Degradation of Concrete Structures

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ABSTRACT

Concrete has been the most useful material of construction in the recent centuries. It is a mixture, the properties of which change over time. In the residential buildings or infrastructure there have been used various forms of concrete. As a very useful material in the construction, concrete is the element that faces extreme environmental conditions. During the service, the quality of designed concrete can be improved by continuous contact with water as in the case of reservoirs, concrete foundations, etc . But the concrete also can worsen over time due to physical and chemical agents. Consequently, the structures are destroyed when they become unsafe.

Degradation of concrete structures has become a crucial matter during the last 20-30 years. Some economically developed countries spend more on repairing and maintenance of structures. As a result, these countries appreciate the longevity of the building rather than the initial cost of its construction.

The aim of this paper is to simplify the destruction schemes of concrete materials from atmospheric agents. As a result it is made an approach to the main phenomen that misbehave with concrete and the way it behaves different from the conditions in which it is located. It is concluded to achieve a long life for concrete, special care should be taken during its preparation and should be maken an intelligent choice as to its constituent materials and their reports.

Key words: *durability, concrete, corrosion, sulfate attack.*

1. INTRODUCTION

Concrete is a mixture, the properties of which change over time. During the service, designed concrete quality can be improved by continuous contact with water as in the case of reservoirs, concrete foundations, etc. But the concrete also can worsen over time due to physical and chemical agents. Consequently, the structures are destroyed when they become unsafe.

Concrete durability has become an important issue for last 20-30 years. Some economically developed countries spend more on repair and maintenance of structures. As a result, these countries assess more the longevity of the building rather than the initial cost of its construction.

Concrete durability depends on many factors such as physical and chemical properties of concrete, the surrounding environment, the projected life expectancy, etc. [1]. So durability is not a distinguishing characteristic of a particular concrete. A good concrete behaves in a certain environment may deteriorate in another environment. This is due to the destruction of various schemes, which depend on various conditions to which the concrete is exposed. The physical properties of concrete represent intercalation agents in concrete and their movement from within to outside or vice versa. Chemical properties refer to the amount and type of hydration products, primarily calcium silicate hydrate, hydrate of aluminum, calcium and calcium hydroxide. Reactions of these hydrants provide agents with inert or expandable products. It is precisely the nature of the products obtained by this reaction, which controls the severity of the action of chemical agents. Physical damage may occur due to expansion or contraction, or as a result of exposure to abrasion, erosion or fire during the service. Therefore, the protective layer plays an important role in durability of concrete , because it is the first element of concrete in contact with chemical agents or physical environment [2].

Degradation or destruction of a reinforced concrete structure is mainly due to the following reasons:

a) The action of various chemical and physical agents . The main phenomena that bring concrete degradation are reaction ASR, sulphatic attack , etc.

b) Degradation of steel rebars comes as a result of corrosion and concrete carbonization.

2. Steel degradation and corrosion process

Steel corrosion and consequently the damage of protective layer of concrete has been a problem in the construction field for many years. In theory the steel rebars introduced in the concrete should not be corroded. They are protected from corrosion due to a mass of ferric oxide inactive (Fe_2O_3), which is formed by the alkaline environment concrete creates by hydration of cement.

Steel corrosion process in concrete can be divided into two phases:

-1.The beginning, coinciding with the entry inside the concrete of aggressive agents such as carbon dioxide and chlorine ions.

-2.Spreading process , which relates to the spread of corrosion in all areas of steel rebars.

2.1 The carbonation process.

Carbonation is defined as the process through which carbon dioxide that is in the air, enters in concrete, dissolves in the solution of pores and then reacts with hydroxide turning them into carbonates. This process is accompanied by a decrease in the pH value to 9 .Steel passivity expires when the pH value decreases below the value 11. To determine the depth of carbonization,they spread a fenolftalin solution into concrete piece. This solution, when the pH is above 9.5 gets a pink to purple. This shows the concrete is not carbonized.

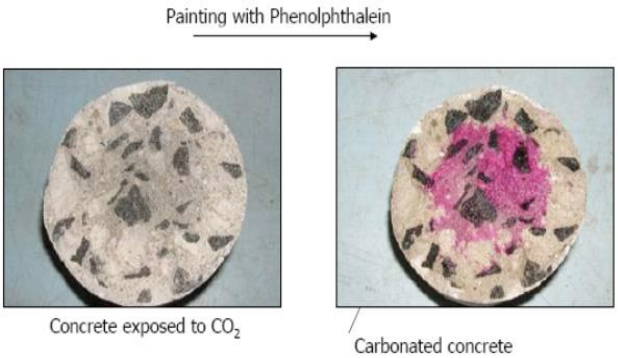

Fig.1 Carbonation of concrete.

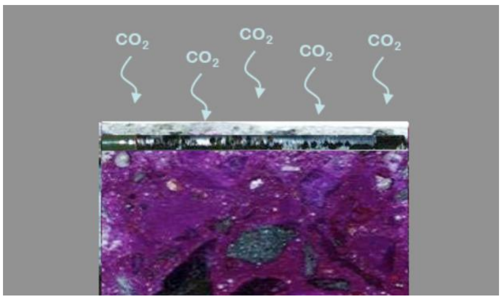

Fig.2 Corrosion by carbonation.

Carbonation speed depends largely on the humidity, so on the weather conditions to which the concrete element is exposed. In practice, the vertical elements of concrete buildings, become carbonated faster than horizontal elements because horizontal surfaces have a more frequent and continuous contact with water [3]. Another factor that affects the speed of carbonation is the temperature. The higher the temperature, the faster carbonation. But the influence of temperature relative humidity is very low. Another factor is the content of carbon dioxide in the air.

2.2 The effect of chlorides.

The chlorides, present in seawater or groundwater, can enter to the concrete by capillary absorption or diffusion of ions of water. Chlorides can be present in the chemical layers or in the water used in the concrete mix. Not all the chlorides in concrete causes the corrosion, but only a part of them. The rest can be chemically linked with the hydrated cement. Another part of chlorides is physically connected to the gel pores. The parts that remains are free chlorides, which are the only ones that cause corrosion of steel rebars.

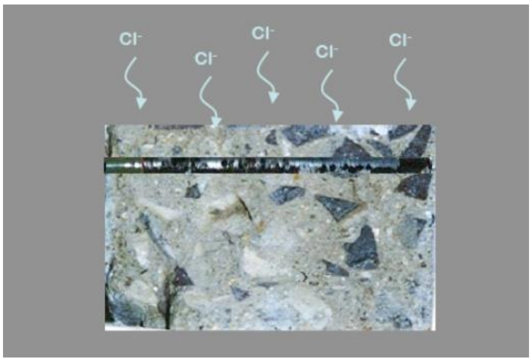

Fig.3 Corrosion by chlorides.

To begin the process of corrosion, a minimum amount of free chlorine ions should be accumulated in the steel rebars surface. This minimum amount ,capable to destroy inactive extent, is about 0.1-0.4% of the total cement mass used .. Buildings and bridges near the coast suffer more the problem of corrosion due to the co-existence of carbonization and the penetration of chlorine ions .

2.3 The spread phase of corrosion

Immediately after the steel rebars within the concrete had broken the state of passivity, corrosion begins with the formation of electro-chemical cells on the surface of steel rebars composed of anodes and cathodes, enabling the creation of a stream that flows between them. Corrosion occurs in the anode. Ions formed at the anode and cathode dive in solution into the pores of the concrete dough and react chemically to produce iron oxide near the anode. This product in more general terms, is called rust.

In concrete environments with relative humidity less than 60%, as claimed are indoors housing or other objects protected from rain, corrosion of steel rebars is not a problem, despite that concrete can be carbonized to a considerable degree.

Corrosion can be neglected when reinforced concrete elements are immersed in water, due to the need for oxygen. Typical examples are structures submerged in the sea, where concrete undergoes aggressive chlorine attack, and because of the small amount of oxygen, corrosion is very slow [3]. The opposite would happen in the structures under constant spraying of water or tidal areas where concrete structures experience a lot of souse-drying cycles. In this case, the corrosion would be very fast.

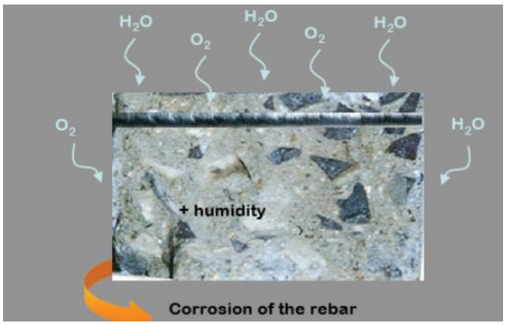

Fig.4 Factors affecting the steel corrosion .

Damage of concrete from corrosion comes from the volume of rust, which is 2-6 times greater than the initial volume of steel that it replaces. This increase in volume exerts considerable pressure on the concrete, causing cracking of the protective layer [4]. In practice, the first signs of corrosion are cracks and rust spots. 0.1-0.5mm thick rust on the iron rod is sufficient to cause cracking. The reduction of steel rebar diameter is considered to have very little impact on reinforced concrete elements capacity. Main concern is the separation and collapse of concrete peaces.

3. Degradation of concrete.

3.1 Alkaline-aggregate reaction.

Some types of rocks contain reactive silicon, which acts with hydroxides in the pore water, causes a lot of damage to the concrete. The reaction between silica and alkali happens more often.The effect of reaction is very similar to the erosion of glass from hydroxide solutions. The first signs of this phenomenon are concrete cracks that appears in the surface, and a gel that comes from the concrete mass through crackings [5].

The reaction begins with attack of alkaline ions, to siliceous minerals that are in the thick concrete bottler. By this action, into the pores of the thick primer or on the surface of it, is formed a viscous mass called alkaline siliceous gel. The gel absorbs water and causes swelling of its bottlers, which can disrupt the integrity of the sand or gravel or their connection with the of hydrated cement mass.. With the continuous absorption of water that is in concrete, gel viscosity decreases more and more until it passes completely into liquid state. Part of the gel liquid flowing through cracks, appears in the damaged concrete surface.

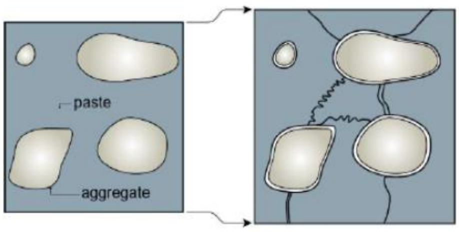

Fig.5 The mechanism of action of sulphates.

It should be noted that the level of damages that brings ASR depends heavily on some essential conditions such as the nature and size of the filler, the amount of reactive silica in the filler, the whereabouts of alkalis and the presence or not of moisture.

3.2 The action of sulphates.

Natural sulphates, sodium, phosphorus, calcium and magnesium can be found in natural soils, seawater, groundwater etc. Sulphates are also used by industry and fertilization. Those sulphates can contaminate soil and surrounding waters. Another source of sulphates can be found in the cement of reinforced concrete elements.

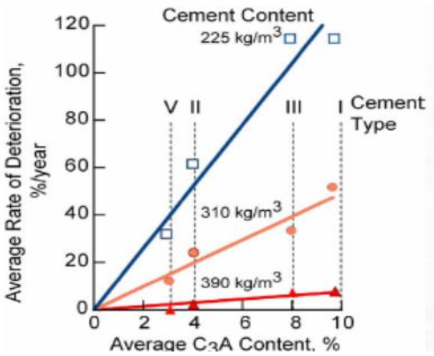

Fig.6 Effect of type of cement and quantity.

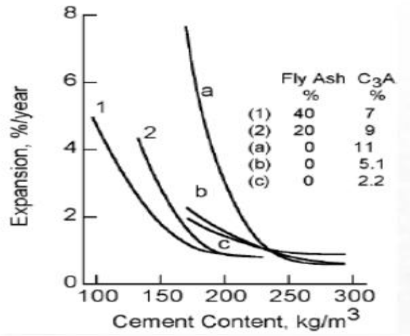

Fig.7 Ash handling effect of EPC

Sulphatic attack may occur in the following forms:

-physical action due to salt crystallization (swelling);

- chemical action of external sulphates that includes chemical reactions between sulphate ions from outside with sulphate ions of cement;

- chemical action of internal sulphates due to delayed sulphates in concrete.

Generally, in the practice of several decades ago, sulphatic attack was not considered a serious problem or a phenomenon that causes serious damage to the concrete.

3.3 The dilation.

This form of sulfates action occurs more in those concretes that are very porous and having upper surfaces exposed in dry and the bottom of them is in contact with the ground, which contains salts solution. In these conditions, sulphates climb to the top and if the speed of evaporation is greater than the speed with which solutions of salt moves towards the surface, under the surface of the salt crystals formed. The conversion of the anhydride to hydrate Na2SO4 brings a significant volume increase. This change volume, additional strains arise in concrete. These strains cause cracking, fractures, disconnect. Damage is usually in the form of staggered surfaces and severance measures by these surfaces.

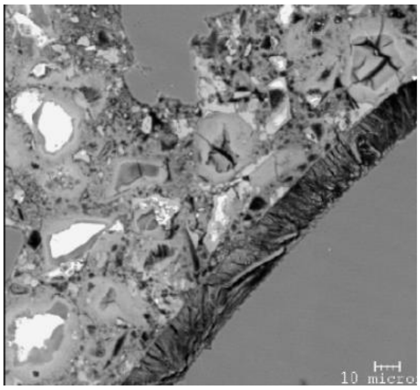

Fig.8 Formation of ettingritit.

These damages should not lead in loss of capacity of element, though its cross section is reduced.Damage of this type has the form of white crystals deposited in the concrete cracks on the surface and should not be confused with flouresence, where crystallization of salts occurs in the surface. Mineralogical analysis of damaged elements note that ettingriti and gypsum are not part of them.

4. CONCLUSIONS

- Degradation of reinforced concrete structures may come as a cause of degradation of concrete , steel rebars or destructive loads coming from construction.

- The degradation of the concrete itself comes from the action of various chemical and physical agents.

- The main phenomenas leading to degradation of concrete structures are ASR reaction sulphatic attack etc.

- To extend the life of a reinforced concrete structure it is important to use a good quality concrete , with good impermeability and an adequate protective layer.
- Corrosion of steel rebars occurs as a result of structural damages of the protective layer of concrete.

- In order to begin the process of steel corrosion, in the steel surface should be accumulated a minimum amount of free chlorine ions . This minimum value that need to destroy inactive mass is about 0.1 - 0.4 % of the total cement used .

- Corrodion most frequently happens in the structures situated on the coast.

- One way to protect structures against corrosion could be the use of corrosion inhibitors (such as sodium nitrate and calcium) and galvanization of iron rods.

REFERENCES

[1] Mohamed A. El-Reedy *"Reinforced concrete structural reliability". December 15, 2012 by CRC Press*

[2] P.Kmiecik, M.Kaminski *"Modelling of reinforced concrete structures and composite structures with concrete strength degradation taken into consideration".* Archives of Civil *and Mechanical Engineering, Volume 11, Issue 3, 2011, Pages 623-636*

[3] L.M. Poukhonto *"Durability of Concrete Structures and Constructions: Silos, Bunkers, Reservoirs, Water Towers, Retaining Walls". January 1, 2003 by CRC Press Reference - 422 Pages ISBN 9789058092298 - CAT# RU41182*

[4] S.Collepardi, Ogoumah Olagot, *"Diagnosi del degrado e restauro delle strutture in c.a ".* F.Simonelli, R.Troli *Libro+CD-Rom ,Editore:ENCRO SRL , 01/2010*

[5] Cesira Macchia, Francesca Ravetta *"Degrado e ripristino delle strutture in calcestruzzo". Maggioli Editore,Lingua: Italiano , Numero di pagine: 132 Formato: idBinding,Isbn-10: 8838700184 , Isbn-13: 9788838700187 Data di pubblicazione: 01/01/1995*