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Study of biological degradation applied to concrete

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ABSTRACT: Concrete structure must conserve all its characteristics and performance during its life time, in order to avoid deterioration. Biological agents can be responsible for concrete degradation. At this moment, a study of detection of biological decay of concrete under the action of two different environments is being carried out and the results from two phases of the research are compared here in. Next step will be to compare these results with those obtained from the concrete of structures submitted to a third different climate.

1 INTRODUCTION

It is very important to maintain the concrete structures in nuclear power plants in good condition, in order to avoid any kind of accident. Besides mechanical strength, all other characteristics, mainly durability, must continue to have safe values during the entire lifetime of structure. The concrete of such structures is submitted to a large number of effects, such as weather, pollution, marine environment, acid substances, biological agents which can be responsible for the deterioration of the concrete in different ways.

Biological agents are very common, but their action on nuclear power plants has not been studied in sufficient detail. These agents are much more active when the structure is in contact with materials such as soil (in containment structures, for example), when there is a proliferation of several types of microorganisms, which can cause deterioration of the concrete. These microorganisms act mainly through the deterioration of the cement but can also damage the aggregates.

Some studies have been carried out in concrete biodeterioration in non nuclear structures but the correct mechanism is not very well understood, mainly because of the large number of families of microorganisms, some as yet probably unknown, that can be found in all construction materials.

Since concrete is a heterogeneous material which contains different compounds having different degrees of resilience to different deterioration agents, there are many types of microorganism that can attack the concrete compounds. Furthermore, there is a large amount of microbes having different metabolisms (sometimes unknown), which can produce substances that will be responsible for the concrete deterioration.

In addition, the great adaptability of certain microorganisms (like bacteriae for example) promotes the growth of them, even under conditions apparently not

favourable to their development. There are some microbes that can store their nutrients inside the cells, utilizing them when they are not available in the environment in such a way that they can grow even without nutrients.

The action of microorganisms on minerals has been studied by many researchers, mainly in Germany, France and Italy. The studies of biodegradation of concrete are very recent and one of its bases is the biodeterioration of minerals of soil and of natural stones, the studies of which are in a more advanced stage.

This paper concerns the studies of deterioration of concrete by microorganisms. The first phase is related to samples taken from structures submitted to a very peculiar climate (high variation of humidity and relatively stable temperature, which average is about 20° C). The second phase, now in progress, consists of the study of concrete submitted to a different climate: high stable temperature and high humidity.

The presence of microorganisms is very similar in both phases and the deteriorated crystals are the same. This research is not finished but it is supposed that the mechanisms of degradation are also similar.

It is evident that the result of this study can be applied to any concrete structure, since the microorganisms are spread everywhere in the world.

2 FOREGOING STUDIES

Among the investigations in the field of the biodeterioration of minerals, three are the most important for the study of the degradation of concrete, because of the similarity of their crystal composition: the minerals of soil, the natural stones of historical monuments and the concrete itself.

The study of the biodeterioration of minerals of soil is developed mainly by the Institut de Pédologie Biologique du C.N.R.S. de l'Université Nancy I, France. These studies are related to the metabolisms of microorganisms and to the production of metabolites, which is very important for determining the way to stop or to avoid this type of deterioration (Berthelin, 1983; Robert, 1983 and Berthelin, 1988).

In Germany (University of Oldenburg) and in France (Monuments Historiques de France), several studies have been developed on biodegradation of natural stones of historical monuments, in order to keep their characteristics and avoid any type of degradation (Pochon, 1975; Krumbein, 1988 and Bock, 1990).

The microflore of a natural soil in contact with concrete has been studied at the Université de Droit, d'Economie et de Sciences d'Aix-Marseille III, France, in relation to the action over the cement of a container for nuclear waste. Besides, Thiobacillus (nitrifiant Bacteria), Perfettini (1989) studied Nitrosomonas (nitrifiant Bacteria), heterotrophic bacteria and fungi. The author concluded that acid substances produced by microorganisms are responsible for the loss of weight, the augmentation of porosity, the dissolution of calcic products (carbonates, portlandite etc.) and consequently for the drop of strength. These factors facilitate the penetration of substances that can produce concrete deterioration.

At the Laboratoire Central des Ponts et Chaussées, in Paris, the degradation of concrete from structures of Brasília has been studied, with the purpose of determining the origin of this deterioration. It has been detected the biodegradation of concrete, as the responsible for a great large of the problems, but the mechanisms and the way to avoid this type of deterioration have not been determined. Some doubts have remained with respect to the interference of the climate, which is very peculiar in that region (Ribas Silva, 1991).

The aim of the continuation of this study, now in progress, is to verify the influence of the climate in the biodegradation of concrete, through the analyses of some samples collected in structures submitted to different conditions of environment.

3 DEVELOPMENT OF RESEARCH

In order to carry out research about the biodeterioration of concrete, it is necessary to study the microstructure using special techniques.

The main technique for this study is scanning electronic microscopy (SEM), with analysis by spectrometry of X-rays of dispersive energy, that permits the visualisation of the presence of the microorganisms and the detection of corroded compounds in addition to products of degradation.

As complementary techniques, the following have been used: chemical and thermogravimetric analyses (TG) which provide the necessary data for informing, through a specific calculation, the mineralogical conditions of concrete; X-ray diffraction (XRD) and thermal differential analysis (TDA). The last two techniques are helpful for determining the deterioration products which are present in the concrete.

Samples have been collected from deteriorated concrete and concrete in good conditions, in order to compare results.

Each sample has been analyzed through the use of the aforementioned techniques and has been observed by using SEM. The results of chemical analysis and thermogravimetry are processed using the program MINERAUX (Deloye, 1986 and 1994), which furnishes the cement content of the concrete and some additional information such as: if the concrete is deteriorated, the type of aggregates, if the cement is a ordinary portland or not, and the potential composition of cement.

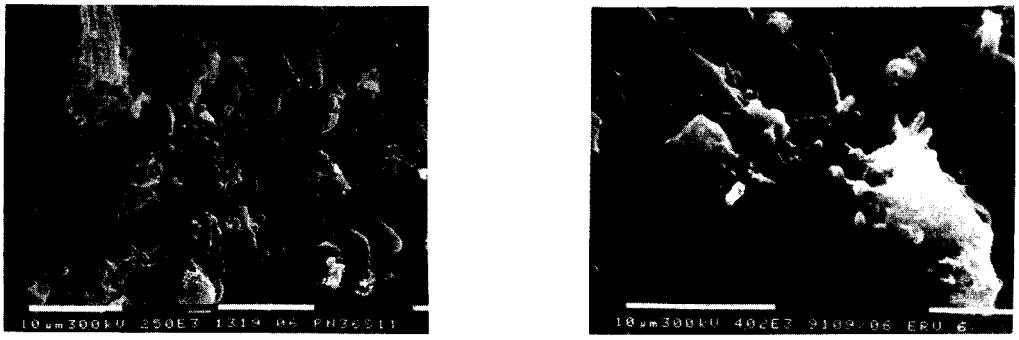
With the aid of the other techniques (XRD and TDA), the products of degradation which are present in the concrete can be identified.

The presence of microorganisms, when above certain levels, is detected through the TDA or the TG. SEM observations of concrete permit the observation of microorganisms and other morphologies present in concrete, such as corroded crystals, strange morphologies and any amorphous compound.

4 RESULTS

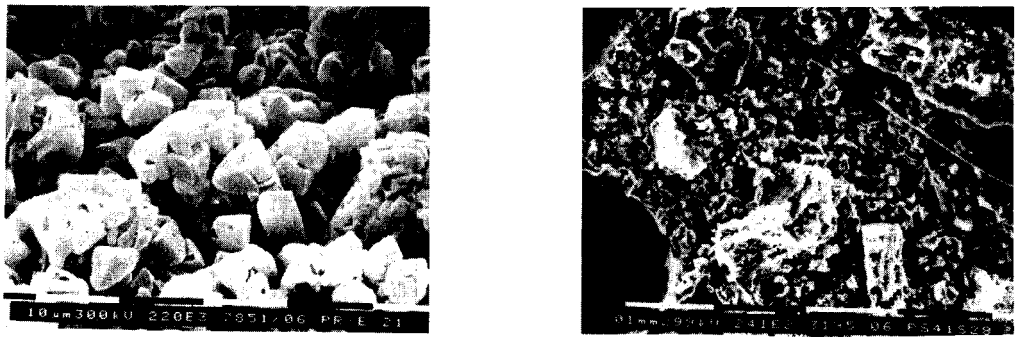
The aim of the first phase of the research which considers samples from Brasília was to try to understand the mechanisms of the development of the deterioration process of the concrete in structures. After a long study, the presence of deterioration products has been detected, as well as the presence of a large number of microorganisms (some unknown) in the proximity of corroded crystals. With the aid of specialists, some of the forms observed have been identified, by morphological similarity, such as Protozoa, Algae, many types of Bacteriae (Figures 1a and 1b), Yeasts Fungi etc..

Among the deteriorated crystals, the most frequent are the calcic compounds, such as carbonates (Figure 2a), aluminates and portlandite (Figure 2b), but other types were also present such as micas, quartz (Figure 3a), and feldspars. Many products of deterioration have been observed in the samples of concrete, such as gypsum, ettringite (Figure 3b), thaumasite and other sulphates (alkaline).



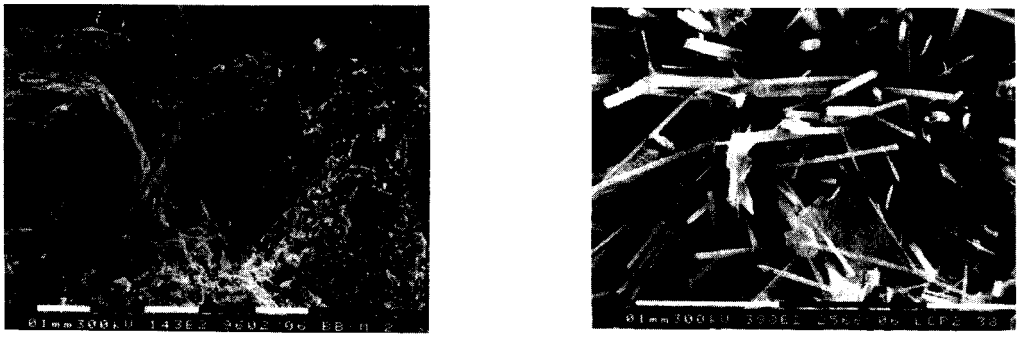
(a) (b)

Figure 1: In the first phase of the study, Bacteriae have been observed on corroded calcium carbonate (a). The same morphology has been found in the concrete analyzed during the second phase. In this microphotograph other morphologies can be seen, such as the empty tube at the left side (b).



(a) (b)

Figure 2: Corroded calcium carbonates are shown in this microphotograph of the first phase. The same morphology has been observed in the concrete from the second phase (a). A zone with many corroded calcic crystals (portlandite) and a empty tube, probably containing a microorganism (b).



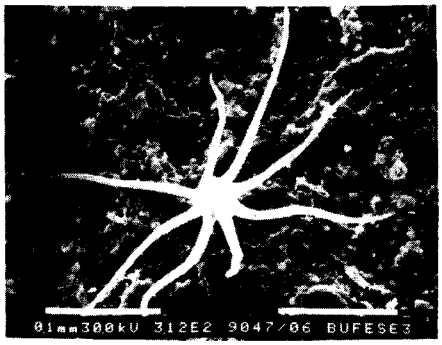
(a) (b)

Figure 3: Among the deteriorated aggregates, grains of quartz appear with a corroded surface, in both phases of the research, as it can be seen in the microphotograph from the first phase (a). One of the products of degradation is the ettringite seen in both phases (b).

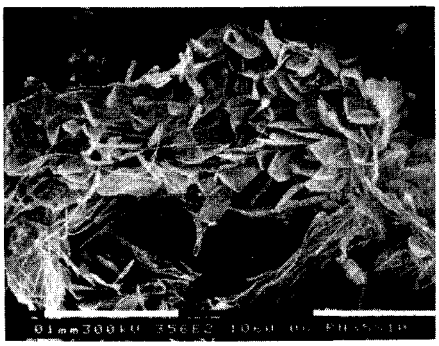
The second phase, now in progress, is related to samples from structures submitted to climates different from that found in Brasilia, where the climate is mild and dry. In the present phase concrete from structures in a very hot climate with high humidity is being studied. However, the deterioration of the observed concrete is similar to that of the concrete from Brasilia. Through the SEM observation, it has been noticed that some microorganisms found in the two phases are similar, but others are quite different.

In both phases, strange morphologies (some unidentified) have been observed, such as those of Figures 4a and 4b. It has been noted that corroded crystals are the same for the concrete submitted to the two different climates.

Further study is necessary in order to permit the correct interpretation of the results obtained.



(a)



(b)

Figure 4: Many unknown morphologies have been observed in both phases. This kind of sea star has been found in the second phase (a). In the first phase, this strange assemblage of leaves and filaments appeared in some samples (b).

5 CONCLUSIONS

According to the researchers in this field, there is no doubt that biodeterioration of minerals of concrete, stones and soil occurs in many structures.

Since these materials have a close mineralogical analogy, it is natural that the related studies are comparable given that the results of one can be useful for the others.

The studies of soil and natural stones are much more developed than those of concrete, but studies of this later material are beginning to be carried out.

Concrete is the building material which is most used worldwide and, in structures of great responsibility such as nuclear power plants, measures to avoid its deterioration are of paramount importance.

The studies carried out till now confirm the presence of biodegradation of concrete, when a large number of known and unknown microorganisms appear near corroded compound crystals of concrete.

It seems that climate is not an important factor in microorganism development, in general, but it can be significant with respect to the development of different types of microorganisms. Further studies of concrete submitted to other climates are necessary in order to verify the behaviour of this type of deterioration. Also, future research is necessary to determine an effective method to combat the biodegradation of concrete.

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