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THE PRINCIPLES OF A.A.R. PREVENTIVE MEASURES ADOPTED BY THE FRENCH MINISTRY OF EQUIPMENT

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The Central Laboratory for Bridges and Roads of the French Ministry of Equipment has just published in 1991 the "Provisional Recommendations for the prevention of damage by the alkali aggregate reaction". This document is the production of a technical committee, the members of which belong to the representative organizations of the French Civil Engineering
At first, the paper presents the context in which these recommendations have been written . Then the paper details the preventive approach which consist in two stages:
At the first stage,it is recommended to fix the level of prevention to be attained among 3 possible levels, the choice depending both on the category of the structure and its exposure class.
At the second stage,the recommendations direct towards possible solution (s). Thereafter the paper presents the five possible ways offered in the general case. To minimize the risk, it is enough that one of the five conditions detailed in the text be verified.

HISTORICAL CONTEXT

While the first signs of phenomena caused by the alkali-aggregate reaction in concretes were conclusively identified in a few dams in France at the end of the 1970s, it was not until 1987 that a number of bridges were also found to be suffering from this "disease", primarily in the North.

The survey in progress of bridges affected by the alkali-aggregate reaction has already shown that the regions most affected are the North of France and Brittany.

Structures affected by the alkali-aggregate reaction pose difficult problems of management, since there is currently no proven way to repair the diseased structures and definitively stop the evolution of the damage. It would therefore seem essential to adopt a preventive approach to ensure the durability of structures with respect to the internal physico-chemical reactions of the material.

The first recommendations were published in France in 1985. They concerned both the alkali-aggregate reaction and sulphate reactions (1). They were issued by the Fédération Nationale des Entreprises de Travaux Publics in response to a number of alkali-aggregate reaction problems encountered by French contractors at sites abroad. These recommendations were updated five years later (2).

In 1989, the French Ministry of Public Works, faced with a significant number of structures affected by the alkali-aggregate reaction, decided to take preventive measures in the building of structures for which it is responsible. The Laboratoire Central des Ponts et Chaussées (L.C.P.C.) was put in charge of a Technical Committee bringing together representatives of the various organizations involved in the building process (suppliers of materials, contractors, operators and project supervisors, laboratories, engineering companies) to draft a document that would be applied as soon as possible. This document was published in January 1991 under the title "Recommandations provisoires pour la prévention des désordres dus à l'alcali-réaction" ("Provisional recommendations for the prevention of damage due to the alkali-aggregate reaction") (3).

The temporary character clearly stated in the title alludes to the constant evolution of knowledge of the mechanisms of reaction, the development of new tests to characterize the potential reactivity of aggregates, and the evolution of the tests intended to detect alkalis likely to be released by aggregates. Finally, it means that these recommendations will be updated periodically

Some provisions appearing in this document are not unanimously supported by the members of the Technical Committee; this applies to the maximum alkali content fixed for concretes, which the contractors' representatives regard as too high.

OBJECTIVE OF THE RECOMMENDATIONS

The purpose of the recommendations is to reduce the risks of damage by the alkali-aggregate reaction, without attempting to eliminate them altogether, given the complexity of the reaction phenomena involved and the large number of parameters that affect the degradation process. This reduction of risks is considered not only in its technical context, with allowance in particular for the small percentage of all structures currently affected (estimated to be 0.1 % in the case of bridges), but also in its economic context. This is because excessively draconian risk prevention measures would cost the community more than would management of the few diseased structures they might eliminate.

These recommendations were according drafted in the light of the technical and economic realities in both of the most affected regions, the North and Brittany; it is especially difficult to obtain cements having a low alkali content in the former, and most aggregates are potentially reactive in the latter.

Another objective of the recommendations is to promote better management of natural resources, in particular aggregates. Until now, a large share of the aggregates used in making concretes have come from ballast-pits (which may explain in part the absence of the alkali-aggregate reaction in older structures).

The depletion of alluvial resources and measures to protect the environment have led to the opening of many quarries in massive rocks, which require a change in the preparation process and involve different management of the deposits. And so, quite apart from qualification of aggregates with respect to non-reactivity or potential reactivity, aggregates should be "sorted" so that the best are used only for the production of concretes and not "wasted" in less noble activities.

Finally, these recommendations aim at having the participants in the act of building assume more responsibility, and continue the quality approach recently adopted in the field of construction of civil engineering works.

The preventive approach adopted in these recommendations is in two steps :

-- In a first step, it is necessary to determine which of 3 possible levels of prevention is to be reached : A, B, or C.

-- In a second step, the possible solution(s) for the level of prevention selected are identified.

CHOICE OF LEVEL OF PREVENTION

The choice of level of prevention is based on both the category of the structure and its exposure class.

Characterization of structure

The operating authority decides to classify the structure to be built in one of the 3 categories proposed by the recommendations. These 3 categories are defined according to the level of risk with respect to the alkali aggregate reaction regarded as acceptable, which is a function of various factors, such as the intended purpose of the structure, its type, its strategic importance, the level of subsequent maintenance it will receive, the safety of users, etc.

Table 1 summarizes the principles of this classification.

TABLE 1 - Classification of structures in 3 categories.

Category	Risk of occurrence of damage	Examples of structures
I	Low or acceptable.	Non load-bearing elements located inside buildings (temporary structures).
II	Barely acceptable.	Most civil engineering structures.
III	Unacceptable	Exceptional bridges and tunnels (buildings and reactors of nuclear power plants).

Characterization of environment

Since the climatic environment in which the structure is located has a major role in the onset and spread of damage caused by the alkali-aggregate reaction, four classes have been chosen, taking account of the role of water, which is a decisive factor in the reaction, together with the criteria of mean ambient humidity and external alkali sources. Table 2 presents the 4 classes used; their names owe much to standard ENV 206.

TABLE 2 - Classes of exposure of structures to the environment.

Class	Type of environment
1	Dry or only slightly damp (RH <80%)
2	Wet or in contact with water
3	Wet with frost and de-icing salts
4	Maritime

Determination of level of prevention

To a structure belonging to a given category, located in a given environment class, there corresponds a necessary level of prevention that involves a type of precaution to be taken (tables 3 and 4). Following long discussions, 3 levels of prevention were selected: A, B, and C.

TABLE 3- Type of precaution for each level of prevention

Level of prevention	Type of precaution
A	No special precaution
B	5 possible solutions.
C	Use of non-reactive aggregates.

TABLE 4 - Determination of the level of prevention

Environment classes / Category of structure	1	2	3	4
I	A	A	A	A
II	A	B	B	B
III	C	C	C	C

It should be noted that for structures located on the seashore in France, it was not judged useful to reinforce the precautions taken, while for structures exposed to de-icing salts, the recommendations refer to regional studies and recommend the use of non-reactive aggregates insofar as it appears difficult to reconcile the requirements of resistance to de-icing salts with the requirements of durability with respect to the alkali-aggregate reaction.

PRECAUTIONS FOR LEVEL OF PREVENTION B

Level of prevention B includes most civil engineering structures. It is also the level at which the precautions that may be taken against later damage are the most varied. The possible approaches are grouped in Figure 1.

Each of the options refers in the document to an appendix that describes the procedures leading to acceptance or rejection. It should be noted that a positive response to one of the questions leads to acceptance of the formula.

Finally, while all the options are theoretically equivalent, there are some that are not yet operational, such as the performance criterion, or that are difficult to use in the absence of documentation on accessible structures, such as references of use.

The criterion of reactivity of aggregates is obtained from a petrographic study, from standardized swelling tests, or from a combination of the two. The recommendations document proposes a methodological diagram that qualifies aggregates (sands and gravels) with respect to the risk of the alkali-aggregate reaction.The figure 2 is a flow chart which gives the methodology for the characterization of aggregates

The assessment of alkalis, in which what is challenged is not the principle but rather the level selected for the threshold, proposes taking into account all active alkalis or alkalis that might be released likely to act in the concrete, either at an early age or in the longer term. Researches still in progress show that the release of alkalis derived from the aggregates can under some conditions reach a level close to 1% of the total alkalis of the aggregates. But most often the measured values do not exceed 0.1 to 0.5%, leaving a comfortable margin for alkalis of other origins. Finally, in its spirit, the document gives a

bonus to the regularity of output of cement plants by proposing the use of an average level determined by the formula :

$$Tm < \frac{3,5}{1+2Vc}$$

where Tm is the average alkali content of the concrete (in kg/m3), and Vc is the coefficient of variation of the alkali content of the cements, in other words the ratio of the standard deviation to the mean of the alkali content values obtained in the last twelve months of production.

When the cements are not OPC, the alkali content to be taken into account is diminished by a coefficient that differs according to the type of addition (slag, fly ash, or pozzolan).

Proper use of the provisional recommendations document should substantially reduce the occurrence of damage caused by the alkali-aggregate reaction. Among the solutions proposed in the short term, only the first two can reasonably be applied. The solution that concerns additions (silica fumes or fly ash in particular) is not backed by sufficient experience. For reasons related as much to proper management of resources as to limiting the risk, the authorities are leaning towards a qualification of aggregates; this appears to be the most reliable approach, because there are examples of damage that has occurred with alkali contents of no more than 2 kg/m3.

In the near future (2nd half of 1992), the document will be completed:

1 - By a guide for the preparation of quarry documentation, which will state the procedure used to qualify an aggregate as non-reactive or of low potential reactivity, with all possible guarantees.

2 - By a Particular Specification (CCTP), for use by the operating authority, that can be incorporated in calls for tender.

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Figure 1 Methological diagram for level of prevention B

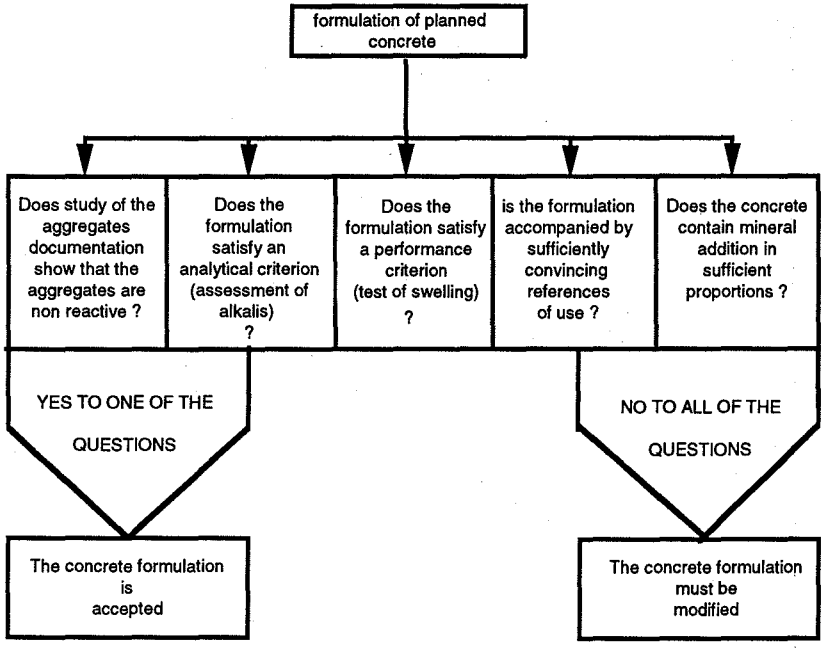
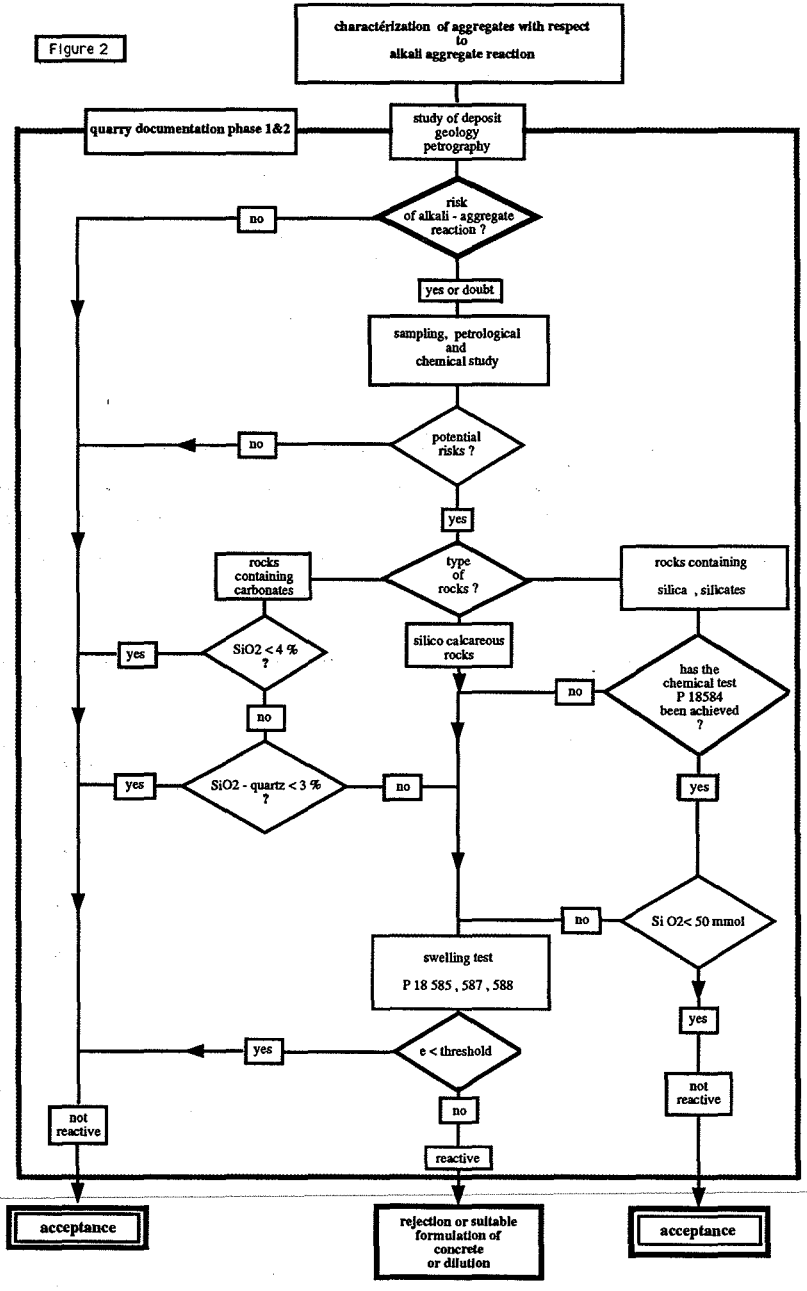


Figure 2


characterization of aggregates with respect to alkali aggregate reaction
quarry documentation phase 1&2
study of deposit geology petrography
risk of alkali - aggregate reaction ?
no
yes or doubt
sampling, petrological and chemical study
potential risks ?
no
yes
rocks containing carbonates
type of rocks ?
rocks containing silica , silicates
yes
SiO2 < 4 % ?
silico calcareous rocks
has the chemical test P 18584 been achieved ?
no
no
yes
SiO2 - quartz < 3 % ?
yes
no
yes
no
Si O2< 50 mmol
swelling test P 18 585 , 587 , 588
yes
yes
e < threshold
not reactive
no
reactive
not reactive
acceptance
rejection or suitable formulation of concrete or dilution
acceptance