1.14.7. NONLINEAR ULTRASONIC SPECTROSCOPY AS A TOOL TO EVALUATE BUILDING MATERIAL STRUCTURE DAMAGE

Korenska M., Matysik M., Manychova M., Brno University of Technology,
Faculty of Civil Engineering, Brno, Czech Republic

Stability of building structures is one of very important issues in the field of non-destructive defectoscopy. Thanks to the stormy development of concrete and reinforced concrete buildings taking place in the last century, the condition of concrete and reinforced concrete became a hot topic in the last decade. Concrete proved to be a durable construction material in the recent years, however, concrete structures often experience degradation after years of service. Structure rehabilitation techniques have reached a high standard recently. However, the absence of an acceptable, relatively fast and cheap monitoring method, which would be capable of detecting bridge faults at an early stage, thus making a simple and cost-effective maintenance possible, is still persisting. Therefore, elaboration of new and simple defectoscopic methods, capable of determining the integrity of a given structure or a building element is of sign importance. It is also essential to develop and/or refine the methods designed to estimate the lifetime of building structures.

The reinforced concrete integrity is impaired frequently in consequence of the reinforcing steel corrosion. The condition of the reinforcing steel makes an important element determining the reinforced concrete structure quality, reliability and applicability. However, the steel reinforcement corrosion deteriorates substantially the reinforced concrete structure technological properties and, consequently, reliability and service life. The reinforced concrete condition monitoring methods, which are currently most frequently used, consist mainly in visual checks supplemented with simple carbonation degree or concrete strength tests, cannot be considered sufficient if an estimate of the structure exploitation period is required. Electromagnetic or ultrasonic methods to determine the reinforcement profile or shielding require a great amount of knowledge about the structure, thus being virtually unavailable. X-ray tests are expensive and locally limited. New non-linear acoustic spectroscopy methods appear to be very promising just in the field of non-destructive testing in the building industry.

The non-linear ultrasonic spectroscopy provides new prospects in the non-destructive acoustic testing of material degradation. Detailed studies of dynamic non-linearities and hysteresis in inhomogeneous media have shown that the occurrence of mesoscopic elements in the material structure gives rise to strongly non-linear dynamic phenomena accompanying the elastic wave propagation. These non-linear effects are observed in the course of the degradation process much sooner than any degradation-induced variations of linear parameters (propagation velocity, attenuation, elastic moduli, rigidity etc.). These non-linear wave methods thus open new horizons to the acoustic non-destructive testing: they provide high sensitivities, application speed and easy interpretation that have never been achieved before. Intensive research in the field of non-linear spectroscopy of elastic waves (NEWS) has proved recently that the methods, which are based on the occurrence of non-linear effects in the spectral response, can serve as a highly sensitive tool to detect material defects. The present paper deals with a study and a research of these novel methods from the viewpoint of their applicability in the field of detecting concrete structure defects.

Based on a theoretical analysis and a comparison of different variants of the non-linear elastic wave spectroscopy (NEWS), which come into question regarding the building material testing, a NWMS (Nonlinear Wave Modulation Spectroscopy) – analysis of the generation of intermodulation products (side bands) resulting from increasing the amplitude of the ultrasonic excitation by means of two different harmonic frequency signals, has been selected.

In the research initial phase, calibration measurements of elastic wave propagation characteristics in test specimens proved to be essential. To this end, appropriate test specimens had to be prepared, i.e., thermally, corrosion-specific or mechanically damaged and intact specimens, to provide appropriate experimental conditions and to select the best applicable non-linear parameter types to evaluate the actual condition of the structure in question. The geometry, composition and distribution of local mechanical properties of the specimens under test influence heavily the experiment procedure as well as configuration, such as the exciter and sensor deployment setup, the exciting signal frequencies and amplitudes, etc. There is no method to be applied universally for this purpose. The test parameters have to be selected individually for each specimen material and shape. The measuring and testing apparatus and control software package design were first tested on homogeneous material specimens and PMMA blocks containing intentionally created cracks. Subsequently, concrete and reinforced concrete specimen were tested. Test cubes and joists made of four different concrete mixes and reinforced concrete joists have been designed and prepared for this purpose. Elementary physical characteristics, ultrasonic wave propagation velocity and attenuation and propagation spectral characteristics have been determined for each test specimen.

Dedicated, special-purpose-made piezoelectric transmitters, powered by an ultrasonic signal from a controlled-output generators, have been included into the measuring apparatus design. The specimen response versus distance from the excitation source dependence was studied by means of piezoelectric sensors. Exciter and sensor spatial distribution on the specimen surface had to be optimized for each specimen regarding the resonance modes and attenuation. When applied to concrete and reinforced concrete specimens featuring various degrees of damage, the NWMS method proved relatively simple to apply and promising. The damage related non-linearities resulted in a prevailing growth of odd-numbered harmonic frequency components with increasing exciting signal amplitude, and, also, in the occurrence of side bands as a consequence of exciting frequency intermodulation. These non-linear effects have been quantified by means of different non-linearity parameters characterizing the presence of defects.