VISUALIZATION OF ALKALI-REACTION PRODUCTSBY FLUORESCENCE. DEVELOPMENT OF THE METHOD FOR THE SURVEY OF STRUCTURES;

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The accumulated results concerning this method of vizualisation by fluorescence of the alkali reaction products shows the selectivity of the uranyl ions in the products in evidence: (gel = fluorescence; crystallized products= absence of fluorescence). On the other hand, this method allows observations over a large period of time without any destruction of the sample. Its plainness as well as the low costs involved allows its use directly on the field;

INTRODUCTION

Taking into account the importance of the research on alkali-reaction effects, it is necessary to have at one's disposal a reliable and rapid method of diagnosis. To satisfy this need we are reproducing here an American method of diagnosis (1).

Alkali-reaction products which are the most harmful for structures appear as a colloïdal heterogeneous solution having the texture of a gel allowing a certain number of exchanges of cations with the internal system as well as with the external system.

This testing (2), (3), (4), (5), (6), is based on the property of exchange between some cations and the silico-calco-alkali-gel, consequence of the reaction in damaged concrete.

PRINCIPLE OF THE METHOD

Considering pathologic products having more or less significant implications in the phenomenon, a valuation of the amorphous phase could allow a better diagnosis regarding the manifestation of the reaction and of its progress.

The chemical reaction responsible for the expansion producing disorder in the concrete leads to an heterogeneous solid solution which, according to the type of reactive aggregate, as well as to the progress of the reaction will not have the same localization:

- it will be located at the interface of aggregate and binder, in the case of a material with coarse-grained texture such as quartzites,
- it will fill aggregate microfissures in the case of a material with a very thin texture such as some siliceous limestones or some opalin cherts.

Alkali-reaction products usually appear with the characteristics of a colloïdal silicate solution including in variable proportions some amorphous silica negatively charged as well as ions Ca^{2+}, Na^{+}, K^{+} absorbed. This gel enables exchanges of cations, a wide range of them being able to replace those initially fixed, with the following affinities:

$$Zr^{4+} > Pu^{4+} > [UO2]^{2+} > Gd^{3+} >> Cu^{2+} > Ca^{2+} \approx Na^{2+} \approx K^{+}$$

In other words, we can say that the zirconium is more strongly adsorbed than the plutonium, the plutonium being more easily adsorbed than the uranyl, and so on :

The uranyl ion $[UO2]^{2+}$ has been chosen for three reasons:
- it can be exchanged in priority with the calcium, sodium, and potassium ions,
- its complete sorption is carried out in less than five minutes,
- it is fluorescent, with a yellow-green shade when it goes through an appropriate ultra-violet excitation, thus becoming more easily identifiable.

Characteristics of the fluorescence depend directly on the intensity of the radiation effect as well as on the number of uranyl ions corresponding to this luminous excitation.

The exchange properties of the silica surfaces are directly connected to the Ph of the solution (1); consequently this uranyl ion is complexed under uranyl acetate put in solution in diluted acetic acid.

EXAMPLES OF APPLICATIONS

Two examples have been selected to demonstrate the possibilities of the method:

Setting up of reaction kinetics applied to a precise case:

- case of a field concrete manufactured with a black limestone which often includes a high content of diffused silica (Photo 1). In a core sample, an aggregate particularly strongly fissured by the alkali-reaction gel has been selected and pictured at well defined dates and under temperature and relative humidity conditions, which are not very sensitive to variations.

During the three weeks time between two terms, a slight evolution in the progression of the gel inside the controlled aggregate has been noticed Photos 2 and 3, (progression zones marked out with circles).

Position of the microfissuration

A polished sample filled in with gel, treated with uranyl acetate and then illuminated, presents a fissured network, when filled in with gel. This information enables an estimate of the importance of the fissuration and to quantify its length and its opening. When the fissuration is located, it is then possible to materialize the main directions of the fissures network (Photo 4). An example of processing (fig.1) is given on Photo 4. Following a graphic processing, we obtain a rosette of the fissuration network, giving an idea of the density of the fissuration, according to the directions in the space. For the precise case concerned we can see two main directions which follow angles of 60° and 115 to 135°. We can easily see that the direction 0° is the least represented.

EXTENSION OF THE METHOD ON WORKING SITES

One of the advantages of the method is the small weight of the equipment needed for testing, thus enabling to perform more easily on the spots, even in difficult field conditions. A testing has been tried out on a work showing all the signs of exterior reaction, an particularly an intense network fissuration at different scales.

On a previous core and after a slight hammer cleaning, we have been able to get a picture at six or seven centimetres of depth and on a section of about fifteen centimetres of diameter.

It still remains the problem of the observation without coring, as we have to deal with the cement slurry of the concrete coating which forms a kind of skin preventing the penetration of the impregnated solution and its action on the more internal gel. Nevertheless, it remains possible with a coring not too deep to obtain pictures to be compared in the future and consequently permit a close watch over the structure.

CONCLUSIONS

The advantages of this method of visualization of alkali-reaction products by fluorescence of the uranyl ions are the following:

- selectiveness of the visualized products:
  amorphous : gel=fluorescence
  crystallizations : absence of fluorescence;
- relatively low cost, as it is limited to the purchase of a deep-UV lamp (protecting eyes systems are compulsory, owing to the harmfulness of the radiations), and to a rather commonly used chemical product : uranyl acetate;
- the small weight of the equipment enabling an autonomy favouring the transportation and the diagnosis on the working sites ;
- response time corresponding to the time necessary for developing the film;
- possibility that the photographs be processed by frame analysis, and maybe in the future by direct shooting with a camescope and instantaneous data processing after scanning;
- possibility to obtain a follow-up of the structure as often as needed as well as on the various spots of the damaged structure (the only limitation being the impossibility of access to certain spots);
- it should always be kept in mind that the diagnosis can only be limited by the presence of amorphous products, the wavelength of the lamp, and the surface of the illuminated concrete.

Considering the present rend towards the new rapid testings on concrete, this method could be welcome. However, it will probably be useful to undertake further investigations in increasing the petrographic natures of the aggregate.

REFERENCES

(1)- K.NATESAIYER et K.C.HOVER (1988): In situ identification of ASR products in concrete. 18
CEMENT AND CONCRETE RESEARCH, vol.8, pp.455-463.

(2)- K.NATESAIYER et K.C.HOVER (1989): Some field studies of the new in situ method for identification of alkali-silica reaction products.
8th INTERNATIONAL CONFERENCE ON ALKALI AGGREGATE REACTION, KYOTO.

(3)- K.NATESAIYER et K.C.HOVER (1989): Further study of an in situ identification method for alkali-silica reaction products in concrete.
CEMENT AND CONCRETE RESEARCH, vol. 19, pp.770-778.

(4)- K.NATESAIYER et K.C.HOVER (1990): Field studies of the in situ technique for identification of alkali-silica reaction products in concrete.
ABREVIATED TEXT OF PRESENTATION MADE AT 2nd INTERNATIONAL WORKSHOP ON AAR, HALIFAX, MAY 1990.

(5)- J-S GUEDON et F. MARTINEAU (1991): Mise en évidence d'un gel d'alcali-réaction par fluorescence dans un béton âgé d'un an.
BULL. DE LIAISON DES L.P.C., N°175, pp. 100-102.

(6)- J-S GUEDON, F.MARTINEAU, A.LE ROUX (1992): Visualisation des produits de l'alcali-réaction par fluorescence. Extension de la méthode au diagnostic sur ouvrage.
TO BE PUBLISHED AT BULL. DE LIAISON DES L.P.C.

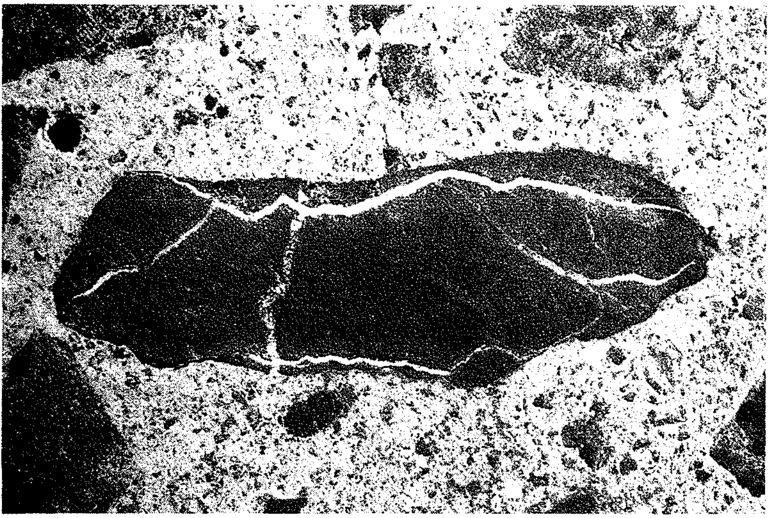

Photo 1 - Béton éclairé en lumière naturelle (x6) à t = 0.

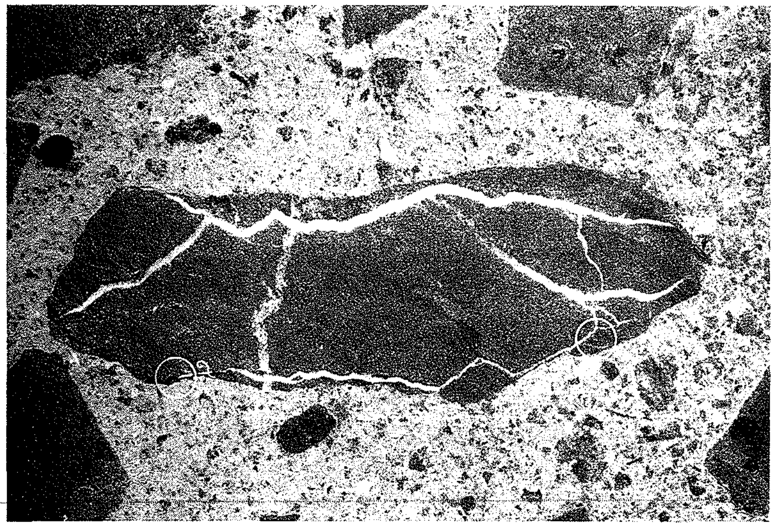

Photo 2 - Béton éclairé en lumière ultraviolette à t = 0.

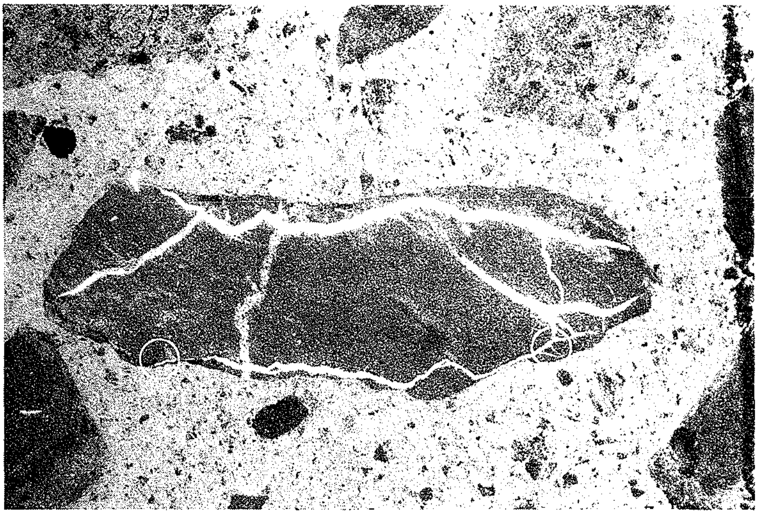

Photo 3 - Béton éclairé en lumière ultraviolette à t = 1 mois.

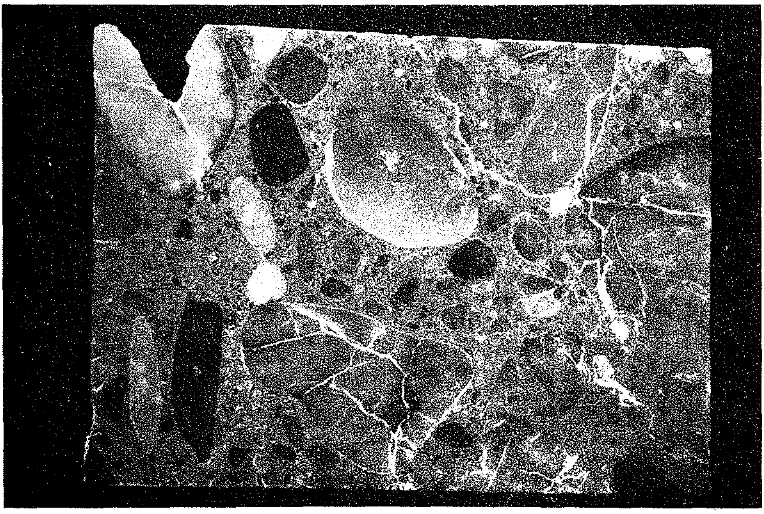

Photo 4 - Autre béton en lumière ultraviolette-Réseau de fissurées.

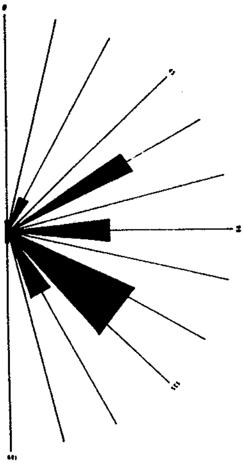

Figure 1 - Orientation des fissures se rapportant à la photo 4.