Monitoring of the mechanical properties of soils using embedded piezoelectric transducers

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Working language: English/ French

Student profile: Civil Engineering

Prerequisites/special skills: An interest in soil mechanics, experimental work and in the field of dynamics

Summary: Ultrasonic techniques can be used in order to estimate the mechanical properties of soils. Commercial systems consist in external piezoelectric transducers which are coupled to a small soil specimen using some coupling agent. A compressive wave is sent by the emitting transducer and is picked up by the receiver after travelling through the sample of soil. An estimate of the time of travel allows to compute the mean velocity of the compressive wave which, in turn, is used to estimate the Young's modulus of the sample. Such a system has been previously used in the laboratory of geomechanics of BATir at ULB. For the estimation of the properties of soil over long periods of time, the system is however not optimal as it requires to recouple the soil sample to the transducers using coupling agent many times. The goal of this thesis is to study the possibility of using very low cost, disposable piezoelectric elements permanently attached to the soil sample instead of the regular transducers.

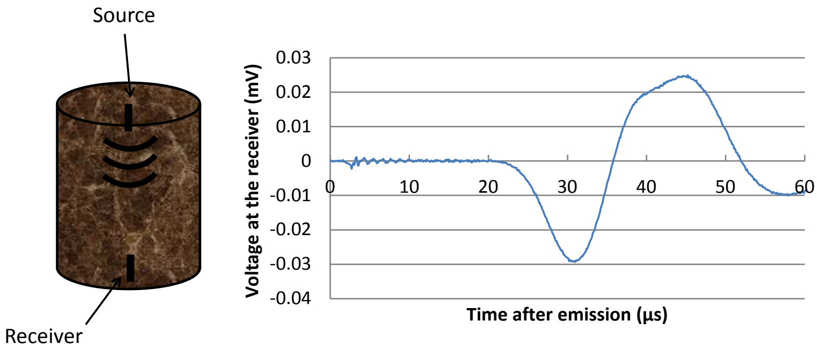

Figure 1 : Soil sample and transmitted ultrasonic wave

The work is essentially experimental and consists in realizing different test setups in which low-cost transducers are attached to the soil sample. The performances of these alternative transducers will be assessed and compared to the performances of the existing system. The possibility to embed the transducers before compaction will also be studied.

References

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[2] Yesiller, N., Hanson, J.L. and Usmen, M.A. 2000. Ultrasonic assessment of stabilised soils. Soft Ground Technology- *Proceedings of the Soft GroundTechnology Conference*, Noordwikerhout, Netherlands, 170-181.

Embedded MEMS accelerometers for long time permanent monitoring of concrete structures

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Prerequisites/special skills: An interest in experimental work and in the field of dynamics

Summary: Permanent monitoring of the quality of concrete is of great importance for optimal maintenance of concrete structures. Vibration based methods can be used in order to track changes in the dynamic signature of structures caused by damage. Traditional sensors used for SHM systems are accelerometers. New types of accelerometers based on the MEMS (micro-electromechanical systems) concept have been developed in the last decade, largely driven by other application markets such as smart phones and airbag systems. These low costs sensors have however lower performances than traditional accelerometers used in vibration analysis. The goals of this thesis are (i) to make a review of the different types of existing MEMS accelerometers outlining their respective performances, and (ii) to develop a test setup in which the best candidate MEMS accelerometer is embedded permanently inside a concrete beam in order to monitor its dynamic response.

The work consists in a market survey of existing MEMS accelerometers and experimental work consisting in the development of a test setup. This setup will consist in a concrete beam in which MEMS accelerometers are embedded in order to monitor the acceleration levels. The performance of the embedded MEMS sensors will be compared with the performance of expensive high quality accelerometers available in the laboratory of civil engineering of BATir at ULB.

References

[1] A. Albarbar, A. Badri, Jyoti K. Sinha, A. Starr, Performance evaluation of MEMS accelerometers, Measurement, Volume 42, Issue 5, June 2009, Pages 790-795 (http://www.sciencedirect.com/science/article/pii/S0263224108002091)

[2]http://www.pcb.com/Accelerometers/MEMS.asp

Design and execution of three-point-bend tests as a basis for identifying material parameters of concrete

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Prerequisites/special skills: An interest in experimental working is required and a basic understanding of concrete damage mechanisms is desirable.

Summary: In recent years, a major step has been made in developing suitable constitutive laws to model progressing damage in concrete structures. Of course, the constitutive laws rely on several material parameters to describe the linear-elastic and softening behavior. Even though most of such parameters have a physical meaning, their accurate prediction is difficult. To reduce the uncertainty of predicted parameters, experimental tests can be performed. One kind of test is a three-point-bend test on a single-edge-notched beam [1] [2].

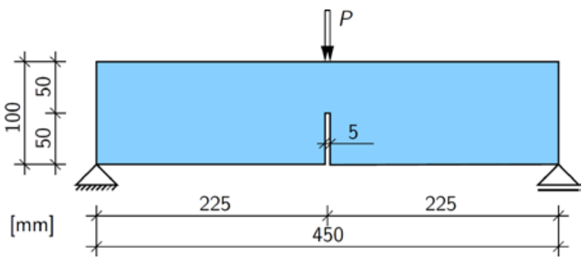

Figure 1: Notched beam

Based on the recommendations from literature, the student has to design and realize a three-point-bend test in the laboratory. This includes the preparation of test specimens, the construction of the test setup and the execution of the tests. To investigate the statistical uncertainties of such tests, ten repetitions need to be performed.

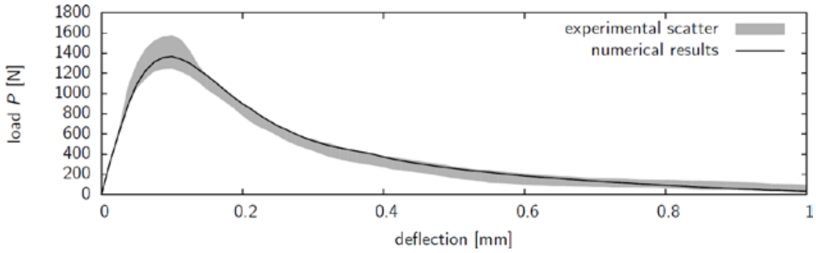

Figure 2: Experimental and numerical load-deflection-curve

References

[1] Körmeling, H. A. and Reinhardt, H. W.: Determination of the fracture energy of normal concrete and epoxy modified concrete, Stevin Laboratory, Delft University of Technology, Report No. 5-83-18, 1983.

[2] Malvar, L. and Warren, G.: Fracture energy for three-point-bend tests on single-edge-notched beams, Experimental Mechanics, 28(3), pp. 266-272, 1988.

Damage detection on a reinforced concrete column using dynamic vibration signals

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Prerequisites/special skills: An interest in the field of structural dynamics and concrete structures

Summary: Assessing the state of health and the level of damage in concrete structures is an important aspect of maintenance of such structures. Among others, vibration based methods have been studied for many years. The underlying principle is that damage occurring in the concrete will result in a change of stiffness which will be reflected by the change of the dynamic signals. The present thesis is based on experimental data made available by the Los Alamos National Laboratory in New Mexico USA. It consists in recordings of the dynamic response of a reinforced concrete column subjected to progressive damage. The aim is to develop an efficient signal processing technique in order to build a suitable damage indicator which can be used in order to assess the state of damage of the column.

Figure 1 : Reinforced concrete column tested up to failure

The work is based on available experimental data but is strictly numerical. It will consist in implementing a new damage indicator recently proposed in the research team at the BATir lab of ULB and to compare its performance with the damage indicator used in the study conducted by the

Los Alamos National Labs research team. The computation of the damage indicator will be performed using Matlab, based on already existing signal processing routines.

References

[1] M. L. Fugate, H. Sohn, and C. R. Farrar, "Vibration-Based Damage Detection Using Statistical Process Control," *Mechanical Systems and Signal Processing*, 2001, **15** (4) pp.707-721.

[2] A. Deraemaeker and A. Preumont. Vibration based damage detection using large array sensors and spatial filters. *Mechanical Systems and Signal Processing*, 20:1615–1630, 2006.

Comparison of damage localization methods based on dynamic strain measurements

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Prerequisites/special skills: An interest in the field of structural dynamics and Matlab programming

Summary: Vibration signals can be used in order to detect and locate damages in structures. In particular, many researchers have shown the interest of using dynamic strain measurements and proposed different methods for damage localization. The goal of this thesis is to compare the efficiency of these different methods. Due to the difficulty to generate experimentally data suitable for all these methods, an existing numerical simulator developed in the Matlab environment will be used.

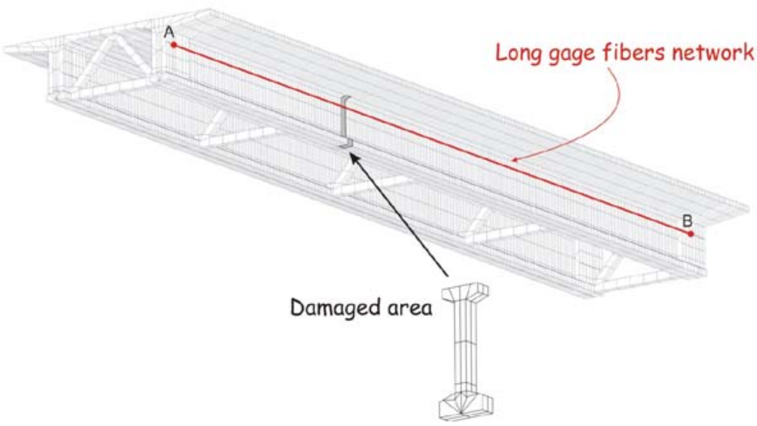

Figure 1 : Finite element model of a concrete bridge with simulated damage and dynamic strain sensors attached to it for damage localization

The work is numerical and consists on one hand in the use of the simulator to generate data on simple examples (simply supported beam with reduced stiffness in a local area) an on the other hand in the application of the different methods proposed in the literature (among which one is developed at BATir lab in ULB) in order to compare the performances. The methods will also be programmed in the Matlab environment.

References

[1] A.K. Pandey,M. Biswas, andM.M. Samman. Damage detection from changes in curvature mode shapes. *Journal of Sound and Vibration*, 145(2):321–332, 1991
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[3] G. Tondreau and A. Deraemaeker. Damage localization in bridges using multi-scale filters and large strain sensor networks. In *Proc ISMA 2010*, Leuven, Belgium, Sept 2010.

Modeling of uncertainties and variability in dynamics

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Prerequisites/special skills: An interest in the field of structural dynamics and Matlab programming

Summary: Variability of material and geometrical properties is an important aspect which should be taken into account for the robust design of structures and systems. If the probability distribution functions of these properties is known, the effect of this variability can be predicted using a numerical discrete model of the structure (such as finite elements). A typical approach is to use Monte-Carlo simulations which require to solve the numerical problem many times. An alternative is to solve the problem for a limited set of parameter values and to fit a stochastical model to this limited set of points in order to be able to approximate the real variability. An approach commonly used is polynomial chaos expansion.

Figure 1 : Dynamic testing of a real-scale building

The work consists in assessing the applicability of polynomial chaos expansion for dynamic problems. Based on simple systems such as a single degree of freedom mass-spring system, the applicability and limitations of the polynomial chaos expansion will be assessed. The work is numerical and will be performed in the Matlab environment.

References

[1] R.G. Ghanem, P.D. Spanos, Stochastic finite elements: A spectral approach, Springer-Verlag, New York, 1991

Design improvement of a resonant piezoelectric sensor for the monitoring of the state of health of structures

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Prerequisites/special skills: An interest in the field of structural dynamics and Matlab programming

Summary: Vibration signals can be used in order to monitor the state of health of structures. Traditionally, this is done using accelerometers which, due to their design, are limited to frequencies below 10 kHz. In some applications, signals of higher frequencies are more interesting for the monitoring of the state of health. An alternative to the classical accelerometer is to use a resonant sensor acting as a band-pass filter focusing on a given frequency band of interest. Such kind of sensor has been previously developed in the company SDT International, targeting frequencies around 40 kHz. The goal of this thesis is to study possible improvements of this design.

The work consists on one hand in the modeling of the existing piezoelectric transducer using the finite element code SAMCEF in order to estimate its resonant frequencies, and on the other hand on the study of alternative designs in order to improve its performances, essentially by tuning the eigenfrequencies.

Figure 1 : Current design of the resonant sensor (SDT International)

References

[1] SDT International : http://www.sdt.eu/