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# MODELING THE EXPANSION OF MORTAR ACCORDING TO THE DIAMETER OF REACTIVE PARTICLES

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*ABSTRACT- The modeling of the alkali reaction is divided into three main parts. Models are found that study the transport of chemicals and water at the aggregate or structural level to predict the amount of gel produced at reactive sites. These models directly use the understanding of reaction mechanisms, making many simplifying assumptions. Mechanical scale models of the structure that take into account a wide variety of phenomena such as transport of chemical species, shrinkage, creep of concrete and its damage on a macroscopic scale. Mechanical models on a microscopic scale try to determine the mechanical consequences of the appearance of a swelling gel in the porosity around the reactive sites. These models have the double objective of helping the direct study of affected works, and of advancing the understanding of the alkali-reaction. For this reason we have developed, in this present work, a model to predict the expansion potential of concrete containing alkali-reactive aggregates. This work gives experimental measurements concerning the effect of the particle size of the alkali-reactive aggregates on the expansion of the mortar. The results show that no expansion was measured on mortars containing small particles (0.15 - 0.80) mm, while the particles (1.25-2.50) mm gave the largest expansions. . Then these measurements were used as a database for the modeling of the alkali-reaction. The proposed model aims to simulate the correlation between these measured expansions and the size of the reactive particles, and to calculate the thickness of the zone porous necessary to resume the volume of the gel created by this reaction.*

**Keywords***:* alkali-reaction, expansion, mortar, aggregates.

## I. Introduction

Concrete is one of the most used materials for construction. A considerable number of structures are built each year, and the economic profitability of the installations depends largely on their lifespan. A number of phenomena can cause premature deterioration of concrete. External aggressions play an important role in the degradation of concretes subjected to a particular environment, such as freeze-thaw cycles or aggression by water containing chemicals, such as salt. The endogenous reactions of concrete are also at the origin of important disorders, which intervene only by interaction of the initial components of the concrete.

In concrete production, there are different ways to prevent the deleterious alkaline aggregate reaction (AAR) in new structures. One is the use of non-reactive aggregates. However, a concrete producer often does not have access to these aggregates either due to regional unavailability or for financial reasons. Another way is to reduce the alkalinity of the pore solution in the concrete to a level where no deleterious AAR occurs with the aggregate used. This can be achieved by using appropriate mineral additives (such as fly ash, slag or silica fumes) to mitigate AAR [1-5], Environmental problems resulting from construction waste are a major concern. Each year, 200 million tonnes of construction waste are continuously discharged into landfills [6]. Most of the disposed building materials can be recycled, which reduces the accumulation of waste in landfills. Concrete is of great concern when considering the waste of materials, since it constitutes most of the total debris after demolition. For example, when an apartment building is demolished, concrete represents around 30 to 40% of the weight of the wreckage [7].

Damage due to the reaction of alkaline silica in concrete is a phenomenon that was first recognized in 1940 by Stanton in North America and has since been observed in many other countries [8-9]. A large number of studies have been published since Stanton's article, but the mechanisms of ASR are not yet sufficiently understood [10-13]. However, the main factors have been identified, for example, reactive silica, present in certain aggregates and alkalis in the pore solution and the presence of water. Other factors can play an important role, such as the type of cement, the porosity of the concrete, the relative humidity of the environment and the mixture in the presence of mineral material additive.

The development of innovative and effective procedures for the evaluation of ASR is becoming an urgent need due to the aging state of concrete structures and the excessive costs associated with their needs for replacement, rehabilitation or repair. On the one hand, such procedures will help to assess the current state of the structures but also their future performance. In many cases, involving deterioration due to the alkali-silica reaction (ASR), only a limited range of investigative techniques are used and their effectiveness has not always been demonstrated.

For example, visual inspection can provide an overall estimate of the amount of damage, but it remains very qualitative, superficial, time-consuming and, moreover, highly dependent on the skill and experience of the inspectors. Semi-quantitative methods have been proposed to assess the surface cracking associated with ASR. These methods are based on the measurement of the lines of intersection of cracks drawn on the surface of the structure [14,15].

## Results and discussion :

The thickness of the porous zone can be estimated as a function of the diameter of the reactive particles so that the gel can be created entirely suited to the porosity of the mortar. In this case, the volume of the gel created is equal to the sum of the volume of the gel produced by the assembly during its reaction and the volume of the porosity (FIG. 1).
The results of the calculations with the map of technical calculation software 12 are plotted in the figure. (2).
The FIG. (3) gives the evolution of "x" and shows that the gel produced in small grains needs less distance to be adapted by the porosity of the dough, however the thickness becomes important for grains larger than 1 mm . Therefore, the results of the calculations in this model indicate that, if there is a large amount of gel, "x" must be large to prevent expansion of the reactive particles.
For a single class of reactive particles the equation is written as follows:

$$\varepsilon_{AAR} = k.\phi_i.\left[\left\langle n.\left(1-\frac{(D_i-2t)^3}{D_i^3}\right)-P.\left(\frac{(D_i+2x)^3}{D_i^3}-1\right)\right\rangle^{+}\right] \tag{1}$$

In order to carry out these calculations and to obtain an expansion comparable to that measured on the mortars, the porosity of the mortar (p), the thickness of the attack of the siliceous grains (t), the volume coefficient of the gel ( n) and the distance (x) up to which the gel must diffuse into the cement paste. These calculations are performed using the Maple 12 technical calculation software. The calculated expansions are shown in the figure:

$$x = \frac{\sqrt[3]{\left[\left(\frac{n-1}{P}\right).\left(D_i^3-(D_i-2t)^3\right)\right]+D_i^3}-D_i}{2} \tag{2}$$

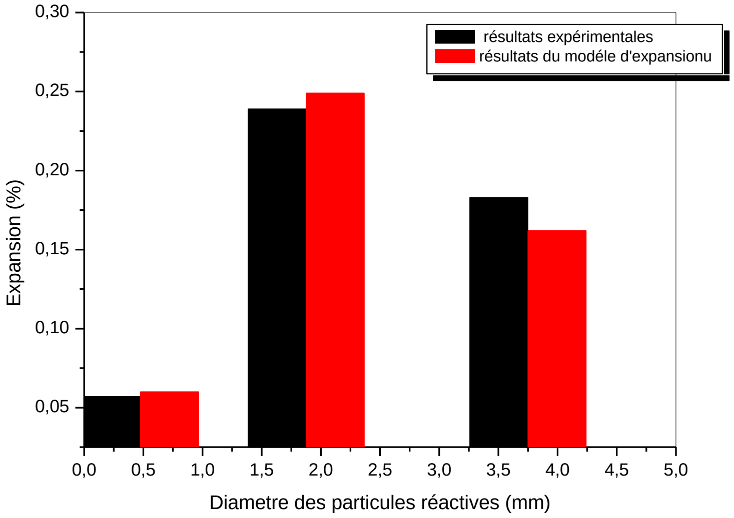

Figure 1.Expansion of the mortar as a function of the diameter of the reactive particles: comparison between the experimental and the expansion model for (PO).

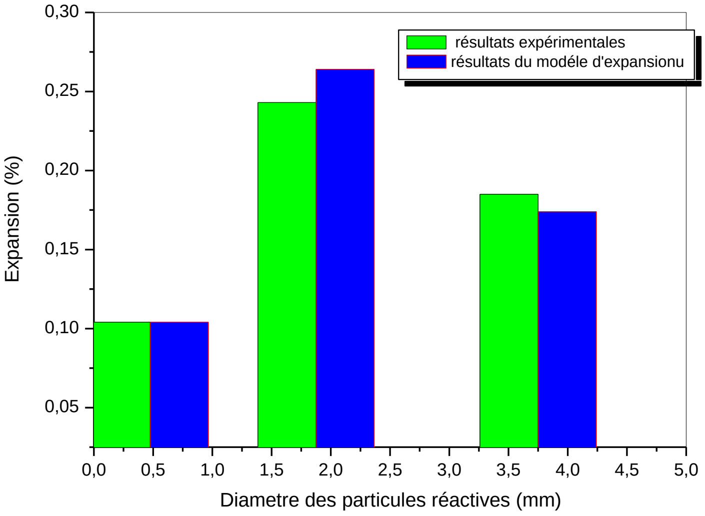

Figure 2.Expansion of the mortar as a function of the diameter of the reactive particles: comparison between the experimental and the expansion model for (NQ).

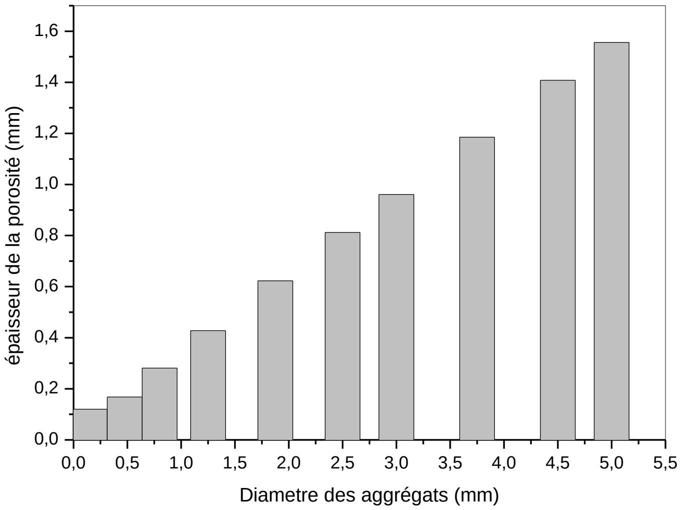

Figure 3. The distance "x" within which the gel must diffuse in the cement paste to be completely adapted by the porosity as a function of the diameter for (PO) and (NQ).

**Conclusion :**

The objective of this work is to analyze and model the alkali-reaction phenomenon of concretes. The models available in the literature can be separated into two distinct classes. "Mesoscopic" and "macroscopic" models. "Mesoscopic models" are based on probable reaction mechanisms to predict the evolution of ionic species in the material and the progress of the reaction at the local level. They boil down to the study of a V.E.R. using appropriate assumptions. The main reaction mechanism is diffusion. Most models assume the existence of a connected porosity zone that the gel must fill to pressurize the matrix. They all take into account the influence of the size of the reactive aggregates. The "macroscopic models" are based on physical phenomena observed experimentally to describe the evolution of the internal swelling induced by the reaction as a function of observable data (loading, temperature, relative humidity, etc.). They describe the development of the swelling in order to assess the structural consequences of the reaction.

After we studied the effect of the particle size of reactive aggregates on reactive alkali expansion by performing a combination between experimental and numerical simulation, for this reason, experimental results from the work of other researchers were used to serve them as an experimental database in our numerical simulation. The selected aggregates were quartz sandstone from Montreal, Canada (PO) and quartzite from Norway (NQ), they were crushed and sieved into three granular classes: (0.15 - 0.80 mm), (1.25 - 2.50 mm) and (2.50 - 5.0 mm) then three mortars were studied, each mortar contains only one size of the reactive particles of the aggregate. The results showed that for the mortar bars containing the granular class (0.15-0.80), mm no expansion was measured while the mortar bars containing the granular class (1.25-2.50 ) mm show the greatest expansion, especially at a young age and for the bars containing the granular class (2.50-5.0) mm, the expansion measured is (0.183% for PO) and (0.185% for NQ) .

Then we proposed a model that summarizes the main experimental observations and allows the modeling of the effect of the size of reactive particles on expansion. These results are similar to the experimental results, the bars containing the granular class (0.15-0.80) mm did not show a reactive alkali expansion, the bars containing the granular class (1.25-2.50) mm gave a greater expansion and the bars containing the granular class (2.50-5.0) mm gave an expansion equal to (0.162% for PO) and (0.174% for NQ). So, we observe that the proposed model represented the experimental data well.

From this model it was also possible to calculate the thickness of the porous zone necessary to take up the entire volume of the gel created by the reactive grains in the cement paste as a function of the diameter of the grains. The results indicate that the thickness increases with the diameter of the reactive grains.

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