Acoustic Monitoring of the Curing Process in Cement and Concrete

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ABSTRACT

Acoustic wave velocity and attenuation measurements are used to monitor Cement and Concrete during hardening. The measured acoustic parameters can then be used to investigate the curing process. The goal of this work is to determine the time required for a given mixture of Concrete to be hard enough for the removal of the forms, in order to speed up the construction process. Currently this removal time is unpredictable. In addition Concrete, Mortar and Cement, before hardening, can be considered as examples of granular materials. The shear, rigidity moduli and acoustic wave velocity of these materials can differ from the values obtained by applying effective-medium theories and Biot’s theory. The complete description of the mechanical properties of these materials requires the consideration of discrete nature of the solid constituents and the effects of contacts between the grains. These effects are included in the theoretical description of the process. The methods of Acoustic Microscopy are also applied to investigate the surface and subsurface physical changes, of cement during hardening. Theoretical and experimental results of this investigation will be presented.

INTRODUCTION

The curing process in a cement mixture is a series of chemical reactions by which the cement mixture, when not stirred, gradually hardens with time until it becomes completely crystallized and rigid. In the construction industry, knowledge of the time interval required for the setting of the concrete for form removal or the addition of a new construction is crucial for speeding up the construction. Although there are published guidelines (tables from the American Concrete Institute), currently this time interval cannot be accurately predicted. It depends on uncontrollable parameters such as ambient temperature and humidity among other factors.

TECHNICAL SUMMARY

The goal of this research is to develop a sensor for monitoring the stiffness and rigidity of concrete mixtures at the construction site, that is, to follow-up the change in its rigidity and stiffness with time, in order to predict the time required for the removal of the forms and the readiness of the concrete for overlay construction. The technical approach consists of monitoring elastic wave propagation in a concrete mixture that is similar to that of wave propagation in multiphase media, which in the case of concrete mixture are mainly cement, water, air bubbles and sand. The theory of elastic waves in two-phase granular materials, for long-wavelengths when the contact effects are not considered is described by Biot’s equations. However, this theory needs to be modified when the ultrasonic wavelengths become comparable to the material grain size. This modification includes the consideration of intergranular contact effects.

The wave velocity in a given granular material is a function of its stiffness and rigidity. The stiffness can be related to Young’s modulus. As a given cement mixture cures, Young’s modulus increases with time. Therefore the ultrasonic wave velocity should also increase with time. Preliminary results obtained in the laboratory for a thin slab of cement are shown in Figure 1. In this figure are shown the increase in Young’s modulus and the decrease in Poisson’s ratio with time (0 to 48 hours), at different temperatures (15 C°, 25 C° and 35 C°), in white cement paste with water to cement ratio of 40%.
The technical approach for this investigation consists of attaching to the concrete ultrasonic transducers with appropriate electronics to monitor the hardening of the concrete. We shall also investigate the use of air-coupled ultrasonic transducers for non-contact measurements. Special signal processing software will be developed to obtain, in real time, the state of hardening of the concrete mixture.

CONCLUSION

The aims of these investigations are the development of a sensor measurement technique applicable to the construction sites. The experimental measurements covering different cement mixtures under different laboratory conditions, show that from the data it is possible for a given cement mixture to predict the time required to reach a particular value of hardness. These results will be used to develop and design a sensor, with appropriate electronics, for potential field use and transfer to the construction industry.

![Variation of Young's modulus and Poisson's ratio with time, in hours (0 to 48h) at different temperatures (15°C, 25°C and 35°C), in white cement paste for water to cement ratio of 40%.](image)

REFERENCES


