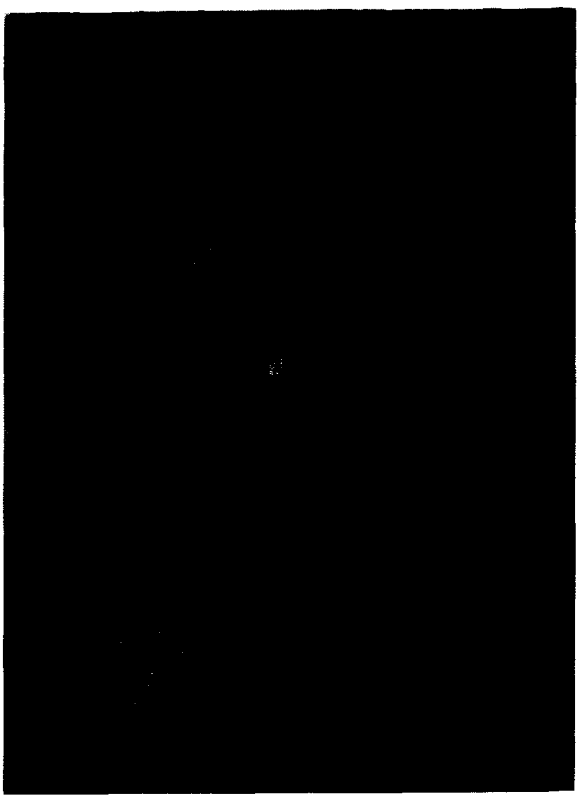

FIG. 8.
Morphology in the crack showed in FIG. 1.

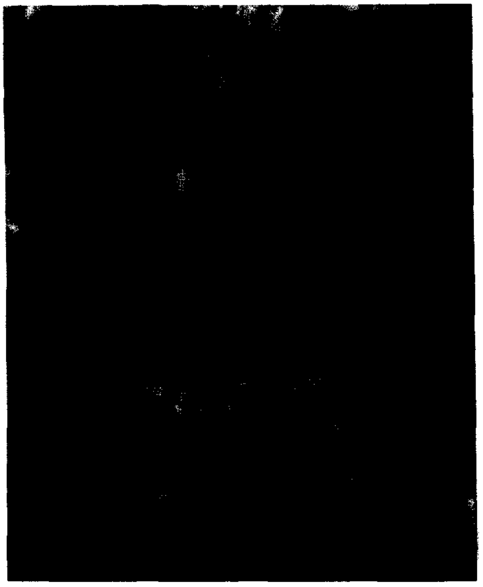

FIG. 9.
Broken surface of the unused WB-2 aggregate showing no deposits on the surface of dolomite rhombs.

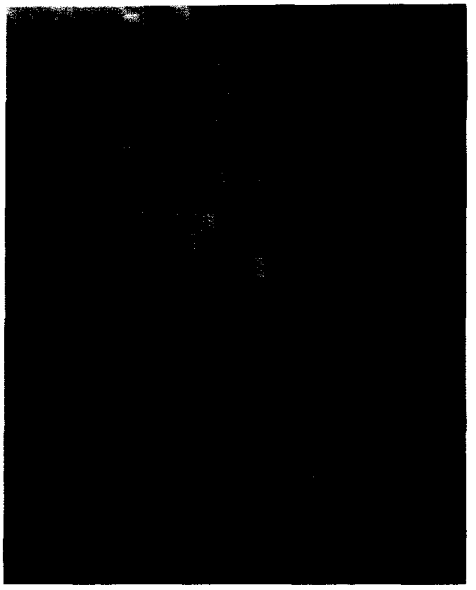

FIG. 10.
Broken surface of WB-2 aggregate used in the airport concrete. A layer of products laid between the interface of dolomite and surrounding matrix.

airport concrete. The cracks in concrete were mainly due to the formation and growth of the reaction products deposited at the interface of dolomite crystals and surrounding matrix. Although small amount of microcrystalline quartz contained in the reactive aggregates is in non-reactive form (7), its dissolving in alkaline solution may lead to enrichment of silica in the production layers. If enough amount of silica available in the layer, brucite produced by dedolomitization may be consumed up by the reaction with silica. Therefore it is reasonable to observe the production layer with the absence of brucite. The case was also observed for other reactive carbonate rocks. Detailed discussion on this chemical reaction will be reported in another document.

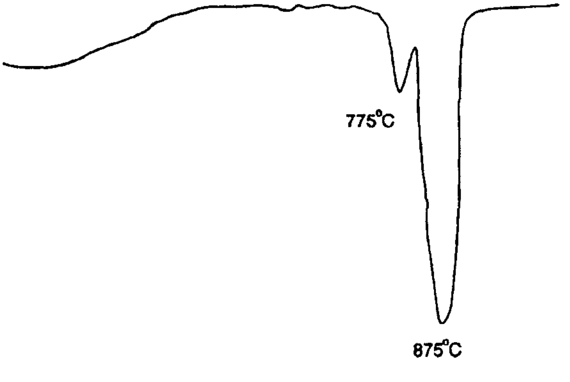

FIG. 11.
DTA curve of WB-2 aggregate used in WF airport concrete.

If aggregates have poor resistance to frost attack, the aggregate may be cracked similar to the case found in the two airports. Therefore, the presence of reaction products at the edge of dolomite crystals can be used as a significant sign of the occurrence of reaction and can be applied to distinguish the deleterious ACR from other processes in diagnosis. Thus, the authors suggest that it is important to perform detailed microstructural investigations in diagnosis ACR affected concrete.

Conclusions

Through the inspection of field concrete and detailed petrographic examinations of the concrete cores, it is concluded that the main reason of the damages in airport concrete is the deleterious ACR.

The procedures of diagnosing a field concrete whether it is affected by deleterious ACR or not should involve detailed petrographic examination of the concrete by proper sampling. The products layer deposited between the interface of dolomite rhombs and the surrounding matrix in reactive aggregates is understood as a significant criteria to monitor the occurrence of alkali-carbonate reaction. The presence of brucite is not always detectable when dedolomitization occurs.

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