

ABSTRACT

Reinforced Portland cement concrete was invented approximately more than one hundred years ago and it has become one of the most widely used industrial materials in the world. Thus, durability of concrete structures is one of the most important considerations in the design of the structures elements and when assessing the condition of existing structures. On the other hand, when the concrete is exposed to a severe environment such as highway bridges or marine structures whether it contains uncommon materials such as high alumina cement or re-cycled aggregates, thus, the knowledge of the concrete durability is a potential key to the long term performance.

Non-destructive tests are one of the greatest economic and social importance techniques, and it can be used to determine the durability of civil engineering structures where these materials are widely used. However, the usage of non-destructive techniques in these materials is not widespread around of the world, motivated mainly by the heterogeneous microstructural characteristics that shown by these materials. Between all non-destructive testing methods available for concrete examining, the use of ultrasonic waves is very essential to characterize the microstructure and material properties of inhomogeneous materials.

The objective of this work is to obtain an evaluation procedure of the cycle-life of precast concrete prepared and put into the service in marine environments. Also, the incorporation of various methodologies (destructive and non-destructive techniques), is studied and analyzed to characterize the degradation process of concrete and mortar degraded by sodium sulfate and ammonium nitrate solution. For this purpose, accurate integration of different techniques is used in order to characterize the properties and to follow the degradation process that affects the concrete.

As additional objectives, the relationship between destructive and non-destructive parameters is studied, also the relationship between the non-destructive parameters each other was studied. Most of the previous studies used the ultrasonic techniques to calculate

the w/c ratio of concrete, mortar and cement paste to follow the effect of variation of w/c ratio on the microstructure changes of such materials during the curing process. However, in this research, we study the effect of the variation of w/c ratio on ultrasonic parameters due to the degradation process by aggressive elements.

For this purpose, Limestone Portland Cement type II A-L 45.5R (LPC), and Sulfo-Resistant Portland Cement type I 42.5R/SR (SRPC) were used to fabricate two pre-cast concrete frames, which were used in this study as a concrete in service (real case). On the other hand, for studying the effect of variation of w/c ratio on ultrasonic parameters due to the degradation process, mortar samples with different water-cement ratios 0.30, 0.375, 0.45 and 0.525 were fabricated by using cement type (LPC) to obtain different degradation levels.

To follow the degradation processes, an integration of ultrasonic techniques was used. For example, Ultrasonic Pulse-echo technique using frequencies (1 and 3.5MHz) is used to obtain the parameter of attenuation profile area (APA) which estimated by (Vergara et al., 2003) and used by (Fuente, 2004) to follow the curing process of mortar and cement paste; this parameter has a high sensitivity to characterize the changing of microstructure of cement based materials along the curing processes. Ultrasonic transmission-reception method is used to calculate wave velocity of ultrasonic longitudinal wave using frequency 1MHz and ultrasonic shear wave using frequency 500 KHz. Velocity of ultrasonic waves also has ability to follow the microstructural changes easily, because it is related by the variation of porosity. Ultrasonic image technique (UIT) using frequency 2MHz also was used for the same purpose.

As a destructive testing, compressive and flexural strength tests are used to follow the change in the strength of mortar and concrete, open porosity is used to observe the variation of porosity inside the material by the effect of the aggressive elements which penetrates the material and causes degradation, Mercury intrusion porosimetry (MIP) is used to observe the variation of the pores volume and finally Scanning Electron Microscopy

(SEM) is used to allow quantifying and detecting the changes in the microstructure of concrete and mortar samples due to the attack by the aggressive elements.

The obtained results showed that, the degradation by sodium sulfate solution has two steps; the first step is due to the formation of ettringite and filling the pores by it, but yet it is not produced cracks. In this step it was observed a variation in the obtained parameters, for example increasing of ultrasonic wave velocity, the compressive and flexural strength or decreasing of porosity. This variation may indicates an increasing of the mechanical performance of materials under investigation, but in fact, this is not true because the pores are filled by ettringite and soon it will be expanded and causes degradation as showed in the second step. In the second step it was observed cracks and micro cracks due to the expansion of ettringite and increasing of its volume inside the pores. This changed the measured parameters to the contrast that was observed in the first step, for example a decreasing of ultrasonic wave velocity, compressive and flexural strength, and increasing of porosity etc. On the other hand one step degradation was observed for the degradation by ammonium nitrate solution due to the decalcification process from the start to the end of exposure time. For both cases the conjunction of the used techniques found to be successful to follow and estimate the degradation process, also it is found a good relationship between the destructive and non-destructive parameters.