

Concrete belongs to the most commonly used material in civil engineering objects. A fundamental problem in maintenance of concrete structures is material cracking due to the fact that concrete is a brittle material. Degradation of mechanical properties of concrete occurs under the influence of environmental and operational loadings. However, before an open crack (macro-crack) emerges, micro-cracks develop within a concrete element. Detection of such micro-scale damage at an early stage of degradation is not a trivial task and it is of great interest in civil engineering.

The proposed research is motivated by the need to improve the safety of concrete structures. For this purpose, a method based on the propagation of elastic waves will be used. Characteristics of propagating waves in a concrete element subjected to mechanical degradation change strongly, enabling the detection of developing damages. In a broader perspective, the project results will have a significant impact on the development of monitoring techniques dedicated to concrete structures. Reliable assessment of the degree of degradation of structural components will enable their rational maintenance and also extend the structure service life.

The aim of the project is to explain the mechanism of propagation and scattering of elastic waves at the aggregate-level and their interaction with micro- and macro-cracking in concrete members subjected to monotonic quasi-static loading. Research investigations consist of two complementary parts: experimental and numerical. In the experimental part, a comprehensive program of monitoring of micro- and macro-cracks' development in concrete specimens will be carried out by means of elastic waves. Two approaches using elastic waves will be used, i.e. the ultrasonic testing, where the elastic wave is generated by a PZT actuator, and the acoustic emission testing, where the elastic wave is generated by cracking of concrete. Additionally, the advanced micro-computed tomography system will be used for imaging the 3D concrete meso-structure and fracture evolution in concrete.

Since concrete has a special structure that is discontinuous and heterogeneous, wave propagation mechanisms in concrete elements will be described using an advanced mathematical model based on the discrete element method. In the numerical part the 4-phase concrete model will be used by including aggregates, cement matrix, macro-pores and interfacial transitional zones around aggregates. Calculations of elastic wave propagation in concrete elements will be conducted taking into account their real meso-structure obtained by means of micro-computed tomography.

The coupled experiments and calculations will yield new insight into the propagation of elastic waves in heterogeneous materials. The influence of concrete meso-structure on elastic wave scattering will be studied. Relationships between the micro/macro-cracks and characteristics of propagating acoustic and ultrasonic waves at the aggregate level will be elaborated. New algorithms capable of detecting micro-defect zones before the formation of visible damage will be developed.