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Guest Editorial

Non-destructive testing of concrete material properties and concrete structures

To keep a high level of structural safety, durability and performance of the infrastructure in each country, an efficient system for early and regular structural assessment is urgently required. The quality assurance during and after the construction of new structures and after reconstruction processes and the characterisation of material properties and damage as a function of time and environmental influences is more and more becoming a serious concern. Non-destructive testing (NDT) methods have a large potential to be part of such a system. NDT methods in general are widely used in several industry branches. Aircrafts, nuclear facilities, chemical plants, electronic devices and other safety critical installations are tested regularly with fast and reliable testing technologies. A variety of advanced NDT methods are available for metallic or composite materials.

In recent years, innovative NDT methods, which can be used for the assessment of existing structures, have become available for concrete structures, but are still not established for regular inspections. Therefore, the intention of this issue is to raise awareness within the civil engineering community about the applicability, performance, availability, complexity and restrictions of NDT.

This Special Issue of *Cement and Concrete Composites* describes recent developments of NDT methods and contains results of laboratory and on-site investigations on concrete and concrete structures. The 11 international papers coming from six countries are related to the development and application of electromagnetic, acoustical and mechanical methods like *active thermography, radar, ultrasonics, pile integrity testing, seismic refraction, acoustic emission, drilling resistance* and *maturity function*. Attention is also drawn on combining the results of different NDT methods enhancing the reliability of results and measures. The papers address a wide range of applications, from the prognosis of maturity of fresh concrete to the structural assessment of concrete bridges.

The characterisation of early age concrete for maturity prognosis analysing transit time and reflectivity of ultrasonic waves is reported in the first two papers by *M. Krauß and K. Hariri (Germany)* and *Th. Voigt, Z. Sun and S.P. Shah (USA)*, respectively. The results are presented for different concrete compositions including high strength concrete and are compared with the maturity method.

The quality of early age concrete piles as well as length and integrity of old piles can be tested with the low strain method, also referred as pile integrity testing (PIT). The analysis of the elastic wave velocity and the reliability of the method related to pile age is described in the third paper by *E. Niederleithinger and A. Taffe (Germany)*.

Methods for the mechanical materials properties of hydrated concrete encountered to different environmental influences are presented in the second group of papers. The drilling resistance test for the assessment of fire damaged concrete was evaluated by *R. Felicetti (Italy)*. The reliability of this technique related to damage depth within structural members has been tested on concrete panels and in situ of pre-cast reinforced concrete structures exposed to real fire. Fracture process in concrete has been quantitatively investigated by *Ch.U. Grosse and F. Finck (Germany)* using acoustic emission techniques. The main advantage of this method is to observe the time dependent damage process during the entire load history of the structure. By analysing the acoustic emission data with the support of reliable momentum tensor inversions, high resolution damage quantification is possible. For the investigation of mechanical material properties of cylindrical concrete structures (e.g. in tunnels and service pipes), *J. Lagarde, O. Abraham, L. Laguerre, P. Cote, J.-P. Piguet, C. Balland and G. Armand (France)* have studied the propagation of surface waves and applied seismic refraction measurements. The data were processed and compared with a numerical model considering the respective geometry of the concave concrete layers. This enhances the accuracy of the determination of layer thickness.

In any dielectric construction material, velocity and absorption of electromagnetic waves depend on its complex permittivity. A methodology for determining this complex permittivity based on measured transmission coefficient and time difference on arrival, is specified by

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O. Büyüköztürk, T.Y. Yu and J.A. Ortega (USA). The main purpose is given on lossy materials implemented into a free-space measurement set-up.

The adhesion between polymer coating and concrete substrate was investigated by *L. Czarnecki, A. Garbacz and M. Krystosiak (Poland)*. The results, based on measurements of the indirect surface ultrasonic pulse velocity, were analysed in relationship to the pull off strength of the composite. As an example, industrial polymer floors were used.

Most of the applied NDT methods are based on the propagation of electromagnetic, acoustic and elastic wave fields. For reliable data interpretation the investigation of wave propagation in terms of a parametric study applying numerical codes to solve the respective underlying wave equations is advisable. Modelling as well as imaging of the synthetic and experimental data is proposed by *K.J. Langenberg, K. Mayer and R. Marklein (Germany)* considering the problem to locate and assess tendon ducts in concrete. The experimental data are based on on-site investigations of a concrete bridge, which are described in more detail in the last paper of this issue.

The last group of papers deals with on-site investigations, which can be regarded as the touchstone for each method developed in laboratory. From the reproducibility, accuracy and reliability of results obtained at real structures, the mean target group of users can assess the applicability and usability of the methods and technologies. *J. Hugenschmidt and R. Mastrangelo (Switzerland)* demonstrate ground penetrating radar (GPR) inspections of several concrete bridges. After the measurement, these concrete bridges were demolished enabling a verification of the radar results and allowing a quantification of accuracy and reliability of radar surveys performed under realistic circumstances.

For the detection of honeycombing, voids and delamination in the area close to the surface (e.g. at concrete covers less or equal than 10 cm), impulse-thermography can be easily applied. The method described by *Ch. Maierhofer, R. Arndt, M. Röllig, C. Rieck, A. Walther, H. Scheel and B. Hillemeier (Germany)* is based on external or internal heating and on observation and analysis of the time dependent surface temperature recorded with an infrared camera. Measurements on a stone floor and a concrete bridge have been carried out in the frame of case studies and are described in detail here.

The interpretation as well as the reliability of NDT data can be enhanced by the combination of complementary methods like radar and ultrasonics. *Ch. Kohl and D. Streicher (Germany)* demonstrate results of mathematical superpositioning of reconstructed radar and ultrasonic data sets recorded automatically at test specimens and on-site at a concrete bridge. Also different configurations of sensors with various frequencies and polarisations were considered. The fused 3D data sets imaging the indication of all measurement configurations concurrently visualise reinforcement bars, tendon ducts, grouting faults inside tendon ducts and voids.

This Special Issue features current developments of equipment and shows its advanced on-site applicability including its automation possibilities. New data analysis tools include data reconstruction and take also advantage of the comparison between experimental data and modelling. Another focus is set on recent developments of data fusion. For further and future information about NDT in civil engineering, the reader is referred amongst others to the past and future NDT-CE conferences (in 2006: St. Louis, USA).

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